4rd INTERNATIONAL PARIS CONGRESS ON MEDICAL & HEALTH SCIENCES

December 18-21, 2025
Paris, France



EDITOR
David John WORTLEY

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PROCEEDINGS BOOK

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CONGRESS ID

CONGRESS TITLE

4th INTERNATIONAL PARIS CONGRESS ON MEDICAL & HEALTH SCIENCES

DATE AND PLACE

December 18-21, 2025 / Paris, France

ORGANIZATION

IKSAD INSTITUTE

EDITOR

David John WORTLEY

COORDINATOR

Samet KUŞKIRAN

PARTICIPANTS COUNTRY (22 countries)

UNITED KINGDOM, ITALY, TÜRKİYE, AZERBAIJAN, ALGERIA, SERBIA, MOROCCO, USA, TURKISH REPUBLIC OF NORTHERN CYPRUS, ROMANIA, POLAND, GEORGIA, BANGLADESH, INDIA, PAKISTAN, IRAN, NIGERIA, SPAIN, IRAQ, ETHIOPIA, ALBANIA, CHINA

Total Accepted Article: 125

Total Rejected Papers: 32

Accepted Article (Türkiye): 55

Accepted Article (Other Countries): 69

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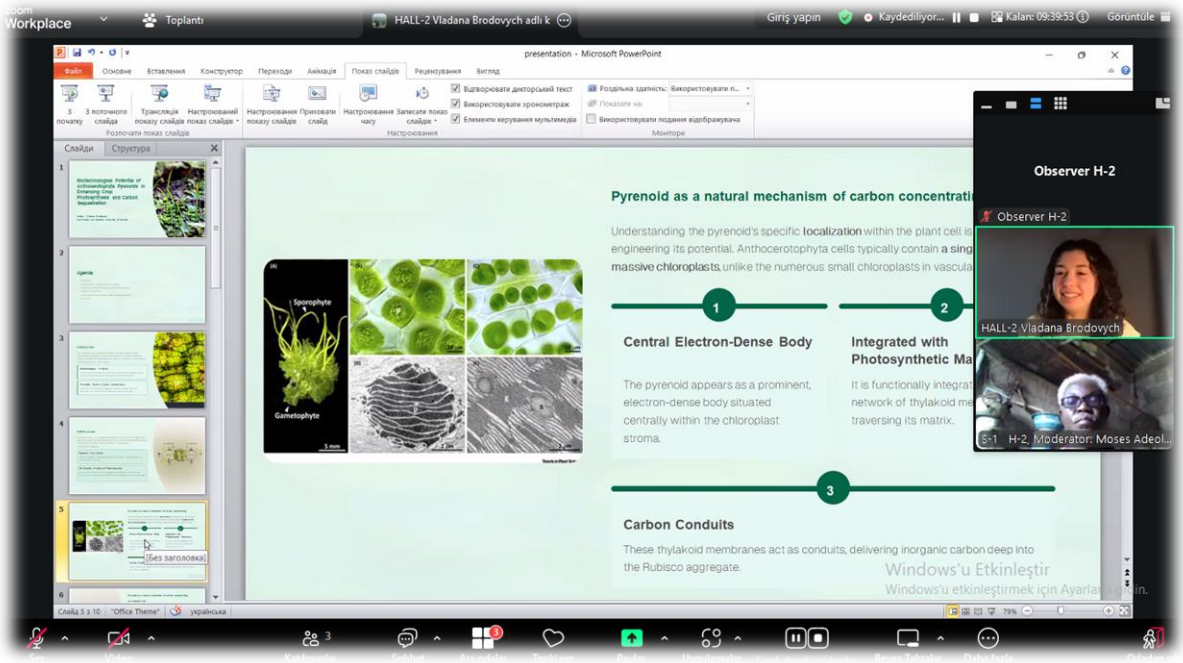
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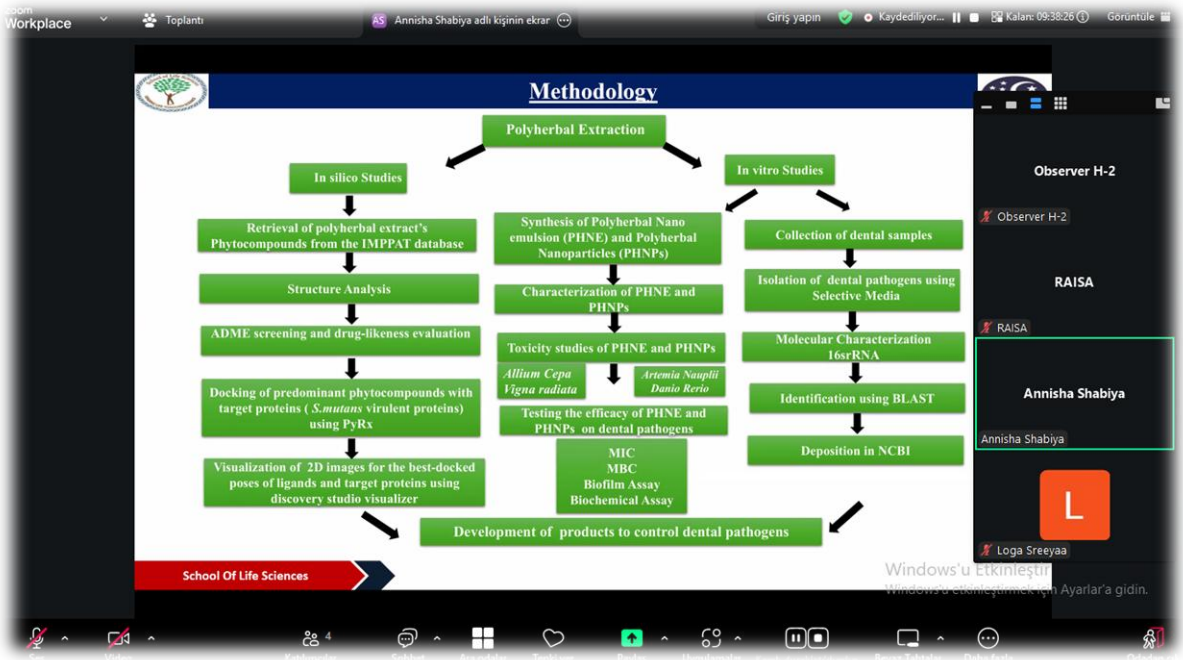
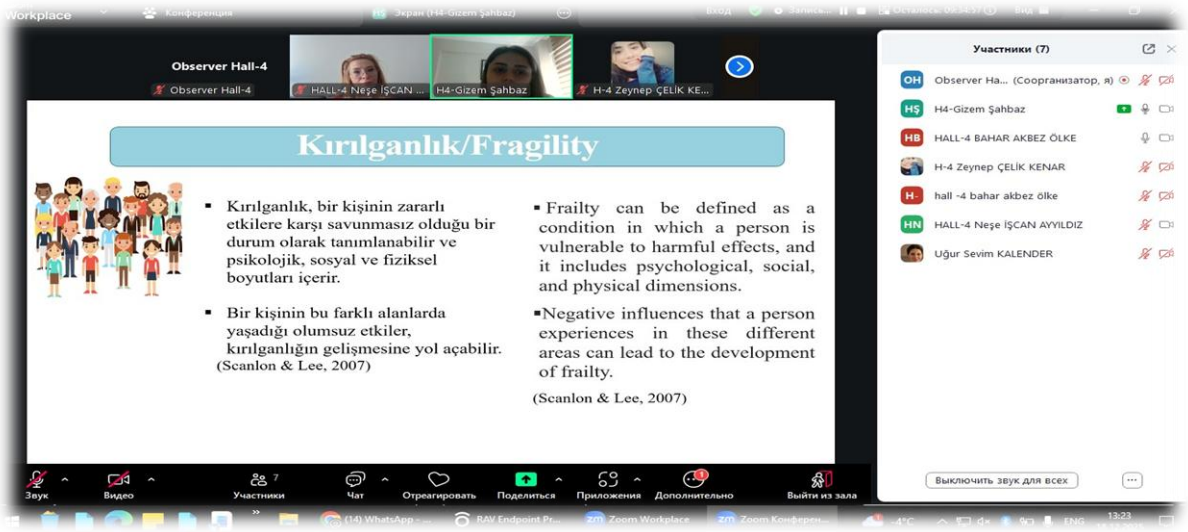


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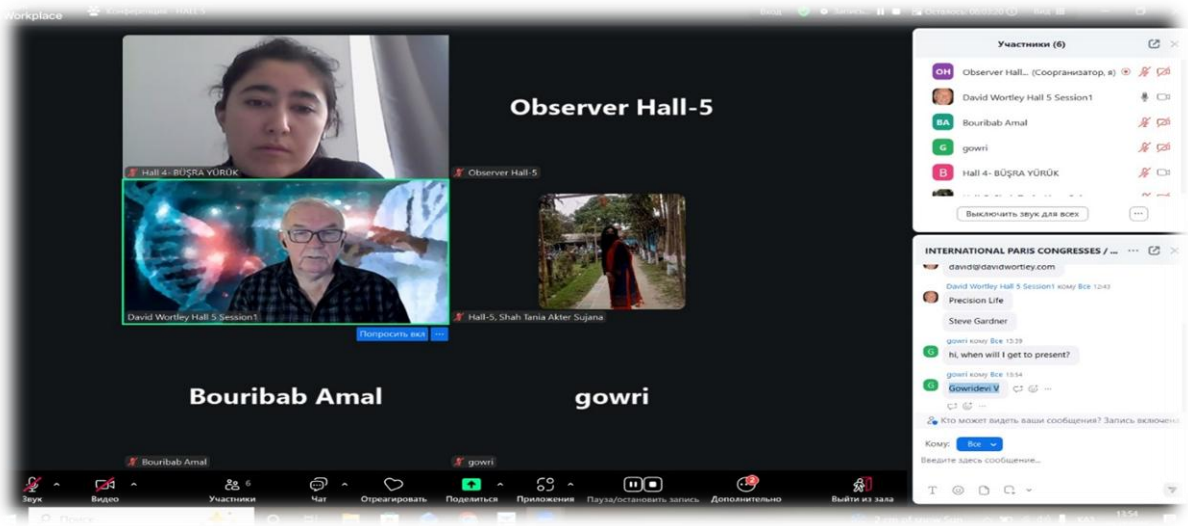




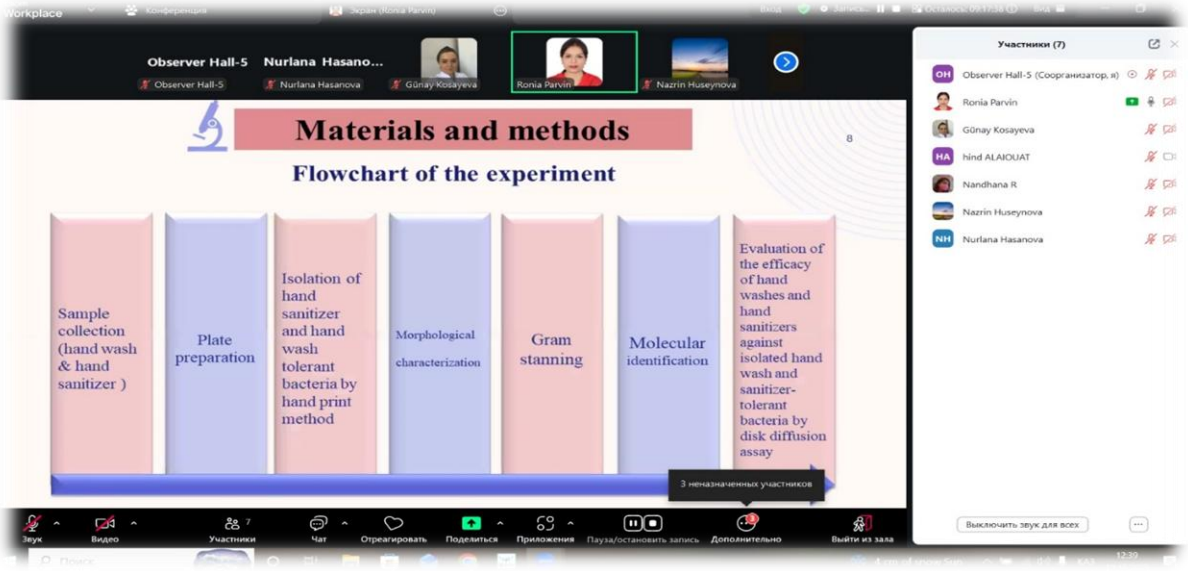
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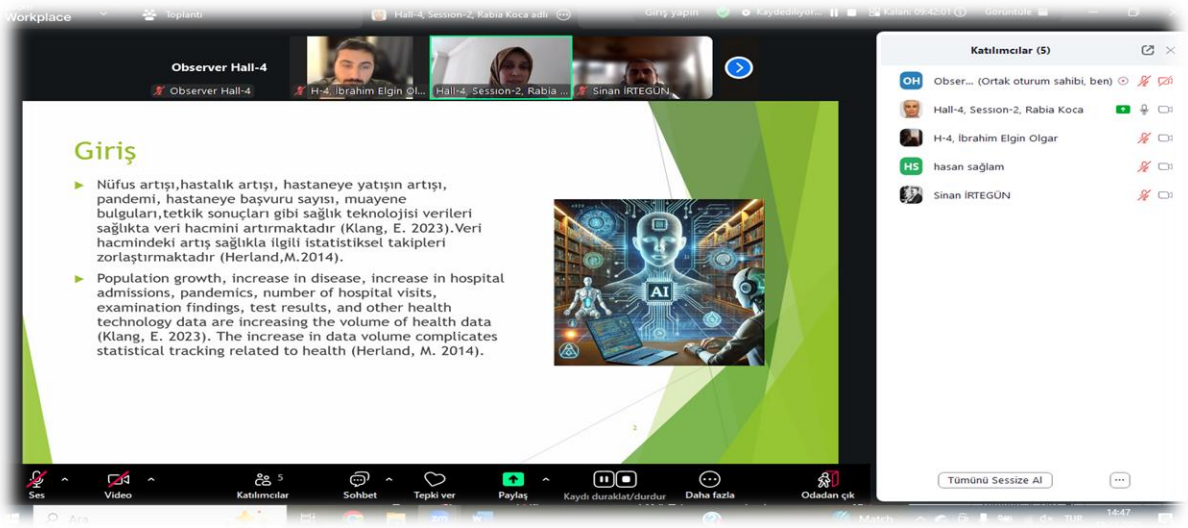






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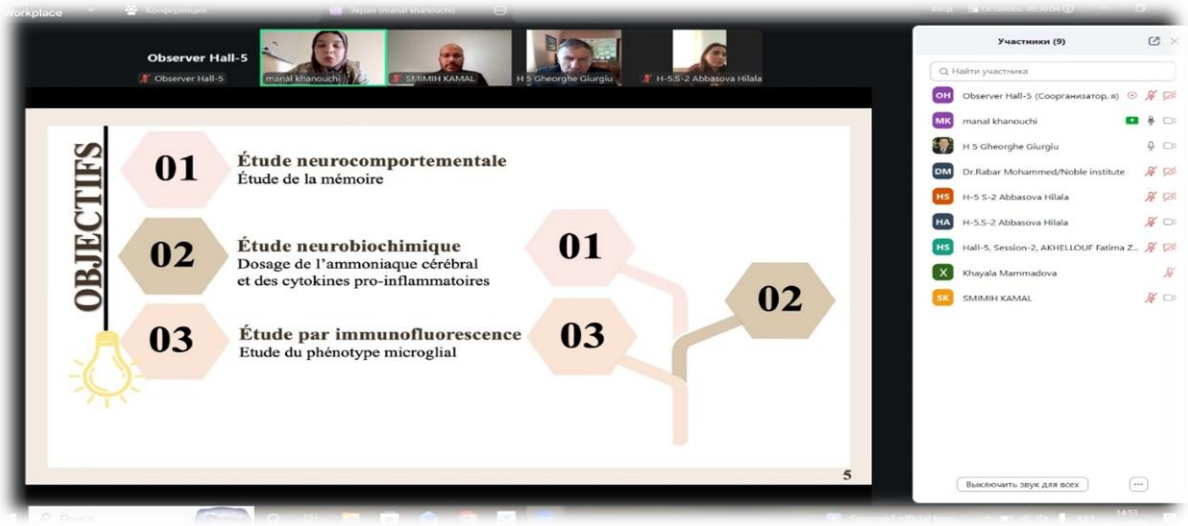
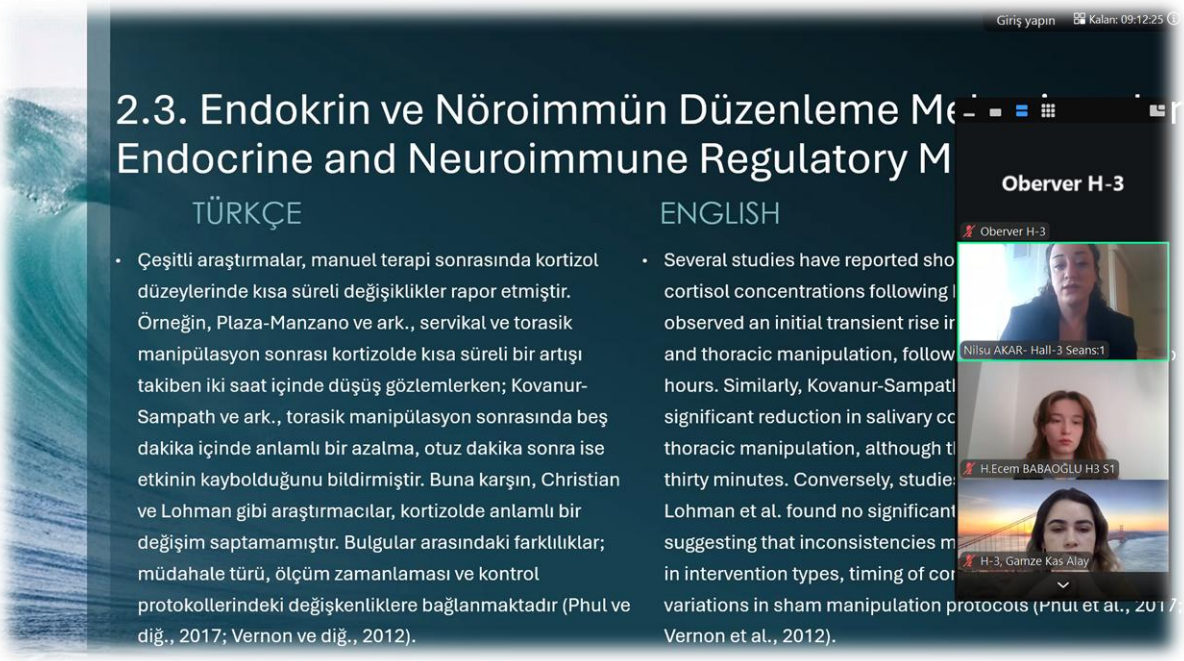


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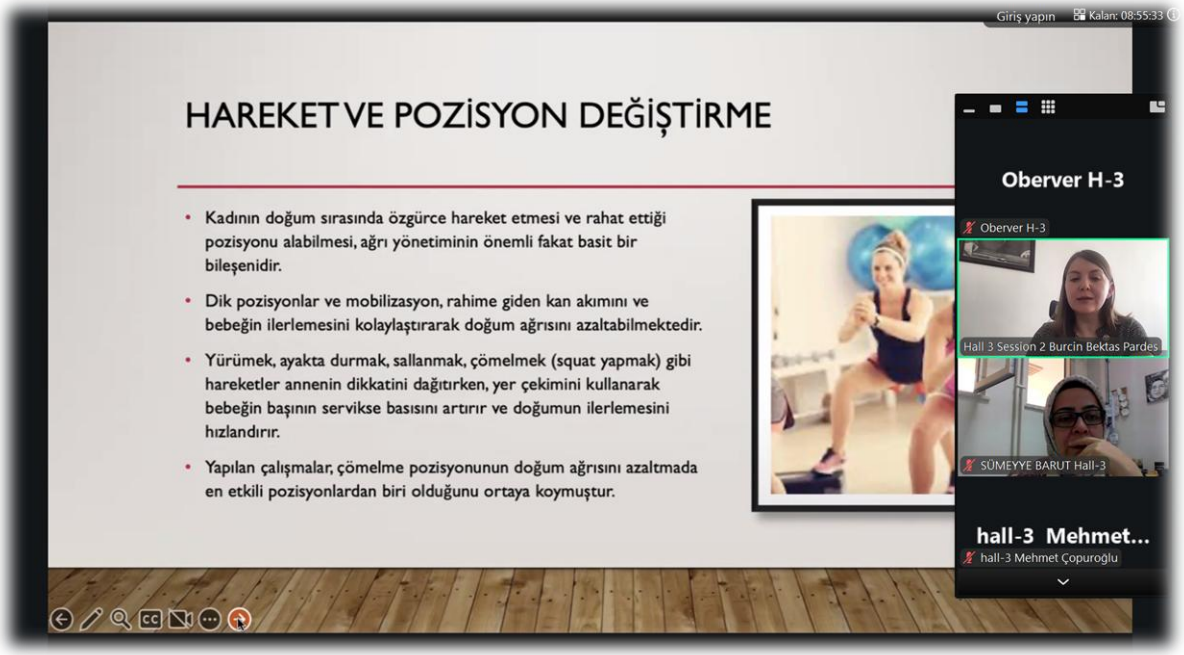
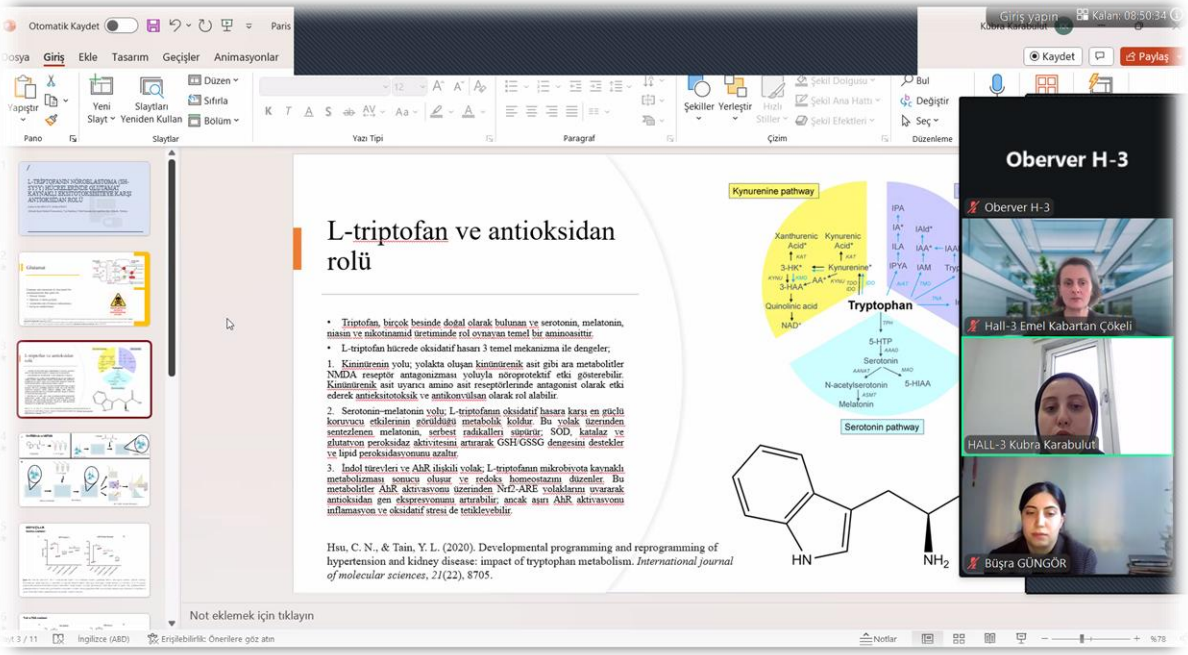


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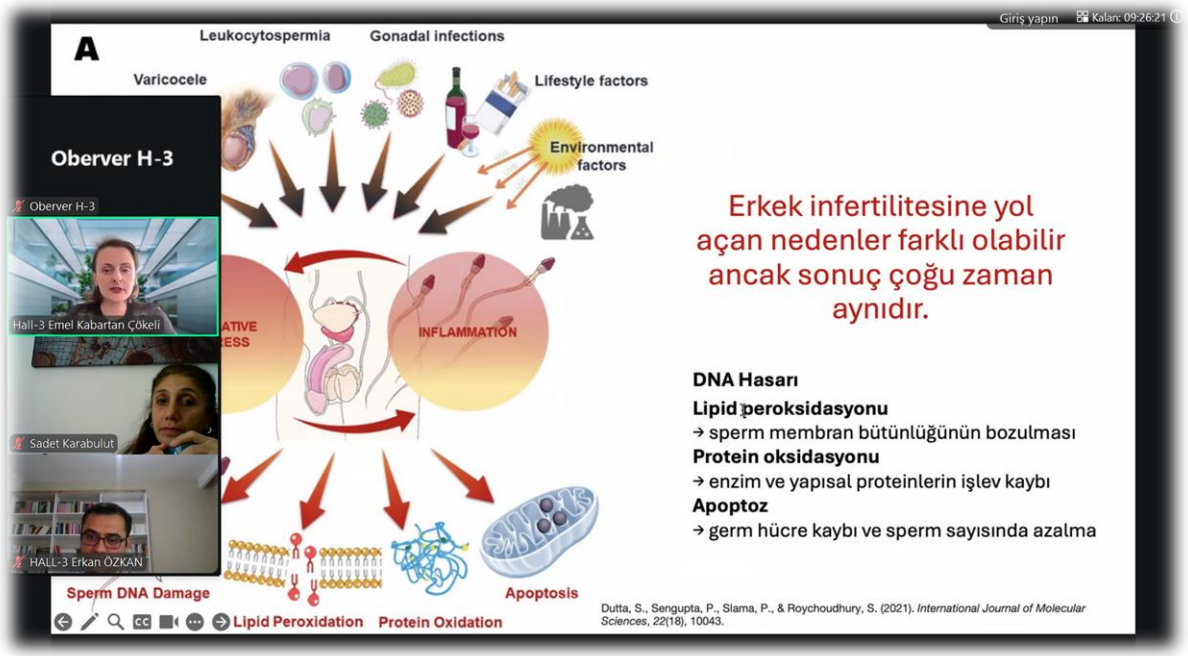
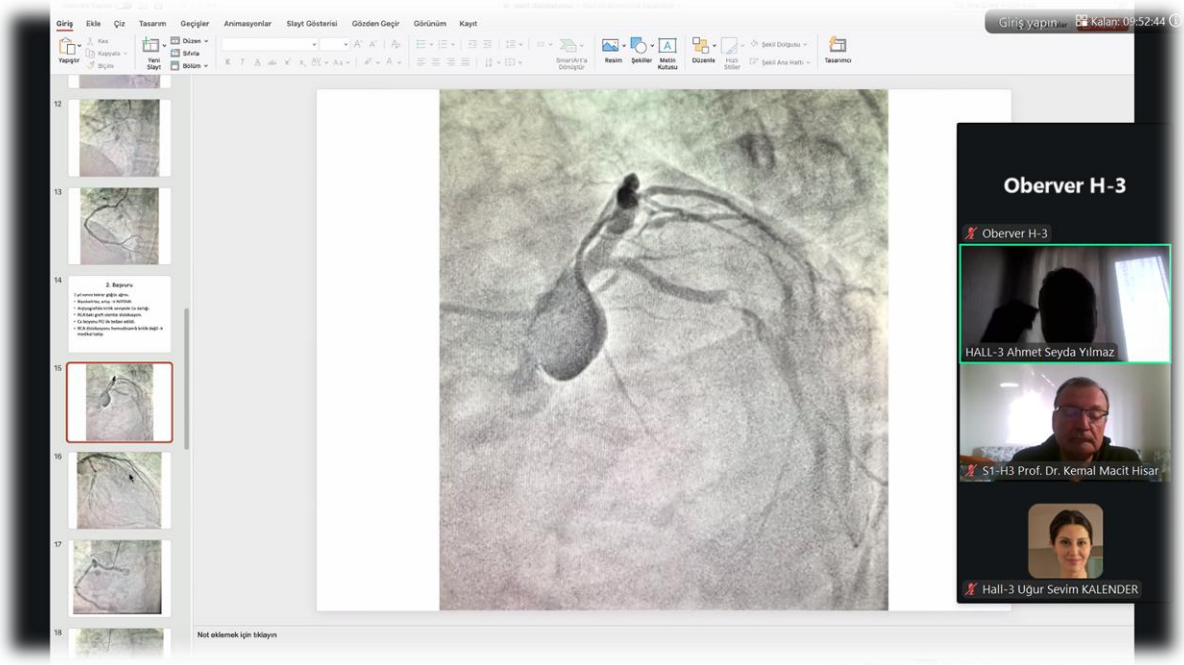


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4th INTERNATIONAL PARIS CONGRESS ON MEDICAL & HEALTH SCIENCES

December 18-21, 2025 / Paris, FRANCE

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Meeting ID: 897 0755 8402
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***

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FACE TO FACE PRESENTATIONS

20.12.2025 / SESSION-1

PARIS LOCAL TIME

13 00 : 15 00

HEAD OF SESSION: Assoc. Prof. Dr. Hasan ÇİFTÇİ

AUTHORS	AFFILIATION	TOPIC TITLE
Prof. Mohamed HAMADOUCHE **Dr. Imen DJEDDOU**	Ferhat Abbas University ALGERIA Setif University Hospital ALGERIA	PREVALENCE OF SLEEP DISORDERS IN THE WORKPLACE
Res. Assist. Burçin AYDEMİR AKKOÇAN **Oğuzhan AKKOÇAN** **Res. Assist. Sude Eylül ULUCAN** **Assoc. Prof. Dr. Nasibe Aycan YILMAZ**	Dokuz Eylül University TÜRKİYE	INFORMATION ON TEETH WHITENING PRESENTED ON INSTAGRAM: A CONTENT SCOPE AND QUALITY ANALYSIS OF TURKISH POSTS

ONLINE PRESENTATIONS

18.12.2025 / HALL-3 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Dr. Gamze Kaş ALAY

Authors	Affiliation	Presentation title
Assist. Prof. Dr. Shanay GULİYEVA KABAOGHLU **Demet BAHÇECİ** **Gaye KAŞ**	Kastamonu University TÜRKİYE Kırşehir Ahi Evran University TÜRKİYE Kastamonu University TÜRKİYE	GRIEF IN CHILDREN AND ADOLESCENTS: MAIN IDEAS, CONCEPTS AND TECHNIQUES
Res. Assist. Dr. Gamze Kaş ALAY **Ümmü Gül AKSU** **Mehmet Emre USTA**	Kastamonu University TÜRKİYE	EXPOSURE TO PEER BULLYING AMONG HEALTHY AND CHRONICALLY ILL SCHOOL-AGE CHILDREN: A COMPARATIVE PILOT STUDY
Hayriye Ecem BABAOĞLU **Assoc. Prof. Dr. Arzu KOÇAK UYAROĞLU**	Selçuk University TÜRKİYE	THE CARE BURDEN EXPERIENCED BY PARENTS OF CHILDREN WITH SPECIAL NEEDS AND NURSING INTERVENTIONS
Nilsu AKAR **Ceren KARADUMAN** **Assist. Prof. Dr. Berkay Eren PEHLİVANOĞLU**	Bahçeşehir University TÜRKİYE	THE EFFECTS OF MANUAL THERAPY ON VAGAL ACTIVITY AND EMOTIONAL REGULATION
Melike BERK **Prof. Dr. Filiz HİSAR**	Necmettin Erbakan University TÜRKİYE	DETERMINING THE RELATIONSHIP BETWEEN ETHICAL VALUES AND SUSTAINABLE CONSUMPTION BEHAVIOR IN YOUNG ADULTS
Özgür BOZDAĞ **Assoc. Prof. Dr. Mümüne Merve PARLAK**	Ankara Yıldırım Beyazıt University TÜRKİYE	A REVIEW OF THESES CONDUCTED ON COMMUNICATION IN ALZHEIMER'S DISEASE
Dr. Deniz YILMAZ	Independent Researcher İstanbul TÜRKİYE	POLICY MEASURES TO REDUCE HEALTH INEQUALITIES FROM A SOCIOECONOMIC PERSPECTIVE: TURKEY AND INTERNATIONAL EXAMPLES

All participants must join the conference 10 minutes before the session time.
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ONLINE PRESENTATIONS

18.12.2025 / HALL-4 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Assist. Prof. Dr. Neşe İŞCAN AYYILDIZ

Authors	Affiliation	Presentation title
Res. Assist. Dr. Zeynep ÇELİK KENAR Prof. Dr. Mustafa ORTATATLI Prof. Dr. Ertan ORUÇ Vet. Dr. M. Yasin GÖÇEN	Selçuk University TÜRKİYE	A CASE OF FELINE INJECTION-SITE LIPOSARCOMA IN A 6-YEAR-OLD DOMESTIC CAT
Res. Assist. Dr. Zeynep ÇELİK KENAR Prof. Dr. Özgür ÖZDEMİR Prof. Dr. Fatih HATİPOĞLU Vet. Dr. Cennet YAKA	Selçuk University TÜRKİYE	A CASE OF ADENOSQUAMOUS CARCINOMA IN AN 8-YEAR-OLD FEMALE GERMAN SHEPHERD DOG
Büşra YÜRÜK	Rome Tor Vergata University ITALY	TRANSNATIONAL MEDICATION PRACTICES AND THERAPEUTIC MOBILITY WITHIN THE CONTEXT OF GLOBAL HEALTH
Gizem ŞAHBAZ Prof. Dr. Filiz HİSAR	Necmettin Erbakan University TÜRKİYE	EXAMINATION OF THE RELATIONSHIP BETWEEN ORAL HEALTH LEVEL AND FRAGILE IN ELDERLY INDIVIDUALS
Assist. Prof. Dr. Neşe İŞCAN AYYILDIZ Assist. Prof. Dr. Uçar KÜÇÜK	Trabzon University TÜRKİYE	DETERMINATION OF KNOWLEDGE AND ATTITUDES TOWARD SCABIES AMONG INDIVIDUALS LIVING IN RURAL AREAS
Bahar AKBEZ ÖLKE Assoc. Prof. Dr. Yasemin BEYHAN	Hasan Kalyoncu University TÜRKİYE	NEW TECHNOLOGIES IN THE FOOD AND BEVERAGE INDUSTRY: FUNCTIONAL FOOD PRODUCTION WITH 3D FOOD SOFTWARE AND ITS USE IN HEALTHCARE

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ONLINE PRESENTATIONS

18.12.2025 / HALL-5 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: David John WORTLEY

Authors	Affiliation	Presentation title
David John WORTLEY	World Lifestyle Medicine Education Services UNITED KINGDOM	THE IMPACT OF AI ON PUBLIC HEALTH
Dr. Odebiyi, O.A Agemo, D.N Ayanrinola, O.W Omoniyi, S.O Adewole, E.T Fatore, T.A	Ladoke Akintola University NIGERIA	INVESTIGATION OF EXISTENCE AND UNIQUENESS OF SOLUTION FOR A COVID-19 TRANSMISSION DYNAMICS MODEL USING PICARD'S METHOD
Shah Tania Akter Sujana Md. Mahafuzur Rahman	Begum Rokeya University BANGLADESH	APPLICATION OF BIOINFORMATIC TOOLS IN CELL TYPE CLASSIFICATION FOR SINGLE-CELL RNA-SEQ DATA
Shah Tania Akter Sujana Md. Mahafuzur Rahman	Begum Rokeya University BANGLADESH	IMMUNE CELL TYPE CLASSIFICATION AND IDENTIFICATION OF CELL TYPE-SPECIFIC GENES USING MACHINE LEARNING IN SINGLE-CELL RNA-SEQ DATA WITH FUNCTIONAL ANALYSIS AND DRUG REPURPOSING
Shah Tania Akter Sujana Md. Mahafuzur Rahman	Begum Rokeya University BANGLADESH	EXPLORING WOMEN'S PREFERENCES FOR HUSBANDS' PRESENCE IN THE DELIVERY ROOM DURING CHILDBIRTH IN NORTHERN BANGLADESH
Zainib Razzaq Samreen Gul Khan Fozia Anjum Kiran Aftab Mehr un Nisa	Government College University PAKISTAN	DESIGN, SYNTHESIS AND MOLECULAR DOCKING EVALUATION OF NOVEL 1,2,4-TRIAZOLE DERIVATIVES AS POTENT ANTI-CANCER CANDIDATES AGAINST HEPG2 CELLS
Amal BOURIBAB El Mehdi KARIM Abdelkbir ERROUGUI Samir CHTITA	Hassan II University MOROCCO	EXPLORING ANTICANCER CANDIDATES FROM MOROCCAN MARRUBIUM VULGARE L. THROUGH IN SILICO APPROACHES: BREAST AND PROSTATE CANCER
Sourov Datta Fatema Mostakin Nesa Fahmida Rahman Mahamuda Fatema Farhana Akter Mohammad Asadujjaman Muhammad Salehuddin Ayubee	Northern University BANGLADESH East West University BANGLADESH	PHYTOCHEMICALS FROM AMARYLLIDACEAE, LYCOPODIACEAE, AND LAMIACEAE FAMILIES EXHIBIT POTENTIAL AS ANTI-ALZHEIMER'S DRUGS: AN IN SILICO APPROACH

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ONLINE PRESENTATIONS

18.12.2025 / HALL-3 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
$10^{30} : 12^{30}$	$12^{30} : 14^{30}$

HEAD OF SESSION: Assoc Prof. Dr. Sümeyye BARUT

Authors	Affiliation	Presentation title
Exp. Dr. Fırat BEDİR	Bahçelievler Medipol Hospital, Istanbul TÜRKİYE	A CHILD PRESENTING WITH SUBGLOTTIC STENOSIS: A CASE OF RECURRENT STRIDOR
Assist. Prof. Dr. Özge BAYKAN ÇOPUROĞLU **Mehmet ÇOPUROĞLU**	Kayseri University TÜRKİYE Kayseri City Hospital TÜRKİYE	SEXUAL DYSFUNCTION AFTER CHILDBIRTH: PHYSIOTHERAPY APPROACHES FOR DYSPAREUNIA AND PELVIC FLOOR HYPERTONICITY
Mehmet ÇOPUROĞLU **Assist. Prof. Dr. Özge BAYKAN ÇOPUROĞLU**	Kayseri City Hospital TÜRKİYE Kayseri University TÜRKİYE	CESAREAN SECTION ON THE RISE: MATERNAL OUTCOMES, PELVIC FLOOR CONSEQUENCES, AND MULTIDISCIPLINARY MANAGEMENT
Assoc Prof. Dr. Sümeyye BARUT **Res. Assist. Dr. Nuray KURT**	Fırat University TÜRKİYE	EFFECTS OF RAMADAN FASTING ON GESTATIONAL DIABETES
Res. Assist. Dr. Nuray KURT **Assoc. Dr. Sümeyye BARUT**	Fırat University TÜRKİYE	MIDWIVES' PREPAREDNESS IN THE FACE OF THE EFFECTS OF CLIMATE CHANGE ON MATERNAL AND CHILD HEALTH
Assist. Prof. Dr. Burçin BEKTAŞ PARDES	University of Health Sciences TÜRKİYE	NONPHARMACOLOGICAL METHODS IN LABOUR PAIN MANAGEMENT AND NURSING APPROACHES
Assist. Prof. Dr. Burçin BEKTAŞ PARDES **Prof. Dr. Gülten GÜVENÇ**	University of Health Sciences TÜRKİYE	NUTRITION AND MICROBIOTA IN PREGNANCY: EFFECTS ON MATERNAL–FETAL HEALTH AND NURSING APPROACHES

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ONLINE PRESENTATIONS

18.12.2025 / HALL-4 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10 30 : 12 30	12 30 : 14 30

HEAD OF SESSION: Dr. Arlinda Hallunovi Ymeri

Authors	Affiliation	Presentation title
Shahla Guliyeva	Nakhchivan State University AZERBAIJAN	THE USE OF INNOVATIVE METHODS IN STRESS MANAGEMENT
Tamara MİLENKOVİĆ **Assist. Prof. Dr. Radica ŽİVKOVİĆ-ZARIC**	Kragujevac University SERBIA	IMPACT OF NON-STEROIDAL ANTI-INFLAMMATORY DRUGS ON QUALITY OF LIFE IN PATIENTS WITH HEADACHE
Rida Fatima **Ayesha**	Rawalpindi Women University PAKISTAN	THE RELATIONSHIP BETWEEN ANUPTAPHOBIA AND SELF-OBJECTIFICATION: THE MEDIATING ROLE OF EMOTIONAL INSTABILITY AMONG YOUTH
Bakhtawar Fakhar **Umm Eman Syed**	Rawalpindi Women University PAKISTAN	ROLE OF EMPATHY IN THE RELATIONSHIP BETWEEN PETS ATTACHMENT AND MENTAL HEALTH AMONG PET OWNERS
Dr. Arlinda Hallunovi Ymeri	University of Shkodra "Luigj Gurakuqi" ALBANIA	TECHNIQUES AND SUPPORTIVE TOOLS IN PSYCHOEDUCATION
Ayla Mici **Alma Robo** **Artan Simaku**	Institute Of Public Health ALBANIA	MENTAL HEALTH AMONG MEDICAL STUDENTS IN ALBANIA, 2025
Mohaddeseh Babaei **Elham Vahidi**	AhlulBayt International University IRAN	A META-SYNTHESIS: ANALYZING THE COMPLEXITIES OF EMPLOYMENT AND MENTAL HEALTH IN WOMEN
Adamu Amanu Asari **Ameyu Godesso** **Zewdie Birhanu**	Jimma University ETHIOPIA	HEALTH LITERACY AMONG ADOLESCENTS IN ETHIOPIA: IMPLICATIONS FOR MENTAL HEALTH
Prof. Nasrin Shokrpour **Dr. Shadab Moslehi** **Mahbubeh Pedram**	Shiraz University of Medical Sciences IRAN	ASSESSMENT OF CLINICAL REASONING OF MEDICAL STUDENTS AT FASA UNIVERSITY OF MEDICAL SCIENCES IN CLINICAL SETTINGS AND ITS RELATIONSHIP WITH PROBLEM-SOLVING SKILLS IN 1403–1404 ACADEMIC YEAR
Assoc. Prof. Dr. Hüseyin ERİŞ	Harran University TÜRKİYE	HEALTHCARE WORKFORCE DEVELOPMENT IN TURKEY OVER THE YEARS

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ONLINE PRESENTATIONS

18.12.2025 / HALL-5 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10 30 : 12 30	12 30 : 14 30

HEAD OF SESSION: Patrycja Widłak

Authors	Affiliation	Presentation title
Fidan Enver Shikhaliyeva	Azerbaijan State Advanced Training Institute for Doctors named after A.Aliyev AZERBAIJAN	COMPLICATIONS OF DENTAL IMPLANTATION AND THEIR MODERN TREATMENT METHODS
F.R.Huseynov	Azerbaijan State Advanced Training Institute for Doctors AZERBAIJAN	MODERN APPROACHES TO THE SURGICAL MANAGEMENT OF CONGENITAL DIAPHRAGMATIC HERNIA IN NEWBORNS
Patrycja Widłak **Bartłomiej Michalak** **M.Sc. Zbigniew Tyc** **Assoc. Prof. Dr. Dariusz Boguszewski** **Assoc. Prof. Dr. Anna Kopiczko**	Józef Piłsudski University of Physical Education POLAND	ASSESSING THE RISK OF SPORTS INJURIES IN PROFESSIONAL FOOTBALLERS USING THE FMS AND Y-BALANCE TEST
LAKHRISSI Alaeddine **BOUGHAZI Souad** **CHERRAJ Safae** **ERRAZKI Imane** **TALAL MOHAMED Abdoul-Latif** **AMAKASSOU Halima** **FAROUDY Mamoun** **Naoufal Himmouche** **BOUZID Jawad**	Hassan The First University MOROCCO Higher Institute of Nursing and Health Techniques (ISPITS) MOROCCO Ibn Sina University Hospital MOROCCO	INTRAOPERATIVE MEASURES TO PREVENT PROSTHETIC JOINT INFECTIONS IN THE ORTHOPEDIC SURGERY UNIT OF THE MOULAY YOUSSEF REGIONAL HOSPITAL, RABAT
Elda Zeqiri **Orges Lena** **Jasemin Todri**	UCAM Catholic University of San Antonio of Murcia SPAIN	CERVICAL DISABILITY INDEX (NDI): THE VALIDITY AND RELIABILITY FOR USE IN THE ALBANIAN-SPEAKING POPULATION
Ali H Dosky	Duhok University IRAQ	IMPACT OF VITAMIN D DEFICIENCY ON CORNEAL HEALTH UPON CHILDREN WITH RICKETS
Aysha Akter Metu **Md. Mansurul Haque** **Md. Mahedi Hasan** **Sadia Afrin** **Nazrul Islam Bhuiyan**	Jahangirnagar University BANGLADESH	ISOLATION AND IDENTIFICATION OF MICROBIAL LOAD FROM THE DRIED POMFRET FISH (PAMPUS CHINENSIS)

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ONLINE PRESENTATIONS

18.12.2025 / HALL-3 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 ^{00} : 15 ^{00}	15 ^{00} : 17 ^{00}

HEAD OF SESSION: Assoc. Prof. Dr. Sıdıka GENÇ

Authors	Affiliation	Presentation title
Emine DOĞAN **Prof. Dr. Semra GÜMÜŞOVA**	Ondokuz Mayıs University TÜRKİYE	AUTOPHAGY AS AN ANTIVIRAL IMMUNE MECHANISM: ROLES AND VIRAL EVASION STRATEGIES
Lect. Dr. Erkan ÖZKAN **Assoc. Prof. Dr. Neşe Hayat AKSOY** **Assoc. Prof. Dr. Caner ÖZTÜRK** **Res. Assist. Ramazan ARSLAN**	Aksaray University TÜRKİYE	EFFECTS OF SHORT-TERM MELOXICAM ADMINISTRATION ON OXIDATIVE STRESS IN THE RAT HIPPOCAMPUS: A PRELIMINARY STUDY
Assist. Prof. Dr. Emel KABARTAN ÇÖKELİ	Ordu University TÜRKİYE	ROLE OF THE TLR4/NF-KB PATHWAY IN MALE INFERTILITY
Büşra GÜNGÖR **Berrin TARAKÇI GENÇER** **İbrahim Halil GÜNGÖR** **Sema TİMURKAAN** **Hatice ERÖKSÜZ** **Emre KAYA**	Fırat University TÜRKİYE	INVESTIGATION OF THE PROTECTIVE EFFECT OF GALANGIN ON HISTOPATHOLOGICAL LESIONS AND SPERMATOLOGICAL PARAMETERS IN PHTHALATE-INDUCED TESTICULAR DAMAGE IN RATS
Assoc. Prof. Dr. Sıdıka GENÇ **Kübra KARABULUT**	Bilecik Şeyh Edebali University TÜRKİYE	THE ANTIOXIDANT ROLE OF L-TRYPTOPHAN AGAINST GLUTAMATE-INDUCED EXCITOTOXICITY IN NEUROBLASTOMA (SH-SY5Y) CELLS
Assoc. Prof. Dr. Ali TAGHIZADEHGHALEHJOUGHI **Assist. Prof. Dr. Ramazan ÇINAR** **Assoc. Prof. Dr. Sıdıka GENÇ** **Esmanur NİĞDE**	Bilecik Şeyh Edebali University TÜRKİYE	Ce_2O_3 NANOPARTICLE THERAPY AGAINST DIABETIC ENDOTHELIAL DYSFUNCTION: EFFECTS ON OXIDATIVE STRESS AND WOUND HEALING
Sadet KARABULUT KALKAN	Yalova University TÜRKİYE	NATURAL STEROIDS OF PLANT ORIGIN AND THEIR PHARMACOLOGICAL APPLICATIONS

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ONLINE PRESENTATIONS

18.12.2025 / HALL-4 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 00 : 15 00	15 00 : 17 00

HEAD OF SESSION: Dr. Gulmammadova Leyla

Authors	Affiliation	Presentation title
Farida Hajiyeva Shalala Ismayilova Fidan Ahadova Aytan Mammadzada Galina Bakhshaliyeva Konul Abbasaliyeva Elnara Gazvinova Aytan Mammadova	Azerbaijan Medical University AZERBAIJAN	FGF-23 LEVELS AND ARTERIAL CALCIFICATION IN ADVANCED CKD PATIENTS
Humay Baylar Orujova	Odlar Yurdu University AZERBAIJAN	THE ROLE OF INFECTIOUS PROCESSES IN THE OCCURRENCE OF CARDIOVASCULAR DISEASES AND OPTIMIZATION OF PREVENTIVE MEASURES
Dr. Gulmammadova Leyla Dr. Alekberzade Arzu Dr. Alizade Gunash	Scientific Research University of Pediatrics named after KY Farajova AZERBAIJAN	FAMILIAL MEDITERRANEAN FEVER (FMF)
Moustakim Rachida El Hendaoui Hajar Friki Firdaous Liba Habiba Barakat Imane Mziwira Mohamed Belahsen Rekia	Chouaib Doukkali University MOROCCO Hassan II University MOROCCO	ASSOCIATION BETWEEN OBESITY AND CHRONIC KIDNEY DISEASE IN MOROCCAN ADULT POPULATION
Assoc. Prof. Zubia Shah Assist. Prof. Dr. Sarah Shahid Assist. Prof. Dr. Farida Ahmad Assoc. Prof. Dr. Afsheen Mahmood	Khyber Girls Medical College PAKISTAN	EFFECT OF SHORT-DURATION MODERATE-INTENSITY PHYSICAL ACTIVITY ON GLYCAEMIC CONTROL AND ANTIOXIDANT CAPACITY OF PREDIABETIC POPULATION
A. I. Yaradua A. J. Alhassan M. K. Atiku K. I. Matazu A. Nasir L. Shuaibu Y.Y. Riko Z. A. Suleman I. Muhammad	Umaru Musa Yar'adua University NIGERIA Bayero University NIGERIA Federal University NIGERIA Umaru Musa Yar'adua University NIGERIA	SERUM LIPID PROFILE PREVALENCE IN MALE AND FEMALE ADOLESCENTS IN KATSINA STATE, NORTH WEST NIGERIA
Jihane HILALI Rochdi DAIBI Amine ARFAOUI Mohamed CHERTI Bouchra TAIB	Ibn Tofail University MOROCCO Mohammed V University MOROCCO Ibn Tofail University MOROCCO	PHYSICAL ACTIVITY, RISK FACTORS, AND CARDIAC HEALTH: FINDINGS FROM A CROSS-SECTIONAL STUDY

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ONLINE PRESENTATIONS

18.12.2025 / HALL-5 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
13 00 : 15 00	15 00 : 17 00

HEAD OF SESSION: Asif Mustafayev

Authors	Affiliation	Presentation title
Shahla Yusubova Rızvan Mammadov Bayramov Gasım Huseynova Parvın	Azerbaijan Medical University AZERBAIJAN	CHRONIC GENERALIZED PERIODONTITIS IN PREGNANT WOMEN WITH CHRONIC KIDNEY DISEASES
Adelya Sabir Hajiyeva Sabina Zaid Medjidova	K. Farajova Research Institute of Pediatrics AZERBAIJAN	CLINICAL CASE OF GOLDENHAR SYNDROME IN A PREMATURE INFANT BOR VIA IVF.
Salehova Gunay Dr. Isgenderova Qemer	Scientific Research University of Pediatrics named after KY Farajova AZERBAIJAN	INFANTILE HYPERCALCEMIA TYPE 2
Asif Mustafayev	Topchibashov Scientific and Surgical Center AZERBAIJAN	COMPARATIVE ANALYSIS OF THE DIAGNOSTIC EFFECTIVENESS OF COMPUTED TOMOGRAPHY AND ULTRASOUND IN THE EXAMINATION OF COMPLICATIONS AFTER CESAREAN SECTION
Loichita Adrian Oros Dacian Suciu Oana Petre Ion Petre Izabella	"Victor Babes" University of Medicine and Pharmacy Timisoara ROMANIA	ANTITHROMBIN DEFICIENCY IN PREGNANCIES WITH THROMBOPHILIA
Aytakin Hasanova Khadija Yusufova	Azerbaijan Medical University AZERBAIJAN	EARLY DETERMINATION OF FETAL SEX USING REAL-TIME PCR DETECTION OF THE TSPY MARKER IN MATERNAL PLASMA
Ardelean Maria Ioana Iurciuc Stela Petre Ion Petre Izabella	"Victor Babes" University of Medicine and Pharmacy Timisoara ROMANIA	EVOLUTION OF AUGMENTATION INDEX AND PULSE WAVE VELOCITY DURING PREGNANCY IN PREGNANT WOMEN WHO PRACTICE PHYSICAL ACTIVITY
Loichita Mihai Petre Ion Suciu Oana Bobora Razvan Furau Alexandru-Marius Petre Izabella	"Victor Babes" University of Medicine and Pharmacy Timisoara ROMANIA Western University ROMANIA	CHARLSON COMORBIDITY INDEX IN ENDOMETRIAL LESIONS

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ONLINE PRESENTATIONS

19.12.2025 / HALL-3 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Prof. Dr. Kemal Macit HİSAR

Authors	Affiliation	Presentation title
Assoc. Prof. Dr. Elif ERGÜL **Assoc. Prof. Dr. Ahmet Seyda YILMAZ**	Recep Tayyip Erdoğan University TÜRKİYE	GRAFT STENT DISLOCATION AND RECURRENT MYOCARDIAL INFARCTION IN THE ANEURYSMATIC RCA SEGMENT: CASE REPORT
Assoc. Prof. Dr. Elif ERGÜL **Assoc. Prof. Dr. Ahmet Seyda YILMAZ**	Recep Tayyip Erdoğan University TÜRKİYE	NON-ST ELEVATION MYOCARDIAL INFARCTION AND CORONARY ARTERY ANOMALY: A CASE REPORT
Assist. Prof. Dr. Bişar AMAÇ	Harran University TÜRKİYE	INVESTIGATION OF AMINO ACID METABOLIC PROFILE IN CORONARY ARTERY DISEASE PATIENTS UNDERGOING CARDIOPULMONARY BYPASS
Prof. Dr. Kemal Macit HİSAR **Prof. Dr. Filiz HİSAR**	Selçuk University TÜRKİYE Necmettin Erbakan University TÜRKİYE	EPIDEMIOLOGY OF HYPERTENSION IN TÜRKİYE
Prof. Dr. Kemal Macit HİSAR **Prof. Dr. Filiz HİSAR**	Selçuk University TÜRKİYE Necmettin Erbakan University TÜRKİYE	GLOBAL SUMMARY REPORT ON THE EPIDEMIOLOGY OF HYPERTENSION
Res. Assist. Dr. Müjgan Ayşenur ŞAHİN **Assoc. Prof. Dr. Hakan DUMAN**	Recep Tayyip Erdoğan University TÜRKİYE	LONGITUDINAL STENT DEFORMATION RELATED TO GUIDE EXTENSION CATHETER USE IN A PATIENT WITH ACUTE CORONARY SYNDROME: A CASE REPORT
Uğur Sevim KALENDER **Prof. Dr. Yasemin BEYHAN**	Hasan Kalyoncu University TÜRKİYE	EFFECTS OF THE MEDITERRANEAN DIET ON MICROBIOTA AND ITS CONTRIBUTION TO SEROTONIN PRODUCTION

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ONLINE PRESENTATIONS

19.12.2025 / HALL-4 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Assoc. Prof. Dr. Gamze ERKILINÇ

Authors	Affiliation	Presentation title
Fulya Yaylacıoğlu TUNCAY	Health Sciences University TÜRKİYE	SNORD17 MAY DRIVE IMMUNOSUPPRESSION AND PREDICTS POOR PROGNOSIS IN UVEAL MELANOMA BY MODULATING T CELL AND B CELL DYNAMICS: BIOINFORMATIC APPROACHES
Prof. Dr. Yüksel GÜMÜRDÜLÜ Dr. Anıl DELİK Assoc. Prof. Dr. Ümit KARAOĞULLARINDAN Assoc. Prof. Dr. Yakup ÜLGER Prof. Dr. Sadık DİNÇER	Çukurova University TÜRKİYE	COMPARISON OF CLINICAL DATA IN PATIENTS WITH ALPHA-FETOPROTEIN-NEGATIVE HEPATOCELLULAR CARCINOMA
Assoc. Prof. Dr. Gamze ERKILINÇ	İzmir Bakırçay University TÜRKİYE	RETROSPECTIVE ANALYSIS OF CLINICOPATHOLOGICAL FEATURES OF GLOMUS TUMORS
Assist. Prof. Dr. Gülsüm KAYA Assist. Prof. Dr. Aslı YILDIRIM Assoc. Prof. Dr. Hasan ERGENÇ	Yalova University TÜRKİYE	EPIDEMIOLOGICAL RISK FACTORS AND MORTALITY IN ADULT CANCER PATIENTS WITH CARBAPENEM-RESISTANT KLEBSIELLA PNEUMONIAE BACTEREMIA
Assist. Prof. Dr. Aslı YILDIRIM	Yalova University TÜRKİYE	CASE REPORT: EFFICASY OF NIVOLUMAB IN ADVANCED STAGE NON- SMALL CELL LUNG PLEOMORPHIC CARCINOMA WIITH SARCOMATOID DIFFERANTIATION CANCER
Anıl Selim APA	Isparta City Hospital TÜRKİYE	ETIOLOGY AND CLINICAL MANAGEMENT OF PAPILLEDEMA

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ONLINE PRESENTATIONS

19.12.2025 / HALL-5 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
08 00 : 10 00	10 00 : 12 00

HEAD OF SESSION: Dr. Nazrin HUSEYNOVA

Authors	Affiliation	Presentation title
Dr. Nazrin HUSEYNOVA Assoc. Prof. Dr. Naila RAHİMOVA Assoc. Prof. Dr. Sabira HUSEYNOVA	Scientific - Research Institute of Pediatrics AZERBAIJAN Azerbaijan Medical University AZERBAIJAN	INTERLEUKIN-33 AS A POTENTIAL BIOMARKER OF BACTERIAL INFECTIONS IN NEWBORNS
Kosayeva G.A. Kosayev A.A.	Azerbaijan Medical University AZERBAIJAN	RESULTS OF ANTIBIOTIC SENSITIVITY IN PATIENTS USING DOXYCYCLINE-ABSORBED COLLAGEN SPONGE
Elnara BAYRAMOVA Nurlana HASANOVA Sevinj KARIMOVA Lala MUSAYEVA	Azerbaijan Medical University AZERBAIJAN	TRICHOMONIASIS AND ADVERSE BIRTH OUTCOMES
Hind ALAIOUAT Zakia BERNOUSSI	Mohamed V University MOROCCO	MONOCLONALITY IN B CELL LYMPHOMA USING BIOMED-2 MULTIPLEX POLYMERASE CHAIN REACTION
Fardin Ahmed Noor Haliza Mahmud Snigdha Bhowmik Sharmin Zaman Emon Md. Latiful Bari Jannatul Ferdous	Dhaka University BANGLADESH Independent University BANGLADESH	COLLATERAL SENSITIVITY PROFILE OF MULTIDRUG RESISTANT BACTERIA: BACILLUS SUBTILIS
Nandhana R Ranjani S S. Hemalatha	B.S. Abdur Rahman Crescent Institute of Science and Technology INDIA	TRI-FLORAL MEDIATED FABRICATION OF COPPER-DOPED ZINC OXIDE NANOPARTICLES TO CONTROL WOUND INFECTION CAUSED BY ACINETOBACTER BAUMANNII
Agomoh, N, G Ukwen, C.O	School of Science and Industrial Technology NIGERIA	BURULI ULCER: A REVIEW
Ronia Parvin Hasinay Zannat Farzana Ashrafi Neela	Rajshahi University BANGLADESH	ANTIBACTERIAL EFFICACY ASSESSMENT OF HAND HYGIENE PRODUCTS COMMONLY USED IN BANGLADESH

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ONLINE PRESENTATIONS

19.12.2025 / HALL-3 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10^{30} : 12^{30}	12^{30} : 14^{30}

HEAD OF SESSION: Assoc. Prof. Dr. Mehmet Sabri BALIK

Authors	Affiliation	Presentation title
Assoc. Prof. Dr. Mehmet Sabri BALIK	Recep Tayyip Erdoğan University TÜRKİYE	EVALUATION OF POSTOPERATIVE COMPLICATIONS IN PATIENTS UNDERGOING WIDE PALMAR FASCIAL EXCISION FOR DUPUYTREN CONTRACTURE
Assoc. Prof. Dr. Mehmet Sabri BALIK	Recep Tayyip Erdoğan University TÜRKİYE	IDENTIFICATION OF SAFE ZONES FOR THE PROTECTION OF CRITICAL ANATOMICAL STRUCTURES DURING PERCUTANEOUS FIXATION OF PROXIMAL HUMERUS FRACTURES
Assoc. Prof. Dr. Mehmet Sabri BALIK	Recep Tayyip Erdoğan University TÜRKİYE	HISTOPATHOLOGICAL EVALUATION OF TISSUE SAMPLES IN PATIENTS UNDERGOING SURGICAL TREATMENT FOR CARPAL TUNNEL SYNDROME
İlker ÇAPRAK **Ayşegül TÜRKMENOĞLU**	Uşak University TÜRKİYE	FREQUENCY OF MAXILLOFACIAL SOFT TISSUE CALCIFICATIONS AND OSSIFICATIONS ON PANORAMIC RADIOGRAPHY
Destina KALKAN **Dr. Tağmaç ÖZBERK** **Assoc. Prof. Dr. İzgen KARAKAYA**	Near East University TURKISH REPUBLIC OF NORTHERN CYPRUS	EFFECT OF ER,CR:YSGG LASER ON ADHESION IN BLEACHED DENTIN
Muhammed Burhan TEKİN **Sabit DERE** **İbrahim AKKOYUN**	Konya City Hospital TÜRKİYE	SIGMOID VOLVULUS IN A 13-YEAR-OLD GIRL: CASE REPORT
Muhammed Burhan TEKİN **Sabit DERE** **İbrahim AKKOYUN**	Konya City Hospital TÜRKİYE	H-TYPE TRACHEOESOPHAGEAL FISTULA IN AN INFANT: CASE REPORT

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ONLINE PRESENTATIONS

19.12.2025 / HALL-4 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
$10^{30} : 12^{30}$	$12^{30} : 14^{30}$

HEAD OF SESSION: Samet KUŞKIRAN (observer)

Authors	Affiliation	Presentation title
Res. Assist. İbrahim Elgin OLGAR **Assoc. Prof. Dr. Muhammet FIDAN** **Assoc. Prof. Dr. Özhan YAGCI**	Uşak University TÜRKİYE	EVALUATION OF TIME-DEPENDENT COLOR DIFFERENCES IN RESIN COMPOSITES: A COMPARATIVE STUDY USING SPECTROPHOTOMETER, MOBILE APPLICATION, AND ARTIFICIAL INTELLIGENCE-BASED METHODS
Rabia KOCA **Assoc. Prof. Dr. Mehmet BULDUK** **Assoc. Prof. Dr. Veysel CAN**	Van Yüzüncü Yıl University TÜRKİYE	THE POTENTIAL OF NATURAL LANGUAGE PROCESSING TECHNOLOGIES IN CLINICAL DOCUMENT ANALYSIS AND DECISION SUPPORT SYSTEMS: A COMPILATION STUDY
Rabia KOCA **Assoc. Prof. Dr. Mehmet BULDUK** **Assoc. Prof. Dr. Veysel CAN**	Van Yüzüncü Yıl University TÜRKİYE	ARTIFICIAL INTELLIGENCE-BASED PREDICTIVE MODEL FOR BIG DATA ANALYSIS IN HEALTH INFORMATICS: A SYSTEMATIC REVIEW
Assist. Prof. Dr. Esin KAVURAN **Hasan SAĞLAM**	Atatürk University TÜRKİYE	THE CONTRIBUTION OF TELE-NURSING INTERVENTIONS TO ADOLESCENT NUTRITIONAL HABITS IN THE CONTEXT OF DIGITAL HEALTH LITERACY: CURRENT EVIDENCE
Assist. Prof. Dr. Esin KAVURAN **Hasan SAĞLAM**	Atatürk University TÜRKİYE	TELE-NURSING INTERVENTIONS IN CHRONIC DISEASE MANAGEMENT: IMPACTS ON PATIENT SAFETY, DIGITAL HEALTH LITERACY, AND HEALTH INEQUITIES
Lect. Sinan İRTEGÜN **Assoc. Prof. Dr. Gönül GÖKÇAY**	Ardahan University TÜRKİYE Kafkas University TÜRKİYE	SEMANTIC INTEROPERABILITY AND ARTIFICIAL INTELLIGENCE INTEGRATION IN DIGITAL HEALTH SYSTEMS THROUGH STANDARD NURSING TERMINOLOGIES: TECHNICAL CHALLENGES AND ETHICAL DIMENSIONS
Lect. Sinan İRTEGÜN **Assoc. Prof. Dr. Gönül GÖKÇAY**	Ardahan University TÜRKİYE Kafkas University TÜRKİYE	TRANSFORMATIONAL EFFECTS OF STANDARDIZED NURSING TERMINOLOGIES ON CLINICAL PRACTICE, QUALITY OF CARE, AND PROFESSIONAL AUTONOMY: AN EVIDENCE-BASED LITERATURE REVIEW

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ONLINE PRESENTATIONS

19.12.2025 / HALL-5 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
$10^{30} : 12^{30}$	$12^{30} : 14^{30}$

HEAD OF SESSION: Major Gheorghe GIURGIU

Authors	Affiliation	Presentation title
Hilala Fariz Abbasova	Azerbaijan Medical University AZERBAIJAN	NEW EXPERIMENTAL MODEL OF ACUTE PANCREATITIS WITH ADJUSTABLE DEGREE OF DESTRUCTIVE CHANGES
Kamal Smimih **Fatima Ez-Zahraa Saad** **Manal Khanouchi** **Mohamed Merzouki** **Omar El Hiba**	Sultane Moulay Slimane University MOROCCO Chouaib Doukkali University MOROCCO	PRENATAL EXPOSURE TO ETHANOL INDUCES ALTERATIONS IN PURKINJE NEURONS POTENTIALLY LINKED TO SENSORIMOTOR DEFICITS
Manal Khanouchi **Bilal EL-Mansoury** **Arumugam R. Jayakumar** **Omar El Hiba**	Chouaib Doukkali University MOROCCO University of Miami School of Medicine USA	THE COMBINED EFFECTS OF NEUROINFLAMMATION AND AMMONIA NEUROTOXICITY CONTRIBUTE TO COGNITIVE IMPAIRMENT IN CHRONIC HEPATIC ENCEPHALOPATHY
Mammadzada A.Y. **Ibrahimova N.Y.** **Safaraliyeva L. Kh.** **Guliyeva A.A.** **Muradova S.R.** **Huseynova N.I.**	Azerbaijan Medical University AZERBAIJAN	MECHANISMS OF INVOLVEMENT OF OXIDATIVE STRESS AND LYMPHATIC DRAINAGE IN THE PATHOGENESIS OF DIABETIC MICROANGIOPATHIES
Sabina GULIYEVA **Khayala MAMMADOVA**	Azerbaijan Medical University AZERBAIJAN	ALLOSTERIC MODULATION OF ENZYMES AND ITS FUNCTIONAL SIGNIFICANCE IN CELLULAR METABOLISM
Dilara ALIYEVA **Tariyel ISMAYILOV** **Asiya AGHAYEVA** **Mehriban KAZIMOVA** **Khayala MAMMADOVA**	Azerbaijan Medical University AZERBAIJAN	INTEGRATED RENAL MECHANISMS OF FLUID AND ELECTROLYTE HOMEOSTASIS
Rabar Mohammed Hussein	Noble Technical Institute IRAQ	EVALUATION OF ERYTHROCYTE SEDIMENTATION RATE (ESR): SAMPLING TECHNIQUES AND CLINICAL INTERPRETATION
Prof. Dr. Manole COJOCARU **Major Gheorghe GIURGIU**	Titu Maiorescu University ROMANIA Deniplant-Aide Sante Medical Center ROMANIA	THE GUT-BRAIN-SKIN AXIS IN ACNE: IMPACT OF POLENODERM
Major Gheorghe GIURGIU **Dr. Cristina FERNOAGA** **Prof. Dr. Manole COJOCARU**	Deniplant-Aide Sante Medical Center ROMANIA University Veterinary Emergency Hospital Prof. Univ.Dr. Alin Bîrțoiu ROMANIA Titu Maiorescu University ROMANIA	GUT DYSBIOSIS IN DOGS WITH SPINAL CORD INJURY: IMPACT OF POLENOPLASMIN
AKHELLOUF Fatima Zahra **QASMAOUI Aicha** **OUAKRIM Houcine** **AZZOUZI Maryame** **ADLAOUI El Bachir** **AMARIR Fatima** **CHAROF Reda**	Hassan II University MOROCCO National Institute of Hygiene MOROCCO	ANTI-INFECTIVE PROPERTIES OF MOROCCAN MYRTUS COMMUNIS L. ESSENTIAL OIL

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ONLINE PRESENTATIONS

19.12.2025 / HALL-6 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
10 30 : 12 30	12 30 : 14 30

HEAD OF SESSION: Prof. Dr. Shalva Zarnadze

Authors	Affiliation	Presentation title
Assoc. Prof. Dr. Anna Kopiczko Patrycja Widłak Joanna Cieplińska Wiktoria Pietrzak M.Sc. Jakub Bałdyka	Józef Piłsudski University of Physical Education POLAND	CROSS-SECTIONAL ANALYSIS OF DIETARY HABITS, DAIRY CONSUMPTION, BODY COMPOSITION, AND PHYSICAL ACTIVITY LEVEL AS PREDICTORS OF FOREARM BONE MINERAL DENSITY IN YOUNG POLISH MEN
Palash Kumar Das	Hajee Mohammad Danesh Science and Technology University BANGLADESH	DIETARY TRADE-OFFS IN HIGHER EDUCATION: A QUANTITATIVE COST-NUTRITION MODEL
Rochdi DAIBI Jihane HILALI Jaouad ROUANE Youssef SQALLI HOUSSAINI El Mokhtar ELOUALI Fouad BOUGHANZAI Walid Bouzid Abdelhalem MESFIOUI	Ibn Tofail University MOROCCO Hassan I University MOROCCO	EFFECTS OF ACUTE AND CHRONIC HIGH-INTENSITY INTERVAL TRAINING ON COGNITIVE AND PHYSICAL PERFORMANCE IN HIGH SCHOOL ADOLESCENTS
Morad Kaddouri Ait Melloul Abdelaziz Omar Ait El Alia Khalid Boutoial	Sultan Moulay Slimane University MOROCCO Higher Institute of Nursing Professions and Health Technology MOROCCO	EPIDEMIOLOGICAL PROFILE OF THE COLLECTIVE FOODBORNE TOXI-INFECTIONS IN MOROCCO
Prof. Dr. Shalva Zarnadze Prof. Dr. Irine Zarnadze	TSMU, Deapartement of Nutrition, Aging Medicine, environmental and occupational health GEORGIA	ONE HEALTH EDUCATION, HEALTH LITERACY, "HEALTHY PEOPLE 2030"AND DEVELOPED PROCESES
S.Rubinthara R.Swathi E.Praveena N.ArshadAhamed D.Aravindhan R.SriArasuvasan K.Vaishnavi K.Dinesh Rajan K. Vijayalakshmi	Bharath Institute Of Higher Education And Research Chennai INDIA	THE ROLE OF COMMUNITY PHARMACISTS IN VACCINATION PROGRAMS
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THE IMPACT OF AI ON PUBLIC HEALTH

David John WORTLEY

World Lifestyle Medicine Education Services, London, United Kingdom

ORCID ID: https://orcid.org/0000-0001-5598-6987

ABSTRACT

Artificial intelligence (AI) is rapidly reshaping public health, offering transformative opportunities while presenting emerging challenges. In clinical settings, AI enhances diagnostic accuracy, supports personalised treatment planning, and enables early detection of diseases through the analysis of large-scale biomedical data. These applications can improve physical health outcomes, reduce healthcare inequalities, and strengthen population-level surveillance. AI-driven decision support tools also augment workforce capacity, particularly in overstretched health systems. However, risks include algorithmic bias, over-reliance on automated systems, reduced clinician–patient interaction, and data privacy concerns, all of which may compromise quality of care or exacerbate disparities.

Beyond clinical environments, AI influences physical and mental health through everyday technologies. Wearables, digital coaching, and behaviour-change applications can promote physical activity, healthier lifestyles, and self-management of chronic conditions. Conversely, algorithmically curated social media and persuasive design may heighten anxiety, loneliness, and misinformation exposure, increasing mental health burdens. Additionally, automation-related job insecurity and rapid societal change may contribute to stress and inequity.

Overall, AI holds significant promise for advancing public health but requires robust governance, ethical design, and interdisciplinary collaboration to maximise benefits while minimising harm. A balanced approach will ensure AI strengthens health systems and supports wellbeing across diverse populations.

Key Words: Artificial intelligence (AI), Public health, Diagnostics, Personalised medicine, Digital health, Wearable technologies, Behaviour change, Social media impact, Ethical AI

SNORD17 MAY DRIVE IMMUNOSUPPRESSION AND PREDICTS POOR PROGNOSIS IN UVEAL MELANOMA BY MODULATING T CELL AND B CELL DYNAMICS: BIOINFORMATIC APPROACHES

Fulya Yaylacıoğlu TUNCAY

Health Sciences University, Gulhane Faculty of Medicine, Department of Medical Biology, Ankara, Turkey

ORCID ID: https://orcid.org/0000-0002-2088-3416

ABSTRACT

Introduction and Purpose: Uveal Melanoma (UM) is the most common primary intraocular malignancy in adults, originating from melanocytes in the uveal tract (the iris, ciliary body, and choroid). Despite its relative rarity compared to cutaneous melanoma, UM is a clinically significant disease due to its high potential for metastasis, predominantly to the liver. The molecular drivers that shape this immunosuppressive versus immunoreactive microenvironment remain poorly understood. In this context, non-coding RNAs, including Small Nucleolar RNAs (snoRNAs), are emerging as novel regulators of cancer biology. SnoRNAs, including SNORD17, traditionally known for guiding ribosomal RNA modification, are now recognized for their potential roles in oncogenesis, metastasis, and immune modulation. This study aims to characterize the expression profile of SNORD17 and its correlation with the tumor immune microenvironment and patient prognosis.

Materials and Methods: SNORD17 expression profiles and their association with clinical parameters in UM were interrogated using the UALCAN portal. Gene correlation analyses with oncogenic pathways were performed with data from OncoDB. The prognostic value of SNORD17 expression was determined through overall survival analysis utilizing the GEPIA2 database. Finally, the relationship between SNORD17 expression levels and the abundance of tumor-infiltrating immune cells was systematically investigated using the TIMER2.0 database.

Results: Our analysis identified high SNORD17 expression as a significant negative prognostic marker in UM. This poor prognosis is mechanistically linked to a suppressed anti-tumor immune response. Specifically, a high SNORD17 environment was associated with the functional impairment of cytotoxic T cells, a finding potentially driven by a significant increase in regulatory T cell (Treg) infiltration coupled with a decrease in naive B cells. These results provide a mechanistic basis for the role of SNORD17 as a driver of tumor immune evasion and a potent negative prognostic biomarker.

Discussion and Conclusion: Our findings show that SNORD17 is an important modulator of the immunosuppressive conditions in UM and a strong prognostic predictor. The gene's association to decreased cytotoxic T cell activity suggests a possible mechanism of immune evasion. Furthermore, the existence of TLS and naïve B cells acts as a counteracting, positive signal. These findings highlight the essential balance of suppressive and activating immunological components in UM, positioning SNORD17 as a possible target for future therapies.

Key Words: Uveal Melanoma; SNORD17; Small Nucleolar RNAs; microenvironment, immune modulation

EFECTS OF THE MEDITERRANEAN DIET ON MICROBIOTA AND ITS CONTRIBUTION TO SEROTONIN PRODUCTION

MSc. Uğur Sevim KALENDER

Hasan Kalyoncu Üniversitesi, Sağlık Bilimleri Enstitüsü, Beslenme ve Diyetetik Bölümü

Prof. Dr. Yasemin BEYHAN

Hasan Kalyoncu Üniversitesi, Sağlık Bilimleri Fakültesi, Beslenme ve Diyetetik Bölümü

ABSTRACT

The Mediterranean diet model characterized by nutrient-dense foods such as olive oil, high-fiber whole grains, fruits and vegetables, legumes, and abundant seafood represents a powerful nutritional approach with well-established scientific evidence supporting its positive health effects. The beneficial influence of this dietary model on the gut microbiota and its reflections on neurobiological processes have become some of the most prominent research topics in recent years. The aim of this study is to comprehensively examine the potential contributions of Mediterranean diet components to serotonin production through their modulatory effects on the gut microbiota profile.English and Turkish articles published between 2013 and 2025 were searched using the PubMed, Scopus, and Web of Science databases. Human or animal studies, reviews, and original research related to the Mediterranean diet, gut microbiota, and/or serotonin production were included. Studies that did not involve a dietary intervention or were unrelated to microbiota or serotonin were excluded. The ovarian inflammation and necrosis were found to be highest in transplantation group ($p<0.05$). The comparison including all groups revealed that tissue necrosis and inflammation were unfavorably affected in HC-treated group. The Mediterranean diet positively influences the microbiota, particularly through polyphenols in olive oil, fibers in grains and fruits-vegetables, and omega-3 fatty acids found in fish and seafood. It promotes increases in beneficial bacterial species such as Bifidobacterium and Faecalibacterium prausnitzii. In addition, short-chain fatty acids produced by the microbiota can modulate neurotransmitters via the gut–brain axis and stimulate serotonin synthesis by increasing enterochromaffin cells, potentially contributing to improved mood and behavior. As serotonin levels in studies are often assessed through plasma or fecal biomarkers, findings on causality remain largely correlational, and evidence regarding central nervous system levels is limited. These studies, considered important for both gastrointestinal health and psychological well-being, carry the potential to inform new therapeutic strategies targeting neuropsychiatric and metabolic health through diet-based interventions within the gut–brain axis. Future research should focus on long-term, controlled human studies exploring the effects of Mediterranean diet components on microbiota and serotonin.

Keywords: Mediterranean diet, Gut microbiota, Serotonin, Tryptophan metabolism, Gut-brain axis

INTRODUCTION

Akdeniz diyeti, özel bir beslenme şekli olmanın ötesinde, bulunduğu coğrafyanın kültürel bir çok rengini eskitmeden taşıyan, içerdiği besin gruplarının yetiştirilmesi, hazırlanması,

saklanması ve sunulması süreçlerini son derece güçlü ve etkisini kaybetmeden kuşaklararsı aktaran, canlı bir beslenme modelidir (Serra-Majem et al., 2019). Koroner kalp hastalıkları ile kansere bağlı mortalite riskine karşı güçlü etkiler sunmuş 1950 yılında yapılan çalışmalarla analiz edilen Akdeniz diyetindeki yağın türü, 'Akdeniz Diyeti' kavramının gelişmesinde öncü olmuştur (Davis et al., 2015; Serra-Majem et al., 2004). Araştırmalar, zaman içerisinde birçok kronik hastalığa olumlu yanıt veren bu diyetin, bağırsak mikrobiyotasını da olumlu yönde etkilediğini göstermiştir. Bu yönüyle bilişsel sağlık üzerinde de önemli ölçüde rol oynadığı kanıtlanmıştır (Kiani et al., 2022; Bucciantini et al., 2021).

Bağırsak mikrobiyotası ile besin tüketimi arasındaki ilişkinin moleküler düzeydeki mekanizması hala tam anlamıyla bilinmese de; aralarındaki çift yönlü ve güçlü etkileşim oldukça fazla kabul görmektedir. Ayrıca mikrobiyal floranın bağışıklık sistemi üzerindeki yanıtları ile vagus siniri aracılığıyla gerçekleşen sinirsel iletim ve mikrobiyal kökenli nörometabolitlerin üretimi gibi çeşitli biyolojik yolakların bu süreçte rol oynadığı düşünülmekte ve beslenme temelli müdahalelerin mikrobiyotayı şekillendiren en etkili çevresel etkenlerden biri olduğu düşüncesi benimsenmektedir (Barrea et al., 2021).

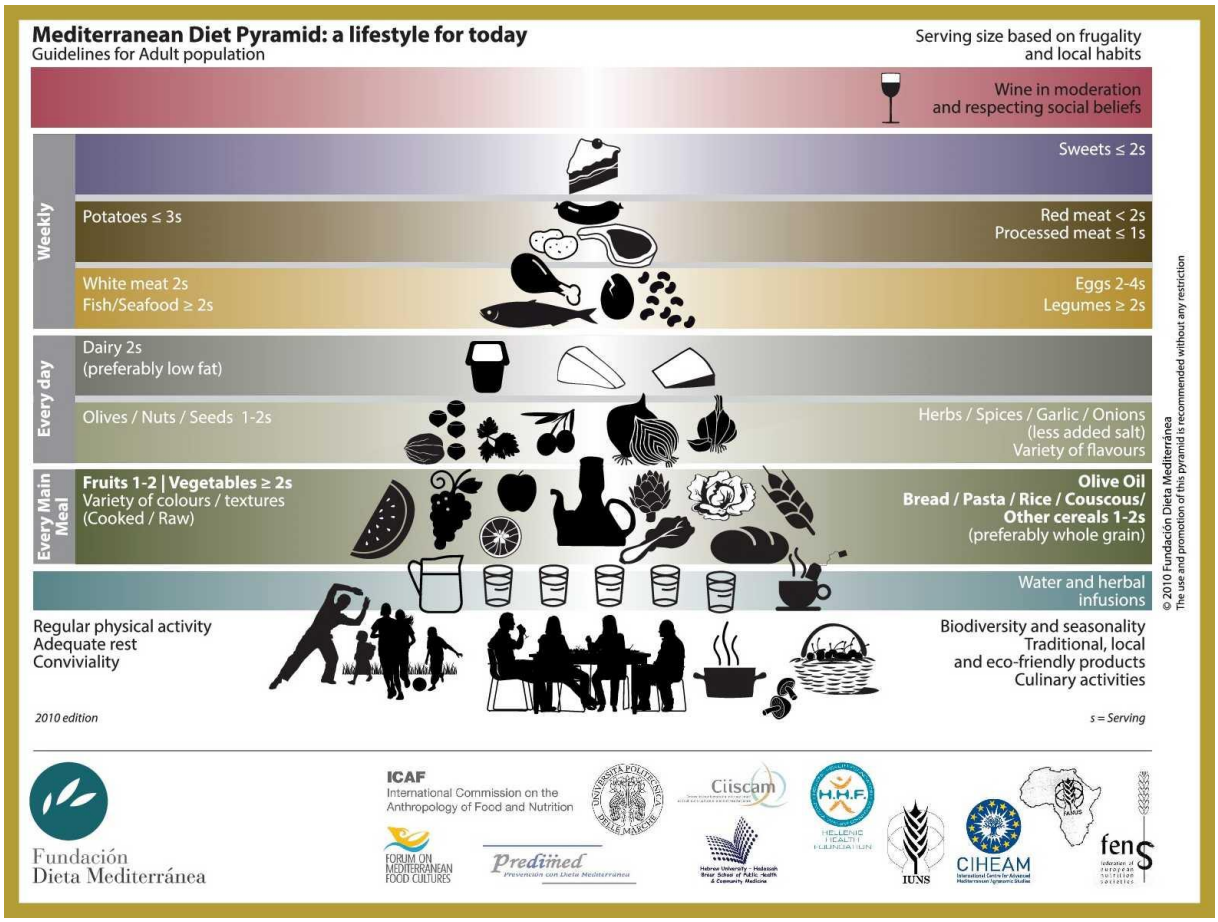
Bu bağlamda, bağırsaktan iletilen nörotransmitterlerin yanıtları büyük önem taşımaktadır. Serotonin (5-hidroksitriptamin), ruh halini etkileyen güçlü metobolitlerden biri olup, triptofan aminoasidinin biyokimyasal dönüşümüyle bağırsaklarda oluşur (Dinan et al., 2013). Pek çok fizyolojik sürecin yönetilmesinde kritik rol oynayan serotonin, merkezi sinir sistemindeki ve bağırsak miyenterik pleksusundaki serotonerjik nöronlar, gastrointestinal sistemin mukozasında bulunan enterokromaffin hücreleri ve kan trombositleri olmak üzere vücutta üç temel hücre tipinde depolanmaktadır (Sarkar et al., 2016). Serotonerjik nöronlar ile enterokromaffin hücreleri, serotonin sentezinde kullanılan öncü molekül L-triptofanı işleyerek bu nörotransmitteri oluşturabilmektedir. Serotonin biyosentezinde ilk adım, L-triptofanın L-triptofan hidroksilaz (TPH) enzimi aracılığıyla 5-hidroksitriptofana (5-HTP) dönüştürülmesidir. Bu süreç, hem bağırsak hem de merkezi sinir sistemi serotonininin oluşumunda temel biyokimyasal yol olarak kabul edilmektedir (Cheng et al., 2019).

CONCEPTUAL FRAMEWORK

Akdeniz Diyetinin Kökeni ve Tarihçesi

Akdeniz diyeti, arkeolojik kazılarda, tarihi sanat eserlerinde ve Homeros gibi antik çağların önemli isimlerinin yazıtlarında dahi yer bulan, kökeni milattan öncesine dayanan bir beslenme modelidir (Kromhout et al., 1989). Akdeniz havzasında yetişen besinler ve bu besinleri tüketen toplumların beslenme şeklinin bilimsel olarak ilk kez tanımlanması, 1952'de araştırmaya başlayan Ancel Keys ve arkadaşlarının, 1960 yılında 'The Seven Country Study' adlı çalışmayı tamamlaması ile gerçekleşmiştir (Selimoğlu & Gültekin, 2018; Ersoy & Özdemir, 2010; Naska & Trichpolou, 2014; Nestle, 1995). UNESCO'nun (Birleşmiş Milletler Eğitim, Bilim ve Kültür Örgütü) 2010 yılında 'İnsanlığın Somut Olmayan Kültürel Bir Mirası' seçtiği Akdeniz diyeti; Akdeniz havzasındaki ülkelerin tüketim sıklığına, çeşidine ve şekline göre gösterdiği benzerlikleri tek bir zeminde toplayarak, bitkisel besinlerin yoğun, hayvansal besinlerin sınırlı olduğu bir piramitle modellenmiştir (Guasch- Ferré &Willet, 2021). 1993 yılında, Dünya Sağlık Örgütü (WHO) ve Gıda ve Tarım Örgütü (FAO)'nün tasarladığı Akdeniz Besin Piramidi, 2009 yılında İtalya'da gerçekleştirilen 'Sürdürülebilir Bir Diyet Olarak Akdeniz Diyeti' adlı bir konferansta tekrar ele alınmış ve 2010 yılında yapılan Uluslararası Bilimsel Konsensüs'te güncel haliyle yayınlanmıştır (Gönder & Akbulut, 2017; Gönder, 2015). Bu piramitte yer alan besinlerden zeytinyağı, Akdeniz havzasındaki ülkelerin tükettiği ortak besinler içinde en büyük paydaya sahip olduğu için, diyetin merkezini de zeytin ve zeytinyağı oluşturur. Piramidin en

alt ve en büyük kısmında, yani sürekli tüketilmesi gereken bölümde yer alan zeytinyağı ile birlikte; tahıllar ve sebze-meyve bulunur. Her öğün tüketime uygun bulunan saflaştırılmamış tam tahıllar günde 1-2 porsiyon, 1 porsiyonu pişmemiş olmak koşulu ile sebze 2 ve üzeri porsiyon ve meyve ise 1-2 porsiyon olmak şartıyla piramidin en altında yer alır. (Tosti et al., 2018; Bach-Faig et al., 2011). Yine her öğün tüketilmesi önerilen ve miktarları belirtilen besinlerden zeytin, zeytinyağı, yağlı tohumlar, baharatlar, soğan ve sarımsak da bu kısımda bulunur (Dernini & Berry, 2015). Piramidin üstlerine doğru çıkıldıkça küçülen orta alanlarda, orta düzeyde tüketilmesi önerilen hayvansal gıdalardan; süt, peynir ve yoğurt yer alır. Yoğurt ve peynir süte kıyasla daha fazla önerilmektedir. Yemekle birlikte tüketilen kırmızı şarap ve bazı alkol türleri de orta düzeyde tüketilen gruplar arasında yer alır (Gönder ve Akbulut, 2017). Haftalık tüketilmesi gereken besinler arasında, piramidin orta kısmında; başta balık ve deniz mahsulleri haftada 2 porsiyon ve üzeri olmak üzere, patates, kuru baklagiller, yumurta ve beyaz et (kümes hayvanları) yer alır. Kırmızı et ve işlenmiş et türleri, haftada 2 porsiyondan daha az tüketilmesi önerilen, piramidin en üst kısımlarında bulunur (Castro-Quezada, Román-Viñas et al., 2014). Piramidin tepesindeki en küçük kısmı, özel günlerle sınırlı tutulması gereken, işlenmiş ve rafine gıdalardan elde edilen basit şeker içeren, enerji oranı yüksek, besin değeri düşük, sağlıksız yağlar açısından yoğun, besinler oluşturur. Ayrıca piramitte günlük en az 1,5-2 litre su tüketilmesi gerektiği de vurgulanmıştır (Dernini & Berry, 2015). Şekil 1'de Akdeniz diyet piramidi gösterilmiştir.



Şekil 1. Akdeniz diyet piramidi (Bach-Faig et al., 2011).

Akdeniz Diyeti Bileşenleri

Zeytinyağı

Akdeniz diyet modelinin mihenk taşını oluşturan zeytinyağı, günde 25-50 mL tüketilmesi önerilen ve 'Olea Europa' olarak bilinen zeytin ağacı meyvesinin soğuk sıkımıyla elde edilen bir yağ türüdür (Serra-Majem, 2019). Zeytinyağının, yağ asidi bileşenleri arasında %98 oranında oleik asit, %2 oranında squalene (C30 H50) doymamış yağ asidi hidrokarbonları yer alır. Ayrıca tokoferol, polifenol ve pigmentler gibi içerikleri ile antioksidan ve antiinflamatuvar bileşenler de ihtiva eder (Kouka et al., 2020). 100 gr yani ortalama 7 yemek kaşığı zeytinyağında; A vitamini öncüllerinden 1-2 mg karetenoid, E vitamini öncüllerinden 25 mg α-tokoferol, 98-185 mg arasında fitosterol ve 20-500 mg arasında da oleuropein yer alır (Bach-Faig et al., 2011). Yetişme koşullarına bağlı olarak luteolin, apigenin ve rutin içerikleri farklılık gösterse de, en temel 4 bileşiği olan; flavonoidler, lignanlar, basit fenolik bileşikler ve sekoiridiodler her çeşidinde mevcuttur (Hoffman & Gerber, 2015). Özellikle antioksidan etkisini, polifenoller ile gösteren zeytinyağının tespit edilemeyen daha fazla bileşiği olduğu düşünülmektedir. Bu polifenollerden en bilineni ve siklooksijenazların aktifleşmesini baskılayarak nörolojik olarak koruyucu etki göstereni oleoktalandir (Huang & Sumpio, 2008). Zeytinyağındaki polifenollerin Akdeniz diyetine antiinflamatuvar etkisinin yanında; antimikrobiyal, antianjiyogenik ve antiproliferatif etkileri olan, aterosklerotik ve trombotik yolaklarda pıhtılaşmayı önleyici, fibrinoliz üzerinde, lipid oksidasyonunda ve trombosit agregasyonunda olumlu etkiler gösteren yapılar olduğu görülmüştür (Bucciantini et al., 2021). Oleik asidin vücutta dönüşerek biyoyararlılık gösterdiği oleamid bileşiği, serotonin reseptörlerinin bağlanmasında etkili, ağrıya olan duyarlılığı azaltan ve uykuya geçişi kolaylaştıran bir zeytinyağı bileşenidir (Casas et al., 2018).

Sebze ve Meyveler

Akdeniz diyetinin en önemli bileşenlerinden biri de taze, kurutularak, veya geleneksel özel yöntemlerle saklanan ve yılın her mevsimi tüketime sunulan sebze ve meyvelerdir (Naska & Trichpolou, 2014). Her ne kadar enerji içeriği ve protein yoğunluğu açısından yetersiz olsa da sebze-meyveler; antioksidan etkili vitamin, mineral ve polifenoller açısından oldukça zengin kaynaklardır. Başta klorofil olmak üzere, karotenoidler ve flavonoidler sayesinde yeşil renk, likopen ve antosiyaninler ile kırmızı renk, karotenoidlerin farklı türleri ile sarı-turuncu renk ve flavonoidlerin diğer türleri ile de beyaz renk veren pigmentler sayesinde sebze-meyveler hem rengarenk bir görsel sunar, hem de güçlü bir antioksidan rezervi taşır. Bununla birlikte, sebze ve meyveler lif içerikleri sayesinde sindirim sisteminin düzenli çalışmasına önemli katkı sunarlar (Liu, 2013). Sebze ve meyveler, sadece içerdikleri bu güzel renk pigmentleri ve vitamin-mineral depoları ile değil ayrıca içerdikleri fenolik bileşikler, alkoloidler, flavonoidler, karotenoidler ve fitosteroller ile de kronik hastalıklar üzerindeki koruyucu etkiler gösterirler. Isıya hassas oldukları için çiğ tüketilmesi gereken ve böylelikle her an tüketime hazır bulunan çiğ sebzeler, salatalar ve az pişirilmiş bitkilerde, yalnızca taze sebzelerin sağladığı antioksidanlar değil; tat zenginliği oluşturmak ve enerji değerini artırmak için eklenen zeytinyağı, kurutulmuş baharatlar, sirke ve probiyotik bakteri içeriği artırılmış baharat karışımları da antioksidan kapasiteyi önemli ölçüde artırmaktadır (Garritano et al., 2005). Mental sağlık üzerinde etkili olan ve depresyon semptomlarını azaltmayı hedefleyen araştırmalar, sebze ve meyve tüketiminin bu açıdan önemli bir rol oynadığını ortaya koymaktadır (Turati et al., 2015). Günde en az bir porsiyon sebze-meyve alımının mental sağlık açısından koruyucu etkisi olduğu, tüketim sıklığı ve miktarının da bu etkiyi belirlediği bildirilmiştir (Godos et al., 2016).

Tam Tahıllar ve Kurubaklagiller

Akdeniz diyetinde, günlük enerji ihtiyacının karşılanmasında en büyük orana sahip olan kompleks karbonhidratlar, diyetle oldukça önemli bir yere sahip tam tahıllı besin kaynakları ile sağlanır (Williamson, 2017). Geleneksel Akdeniz beslenme modelinde yer alan yulaf, çavdar ve kepek gibi lif açısından zengin gıdalar; modern Batı ülkelerinin beslenme rutininde yaygın olan beyaz ekmek, patates, pirinç gibi yüksek glisemik indeksli gıdalar yerine, daha düşük ve dengeli bir glisemik indekse sahiptir (D'Alessandro et al., 2016; Widmer et al., 2015). Tam tahıllar, fizyolojik süreçlerde pek çok reaksiyona katılan biyoaktif bileşenlerle zenginleştirilmiştir. Kükürtlü aminoasitler ve elzem yağ asitlerinden *ω*-3 yağ asitlerini içerirler (Gangwisch et al., 2015). Nöronal işlevlerin sürdürülmesi için gerekli B grubu vitaminlerinden B6 vitamini, serotonin sentezinde görev alır. Bu durum, Gangwisch ve arkadaşlarının (Kim et al., 2016), tam tahıl tüketimi ile psikolojik bozukluklar arasındaki ilişkiyi incelemesine yol açmıştır. Sonuçlar, tam tahıllı karbonhidrat tüketen bireylerin psikolojik durumlarının daha iyi olduğunu göstermiştir (Crichton et al., 2013).

Baklagillerde bulunan polifenollerden flavonoller; enerji homeostazında görev alır, kan basıncını ve kolsterolü düşürür ayrıca endotel disfonksiyonunu azaltmaya yardım eder (Williamson, 2017). Çözünebilir ve çözünemez lif yapılarının yanı sıra rafinoz ve dirençli nişasta gibi oligosakkaritler açısından da zengin olan baklagiller, bağırsak mikrobiyotası için oldukça değerli bir besin ortamı sağlar (Papandreou et al., 2019).

Balık ve Deniz Ürünleri

Akdeniz beslenme modelinde temel protein kaynaklarından biri olan balık ve deniz ürünleri, A, D, K ve B grubu vitaminleri ile iyot, fosfor, çinko, demir, selenyum ve kalsiyum gibi önemli mineraller bakımından oldukça zengindir (Naska & Trichopoulou, 2014). Bu besinler, yüksek biyo-yararlanımlı protein içeriğine ek olarak düşük kolesterol düzeyi ve çoklu doymamış yağ asitleri (ÇDYA) açısından da dikkat çekici bir profile sahiptir. Özellikle Akdeniz diyetinin temel bileşenlerinden biri olarak kabul edilen ω-3 yağ asitleri, sağlıklı metabolik işlevlerin sürdürülebilmesi için gereklidir (Ortega, 2006). Balık tüketimi ile depresyon arasındaki ilişkiyi inceleyen 10 farklı çalışmanın meta-analiz sonuçlarına göre, yüksek düzeyde balık tüketen bireylerde depresyon gelişme riski, düşük balık tüketen bireylere kıyasla %11 daha az bulunmuştur (Gillum et al., 1996).

Yağlı Tohumlar, Sert Kabuklu Yemişler ve Süt Ürünleri

Yağlı tohumlar olarak adlandırılan fındık, fıstık, susam ve ceviz gibi besinler; protein, tekli ve çoklu doymamış yağ asitleri (TDYA, ÇDYA), E vitamini, B vitaminleri ve mineraller açısından değerli kaynaklardır (Liu, 2013). Sert kabuklu yemişler; protein, elzem yağ asitleri, B6 vitamini, folik asit, niasin, E vitamini, kalsiyum, magnezyum, potasyum, çinko, selenyum, fitosteroller ve fenolik bileşikler bakımından oldukça zengindir (Huang & Sumpio, 2008). Bitkisel yağ içeren besinler, kolesterole benzer şekilde esterleşebilen yağ fraksiyonları olan fitosteroller bakımından zengindir. Bu fitosteroller, plazmadaki kolesterolün çözünürlüğünü artırarak dokularda emilimini azaltır ve böylece damar içinde birikebilecek veya kanın yoğunluğunu artırabilecek kolesterol birikiminin önüne geçer (Ortega, 2006).

Akdeniz beslenme modelinde süt ve süt ürünleri en çok yoğurt ve peynir formunda tüketilmektedir (Naska & Trichopolou, 2014). Karbonhidrat, protein ve yağı bir arada bulunduran bu besin grubu; ayrıca yoğun miktarda vitamin, mineral ve su içeriğiyle beslenmede özel bir konuma sahiptir (Liu, 2013). Akdeniz diyetinde süt ve süt ürünlerinin düşük ila orta düzeyde tüketilmesi önerilmekte olup (Hockey et al., 2019), bu besinler biyoaktif bileşikler bakımından da oldukça zengindir.

Prebiyotikler ve faydalı mikroorganizmalar açısından değerli kaynaklar olan süt ürünleri; pastörizasyon, fermentasyon ve filtrasyon gibi işlemler sonrasında farklı biyoyararlılık profili kazanırlar (Bartram et al., 1994). Beyin–bağırsak ekseninde önemli rol oynayan probiyotik bakteriler, depresyon gibi nöropsikiyatrik bozukluklarda beslenmenin etkisini açıklayan önemli bileşenlerdir. Prebiyotik potansiyeli yüksek süt ve süt ürünleri, bu açıdan depresyon riskini azaltabilecek besin grupları arasında değerlendirilmektedir. Fermente süt ürünlerinde bulunan mikroorganizmalar, bağırsak probiyotik çeşitliliğini artırarak dolaylı yoldan ruhsal durum üzerinde olumlu etkiler yaratabilirken; bunun tersine tam yağlı süt ürünleri ise bileşimlerinde yer alan doymuş yağ asitleri nedeniyle bunların plazma düzeyini yükselterek inflamatuvar süreçleri ve depresif semptomları tetikleyebildiği bildirilmektedir (Zelber-Sagi et al., 2018).

Kırmızı Et ve Kümes Hayvanları

Akdeniz beslenme modelinde oldukça sınırlı bir yere sahip et ve işlenmiş et ürünleri; yüksek protein ve yağ içeriklerinin yanı sıra B12 vitamini, demir, çinko, doymuş yağ asitleri ve sodyum açısından zengin olan bir besin grubudur (Gnagnarella et al., 2013). Bununla birlikte kırmızı etin aynı zamanda metabolizmasında ortaya çıkan araşidonik asit (AA), eikosapentaenoik asit (EPA) ve dokosahekzaenoik asit (DHA) gibi yağ asitlerinin inflamasyon seyrini etkileyebildiği bilinmektedir. Özellikle aşırı miktarda alınan AA, bağırsak mikrobiyotasında Bacteroides enterotype üyelerinin artışıyla birlikte beyin–bağırsak ekseninde depresif süreçleri tetikleyebilmektedir (Abildgaard et al., 2011). Hayvan deneylerinde yapılan çalışmalar da bu ilişkiyi desteklemekte; özellikle tam yağlı kırmızı etle beslenen ratlarda depresif davranışların arttığı, yağsız veya az yağlı kırmızı etle beslenen gruplarda ise bu etkinin belirgin şekilde azaldığı gösterilmiştir (Abildgaard et al., 2011; Haseeb et al., 2018).

Kırmızı Şarap

Romalıların İtalya ve çevresinden tüm dünyaya yaydıkları ve özellikle kırmızı üzümden elde edilen kırmızı şarap, Avrupa'daki Akdeniz ülkelerinin yemekle birlikte tüketmesiyle Akdeniz diyetinde orta düzeyde tüketilmesi önerilen ve antioksidanlar ile flavonoidler bakımından zengin bir içecektir (Chaplin et al., 2018; Dayi & Ozgoren, 2022). Serotonin senteziyle birlikte melatonin sentezini de uyaran L-triptofan aminoasidi, vücutta şaraptan üretilen geniş spektrumlu bir antioksidan indolamindir. Üzüm kabuğunda bulunan melatoninin, şarap üretiminde kullanılan üzümlerin erken gelişim evresi olan veraison aşamasından kaynaklandığı belirlenmiş olup, detoksifikasyonda reaktif oksijen ve azot türlerine karşı etkili olduğu gözlenmiştir (Carluccio et al., 2003). Ayrıca, üzüm kabuğundaki resveratrol fermentasyon sırasında trans forma dönüşerek, tümör hücrelerinin in-vitro kemopreventif aşamada oluşumunu baskılayıcı etki gösterir (Vachon et al., 2000; Fardet, 2010).

Akdeniz Diyetinin Sağlık Üzerine Etkileri

Beslenme ve yaşam tarzına yönelik düzenlemeler, hem belirli gıdaların bilinçli tüketimi hem de düzenli fiziksel aktivite yoluyla hastalıkların önlenmesine ve sağlıklı yaşlanmanın desteklenmesine önemli katkılar sağlar. Akdeniz Diyeti, Akdeniz'e kıyısı olan ülkelerin geleneksel beslenme alışkanlıklarından doğmuş olup, son yıllarda dünya çapında sağlıklı bir beslenme modeli olarak yaygın şekilde kabul görmüştür. Bu diyetin koruyucu özellikleri, başta zeytinyağında bulunan MUFA'lar ve balıklardaki PUFA'lar olmak üzere; meyve, sebze, baklagiller ve şarap gibi gıdalarda yer alan çeşitli antioksidan bileşikler sayesinde kronik hastalık risklerinin azalmasına yardımcı olur (Bach-Faig vd., 2011).

Son yıllarda, Akdeniz Diyeti'nin metabolik sağlık üzerindeki bu olumlu etkilerinin toplum tarafından daha iyi anlaşılması, diyetin önemini artıran önemli bir faktör olmuştur (Gantenbein

& Kanaka-Gantenbein, 2021). Diyetin ana yağ kaynağı olan zeytinyağı, çoğunlukla tekli doymamış yağ asitlerinden oluşur ve kardiyovasküler hastalık riskini artırdığı bilinen trimetilamin-1-oksit (TMAO) oluşumunu baskılayan biyoaktif bileşenler içermesiyle dikkat çeker (Calabrese vd., 2021). Zeytinyağı ile birlikte lif bakımından zengin sebze, meyve ve tam tahılların düzenli tüketimi bağırsak mikrobiyomunun çeşitliliğini artırarak bağışıklık sistemi üzerinde olumlu etkiler yaratmakta ve inflamatuvar süreçlerin baskılanmasına katkı sağlamaktadır (Gantenbein & Kanaka-Gantenbein, 2021).

Anderson ve çalışma arkadaşları, lif içeriği yüksek olan Akdeniz tipi beslenmenin kardiyovasküler hastalıklar, diyabet, metabolik sendrom ile gastroözofageal reflü, mide ülseri ve divertikülit gibi gastrointestinal hastalıkların daha düşük düzeyde görülmesiyle ilişkili olduğunu ortaya koymuştur (Anderson vd., 2009). Bununla beraber, Akdeniz Diyeti'nin; zeytinyağındaki oleik asit gibi tekli doymamış yağ asitleri (MUFAs), ceviz gibi kuruyemişlerde bulunan omega-3 içerikli çoklu doymamış yağ asitleri (PUFAs), çeşitli meyve ve sebzelerde yer alan flavonoidler ve antioksidanlar ile bağırsak mikrobiyotasını şekillendiren yüksek lif içeriği sayesinde yaşam süresi ve kalitesini artırıcı etkiler sunduğu belirtilmektedir (Widmer vd., 2015).

Mikrobiyota

Mikrobiyom, insan ve hayvan vücudunda ya da derisinde yaşayan trilyonlarca komensal, simbiyotik ve patojen mikroorganizmanın oluşturduğu karmaşık ekosistemi ifade eder ve bu topluluk bakteriler, arkeler, mantarlar, protozoalar ile virüsler gibi çok çeşitli türleri içerir (El-Sayed et al., 2021). Doğumdan itibaren farklı suşlarla kolonize olan bağırsak mikrobiyotası, yaşam boyunca anatomik, beslenmeye ilişkin, çevresel ve farmakolojik değişimlere bağlı olarak dalgalanır ve bu dinamik yapı, sindirilemeyen kompleks karbonhidratların parçalanmasıyla kısa zincirli yağ asitlerinin (asetat, propiyonat, bütirat) üretilmesini mümkün kılarak bağırsak sağlığı için temel süreçleri düzenler (Kim et al., 2019). Sağlıklı bireylerde mikrobiyal bileşim; beslenme düzeni, yaşam tarzı, çevresel etmenler, genel sağlık durumu ve ilaç kullanımı gibi faktörlerle sürekli değişkenlik gösterir (El-Sayed et al., 2021). Mikrobiyota ayrıca emilmeyen şeker ve alkolü enerji metabolizmasında kullanılmak üzere kısa zincirli yağ asitlerine dönüştürmekte ve ince bağırsaktan sindirilmeden ulaşan proteinleri kolondaki bakteriyel enzimler aracılığıyla GABA, dopamin, norepinefrin, histamin ve serotonin gibi nöroaktif moleküllere metabolize etmektedir (Quigley, 2010; Adak & Khan, 2019). Bu KZYA'lar bağırsak epitelyumunun gelişimi ile farklılaşmasını desteklerken, bağırsak pH'sını düşürerek Escherichia coli gibi patojen mikroorganizmaların çoğalmasını engeller (Lepage et al., 2013; Zimmer et al., 2012). Mikrobiyal popülasyonların niceliksel ve niteliksel yapısının; gıdalar, antibiyotikler ve pre/probiyotikler gibi unsurlardan ciddi şekilde etkilenebildiği de son yıllarda yapılan araştırmalarla ortaya konmuştur (Scarpellini et al., 2015). Bu değişken topluluk, lipoprotein lipaz inhibisyonunun baskılanması yoluyla lipit metabolizmasına katkı sağlamakta (Şahin, 2011), fenilalanin ve tirozin gibi aromatik amino asitlerin katabolizmasıyla amino asit metabolizmasında görev almakta (Collino et al., 2013) ve aynı zamanda K vitamini ile biotin, riboflavin, folat ve tiamin gibi çeşitli B grubu vitaminlerin sentezinde rol oynamaktadır (Rowland et al., 2018). Mikrobiyotanın yapısındaki değişimlerin birkaç gün içinde beslenmeye yanıt verebildiği, ancak bu değişimin çoğu zaman geri dönüşümlü olduğu belirtilmektedir. Tüm bu biyokimyasal ve metabolik etkiler, bağırsak mikrobiyotasının kanser, metabolik bozukluklar, kardiyovasküler hastalıklar ve hatta bazı psikiyatrik durumlar gibi sağlık sorunlarının gelişimini doğrudan veya dolaylı olarak etkileyebildiğini göstermektedir (Devaraj et al., 2013).

Akdeniz Diyeti Bileşenlerinin Mikrobiyota Çeşitliliği Üzerine Etkisi

Gastrointestinal sistemde yer alan mikrobiyota ile merkezi sinir sistemi arasındaki ilişki, beyin-bağırsak ekseni kapsamında nöroendokrin sistem aracılığıyla açıklanmaktadır. Bu sistemin stres yanıtının düzenlenmesinde önemli bir role sahip olduğu bilinmektedir. Bağırsak ve beyin arasındaki iletişim; enterik sinir sistemi, nöroimmün mekanizmalar ve nöroendokrin yollar gibi birden fazla etkileşimle gerçekleştirilmektedir. Mikrobiyota bu çoklu yollar üzerinden sinir, endokrin ve bağışıklık sistemini etkileyerek beyin fonksiyonlarını modüle edebilmektedir. Nörotransmitter ve nöropeptit üretebilme kapasitesine sahip olan bağırsak mikroorganizmaları, nöroaktif metabolitlerin sentezini değiştirerek beyin işlevlerini doğrudan etkileyebilmektedir (Cyran & Dinan, 2012).

Beslenme alışkanlıkları, bağırsak mikrobiyotasının bileşimini belirleyen en kritik faktörlerden biridir ve dolayısıyla genel sağlık üzerinde önemli etkilere sahiptir (O'Mahony et al., 2015). Polifenoller bu kapsamda dikkat çekmekte olup, bağırsak mikrobiyotasını düzenleyerek beyin-bağırsak ekseni üzerinde modülatör bir etki oluşturabilecek yeni bir strateji olarak değerlendirilmektedir (Petschow et al., 2013). İnsan ve hayvan çalışmalarının büyük bir bölümü polifenollerin nörotransmitter düzeylerini artırarak ruh hali ve bilişsel fonksiyonlar üzerinde iyileştirici etkiler gösterebildiğini ortaya koymaktadır (Aura et al., 2005; Guergoletto et al., 2016; Sudo et al., 2004). Ayrıca meyveler gibi polifenol açısından zengin besinlerin obezite, kardiyovasküler hastalıklar ve kanser gibi kronik hastalıkları önleyebildiği bildirilmektedir (Zhang et al., 2015a; Zhao et al., 2017).

İngiltere'de 122 katılımcı ile yürütülen randomize kontrollü bir araştırmada, meyve ve sebze tüketiminin artırılması sonucu Clostridium leptum, Ruminococcus bromii ve Ruminococcus flavefaciens türlerinde artış; potansiyel patojen olan Clostridia'da ise azalma tespit edilmiştir. Bu bulgular polifenollerin bağırsak mikrobiyota kompozisyonunu değiştirip düzenleyebileceğini ve bunun obeziteyi önleme açısından da önemli olduğunu göstermektedir (Klinder et al., 2016).

Polifenol içeriği yüksek bir meyve olan üzüm, özellikle resveratrol bakımından oldukça zengindir (Zhang et al., 2015a; Zhang et al., 2015b). Resveratrolün adipoz doku ağırlığını azaltarak kilo artışını engelleyebildiği bilinmektedir. Yüksek yağlı diyetle beslenen farelerde yapılan bir çalışmada resveratrolün Bacteroidetes/Firmicutes oranını iyileştirdiği, Lactobacillus ve Bifidobacterium türlerini artırdığı, Enterococcus faecalis düzeylerini ise azalttığı saptanmıştır (Qiao et al., 2014). Pozuelo ve arkadaşları ise polifenol bakımından zengin üzüm lifinin, Lactobacillus reuteri ve Lactobacillus acidophilus üzerinde uyarıcı etki gösterdiğini bildirmiştir (Pozuelo et al., 2012). Benzer şekilde, broiler civcivlerde üzüm çekirdeği ekstraktının E. coli, Enterococcus ve Lactobacillus popülasyonlarını ve mikrobiyal çeşitliliği artırdığı gösterilmiştir (Viveros et al., 2011).

Tarih boyunca hem lezzet artırıcı hem de sağlık destekleyici özellikleri nedeniyle kullanılan baharatlarda bulunan polifenollerin antienflamatuar, antikanser, antibakteriyel ve antiobezite etkileri olduğu bilinmektedir (Carrera et al., 2018). Zhang ve arkadaşları tarafından yapılan bir çalışmada, östrojen eksikliği olan farelere kurkumin ekstraktı verilmiş ve bunun sonucunda Firmicutes ve Bacteroides yoğunluğunun azaldığı bildirilmiştir. Aynı çalışmada kurkuminin kilo alımını baskıladığı ve östradiol serum seviyelerini düşürdüğü de gösterilmiştir (Zhang et al., 2017). Kurkuminin nanopartikül formu olan Theracurmin'in bütirat üreten bakterileri artırarak kolonik enflamasyonu baskıladığı ve NF-κB aktivitesini azaltarak bağırsak iltihaplanmasını önlediği belirlenmiştir (Ohno et al., 2017). Kurkumin ve türevlerinin nörodejeneratif hastalıklara karşı koruyucu olabileceği; oksidatif stres, ROT seviyeleri, monoamin oksidaz aktivitesi ve mitokondriyal fonksiyonlar üzerinde etkiler gösterdiği çeşitli çalışmalarda bildirilmiştir (Ohno et al., 2017; Amic et al., 2007; Bors et al., 1990; Smolensky

et al., 2018; Di Meo et al., 2019; Rejeswari & Sabesan, 2008; Singh et al., 2013). Tarçın kabuğu ekstraktları üzerine yapılan bir çalışmada ise yüksek yağlı diyet tüketen farelere 8 hafta boyunca ekstrakt takviyesi uygulanmış ve bağırsaklardaki antimikrobiyal peptitler ile hücreler arası bağlantı proteinlerinin düzenlendiği; Peptococcus seviyelerinin azaldığı ve kilo artışı ile yağ dokusu enflamasyonunun azaldığı tespit edilmiştir (Van et al., 2018).

Serotonin Mekanizması

Serotonin, norepinefrin ve dopamin gibi duygudurumla ilişkili nörotransmitterler; insan davranışlarını ve duygularını yönlendiren çeşitli moleküler ve hücresel mekanizmalar çerçevesinde ele alınmaktadır (Krishnan & Nestler, 2008). "Mutluluk hormonu" olarak bilinen serotonin, ruh hâlinin düzenlenmesinde önemli bir role sahiptir. Elzem bir aminoasit olan triptofanın diyetle alınmasını takiben serotonin sentezi başlamakta; bu sentez çoğunlukla gastrointestinal sistemdeki enterokromafin hücrelerinde ve bir ölçüde beyinde gerçekleşmektedir. Serotonin üretiminde hız sınırlayıcı basamağı oluşturan triptofan hidroksilaz enzimi, kısa zincirli yağ asitleri gibi mikrobiyota kökenli metabolitlerden etkilenebilmektedir (Klimova et al., 2020; Meyyappan et al., 2020).

Bağırsak mikrobiyotasının nörotransmitterler ile ilişkisini inceleyen çalışmalarda, mikrobiyal topluluğun serotonin ve dopamin gibi nöroaktif bileşenlerle bağlantılı olduğu; ayrıca sinir hücreleri arasında iletişimi sağlayan asetilkolin gibi temel nörotransmitterleri de içerebildiği gösterilmiştir (Ma et al., 2021).

Akdeniz Diyeti Bileşenlerinin Mikrobiyota ve Serotonin Üretimine Etkisi

Beslenme, tüketilen besinlerin içeriğine bağlı olarak bağırsak mikrobiyotası üzerinde önemli etkiler yaratmaktadır; ancak mikrobiyotayı yalnızca diyet yoluyla değiştirmek, bireyler arası önemli farklılıklar nedeniyle oldukça güçtür (Jacka, 2017). Bağırsak mikrobiyotasındaki bazı bakteri türleri nörotransmitter üretiminde doğrudan rol almaktadır. Bifidobacterium ve Lactobacillus türleri GABA ve asetilkolin üretirken; Escherichia, Streptococcus ve Enterococcus türleri serotonin, dopamin ve norepinefrin sentezinde görev almaktadır. Mikrobiyota tarafından salgılanan bu nöroaktif bileşikler, bağırsak sinirleri üzerinden merkezi sinir sistemine afferent sinyaller gönderebilmekte; aynı şekilde merkezi sinir sisteminden gelen efferent sinyalleri de yanıtlayabilmektedir (Louwies et al., 2020).

Sağlıklı bir diyetin inflamasyon, oksidatif stres, hipotalamus-hipofiz-adrenal (HPA) ekseni, beyin kaynaklı nörotrofik faktör (BDNF), triptofan–kinürenin metabolizması ve bağırsak mikrobiyota dengesi gibi serotoninle ilişkili mekanizmalar üzerinde olumlu etkiler oluşturabileceği bildirilmektedir (Robertson et al., 2017; Marx et al., 2021; Park, Choi & Lee, 2020). Beslenme şekline bağlı olarak mikrobiyota üç temel enterotipe; protein ve hayvansal yağdan zengin diyetle Bacteroides-dominant enterotip; çay şekeri ve karbonhidrat yönünden zengin diyetle Prevotella-dominant enterotip; alkol ve çoklu doymamış yağ asitlerinden zengin diyetle Firmicutes-dominant enterotipe ayrılmaktadır (Klimova et al., 2020). Bu enterotiplerdeki değişikliklerin serotonin mekanizmasını etkileyebileceği düşünülmektedir (Bear et al., 2020).

Bununla birlikte mikrobiyotadaki bireysel çeşitlilik, diyet müdahalelerinin etkinliğini değiştirebilmekte; ayrıca sağlıklı beslenen bireylerin dahi depresif bozukluklar yaşayabildiği ifade edilmektedir (Jacka, 2017).

Sağlıklı diyetlerde yaygın olarak bulunan polifenollerin bir alt grubu olan flavonoidler; meyveler, sebzeler, zeytinyağı ve baharatlar gibi birçok besinde yer almakta ve antioksidan etkileri sayesinde mikrobiyota üzerinde belirgin değişiklikler yaratabilmektedir. Flavonoidlerin depresyon tedavisindeki olası etkilerini araştıran bir çalışmada, 40 depresyon hastası sekiz hafta boyunca flavonoid yönünden zengin portakal suyu tüketmiş ve kısa zincirli yağ asidi üreten bakterilerin sayısında artış gözlenmiştir (Park et al., 2020). Polifenollerin diğer alt grubu olan fenolik asitlerden koniferil ferulat ise antioksidan, antibakteriyel ve vazodilatör özellikleri nedeniyle dikkat çekmektedir. Farelerde kronik öngörülemeyen hafif strese bağlı oluşan depresif davranışlar üzerinde yapılan çalışmada, koniferil ferulatın mikrobiyotayı düzenleyerek ve proinflamatuar bileşenleri azaltarak olumlu etki gösterdiği; ayrıca B1 vitamini (tiamin) ve dopamin öncüsü tirozin metabolizmasında rol oynayan metabolitleri etkilediği rapor edilmiştir (Hao, Ma, Tao, Huang & Chen, 2021).

Vücutta artan inflamasyon, proinflamatuar sitokinler aracılığıyla triptofan metabolizmasını kinürenin yoluna kaydırarak serotonine dönüşümünü azaltabilmekte; aynı zamanda oksidatif stres de bu bozulmuş yolağı etkileyebilmektedir (Rudzki et al., 2021). Ayrıca triptofanın bağırsak bariyeri fonksiyonu ve inflamatuar yanıtla ilişkili aril hidrokarbon reseptörü (AhR) üzerinden depresyon gelişiminde rol oynayabileceği; triptofan azalması veya disbiyozisin bu yolağı değiştirebileceği öne sürülmektedir. Ancak bu konuda daha fazla çalışmaya ihtiyaç vardır (Li et al., 2017).

Bu ilişkiyi destekleyen bir diğer çalışmada, kronik öngörülemeyen hafif strese maruz bırakılan farelere probiyotik Lactobacillus casei verilmiş ve uygulama sonucunda stres tepkilerinde azalma, serotonin–dopamin–norepinefrin düzeylerinde artış ve mikrobiyal bileşimde iyileşme gözlemlenmiştir (Gu et al., 2020).

METHODOLOGY

Data collection and examination of ethical principles

Bu çalışmada, Akdeniz diyetinin tarihsel gelişimini, temel bileşenlerini ve bu bileşenlerin sağlık üzerine etkilerini ortaya koymak amacıyla kapsamlı bir literatür taraması yapılmıştır. Araştırma kapsamında öncelikle Akdeniz diyetinin kökeni ve tarihçesine ilişkin klasik kaynaklar ile modern epidemiyolojik çalışmalar incelenmiştir. Bu doğrultuda, Akdeniz havzasının beslenme kültürünü tanımlayan temel metinlerden Kromhout ve arkadaşlarının (1989) arkeolojik ve tarihsel bulguları temel alan çalışması ile diyetin bilimsel çerçevesini oluşturan Ancel Keys ve ekibinin 1960 yılında tamamladığı “Seven Countries Study” (Selimoğlu & Gültekin, 2018; Ersoy & Özdemir, 2010; Naska & Trichopolou, 2014; Nestle, 1995) incelemenin temelini oluşturmuştur.

Akdeniz diyet piramidinin gelişimini değerlendirmek amacıyla, WHO ve FAO tarafından 1993’te yayımlanan model ile 2010 yılında uluslararası bilimsel konsensüs sonucu güncellenen piramit yapısı ele alınmış ve bu yapıdaki besin grupları, ilgili bilimsel veriler ışığında sınıflandırılmıştır (Gönder & Akbulut, 2017; Gönder, 2015; Guasch-Ferré & Willett, 2021).

Diyet bileşenlerini değerlendirmek için; zeytinyağının kimyasal içeriği, sebze-meyvelerin antioksidan yapısı, tam tahılların biyoaktif bileşenleri, baklagiller, balık ve deniz ürünleri, kuruyemişler, süt ürünleri ve sınırlı tüketilen et grubu hakkında detaylı veri sunan çalışmalar taranmıştır. Bu aşamada, zeytinyağının polifenol yapısını açıklayan Kouka et al. (2020) ve Hoffman & Gerber (2015); sebze ve meyve tüketimi ile mental sağlık ilişkisini ele alan Godos et al. (2016) ve Turati et al. (2015); tam tahılların psikolojik süreçlere etkisini inceleyen Gangwisch et al. (2015) ve Crichton et al. (2013) gibi çalışmalar referans olarak kullanılmıştır.

Ayrıca balık, kuruyemiş ve süt ürünlerinin Akdeniz diyetindeki yeri ve metabolik etkileri, Naska & Trichopoulou (2014), Ortega (2006), Liu (2013) ve Huang & Sumpio (2008) gibi temel kaynaklar aracılığıyla değerlendirilmiştir. Et ve işlenmiş et tüketimine ilişkin inflamatuvar mekanizmalar ve mikrobiyota ilişkisi ise Gnagnarella et al. (2013) ve Abildgaard et al. (2011) doğrultusunda yorumlanmıştır.

Literatür taraması 2013–2021 yılları arasındaki güncel ve uluslararası nitelikli çalışmalar öncelikli alınarak yapılmış; ancak tarihsel çerçeveyi tamamlamak amacıyla daha eski temel kaynaklara da yer verilmiştir. İncelemeye alınan tüm yayınlar, Akdeniz diyetinin beslenme modeli, kimyasal bileşenler, sağlık etkileri ve kültürel yapısı ile doğrudan ilişkili olmaları temelinde seçilmiştir.

Analysis of the research problem

Günümüzde beslenme, yalnızca enerji alımıyla ilişkili temel bir biyolojik süreç olmaktan çıkmış; bağırsak mikrobiyotası, nörotransmitter üretimi ve davranışsal sonuçlarla doğrudan ilişkisi bulunan çok boyutlu bir sağlık belirleyicisi haline gelmiştir (Cryan & Dinan, 2012; Mayer et al., 2015). Bu doğrultuda, besin bileşenlerinin mikrobiyota kompozisyonu üzerindeki etkilerini ve bu kompozisyonun serotonin metabolizmasına katkısını anlamak, beslenme bilimlerinde giderek önem kazanan bir araştırma alanını temsil etmektedir.

Akdeniz diyeti; zeytinyağı, sebzeler, meyveler, baklagiller, tam tahıllar, kuruyemişler ve fermente ürünler gibi prebiyotik ve biyoaktif bileşikler açısından zengin besinlerden oluşur (Bach-Faig et al., 2011). Bu öğelerin yüksek polifenol, lif ve antioksidan içerikleri, bağırsak mikrobiyotasında yararlı bakteri türlerinin çoğalmasını teşvik ederek mikrobiyal çeşitliliği artırmakta ve bağırsak bariyer bütünlüğünü desteklemektedir (Kouka et al., 2020; Scott et al., 2013).

Bağırsak mikrobiyotası, vücuttaki toplam serotonin üretiminin yaklaşık %90'ından sorumludur (Yano et al., 2015). Mikroorganizmaların ürettiği kısa zincirli yağ asitleri (SCFA'lar), triptofan metabolizması ve enterochromaffin hücre aktivitesi gibi mekanizmalar serotonin sentezinde belirleyici rol oynamaktadır (O'Mahony et al., 2015). Bu nedenle Akdeniz diyetinin mikrobiyotayı düzenleyici etkilerinin, serotonin biyosentezi üzerindeki katkısının açıklığa kavuşturulması; ruh sağlığı, stres yönetimi ve inflamatuvar süreçler açısından önemli bilimsel çıktılar sunma potansiyeline sahiptir.

Ancak mevcut literatürde Akdeniz diyetinin mikrobiyota-serotonin ekseni üzerindeki etkilerini bütüncül biçimde açıklayan sentezlerin sınırlı olduğu görülmektedir. Çalışmalar genellikle ya diyetin mikrobiyota üzerindeki etkilerine (Godos et al., 2016; De Filippis et al., 2016) ya da mikrobiyotanın serotonin üretimine katkısına odaklanmaktadır (Yano et al., 2015; Reigstad et al., 2015). Bu iki mekanizmanın birlikte değerlendirilmesi, alanda önemli bir boşluğu temsil etmektedir.

Bu doğrultuda literatürdeki çalışmalardan yola çıkılarak ele alınan temel problemi şu şekilde tanımlanmaktadır:

Akdeniz diyetinde yer alan bileşenler bağırsak mikrobiyotasını nasıl etkilemektedir ve bu etkiler bağırsak kaynaklı serotonin üretimine ne ölçüde katkı sağlamaktadır?

Bu problem kapsamında Akdeniz diyetinin yapısal bileşenleri ile mikrobiyota-serotonin etkileşim mekanizmalarını bilimsel bir çerçevede bütünleştirerek, diyetin nörobiyolojik ve metabolik etkilerinin açıklandığı çalışmalardan faydalanılmıştır.

Model of the Research

Bu derleme, Akdeniz diyetinin tarihsel arka planı, temel besin bileşenleri ve sağlık etkilerini bütüncül bir çerçevede incelemeyi amaçlayan nitel araştırma modeli kapsamında yapılandırılmıştır. Çalışma, tarihsel doküman incelemesi ve sistematik literatür sentezini bir araya getiren betimsel araştırma modeli ile yürütülmüştür.

Akdeniz diyetinin kökeni arkeolojik ve kültürel veriler ışığında değerlendirilmiş; diyetin bölgesel beslenme alışkanlıklarından modern bilimsel modele dönüşüm süreci incelenmiştir (Selimoğlu & Gültekin, 2018; Naska & Trichopolou, 2014; Nestle, 1995).

Bu aşamada diyetin temel öğeleri olan zeytinyağı, sebzeler, meyveler, tam tahıllar, baklagiller, balık, kuruyemişler ve fermente süt ürünleri; kimyasal içerikleri, biyoaktif bileşenleri ve metabolik etkileri açısından sistematik biçimde sınıflandırılmıştır (Kouka et al., 2020; Hoffman & Gerber, 2015; Guasch-Ferré & Willett, 2021).

Bu bölümde diyet bileşenlerinin inflamasyon, oksidatif stres, glisemik kontrol, bağırsak mikrobiyotası, serotonin sentezi ve kardiyometabolik sağlık üzerine etkileri literatür bulgularına dayanarak sentezlenmiştir (Godos et al., 2016; Crichton et al., 2013; Huang & Sumpio, 2008; Gillum et al., 1996).

CONCLUSION

Akdeniz diyetinin tarihsel gelişimi ve biyokimyasal açıdan zengin içerikleri değerlendirildiğinde, diyetin hem kültürel hem de fizyolojik düzeyde güçlü bir temele sahip olduğu görülmektedir. Akdeniz piramidinin en altında yer alan zeytinyağı, sebzeler, meyveler ve tam tahıllar; güçlü antioksidan yapıları, polifenol içerikleri ve lif yoğunluklarıyla diyetin koruyucu etkisinin en önemli belirleyicileri olarak öne çıkmaktadır (Bach-Faig et al., 2011; Dernini & Berry, 2015). Özellikle zeytinyağının sahip olduğu oleik asit ve polifenolik bileşiklerin antiinflamatuvar etkileri, literatürde pek çok çalışmada doğrulanmıştır (Kouka et al., 2020; Hoffman & Gerber, 2015). Bu bileşenlerin oksidatif stres ve inflamasyon üzerinde düzenleyici rol üstlenmesi, Akdeniz diyetinin kardiyovasküler hastalıklar kadar nöropsikiyatrik süreçler üzerinde de olumlu etkiler gösterebilmesini mümkün kılmaktadır.

Tam tahıllar ve baklagillerde bulunan lif ve biyoaktif bileşiklerin metabolik süreçler üzerindeki olumlu etkileri, özellikle glisemik kontrol, enerji dengesinin sağlanması ve bağırsak mikrobiyotasının düzenlenmesine katkılarıyla ilişkilendirilmiştir (D'Alessandro et al., 2016; Williamson, 2017). Bu etki, serotonin sentezinde görev alan B6 vitamini gibi ko-faktörlerin varlığıyla birleştiğinde, tam tahılların ruh sağlığı açısından da koruyucu bir role sahip olduğunu göstermektedir (Gangwisch et al., 2015; Crichton et al., 2013).

Balık ve deniz ürünlerinin yüksek ω-3 yağ asidi içeriği, depresyon riskini azaltan önemli metabolik yolaklar üzerinden etki gösterirken (Gillum et al., 1996), kuruyemişlerdeki fitosteroller dolaşım sistemindeki kolesterol metabolizmasını destekleyerek damar sağlığını güçlendirmektedir (Huang & Sumpio, 2008; Ortega, 2006). Fermente süt ürünlerinde bulunan probiyotik bakterilerin bağırsak-beyin eksenindeki düzenleyici rolü ise, Akdeniz diyetini nöropsikiyatrik bozukluklarda koruyucu bir model haline getirmektedir (Bartram et al., 1994; Zelber-Sagi et al., 2018).

Buna karşın, kırmızı et ve işlenmiş et ürünlerinin sınırlı tüketilmesini öneren piramit yapısı, bu besinlerin inflamatuvar mekanizmaları tetikleyebileceğine dair kanıtlarla tutarlıdır. Araşidonik asidin bağırsak mikrobiyotasında bazı türleri artırarak depresif süreçleri etkileyebileceğini

gösteren çalışmalar, Akdeniz diyetinin neden bitkisel ağırlıklı bir model üzerine kurulduğunu desteklemektedir (Abildgaard et al., 2011; Gnagnarella et al., 2013).

Tüm bu bulgular değerlendirildiğinde Akdeniz diyetinin, yalnızca bir beslenme modeli değil; tarihsel, kültürel ve biyokimyasal açıdan bütüncül bir sağlık yaklaşımı sunduğu görülmektedir. Bu model, kronik hastalıkların önlenmesi ve zihinsel sağlığın desteklenmesi açısından güçlü bir bilimsel temele sahiptir.

Akdeniz diyetinin tarihsel gelişimi ve temel bileşenlerinin sağlık üzerindeki etkilerini literatür doğrultusunda incelemiş ve diyetin bilimsel geçerliliğini destekleyen çok yönlü bulgular ortaya koymuştur. Arkeolojik bulgulardan modern klinik araştırmalara kadar geniş bir yelpazede değerlendirildiğinde, Akdeniz diyetinin antioksidan, antiinflamatuvar ve metabolik açıdan güçlü bir profil sunduğu görülmektedir. Zeytinyağı, sebze-meyve çeşitliliği, tam tahıllar, baklagiller, balık ve kuruyemişler gibi besinlerin öne çıktığı bu model, hem fiziksel hem de mental sağlık üzerinde koruyucu bir etkiye sahiptir.

Akdeniz diyetinin sürdürülebilir, kültürel olarak köklü ve sağlık açısından kanıt temelli bir beslenme yaklaşımı olduğu; modern toplumlarda kronik hastalıklarla mücadelede etkili bir strateji sunabileceği sonucuna varılmaktadır.

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LONGITUDINAL STENT DEFORMATION RELATED TO GUIDE EXTENSION CATHETER USE IN A PATIENT WITH ACUTE CORONARY SYNDROME: A CASE REPORT

AKUT KORONER SENDROMLU BİR HASTADA GUIDE EXTENSION KATETER KULLANIMINA BAĞLI LONGİTUDİNAL STENT DEFORMASYONU: BİR OLGU SUNUMU

Müjgan Ayşenur ŞAHİN

Arş. Gör. Dr. Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi, Kardiyoloji Anabilim Dalı

Hakan DUMAN

Doç. Dr. Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi, Kardiyoloji Anabilim Dalı

Özet

Akut koroner sendrom ile başvuran 55 yaşındaki kadın hastada sağ koroner arterde saptanan kritik darlığa yönelik yapılan stent implantasyonu sonrası gelişen proksimal ve distal kenar diseksiyonu nedeniyle yeniden girişim planlandı. Lezyonun özellikleri ve stent ilerletme güçlüğü nedeniyle balon destekli teknikle guide extension kateter kullanıldı. Distal diseksiyon başarıyla kapatılırken, bu işlem sırasında daha önce yerleştirilen proksimal stentte belirgin longitudinal deformasyon ve migrasyon geliştiği görüldü. Deforme segmentin tamir edilmesi amacıyla ek ilaç salınımlı stent implantasyonu yapıldı ve post-dilatasyon sonrasında optimal sonuç elde edildi. Longitudinal stent deformasyonu modern ince strutlu stentlerde nadir ancak önemli bir komplikasyon olup özellikle guide extension kateter kullanımının gerekli olduğu kompleks lezyonlarda ortaya çıkabilmektedir. Bu olgu, guide extension kullanımına bağlı gelişen stent deformasyonunun dikkatle değerlendirilmesi gerektiğini göstermekte ve operatör farkındalığının artırılmasının önemini vurgulamaktadır.

Anahtar Kelimeler: longitudinal stent deformasyonu, guide extension kateter, perkütan koroner girişim, stent komplikasyonu

Abstract

A 55-year-old woman presenting with acute coronary syndrome underwent stent implantation for a critical mid–right coronary artery lesion. Following the initial procedure, proximal and distal edge dissections were detected, necessitating repeat intervention. Due to difficulty advancing the distal stent, a balloon-assisted guide extension catheter technique was employed. Although the distal dissection was successfully sealed, significant longitudinal deformation and proximal migration of the previously implanted stent occurred during catheter advancement. An additional drug-eluting stent was deployed to repair the deformed segment, followed by high-pressure post-dilatation, resulting in optimal angiographic expansion. Longitudinal stent deformation is a rare but clinically important mechanical complication, particularly associated with the use of guide extension systems in complex, tortuous, or calcified lesions. This case

highlights the need for heightened operator awareness regarding potential mechanical interactions between extension catheters and thin-strut stents. Recognition of this complication is crucial to prevent adverse outcomes and to optimize procedural safety during challenging percutaneous coronary interventions.

Keywords: longitudinal stent deformation, guide extension catheter, percutaneous coronary intervention, stent complication

INVESTIGATION OF AMINO ACID METABOLIC PROFILE IN CORONARY ARTERY DISEASE PATIENTS UNDERGOING CARDIOPULMONARY BYPASS

Asst. Prof. Dr. Bişar AMAÇ

Harran University, Faculty of Health Sciences, Department of Perfusion, Sanliurfa, Turkiye

ORCID ID: https://orcid.org/0000-0003-0320-4239

ABSTRACT

Introduction: Coronary artery disease is one of the major cardiovascular diseases causing high morbidity and mortality worldwide. Reliable diagnosis of the disease in its early stages is critical for improving clinical outcomes. Current biochemical and molecular tests have limited sensitivity and specificity and do not fully reflect the pathophysiology of the disease. Therefore, the systematic investigation of changes in cardiac metabolism using metabolomic approaches and the identification of new biomarker candidates for early diagnosis are of great importance.

Objective: The aim of this study is to determine amino acid levels in the serum and pericardial fluid of coronary artery disease patients who have undergone cardiopulmonary bypass, thereby identifying disease-specific metabolic signatures and evaluating these amino acids as potential biomarker candidates. The targeted amino acids are: Thiaproline, Histamine, Cystine, Beta-Alanine, Alpha-aminobutyric acid, Beta-aminoisobutyric acid, Aspartic Acid, Serine, Argininosuccinic Acid, and Ornithine.

Method: The study was conducted on three groups: healthy control subjects (group 1) (n=30), serum samples from patients undergoing cardiopulmonary bypass with a diagnosis of coronary artery disease (group 2), and pericardial fluid samples from the same patients (group 3) (n=30). The selected ten amino acids were derivatised according to the commercial kit protocol and analysed by liquid chromatography-tandem mass spectrometry (LC-MS/MS). Amino acids obtained from each sample were esterified, ionisation efficiency was increased, and they were measured quantitatively. Differences between groups were statistically evaluated using one-way analysis of variance, and P values were determined.

Results: The levels of the ten target amino acids analysed showed significant differences between the control, patient serum, and patient pericardial fluid groups. Aspartic Acid ($P < 0.001$), Serine ($P < 0.001$), Ornithine ($P < 0.001$), Thiaproline ($P < 0.001$) and Histamine ($P < 0.001$) levels were significantly increased in pericardial fluid compared to the control group; indicating that pericardial fluid reflects disease-specific metabolic signatures. In serum samples, significant changes were observed in the levels of Beta-Alanine ($P < 0.001$), Alpha-aminobutyric acid ($P < 0.001$) and Beta-aminoisobutyric acid ($P < 0.001$), representing the systemic metabolic responses to the disease. According to variance analysis, all ten amino acids showed statistically significant differences, with Aspartic Acid, Serine, Ornithine, Thiaproline, and Histamine reaching the highest significance levels and emerging as strong biomarker candidates. Furthermore, the comparison between serum and pericardial fluid revealed that the two biological sample types reflect the pathophysiology of the disease from different perspectives.

Conclusion: The metabolic profiling of the selected ten amino acids has revealed metabolic changes with high sensitivity in coronary artery disease patients undergoing cardiopulmonary bypass. In particular, Aspartic Acid, Serine, Ornithine, Thiaproline, and Histamine showed the most pronounced differences between groups and were identified as strong candidates in terms of biomarker potential. These findings support the integration of the target amino acid panel into clinical practice for the early diagnosis and metabolic classification of coronary artery disease.

Keywords: Coronary artery disease, Amino acids, Pericardial fluid, Metabolic, Biomarker.

NON-ST ELEVATION MYOCARDIAL INFARCTION AND CORONARY ARTERY ANOMALY: A CASE REPORT

NON-ST ELEVASYONLU MİYOKARD İNFARKTÜSÜ VE KORONER ARTER ANOMALİSİ: BİR OLGU SUNUMU

Doç. Dr. Elif ERGÜL

Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi Kardiyoloji Anabilim Dalı

ORCID ID: https://orcid.org/0000-0003-3192-4719

Doç. Dr. Ahmet Seyda YILMAZ

Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi, Kardiyoloji Anabilim Dalı

ORCID ID: https://orcid.org/0000-0003-3864-4023

Özet

Giriş: Non-ST elevasyonlu miyokard infarktüsü (NSTEMI), koroner arter hastalığının önemli bir klinik tablosu olup, eşlik eden yapısal kalp hastalıkları ve koroner anomaliler tanı ve tedaviyi karmaşık hâle getirebilir. Koroner arter fistülleri veya anormal koroner bağlantılar nadir görülmekle birlikte, çoğunlukla asemptomatiktir ve akut koroner sendrom sırasında tesadüfen saptanabilir.

Olgu: 66 yaşında, bilinen hipertansiyonu olan bayan hasta, göğüs ağrısı şikayetiyle başvurduğu acil serviste kardiyak biyobelirteçlerinde yükselme saptanması üzerine non-ST elevasyonlu miyokard infarktüsü (NSTEMI) tanısıyla koroner yoğun bakım ünitesine alındı. Elektrokardiyografisinde iskemik bulgu izlenmedi. Transtorasik ekokardiyografide sol ventrikül konsantrik hipertrofisi, orta derecede mitral kapak yetersizliği ve hafif derecede triküspit kapak yetersizliği tespit edildi. Ejeksiyon fraksiyonu ise normaldi. Koroner anjiyografide, sol ön inen dal (LAD) ve circumflex (Cx) arterlerde kritik darlıklar gözlemlendi. Ayrıca sağ koroner arter (RCA) ile sol koroner sistem arasında anormal bir bağlantı tespit edildi. Bu bağlantı, genellikle koroner arter fistülü veya koroner arter anomalisini düşündürmektedir. Hastaya perkütan koroner girişim uygulanması planlanmış olup, LAD ve Cx arterlerindeki kritik darlıklara yönelik müdahale yapıldı. RCA ile sol sistem arasındaki bağlantı ise izlem altında tutulacak ve gerektiğinde ileri tetkikler ile değerlendirilmesi sağlanacaktır.

Tartışma ve Sonuç: Bu olgu, NSTEMI ile başvuran ve birlikte koroner arter anomalisi bulunan nadir bir klinik durumu temsil etmektedir. RCA ile sol koroner sistem arasındaki anormal bağlantı ise, düşük akımlı ve hemodinamik olarak önemsiz görünmekle birlikte, ilerleyen dönemde potansiyel hacim yükü, iskemi veya aritmojenik etkiler oluşturabileceğinden dikkatli izlem gerektirir. Eşlik eden mitral ve triküspit yetersizlikleri ile sol ventrikül hipertrofisi, hastanın kardiyovasküler risk profilini genişleten ek faktörler olup uzun dönem takipte klinik yönetimde bütüncül bir yaklaşımın önemini vurgulamaktadır. Bu bakımdan, koroner arter

anomalilerinin akut koroner sendrom bağlamında doğru tanımlanması ve tedavi önceliklerinin hemodinamik etkiler ışığında bireyselleştirilmesi klinik sonuçları iyileştirebilir.

Anahtar kelimeler: koroner anomali, perkutan girişim, koroner fistül

Abstract

Introduction: Non-ST elevation myocardial infarction (NSTEMI) is a significant clinical manifestation of coronary artery disease, and coexisting structural heart disease and coronary anomalies can complicate diagnosis and treatment. Coronary artery fistulas or anomalous coronary connections are rare, but are often asymptomatic and can be detected incidentally during acute coronary syndrome.

Case: A 66-year-old woman with known hypertension presented to the emergency department with chest pain and was admitted to the coronary intensive care unit with a diagnosis of non-ST elevation myocardial infarction (NSTEMI). Her electrocardiogram showed no ischemic findings. Transthoracic echocardiography revealed concentric left ventricular hypertrophy, moderate mitral valve regurgitation, and mild tricuspid valve regurgitation. Ejection fraction was normal. Coronary angiography revealed critical stenoses in the left anterior descending branch (LAD) and circumflex arteries (Cx). An anomalous connection was also detected between the right coronary artery (RCA) and the left coronary system. This connection is generally suggestive of a coronary artery fistula or coronary artery anomaly. The patient was scheduled for percutaneous coronary intervention, and intervention was performed to address the critical stenoses in the LAD and Cx arteries. The connection between the RCA and the left coronary system will be monitored and evaluated with further investigations as needed.

Discussion and Conclusion: This case represents a rare clinical entity presenting with NSTEMI and concomitant coronary artery anomaly. Although the anomalous connection between the RCA and the left coronary system appears to be low-flow and hemodynamically insignificant, it requires careful monitoring due to the potential for volume overload, ischemia, or arrhythmogenic effects in the future. Coexisting mitral and tricuspid regurgitation and left ventricular hypertrophy are additional factors that broaden the patient's cardiovascular risk profile, highlighting the importance of a holistic approach to long-term clinical management. Therefore, accurate identification of coronary artery anomalies in the context of acute coronary syndromes and individualization of treatment priorities based on hemodynamic effects may improve clinical outcomes.

Keywords: coronary anomaly, percutaneous intervention, coronary fistula

GRAFT STENT DISLOCATION AND RECURRENT MYOCARDIAL INFARCTION IN THE ANEURYSMATIC RCA SEGMENT: CASE REPORT

ANEVRİZMATİK RCA SEGMENTİNDE GELİŞEN GREFT STENT DİSLOKASYONU VE TEKRARLAYAN MİYOKARD İNFARKTÜSÜ: OLGU SUNUMU

Doç. Dr. Elif ERGÜL

Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi, Kardiyoloji Anabilim Dalı

ORCID ID: https://orcid.org/0000-0003-3192-4719

Doç. Dr. Ahmet Seyda YILMAZ[2]

Recep Tayyip Erdoğan Üniversitesi Tıp Fakültesi, Kardiyoloji Anabilim Dalı

[2]ORCID ID: https://orcid.org/0000-0003-3864-4023

Özet

Giriş :Koroner arter hastalığının tedavisinde stent implantasyonu etkin bir yaklaşım olmakla birlikte, özellikle anevrizmatik damar segmentlerine uygulanan greft stentlerde geç dönem komplikasyonlar gelişebilir.

Olgu : Hipertansiyon ve aktif sigara kullanımı dışında ek risk faktörü bulunmayan 53 yaşındaki erkek hasta, bir yıl önce akut göğüs ağrısı ile başvurduğu acil serviste yapılan değerlendirmede akut inferior miyokard infarktüsü tanısıyla yatırılmıştır. Koroner anjiyografisinde sağ koroner arterin (RCA) anevrizmatik segmentinde kritik lezyon izlenmiş ve ilgili bölgeye greft stent implantasyonu uygulanmıştır. Klinik olarak stabil seyreden hasta medikal tedavi ile taburcu edilmiştir.Yaklaşık bir yıl sonra hasta yeniden göğüs ağrısı şikayetiyle acil servise başvurmuş, kardiyak biyobelirteçlerde yükselme saptanması üzerine non-ST elevasyonlu miyokard infarktüsü (NSTEMI) tanısı ile yatırılmıştır. Koroner anjiyografide circumflex (Cx) arterde ciddi darlık tespit edilmiş ve aynı zamanda RCA'daki daha önce yerleştirilmiş greft stentinde dislokasyon izlenmiştir. Cx arterindeki lezyona perkütan koroner girişim (PCI) başarıyla uygulanmış, RCA'daki stent dislokasyonunun hemodinamik açıdan kritik düzeyde obstrüksiyon oluşturmadığı değerlendirilerek bu bölge için medikal takip planlanmıştır.

Tartışma ve Sonuç : Bu vakada izlenen greft stent dislokasyonu, koroner stentlemenin geç dönem komplikasyonları arasında yer alan nadir ancak klinik açıdan önemli bir durumdur. Greft segmentlerinin anevrizmatik veya dejeneratif yapısı, stentin damar duvarına yeterli appozisyon sağlayamamasına ve zaman içinde pozisyon kaymasına zemin hazırlayabilir. Dislokasyon, lümen geometrisinin bozulmasına ve iskemik semptomların yeniden ortaya çıkmasına neden olabilmektedir. Tedavi stratejisi, dislokasyonun derecesi, eşlik eden stenozun ciddiyeti ve hemodinamik etkiler göz önünde bulundurularak belirlenir. Bu olguda olduğu gibi, bazı hastalarda yeniden girişim yerine yakın izlem ve optimal medikal tedavi uygun olabilir.

Anahtar Kelimeler: greft stent, perkutan koroner girişim, koroner anjiyografi

Abstract

Introduction: While stent implantation is an effective approach in the treatment of coronary artery disease, late complications can develop, particularly with graft stents placed in aneurysmal vessel segments.

Case: A 53-year-old man, with no additional risk factors other than hypertension and active smoking, presented to the emergency department one year ago with acute chest pain. He was evaluated and admitted with a diagnosis of acute inferior myocardial infarction. Coronary angiography revealed a critical lesion in the aneurysmal segment of the right coronary artery (RCA), and a graft stent was implanted in the affected area. The patient, who is clinically stable, was discharged with medical treatment.Approximately one year later, the patient presented to the emergency department again with chest pain and was admitted with a diagnosis of non-ST elevation myocardial infarction (NSTEMI) due to elevated cardiac biomarkers. Coronary angiography revealed severe stenosis in the circumflex (Cx) artery and also revealed dislocation of the previously placed graft stent in the RCA. Percutaneous coronary intervention (PCI) was successfully performed on the Cx artery lesion. The RCA stent dislocation was assessed as not causing critical hemodynamic obstruction, and medical follow-up was planned for this region.

Discussion and Conclusion: The graft stent dislocation observed in this case is a rare but clinically significant late complication of coronary stenting. The aneurysmal or degenerative nature of the graft segments may predispose the stent to inadequate apposition to the vessel wall and to displacement over time. Dislocation can lead to deterioration of the lumen geometry and the recurrence of ischemic symptoms. The treatment strategy is determined by considering the degree of dislocation, the severity of the accompanying stenosis, and hemodynamic effects. In some patients, as in this case, close monitoring and optimal medical therapy may be appropriate rather than reintervention.

Keywords: Graft stent, percutaneous coronary intervention, coronary angiography

EVOLUTION OF AUGMENTATION INDEX AND PULSE WAVE VELOCITY DURING PREGNANCY IN PREGNANT WOMEN WHO PRACTICE PHYSICAL ACTIVITY

Ardelean Maria Ioana
University of Medicine and Pharmacy "Victor Babes" Timisoara, (ROMANIA)

Iurciuc Stela
University of Medicine and Pharmacy "Victor Babes" Timisoara, (ROMANIA)

Petre Ion
University of Medicine and Pharmacy "Victor Babes" Timisoara, (ROMANIA)

Petre Izabella
University of Medicine and Pharmacy "Victor Babes" Timisoara, (ROMANIA)

Abstract

Introduction: In this paper we tried to assess hemodynamic parameters and arterial stiffness in pregnant women before and after a physical training program and to demonstrate that structured training program improves the hemodynamic parameters.

Material and Method: This study was follow-up and included 40 patients between the years 2017-2018 admitted within Obstetrics and Gynaecology Departments of "Pius Brînzeu" Emergency Clinical Hospital Timişoara who performed a training program under the guidance of an obstetrician in collaboration with a cardiologist and physiotherapist in a multidisciplinary team. We assessed Aix and PWV as arterial stiffness parameters to quantify the improvement of arterial rigidity and cardiovascular risk before and after physical training and we tried to evaluate the correlation of their evolution throughout the pregnancy.

Conclusion: Physical training, coordinated with the obstetrician and the cardiologist, improved hemodynamic parameters of the pregnant woman during pregnancy. The arterial stiffness parameters improved due to physical training. In the last part of our study we studied through regression analysis the Aix brachial and the SD PWVao values in the second trimester (Trim II) and the third trimester (Trim III). We noticed major differences between these two time periods but we also tested if these variables interrelated. For this, we performed a regression analysis, in which we considered the values from Trim II as predictors and the values from Trim III as a response. We concluded that the association between the Aix brachial values in the second and third trimester of pregnancy was a positive strong extremely significant one and the one between the SD PWVao values was a weak negative and insignificant. Thus, statistically speaking, Aix brachial values decreased constantly for the whole sample, but for the SD PWVao values the decreasing process did not have the same dynamics for the whole sample.

Keywords: pregnancy, arterial stiffness, pulse wave velocity, augmentation index, cardiovascular risk, physical training

EARLY DETERMINATION OF FETAL SEX USING REAL-TIME PCR DETECTION OF THE TSPY MARKER IN MATERNAL PLASMA

Aytakin Hasanova

Azerbaijan Medical University, Faculty of Medicine, Department of Medical Biology and Genetics, Azerbaijan, Baku

ORCID ID: https://orcid.org/0009-0002-9784-4391

Khadija Yusufova

Azerbaijan Medical University, Faculty of Medicine, Department of Medical Biology and Genetics, Azerbaijan, Baku

ORCID ID: https://orcid.org/0009-0008-2859-4468

ABSTRACT

Introduction and Purpose: Early determination of fetal sex is clinically and socially important, particularly for managing sex-linked disorders such as Duchenne and Becker muscular dystrophies, hemophilia, and congenital adrenal hyperplasia. Ultrasound is the conventional method for prenatal sex determination, but it is effective only after the first trimester. Non-invasive prenatal testing (NIPT) using cell-free fetal DNA (cfDNA) in maternal plasma allows earlier detection. Sequencing-based NIPT, however, is expensive and time-consuming. Real-time PCR (qPCR) targeting the Y-chromosome TSPY gene offers a rapid, cost-effective alternative.

Materials and Methods: Plasma samples from 468 women with singleton pregnancies (embryonic age 4–32 weeks) were analyzed. Blood samples were collected in EDTA tubes, and plasma was separated and centrifuged to minimize maternal DNA contamination. Fetal cfDNA was extracted and analyzed via real-time PCR targeting the TSPY gene. Amplification curves were classified as male, female, male with reduced reliability, or undetermined. Results were validated against ultrasound at 20–22 weeks and postnatal phenotypic sex. Repeated sampling was performed for early gestational ages when Y-specific cfDNA signals were inconsistent.

Results: The TSPY marker was unambiguously detected in 46.7% of samples and with reduced reliability in 5.3%**.** Detection rates increased with gestational age, reaching a stable maximum after the 7th embryonic week. Sensitivity and specificity for sex determination from week 7 onward were 97.9% and 99%**,** respectively. Repeat testing further increased diagnostic accuracy to nearly 100%**.** Y-specific cfDNA could be detected as early as weeks 4–5, although results were less consistent at this stage.

Discussion and Conclusion: Real-time PCR detection of the TSPY marker in maternal plasma provides a rapid, accurate, and minimally invasive method for early fetal sex determination. The method is highly reliable from the 7th embryonic week, with repeat testing improving accuracy, making it a practical alternative to sequencing-based NIPT and early ultrasound.

Key Words: Non-invasive prenatal testing (NIPT); cell free fetal DNA (cffDNA), fetal sex determination, qPCR.

ANTITHROMBIN DEFICIENCY IN PREGNANCIES WITH THROMBOPHILIA

Loichita Adrian
University of Medicine and Pharmacy "Victor Babes" Timisoara, ROMANIA

Oros Dacian
University of Medicine and Pharmacy "Victor Babes" Timisoara, ROMANIA

Suciu Oana
University of Medicine and Pharmacy "Victor Babes" Timisoara, ROMANIA

Petre Ion
University of Medicine and Pharmacy "Victor Babes" Timisoara, ROMANIA

Petre Izabella
University of Medicine and Pharmacy "Victor Babes" Timisoara, ROMANIA

Abstract

Introduction: Thrombophilia can be defined as an abnormality of the coagulation or fibrinolytic system that results in a hypercoagulable state, leading to an increased risk for a thrombotic event of an individual to occur, in which the intravascular thrombus may be arterial or venous. Recurrent miscarriage and has also been linked with thrombophilia. Finally, thromboembolism in pregnancy as in the non-pregnant state is linked to thrombophilia.

Material and Methods: In this study we wanted to see if the amount of Antithrombin can influence the pregnancy of our patients or the foetus's development. For this we included in our study 116 pregnant patients who suffer from thrombophilia.

Results and Discussions: We have gathered information about the antithrombin values and about the number of pregnancies and deliveries and about the new-born: gestational period, weight, APGAR score at birth. As well we calculated the difference between the number of pregnancies (Gesta) and the number of deliveries (Para) and we denoted this difference with DIFF, because is known in the literature that women with thrombophilia are more prone to having abortions.

Conclusions: Evolution and complications are related to the complexity of thrombophilia, age, severity of clinical manifestations – the presence of thrombotic events with various localizations and their severity, associated pathology.

Keywords: Thrombophilia, antithrombin values, Fetus weight, APGAR score

CLINICAL CASE OF GOLDENHAR SYNDROME IN A PREMATURE INFANT BOR VIA IVF

K. Farajova

Research Institute of Pediatrics, Baku, Azerbaijan.

Adelya Sabir Hajiyeva

MD, PhD (Doctor of Medical Sciences

Junior Research Fellow

Department of Pathology of Newborns and Preterm Infants,
Sabina Zaid Medjidova

ORCID ID 0009-0003-5914-1908

Goldenhar syndrome (hemifacial microsomia) is a rare congenital disorder characterized by multiple malformations of the facial skeleton, often accompanied by internal organ defects (cardiac, renal, pulmonary) and mental retardation.

We present a clinical case of Goldenhar syndrome in a premature male infant, the first of twins conceived via IVF. The mother had antiphospholipid syndrome (APS) and anemia, and throughout the pregnancy received treatment with clexane and iron supplements.

The infant's clinical phenotypic features included marked facial dysmorphism (D < S), right-sided facial muscle hypoplasia, right-sided anotia with absence of the external auricle, micrognathia, and a right-sided limbal dermoid cyst. These abnormalities were associated with congenital heart defects (atrial septal defect and patent ductus arteriosus) and a congenital brain anomaly.

Goldenhar syndrome is a rare congenital disorder involving malformations of structures derived from the first and second branchial arches. The American physician Maurice Goldenhar first described it in 1952. The epidemiology of the syndrome is not yet fully understood. In most cases, it arises from impaired differentiation of the first and second branchial arches, associated with mutations in genes located on chromosomes 14 (locus 14q32), 5 (locus 5p15), and 20 (MYT1 gene, locus 20q13.33). Familial occurrence has been reported in approximately 2% of cases.

Predisposing factors may include early prenatal exposure to teratogenic agents, a history of abortion or miscarriage, maternal diabetes mellitus, and obesity. The prevalence is estimated at 1 in 3,500–7,000 live births. Diagnosis is typically made using the OMENS classification, which evaluates the presence of anomalies in the following domains: O – ocular, M – mandibular, E – auricular, N – neural and S – soft tissue.

The most severe presentation is the first and second branchial arch syndrome, involving anomalies of all five sensory organs along with internal organ and central nervous system defects, observed in approximately 70% of cases. A milder form, first branchial arch syndrome,

involves three anomalies, while second branchial arch syndrome typically presents with an isolated auricular anomaly.

Management of Goldenhar syndrome is multidisciplinary and may involve otolaryngologists, ophthalmologists, speech therapists, neurologists, cardiologists, psychologists, and, when indicated, surgeons and prosthetists.

Key Points: oculo-auriculo-vertebral dysplasia, hemifacial microsomia, anotia, micrognathia, right eye dermoid cyst

Clinical Observation

A three-day-old premature male infant, the first of twins, was admitted to the Research Institute of Pediatrics. The mother, 19 years old, conceived via IVF after three years of infertility. During pregnancy, due to antiphospholipid syndrome (APS) and anemia, she received enoxaparin and iron supplements. At 20 weeks of gestation, Doppler ultrasonography revealed the absence of the external right auricle in the fetus.

The infant was delivered prematurely at 33 weeks of gestation via cesarean section, with a birth weight of 1900 g and a length of 47 cm. The second twin, a female, was healthy.

The male infant was admitted to the Neonatal Pathology Unit with respiratory distress syndrome (RDS) and neonatal jaundice, weighing 1740 g and lacking the sucking reflex. On physical examination, the following were noted: right-sided facial dysmorphism, anotia, micrognathia, and a right-sided limbal dermoid cyst.

Congenital heart defects were identified, including an atrial septal defect (ASD) and a patent ductus arteriosus (PDA), as well as central nervous system involvement, hypotonia of the limb muscles, and impaired primitive sucking reflexes. The infant was fed via nasogastric tube.

Clinical Diagnosis:

- Goldenhar syndrome (hemifacial microsomia), first and second branchial arch syndrome (OMENS classification)
- Anotia
- Respiratory distress syndrome
- Neonatal jaundice
- Congenital heart defects (ASD, PDA)
- Congenital brain atrophy
- Prematurity, second degree
- First twin

Investigations:

- **Echocardiography:** Atrial septal defect, diameter 3 mm; patent ductus arteriosus, diameter 3.6 mm
- **Chest X-ray:** No focal lesions; thymic enlargement noted
- **Cranial ultrasound:** Microgyria of brain structures
- **Abdominal ultrasound:** No abnormalities detected
- **Biochemistry:** Total bilirubin elevated to 13.6 mg/dL, predominantly indirect fraction

- **Complete blood count:** Within normal limits

Specialist Consultations:

- **ENT:** Anotia, absence of the right external auricle
- **Ophthalmology:** Right-sided limbal dermoid cyst
- **Cardiology:** ASD and PDA
- **Neurology:** Congenital brain atrophy

The infant received phototherapy and metabolic therapy. He was discharged after ten days in satisfactory condition.

Recommendations:

Follow-up consultations with an otolaryngologist, maxillofacial surgeon, ophthalmologist, cardiologist, and neurologist.

Genetic evaluation and consultation with a clinical geneticist and other relevant specialists.

Conclusion: Women in the first trimester of pregnancy should observe preventive measures, avoid exposure to chemical agents and ionizing radiation, and minimize the risk of viral infections and teratogenic drug effects, as this period is critical for skeletal development. This clinical case emphasizes the importance of comprehensive evaluation of neonates with Goldenhar syndrome to ensure timely therapeutic and rehabilitative interventions aimed at improving long-term outcomes and quality of life.

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CHRONIC GENERALIZED PERIODONTITIS IN PREGNANT WOMEN WITH CHRONIC KIDNEY DISEASES

Shahla Yusubova

Azerbaijan Medical University

Rizvan Mammadov

Azerbaijan Medical University

Bayramov Gasim

Azerbaijan Medical University

Huseynova Parvin

Azerbaijan Medical University

Introduction: Chronic generalized periodontitis is a multifactorial inflammatory disease characterized by progressive destruction of periodontal tissues, ultimately leading to tooth loss if untreated. Its course and severity are strongly influenced by systemic conditions. Pregnancy introduces profound hormonal, vascular, and immunological modifications that increase tissue susceptibility to periodontal inflammation, while chronic renal failure (CRF) causes uremia-related immune dysfunction, oxidative stress, mineral–bone metabolism disturbances, and endothelial impairment. The coexistence of pregnancy and CRF creates a unique biological environment that predisposes patients to rapid periodontal breakdown and elevated systemic inflammatory burden.

Objective: This review aims to analyze the interrelationship between chronic generalized periodontitis, pregnancy-related physiological changes, and the systemic complications of chronic renal failure, emphasizing pathophysiological mechanisms, clinical manifestations, diagnostic considerations, and potential maternal–fetal implications.

Material and Methods: A comprehensive examination of current medical and dental literature was conducted, focusing on periodontal health during pregnancy, oral manifestations of CRF, and the impact of systemic inflammation on maternal and fetal outcomes. Examinations were conducted on a total of **179 patients**, including **92 men** and **87 women** with chronic kidney disease. The **outpatient records and medical histories** of these 179 patients were thoroughly analyzed, and all individuals were subjected to a **comprehensive dental examination**.

Results: Pregnant women with CRF demonstrate heightened periodontal vulnerability due to the convergence of multiple pathogenic factors. Elevated estrogen and progesterone levels promote vascular dilation, increased gingival crevicular fluid, and exaggerated inflammatory responses to plaque biofilm. CRF contributes additional challenges through impaired neutrophil function, reduced phagocytosis, accumulation of pro-inflammatory cytokines (including IL-6 and TNF-α), and persistent oxidative stress. Disorders of calcium–phosphate metabolism and secondary hyperparathyroidism may accelerate alveolar bone loss. Furthermore, reduced

salivary flow, altered pH, and changes in the oral microbiome support growth of anaerobic periodontal pathogens.

Clinically, these patients often present with severe gingival inflammation, deeper periodontal pockets, rapid attachment loss, spontaneous bleeding, and increased mobility of teeth. Systemically, the inflammatory mediators derived from periodontal infection may exacerbate endothelial dysfunction and contribute to adverse pregnancy outcomes such as preterm birth, low birth weight, preeclampsia, and intrauterine growth restriction. For patients with CRF, chronic periodontal inflammation may additionally worsen cardiovascular strain and systemic inflammatory load, potentially affecting renal function stability.

Conclusion: Chronic generalized periodontitis in pregnant women with chronic renal failure represents a high-risk clinical condition requiring meticulous interdisciplinary management. Early periodontal assessment, individualized treatment strategies adapted to pregnancy and renal status, and close collaboration among periodontologists, obstetricians, and nephrologists are essential to minimize complications and optimize maternal, fetal, and systemic health outcomes.

Keywords: chronic periodontitis, pregnancy, chronic kidney diseases, periodontal inflammation, maternal–fetal health, systemic disease.

PHYSICAL ACTIVITY, RISK FACTORS, AND CARDIAC HEALTH: FINDINGS FROM A CROSS-SECTIONAL STUDY

Jihane HILALI

Institute of Sports Professions, Interdisciplinary Laboratory of Sport Sciences, Ibn Tofail University, Kenitra, Morocco

Rochdi DAIBI

Cognitive-Behavioral Neurosciences and Applied Nutrition, Laboratory of Biology and Health / Laboratory of Nutrition, Health and Environment, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

Amine ARFAOUI

Institute of Sports Professions, Interdisciplinary Laboratory of Sport Sciences, Ibn Tofail University, Kenitra, Morocco

Mohamed CHERTI

Faculty of Medicine and Pharmacy, Mohammed V University in Rabat

Bouchra TAIB

Institute of Sports Professions, Interdisciplinary Laboratory of Sport Sciences, Ibn Tofail University, Kenitra, Morocco

Abstract

Cardiovascular diseases remain a leading cause of morbidity and mortality worldwide. Regular physical activity (PA) plays a crucial role in prevention and secondary rehabilitation. However, PA levels among hospitalized cardiac patients in Morocco remain poorly documented. This study aims to assess PA levels and their association with cardiovascular risk factors.

Methods: A cross-sectional study was conducted among 74 cardiac patients hospitalized in a cardiology department. Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ). Sociodemographic data, clinical characteristics, and major cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, alcohol consumption, heredity) were collected. Associations between PA intensity and risk factors were analyzed.

Results: The sample included 63.51% males with a mean age of 53.2 years. The main cardiovascular risk factors were hypertension (47.3%), smoking (45.9%), diabetes (40.5%), and dyslipidemia (24.3%). GPAQ results showed that 59.46% of patients had low PA levels, 29.73% moderate, and only 10.81% high PA levels. Notably, 52.7% reported no leisure-time

physical activity. A significant association was found between low PA and hypertension (p=0.009), as well as diabetes (p=0.009). No significant association was observed with age, sex, dyslipidemia, smoking, alcohol consumption, or hereditary factors.

Conclusion: Most hospitalized cardiac patients exhibit insufficient physical activity, particularly in leisure-time domains. Low PA is significantly associated with hypertension and diabetes. These findings highlight the need to strengthen cardiac rehabilitation programs and promote tailored physical activity interventions to reduce cardiovascular risk and improve patient outcomes.

Keywords: Physical activity, GPAQ, cardiovascular diseases, cardiac patients, hypertension, diabetes, risk factors, Morocco, cross-sectional study.

EFFECT OF SHORT-DURATION MODERATE-INTENSITY PHYSICAL ACTIVITY ON GLYCAEMIC CONTROL AND ANTIOXIDANT CAPACITY OF PREDIABETIC POPULATION

Associate Professor Zubia Shah
Department of Physiology, Khyber Girls Medical College, Peshawar, Pakistan.

Assistant Professor Dr. Sarah Shahid
Department of Physiology, Khyber Girls Medical College, Peshawar, Pakistan.

Assistant Professor Dr. Farida Ahmad
Department of Physiology, Khyber Girls Medical College, Peshawar, Pakistan.

Assoc. Professor Dr. Afsheen Mahmood
Department of Physiology, Khyber Girls Medical College, Peshawar, Pakistan.

Abstract

Objectives: To determine the effect of moderate-intensity physical activity on glycaemic control and antioxidant capacity in the prediabetic population.

Methods: This experimental study was carried out in the Physiology Department, Institute of Basic Medical Sciences, Khyber Medical University, Peshawar, Pakistan. A total of 50 adult prediabetic subjects, 22 females and 28 males, aged 18 to 35 years, were included. Diagnosis of prediabetes

The condition was diagnosed based on glycated haemoglobin levels ranging from 5.7% to 6.4% and impaired fasting glucose (100-125 mg/dL). Anthropometric measurements and biochemical assays were performed before and after the exercise intervention. Participants engaged in moderate exercise for 30 minutes, with a maximum heart rate of 7% ± 5%, five days a week for eight weeks, monitored using a pedometer. An enzyme-linked immunosorbent assay was used to measure individual and total antioxidants.

Results: Anthropometric parameters decreased significantly after exercise. Similar changes were observed for fasting glucose ($p < 0.001$) and glycated hemoglobin ($p < 0.001$). A slight increase was noted in uric acid ($p<0.005$) and total antioxidant concentration ($p<0.001$). However, levels of superoxide dismutase, glutathione peroxidase, vitamin C, and nitric oxide decreased ($p<0.001$).

Conclusion: Moderate physical activity for 8 weeks significantly reduced individual antioxidant levels, led to a nominal increase in total antioxidant capacity and uric acid, and was associated with an explicit decline in the anthropometric and diabetic profile of the prediabetic population.

Keywords: anthropometry, antioxidants, physical activity, prediabetes, total antioxidant capacity

ASSOCIATION BETWEEN OBESITY AND CHRONIC KIDNEY DISEASE IN MOROCCAN ADULT POPULATION

Moustakim Rachida
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

El Hendaoui Hajar
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

Friki Fidaous
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

Liba Habiba
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

Barakat Imane
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

Mziwira Mohamed
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School of Hassan II University, Casablanca, Morocco.

Belahsen Rekia
Laboratory of Biotechnology, Biochemistry & Nutrition.Training and Research Unit on Nutrition & Food Sciences. Chouaib Doukkali University. Faculty of Sciences, El Jadida, Morocco.

Abstract

Introdution: Chronic kidney disease (CKD) is considered as a serious public health problem, associated with high cardiovascular morbidity, mortality and low quality of life. The aim of this study was to estimate the prevalence and the association of CKD with obesity among Moroccan population of Sidi Bennour a province of Morocco.

Subjects and Methods: A prospective cohort was carried out involving 210 subjects aged 18 or older, randomly selected from the province health care centers. Socio demographic and clinical data as well as information on the participants'lifestyle were collected using a structured questionnaire. Blood samples were collected and the serum creatinine was determined.

Subsequent Glomerular Filtration Rate (eGFR) was estimated by the Modification of Diet in Renal Disease (MDRD) formula and the CKD was defined by an eGFR<60ml/min/1.73m².

Results : The participants mean age was 54.18 ± 13.45 years, with a sex ratio of 0.30 and the prevalence of CKD was 4.4%. Although obesity is considered among multiple risk factors for CKD, however, in our study no statistical significant association was found between obesity and CKD. Indeed, the results show a negative correlation between CKD and abdominal obesity (r=-0,239 ; p=0,001).

Conclusion: The study data show no relationship between chronic kidney disease and obesity. The study results recommend a monitoring of obesity and especially abdominal obesity considered as a cause of this noncommunicable disease (NCD).

Keywords: Chronic kidney disease, obesity, eGFR, NCD, Sidi Bennour

THE ROLE OF INFECTIOUS PROCESSES IN THE OCCURRENCE OF CARDIOVASCULAR DISEASES AND OPTIMIZATION OF PREVENTIVE MEASURES

Humay Baylar Orujova

Biology, Psychology and Pedagogical Subjects department of Odlar Yurdu University, Baku

ORCID ID: https://orcid.org/0009-0006-8503-696X

ABSTRACT

In the research group consisting of patients suffering from viral respiratory infections concurrent with cardiovascular diseases (n=22), 5 individuals had been hospitalized with gastroenteritis complaints in the past six months and were subsequently diagnosed and treated for the condition. These individuals accounted for 22.7% of the respective group. However, in the research group consisting of patients diagnosed solely with viral respiratory infections, without concurrent cardiovascular disease (n=18), only 2 individuals were found to have sought medical attention and 16 received treatment for gastroenteritis. This accounted for 11.1% of the respective group. Since preventive, therapeutic, and rehabilitation measures for cardiovascular disorders and chronic heart diseases are still not fully effective, these conditions have a significant place in overall morbidity rates. The high frequency of autonomic dysfunctions is noted in connection with various forms of somatic pathology, including pathological changes in the heart and blood vessels, which often result from the negative effects of certain infectious agents, particularly viral pathogens. Among the etiological and pathogenetic risk factors for cardiovascular diseases, infectious diseases of bacterial, viral, and other origins, along with immune system disorders, endocrine pathologies, and increasing environmental pollution, are of particular significance. Studying the characteristics of the relationship between cardiovascular diseases and various inflammatory-infectious conditions can contribute to the prevention of cardiovascular diseases. The reason for selecting specific age intervals in patients is to ensure the reliability of the results by allowing for the comparison of pathological, physiological, biological, and microbiological indicators obtained from patients of corresponding age groups.

Key words: cardiovascular diseases, infectious, prevention, optimization

INTRODUCTION

Myocarditis is a disease caused by inflammation of the heart muscle, most commonly resulting from an infectious process [1]. However, it can also arise due to drug hypersensitivity, radiation, metabolic disorders, collagen diseases, sarcoidosis, Kawasaki disease, or excessive exposure to heat or chemical [2]. Determining the prevalence of myocarditis in the general population is challenging, as many patients remain undiagnosed [3]. However, it affects approximately 10.2 to 105.6 per 100,000 people worldwide, with an estimated annual incidence of around 1.8 million cases [4].

Myocarditis is an inflammatory disease of the myocardium characterized by broad etiological, clinical, and histopathological heterogeneity. It may occur as an isolated condition or as part of systemic infectious/immune/autoimmune disorders. The wide spectrum of myocarditis can be

classified according to the predominant histopathological pattern, including lymphocytic, lymphohistiocytic, eosinophilic, neutrophilic forms, giant cell myocarditis, and myocarditis with granulomas. Different histopathological substrates typically reflect distinct etiologies and pathogenetic mechanisms, which may be critical for clinical decision-making. When present, active vasculitis complements the inflammatory spectrum. Unfortunately, the correlation between histopathological patterns, clinical presentation, and disease course in myocarditis remains unresolved due to limited biopsies at certain disease stages and the impossibility of obtaining serial samples.

The study included a total of 200 patients with cardiovascular diseases (main group), comprising 98 individuals with bacterial ENT diseases, 80 with rheumatism, and 22 with frequent respiratory viral infections. Besides, there were 125 patients without any cardiovascular diseases (control group), which included 55 with bacterial ENT diseases, 52 with rheumatism, and 18 with respiratory viral infections. This division aimed to analyze the age and weight classification of patients in the research groups, particularly those with infectious myocarditis associated with cardiac arrhythmias, characterized by subfebrile body temperature, increasing weakness, tachycardia, and shortness of breath.

In the research group consisting of patients suffering from viral respiratory infections concurrent with cardiovascular diseases (n=22), 5 individuals had been hospitalized with gastroenteritis complaints in the past six months and were subsequently diagnosed and treated for the condition. These individuals accounted for 22.7% of the respective group. However, in the research group consisting of patients diagnosed solely with viral respiratory infections, without concurrent cardiovascular disease (n=18), only 2 individuals were found to have sought medical attention and 16 received treatment for gastroenteritis. This accounted for 11.1% of the respective group.

An analysis of medical records revealed that in the research group consisting of patients diagnosed with both bacterial ENT infections and cardiovascular disorders (n=98), 33 individuals had been hospitalized for infectious gastrointestinal diseases, specifically enterocolitis, within the past six months. These cases accounted for 33.7% of the respective group. In contrast, in the research group composed of patients suffering from bacterial ENT infections without any diagnosed cardiovascular disease (n=55), 17 individuals had sought medical attention for enterocolitis—the most severe form of gastrointestinal infection—within the same period. In the research groups consisting of patients suffering from combinations of bacterial ENT diseases, rheumatism, and viral respiratory infections, the examination of hospital visits related to gastroenterocolitis involving inflammation of the complex structures of the gastrointestinal system within the past six months, and the confirmation of the diagnosis through primary and additional examination methods, revealed the following: In the research group composed of patients with bacterial ENT infections and cardiovascular diseases (n=98), medical record analysis showed that 52 individuals had sought medical attention and undergone treatment related to gastroenterocolitis, accounting for 53.1% of the respective group. Unlike the combination of bacterial ENT diseases with cardiovascular diseases, in the research group consisting of 55 patients with bacterial ENT diseases without cardiovascular diseases, 33 individuals sought medical attention for gastroenterocolitis during the study period.

During the identification of inflammatory diseases affecting various gastrointestinal structures or departments based on medical records, in the research groups consisting of different combinations of patients with cardiovascular diseases or pathologies, bacterial ENT infections, rheumatism, and viral respiratory infections, the following results were observed: The highest incidence of gastroenteritis-related medical visits was observed in the group where cardiovascular diseases were combined with rheumatism. For 17 enterocolitis, the highest visit

rate was observed in the group of patients suffering from rheumatism. For gastroenterocolitis-related visits, the maximum visit rate was recorded in the group of patients where both cardiovascular diseases and bacterial ENT infections were present, and finally, for gastroenterocolitis-related visits, the highest rate was noted in the group of patients suffering only from bacterial ENT infections without cardiovascular diseases.

Overall, when grouping the most common gastrointestinal diseases leading to medical visits in the research groups, the highest rate of hospital visits in the past six months was observed in the group where cardiovascular diseases and bacterial ENT infections were found together. The main reason for the visits was gastroenterocolitis, recorded for 52 individuals, accounting for 53.1% of the group. In the research group consisting of patients with both cardiovascular diseases and rheumatism, the most common reason for medical visits related to gastrointestinal issues was gastroenteritis, which was recorded for 39 individuals, accounting for 48.8% of the group. In the research group consisting of patients with a predisposition to viral respiratory infections along with cardiovascular diseases, the most common reason for medical visits was gastroenterocolitis, affecting 11 patients, or 50% of the group. The same gastrointestinal disease also showed the highest visit rate in the research group of individuals predisposed to bacterial ENT infections without cardiovascular diseases, with 33 patients, or 60% of the group, being affected. During the examinations, in the research group consisting of patients with confirmed rheumatism and no cardiovascular diseases, the most common gastrointestinal disease that led to hospital visits and required treatment in the past 6 months was gastroenteritis. It was recorded in the medical documents of 28 patients, accounting for 53.8% of the group. In this case, among the patients in the research group with a predisposition to viral respiratory infections without any cardiovascular diseases, the gastrointestinal disease with the highest incidence in the past 6 months was gastroenterocolitis, which was also observed in the research groups consisting of patients with bacterial LOR infections accompanied by cardiovascular diseases, 18 viral respiratory infections with cardiovascular diseases, and patients with a predisposition to bacterial LOR infections without cardiovascular diseases. In the group of 80 patients where both cardiovascular diseases and rheumatism were detected, acute pancreatitis as a complication of gastrointestinal diseases was recorded in 3 patients, which constitutes 3.8% of the research subjects in that group. However, in the group of 52 patients who had only rheumatism without any cardiovascular diseases and were diagnosed with various clinical and laboratory tests, no cases of acute pancreatitis as a complication during the treatment of gastrointestinal inflammatory processes were observed.

As a result of the study, in the group of 18 patients without cardiovascular diseases but with a documented predisposition to viral respiratory infections, no cases of gastrointestinal diseases progressing to acute pancreatitis were observed. However, in the group of 22 patients who had both cardiovascular diseases and a predisposition to viral respiratory infections, this condition was recorded in 2 individuals, accounting for 9.1% of the respective group. When examining cases of anemia complications during the treatment of gastrointestinal diseases across different groups, laboratory tests confirmed that 4 patients in the group with a documented medical history of both cardiovascular diseases and a predisposition to bacterial ENT diseases (n=98) experienced this complication. This accounts for 4.1% of the respective group. However, in the research group consisting of patients without cardiovascular diseases but with a documented high susceptibility to bacterial ENT infections (n=55), anemia was observed in 5 individuals, accounting for 9.1% of the group, based on the results of a complete blood count. Besides, in the group of patients suffering from both rheumatism and cardiovascular diseases (n=80), laboratory and clinical examinations confirmed the presence of rheumatism, and anemia was detected during the treatment of gastrointestinal diseases in 5 individuals, representing 6.3% of this group. In this case, in the group consisting of patients without any diagnosed form of

cardiovascular disease but with rheumatism fully confirmed through examinations (n=52), anemia was observed in 5 individuals during the treatment of gastrointestinal conditions. This accounted for 9.6% of the total group. In the research group consisting of patients with both cardiovascular diseases and an excessive predisposition to viral 20 respiratory infections (n=22), anemia complications were observed in 1 patient during the treatment of gastrointestinal diseases within the last six months. This accounted for 4.5% of the group. Similarly, in the group of patients without any diagnosed form of cardiovascular disease but with an abnormally high sensitivity to viral respiratory infections (n=18), anemia developed in 1 patient during the treatment of gastrointestinal diseases, representing 5.6% of the group. When determining the number of patients diagnosed with both gastrointestinal problems and urinary tract infections, 3 individuals in the research group consisting of patients with both cardiovascular diseases and a predisposition to bacterial ENT infections (n=98) had documented cases of these infections confirmed through clinical and laboratory examinations. This accounted for 3.1% of the group.

However, in the research group consisting of patients with a predisposition only to bacterial ENT infections and no diagnosed form of cardiovascular disease (n=55), no cases of urinary tract infections were recorded. As a result of the retrospective study, in the research group consisting of individuals with both cardiovascular diseases and a predisposition to viral respiratory infections (n=22), one patient (4.5% of the group) experienced gastrointestinal issues in the past six months and developed a secondary urinary tract infection during treatment. However, in the research group consisting of 18 patients with a predisposition only to viral respiratory infections and no diagnosed cardiovascular diseases, no such cases were observed. Overall, when examining various secondary complications arising during the treatment of gastrointestinal issues - previously analyzed in terms of their nature and distribution across groups - the group with both cardiovascular diseases and bacterial ENT infections (n=98) recorded complications in 9 patients, accounting for 9.2% of the study subjects in this group. In the group of patients suffering from bacterial ENT diseases without cardiovascular diseases (n=55), 6 patients experienced one or more of the complications mentioned above, accounting for 10.9% of the group. Besides, in the group consisting of individuals with both cardiovascular diseases and confirmed rheumatism (n=80), medical 21 records showed that 11 patients experienced various complications during antimicrobial treatment for gastrointestinal diseases, representing 13.8% of the group. In this stage of the study, in the group of patients suffering from rheumatism without cardiovascular diseases (n=52), 8 patients exhibited one of the complications mentioned above, accounting for 15.4% of the total group. During the relevant phase of the study, in the group of patients with both cardiovascular diseases and a tendency toward viral respiratory infections (n=22), 4 patients showed one of the mentioned complications, representing 18.2% of the study objects in this group. However, in the group of individuals with a tendency toward viral respiratory infections without cardiovascular diseases (n=18), only 1 patient, or 5.6% of the study subjects, exhibited various secondary complications. Thus, during the treatment of gastrointestinal diseases, the most common complication observed was acute pancreatitis in the group of 22 patients with cardiovascular diseases and a tendency to viral respiratory infections, accounting for 9.1%. In this regard, the corresponding group of 80 patients, in which the presence of both cardiovascular diseases and confirmed rheumatism by laboratory tests was observed, showed a 3.8% occurrence. During this phase, no cases of acute pancreatitis were observed in the group consisting of individuals without cardiovascular diseases but with rheumatism, as well as in the group without cardiovascular diseases but prone to viral respiratory infections. When the secondary development of anemia during the treatment of gastrointestinal problems was examined, the maximum and minimum occurrence rates were 9.6% and 4.1%, respectively, observed in the

group of patients with rheumatism without cardiovascular diseases (n=52) and in the group with cardiovascular diseases and bacterial LOR diseases (n=98). In the phase of the study covering the last month, where acute otitis cases were examined, in the group of patients with cardiovascular diseases and a predisposition to bacterial LOR infections, only 1 person was found to have acute inflammation of the middle ear, which constitutes 1% of that group. Similarly, in the group of patients without cardiovascular diseases but with a 22 predisposition to bacterial LOR infections, only 1 person was observed to have acute otitis, but this represents 1.8% of that group. During the relevant phase of the study, in the group of patients suffering from both cardiovascular diseases and rheumatism, no cases of acute otitis were found within the last month. However, in the group of patients with rheumatism but no cardiovascular diseases, 2 individuals were found to have acute otitis, constituting 3.8% of the total research subjects in that group. In the corresponding study period, neither the group of patients with both cardiovascular diseases and a predisposition to viral respiratory infections nor the group of patients without cardiovascular diseases but with a predisposition to viral respiratory infections, had any complaints related to acute otitis within the last month. When we identified cases of patients being referred for treatment related to atopic dermatitis in the last month, in the group of patients with a combination of cardiovascular diseases and an excessive predisposition to bacterial ENT infections, 12 individuals were noted to have sought medical attention for the aforementioned dermatological problems. These individuals constitute 12.2% of the total research subjects in this group. At the same time, in the group of patients with sensitivity to bacterial ENT infections but without cardiovascular diseases, 7 individuals sought medical attention and received analogous treatment measures due to clinical manifestations of atopic dermatitis in the last month. These patients constitute 12.7% of the total contingent in this group. In the study conducted to observe changes during ECG and Echo-ECG tests and detect various heart problems, it was found that out of a total of 200 patients with cardiovascular diseases, 147 patients had systolic murmurs detected during auscultation, which accounts for 73.5% of the respective patient group. However, in the conditional group consisting of 125 patients who had bacterial ENT diseases, rheumatism, and viral respiratory infections without any cardiovascular issues, no patients with systolic murmurs were found during clinical examinations. The statistical significance between the groups was determined as p=0.0001.

During the study, in a group of 200 patients, consisting of those with a tendency to bacterial ENT diseases, rheumatism, and viral respiratory infections along with cardiovascular diseases, 72 patients were observed to have muffled heart sounds, which accounts for 36% of the total research subjects in the group. However, as in the case of identifying the presence of systolic murmurs, in a group of 125 patients with a tendency to bacterial ENT diseases, rheumatism, and viral respiratory infections without cardiovascular diseases, no patients were found to have muffled heart sounds. The statistical relationship between the groups during this period was p=0.0001. During the study, in a group of patients with cardiovascular diseases who sought medical attention due to a bacterial ENT infection suspected to be of viral origin in the past month (n=98), 15 samples tested positive for parainfluenza viruses in nasalpharyngeal swabs, accounting for 15.3% of the total cases in the group. In contrast, in a group of patients without cardiovascular diseases, who sought medical attention for a bacterial ENT infection within the past month (n=55), parainfluenza viruses were detected in 7 samples, representing 12.7% of the total cases in the group. However, in none of the groups – namely, the group of patients with cardiovascular diseases and concomitant rheumatism (n=80), the group of patients with cardiovascular diseases who had a viral respiratory infection in the past month (n=22), the group of patients without cardiovascular diseases but with rheumatism (n=52), and the group of patients without cardiovascular diseases who had a viral respiratory infection in the past month (n=18) - were adenovirus representatives detected in the nasal-pharyngeal swabs. Overall, in

the group of patients with cardiovascular diseases who had a bacterial LOR infection in the past month (n=98), 19 individuals had various virus representatives detected in their nasal-pharyngeal samples, which accounts for 19.4% of the group. In the group of patients with both cardiovascular diseases and rheumatism (n=80), this indicator was 15 individuals, which accounts for 18.8% of the group. In the group of patients with cardiovascular diseases and who had a viral respiratory infection in 24 the past month (n=22), this indicator was 7 individuals, or 31.8% of the group. In the group of patients with no cardiovascular disease but who had a bacterial LOR infection in the past month (n=55), this indicator was 12 individuals, or 21.8% of the group. In the group of patients with no cardiovascular disease but with rheumatism (n=52), 11 individuals had the same indicator, representing 21.2% of the group. Finally, in the group of patients with no cardiovascular disease and who had a viral respiratory infection in the past month (n=18), 2 individuals were identified, representing 11.1% of the group.

Thus, since preventive, therapeutic, and rehabilitation measures for cardiovascular disorders and chronic heart diseases are still not fully effective, these conditions have a significant place in overall morbidity rates.

The high frequency of autonomic dysfunctions is noted in connection with various forms of somatic pathology, including pathological changes in the heart and blood vessels, which often result from the negative effects of certain infectious agents, particularly viral pathogens. Among the etiological and pathogenetic risk factors for cardiovascular diseases, infectious diseases of bacterial, viral, and other origins, along with immune system disorders, endocrine pathologies, and increasing environmental pollution, are of particular significance. Studying the characteristics of the relationship between cardiovascular diseases and various inflammatory-infectious conditions can contribute to the prevention of cardiovascular diseases. The reason for selecting specific age intervals in patients is to ensure the reliability of the results by allowing for the comparison of pathological, physiological, biological, and microbiological indicators obtained from patients of corresponding age groups.

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COMPARATIVE ANALYSIS OF THE DIAGNOSTIC EFFECTIVENESS OF COMPUTED TOMOGRAPHY AND ULTRASOUND IN THE EXAMINATION OF COMPLICATIONS AFTER CESAREAN SECTION

Ph.D. Asif Mustafayev

Academician M.A. Topchibashov Scientific and Surgical Center

Doctor of Philosophy in Medicine, Head of the Department of Radiology, Baku, Azerbaijan

ORCID ID: https://orcid.org/0009-0003-0715-4360

ABSTRACT

The study was conducted between 2022 and 2024 at the Radiodiagnostics Department of the M.A. Topchubashov Scientific Surgical Center. A total of 21 women who had undergone cesarean section were included in the study. All participants experienced postpartum complications during the early neonatal period. In summary, US showed very low diagnostic efficacy for bladder and urethral changes as well as for foreign bodies in the abdominal cavity, while CT demonstrated high sensitivity, specificity, and overall diagnostic reliability for all examined pathologies (Se: 0.97–1.00, Sp: 1.00, Acc: 0.98–1.00).

In both groups, alongside cesarean section, some women underwent other surgical procedures: 44.4% in Group I (US) and 41.6% in Group II (CT). Bladder and urethral abnormalities were more frequently detected in the CT group. Bladder disorders were identified in 22.2% of patients in Group I and 33.3% in Group II, while urethral disorders were found in 11.1% of Group I and 16.7% of Group II. No foreign bodies were detected in the abdominal cavity of Group I, whereas 8.3% of patients in Group II had foreign bodies. Inflammatory changes in the small pelvic organs were not detected in Group II, while they were recorded in 22.2% of Group I.

For the purpose of evaluating the diagnostic efficacy of CT and ultrasound (US), the patients were divided into two groups: Group I included 9 women who underwent only US, and Group II included 12 women who underwent CT. When bladder abnormalities were not detected, the diagnostic efficacy of ultrasound (US) (sensitivity, specificity, accuracy) could not be recorded. This examination was completely unsuccessful in detecting this feature. In contrast, CT achieved high values and demonstrated very high diagnostic quality for detecting this pathology. In cases of urethral trauma, US sensitivity and accuracy were very low. CT sensitivity and specificity were very high, proving to be a highly accurate and reliable method. Detection of foreign bodies in the abdominal cavity using US also yielded low values.

INTRODUCTION

Cesarean section (C-section) is a surgical procedure used to deliver a baby through incisions made in the mother's abdomen and uterus. While it can be life-saving in certain situations, it carries risks and potential complications for both the mother and the baby.

Cesarean section (CS), also known as cesarean delivery, refers to the delivery of the fetus, placenta and membrane through abdominal and uterine incision after fetal viability. Globally,

the cesarean section rate is unevenly distributed and results in 21.1% of abdominal deliveries. Africa accounts for 5.0% cesarean deliveries in the world.

Common Complications After Cesarean Section

1. Infections: Postoperative infections can occur at the incision site, in the uterus (endometritis), or in the urinary tract. Infections may lead to prolonged hospital stays and require additional treatments.

2. Blood Clots: C-sections increase the risk of developing blood clots in the legs (deep vein thrombosis) or lungs (pulmonary embolism), which can be life-threatening.

3. Injury to Organs: During the procedure, there is a risk of accidental injury to surrounding organs, such as the bladder or bowel.

4. Adhesions: Scar tissue (adhesions) can form between abdominal tissues and organs, potentially leading to chronic pain or bowel obstructions.

5. Long-Term Risks: Multiple C-sections can increase the risk of complications in future pregnancies, including placenta accreta (abnormal placental attachment), uterine rupture, and the need for hysterectomy.

Factors Influencing Complications

– Previous C-sections: Each subsequent C-section increases the risk of complications, such as adhesions and abnormal placentation.

– Maternal Health: Conditions like obesity, diabetes, and hypertension can elevate the risk of complications during and after surgery.

– Emergency Procedures: Emergency C-sections, performed when complications arise unexpectedly, may carry higher risks compared to planned procedures.

Preventive Measures and Recommendations

– Preoperative Counseling: Discussing the reasons for a C-section and potential risks with healthcare providers can help in making informed decisions.

– Postoperative Care: Following medical advice on wound care, activity restrictions, and signs of complications can aid in recovery.

– Future Pregnancies: Women with a history of C-sections should consult their healthcare provider about the safest delivery options for subsequent pregnancies.

Cesarean delivery, while often necessary for maternal and fetal health, carries risks that can affect both immediate and long-term recovery. Understanding these complications is crucial for healthcare providers and patients alike.

Women undergoing C-sections report higher levels of postoperative pain and are 16% more likely to develop sleep disorders compared to those who have vaginal deliveries.

Common infections include endometritis, urinary tract infections, and wound infections. Septic pelvic thrombophlebitis, a rare but serious condition, can occur if postpartum fever persists despite broad-spectrum antibiotics.

Adhesions can lead to bowel obstruction, with a threefold increased risk following C-section compared to vaginal delivery. These adhesions may require surgical intervention.

Postpartum depression, anxiety, and feelings of inadequacy in newborn care are more prevalent among mothers who have had a C-section. Supportive care and counseling are vital components of recovery.

When discussing the optimal frequency of CS, it is essential to analyze the balance between the risks associated with surgery and the benefits of the procedure. This requires objective data on the differences in outcomes between CS and vaginal births, taking into account the conditions under which they are performed: indications for CS, urgency, surgical and anesthesia methods, use of complication prevention, and the overall health care environment [1]. In this context, not only data on perioperative complications, including life-threatening ones, are important, but also information on the long-term consequences of CS. Long-term complications of CS include decreased fertility, complications in subsequent pregnancies, and maternal and child morbidity. [2].

Although ultrasound is recognized as the most effective method for diagnosing uterine scarring, superior to MRI, the absence of signs of uterine scar failure does not exclude the risk of uterine rupture during childbirth [3].

Comprehensive examination of the uterine scar before pregnancy is gaining popularity: ultrasound with contrast, hysterography with contrast, hysteroscopy, biopsy with subsequent histological examination, computed tomography (CT) and MRI [4].

To date, the choice of treatment strategy for genitourinary tract infections remains controversial. The widespread introduction of third- and fourth-generation antibacterial agents into clinical medicine, advances in endoscopic surgery, and the development of new technologies for invasive interventions guided by transvaginal ultrasound and computed tomography have opened up new opportunities for clinicians [5].

CT with multiplanar reformatted reconstruction can be considered a good initial imaging method due to its availability, fast acquisition time, and the ability to use reformatted images perpendicular to the plane of cut [1]. However, MRI may be superior to CT for differentiating between uterine dehiscence and rupture, as it allows for visualization of all layers of the uterine wall and the intact serosa covering the myometrial rupture. Furthermore, MRI can easily detect large hematomas or abscesses, which are usually associated with true uterine dehiscence. Differential diagnosis is important, as uterine dehiscence can be treated conservatively, while uterine rupture requires surgical treatment [6].

Computed tomography (CT) and magnetic resonance imaging are useful for characterizing postpartum hemorrhage when medical treatment is ineffective. Multidetector CT is important in cases of suspected intra-abdominal hemorrhage and can be considered in cases of recurrent bleeding after embolization, as well as for assessing postoperative complications. A proposed algorithm for clinical and CT imaging in postpartum hemorrhage is presented. A multidisciplinary approach to postpartum hemorrhage is necessary to optimize the role of diagnostic and interventional radiology in obstetric hemorrhage, thereby avoiding hysterectomy and thus preserving fertility. [7].

Researchers K. Shuchi et al. demonstrated the effectiveness of CT in detecting complications following cesarean section, as well as identifying errors in surgical technique [8].

METHODOLOGY

The study was conducted between 2022 and 2024 at the Radiodiagnostics Department of the M.A. Topchubashov Scientific Surgical Center. A total of 21 women who had undergone cesarean section were included in the study. All participants experienced postpartum complications during the early neonatal period.

For the purpose of evaluating the diagnostic efficacy of CT and ultrasound (US), the patients were divided into two groups: Group I included 9 women who underwent only US, and Group II included 12 women who underwent CT.

All patients underwent computed tomography and ultrasound examinations (Siemens Healthineers, Germany). For contrast-enhanced transabdominal US, a contrast agent based on microbubbles was administered as a single intravenous injection in 5–10 ml of saline. For contrast-enhanced CT, an iodine-containing solution was administered intravenously via catheter. In our study, the iodine-based contrast agent used was Ultravist 370. Initially, a statistical analysis of the results of non-contrast transabdominal US was performed.

In both groups, alongside cesarean section, some women underwent other surgical procedures: 44.4% in Group I (US) and 41.6% in Group II (CT). Bladder and urethral abnormalities were more frequently detected in the CT group. Bladder disorders were identified in 22.2% of patients in Group I and 33.3% in Group II, while urethral disorders were found in 11.1% of Group I and 16.7% of Group II. No foreign bodies were detected in the abdominal cavity of Group I, whereas 8.3% of patients in Group II had foreign bodies. Inflammatory changes in the small pelvic organs were not detected in Group II, while they were recorded in 22.2% of Group I.

When bladder abnormalities were not detected, the diagnostic efficacy of US (Se, Sp, Acc) was not recorded. US was completely unsuccessful in detecting this feature. High values were achieved with CT, which demonstrated very high diagnostic quality for detecting this pathology. In urethral trauma, US sensitivity and accuracy were very low. CT sensitivity and specificity (0.97 and 1.00, respectively) were very high, demonstrating CT as a highly accurate and reliable method.

Detection of foreign bodies in the abdominal cavity using US also yielded low values (Se: 0.27, Acc: 0.08), indicating that detection was nearly impossible with US. In contrast, CT showed high accuracy (Se, Sp, Acc – 1.00), effectively detecting this feature.

In summary, US showed very low diagnostic efficacy for bladder and urethral changes as well as for foreign bodies in the abdominal cavity, while CT demonstrated high sensitivity, specificity, and overall diagnostic reliability for all examined pathologies (Se: 0.97–1.00, Sp: 1.00, Acc: 0.98–1.00).

When bladder abnormalities were not detected, the diagnostic efficacy of ultrasound (US) (sensitivity, specificity, accuracy) could not be recorded. This examination was completely unsuccessful in detecting this feature. In contrast, CT achieved high values and demonstrated very high diagnostic quality for detecting this pathology. In cases of urethral trauma, US sensitivity and accuracy were very low. CT sensitivity and specificity were very high, proving to be a highly accurate and reliable method. Detection of foreign bodies in the abdominal cavity using US also yielded low values.

While cesarean sections are essential in certain medical situations, they are not without risks. Understanding potential complications and engaging in preventive care are crucial for maternal and fetal health. Open communication with healthcare providers ensures that women can make informed decisions regarding their delivery options.

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FGF-23 LEVELS AND ARTERIAL CALCIFICATION IN ADVANCED CKD PATIENTS

Farida Hajiyeva
Shalala Ismayilova
Fidan Ahadova
Aytan Mammadzada,
Galina Bakhshaliyeva
Konul Abbasaliyeva
Elnara Gazvinova
Aytan Mammadova

Azerbaijan Medical University, Baku, Azerbaijan

Relevance: In chronic kidney disease (CKD), declining glomerular filtration rate (GFR) leads to phosphate retention, prompting osteocytes and osteoblasts to increase FGF-23 production. Elevated FGF-23 reduces active vitamin D synthesis and thereby lessens its suppressive effect on parathyroid hormone (PTH) — contributing to secondary hyperparathyroidism. The resulting disturbances in calcium-phosphate homeostasis (hypercalcemia and hyperphosphatemia) may lead to vascular calcification in end-stage CKD patients. Vascular calcification risk factors are divided into traditional (age, diabetes, male sex, tobacco use, inflammation, warfarin use, cardiovascular and peripheral vascular disease) and non-traditional. Considering disrupted FGF-23 metabolism, we investigated the association between FGF-23 levels and vascular calcification in both diabetic and non-diabetic end-stage CKD patients.

Methods and materials: 124 end-stage CKD patients (64 women, 60 men) undergoing maintenance dialysis over the last 12 years were included. Based on underlying cause, patients were split into two groups: **Group I** — 68 patients with diabetic nephropathy; **Group II** — 56 patients with non-diabetic end-stage CKD. Immediately before a dialysis session, blood was collected via arteriovenous fistula or catheter. Biochemical tests (phosphate, creatinine, hs-CRP) were done; plasma FGF-23 (C-terminal) concentration was measured using a 2nd-generation two-site immunoassay. The reference normal range was defined as mean±SD: 129±34 RU/ml. All patients underwent ECG, echocardiography, radiographic imaging, and vascular ultrasound examinations.

Results: FGF-23 levels in Group I (diabetic CKD) averaged 3674.3 ± 406 pg/ml; in Group II (non-diabetic CKD) 2572.7 ± 471 pg/ml — difference statistically significant ($p < 0.001$). No significant difference between men and women ($p > 0.05$). Aortic calcification index (ACI) was positively associated with duration of dialysis: among patients dialyzed >5 years, 92% had aortic calcification. Abdominal aortic calcification was identified in 98 of 124 patients. Correlation analysis showed ACI positively correlated with hs-CRP ($R = 0.68$, $p < 0.01$) and with FGF-23 ($R = 0.42$, $p < 0.001$).

Conclusion: In end-stage CKD patients, elevated FGF-23 is associated with inflammation and oxidative stress markers, and may contribute to vascular calcification. These findings imply that FGF-23 might play a role in the pathogenesis of vascular calcification in this population.

Key words: vascular calcification, end-stage CKD, diabetic nephropathy, fibroblast growth factor-23,

MECHANISMS OF INVOLVEMENT OF OXIDATIVE STRESS AND LYMPHATIC DRAINAGE IN THE PATHOGENESIS OF DIABETIC MICROANGIOPATHIES

Mammadzada A.Y.
Ibrahimova N.Y.
Safaraliyeva L. Kh.
Guliyeva A.A.
Muradova S.R.
Huseynova N.I.

Azerbaijan Medical University, Baku, Azerbaijan

Despite advances in medicine, diabetes mellitus (DM) remains a pressing issue due to its high prevalence and severe complications, particularly angiopathies that lead to disability and mortality. Microangiopathies (retinopathies, nephropathies, neuropathies) occur exclusively in DM and are associated with oxidative stress caused by hyperglycemia and hyperlipidemia. This leads to endothelial damage, platelet activation, and impaired microcirculation. However, the impact of oxidative stress on lymphatic vessels, which play a key role in tissue drainage, remains poorly studied, which served as the basis for the present study.

Aim: The aim of this study was to assess the impact of oxidative stress induced by experimental diabetes mellitus on tissue microlymphocirculation.

Materials and methods: The experiment involved 60 Chinchilla rabbits of both sexes, weighing 2.5–3.0 kg. All procedures complied with the requirements of the European Convention (1986) and were approved by the local ethics committee. Animals were housed individually under standard conditions.Surgical procedures were performed under general anesthesia using intravenous ketamine (8 mg/kg) and diphenhydramine (0.15 ml/kg of a 1% solution). Diabetes mellitus was induced by intravenous administration of a 5% alloxan solution at a dose of 100 mg/kg. Blood glucose levels were monitored on an empty stomach before and after the injection, as well as on days 5, 15, 30, 60, and 90 using a SensoLite Nova glucometer (Budapest, Hungary). To prevent hypoglycemic shock, animals were given a glucose solution instead of water. Rabbits exhibiting severe hyperglycemia (25%) were excluded from the experiment on day 12. Only animals with blood glucose levels between 11 and 15 mmol/L were included in the study.Lymph was collected from the thoracic duct according to the method of A.A. Kornienko et al. Lipid peroxidation (LPO) was assessed by measuring the levels of diene conjugates (DC) and malondialdehyde (MDA). The state of the antioxidant system was evaluated by the activity of superoxide dismutase (SOD) and catalase (CAT). Lymphatic drainage efficiency was assessed by the volume of lymph collected per unit of time per kilogram of body weight.

Result s and Discussions: Despite the variety of mechanisms involved, most researchers agree that intracellular oxidative stress plays a key role in the pathogenesis of endothelial dysfunction (ED) in diabetes mellitus (DM). Oxidative stress is characterized by an imbalance between excessive free radical production and insufficient antioxidant defense mechanisms Numerous studies have shown that free radicals contribute to the inactivation of nitric oxide, leading to endothelial dysfunction , which is supported by the results of the present study. Oxidative stress results in endothelial cell damage and decreased nitric oxide (NO) production, causing impaired endothelial function and reduced resistance to thrombosis. It is also suggested that endothelin-

1-21 serves as a predictor of vascular complications in both type 1 and type 2 diabetes .Under oxidative stress conditions, endothelin-1-21 levels increase, further indicating the disruption of the balance between free radicals and antioxidant defenses.Our results demonstrated that after diabetes modeling, lipid peroxidation (LPO) processes in lymph change significantly. Additionally, these changes are accompanied by impaired lymphatic drainage of tissues.

Conclusions: The study demonstrated that in experimental diabetes mellitus, changes in lipid peroxidation and antioxidant system parameters affect tissue drainage in both the microhemocoagulation and microlymphocoagulation systems. This highlights the importance of considering the condition of not only the blood vascular system but also the lymphatic system in the prevention of microangiopathies in diabetes mellitus.

Keywords: diabetes mellitus, oxidative stress, lymphatic drainage, lymph circulation.

NATURAL STEROIDS OF PLANT ORIGIN AND THEIR PHARMACOLOGICAL APPLICATIONS

BİTKİSEL KÖKENLİ DOĞAL STEROİDLER VE FARMAKOLOJİK UYGULAMALARI

Sadet KARABULUT KALKAN

Yalova University Faculty of Medicine, Department of Medical Pharmacology, Yalova, Turkey

ORCID ID:0009-0007-4257-1708

ABSTRACT

Natural steroids are organic compounds that play important physiological roles in various organisms. They are essential components of the cell and are important for their therapeutic potential in a wide range of conditions, including inflammatory diseases, metabolic disorders, prostate diseases, neurodegenerative processes, and cardiovascular diseases. Steroidal compounds constitute an important class of secondary metabolites in plants. Chemically, they are based on the sterane structure containing four rings and, due to their biological activities, are widely used in phytotherapy, the pharmaceutical industry, and as raw materials for pharmaceuticals. Steroid derivatives can mimic human hormones and exert their activity by augmenting deficient enzymes in the body. Clinically, synthetic steroids are clearly highly utilized in pharmaceuticals for hormonal abnormalities, but they can cause adverse side effects with long-term use. Steroids act as immunosuppressants to control many autoimmune disorders related to inflammation, but they also reduce the activity of the immune system, the body's natural defense against infection and disease. The use of natural steroids derived from botanical plants, marine invertebrates, bacteria, algae, and fungi as substitutes has medicinal value, helping to treat a variety of conditions. In addition to their hormonal functions, bioderived steroids exhibit a safe and rich pharmacological profile, including antioxidant, anti-inflammatory, anticarcinogenic, anti-neoplastic, neuroprotective, and cardioprotective activities. The structural diversity of plant steroids constitutes an important area of research for drug development and phytotherapeutic applications. More comprehensive clinical studies are critical to assessing the safety and efficacy of these compounds. The purpose of this study is to evaluate natural steroid-containing plant species, their steroid-type compounds, pharmacological effects, and clinical application potential in light of current literature.

Keywords: Steroids, hormones, pharmaceutical, sterane, inflammation

ÖZET

Doğal steroidler, çeşitli organizmalarda önemli fizyolojik roller oynayan organik bileşiklerdir. Hücrenin temel bileşenleri olup, inflamatuvar hastalıklar, metabolik bozukluklar, prostat hastalıkları, nörodejeneratif süreçler ve kardiyovasküler hastalıklar gibi geniş bir alanda terapötik potansiyel taşımaların açısından önemlidir. Steroidal bileşikler bitkilerde sekonder metabolitler arasında önemli bir sınıfı oluşturur. Kimyasal olarak dört halka içeren steran yapısını temel alırlar ve biyolojik aktiviteleri nedeniyle fitoterapide, farmasötik sektöründe ve

ilaç ham maddesi olarak geniş kullanım alanına sahiptir. Steroid türevleri insan hormonlarını taklit edebilir ve vücutta eksik olan enzimleri artırarak aktivitelerini sergileyebilir. Klinik olarak, sentetik steroidlerin hormonal anomaliler için farmasötik kullanımının yüksek olduğu açıktır, ancak uzun süreli kullanımda olumsuz yan etkilere neden olurlar. Steroidler, inflamasyonla ilgili birçok otoimmün bozukluğu kontrol altına almak için immünosüpresan olarak çalışırlar, ancak aynı zamanda vücudun enfeksiyon ve hastalıklara karşı doğal savunması olan bağışıklık sisteminin aktivitesini de azaltırlar. Bitkisel bitkilerden, deniz omurgasızlarından, bakterilerden, alglerden ve mantarlardan elde edilen doğal steroidlerin yerine kullanılması, çeşitli rahatsızlıkların tedavisine yardımcı olan tıbbi bir değere sahiptir. Hormonal fonksiyonlarının yanı sıra, biyolojik olarak elde edilen steroidler antioksidan, anti-inflamatuar, antikarsinojenik, anti-neoplastik, nöroprotektif ve kardiyoprotektif aktiviteler açısından da güvenli ve zengin bir farmakolojik profil sergilemektedir. Bitkisel steroidlerin yapısal çeşitliliği, ilaç geliştirme süreçleri ve fitoterapötik uygulamalar açısından önemli bir araştırma alanı oluşturmaktadır. Daha kapsamlı klinik çalışmalar, bu bileşiklerin güvenilirliğini ve etkinliğini değerlendirmek açısından kritik öneme sahiptir. Bu çalışmanın amacı doğal steroid içeren bitki türlerini, içerdiği steroid tipi bileşikleri, farmakolojik etkileri ve klinik uygulama potansiyelini güncel literatür ışığında değerlendirmektedir.

Anahtar kelimeler: Steroidler, hormonlar, farmasötik, steran, inflamasyon

INVESTIGATION OF THE PROTECTIVE EFFECT OF GALANGIN ON HISTOPATHOLOGICAL LESIONS AND SPERMATOLOGICAL PARAMETERS IN PHTHALATE-INDUCED TESTICULAR DAMAGE IN RATS

RATLARDA FTALAT İLE İNDÜKLENEN TESTİS HASARINDA HİSTOPATOLOJİK LEZYONLAR VE SPERMATOLOJİK PARAMETRELER ÜZERİNE GALANGİN'İN KORUYUCU ETKİSİNİN İNCELENMESİ

Büşra GÜNGÖR
Fırat Üniversitesi, Veteriner Fakültesi, Histoloji ve Embriyoloji Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-0416-8834

Berrin TARAKÇI GENÇER
Fırat Üniversitesi, Veteriner Fakültesi, Histoloji ve Embriyoloji Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-5931-9919

İbrahim Halil GÜNGÖR
Fırat Üniversitesi, Veteriner Fakültesi, Dölerme ve Suni Tohumlama Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-5250-1478

Sema TİMURKAAN
Fırat Üniversitesi, Veteriner Fakültesi, Histoloji ve Embriyoloji Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-1197-6936

Hatice ERÖKSÜZ
Fırat Üniversitesi, Veteriner Fakültesi, Patoloji Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-8407-5792

Emre KAYA
Fırat Üniversitesi, Veteriner Fakültesi, Biyokimya Anabilim Dalı, Elazığ, Türkiye
ORCID ID: https://orcid.org/0000-0002-7445-3091

ÖZET

Giriş ve Amaç: Günümüzde yaygın olarak görülen erkek kısırlığının önemli nedenlerinden biri plastiklerde yaygın olarak kullanılan di-(2 etilhekzil) ftalat (DEHP)'lardır. DEHP'nin oluşturduğu testis hasarlarını incelemek ve testis hasarlarında ilk kez kullanılan Galanginin etkisini incelemek amacıyla 10-12 haftalık ratlara 14 gün boyunca DEHP verilerek oluşturulan testis hasarı üzerine galanginin farklı dozlarının koruyucu etkisi incelendi.

Materyal ve Metot: Bu amaçla, 14 günlük deney grupları (Kontrol: hiçbir uygulama yapılmayan, Çözücü: 5 ml/kg/gün mısır yağı, Ftalat (FT): 2 g/kg DEHP, Galangin: GL-5, GL-10 ve GL-15: sırasıyla 5, 10 15 mg/kg dozlarda, FT+GL-5, FT+GL-10 ve FT+GL-15: 2g/kg

ftalat 5 ml/kg mısır yağında çözdürülüp verildikten 1 saat sonra sırasıyla 5, 10, 15 mg/kg dozlarında galangin) dizayn edildi. Deney sonunda dekapite edilen ratlardan alınan dokularda histopatolojik ve spermatolojik analizler yapıldı.

Bulgular: FT grubunda testislerde seminifer tubullerde dejenerasyon/atrofi, intersitisyel ödem, intersitisyel vasküler hiperemi ile Johnsen skorlamada, seminifer tubul çaplarında ve epitel kalınlığında azalma görüldü. Galangin uygulaması ile doza bağlı olarak bu histopatolojik değerlerde düzelmeler olduğu tespit edildi. Spermatolojik analizlerde FT gruplarında bazı parametrelerde (GSI, Yoğunluk, Total Motilite, Akrozomal Hasar Oranı, Mitokondriyal Membran Potansiyeli, Morfolojik Değerler) olumsuz etkiler oluştuğu galangin verilen gruplarda doza bağlı olarak bu olumsuz etkinin ortadan kalktığı görüldü.

Tartışma ve Sonuç: Bu çalışma, DEHP maruziyeti ile oluşan testis hasarında galanginin iyileşme sağladığını doğrulayarak, DEHP' ye bağlı infertilite tedavisinde galanginin kullanımına ilişkin güçlü veriler sağladı.

Anahtar Kelime: DEHP, testis hasarı, Galangin, sperma

ABSTRACT

Introduction and Purpose: One of the major causes of male infertility, which is increasingly common today, is di-(2-ethylhexyl) phthalate (DEHP), a plasticizer widely used in plastics. This study aimed to investigate the testicular damage induced by DEHP and to evaluate, for the first time, the effect of Galangin in such testicular injury. To induce testicular damage, 10–12-week-old rats were administered DEHP for 14 days, and the protective effects of different doses of Galangin were examined.

Materials and Methods: For this purpose, the 14-day experimental groups were designed as follows: Control (no treatment), Vehicle (5 mL/kg/day corn oil), Phthalate (FT: 2 g/kg DEHP), Galangin groups (GL-5, GL-10, and GL-15: 5, 10, and 15 mg/kg, respectively), and combined groups FT+GL-5, FT+GL-10, and FT+GL-15 (2 g/kg DEHP dissolved in 5 mL/kg corn oil and administered, followed 1 hour later by Galangin at 5, 10, or 15 mg/kg). At the end of the experiment, tissues collected from decapitated rats were subjected to histopathological and spermatological analyses.

Results: In the FT group, degeneration/atrophy of seminiferous tubules, interstitial edema, and interstitial vascular hyperemia were observed, along with decreases in Johnsen's score, seminiferous tubule diameters, and epithelial thickness. Galangin administration improved these histopathological parameters in a dose-dependent manner. Spermatological analyses showed that DEHP caused adverse effects in several parameters (GSI, sperm density, total motility, acrosomal damage rate, mitochondrial membrane potential, and morphological values), while these negative effects were reversed in a dose-dependent manner in the Galangin-treated groups.

Discussion and Conclusion: This study confirms that Galangin promotes recovery from DEHP-induced testicular damage and provides strong evidence supporting its potential use in the treatment of DEHP-related infertility.

Keywords: DEHP, testicular damage, Galangin, semen

AUTOPHAGY AS AN ANTIVIRAL IMMUNE MECHANISM: ROLES AND VIRAL EVASION STRATEGIES

Emine DOĞAN

Ondokuz Mayıs University, Faculty of Veterinary Medicine, Department of Virology, Samsun, Turkey

ORCID ID: https://orcid.org/0009-0009-3514-4235

Semra GÜMÜŞOVA

Ondokuz Mayıs University, Faculty of Veterinary Medicine, Department of Virology, Samsun, Turkey

ORCID ID: https://orcid.org/0000-0001-8574-521X

ABSTRACT

Autophagy is a conserved and dynamic cellular process that maintains homeostasis by degrading damaged organelles, misfolded proteins, and intracellular pathogens through lysosome-mediated pathways. In the context of viral infections, autophagy—especially xenophagy—acts as an intrinsic antiviral defense mechanism by targeting viral particles and components for degradation. This literature-based review aims to provide a comprehensive overview of autophagy's antiviral roles and the molecular strategies developed by viruses to subvert or exploit this pathway for their replication and persistence.

Some viruses, such as Herpes Simplex Virus 1 (HSV-1), encode proteins like ICP34.5, which bind and inhibit Beclin-1, a key regulator of autophagy initiation. Similarly, HIV-1 utilizes its Nef protein to block autophagosome maturation. While such mechanisms prevent viral clearance, other viruses co-opt autophagic membranes as scaffolds for replication, as observed in Flaviviruses and Picornaviruses. These interactions highlight a complex virus-host interplay in which autophagy can either suppress or be hijacked to support viral lifecycles.

Autophagy also interfaces with both innate and adaptive immunity. It facilitates antigen processing and presentation via MHC class II pathways, enhancing CD4+ T cell responses. This immune-modulatory function positions autophagy as a critical link between pathogen sensing and immune activation.

The current review is based on an extensive literature survey conducted through PubMed, Scopus, and Web of Science databases using keywords such as "autophagy," "xenophagy," "virus," "immune evasion," and "antiviral response." Studies published between 2000 and 2024 were included to reflect recent advancements.

Understanding the molecular crosstalk between viruses and the autophagic machinery not only sheds light on viral pathogenesis but also opens new avenues for antiviral drug development and vaccine strategies. Targeting viral proteins that manipulate autophagy or enhancing host autophagic responses may represent promising therapeutic interventions, particularly in persistent viral infections.

Key Words: Autophagy; xenophagy; viral immune evasion; antigen presentation; MHC class II; antiviral therapies; immune response

ISOLATION AND IDENTIFICATION OF MICROBIAL LOAD FROM THE DRİED POMFRET FISH (PAMPUS CHINENSIS)

Aysha Akter Metu
Department of Zoology, Faculty of Biological Sciences, Jahangirnagar University, Savar-1342, Dhaka, Bangladesh

Md. Mansurul Haque
Department of Zoology, Faculty of Biological Sciences, Jahangirnagar University, Savar-1342, Dhaka, Bangladesh

Md. Mahedi Hasan
Department of Zoology, Faculty of Biological Sciences, Jahangirnagar University, Savar-1342, Dhaka, Bangladesh

Sadia Afrin
Department of Zoology, Faculty of Biological Sciences, Jahangirnagar University, Savar-1342, Dhaka, Bangladesh

Nazrul Islam Bhuiyan
Bangladesh Council of Scientific and Industrial Research, Dr. Qudrat-E-Khuda Road, Dhanmondi, Dhaka-120, Bangladesh

ABSTRACT

Dried fish is one of the most common and important protein sources in our country but dried fish contain different microbes, some are pathogenic. The aims of this study to determine the bacterial loads in the dried pomfret fish (*Pampus chinensis*). Samples were collected from two major fish markets, one of Dhaka city, Karwanbazar fish markets (KFM) and other from Cox's Bazar Fisheries Ghat fish market (CBFM) and one sample was made at home (control) to compare it with the quality of dried fish. In this study, the total bacterial counts (TBC) and total yeast mold counts (TYMC) were recorded in different dilutions. The result varied in the fish samples of two markets. The highest bacterial load was found in the home-made dried fish samples (TBC was TNTC in 1^{st} and 2^{nd} dilution, $8.2x\ 10^4$ in 3^{rd} dilution and in 4^{th} dilution it was 4.5×10^3 cfu/gm) followed by medium load in the sample of Cox's Bazar Fisheries Ghat fish market (TNTC in 1^{st} and 2^{nd} dilution but in 3^{rd} and 4^{th} dilution it was 4.3×10^4 cfu/gm and 1.5×10^2 cfu/gm respectively) and lowest load was in the sample of Karwanbazar fish market(1^{st}, 2^{nd} dilution was TNTC and 3^{rd} and 4^{th} dilution containing 2.8 × 103 cfu/gm and 1.4 x 102 cfu/gm respectively). Again, the highest load of yeast and mold was observed in the home-made fish sample (for 1^{st} dilution it was $1.3\times\ 10^4$ but in 2^{nd} dilution it was $1.2x\ 10^3$), medium in the fish sample of Cox's Bazar Fisheries Ghat fish market (for 1^{st} dilution 6.3×10^3 but in the 2^{nd} dilution it was 1.2×10^3) and lowest in the sample of Karwanbazar (for 1^{st} and 2^{nd} dilution 4.6×10^3 and $5.5x\ 10^2$ cfu/gm respectively). Pathogenic bacteria like Salmonella, Pseudomonas and Staphylococcus were detected in all the fish samples of dried pomfret fish. From that study it was found that the home-made dried fish sample of pomfret fish contains more bacterial loads than that of the dried fish sample of the markets which might be due to no use of pesticides that are usually used in the dried fish samples of the markets.

Keyword: Pomfret fish, Microbial Load, Pathogenic, TBC, TYMC

IMPACT OF VITAMIN D DEFICIENCY ON CORNEAL HEALTH UPON CHILDREN WITH RICKETS

Ali H Dosky
Department of Medical Chemistry, College of Medicine, University of Duhok, Iraq

Abstract

Background: Vitamin D is crucial for enhancing general health, particularly in the development of strong bones and bolstering the immune system. In children, a substantial deficiency of vitamin D can lead to a condition known as rickets, characterized by weakened bones and skeletal abnormalities. While extensive research has been conducted on the impact of rickets on the musculoskeletal system, there is limited investigation into the effects of vitamin D deficiency on ocular health, specifically focusing on the cornea of the eye. This research aims to investigate the consequences of vitamin D deficiency on the cornea in children diagnosed with rickets.

Objectives: To identify any effect on corneal or structural changes associated with vitamin D deficiency in these children. To find relationship between vitamin D levels and corneal health.

Methodology: A case-control study design to identify the impact of vitamin D deficiency on the corneal health in children diagnosed with rickets the study started from OCT20th, 2023 to Jan 5,2024 The study was carried out in pediatric clinics and hospitals across various locations in the Kurdistan Region and Najaf city of Iraq, with the informed consent of the children's parents being obtained such as Rehabilitation center, a nutrition clinic counseling from pediatric and ophthalmology center test A purposive sample of (50) child divided into two groups. The first group comprised 25 children (13 males and 12 females) diagnosed with rickets, selected from a nutrition clinic along with their parents and received counseling from pediatric and ophthalmology center test during the data collection period. The second group consisted of 25 healthy children (13 males and 12 females). The Questionnaire for this current study was gathered and conducted using study instruments to assess serum levels of Vitamin D, Calcium, and phosphate, along with ophthalmological evaluations. Additionally, participants will be given a questionnaire to gather variable’s on their dietary pattern sun exposure, and lifestyle factors. Data were analyzed using SPSS 27. Descriptive statistics of range, mean and standard deviation were used, in addition to inferential statistic such as t-test to find significant difference in means. A p value less than 0.05 were considered significant.

The results of study reveal that the mean of vitamin D level in study group was found to be 9.1 ng/mL, significantly lower than the control group mean of 60.0 ng/mL ($p<0.001$). the study observed a marked difference in the mean calcium levels, where the patient group exhibited a mean of 1.3 compared to the control group's mean of 2.0 ($p<0.001$). Similarly, the mean phosphate levels in the patient children group were 1.3, significantly lower than the control children group mean of 2.2 ($p<0.001$).

Conclusion & Recommendation: The mean vitamin D level in the study group was found to be 9.1 ng/ mL, significantly lower than the control group mean of 60.0 ng/mL ($p<0.001$). the study observed a marked difference in the mean calcium levels, where the patient group exhibited a mean of 1.3 compared to the control group's mean of 2.0 ($p<0.001$). Similarly, the mean phosphate levels in the patient children group were 1.3, significantly lower than the control children group mean of 2.2 ($p<0.001$). according to this finding it is recommends to emphasize on post natal care for children to give immunization and give good nutrition with exposure to sun in morning.

Key word; vitamin D, rickets, corneal, children, health

INTRAOPERATIVE MEASURES TO PREVENT PROSTHETIC JOINT INFECTIONS IN THE ORTHOPEDIC SURGERY UNIT OF THE MOULAY YOUSSEF REGIONAL HOSPITAL, RABAT

LAKHRISSI Alaeddine
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.
Ibn Sina University Hospital Center Mfadel Cherkaoui Street Souissi district, 10100 RABAT - Morocco

BOUGHAZI .Souad
Higher Institute of Nursing and Health Techniques (ISPITS), Avenue Hassan II, Km 4.5, Casablanca Road, Rabat, Morocco.

CHERRAJ Safae
Higher Institute of Nursing and Health Techniques (ISPITS), Avenue Hassan II, Km 4.5, Casablanca Road, Rabat, Morocco.

ERRAZKI Imane
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.

TALAL MOHAMED Abdoul-Latif
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.

AMAKASSOU Halima
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.

FAROUDY Mamou
Ibn Sina University Hospital Center Mfadel Cherkaoui Street Souissi district, 10100 RABAT - Morocco

Naoufal Himmouche
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.

BOUZID Jawad
Hassan The First University, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Casablanca Road, Km 3.5, BP 555, Settat, Morocco.

Abstract

Introduction : Prosthetic joint infections (PJI) represent a major complication in orthopedic surgery, leading to significant functional impairment and substantial socioeconomic impact. In this context, intraoperative prevention emerges as a critical strategic component. The **objective of this study is** to identify the measures implemented during the intraoperative period to prevent PJI.

Methods: This was a quantitative descriptive study. Data were collected using a questionnaire addressed to healthcare professionals, including operating room nurses, surgeons, intensivists, and nurse anesthetists. The sample consisted of 30 professionals working in the operating theater. Data analysis was conducted using Excel software.

Results : The findings showed that 91% of professionals use cephalosporins for antibiotic prophylaxis, mainly cefazolin (82%) and cefuroxime (9%), administered 30 minutes before incision (90%). In addition, only 30% reported using spinal anesthesia for arthroplasty. Regarding surgical hand scrubbing, 45% of professionals performed it for 5 to 7 minutes, while 30% exceeded 7 minutes. Furthermore, 90% did not use sterile brushes. The presence of a laminar airflow ventilation system was unknown to 60% of respondents. Only 30% affirmed that strict limitation of the number of individuals present in the operating room was enforced, while 60% stated that the measure exists but is poorly controlled. Antibiotic-loaded bone cement was systematically used according to 70% of respondents. Conversely, regional intraosseous antibiotic injection was not practiced by 45%, whereas 30% reported using it occasionally. All professionals stated that they changed gloves at critical steps of the procedure. Additionally, 100% reported irrigating the surgical wound, although exclusively with normal saline.

Conclusion: This study highlights the crucial importance of rigorous and systematic application of current recommendations, while emphasizing the need for continuous and collective commitment from the surgical and anesthesia teams.

Keywords: Infection, prosthetic joint, intraoperative period.

CROSS-SECTIONAL ANALYSIS OF DIETARY HABITS, DAIRY CONSUMPTION, BODY COMPOSITION, AND PHYSICAL ACTIVITY LEVEL AS PREDICTORS OF FOREARM BONE MINERAL DENSITY IN YOUNG POLISH MEN

Prof. (Assoc.) PhD. Anna Kopiczko

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Human Biology, Warsaw, Poland

PhD. Patrycja Widłak

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Human Biology, Warsaw, Poland.

PhD. Joanna Cieplińska

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Rehabilitation, Department of Clinical Physiotherapy, Warsaw, Poland

PhD Student Wiktoria Pietrzak

Doctoral School at Józef Piłsudski University of Physical Education in Warsaw

M.Sc. Jakub Bałdyka

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Theory of Sport, Warsaw, Poland

ABSTRACT

The interaction between nutrition, physical activity, and body composition plays a crucial role in shaping bone health during early adulthood. Calcium and protein-rich foods, especially dairy products, provide key nutrients for skeletal remodeling, yet their combined effect with lifestyle and body composition remains insufficiently characterized in young men. This cross-sectional investigation evaluated how dietary behaviors, dairy intake, nutrient consumption, physical activity level, and body composition indicators predict forearm bone mineral density (BMD) in a sample of 450 Polish men (mean age: 21.5 years) representing three activity categories: professional athletes (n = 110), recreationally active individuals (n = 170), and non-active controls (n = 170). This work was written with the financial support of the Ministry of Education and Science as part of the Research Project (UPB No. 14): “Determinants of bone mineral status in recreational and professional sports of different age groups”. The project is being implemented at the Józef Piłsudski University of Physical Education in Warsaw, Poland, by a multidisciplinary team of researchers. The project complies with the principles of bioethics, as confirmed by the Bioethics Committee of the National Institute of Public Health, National Institute of Hygiene in Warsaw, Poland, and the study was conducted according to the rules and regulations of the Declaration of Helsinki for experiments involving humans. Distal

and proximal forearm BMD were measured using densitometry. Body composition was assessed with bioelectrical impedance analysis (Jawon Medical Scan), while dietary intake was recorded via a standardized 24-hour recall. Four distinct dietary patterns were identified: (1) traditional mixed diet, (2) restrictive lactose- and gluten-free pattern, (3) nutrient-dense plant- and dairy-rich pattern, and (4) high-protein diet. Statistical analyses included factor ANOVA with Bonferroni corrections and evaluation of effect sizes (η^2). Two-way ANOVA was used to examine interactions between dietary patterns, body composition variables, activity level, and BMD outcomes. The highest BMD of the forearm was found in the group of professional athletes, and the lowest in the control group of non-athletes. Distal BMD was significantly associated with fat-free mass and dietary pattern ($\eta^2 = 0.12$), indicating that lean tissue and overall dietary structure are major contributors to bone density at this site. Proximal BMD was influenced by physical activity level ($\eta^2 = 0.09$), fat mass ($\eta^2 = 0.04$), fat-free mass ($\eta^2 = 0.02$), and daily dairy intake, which demonstrated the strongest effect ($\eta^2 = 0.14$). Collectively, these findings show that lifestyle behaviors, body composition, and specific dietary choices each play a meaningful role in determining forearm BMD in young Polish men, supporting the need for integrated nutritional and activity-based strategies to promote peak bone health.

Keywords: cross-sectional study, bone mineral density, dairy consumption, dietary habits, physical activity, body composition, young men

ASSESSING THE RISK OF SPORTS INJURIES IN PROFESSIONAL FOOTBALLERS USING THE FMS AND Y-BALANCE TEST

PhD. Patrycja Widłak

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Human Biology, Warsaw, Poland.

patrycja.widlak@awf.edu.pl, + 48 22 834 04 31

PhD. Bartłomiej Michalak

Department of Sport Theory, Faculty of Physical Education, Józef Piłsudski University of Physical Education in Warsaw, Warsaw, Poland

bartłomiej.michalak@awf.edu.pl, + 48 22 834 04 31

M.Sc. Zbigniew Tyc

Department of Sport Games, Faculty of Physical Education, Józef Piłsudski University of Physical Education in Warsaw, Warsaw, Poland

zbigniew.tyc@awf.edu.pl, + 48 22 834 04 31

Prof. (Assoc.) PhD. Dariusz Boguszewskı

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Individual Sports, Warsaw, Poland

dariusz.boguszewski@awf.edu.pl, +48 22 834 04 31

Prof. (Assoc.) PhD. Anna Kopiczko

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Human Biology, Warsaw, Poland

anna.kopiczko@awf.edu.pl, + 48 22 834 04 31

ABSTRACT

Functional assessment plays a vital role in modern injury prevention, as it allows practitioners to identify movement limitations, stability deficits, and musculoskeletal asymmetries before they manifest as injuries. Tools such as the Functional Movement Screen (FMS) and the Y-Balance Test (YBT) provide valuable insight into an athlete's neuromuscular control and overall functional capacity, supporting the design of individualized corrective and training interventions. Regular application of these tests enhances the ability to detect injury-related risk factors and contributes to safer and more efficient training processes. The purpose of this study was to evaluate injury risk among 22 professional football players using the FMS and YBT, both of which assess the quality of movement patterns, postural control, and dynamic balance performance. Average Y-Balance Test scores revealed a consistent advantage of the left limb

in all measured directions: anterior (106.97 cm vs. 103.64 cm), posterolateral (87.23 cm vs. 85.71 cm), and posteromedial (84.64 cm vs. 80.89 cm). This pattern suggests superior functional capacity and stability on the left side. The composite scores (99.16% vs. 96.10%) further confirmed excellent dynamic stability, with a slight dominance of the left limb. The mean FMS score for the team was 16.07 ± 1.77, indicating a moderate level of movement quality. The highest performance was observed in the trunk stability push-up (2.68 ± 0.89), while the deep squat (1.95 ± 0.21) and rotary stability (2.07 ± 0.18) received the lowest ratings. The remaining tasks averaged around 2 points, highlighting the presence of functional deficits that may predispose athletes to injury. Overall, the Y-Balance Test results demonstrated high dynamic stability among professional football players, with slightly better performance on the left side. However, the FMS outcomes point to moderate movement efficiency and reveal specific limitations, particularly in the squat and rotational stability tasks. Implementing targeted corrective exercises may help address these weaknesses and lower the potential injury risk.

Source of funding: This study was supported by the Ministry of Education and Science as part of research projects UPB no. 13: “Assessment of the Relationship Between Selected Lifestyle Factors and the Risk of Sports Injuries in a Young Adult Population,” conducted at the Józef Piłsudski University of Physical Education in Warsaw (Poland), Project manager: PhD. Patrycja Widłak.

Keywords: functional assessment, professional football, Functional Movement Screen, Y-Balance Test

COMPLICATIONS OF DENTAL IMPLANTATION AND THEIR MODERN TREATMENT METHODS

Fidan Enver Shikhaliyeva

Azerbaijan State Advanced Training Institute for Doctors named after A.Aliyev, Department of periodontology, Baku, Azerbaijan

https://orcid.org/0009-0004-0229-4900

ABSTRACT.

In the course of the study, the dental status of patients with various forms of peri-implantitis was assessed, and based on the analysis of the observed clinical changes, diagnostic indicators for the accurate identification of peri-mucositis were determined. Clinical management schemes were optimized for the examination and treatment of patients at all stages of dental implant placement and prosthetic rehabilitation in order to minimize the risk of complications. Indications for the use of a hyaluronic acid–containing preparation (Hy+Al Gel) in the prevention and treatment of early postoperative complications after dental implantation were identified as part of the complex therapy. Clinical investigations were conducted at the Department of Periodontology of the Azerbaijan State Institute for Advanced Training of Doctors named after Aziz Aliyev and at the "El Esthet" Clinic. The study included 60 patients with specific dental pathologies. According to the treatment protocol applied, the patients were divided into three groups**:** Control group: supragingival and subgingival plaque was mechanically removed using special plastic curettes (n=20). Conventional control group: plaque removal was performed using the Vector system by a specialist, followed by the patient's use of an antiseptic containing 0.05% chlorhexidine bigluconate (n=20). Thus, as reported by the patients themselves, the new therapeutic approach used in the treatment of inflammatory peri-implant diseases resulted in a significant decrease in pain intensity compared with the control group during the intermediate stage of the study. Numerical VAS values and their statistical analysis provided an objective clinical basis for evaluating pain reduction and enabled comprehensive assessment of the proposed methods and agents.

INTRODUCTION

Dental implantation is considered one of the most effective methods for the restoration of missing teeth. Despite its high success rate—reported to be 90–95%—a variety of biological and technical complications may occur. Understanding these complications and applying evidence-based treatment strategies are crucial to ensuring long-term implant success.

According to data from the World Health Organization (WHO), secondary partial edentulism is diagnosed in 75% of the world's population**.** In Russia, secondary edentulism is detected in 40–75% of patients across all age groups. At the same time, WHO reports that complete tooth loss is found in 15% of the adult population worldwide**.**

The current and projected prevalence of both complete and partial edentulism, as well as its effects on changes in the dentoalveolar system and on patients' quality of life, makes the treatment of this pathology an urgent general medical and social problem.

One of the causes of this pathology is complications of dental caries that lead to the loss of permanent teeth in children over the age of 10. In adult patients, the most common cause of tooth loss is periodontal disease**,** resulting in a significant increase in the number of patients with partial edentulism.

Inflammatory periodontal diseases, aseptic inflammation of the oral tissues, and resorption of the alveolar processes of the jaws in periodontitis usually lead to tooth loss. At the same time, tooth extraction causes atrophy of the bone tissue**,** accompanied by the disruption of its supportive and regulatory–homeostatic functions.

Partial or complete loss of dentition impairs chewing and digestive physiological processes to varying degrees and also affects the patient's appearance.

Taking these factors into account, we set the objective to investigate the effectiveness of a hyaluronic acid–based agent in the complex corrective therapy of peri-implant complications**.**

In the course of the study, the dental status of patients with various forms of peri-implantitis was assessed, and based on the analysis of the observed clinical changes, diagnostic indicators for the accurate identification of peri-mucositis were determined. Clinical management schemes were optimized for the examination and treatment of patients at all stages of dental implant placement and prosthetic rehabilitation in order to minimize the risk of complications.

Indications for the use of a hyaluronic acid–containing preparation (Hy+Al Gel) in the prevention and treatment of early postoperative complications after dental implantation were identified as part of the complex therapy. Clinical data were analyzed to evaluate the long-term effectiveness of preventive measures in patients following dental implant placement and prosthetic treatment. A comparative assessment of patients' quality of life before and after the treatment of implant-related complications was also carried out.

Clinical investigations were conducted at the Department of Periodontology of the Azerbaijan State Institute for Advanced Training of Doctors named after Aziz Aliyev and at the "El Esthet" Clinic. The study included 60 patients with specific dental pathologies. According to the treatment protocol applied, the patients were divided into three groups**:**

- **Control group:** supragingival and subgingival plaque was mechanically removed using special plastic curettes (n=20).
- **Conventional control group:** plaque removal was performed using the Vector system by a specialist, followed by the patient's use of an antiseptic containing **0.05% chlorhexidine bigluconate** (n=20).

After one month from the initiation of treatment and preventive measures, evaluation of probing depth (PD) around teeth and implants demonstrated that the mean probing depth in the main group was significantly reduced to 2.53 ± 0.046 mm. In the control group, where conventional methods were used, the probing depth measured 2.96 ± 0.063 mm at the same time point. Comparative intergroup analysis confirmed that these differences were statistically significant.

Although the global literature includes a substantial number of scientific publications devoted to dental implantology, only about 2% of these studies assess treatment outcomes in terms of patient-reported symptoms and quality of life, which may represent one of the essential indicators of implant success [45]. To monitor pain during therapeutic interventions, a pain questionnaire—specifically, the Visual Analogue Scale (VAS)—was used. Prior to treatment,

patients from all three groups who had previously undergone prosthetic treatment on dental implants reported severe pain associated with inflammatory changes in peri-implant soft tissues.

Before treatment, the most pronounced pain intensity was observed in the comparison group, averaging 3.24 ± 0.168 points. In the main group, pain intensity was slightly lower, averaging 3.12 ± 0.139 points. Based on the results obtained after three months, it can be concluded that at this stage of therapeutic–preventive measures, pain intensity was predominantly characterized as mild ($0 < VAS \leq 3$).

All 60 patients included in the present study demonstrated a significantly reduced quality of life before treatment due to pathological alterations in peri-implant tissues. The mean values of questionnaire responses obtained before treatment are presented below. Comparative evaluation of the three groups across all domains showed that in most cases the intergroup differences were not statistically significant ($p > 0.05$).

Except for patient-reported symptoms—such as altered tactile sensitivity, transient anesthesia in certain areas of the oral mucosa (particularly the tongue tip), and occasional numbness after antiseptic use in the comparison and control groups - no serious adverse effects were recorded during the therapeutic and preventive interventions.

Conclusion.
The observed differences in plaque index and bleeding index during probing may be attributed to the hypothesis that the hyaluronic acid–based preparation more effectively destabilizes existing plaque while simultaneously inhibiting the formation of new plaque deposits. These findings correspond with previous studies using similar combined agents. One of the notable achievements of the current research is the ideal primary endpoint of the BOP index - absence of bleeding upon probing both immediately and at later stages after therapy - which was facilitated by the adequate sample size.

This study contributes to understanding the feasibility of comprehensive management of inflammatory oral diseases through the combined use of traditional professional hygiene measures and the proposed anti-inflammatory agent, which also plays a crucial role as supportive therapy in the treatment of peri-implant mucositis.

Results. A clear overlap between hygienic and periodontal aspects of therapeutic–preventive interventions was observed in the orthopedic patients examined. Regular use of oromucosal hyaluronic-acid gel applications (HY + AL Oromucosal Gel) is recommended as supportive therapy for the management and prevention of peri-mucositis.

The highest degree of intragroup correlation and the statistically significant differences in mean values at the indicated time points confirm that the main group demonstrated the most pronounced improvement, particularly during complete rehabilitation, with a mean difference of –2.30 ± 0.05 (95% CI: –2.00; –2.83; $p<0.0001$, $t=18.79$), attributable to the addition of the hyaluronic acid–based supportive therapy.

The present study revealed a statistically significant reduction in the mean value of the simplified oral hygiene index (OHI-S) from baseline (before treatment) to one month and three months after treatment ($p < 0.0001$).

The difference between baseline and 3-month OHI-S values was statistically significant in all patient groups. In other words, throughout the entire study period, all three groups demonstrated a marked decrease in OHI-S values, with clearly positive changes evident both at the intermediate phase and at the later stage (3 months).

However, comparison of OHI-S changes between the groups showed that the third (main) group significantly outperformed both the comparison and control groups during the entire observation period. If the difference in mean OHI-S values before and after the 3-month observation period in the main group was RR=–2.30 ± 0.05 (95% CI: –2.83; –2.00; $p < 0.0001$, $t=18.79$), in the control group the corresponding value was less significant: RR=–1.83 ± 0.05 (95% CI: –2.33; –1.33; $p < 0.0001$, $t=14.57$), indicating weaker treatment effectiveness.

In addition to the plaque index (PI), which can be used to assess the extent of biofilm formation responsible for pathological changes in periodontal and peri-implant soft tissues, the most widely used indicator among researchers is the periodontal pocket depth (probing depth, PD).

After one month from the initiation of treatment and preventive measures, the evaluation of PD around teeth and implants showed a significant reduction in the main group (mean PD: 2.53 ± 0.046 mm). In the control group, where conventional therapy was applied, the mean PD at the same time point was 2.96 ± 0.063 mm. Intergroup comparative analysis confirmed that these differences were statistically significant.

Thus, as reported by the patients themselves, the new therapeutic approach used in the treatment of inflammatory peri-implant diseases resulted in a significant decrease in pain intensity compared with the control group during the intermediate stage of the study. Numerical VAS values and their statistical analysis provided an objective clinical basis for evaluating pain reduction and enabled comprehensive assessment of the proposed methods and agents.

ASSESSMENT OF CLINICAL REASONING OF MEDICAL STUDENTS AT FASA UNIVERSITY OF MEDICAL SCIENCES IN CLINICAL SETTINGS AND ITS RELATIONSHIP WITH PROBLEM-SOLVING SKILLS IN 1403–1404 ACADEMIC YEAR

Prof. Nasrin Shokrpour
Shiraz University of Medical Sciences IRAN

Dr Shadab Moslehi
Shiraz University of Medical Sciences IRAN

Mahbubeh Pedram
Shiraz University of Medical Sciences IRAN

Abstract

Introduction: Understanding the factors influencing and associated with clinical reasoning is essential to strengthening this skill in medical students. According to various studies, one of these factors is problem-solving ability. Considering the importance of this topic, the present study was designed and conducted to assess the clinical reasoning of medical students at Fasa University of Medical Sciences in clinical settings and its relationship with problem-solving during the 1403–1404 academic year

Materials and Methods: This cross-sectional study was conducted on 318 medical students from the first to seventh years at Fasa University of Medical Sciences. The sampling method was a census of all eligible students. Data collection tools included the standardized Clinical Reasoning Questionnaire by Bordage et al. (1990) and the Problem-Solving Questionnaire by Heppner and Petersen (1982), which were completed in person by the students. The data were entered into SPSS version 27 and analyzed using Chi-square, Fisher's exact test, and Kruskal-Wallis tests.

Results: The mean ± standard deviation of the total clinical reasoning score was 142.42 ± 13.24, and the mean standard deviation of the total problem-solving score was 102.76 ± 11.18. According to the results, students' problem-solving ability showed a relatively weak but positive and significant correlation with total clinical reasoning skills ($r = 0.111$, $p = 0.049$) and the memory structure dimension ($r = 0.119$, $p = 0.037$), while no significant correlation was found with the flexibility dimension of clinical reasoning ($r = -0.008$, $p = 0.892$). No significant relationships were observed between clinical reasoning and gender ($p = 0.769$), marital status ($p = 0.821$), academic year ($p = 0.907$), age ($p = 0.614$), or GPA ($p = 0.064$). Similarly, problem-solving showed no significant correlation with gender ($p = 0.131$), marital status ($p = 0.107$), academic year ($p = 0.450$), age ($p = 0.474$), or GPA ($p = 0.170$).

Conclusion: The results of this study indicated that most medical students scored at a moderate level in both clinical reasoning and problem-solving variables. There was a significant relationship between clinical reasoning and problem-solving. Given that the scores of clinical reasoning and problem-solving among medical students were moderate, educational authorities must take appropriate measures to improve this situation.

Keywords: Clinical reasoning, Problem-solving, Medical students, Fasa

HEALTH LITERACY AMONG ADOLESCENTS IN ETHIOPIA: IMPLICATIONS FOR MENTAL HEALTH

Adamu Amanu Asari
Department of Health, Behavior, and Society, Faculty of Public Health, Jimma University, Oromia, Ethiopia
Department of Sociology, College of Social Sciences, Jimma University, Oromia, Ethiopia

Ameyu Godesso
Department of Sociology, College of Social Sciences, Jimma University, Oromia, Ethiopia

Zewdie Birhanu
Department of Health, Behavior, and Society, Faculty of Public Health, Jimma University, Oromia, Ethiopia

Abstract

Background and objective: Adolescence is a pivotal period during which individuals develop health knowledge and behaviors that can have lasting implications not only for their health but also for the overall wellbeing of their society, especially in developing countries like Ethiopia, where young people share larger portion of the total population. Thus, adolescent health literacy (HL) that represents the ability to access, understand, evaluate, and use health information to make informed decisions in their daily life is a critical issue. Adolescents with low HL often engage in risky behaviors, including substance abuse that harms their mental health, and have poor understanding of (mental) health promoting behaviors. As the issue is less explored in Ethiopia, this study aims to examine HL status among adolescents and ascertain the implications for mental health, policy, and intervention efforts.

Methods: This study employed cross-sectional survey design and was conducted among secondary school adolescents in 2024. Data were collected using a locally developed and validated HL scale, comprising 33 items with five dimensions (health information competency, communication, health awareness and knowledge, decision-making and behavior, and citizenship and responsibility). Data analysis performed using descriptive and inferential statistics in SPSS version 27.0.

Results and implications for mental health: Of the total 722 adolescents participated in this study, 74.8% had inadequate overall HL status. Across all the dimensions, also, the percentage of respondents with inadequate HL was high, with variations based on sociodemographic factors. This implies that these disadvantaged adolescents have poor knowledge and understanding of mental health, poor understanding of preventive strategies, poor self-management or coping skills, and are more likely to engage in risky behaviors that deteriorate their mental health.

Conclusion and implications for policy, interventions, and future research: Low HL is widespread among adolescents with critical implications for mental health. Thus, this study underscores that improving adolescent HL need to be both educational and public health priorities to empower adolescents to make informed decisions, foster their resilience, and enhance their (mental) well-being through tailored and targeted interventions. As well, further and follow-up studies are needed for deeper understanding of the issue and establishing the causal factors.

A META-SYNTHESIS: ANALYZING THE COMPLEXITIES OF EMPLOYMENT AND MENTAL HEALTH IN WOMEN

Mohaddeseh Babaei
MA Student, Women's Studies, Faculty of Social Sciences, AhlulBayt International University, Iran

Elham Vahidi
Assistant ProfessorWomen's Studies, Faculty of Social Sciences, AhlulBayt International University, Iran
https://orcid.org/0009-0006-5578-7578

Abstract

Women's employment, as a complex socioeconomic phenomenon, has multifaceted effects on their mental health. Despite the general perception of its positive impacts, research evidence reveals context-dependent and contradictory patterns. This review article was conducted with the aim of synthesizing and analyzing research findings on the relationship between employment and women's mental health and explaining the underlying mechanisms of this relationship.

Method: This study employed a meta-synthesis approach, analyzing 28 selected qualitative studies that examined various dimensions of employment and women's mental health. The studies were selected through systematic search strategies in domestic and international academic databases based on defined inclusion and exclusion criteria, and were then reviewed and synthesized using the seven-step approach by Noblit and Hare (1998).

Findings: The meta-synthesis analysis led to the extraction of four main themes:

1. Double Suffering and Role Conflict: Employment alongside traditional household responsibilities leads to multiple role strain, reduced marital satisfaction, and "double suffering" (Dehghanizadeh et al., 2021).
2. Individual Resilience and Coping Strategies: Individual variables such as "restraint of anger" and the use of adaptive strategies (e.g., responsibility management and positive interaction) can mitigate negative outcomes, but their effects are moderated by contextual variables (e.g., spousal support) (Saffara et al., 2021).
3. Discriminatory Organizational Structures: Exposure to gender discrimination, sexual harassment, male-dominated structures, and a lack of supportive policies (such as flexible working hours) directly threaten women's mental health in the workplace (Jabbar et al., 2024; Miraskandari et al., 2023).
4. Mental Load and Invisible Emotional Labor: In addition to physical work, women bear the invisible, boundless, and persistent "cognitive and emotional labor" associated with managing and planning household affairs, which acts as a chronic stressor (Dean et al., 2022).

Conclusion: The relationship between employment and women's mental health is not linear or straightforward; rather, it is mediated and moderated by a complex network of individual, interpersonal, organizational, and socio-cultural factors. To promote the mental health of employed women, an integrated, multi-level approach encompassing individual empowerment, marital and family interventions, organizational restructuring, and changes to entrenched cultural norms is essential.

Keywords: Women's mental health, Women's employment, Double suffering, Mental load, Gender discrimination, Meta-synthesis

MENTAL HEALTH AMONG MEDICAL STUDENTS IN ALBANIA, 2025

Ayla Mici

Institute Of Public Health, Tirana, Albania

Alma Robo

Institute Of Public Health, Tirana, Albania

Artan Simaku

Institute Of Public Health, Tirana, Albania

Abstract

Mental-health problems among medical students have escalated globally, and Albania is no exception. In 2025, the Medical University of Tirana continues to face a growing burden of anxiety, depression, stress, and burnout among its student population. This study aims to assess the prevalence and pattern of psychological distress among undergraduate medical students and to identify academic and personal factors that contribute to worsening mental-health outcomes. A cross-sectional design was employed during the 2025 academic year, using validated mental-health instruments to measure anxiety, depressive symptoms, perceived stress, and burnout. Data on demographics, academic workload, financial strain, living conditions, and access to support services were also collected.

The results reveal a high prevalence of psychological distress, with anxiety and academic-related stress representing the dominant concerns. First- and second-year students, female students, and those balancing coursework with part-time employment demonstrated significantly higher vulnerability. Heavy curricular demands, competitive learning environments, and limited institutional mental-health resources emerged as the strongest contributing factors. Students reported difficulties accessing timely psychological support, highlighting gaps in university-level mental-health infrastructure.

The study underscores the urgent need for structured mental-health programs at the Medical University of Tirana, including routine screening, increased counselling capacity, academic-load management strategies, and preventive interventions tailored to vulnerable groups. Strengthening institutional support systems is essential to address the rising mental-health burden and safeguard the well-being of Albania’s future healthcare workforce.

Keywords: mental health; medical students; Albania; stress; burnout

TECHNIQUES AND SUPPORTIVE TOOLS IN PSYCHOEDUCATION

Dr. Arlinda Hallunovi Ymeri

Universiteti Shkodrës "Luigj Gurakuqi"

Abstract

Psychoeducation refers to a form of intervention that focuses on educating individuals about mental health, emotional well-being, and strategies for managing psychological symptoms. The goal of psychoeducation is to empower individuals with knowledge and skills that can help them better understand and cope with their mental health challenges.

Psychoeducational programs may cover a wide range of topics, including:

- **Understanding mental health:** Providing information about common mental health conditions, their symptoms, and their impact on daily functioning.
- **Treatment options:** Explaining different treatment approaches, such as therapy, medication, and lifestyle changes.
- **Coping strategies:** Teaching practical strategies to manage stress, anxiety, depression, or other mental health issues. This may include relaxation techniques, mindfulness, and problem-solving skills.
- **Communication skills:** Enhancing interpersonal and communication skills to promote healthier relationships.
- **Prevention:** Educating individuals on recognizing early signs of mental health difficulties and promoting preventive measures.

Psychoeducation can be delivered in various formats, including individual sessions, group workshops, or as part of a comprehensive mental health treatment plan. It is often used in combination with other therapeutic interventions and may involve collaboration between mental health professionals, individuals, and their support networks.

This approach is not limited to specific mental health conditions and can be applied in different settings, including schools, workplaces, and community organizations, to promote mental health awareness and well-being.

Although the term has been in use for much of the 20th century, it did not gain widespread recognition until movements addressing the stigma of mental health concerns began and efforts were made to raise awareness about mental health.

Psychoeducation includes a range of techniques and tools to provide knowledge and skills related to mental health. The specific techniques used may depend on the goals of the psychoeducational program, the target audience, and the context in which it is delivered.

The use of techniques and tools to support psychoeducation is crucial for several reasons, as it enhances the effectiveness and efficiency of the educational process in the field of mental health.

Psychoeducational techniques and tools are invaluable in promoting psychological well-being, facilitating lifelong learning, and fostering a society that is more aware of and accepting of mental health. They empower individuals with knowledge and skills that help them better manage their emotional health and overall quality of life.

with the skills necessary to navigate life's challenges, while reducing the barriers that often surround discussions about mental health.

This paper is based on the following hypothesis:

The strategic implementation of various psychoeducational techniques plays a crucial role in enhancing psychological well-being, fostering effective learning, and promoting mental health awareness among individuals.

In support of this hypothesis, this paper will examine several psychoeducational techniques and supporting tools. We will also focus on psychological well-being and the ways in which these techniques influence it. In addition, the role of psychoeducational techniques in promoting active learning will be analyzed.

II. A Brief Overview of Psychoeducational Techniques

Psychoeducational techniques refer to a range of strategies and interventions aimed at providing individuals with knowledge, skills, and support to improve their psychological well-being, address mental health issues, and promote personal growth. These techniques are commonly used in therapeutic, educational, and community settings. In this paper, we present a brief overview of some psychoeducational techniques:

Informational Seminars

The organization of seminars to disseminate information on specific mental health topics, coping strategies, and life skills. These sessions often include presentations, discussions, and interactive activities to engage participants.

Group Psychoeducation

The delivery of group sessions in which individuals with similar concerns or challenges come together to learn and share experiences. Group psychoeducation fosters a sense of community, reduces isolation, and allows participants to support one another.

Educational Materials

The development and distribution of written or multimedia materials such as leaflets, brochures, videos, or online resources that provide information on mental health, coping techniques, and available support services.

Skills Training

Teaching practical skills to enhance coping mechanisms, problem-solving abilities, communication skills, and emotional regulation. Skills training may be delivered individually or in group formats.

Crisis Intervention Education

Providing education on recognizing and managing crises, including information on emergency helplines, coping strategies during crises, and access to appropriate professional help.

Mindfulness and Relaxation Techniques

Introducing mindfulness practices, relaxation exercises, and meditation as tools for stress reduction, anxiety management, and overall mental well-being.

Family Psychoeducation

Involving family members in educational sessions to improve their understanding of a loved one's mental health condition, strengthen communication, and promote support within the family system.

Online and App-Based Interventions

Using digital platforms and applications to deliver psychoeducational content, offering accessible resources for self-directed learning and support.

Assertiveness Training

Teaching individuals how to express their thoughts and feelings confidently and appropriately, fostering healthier communication and interpersonal relationships.

Problem-Solving Training

Guiding individuals through structured problem-solving techniques to enhance their ability to identify, analyze, and resolve challenges in different areas of life.

Feedback and Evaluation

Incorporating feedback mechanisms and assessment tools to evaluate the effectiveness of psychoeducational interventions and make necessary adjustments based on participants' responses.

Cognitive-Behavioral Education

Integrating principles of Cognitive Behavioral Therapy (CBT) into educational sessions to help individuals understand the connection between thoughts, emotions, and behaviors and to develop strategies for positive change.

Overall, psychoeducational techniques aim to empower individuals, families, and communities by providing the knowledge and skills necessary to navigate life's challenges, improve mental health, and enhance overall well-being. The diverse nature of these techniques allows for flexibility in addressing a wide range of needs and circumstances.

III. How Psychoeducational Techniques Contribute to Psychological Well-Being

Psychological well-being refers to a person's overall mental health and the presence of positive psychological functioning. It includes an individual's emotional, cognitive, and social well-being, reflecting their ability to manage stress, build positive relationships, and experience a sense of purpose and fulfillment in life. Psychological well-being consists of several dimensions, including:

Emotional Well-being: The ability to understand and manage one's emotions effectively, to experience a range of positive emotions, and to cope with negative feelings.

Social Well-being: Healthy and positive relationships with others, a sense of belonging, and effective communication and interpersonal skills.

Cognitive Well-being: The ability to think clearly, make decisions, and solve problems. This includes having a positive self-concept and a sense of mastery in dealing with life challenges.

Spiritual Well-being: A sense of purpose, meaning, and connection to something greater than oneself. This dimension is often associated with a person's values, beliefs, and existential understanding.

Physical Well-being: The connection between mental and physical health, including factors such as exercise, nutrition, and sleep that influence psychological well-being.

Well-being is an essential construct in young people's lives, directly affecting their overall quality of life, academic performance, and social relationships. Although the importance of positive psychological states in mental health is increasingly recognized, relatively little

attention has been given to these positive states, and psychological well-being is often conceptualized using negative mental health indicators.

In recent years, there has been growing interest among researchers and practitioners in the psychological well-being of young people. While early interventions for mental health disorders are considered crucial for reducing long-term consequences, it has been emphasized that mental health is not merely the absence of psychological symptoms, but also the presence of positive psychological states. However, several scholars have noted that most research has primarily assessed psychological well-being using negative indicators such as depressive symptoms, anxiety, and stress.

Therefore, evaluating psychological well-being is essential, as it is integral to the development of effective policies aimed at improving the quality of life of children and adolescents. Moreover, considering the impact of adverse experiences, such as the COVID-19 pandemic, on young people's mental health and well-being, it is critical for mental health professionals to recognize these effects and design targeted interventions to support psychological well-being during and after such challenging experiences.

Psychoeducation, on the other hand, as an educational approach, aims to empower individuals to understand, manage, and improve their mental health through knowledge and practical strategies.

The relationship between psychological well-being and psychoeducation includes the following:

Psychoeducation increases awareness of mental health, mental disorders, and the factors that contribute to psychological well-being.

Psychoeducational programs often equip individuals with practical skills to manage stress, regulate emotions, improve communication, and build resilience. These skills contribute to enhanced psychological well-being by providing effective coping mechanisms.

Psychoeducation plays a significant role in reducing the stigma associated with mental health issues. By providing accurate information and encouraging open discussion, it promotes a more supportive and understanding community, positively influencing social and emotional well-being.

Psychoeducation empowers individuals to take an active role in their mental health. It encourages self-care practices, healthy lifestyle choices, and a proactive approach to managing mental health challenges, thereby positively affecting emotional and social well-being.

Psychoeducational interventions often include components focused on interpersonal relationships and communication skills. Improved social well-being is a natural outcome, as individuals learn to relate more effectively to others and build stronger social connections.

In summary, psychoeducation is a valuable tool for promoting psychological well-being by offering education, skills, and support that contribute to the development of more informed and resilient individuals. The relationship between the two lies in empowering individuals to understand, manage, and enhance their psychological well-being through knowledge and practical application.

Psychoeducational techniques and tools play a crucial role in promoting psychological well-being.
Some psychoeducational techniques and tools used for well-being purposes include:

EducationalTrainingsandWorkshops:
Structured activities and seminars covering topics such as stress management, resilience-

building, and positive psychology, providing participants with practical knowledge and well-being strategies.

Printed Materials and Leaflets:

The distribution of informational leaflets or brochures covering mental health topics, coping strategies, and available resources can serve as a valuable psychoeducational tool.

Online Resources and Webinars

Digital platforms offer a wide range of psychoeducational resources, including webinars, online courses, and interactive modules. These resources are easily accessible to a broad audience.

Mobile Applications

Mental health and well-being applications often include psychoeducational content, offering features such as guided meditation, stress-reduction exercises, and mood tracking.

Worksheets and Interactive Exercises

Providing individuals with worksheets and interactive exercises can facilitate self-reflection and the practical application of well-being strategies. These may include goal-setting worksheets, gratitude journals, or mood-tracking logs.

Visual Aids and Infographics

Visual tools such as infographics and posters can effectively convey key information on mental health topics, making it easier for individuals to understand and remember the material.

Role-Playing and Simulations

Interactive activities such as role-playing and simulations allow participants to practice and apply well-being strategies in a controlled environment, enhancing skill development and confidence.

Peer Support Programs

Establishing peer support programs in which individuals with shared experiences exchange knowledge and provide emotional support can be a powerful psychoeducational approach.

Therapeutic Games and Activities

Incorporating games and therapeutic activities into psychoeducational sessions can make learning more engaging and enjoyable while addressing well-being-related themes.

Narrative Therapy Techniques

Narrative therapy, which focuses on individuals' stories and personal narratives, can be used to explore and reshape how people perceive their well-being and life experiences.

Mindfulness and Relaxation Exercises

Integrating mindfulness and relaxation techniques into psychoeducational sessions can promote emotional regulation and stress reduction.

Cognitive Behavioral Therapy (CBT) Worksheets

CBT worksheets, including thought records and behavioral activation sheets, can help individuals identify and modify negative thought patterns to improve well-being.

Goal Setting and Action Planning

Guiding individuals through the process of setting realistic well-being goals and creating action plans can enhance motivation and a sense of achievement.

Lectures and Guest Speakers

Inviting mental health professionals or experts in well-being to deliver lectures or presentations can provide valuable insights and perspectives.

Expressive Arts Therapies

Incorporating expressive arts therapies, such as art or music therapy, into psychoeducation can offer alternative ways for individuals to explore and express their emotions.

Self-Help Books and Audiobooks

Recommending well-being-focused self-help books or providing access to audiobooks can support self-directed psychoeducation.

Wearable Digital Devices

Wearable devices that track physical activity, sleep patterns, and stress levels can help individuals monitor and improve their overall well-being.

Podcasts and Audio Content

Well-being-focused podcasts and audio content offer a convenient way for individuals to access information and guidance related to mental health improvement.

Adapting psychoeducational techniques and tools to individuals' specific needs and preferences can increase their effectiveness in promoting well-being. Moreover, combining different approaches and strategies can ensure a comprehensive and personalized psychoeducational framework aimed at enhancing well-being.

IV. The Role of Psychoeducational Techniques in Promoting Effective Learning

Psychoeducational techniques play a vital role in promoting effective learning by addressing various psychological and cognitive factors that influence an individual's ability to acquire, retain, and apply knowledge. Below are the main aspects of their role in enhancing effective learning:

Understanding Individual Learning Styles

Role:
Psychoeducational techniques help individuals identify their preferred learning styles, whether visual, auditory, kinesthetic, or a combination of these. Understanding how one learns best allows for the personalization of learning strategies.

Example:
Workshops or training sessions that explore learning preferences and styles, providing participants with insights into their individual strengths and optimal learning methods.

Enhancing Study Skills and Learning Strategies

Role:
Psychoeducational interventions teach effective study skills, time management, and organizational strategies. These skills are essential for optimizing the learning process and improving information retention.

Example:
Seminars on note-taking techniques, effective reading strategies, and time-management tools that empower students to structure their study routines more efficiently.

Fostering Motivation and Engagement

Role:
Psychoeducational techniques address motivational factors by helping individuals understand the relevance of learning material, set realistic goals, and develop a sense of competence and achievement.

Example:
Motivational workshops, goal-setting exercises, and interventions that highlight the connection between academic content and students' personal and professional goals.

Teaching Stress Management and Coping Skills

Role:
Psychoeducational programs recognize the impact of stress on learning and provide individuals with effective stress management and coping skills to create a supportive learning environment.

Example:
Stress-reduction activities, mindfulness sessions, and relaxation techniques included in educational programs to help students manage anxiety and enhance cognitive performance.

Developing Cognitive Skills

Role:
Psychoeducational techniques focus on developing cognitive abilities such as critical thinking, problem-solving, and information processing, which are essential for effective learning.

Example:
Training sessions that teach specific cognitive strategies, such as concept mapping, reflective thinking, and analytical reasoning, to strengthen learners' cognitive skills.

Promoting a Growth Mindset

Role:
Psychoeducational interventions cultivate a growth mindset by encouraging students to embrace challenges, persist in the face of obstacles, and view effort as a pathway to mastery.

Example:
Programs that emphasize the importance of effort, resilience, and the belief that intelligence can be developed through dedication and hard work.

Improving Self-Regulation and Metacognition

Role:
Psychoeducational techniques develop self-regulation skills, including goal-setting, progress monitoring, and reflection on the learning process (metacognition).

Example:
Training sessions that guide students in setting achievable goals, monitoring their learning strategies, and reflecting on their understanding and application of new information.

Encouraging Collaborative Learning

Role:
Psychoeducational strategies promote collaborative and cooperative learning by recognizing the benefits of peer interaction and group dynamics in the learning process.

Example:
Group activities, team projects, and collaborative learning exercises that encourage students to share knowledge, engage in discussion, and learn from one another.

Providing Information on Learning Resources

Role:
Psychoeducational interventions inform students about available learning resources, including libraries, online platforms, and academic support services.

Example:
Orientation sessions that guide students in accessing and using various learning resources to enhance their educational experience.

In summary, psychoeducational techniques contribute to effective learning by addressing individual differences, fostering motivation, developing cognitive and metacognitive skills, and creating a supportive learning environment. These interventions acknowledge the holistic nature of learning and aim to empower individuals with the knowledge and skills necessary to maximize their learning potential.

Specific Strategies for Implementing Psychoeducational Techniques

The strategic implementation of psychoeducational techniques may vary depending on the setting, such as schools, workplaces, or community environments. Below are specific strategies for implementation in school contexts:

Incorporate Interactive Workshops

Organize interactive activities that address important topics such as stress management, study skills, and resilience. Encourage student participation through group discussions, role-playing, and practical exercises.

Implement Peer Tutoring Programs

Establish peer tutoring programs where students teach and learn from one another. This fosters a collaborative learning environment, supports academic achievement, and builds a sense of community within the school.

Integrate Social and Emotional Learning (SEL) Programs

Include SEL programs in the curriculum, focusing on emotional intelligence, self-awareness, and interpersonal skills. SEL programs contribute to a positive school climate and support students in developing essential life skills.

Promote a Growth Mindset

Implement initiatives that encourage a growth mindset by emphasizing the belief that intelligence and abilities can be developed through effort and perseverance. This can be achieved through targeted messaging, workshops, and classroom activities.

Create Mental Health Awareness Campaigns

Launch mental health awareness campaigns to reduce stigma, provide information about available resources, and encourage students to seek help when needed. Use various communication channels, including posters, school assemblies, and social media.

Offer Study Skills and Time Management Workshops

Conduct workshops on effective study skills, time management, and organization. Equip students with practical strategies to improve academic performance and reduce stress.

Adapting psychoeducational strategies to the specific needs of each context ensures that interventions are relevant, impactful, and well-received by the target audience. It is essential to consider the unique characteristics and challenges of each setting to maximize the effectiveness of psychoeducational approaches. It is also important to emphasize community involvement, as teachers and parents should work in partnership to support children in solving problems and promoting positive development.

While psychoeducational techniques offer valuable benefits, their implementation may face challenges in different contexts. It is essential to anticipate and address these challenges to ensure the success and sustainability of such initiatives.

Potential Challenges in Implementing These Techniques

(Ethical Considerations and Potential Limitations)

While psychoeducational techniques offer significant benefits, their implementation may encounter various challenges across different settings. Anticipating and addressing these challenges is crucial for the success and sustainability of such initiatives. Below are some common challenges and possible mitigation strategies:

Common Challenges:

Resistance to Change:

VI. Potential Challenges and Limitations in Implementing Psychoeducational Techniques

Resistance to Change

People may resist adopting new practices or ideas, especially if they perceive them as unfamiliar or disruptive.

Strategy:
Provide clear explanations about the purpose and benefits of psychoeducational techniques. Involve key stakeholders early in the planning process to build support and address concerns.

Limited Resources

Schools, workplaces, and communities may face constraints related to time, budget, and staffing when implementing psychoeducational programs.

Strategy:
Prioritize initiatives based on available resources. Seek external funding, partnerships, or volunteers to support implementation. Consider phased implementation to better manage resource limitations.

Cultural Sensitivity

Cultural differences may influence the acceptance and relevance of psychoeducational content.

Strategy:
Adapt interventions to the cultural context and involve community members in the planning process. Seek input from diverse perspectives and adjust materials to ensure they resonate with different cultural backgrounds.

Limited Accessibility

Barriers such as transportation difficulties or language differences may prevent participation in psychoeducational programs.

Strategy:
Select accessible locations for workshops and use multiple communication channels. Provide translated materials and consider virtual or remote options to increase accessibility.

Sustainability

Maintaining the momentum of psychoeducational initiatives over the long term can be challenging.

Strategy:
Develop sustainable models by integrating psychoeducation into existing structures, securing ongoing funding or institutional support, and fostering a culture that values continuous learning.

School-Specific Challenges

Curriculum Constraints

Schools may face difficulties in incorporating psychoeducational content into existing curricula.

Strategy:
Collaborate with teachers and administrators to align psychoeducational content with curriculum objectives. Integrate relevant themes into existing subjects or allocate specific time for psychoeducational activities.

Parental Involvement

Engaging parents in school-based psychoeducational initiatives may be challenging due to time constraints or lack of interest.

Strategy:
Offer flexible schedules for parent involvement, provide incentives for participation, and communicate the benefits of parental engagement for children's education and well-being.

Student Engagement

Students may not fully engage if psychoeducational content is perceived as irrelevant or uninteresting.

Strategy:
Design age-appropriate and interactive activities. Gather student input on topics of interest and involve them in the planning process. Use multimedia and technology to increase engagement.

Limitations of Psychoeducational Techniques

Generalization of Content

Limitation:
Psychoeducational content may not be universally applicable, and some participants may find it less relevant.

Mitigation:
Adapt examples and case studies to be inclusive and diverse. Acknowledge individual differences and encourage participants to apply general principles to their unique situations.

Short-Term Impact

Limitation:
Psychoeducational interventions may have immediate effects, but long-term behavioral change may vary.

Mitigation:
Complement psychoeducation with follow-up sessions or resources that support continued learning and application. Encourage participants to develop long-term habits and seek additional support when needed.

Resource Limitations

Limitation:
Limited resources may affect the depth and reach of psychoeducational programs.

Mitigation:
Prioritize key topics based on available resources. Seek external funding or partnerships to expand program reach and effectiveness. Use technology to deliver content in a cost-effective manner.

Participant Engagement

Limitation: Some participants may not fully engage in psychoeducational activities, affecting the intervention's effectiveness.

Mitigation: Use interactive and participatory methods. Foster a supportive and inclusive environment. Employ diverse teaching strategies to accommodate different learning preferences.

Cultural Differences

Limitation: Cultural variations may influence the acceptance and applicability of psychoeducational content.

Mitigation: Conduct cultural sensitivity assessments, include diverse perspectives in program planning, and adapt content to resonate with the cultural context. Encourage open dialogue about cultural differences.

Addressing these ethical considerations and minor limitations ensures that psychoeducational interventions are implemented with integrity, respect, and effectiveness. Regular evaluations, feedback mechanisms, and ongoing improvement processes contribute to the sustained ethical and practical success of these programs.

Recommendations and Conclusions

When using psychoeducational techniques and tools, it is essential to consider the specific context, audience, and educational program goals. Below are key recommendations for the effective use of psychoeducational methods:

Conduct a needs assessment to identify the specific needs, preferences, and challenges of the target audience. This will help tailor psychoeducational content to be relevant and engaging.

Use interactive learning methods, such as group discussions, role-playing, and case studies, to actively engage participants. Interactive approaches enhance understanding and skill development.

Implement multimodal formats, including visual aids, audio content, written materials, and practical activities, to accommodate different learning styles and preferences.

Leverage digital platforms, apps, and online resources to increase access and reach a broader audience. Ensure the digital tools used are user-friendly and accessible to diverse populations.

Ensure cultural sensitivity and relevance of psychoeducational content for participants from different backgrounds. This promotes inclusivity and enhances educational effectiveness.

Tailor programs to individual participant needs, including setting personalized goals, providing self-assessment tools, and adapting content to specific challenges or strengths.

Integrate skill-building exercises that allow participants to practice and apply what they have learned, such as guided imagery, mindfulness exercises, or problem-solving scenarios.

Create feedback mechanisms to collect participant data. Regularly evaluate the effectiveness of the psychoeducational program and adjust based on feedback.

Collaborate with mental health professionals or subject-matter experts to ensure accuracy and credibility of psychoeducational content. Expert input adds depth and authority.

Design activities that empower participants to take an active role in their well-being. Encourage self-reflection and goal setting to enhance motivation and personal agency.

Establish peer support groups where individuals can share experiences and learn from one another. Peer support enhances community feeling and reduces isolation.

Use clear, jargon-free language to communicate complex concepts, ensuring participants easily understand the information presented.

Provide resources and support for long-term learning and application, including follow-up sessions, ongoing access to digital resources, or referrals for additional services.

Emphasize the importance of self-care practices within psychoeducation. Encourage participants to integrate self-care routines into daily life for sustainable well-being.

Be mindful of potential challenges with digital tools, such as privacy concerns or accessibility issues. Select technology that aligns with ethical considerations and inclusivity.

Implement pre- and post-assessments to measure the impact of psychoeducation on participants. Evaluation data can guide program improvements and adjustments.

Develop and communicate clear protocols for managing crisis situations that may arise during sessions. Ensure participants know where to seek additional support if needed.

Promote a positive and supportive learning environment where participants feel comfortable sharing and learning from each other. A safe space increases the effectiveness of psychoeducation. 6. Tailor psychoeducational programs to the individual needs of participants.

This may include setting personalized goals, using self-assessment tools, and adapting content to specific challenges or strengths.

Integrate skill-building exercises that allow participants to practice and apply what they have learned.

This may include activities such as guided imagery, mindfulness exercises, or problem-solving scenarios.

Establish feedback mechanisms to collect data from participants.

Regularly evaluate the effectiveness of the psychoeducational program and make adjustments based on feedback.

Collaborate with mental health professionals, psychologists, or subject-matter experts.

This ensures the accuracy and credibility of the psychoeducational content. Expert input adds depth and authority to the information presented.

Design activities that empower participants to take an active role in their well-being.

Encourage self-reflection and goal setting to enhance motivation and a sense of personal agency.

Create peer support groups where individuals can share experiences and learn from one another.

Peer support fosters a sense of community and reduces feelings of isolation.

Use clear, jargon-free language to communicate complex concepts.

Ensure participants can easily understand the information provided.

Provide resources and support for long-term learning and application.

This may include follow-up sessions, ongoing access to digital resources, or referrals for additional services.

Emphasize the importance of self-care practices within psychoeducation.

Encourage participants to integrate self-care routines into daily life for sustainable well-being.

When using digital tools, be aware of potential challenges such as privacy concerns or accessibility issues.

Choose technology that aligns with ethical considerations and promotes inclusivity.

Implement pre- and post-assessment tools to measure the impact of psychoeducation on participants.

Assessment data can guide program improvements and adjustments.

Develop and communicate clear protocols for managing crisis situations that may arise during sessions.

Ensure participants know where to seek additional support if needed.

Promote a positive and supportive learning environment where participants feel comfortable sharing and learning from one another.

A safe space enhances the effectiveness of psychoeducation.

By carefully implementing these recommendations, psychoeducational programs can be designed and delivered to maximize their impact on participants' well-being. Continuous evaluation and adaptation based on participant feedback contribute to ongoing improvement and effectiveness.

Conclusions

Based on the hypothesis that the strategic implementation of diverse educational techniques plays a decisive role in enhancing psychological well-being, fostering effective learning, and promoting mental health awareness, the following conclusions can be drawn:

Educational diversity contributes to psychological well-being:

Strategic inclusion of diverse educational techniques positively impacts psychological well-being. Exposure to a range of methods, styles, and teaching approaches contributes to a more comprehensive and enriching learning experience.

Effective learning is facilitated by diverse educational techniques: The hypothesis suggests that applying diverse educational techniques is instrumental in promoting effective learning. Incorporating a variety of learning strategies accommodates different learning styles, making education more accessible and engaging for a wider range of individuals.

Promoting mental health awareness through education: Strategic implementation of various educational techniques serves as a tool for promoting mental health awareness. Education that includes knowledge about mental health, coping mechanisms, and emotional intelligence can help reduce stigma, increase sensitivity, and equip individuals with tools to address mental health challenges.

A holistic approach to education and mental health: The hypothesis suggests that integrating diverse educational techniques supports a holistic approach to education that extends beyond traditional academic content. By addressing individuals' psychological well-being, education becomes a tool not only for imparting knowledge but also for fostering overall mental health.

The need for continuous exploration and innovation in education: To maximize the benefits described in the hypothesis, continuous exploration and innovation in educational strategies are required. Adapting to emerging research, technological advances, and evolving societal needs is essential to maintain the effectiveness of diverse educational techniques in promoting psychological well-being.

Collaboration between education and mental health professionals: Given the interconnection between education and mental health, collaboration between educators and mental health professionals is essential. Joint efforts can lead to the development of comprehensive programs that address both educational and mental health needs, creating a supportive environment for learners.

In summary, the strategic implementation of diverse educational techniques appears to offer multifaceted benefits, including enhanced psychological well-being, effective learning, and increased mental health awareness. These conclusions highlight the importance of adopting a holistic and innovative approach to education to improve overall individual well-being.

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ROLE OF EMPATHY IN THE RELATIONSHIP BETWEEN PETS ATTACHMENT AND MENTAL HEALTH AMONG PET OWNERS

Bakhtawar Fakhar

Department Of Psychology Rawalpındı Women Unıversıty Rawalpındı

Umm Eman Syed

Department Of Psychology Rawalpındı Women Unıversıty Rawalpındı

Abstract

This study examines the relationship between pet attachment, empathy, and mental health among pet owners, drawing on principles from attachment theory. A quantitative co relational approach was employed with a sample of 250 pet owners (balanced by gender) from Rawalpindi and Islamabad, Pakistan. Standardized measures including the Animal Empathy Scale–Short Form (AES-SF), Lexington Attachment to Pets Scale (LAPS), and Depression, Anxiety, and Stress Scale (DASS-21) were used to assess key variables. Findings demonstrated that stronger emotional bonds with pets were associated with lower levels of depression ($r=0.27$, $p<.01$), anxiety ($r=-0.28$, $p<.01$), and stress ($r=-0.31$, $p<.01$), supporting the mental health benefits of human-animal connections. Empathy was found to enhance these benefits, particularly in mitigating stress and anxiety, suggesting that individuals with greater empathy derive more psychological support from their pets (*B*=-3.40, P=<.05). Demographic variations emerged, with married participants reporting higher empathy and better mental health outcomes compared to unmarried individuals. Conversely, unemployed respondents exhibited stronger pet attachment but poorer mental health, implying that pets may serve as compensatory sources of emotional support in the absence of other social resources. Gender differences were also observed, with women displaying higher levels of both empathy and pet attachment. These results highlight the potential of pet companionship as a therapeutic tool, particularly for emotionally attuned individuals. The study contributes to existing knowledge on animal-assisted support and suggests practical applications for mental health interventions. Methodological limitations, such as the cross-sectional design and geographically restricted sample, indicate a need for future longitudinal and cross-cultural research to validate and expand these findings.

Keywords*:* pet attachment, empathy, mental health, human-animal bond, stress, depression, anxiety, animal-assisted support, gender differences, Pakistan

THE RELATIONSHIP BETWEEN ANUPTAPHOBIA AND SELF-OBJECTIFICATION: THE MEDIATING ROLE OF EMOTIONAL INSTABILITY AMONG YOUTH

Rida Fatima

Department of Psychology Rawalpindi Women University Rawalpindi-Pakistan

Ayesha

Department of Psychology Rawalpindi Women University Rawalpindi-Pakistan

Abstract

The present study aimed to examine the relationship between Anuptaphobia (fear of being single) and self-objectification, with emotional instability acting as a mediating variable among Pakistani youth. A cross-sectional correlational design was Conducted. A sample of 300 single individuals (150 males, 150 females) aged 18 to 30 years was recruited from universities and workplaces in Rawalpindi and Islamabad. Participants completed the Fear of Being Single Scale (FBSS), the Objectified Body Consciousness Scale (OBCS), and the Difficulties in Emotion Regulation Scale 16 items (DERS 16). Pearson correlation, regression, and mediation analyses were conducted using SPSS (version 21). The results indicated significant positive correlations among all three variables. Anuptaphobia was significantly related to both emotional instability ($r = .879$, $p < .01$) and self-objectification ($r = .276$, $p < .01$). Mediation analysis revealed that emotional instability significantly mediated the relationship between Anuptaphobia and self-objectification ($\beta = .247$, $p < .01$, $F = 12.829$, $\eta^2 = .658$). These findings suggest that individuals with Anuptaphobia are more likely to experience emotional dysregulation, which subsequently increases their levels of self-objectification. The study highlights the psychological vulnerabilities youth face in collectivist cultures where romantic relationships are heavily emphasized. These findings have important implications for developing culturally sensitive interventions, such as cognitive-behavioral therapy (CBT) workshops, self-compassion training, media literacy programs, and group counseling that promote emotional regulation, enhance self-acceptance, and encourage critical thinking toward unrealistic societal beauty standards. Such interventions can help reduce emotional instability and foster healthier self-concepts among young individuals navigating these pressures.

Keywords. Anuptaphobia, Self-Objectification, Emotional Instability, Pakistani Youth

IMPACT OF NON-STEROIDAL ANTI-INFLAMMATORY DRUGS ON QUALITY OF LIFE IN PATIENTS WITH HEADACHE

MPharmSci Tamara MİLENKOVİĆ

Faculty of Medicine, University of Kragujevac, Serbia

ORCID ID: https://orcid.org/0009-0001-1180-7913

Ass.Prof. Dr. Radica ŽİVKOVİĆ-ZARIC

Faculty of Medicine, University of Kragujevac, Serbia

ORCID ID: https://orcid.org/0000-0002-6305-5485

ABSTRACT

Introduction and Purpose: Headache is a common neurological condition that significantly affects daily functioning and quality of life. Non-steroidal anti-inflammatory drugs (NSAIDs) are among the most frequently used treatments for acute headache episodes, yet their impact on life quality remains insufficiently explored in clinical settings.

Materials and Methods: This study assessed the quality of life in 224 patients (68.2% female) suffering from headaches and regularly using NSAIDs, employing validated Serbian versions of the HURT and MIDAS scales.

Results: The results demonstrated that headache negatively influenced both professional and social activities, particularly among women and participants living in rural areas. Although most respondents reported partial control of their headaches, a substantial proportion indicated the need for improved management strategies.

Discussion and Conclusion: The findings underline the importance of individualized headache care, rational NSAID use, and greater emphasis on patient education to enhance long-term treatment outcomes and life quality

Key Words: NSAIDs, headache, migraine, quality of life, HURT, MIDAS

THE USE OF INNOVATIVE METHODS IN STRESS MANAGEMENT

Shahla Guliyeva

Nakhchivan State University University, Department of Basic Medical Sciences, Nakhchivan, Azerbaijan

ORCID ID: https://orcid.org/0009-0007-0848-4360

ABSTRACT

The article discusses stress management and various strategies and techniques applied to reduce its negative effects on physical, emotional, and cognitive functions. The study demonstrates that combining traditional, technological, and creative strategies yields the most effective results. Individualized interventions are essential, as responses to stress vary significantly among individuals. Although innovative methods are promising, broader studies are required to confirm their long-term effectiveness, accessibility, and cost-efficiency.

Introduction and Purpose: Digital psychology, artificial intelligence-based applications, virtual reality technologies, and biofeedback devices, which measure physiological processes in the human body (e.g., respiration, heart rate, muscle tension, skin temperature, brain waves, etc.) and provide real-time feedback to the user, have personalized and made stress management more efficient. In this context, the nature of stress, its causes, and traditional stress management techniques have been analyzed, alongside modern innovative approaches, including digital therapeutic technologies, mindfulness programs, virtual reality-based relaxation methods, and the role of mobile applications

Materials and Methods: Digital technologies, by being integrated into people's daily lives, provide opportunities to prevent stress and minimize its negative consequences. In the future, the advancement of digital technologies and their integration into pedagogical practice will become one of the primary directions in stress management.

Results: Innovative methods demonstrate higher efficiency compared to traditional approaches. Digital technologies facilitate stress management, while cognitive-behavioral therapy (CBT) and mindfulness enhance individual emotional stability.

Discussion and Conclusion: Digital technologies, by being integrated into people's daily lives, provide opportunities to prevent stress and minimize its negative consequences. In the future, the advancement of digital technologies and their integration into pedagogical practice will become one of the primary directions in stress management.

Key Words: stress, creative intervention, well-being, cognitive-behavioral therapy, mindfulness, innovative methods.

MIDWIVES' PREPAREDNESS IN THE FACE OF THE EFFECTS OF CLIMATE CHANGE ON MATERNAL AND CHILD HEALTH

İKLİM DEĞİŞİKLİĞİNİN ANNE VE ÇOCUK SAĞLIĞINA ETKİLERİ KARŞISINDA EBELERİN HAZIRLIĞI

Arş. Gör. Dr. Nuray KURT

Fırat Üniversitesi, Ebelik, Sağlık Bilimleri Fakültesi

Doç. Dr. Sümeyye BARUT

Fırat Üniversitesi, Ebelik, Sağlık Bilimleri Fakültesi

ÖZET

İklim değişikliği, anne ve çocuk sağlığı üzerinde ciddi olumsuz etkilere sahip olan 21. yüzyılın en önemli küresel sağlık sorunlarından biridir. Sıcak hava dalgaları, aşırı hava olayları, kötü hava kalitesi, beslenme eksiklikleri, su ve gıda kaynaklı enfeksiyonlar ile ruh sağlığı problemleri, gebeler ve yenidoğanlar açısından yüksek risk oluşturur. Ebeler, gebelik ve yenidoğan bakımında kritik bir rol üstlenerek iklim değişikliğinin sağlık üzerindeki olumsuz etkilerini azaltmada merkezi sorumluluğa sahiptir. Ancak güncel araştırmalar, ebelerin iklim değişikliği ve bunun anne-çocuk sağlığı üzerindeki etkilerine ilişkin bilgi ve hazırlık düzeylerinin sınırlı olduğunu ve ebelik müfredatında bu konuların sistematik olarak yer almadığını ortaya koymaktadır. Bölgesel farklılıklar, kaynak eksikliği ve eğitim boşlukları, ebelerin riskleri etkili şekilde yönetmesini zorlaştırmaktadır. Ebeler, gebelerin güvenli ve sağlıklı bir gebelik geçirmelerini sağlamak amacıyla önleyici stratejiler sunmalı, eğitim ve danışmanlık vermeli, çevresel riskler konusunda farkındalık oluşturmalı ve ruhsal sağlık etkilerini takip etmelidir. Ayrıca, sürdürülebilir sağlık uygulamalarını desteklemek, çevresel emisyonları azaltmak ve kanıta dayalı halk sağlığı girişimlerine katılmak ebelerin sorumlulukları arasındadır. Sonuç olarak, ebelerin iklim değişikliğine uyum sağlaması ve riskleri azaltabilmesi için ebelik eğitim müfredatlarının güncellenmesi, mesleki gelişim fırsatlarının artırılması ve çevresel sağlık bilgilerinin sistematik entegrasyonu gereklidir. Kültürel ve bağlamsal faktörler göz önünde bulundurularak tasarlanacak eğitim ve kapasite geliştirme programları, ebelerin iklim kaynaklı sağlık risklerine karşı daha hazırlıklı olmalarını ve bu risklere etkili bir şekilde yanıt verebilmelerini sağlayacaktır.

Anahtar Kelimeler: Anne sağlığı, Ebelik, Hazırlık, İklim değişikliği

ABSTRACT

Climate change is one of the most significant global health issues of the 21st century, with serious negative impacts on maternal and child health. Heat waves, extreme weather events, poor air quality, nutritional deficiencies, water- and food-borne infections, and mental health problems pose high risks for pregnant women and newborns. Midwives play a critical role in pregnancy and newborn care and have a central responsibility in mitigating the negative health

effects of climate change. However, current research shows that midwives have limited knowledge and preparedness regarding climate change and its effects on maternal and child health, and that these topics are not systematically included in midwifery curricula. Regional differences, lack of resources, and gaps in education make it difficult for midwives to effectively manage these risks. Midwives should offer preventive strategies, provide education and counseling, raise awareness about environmental risks, and monitor mental health effects to ensure pregnant women have safe and healthy pregnancies. Supporting sustainable health practices, reducing environmental emissions, and participating in evidence-based public health initiatives are also among midwives' responsibilities. In conclusion, updating midwifery education curricula, increasing professional development opportunities, and systematically integrating environmental health knowledge are necessary for midwives to adapt to climate change and reduce risks. Education and capacity-building programs designed with cultural and contextual factors in mind will enable midwives to be better prepared for climate-related health risks and respond effectively to these risks.

Keywords: Maternal health, Midwifery, Preparation, Climate change

GİRİŞ

İklim değişikliği, 21. yüzyılın en büyük küresel sağlık tehditlerinden biri olarak tanımlanmaktadır ve halk sağlığını tehdit etmektedir (Watts ve ark., 2021; WHO, 2021). İklim değişikliğinin sıcak hava dalgaları, kötü hava kalitesi, aşırı hava olayları, çevredeki toksik maddelerin daha yüksek seviyelere çıkması, gıda ve suyla ilgili enfeksiyonlar, vektör kaynaklı hastalıklar, beslenme eksiklikleri ve ruh sağlığı ile ilişkili riskleri de içeren sağlık üzerinde pek çok olumsuz etkisi bulunmaktadır (IPCC, 2022; Giudice ve ark., 2021; Watts vd., 2021). Gebeler, iklim değişikliğinin olumsuz sağlık etkilerine karşı en savunmasız gruplardan biridir.

İklim değişikliği; düşük doğum ağırlığı, erken doğum, erken membran rüptürü, ölü doğum, gestasyonel diyabet, kardiyovasküler hastalıklar, gebelik hipertansiyonu ve preeklampsi, spontan abortus, dehidratasyon ve buna bağlı böbrek yetmezliği, yetersiz beslenme, ishal, solunum yolu hastalıkları ve stres, depresyon, travma sonrası stres bozukluğu gibi ruh sağlığı problemleri de dahil olmak üzere olumsuz gebelik sonuçlarına yol açabilmektedir (Kılıç & Yılmaz, 2025; Attawet ve ark., 2025). Bu nedenle, iklim değişikliğinin anne ve çocuk sağlığı ile gelecek nesiller üzerindeki olumsuz etkilerini azaltma ve iklim değişikliğine uyum sağlamada ebelik bakımı büyük önem taşımaktadır (Churchill & Avery, 2023). Ancak Bonell (2024) ve Rise (2022) tarafından yapılan güncel çalışmalar, iklim değişikliğiyle ilişkili olaylara hazırlık ve müdahalede, özellikle de aşırı iklim koşullarında anne ve çocuk bakımı gibi savunmasız gruplara yönelik hizmetleri yöneten sağlık profesyonelleri için etkili eylem planlarının değerlendirilmesinde önemli bir boşluk bulunduğunu ortaya koymuştur (Bonel ve ark., 2024; Rise ve ark., 2022).

Mevcut klinik uygulamada sağlık profesyonelleri için mevcut bir eylem planının olmaması, hem sağlık sistemi, hem bireyler hem de ekonomik yönden olumsuz etkilere sahiptir (Attawet ve ark., 2025). Bu olumsuzlukların üstesinden gelmede, iklim değişikliğinin yarattığı tehditleri fark eden ve iklimle ilişkili olaylar sırasında anne ile yenidoğan sağlığını korumada kritik rol üstlenen ebelerin güçlendirilmesi büyük önem taşımaktadır (Kılıç & Yılmaz, 2025; Attawet ve ark., 2025). Küresel ve ulusal politika belgeleri, ebelerin iklim değişikliğine uyum ve dayanıklı sağlık sistemlerindeki sorumluluklarını ve merkezi rollerini açıkça vurgulamaktadır (Attawet ve ark., 2025).

Uluslararası Ebeler Konfederasyonu, bu yılın temasını "Ebeler: Hayati Bir İklim Çözümü" olarak belirlemiştir. Temada, ebelerin güvenli ve çevresel olarak sürdürülebilir sağlık hizmetleri

sağladığı ve ebelerin iklim değişikliğinin neden olduğu doğal afetler gibi felaketlerde ilk müdahale edenler olduğu vurgulanmıştır (ICM, 2024). O'Connell ve meslektaşları (2024), küresel iklim krizine yanıt olarak ebelik uygulamalarını güçlendirmenin acil ihtiyacını vurgulayarak, ebeleri anne ve yenidoğan sağlığını korumada merkezi bir konuma getirmişlerdir (O'Connell ve ark., 2024). Ulusal düzeyde, Avustralya Hemşirelik ve Ebelik Federasyonu (ANMF), acil iklim eylemi çağrısında bulunan bir pozisyon bildirisi yayınlamış ve ebelik eğitimine, işyeri protokollerine, acil durum hazırlığına ve tedarik stratejilerine çevre sağlığı, iklim değişikliğiyle ilişkili olaylar ve sürdürülebilir sağlık uygulamalarının dahil edilmesini talep etmiştir (ANMF, 2023).

İklim değişikliği ve buna bağlı doğal afetlerin sıklığının artması, kadın ve çocukların bu süreçlerden en fazla etkilenen gruplar arasında olduğunu göstermektedir. Bu doğrultuda hazırlanan bu derleme, ebelerin iklim değişikliğiyle ilişkili olaylar sırasında gebelik, anne ve bebek bakımına yönelik bilgi düzeylerini, iyileştirmeye ihtiyaç duyulan öncelikli alanları ortaya koymak, uyum stratejileri ve hazırlık durumlarına ilişkin mevcut literatürü özetlemek amacıyla yazılmıştır.

ARAŞTIRMA VE BULGULAR

Ebelerin Bilgi ve Hazırlık Düzeyi

Ebeler, sürekli gelişen ve ilerleyen bakım hizmetlerindeki güncel gelişmeler ışığında bakım sağlayan, iklim değişikliği gibi küresel krizleri önlemek ve yönetmek için bilgi ve deneyimlerini geliştiren, sürdürülebilir sağlık açısından kritik öneme sahip sağlık çalışanlarıdır. Ebeler, kadın sağlığını koruma ve geliştirme noktasında önemli rol oynamaktadır (Reyhan ve ark., 2024).

Reyhan ve arkadaşları yaptıkları çalışmada, geleceğin ebelerinin iklim değişikliğinin kadın sağlığı üzerindeki etkileri hakkında sınırlı düzeyde bilgiye sahip olduğunu tespit etmiştir. İklim değişikliği ile sağlık arasındaki bağlantı bilinmesine rağmen, bu önemli bilgi henüz ebelik müfredatına sistematik olarak entegre edilmemiştir. Bu durum, ebelerin yeni ortaya çıkan insan sağlığı sorunlarına hazırlıklı olmaları için acil eylem gerekliliğini ortaya koymaktadır (Reyhan ve ark., 2024). Ayrıca Attawet ve arkadaşları yaptıkları çalışmada birçok ebenin gebeleri ve yenidoğanları iklim değişikliği ile ilgili risklerden etkili bir şekilde korumak için gerekli bilgi ve beceriye sahip olmadığını ortaya koymuştur (Attawet ve ark., 2025). Bazı çalışmalar ise, ebelerin iklimle ilişkili sağlık risklerini anlama ve bu risklere hazırlanma düzeylerinin bölgelere göre önemli ölçüde değiştiğini göstermektedir. Uganda ve Türkiye'deki ebeler temel farkındalığa sahip olsa da kaynak yetersizliği ve kurumsal destek eksikliği gibi nedenlerden ötürü bu bilgiyi uygulamada zorlanmaktadır (Cartwright ve ark., 2022; Dağlı ve ark., 2024). Amerika Birleşik Devletleri'nde ise ebelerin, aşırı sıcağın gebeler için oluşturduğu riskleri yeterince bilmediği görülmüş ve bu durum eğitimde bir boşluğa işaret etmiştir (Monteblanco & Vanos, 2021). Bu farklılıklar, ebelerin iklimle ilişkili riskleri daha etkili yönetebilmesi için bağlama duyarlı ebelik eğitimi ve kaynak planlamasına ihtiyaç olduğunu göstermektedir. Ayrıca çalışmada, iklim değişikliğiyle ilişkili olaylara yönelik küresel ölçekte tutarlı tanım ve kriterlerin bulunmadığı belirtilmektedir. İklim krizinde farklı olayları ayırt eden ve her durum için uygun müdahaleleri tanımlayan net yönergelerin ve rehberlerin geliştirilmesi gerektiğini vurgulamaktadır. Böyle bir çerçeve, ebelerin iklimle ilişkili sağlık riskleri karşısında daha etkili ve tutarlı bakım sunmasını destekleyerek anne ve yenidoğan sağlığı için daha iyi sonuçlar sağlayabilir (Attawet ve ark., 2025). Ebelerin ulusal ve uluslararası düzeydeki devam eden rolü, araştırma kapasitesinin artırılması ve sorunları tanımlayabilen, uygun şekilde tasarlanmış çalışmalar yürütebilen disiplinlerarası ve çok disiplinli ekiplerin oluşturulması yoluyla iklim

krizi gibi acil sağlık sorunlarının ele alınmasında somut ve ölçülebilir bir etki yaratabilir (O'Connell ve ark., 2024).

İklim Değişikliğinin Anne ve Çocuk Sağlığına Etkilerini Azaltma ve Önlemede Ebelerin Sorumlulukları

Ebeliğin temel rollerinden biri anne ve yenidoğan ölümlerini azaltmaya yönelik sağlık savunuculuğu olduğundan, ebelerin küresel iklim değişikliğinin yarattığı tehditleri anlamak, azaltmak ve bu tehditlere uyum sağlama çabalarına bilgi birikimleri ve aktif katılımlarıyla katkıda bulunma sorumluluğu vardır. Bu kapsamda sağlık profesyonelleri, iklim değişikliğinin anne ve bebek sağlığı üzerindeki etkilerini kavramak ve küresel ölçekte daha sürdürülebilir bir gelecek için savunuculuk faaliyetlerini desteklemekle yükümlüdür (Homer ve ark., 2009).

Ebelerin, öncelikle iklim değişikliğinin gebe ve fetüs üzerindeki olumsuz etkilerinin farkında olmaları gerekmektedir (Atkin ve ark., 2023). Ebeler, gebelerin ihtiyaçlarına uygun planlamalarla kaliteli doğum öncesi bakım sunarak, iklim değişikliğinin anne ve yenidoğan sağlığı üzerindeki olumsuz etkilerini azaltmaya çalışmalı ve aşırı koşullar altında bile doğum öncesi bakımın sürdürülmesi için çaba göstermelidir (Rylander ve ark., 2013; Rasmussen & Jamieson, 2022).

Ebeler sürdürülebilirlik ve gebelerin sağlıklı bir gebelik dönemi geçirmeleri için iklim değişikliğinin olumsuz etkileri konusunda temel rehberlik sağlamak ve kritik önleme yöntemlerini (örneğin, mümkünse günün en yoğun saatlerinde güneşten uzak durmak ve yeterli sıvı alımını sürdürmek) öğretmek amacıyla eğitim ve danışmanlık vermeli, gelecek nesiller üzerindeki olumsuz etkilerini azaltma ve uyum sağlamaları amacıyla gebelerde farkındalık oluşturmalıdır (Wheeler vd., 2022; Giudice vd., 2021; Atkin vd., 2023). Ayrıca ebeler, doğum öncesi bakım ziyaretlerinde görüşmelerine iklim değişikliğiyle ilgili soruları dahil etmeli; gebelerin bu konuya ilişkin stres ve kaygılarını ele alarak, iklim değişikliğinin ruh sağlığı üzerindeki olumsuz etkileri açısından onları dikkatle değerlendirmelidir (Potter & Jonker, 2023). Bunun yanı sıra, gebelerin sağlıklı beslenmelerine, gıda ve su güvenliğine dikkat etmelerine yardımcı olmalıdır (Saha ve ark., 2023). Yapılan bir çalışmada, ebelerin iklim değişikliğinin kadın sağlığı üzerindeki olumsuz etkilerini önlemek ve iklim değişikliğiyle mücadele etmek için kadınları formül süt yerine çevre dostu emzirmeyi teşvik etmeleri gerektiği bildirilmiştir. Nitekim, ebeler iklim değişikliğiyle mücadele etmede bakım hizmetlerine bu tür uygulamaları dahil etmelidirler (Dağlı ve ark., 2024). Ek olarak, ebeler iklim değişikliğini ele alan kanıta dayalı halk sağlığı girişimlerini desteklemeli; bulundukları kurumlarda ve yerel düzeyde emisyonların azaltılmasına katkıda bulunmalı ve fosil yakıtların zararlı etkilerine ilişkin doğru bilgileri paylaşarak perinatal ve üreme sağlığının geleceğini koruma sorumluluğunu üstlenmelidir (Churchill ve Avery, 2023).

SONUÇ

İnsan kaynaklı iklim değişikliğiyle bağlantılı çevresel tehlikelerin giderek yaygınlaşması, anne ve çocuk sağlığı üzerinde ciddi riskler oluşturmaktadır. Ebeler, bu risklerin erken tanınması ve yönetilmesinde kritik bir konuma sahiptir. Bu durum, ebelerin iklim değişikliğine uyum ve risk azaltma süreçlerinde daha donanımlı hale gelmeleri için eğitim müfredatlarının güncellenmesi, mesleki gelişim olanaklarının güçlendirilmesi ve çevresel sağlık bilgilerinin ebelik uygulamalarına sistematik olarak entegre edilmesi gerektiğine işaret etmektedir.

Kültürel ve bağlamsal faktörler, iklim değişikliğiyle ilgili eğitim programlarının etkinliğini önemli ölçüde etkileyebilir; bazı toplulukların iklim kaynaklı olayları öncelikli bir sağlık sorunu olarak görmemesi bu duruma örnektir. Bu zorlukların aşılabilmesi için kaynak tahsisi, kapasite geliştirme ve kültürel açıdan duyarlı eğitim içeriklerini kapsayan çok yönlü bir yaklaşım

gereklidir. Bu doğrultuda, sağlık politikalarının geliştirilmesi, teknolojiye yatırım yapılması, sağlık profesyonellerinin iklim değişikliği ve bunun sağlık üzerindeki etkileri konusunda eğitiminin genişletilmesi ve halk sağlığı uygulamaları ve bölgesel çalışmalar yoluyla iklim değişikliğinin hastalık yükü ve sağlık hizmetleri ile ilişkisini belirleme gibi girişimlerin gerçekleştirilmesi gerektiği belirtilmektedir. Metropol ve kırsal bölgelerde çalışan ebelerin farklı gereksinimlerine uygun şekilde uyarlanmış eğitim programları, iklim kaynaklı sağlık risklerine verilen yanıtı güçlendirebilir. Ayrıca, iklim değişikliği, çevresel sağlık ve afet hazırlığına yönelik bilgilerin ebelik eğitim müfredatına entegre edilmesi, ebelerin bu tehditlerle baş etme kapasitesini artırmada kritik öneme sahiptir.

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PHYTOCHEMICALS FROM AMARYLLIDACEAE, LYCOPODIACEAE, AND LAMIACEAE FAMILIES EXHIBIT POTENTIAL AS ANTI-ALZHEIMER'S DRUGS: AN *IN SILICO* APPROACH

Sourov Datta
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

Fatema Mostakin Nesa
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

Fahmida Rahman
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

Mahamuda Fatema
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

Farhana Akter
Department of Pharmacy, East West University, Dhaka-1212, Bangladesh

Mohammad Asadujjaman
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

Muhammad Salehuddin Ayubee
Department of Pharmacy, Northern University Bangladesh, Dhaka-1230, Bangladesh

ABSTRACT

Worldwide, almost 50 million people have dementia, with two-thirds of them having Alzheimer's disease (AD). The deficit of acetylcholine and butyrylcholine neurotransmitters aggravates the symptoms of AD. Symptomatic relief can be obtained with cholinesterase inhibitors, which block the hydrolysis of neurotransmitters. This study aims to identify potential cholinesterase inhibitors with improved efficacy and reduced side effects compared to existing drugs. A literature review identified plant extracts reported to have anti-Alzheimer's activity from the Amaryllidaceae, Lycopodiaceae, and Lamiaceae plant families. Molecular docking was performed for the potential lead compounds with rivastigmine and donepezil using AutoDock Vina (v1.2.0), and the results were visualized with BIOVIA Discovery (v21.1.0.20298). Afterwards, ADME (Absorption, Distribution, Metabolism, and Excretion) profiling, toxicity prediction, and PASS (Prediction of Activity Spectra for Substances) analysis were performed through SwissADME, ProTox-3.0, and Way2Drug websites, respectively. Molecular dynamics (MD) simulations were also performed using GROMACS (2025.3) to assess binding stability and free energy of the hit compounds. From an initial set of 33 compounds, 12 were shortlisted based on docking scores (less than -7.0 kcal/mol) and their ability to cross the blood-brain barrier (BBB). Four compounds were excluded due to high toxicity (LD50 $\leq$ 300 mg/kg), leaving eight candidates. PASS analysis identified four compounds: Oxoassoanine, Assoanine, Anhydrolycodoline, and Isomucronulatol, with activity levels comparable to or exceeding standard drugs. MD simulations further confirmed their stability and favorable binding properties. These findings identify promising candidates for further investigation as anti-Alzheimer's drugs, including *in vitro* and *in vivo* studies.

Keywords: Alzheimer's disease, Cholinesterase inhibitors, Acetylcholinesterase, Butyrylcholinesterase, Dynamic simulation, PASS prediction

EXPLORING ANTICANCER CANDIDATES FROM MOROCCAN *MARRUBIUM VULGARE* L. THROUGH IN SILICO APPROACHES: BREAST AND PROSTATE CANCER

Amal BOURIBAB

Laboratory of analytical and molecular chemistry, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Morocco

ORCID ID: https://orcid.org/0009-0008-4026-1367

El Mehdi KARIM

Laboratory of analytical and molecular chemistry, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Morocco

ORCID ID: https://orcid.org/0000-0002-6463-2408

Abdelkbir ERROUGUI

Laboratory of analytical and molecular chemistry, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Morocco

ORCID ID: https://orcid.org/0000-0001-9972-7522

Samir CHTITA

Laboratory of analytical and molecular chemistry, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Morocco

ORCID ID: https://orcid.org/0000-0003-2344-5101

ABSTRACT

Introduction and Purpose: Breast and prostate cancers are among the most prevalent malignancies worldwide, with current treatment strategies often limited by modest efficacy and adverse side effects. This highlights the urgent need for safer and more effective alternatives. Medicinal plants have attracted considerable interest due to their anticancer potential. *Marrubium vulgare* L., traditionally used in Moroccan medicine, is known for its therapeutic properties and promising bioactive constituents. The present study aimed to investigate the anticancer potential of *Marrubium vulgare* L. phytochemicals against breast and prostate cancers using an in silico approach.

Materials and Methods: Computational techniques including virtual screening, molecular docking, ADMET profiling, density functional theory (DFT), and molecular dynamics simulations were employed. These methods were applied to assess the binding affinities, interaction mechanisms, and pharmacokinetic properties of *Marrubium vulgare* L. phytoconstituents with cancer-associated targets.

Results: Among the screened compounds, three phytoconstituents (L31, L39, and L49) demonstrated strong binding affinities and favorable pharmacokinetic profiles. Molecular

dynamics simulations further confirmed the stability of their interactions with the selected cancer-related targets.

Discussion and Conclusion: The findings suggest that L31, L39, and L49 from *Marrubium vulgare* L. possess promising anticancer potential against breast and prostate cancers. These results provide a foundation for further biological validation, and future in vitro and in vivo studies are warranted to confirm their therapeutic efficacy.

Keywords: *Breast cancer; Prostate cancer; Molecular docking; ADMET analysis; Marrubium vulgare L; DFT; Molecular dynamics*

DESIGN, SYNTHESIS AND MOLECULAR DOCKING EVALUATION OF NOVEL 1,2,4-TRIAZOLE DERIVATIVES AS POTENT ANTI-CANCER CANDIDATES AGAINST HEPG2 CELLS

Zainib Razzaq

Samreen Gul Khan

Fozia Anjum

Kiran Aftab

Department of Chemistry, Drug Design and Medicinal Chemistry Laboratory, Faculty of Physical Science, Government College University, Faisalabad 38000, Pakistan

Mehr un Nisa

Department of Chemistry, University of Lahore, Lahore 40100, Pakistan

Abstract

Triazole-based acetamides serve as important scaffolds for various pharmacologically active drugs. In the present work, structural hybrids of 1,2,4-triazole and acetamides were furnished by chemically modifying 2-(4-isobutylphenyl) propanoic acid (1). Target compounds 7a–f were produced in considerable yields (70–76%) by coupling the triazole of compound 1 with different electrophiles under different reaction conditions. These triazole-coupled acetamide derivatives were verified by physiochemical and spectroscopic (HRMS, FTIR, ^{13}CNMR, and ^{1}HNMR,) methods. The anti-liver carcinoma effects of all of the derivatives against a HepG2 cell line were investigated. Compound 7f, with two methyl moieties at the ortho-position, exhibited the highest anti-proliferative activity among all of the compounds with an IC50 value of 16.782 g/mL. 7f, the most effective anti-cancer molecule, also had a very low toxicity of 1.190.02%. Molecular docking demonstrates that all of the compounds, especially 7f, have exhibited excellent binding affinities of 176.749 kcal/mol and 170.066 kcal/mol to c-kit tyrosine kinase and protein kinase B, respectively. Compound 7f is recognized as the most suitable drug pharmacophore for the treatment of hepatocellular carcinoma.

Key words: 2-(4-isobutylphenyl) propanoic acid; hepatocellular carcinoma; anti-cancer; 1,2,4-triazole; molecular docking; acetamides

EXPLORING WOMEN'S PREFERENCES FOR HUSBANDS' PRESENCE IN THE DELIVERY ROOM DURING CHILDBIRTH IN NORTHERN BANGLADESH

Shah Tania Akter Sujana

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

ORCID: 0009-0008-3416-9003

Md. Mahafuzur Rahman

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

Abstract

Background: Despite progress in maternal health in Bangladesh, husbands are still rarely present during childbirth. Understanding women's true preferences requires looking beyond medical care to the social, cultural, and family influences. This study examines what women in northern Bangladesh feel about having their husbands by their side during childbirth and the factors that shape these preferences.

Methods: A cross-sectional study in five Rangpur districts (Oct 2023–Aug 2024) surveyed 384 women (≥18 years) via questionnaire and interviews. Demographic, sociocultural, and institutional factors were analyzed using Chi-square and logistic regression. Ethical approval was from Begum Rokeya University.

Findings: Most respondents were young (62.7% ≤30 years), and 86.2% preferred their husbands' presence during childbirth. Emotional support was the dominant motivator, with 74.2% reporting that a husband's presence would significantly improve emotional wellbeing. Preferences were strongly associated with younger age, student status, family support, positive cultural influences, and high-quality spousal communication (all $p < 0.05$). Logistic regression showed that emotional wellbeing (AOR large; $p=0.002$), communication with husbands ($p=0.006$), and supportive cultural views ($p=0.006$) were the strongest predictors of preferring husband participation. In contrast, concerns about social approval ($p=0.004$), negative family attitudes ($p=0.020$), lower empowerment ($p=0.005$), and restrictive hospital policies ($p=0.030$) significantly reduced this preference. Notably, 70% of women reported that healthcare providers had never discussed birth companionship with them, and half were unaware of facility policies, indicating significant information gaps within the health system.

Interpretation: Women's preference for husband involvement in childbirth in northern Bangladesh is driven by emotional support and sociocultural factors, while social norms, family resistance, and unclear hospital policies limit it. Promoting partner presence, empowering women, and clear facility guidelines could improve childbirth experiences.

Keywords: Husband involvement, Birth companionship, Women's preferences, Maternal health, Childbirth experience

IMMUNE CELL TYPE CLASSIFICATION AND IDENTIFICATION OF CELL TYPE-SPECIFIC GENES USING MACHINE LEARNING IN SINGLE-CELL RNA-SEQ DATA WITH FUNCTIONAL ANALYSIS AND DRUG REPURPOSING

Shah Tania Akter Sujana

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

ORCID: 0009-0008-3416-9003

Md. Mahafuzur Rahman

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

Abstract

Single-cell RNA sequencing (scRNA-seq) has revolutionized the understanding of cellular heterogeneity, particularly in complex immune systems. In this study, we present a robust ensemble based computational pipeline to classify major immune cell types and identify biologically informative gene signatures using three publicly available and well-annotated Peripheral Blood Mononuclear Cell (PBMC) datasets: PBMC1, PBMC2, and PBMC3K. These datasets span nine canonical immune cell types and were preprocessed using the Seurat package with log-normalization and Z-score scaling to ensure data harmonization and comparability. We employed a one-vs-rest classification approach, independently applying three machine learning algorithms—Support Vector Machine (SVM) with a linear kernel, Random Forest (RF), and LASSO—for each cell type. Feature importance was derived through absolute SVM weight magnitudes, Mean Decrease Accuracy (RF), and non-zero coefficients (LASSO). A nested cross-validation strategy was adopted to determine the optimal number of top ranked genes, defined as the largest gene set before F1 score decline. The SVM model consistently outperformed other methods, achieving an average F1 score exceeding 98%, followed by RF with ~95%, and LASSO with a lower but reasonable ~90 % performance, particularly limited in classifying rare cell populations. The union of the top-performing gene sets from all models was subjected to Gene Ontology (GO) and KEGG pathway enrichment analysis using DAVID, revealing key immune-related biological processes and signaling cascades. To explore clinical relevance, gene-disease association networks were constructed by integrating data from OMIM, UniProt, and DisGeNET. Diseases were selected based on an adjusted Benjamini-Hochberg (BH) p-value threshold, and associated genes were identified using a kappa similarity score of 1 to ensure strong functional relatedness. Finally, gene-drug interaction analysis using DrugBank uncovered several potential repurposable therapeutic candidates targeting the identified genes. Our integrative pipeline demonstrates high accuracy and clinically meaningful gene signatures, paving the way in precision medicine.

Keywords: Immune cell classification, Machine learning, Feature selection, Drug repurposing, Gene enrichment analysis.

APPLICATION OF BIOINFORMATIC TOOLS IN CELL TYPE CLASSIFICATION FOR SINGLE-CELL RNA-SEQ DATA

Shah Tania Akter Sujana

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

ORCID: 0009-0008-3416-9003

Md. Mahafuzur Rahman

Begum Rokeya University, Faculty of Science, Department of Statistics, Rangpur-Bangladesh

Abstract

The advancements in single-cell RNA sequencing (scRNAseq) technology have significantly transformed geno-mics research, enabling the handling of thousands of cells in each experiment. As of now, 32,068 research studies have been cataloged in the Pubmed database. The primary aim of scRNAseq investigations is to identify cell types, understand the antitumor immune response, and identify new and uncommon cell types. Traditional techniques for identifying cell types include microscopy, histology, and pathological characteristics. However, the complexity of instruments and the need for precise experimental design make it difficult to fully capture the overall heterogeneity. Unsupervised clustering and supervised classification methods have been used to solve this task. Supervised cell type classification methods have gained popularity as large-scale, high-quality, well annotated and more robust results compared to clustering methods. A recent study showed that support vec-tor machine (SVM) gives a high-quality classification performance in different scenarios. In this article, we compare and evaluate the performance of four different kernels (sigmoid, linear, radial, polynomial) of SVM. The results of the experiments on three standard scRNA-seq datasets indicate that SVM with linear and SVM with sigmoid kernel classify the cells more accurately (approx. 99 %) where SVM linear kernel method has remarkably fast computation time and we also evaluate the results using some single cell specific evaluation matrices F-1 score, MCC, AUC value. Additionally, it sheds light on the potential use of kernels of SVM to give underlying information of single-cell RNA-Seq data more effectively.

Keywords: scRNAseq, Cell type, Classification, Support vector machine (SVM), Kernel functions.

INVESTIGATION OF EXISTENCE AND UNIQUENESS OF SOLUTION FOR A COVID-19 TRANSMISSION DYNAMICS MODEL USING PICARD'S METHOD

Dr. Odebiyi, O.A

Orchid: 0009-0007-8173-0625

Agemo, D.N

Ayanrinola, O.W

Omoniyi, S.O

Adewole, E.T

Fatore, T.A

Department of Pure and Applied Mathematics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Abstract

The COVID-19 pandemic, a global health crises caused by SARS-CoV-2 virus, has had a profound impact on humanity, with widespread social, economic, and public health consequences. The ongoing impact of the COVID-19 pandemic continues to pose a significant public health concern, with varying degrees of risk and challenges across different regions and countries. Although the development and distribution of effective vaccines have been instrumental in controlling the pandemic, ongoing efforts are focused on improving treatment options, addressing emerging variants, and enhancing global vaccination efforts. This study presents a four-compartmental model of COVID-19 transmission dynamics, comprising susceptible, quarantined, infected, and treated populations. Employing Picard's method, the model is rigorously analyzed to investigate the existence and uniqueness of its solution, with the aim of establishing the well-posedness of the model, thereby providing a solid founding for further analysis and prediction of COVID-19 spread.

Keywords: Existence and uniqueness, COVID-19, Dynamics, Picard's method.

EXAMINATION OF THE RELATIONSHIP BETWEEN ORAL HEALTH LEVEL AND FRAGILE IN ELDERLY INDIVIDUALS

Gizem ŞAHBAZ

Necmettin Erbakan University, Institute of Health Sciences, Department of Nursing, Konya, Türkiye

ORCİD ID: https://orcid.org/0009-0008-7575-9261

Filiz HİSAR

Necmettin Erbakan University, Faculty of Nursing, Department of Public Health Nursing, Konya, Türkiye

ORCİD ID: https://orcid.org/0000-0003-0640-0091

ABSTRACT

Advancements in technological, economic, and healthcare fields worldwide have enabled individuals to live longer and healthier lives, and consequently, the proportion of older adults in the global population is rapidly increasing. The increase in the number of elderly individuals in the population causes the health needs specific to this period to gain more importance. Aging is a natural process that brings about various physical, psychological, and biological changes. Among these changes, oral and dental health holds a significant place as a fundamental component of healthcare services. In addition to age-related physiological changes in oral health, limitations in daily living activities may also reduce the attention older adults give to maintaining oral hygiene. Inadequate oral health negatively affects individuals' quality of life, nutritional status, and overall health. Therefore, maintaining oral hygiene is crucial for preventing potential complications and preserving the integrity of the oral mucosa. The concept of frailty, which has gained increasing attention in recent literature, is considered a natural consequence of aging and is defined as a geriatric syndrome characterized by declines in physical, metabolic, and physiological capacity. Reduced muscle strength, loss of endurance, and increased vulnerability to stressors are key features of frailty. Chronic diseases, inflammation, malnutrition, prolonged immobility, and polypharmacy are recognized as major risk factors contributing to its development. Recent studies have also indicated that deterioration in oral and dental health may increase frailty risk, particularly by impairing oral functions and negatively affecting nutrition, thereby accelerating the progression of frailty.

Key Words: Aging, Oral Health, Frailty

TRANSNATIONAL MEDICATION PRACTICES AND THERAPEUTIC MOBILITY WITHIN THE CONTEXT OF GLOBAL HEALTH

Büşra YÜRÜK

Toros University, Faculty of Health Sciences, Department of Nursing, Mersin, Türkiye;

PhD Student, University of Rome Tor Vergata, Department of Public Health and Nursing, Rome, Italy.

PhD Student, Izmir Katip Çelebi University, Public Health Nursing, İzmir, Türkiye.

ORCID ID: https://orcid.org/ 0000-0002-1428-9242

ABSTRACT

Introduction and Purpose: Globalization and the increasing mobility of populations have extended healthcare-seeking behaviors and treatment modalities beyond national borders. In this context, "transnational medication practice" refers to the process whereby migrants or mobile populations bypass local healthcare systems in their host countries to procure pharmaceutical products from their countries of origin or third nations. The objective of this paper is to search the socio-cultural mechanisms facilitating this cross-border movement of medicines—conceptually termed "therapeutic mobility"—and to critically discuss its implications for public health and patient safety.

Materials and Methods: A narrative literature review was conducted to synthesize existing evidence on cross-border pharmaceutical flows. Major electronic databases (PubMed, Scopus, Web of Science) were searched for studies focusing on "transnational medicine," "informal care networks," and "migrant health." The reserach integrates qualitative and quantitative data to categorize the structural drivers and safety risks associated with unregulated medication practices.

Results: Findings indicate that therapeutic mobility operates primarily through informal networks known as the "suitcase trade" and cross-border visits. The reserch reveals that determinants are not solely economic but rooted in structural barriers within host countries, such as strict prescription policies (e.g., for antibiotics) and language obstacles. Furthermore, a key cultural driver is the patients' belief that their physiology is biologically better suited to pharmaceuticals from their country of origin, leading to "cultural security" stockpiling.

Discussion and Conclusion: Transnational medication use creates an "information shadow" in clinical practice, posing risks of drug interactions invisible to Electronic Health Records (EHR). These practices reflect global healthcare inequalities rather than mere non-compliance. Clinicians must enhance cultural competence to uncover this invisible use, while policies should acknowledge these cross-border therapeutic networks.

Key Words: Transnational, Medication, Public Health

POLICY MEASURES TO REDUCE HEALTH INEQUALITIES FROM A SOCIOECONOMIC PERSPECTIVE: TURKEY AND INTERNATIONAL EXAMPLES

Deniz YILMAZ

Independent Researcher/ Department of Health Policy Istanbul, Turkey

ORCID ID: https://orcid.org/0009-0004-3755-4397

ABSTRACT

Health inequalities create significant differences in access to health care, service quality and health outcomes depending on individuals' socioeconomic status. These differences increase the burden of disease in low-income groups and restrict access to chronic disease management and preventive health care. The aim of this study is to examine the policy measures aimed at reducing health inequalities from a socioeconomic perspective in the light of Turkish and international examples.The research included a literature review and analysis of existing health policies. Education level, income level, geographical location and gender were evaluated as socioeconomic indicators and their effects on access to health services and health outcomes were discussed systematically. The findings show that low-income groups have limited opportunities to access basic health services, health literacy is limited in individuals with low educational levels, and geographical remoteness in rural areas makes access to services difficult.In terms of policy measures, free basic health services, community-based health programs, targeted health reforms and education-based awareness projects have been found effective in reducing inequalities. Multisectoral approaches, social support mechanisms and data-oriented monitoring systems increase policy effectiveness, especially in at-risk groups.In conclusion, holistic health policies that take into account socioeconomic differences are critical to increasing access to health care, strengthening social justice and improving public health. Moreover, the "reduction of inequalities" perspective, which is one of the most important among the 17 Sustainable Development Goals aimed to be achieved by 2030, is a guide in the design and implementation of health policies. This approach provides guidance especially for measures to be implemented in low-income and rural areas.

Key Words: Health Inequalities, Socioeconomic Indicators, Health Policies, Sustainable Development Goals, Turkey

DETERMINING THE RELATIONSHIP BETWEEN ETHICAL VALUES AND SUSTAINABLE CONSUMPTION BEHAVIOR IN YOUNG ADULTS

Melike BERK

Necmettin Erbakan University, Institute of Health Sciences, Department of Nursing, Konya, Türkiye

ORCİD ID: https://orcid.org/0009-0005-9805-2937

Filiz HİSAR

Necmettin Erbakan University, Faculty of Nursing, Department of Public Health Nursing, Konya, Türkiye

ORCID ID: https://orcid.org/0000-0003-0640-0091

ABSTRACT

The protection and improvement of public health is not limited to the prevention of physical illnesses; it also encompasses enabling individuals to make conscious and responsible choices in their daily lives by adopting sustainable lifestyle habits. The holistic approach offered by the fields of nursing and public health requires addressing the individual's lifestyle, value system, and consumption behaviours together. Based on this holistic perspective, this study will reveal how individuals' ethical understanding relates to sustainable consumption behaviours. While the concept of ethics is associated with developing a virtuous attitude aimed at human well-being, the concept of sustainability is based on meeting today’s needs while considering future generations. Increasing environmental problems, depletion of resources, and social inequalities have made it imperative to consider sustainable consumption in individual choices. Understanding the consumption choices of young adults in line with sustainability principles is critically important for long-term environmental and social benefits. It has been observed that individuals with a high propensity for ethical values place greater importance on principles such as social responsibility, sacrifice, and environmental awareness, thereby shaping their consumption decisions in a more sustainable manner. Research shows that ethical orientation strengthens attitudes toward environmentally friendly products and purchase intentions; however, this relationship can be influenced by factors such as the individual's level of maturity, knowledge, and economic conditions. Personal norms, moral identity, and an individual's sense of responsibility for the environmental consequences of their behaviour play a decisive role in this process. Consequently, ethical orientations are a powerful explanatory factor in understanding young adults' sustainable consumption behaviours. Individuals who place greater importance on ethical values are more likely to develop environmentally conscious consumption habits that consider long-term effects and prioritize social benefit. This relationship is further supported by environmental knowledge, perceived behavioural control, and socio-economic conditions, and the literature consistently shows that ethical orientation positively influences sustainable consumption behaviours.

Keywords: Ethics, Sustainability, Young Adults

INFORMATION ON TEETH WHITENING PRESENTED ON INSTAGRAM: A CONTENT SCOPE AND QUALITY ANALYSIS OF TURKISH POSTS

Burçin AYDEMİR AKKOÇAN

Dokuz Eylül University, Faculty of Dentistry, Department of Restorative Dentistry, Izmir, Turkey

ORCID ID: https://orcid.org/0009-0005-0658-6086

Oğuzhan AKKOÇAN

Dokuz Eylül University, School of Health Sciences, Department of Dental Biomaterials, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0002-1500-830X

Sude Eylül ULUCAN

Dokuz Eylül University, Faculty of Dentistry, Department of Restorative Dentistry, Izmir, Turkey

ORCID ID: https://orcid.org/ 0009-0009-5502-5057

Nasibe Aycan YILMAZ

Dokuz Eylül University, Faculty of Dentistry, Department of Restorative Dentistry, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0001-5939-8170

INTRODUCTION AND PURPOSE: Social media platforms have become a widely used interface for patient information and health communication regarding dental procedures. Teeth whitening (bleaching), one of the most popular and conservative applications in aesthetic dentistry, is a topic that reaches a wide audience on Instagram via hashtags. However, the unsupervised nature of user-generated content, along with the abundance of posts from both professional and non-professional sources, complicates patients' access to evidence-based and reliable information and increases the risk of misinformation. This study aimed to systematically evaluate the scope (Content Score) and information quality (Modified DISCERN Score) of Instagram posts related to teeth whitening.

MATERIALS AND METHODS: In this observational study, publicly available Instagram posts tagged with #dişbeyazlatma were evaluated. The "top" (most popular) posts listed by the Instagram search algorithm were collected over a one-week period in October 2025. After applying predefined exclusion criteria, a final sample of 500 posts was evaluated. Posts were categorized by poster role (dentist/clinic, influencer, brand), post purpose (marketing, educational, experience), treatment type (in-office, over-the-counter [OTC], DIY/natural products, multiple types, other), and content format (photo, reel, carousel). Like and comment

counts were analyzed as interaction metrics, while follower count was recorded as an indicator of account popularity and potential reach.

Content analysis was conducted using an eight-item checklist, and overall information quality was assessed using an eight-item modified DISCERN scale. The Shapiro–Wilk test was used to assess normality. When the assumption of normal distribution was not met, non-parametric tests (Mann–Whitney U, Kruskal–Wallis with Bonferroni post-hoc correction, and Spearman correlation analysis) were employed. The level of statistical significance was set at $p < 0.05$.

RESULTS: Most of the content on the platform consisted of 'Marketing' (74.2%) focused posts produced by 'Influencers' (47.4%). Although the 'Dentist/Clinic' group was found to be statistically significantly superior to other groups in terms of content quality and reliability (Total Content/modified DISCERN Scores) ($p < 0.001$), it was determined that the highest engagement (Likes and Comments) was concentrated not in these reliable 'Educational' posts, but in 'Marketing' focused posts ($p < 0.001$). Posts were concentrated in 'Photo' (47.2%) and 'Reels' (42.2%) formats, and their overall quality was low, as supported by the median values (DISCERN Median=2.00) (Content Median=3.00).

DISCUSSION AND CONCLUSION:

The findings of this study demonstrate a statistically significant discrepancy between the content quality of Instagram posts under the #dişbeyazlatma hashtag and user engagement ($p < 0.05$). Current platform dynamics appear to promote low-quality, marketing-focused content created by influencers, rather than high-quality, educational content produced by dentist/clinic accounts. This pattern may reflect a digital environment in which visibility (high engagement) is inversely related to reliability.

The predominance of in-office treatment promotions, combined with the overall insufficiency of information (low median DISCERN and Content scores), suggests a potential commercial bias. High engagement driven by influencers, who prioritize aesthetic appeal over professional accuracy, may constitute a source of misinformation and a significant information pollution problem from a public health perspective. Although Instagram is an effective tool for patient engagement and marketing, the high density of potentially misleading content raises serious concerns. It is therefore crucial for healthcare professionals to take an active role on such platforms to increase the dissemination of evidence-based information and help counter the spread of misinformation.

KEY WORDS: Teeth whitening; Instagram; Social media; Information quality; Misinformation

GRIEF IN CHILDREN AND ADOLESCENTS: MAIN IDEAS, CONCEPTS AND TECHNIQUES

ÇOCUK VE ERGENLERDE YAS: TEMELLER, KAVRAMLAR VE TEKNİKLER

Shanay Guliyeva Kabaoghlu

Dr. Öğr. Üyesi Kastamonu Üniversitesi Eğitim fakültesi, Eğitim bilimleri Psikolojik danışmanlık ve Rehberlik

ORCID:0000-0001-6346-9146

Demet Bahçeci

Kırşehir Ahi Evran Üniversitesi Eğitim bilimleri bölümü Psikolojik danışmanlık ve Rehberlik Yüksek lisans öğrencisi

ORCİD:0009-0005-9119-1556

Gaye Kaş

Kastamonu Üniversitesi Eğitim Fakültesi, Eğitim bilimleri Psikolojik danışmanlık ve Rehberlik Yüksek lisans öğrencisi

ORCİD:0009-0009-6129-128X

Özet

Çocukluk ve ergenlik dönemi, bireylerin psikolojik gelişiminde kritik bir süreçtir. Bu dönemde yaşanan kayıplar, özellikle duygusal ve psikolojik anlamda önemli etkiler yaratabilir. Aile üyelerinin veya yakınların kaybı gibi trajik olaylar, çocuk ve ergenlerin dünyasında kalıcı izler bırakabilir. Yas, sadece yetişkinlerin değil, aynı zamanda çocukların ve ergenlerin de karşılaştığı evrensel bir durumdur. Yas, yalnızca duygusal bir süreç olmanın ötesinde, aynı zamanda bireylerin psikolojik ve sosyal uyum süreçlerini etkileyen bir deneyimdir. Ancak, bu konuda yapılan araştırmalar, yetişkinlere yönelik çalışmalara kıyasla sınırlı kalabilir. Bu da, çocuk ve ergenlerin yas süreçleri hakkında daha fazla bilgi ve profesyonel desteğe ihtiyaç duyduğunu ortaya koymaktadır. Bu makale, çocuk ve ergenlerde yas sürecinin önemini, bu süreçte normal ve patolojik yas tepkilerini inceleyerek patolojik yas tepkilerine etkin müdahale stratejilerini açıklamayı amaçlamakta olup; çocuk ve ergenlerde yas süreçlerinin temelleri, kavramları ve teknikleri literatür ışığında tartışılacaktır.

Anahtar kelimeler: Çocuk, ergen, yas, patolojik yas, normal yas

Abstract

Childhood and adolescence are critical periods in the psychological development of individuals. Losses experienced during this period can have significant emotional and psychological impacts. Tragic events such as the loss of family members or loved ones can leave lasting marks on the lives of children and adolescents. Grief is a universal phenomenon faced not only by adults but also by children and adolescents. Grief is more than just an emotional process; it is

also an experience that impacts individuals' psychological and social adaptation processes. However, research on this topic may be limited compared to studies on adults. This highlights the need for more information and professional support regarding the grief processes of children and adolescents. This article aims to explain the importance of the grief process in children and adolescents, examine normal and pathological grief reactions, and explain effective intervention strategies for pathological grief reactions. The foundations, concepts, and techniques of grief processes in children and adolescents will be discussed in light of the literature.

Keywords: Child, adolescent, grief, pathological grief, normal grief

GİRİŞ

İnsan çok aşamalı gelişim dönemlerinden geçerek doğan büyüyen ve ölen bir varlıktır. İnsan en temelde çocukluk, gençlik, yetişkinlik ve yaşlılık olmak üzere dört farklı gelişim döneminden geçer. Çocukluk dönemi çeşitli açılardan (fiziki, ruhsal vb.) yeterliliğe ulaşılmamış dönemi kapsamaktadır (Karadoğan, 2019). Ergenlik dönemi ise fiziksel olarak cinsel gelişimle başlayan, sosyal ve duygusal açıdan gelişmeler kaydettikleri, gittikçe bakım verenden bağımsızlaşarak akranlara yönelim gösteren bir dönemdir (Bıçakcı, 2024). Çocuklar; yaşam deneyimleri kısıtlı, pek çok konuda ebeveynlerine bağlı bir konumda olan gelişim dönemi içerisindedirler. Yaşam tecrübeleri kısıtlı olduğu için karşılaştıkları olaylara ya ebeveynlerinden rol model olarak öğrendikleri tepkilerle ya da içinde bulundukları gelişim dönemine özgü yöntemlerle tepki verebilmektedirler. Ergenler ise içinde bulundukları gelişim döneminde fiziksel ve ruhsal açıdan pek çok değişimi aynı anda yaşadıkları bir süreci deneyimlemektedirler. Özellikle bu dönemde okula, aileye, arkadaşlara uyum konusunda zorlanmalar yaşamaktadırlar. Ergenler ve çocukların her ne kadar içinde bulundukları gelişim döneminde farklı anlamlarda riskli durumları bulunsa da bu bazen gelişimsel dönemden kaynaklanabileceği gibi bazen de dışsal etkenlerden kaynaklanabilir (İnan ve Özomay, 2022).

Öte yandan yas, bireyin kayıp sonucu yaşadığı duygusal sıkıntıyı yani üzüntüyü de içeren içsel ve dışsal tepkileri kapsayan süreçtir. Kayıp ve yas birbiri içine geçmiş süreçlerdir ve kaybın geride bıraktığı acıyı yaşamaya yas adı verilir (Çakar 2020, s.91). Evrensel bir kavram olan ölüm, her canlının yaşayacağı kaçınılmaz bir sondur. Genellikle sevilen bir kişi, hayvan veya nesnenin kaybı (ölüm veya ayrılık) sonrasında yaşanılan yoğun üzüntü, acı ve kederle gelen yas süreci, insanın hayatında yaşadığı sarsıcı bir yaşam olayıdır. Gizir'e (2006) göre yas, kayıp yaşayan bireyler tarafından gösterilen fiziksel, duygusal, bilişsel ve davranışsal olarak nitelendirilebilen normal ve doğal tepkilerdir. Bireyin yaşama normal ve sağlıklı bir şekilde devam edebilmesi için yasını yaşaması ve bu süreci tamamlaması gerekmektedir. Bu süreci yaşamayan veya erteleyen kişiler, yaşamlarının ileriki yıllarında bazı zorluklarla karşılaşabilmektedirler. Kişi yas tutma sürecinin sonunda, kaybı kabullenip bununla hayatını devam ettirmeyi öğrenmektedir (Önal ve Köseoğlu, 2021).

Yas sürecinin evrensel ve ortak tepkileri olsa da yas kişiye özgü olarak deneyimlenmektedir. Kişinin daha önce yas deneyimi olup olmaması, cinsiyeti ve kültürü yas tepkisinin boyutunu etkilemektedir. İnsanlar bir hayvanın ölümüne aile üyesinden biri ölmüş gibi üzülebilir. Kişilerin yasa verdiği tepkiler çeşitlilik gösterebilir. Yas yaşayan kişinin bireysel özellikleri, ölen kişi ile arasındaki ilişkisi, yas ile ilgili dini ve kültürel inançları, ruhsal durumu, çevresindeki destek faktörleri, ölüm algısı, daha önce yas geçmişi olması, ölüm şekli ve sosyoekonomik durumu gibi faktörler kişinin duruma verdiği tepkiyi etkilemektedir. Yas sürecinde bu faktörler göz önüne alınarak kişiye yaklaşım önemlidir (Özel ve Özkan, 2020). Her ne kadar bireysel farklılıklar bulunsa da Elishabeth Kübler-Ross (1993) yas sürecini sağlıklı ve sağlıksız tepkiler olarak ayırmıştır. Sağlıklı tepkileri; 1) inkâr, 2) öfke, 3) pazarlık, 4)

içedönüklük (çökkünlük), 5) kabullenme, 6) umut olarak altı aşamada değerlendirmiştir. Fakat aşamalar şeklinde açıklanan bu yas süreçleri bir takvim dâhilinde olmayabilir, yer değiştirebilir ve bireyden bireye sürelerinin uzunluğunun farklılaşabileceği, göz ardı edilmemelidir (Uslu vd., 2023).

Çocuklarda yas süreci yetişkinlerden farklı yaşanmaktadır. Bu durum çocuğun gelişim düzeyine, kaybettiği kişi ile iletişimine ve yakınlığına; çocuğun başa çıkma yeterliğine ve kişisel özelliklerine bağlı olarak değişebilir. Özellikle küçük yaş grubundaki çocuklar da uyku, yeme ve dışkılama sorunları gözlenirken daha büyük yaş gruplarında uyku, duygusal huzursuzluk, dış görünüşüyle ilgili bedeniyle fazla ilgilenme görülebilmektedir (Fiş ve Berkem, 2005). Çocuklar sevdikleri birini kaybettiğinde, kaybettikleri kişiyi hatırlama ve onun hakkında konuşma ihtiyacı hissederler. Bu sebeple, istedikleri zaman onlara ölen kişinin resminin gösterilmesi, olanlarla ilgili sorularına yanıt verilmesi, ölen kişiyle ilgili anılar istendiğinde anlatılması yararlı olacaktır. Bütün bunlar, çocuğun olanları olduğu gibi kabul edip, hayaller yerine, gerçekte olanlarla ilgili düşünebilmesine ve ölen kişiyle ilgili iyi anılarını canlı tutabilmesine yardımcı olur (Çakar 2020, s.91).

Bu araştırma ise çocuk ve ergenlerin yas sürecinde gösterdikleri tepkileri önce kriz ve travma kavramlarının tanımlanması; kriz ve travmanın yas ile birleşmesi sonucunda ortaya çıkan normal-patolojik yas tepkilerinin literatür ışığında incelenerek patolojik yas sürecine dair örnekler ve uygulamaların neler olduğunu ortaya koymayı amaçlamaktadır.

Kriz ve Travma

Kriz farklı duygusal zorlanmalar sonucu ortaya çıkan akut ve sınırlı süreli denge bozukluğudur. Kriz zorlayıcı yaşam olaylarını izleyen bir dönem, bir "dönüm noktası" olarak tanımlanır. Kriz, patolojik bir durum değildir. Ancak yeterince ve uygun bir biçimde ele alınmazsa patolojik durumlara özellikle psikolojik sorunlara neden olur. Krize müdahalenin hedefi yeniden yaşam şekli oluşturmaktır (Sözer, 1992). Kriz türleri gelişimsel ve durumsal olmak üzere iki kategoriye ayrılabilir. Gelişimsel krizler, bireyin hayatı boyunca meydana gelen beklendik yaşam olaylarını ifade ederken; Durumsal krizler, bireyin sosyal, psikolojik ve biyolojik bütünlüğünü tehdit eden olayları ifade etmektedir. Her kriz farklıdır ve kendine özgüdür ama bütün krizler, kriz reaksiyonlarını azaltmak veya durdurmak için ve etkilenen bireyleri kriz öncesi fonksiyonlarına döndürmek için acil müdahale gerektirir. (Aydoğdu vd., 2012)

Kriz danışmanlığının amacı ise acı veren gerçeği inkar etmek değil, acı, öfke, üzüntü gibi negatif duyguları ifade etmesi yönünde danışanı cesaretlendirmek, desteklemek ve duygularını paylaşmasını sağlamaktır. (Sözer, 1992). Kriz danışmanı dinleyerek, anlayarak ve duygu yansıtması ile danışanın duygularını ifade etmesini desteklemektedir. Bu esnada, danışmanın bilgilendirme ve yeniden yapılandırmaya yönelik çalışması da gerekmektedir.

Travma kavramı yara, deri bütünlüğünün bozulması anlamına gelmektedir. Fiziksel bir bütünlüğün tanımı için kullanılmaya başlansa da özellikle 1.Dünya Savaşından sonra askerlerin savaş sonrası ruh halini tanımlamak için yeni kavramlar bu bağlamda kullanılmaya başlanmıştır (Özdemir, 2023). Travma süreğen hayatı sekteye uğratan, bireylerin psikolojik olarak yaralanmalarını, travmaya maruz kalma sonucunda hayat içerisindeki yaşantılara karşı baş etme mücadelesini zorlayan bir durumu ifade eder (Toledo, 2014). Bir olayın travmatik olarak nitelendirilmesi için olayın ani oluşu, kontrol edilemezliği ve birey tarafından olumsuz olarak değerlendirilmesi gerekmektedir (Ogan vd., 2023). Travmatik olaylar yetişkin hayatında bile çeşitli açılardan baş etme mekanizmasını zorlayan etkilere sahip olduğu düşünüldüğünde çocuklar için daha yıpratıcı etkilere sahip olabilmektedir. Çünkü çocukluk dönemi dışsal uyaranlara veya tehditlere karşı yetişkin koruması olmaksızın yönetilemeyecek bir dönemdir

(Özdemir, 2023). Erken dönem yaşantılarının yetişkinlik döneminde veya öncesinde ortaya çıkan davranış bozukluklarını anlama da ki rolü düşünüldüğünde çocukluk çağı travmaları da bu yaşantılara dâhil edilebilir (Bıçakcı, 2024). Çocukluk döneminde yaşanılan ve travmatik etkilere sebep olabilecek durumlar ihmal, istismar, bir kayıp veya duygusal açıdan yıpratıcı başka herhangi bir olay olabilmektedir (Dönmez, 2024). Özellikle bir ebeveynin kaybı çocuğun hayatında büyük bir boşluğun oluşmasına sebep olması dolayısıyla travmatik bir etkiye sahip olabilir (Ürer, 2017).

Çocuk ve Ergenlerin Yasa Karşı Tutumları ve Yas Terapisine Gereksinim

Yas; kaybedilen kişiye karşı matem sürecini de kapsayan, o kişiye dair geçmiş anıları gelecek planlarını içeren, fiziksel (uyku yeme sorunları), duygusal (öfke, kızgınlık, üzüntü vb.), sosyal ortamlardan uzaklaşma gibi tepkilerin verildiği bir süreçtir (Yıldız, 2004). Hem çocuklar hem ergenler için sevdikleri bir kişinin ve özellikle bir ebeveynin kaybı yaşamlarında karşılaşacakları en travmatik olaylar arasındadır. Çocukların yeterli zihinsel becerilere sahip olamamalarından kaynaklı uzun bir zamandır yasa karşı yalıtılmış bir tepki verecekleri düşünülmüştür. Ama yakın zamanlı araştırmalarda herhangi bir gelişim döneminde ortaya çıkan bozukluğun çocukluk döneminde deneyimlenen yastan kaynaklanabileceği ortaya çıkmıştır (Dyregrov vd., 2015). Çocukların hangi gelişim evresinde olduğu ve ölümün onlara aktarılma şekli gibi değişkenler dolayısıyla yasa karşı tutumları da değişebilmektedir. Bowlby'e göre 17 ay itibariyle bir çocuğun kaybolan bir şeyi fark ettiği ve buna yönelik duygusal tepkiler verdikleri gözlemlenmiştir. Okul öncesi dönem de henüz soyut düşünceler gelişmediği burada sadece hayali oyun arkadaşları gibi bir süreci deneyimledikleri için bu özellikleri ölümü açıklamak için avantajlı olmaktadır. Kaybedilen kişinin artık onlarla olmayacağını anlayıp bunun sürekli oluşu ve süresi konusunda kafa karışıklığı yaşamaktadırlar (Sezer ve Saya, 2009). 6-11 yaş grubundaki çocukların zaman kavramını kendi yaşantıları ile ilişkilendirip öğrenmeleri hayatlarında ki zaman geçişleri ile ilişki kurmalarından kaynaklı ölüm kavramını da daha kolay anlamlandırabilirler. Ölen kişinin geri gelmeyeceğini bilirler. Bu dönemde üzüntülü olmaları, ağlamaları, çeşitli temel ihtiyaçlarını (uyku, yemek vb.) gidermek istememeleri, ölen kişi gibi davranmaya çalışmaları normal tepkilerden sayılabilir. Zaman geçtikçe çocuklar ölen kişinin yokluğu ile yaşamaya devam etmeyi öğrenirler (Yıldız, 2004). Ergenlik döneminde ise özellikle soyut düşünme geliştiği için bir yetişkin gibi ölümü algılama söz konusudur. Sadece içlerinde bulundukları dönemde her şeyi yapabilecek güçleri olduğuna dair bir örüntü sergiledikleri için ölümün geri dönülemezliği onları şaşkına çevirebilir. Yaşadıkları kayıptan sonra hayat kalitelerinde ciddi düşüşler, sosyal ilişkilerde bozulmalar, aidiyet duyma da düşüşler yaşanmaktadır (Avcı, 2019). Çocuk ve ergenlerin bir kayıp yaşadıktan sonra yukarıda sayılan bazı tepkileri vermeleri beklenir ve bu tepkilerin zaman geçtikçe azaldığı görülmektedir. Fakat bazı durumlarda kayıp sonrası yas terapisine de ihtiyaç duyulmaktadır. Yas türleri içerisinde karmaşık yas olarak tanımlanan bu süreç çocuk ve ergenlerde de görülebilmektedir. Karmaşık yas sürecinde çocuk veya ergenin günlük rutinlerini devam ettiremediği, kayba uyum sağlayamadığı görülmektedir. Karmaşık yas tepkileri de dört başlıkta toplanmıştır. Yasın süresi, yas duygularını yaşamadan bastırma, yas sürecinde depresyon, anksiyete gibi aşırı tepkilerin verilmesi, yası bastırmaya çalıştıkları için psikosomatik tepkilerin verilmeye başlanması bu dört başlıktaki tepkilere örnek olarak görülmektedir. Yukarıda sayılan tepkilere sahip çocuk veya ergen için Worden yas terapisine gereksinim olabileceğini ifade etmiştir (Sanghvi, 2109).

Çocuk ve Ergenlerde Yasa Karşı Patolojik Tepkiler, Dünya ve Türkiye Örnekleri

Yakın bir kişinin kaybı, kitlesel travmaya maruz kalan çocuklarda dikkat eksikliği, depresyon ve travma sonrası stres bozukluğu (TSSB) gibi ruh sağlığı sorunları açısından önemli bir risk faktörüdür. Doğal afetler sonrası yapılan meta-analizlerde, yasın depresyon için güçlü bir öngörücü olduğu bulunmuştur. Ölüm yaşamayan travma mağdurlarına kıyasla, yas tutan çocuklarda daha fazla TSSB semptomu, kaygı, uyarılma ve depresyon tepkileri görülmektedir. Ancak bazı araştırmalarda, örneğin Galante'nin çalışmasında, depremde kayıp yaşayan çocukların daha fazla risk taşımadığı belirtilmiş; bu durumun değerlendirme aracının (Rutter Davranış Anketi) travma ve yas tepkilerini yeterince ölçememesiyle ilişkili olabileceği vurgulanmıştır. Goenjian ve arkadaşlarının uzun dönemli çalışması ise, ebeveyn kaybı yaşayan ergenlerde özellikle yetim kalanlarda daha yüksek düzeyde depresyon ve TSSB görüldüğünü ortaya koymuştur. Babasını kaybeden çocukların daha fazla depresyon yaşaması, ekonomik zorluklarla açıklanmıştır. Benzer şekilde Kalantari ve Vostanis, İran'daki Bem depreminde ebeveynlerini kaybeden çocuklarda ciddi davranışsal ve duygusal sorunlar bildirmiş ve bu durumun ebeveyn-çocuk etkileşimi üzerinden sürdüğünü belirtmiştir. Endonezya tsunamisi sonrası yapılan çalışmalarda, yas tepkilerinin cinsiyet, kaybedilen kişi sayısı ve bilişsel kaçınma gibi bireysel faktörlerden etkilendiği görülmüştür. Nairobi bombalaması ve Darfur'daki yerinden edilmeler gibi insan eliyle gerçekleşen travmalar da yas sürecini olumsuz etkileyerek, çocukların cenaze ritüellerine katılamaması veya anıları paylaşamaması gibi durumların, yasın sağlıklı işlenmesini engellediği saptanmıştır. Norveç'teki Utøya terör saldırısı sonrası yapılan araştırmalarda, kardeşini kaybeden gençlerin büyük çoğunluğunda karmaşık yas ve akademik işlev bozukluklar gözlenmiştir. Tüm bu bulgular, çocuklarda yas tepkilerinin travmanın türüne, kaybın kapsamına ve iyileşme ortamına bağlı olarak değiştiğini göstermektedir. Normal yas süreci 6–24 ay arasında sürerken, bu sürecin uzaması ya da yoğun şekilde devam etmesi patolojik yası işaret edebilir. Patolojik yas, bireyin işlevselliğini bozarak çözülmemiş, maskelenmiş ya da kronik formlarda ortaya çıkabilir; birey, kaybın gerçekliğini inkâr edebilir ya da geçmişteki kayıplarla birleşen yoğun suçluluk ve yalnızlık duyguları yaşayabilir. Travmatik koşullarda kaybın ardından gelişen bu karmaşık yas tepkileri, çocuğun hem bireysel hem de sosyal düzeyde desteklenmesini gerekli kılar. Travma ve yasın iç içe geçtiği bu durumlarda, ruh sağlığı hizmetlerinin kültürel duyarlılık içeren, uzun vadeli ve bütüncül yaklaşımlar benimsemesi büyük önem taşımaktadır (Dyregrov, 2015)

Çocuk ve Ergenlerle Yas Terapisinde Kullanılan Yöntem ve Teknikler

Yas danışmanlığı ve yas terapisi arasında ayrım yapan Worden, yas terapisine birey kayıp ile yüzleşmek istemediğinde ve karmaşık yas tepkileri görüldüğünde başvurulacağını ifade etmiştir. Yas danışmanlığı ise karmaşık olmayan yas sürecinde kullanılmaktadır. Yas terapisinin amacı çocuk ve ergenlerin kayıpları ile yüzleşmeleri, bu kayıp ile hayatlarını birleştirerek yaşamalarını düzenlemektir. Terapi sürecinde bazı yöntem ve teknikler kullanılmaktadır (Sanghvi, 2019).

- **Oyun Terapisi:** Çocuk ve ergenin sözel yollarla ifade edemediği duygu ve düşüncelerini bir oyun terapisi ortamında ifade etmesine olanak tanıyan bu yöntemle çocuklar çeşitli oyun malzemeleri ile (bebekler, arabalar vb.) ölüme dair bir ortam kurgularlar. Yönlendirici ve yönlendirici olmayan oyun terapisi olmak üzere ikiye ayrılır. Yölendirici terapide terapist çocuklara sadece bazı oyuncakları kullanarak kayıp anını kurgulamasını isterken, yölendirici olmayan terapist çocuğu hem oyuncak hem de kurgulamak istediği şey hakkında özgür bırakır (Chandran vd., 2025).
- **Sanat Terapisi:** Dışavurumcu teknikler arasında bulunan sanat terapisi çocuk ve ergenlerde yasın iyileştirilmesi sırasında kullanılmaktadır. Çocukların veya ergenlerin ruhsal ve

fiziksel iyilik halini yükseltmek için resim, heykel, çizim gibi yollarla ortaya konan ürünlerde ki ruhsal durumla ilgili ipuçlarını sanat terapistlerinin belirlemesi gerekmektedir (Sanghvi, 2019).

- **Bireysel ve Grup Müdahaleleri:** Özellikle ergenlik döneminde ki bireyler için akran desteği gruplarının kullanılması yası yeniden anlamlandırmalarına, yasla ilgili deneyimlerini paylaşmalarına, ölen kişi ile ilgili anıların konuşulması destek bağlamında destekleyici bir etkiye sahiptir. Bireysel müdahaleler travmatik veya depresif belirtilerin ortadan ladırılması sürecinde kullanımı etkili olan bir yöntemdir (Chen vd., 2025).
- **Yaratıcı İfade Yolları:** Kendisini yazılı veya sözel yollarla ifade etmekte zorlanan çocuklar için mektup yazma, bibliyoterapi, müzik kullanımı, drama çalışmaları, hikaye anlatımı gibi yollar kullanılabilir (Chandran vd., 2025). Yaratıcı ifade etme yöntemleri arasına metafor kullanımı da eklenebilir. Duygularrı ifade etmekte ve anlamlandırmakta zorlanıldığında kullanılabilir (Sanghvi, 2019).
- **Başa Çıkma Becerileri Araç Kutusu:** Çocuğun kendine özgü olarak oluşturabileceği bu kutuda yönetme konusunda zorlandığı duyguları ile baş edebilmek için duygu kartları, baş etme teknikleri, rahatlama yolları gibi araçları kişisel kutularına ekledikleri tekniktir (Chandran vd., 2025).

Sonuç ve Öneriler

İnsan hayatı boyunca pek çok gelişim döneminden geçer. Bu gelişim dönemlerinden ikisi de çocukluk ve ergenliktir. Çocukluk dönemi yetişkin desteğine en çok ihtiyaç duyulan yanı ile ön plana çıkarken ergenlik döneminde ise özellikle bakım veren ebeveynlerden bir uzaklaşma aktif olarak sosyal çevre ile yakınlaşma görülmektedir. Hem çocuklar hem ergenler içlerinde bulundukları gelişim döneminde pek çok yaşantıyı tecrübe etmektedirler. Çocukluk ve ergenlik dönemindeki yaşantılar yetişkinlik dönemini de pek çok açıdan etkilemektedir. Bu bağlamda yas süreci de her iki gelişim döneminde deneyimlenme ihtimali bulunan bir yaşantıdır.

Yas bireylerin yaşadıkları bir kayıp sonucunda verdikleri duygusal, sosyal, fiziksel ve davranışsal tepkileri içeren süreçtir. Öfke, kızgınlık, üzüntü, sosyal yalıtım vb. tepkilerin yaşanması yas sürecinde görülmektedir. Çocuk ve ergenler de bu süreçte normal olarak kaybettikleri kişileri kendi gelişim dönemlerine uygun olacak şekilde deneyimlemektedir. Çocuklarda uyku, dışkılama, yemek sorunları görülürken, ergenlerde de yine yemek, uyku, okula devam sorunları görülebilmektedir. Bu gelişim döneminde bulunan bireylere yönelik gelişim dönemlerine uygun olacak şekilde yaklaşılması ve yas sürecini yaşamaları diğer gelişim dönemleri için önemli bir basamağı oluşturmaktadır. Nitekim yas sürecini yaşayamayan veya travmatik yas deneyimine sahip çocuk ve ergenlerin depresyon, anksiyete, TSSB semptomları gibi karmaşık yas tepkilerinin ortaya çıktığı görülebilmektedir. Karmaşık yas sürecinde çocuk ve ergen kaybı kabul etmemekte, günlük rutinlerine devam edememekte, yası bastırmaktadırlar.

Karmaşık yas tepkilerine ilişkin olarak oyun-sanat terapisi, bireysel veya grup müdahaleleri vb. yas terapisinde kullanılmaktadır. Ulusal anlamda yas sürecine dair çocuk ve ergenlere dair yapılan çalışmalar incelendiğinde çocukların yas sürecine dair bazı araştırmaların yapıldığı görülmektedir. Çocuk ve ergenler zorunlu eğitim döneminde bulunmaları dolayısıyla olası bir yas sürecinde rehber öğretmenlerin bu süreci yapılandırmaları önemli olacaktır. Bu bağlamda MEB tarafından rehber öğretmenlere bu süreci deneyimleyebilecekleri simülasyon eğitimlerinin verilmesinin verimli olacağı düşünülmektedir.

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IDENTIFICATION OF SAFE ZONES FOR THE PROTECTION OF CRITICAL ANATOMICAL STRUCTURES DURING PERCUTANEOUS FIXATİON OF PROXIMAL HUMERUS FRACTURES

Doç. Dr. Mehmet Sabri BALIK

Recep Tayyip Erdoğan University, Faculty of Medicine

ABSTRACT

Aim: Proximal humerus fractures are common injuries, particularly in elderly individuals, often resulting from low-energy trauma. These fractures can significantly impair upper extremity function and daily activities. The management of such fractures aims to achieve anatomical reduction using minimally invasive methods, allow early mobilization through appropriate fixation techniques, and minimize complication rates. However, due to the proximity of critical anatomical structures around the shoulder region, percutaneous fixation procedures carry a substantial risk of iatrogenic injury. The aim of this study was to determine the safe zones for percutaneous Kirschner wire insertion during the fixation of proximal humerus fractures, in order to protect vital anatomical structures surrounding the shoulder. Methods: Magnetic resonance imaging (MRI) scans of 60 shoulders from 80 patients (43 males, 37 females) were evaluated using a 1.5 Tesla MRI device (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) at Recep Tayyip Erdoğan University Training and Research Hospital. Images were obtained in the supine position with the upper extremity in the neutral zero position. Axial and coronal sections demonstrating the axillary nerve, the circumflex humeral artery, and the suprascapular nerve were analyzed. In the coronal plane, two parallel lines were drawn from the upper and lower borders of the glenoid to the ground. From these levels, axial images were used to draw reference lines along the scapular axis. From the points determined outside the skin on both planes, distances and angles to key anatomical structures around the shoulder were measured.

Results: In axial sections, the mean distances and angles were as follows: for the axillary nerve and circumflex humeral artery, 59 mm and 18.7° in males, and 73 mm and 20.3° in females; for the suprascapular nerve, 73 mm in males and 89.9 mm in females; and for the glenoid margin and corresponding angle, 62.5 mm and 31.8° in males, and 70.6 mm and 21.53° in females. In coronal sections, the upper glenoid margin distance was 52.0 mm in males and 57.4 mm in females, while the lower glenoid margin distance was 62.0 mm in males and 68.1 mm in females. The angle between the lower glenoid margin and the axillary nerve was 17.2° in males and 18.8° in females. The distance and angle between the upper glenoid line and the axillary nerve were 73 mm and 44° in males, and 44 mm and 42.6° in females, respectively. Conclusion: In percutaneous fixation of proximal humerus fractures, awareness of the distance and anatomical variability of critical shoulder structures relative to the skin is essential for a safe and complication-free procedure. Preoperative planning that considers gender-related differences in the distances and angles of these vital structures from potential percutaneous entry points can help define safe surgical zones, thereby reducing the risk of iatrogenic injury.

Keywords: Proximal Humerus; Fracture; Vascular Injury; Nerve Injury

INTRODUCTION

Proximal humerus fractures occur frequently, especially in the elderly with osteoporotic bone, often resulting from low-energy trauma. These fractures account for approximately 5–6% of all humeral fractures and may severely impair range of motion and functional integrity of the upper extremity, thereby restricting patients' activities of daily living (Court-Brown & Caesar, 2006). Accordingly, achieving anatomical reduction, applying stable fixation, enabling early mobilization, and minimizing complications remain central therapeutic objectives.

In recent years, minimally invasive surgical techniques have gained traction as alternatives to open approaches in the treatment of proximal humerus fractures. Such approaches aim to reduce soft tissue injury, lower infection risk, shorten the recovery period, and improve functional outcomes (Acklin et al., 2013). Among these, percutaneous Kirschner wire (K-wire) fixation is commonly used, especially in 2- and 3-part fractures, as an effective minimally invasive stabilization method (Resch, 2000).

However, during percutaneous pinning, critical anatomical structures around the shoulder—particularly the axillary nerve (n. axillaris), posterior circumflex humeral artery (a. circumflexa humeri posterior), cephalic vein, branches of the brachial plexus, and the deltoid muscle—are at risk of iatrogenic injury. Anatomical studies have demonstrated that the proximity of these structures can be narrow, rendering percutaneous interventions susceptible to neurovascular complications (Bittmann et al., 2001; Bono et al., 2011). For example, Bittmann et al. (2001) reported that percutaneously placed K-wires may approach the axillary nerve by as little as ~3 mm, especially for lateral and anterior pins. Similarly, Bono et al. (2011) showed that proximal humeral locking plate screws placed via external targeting guides may come within 2–6 mm of the nerve in certain holes.

Efforts to delineate safe surgical zones have proposed using anatomical landmarks to predict the projection of the axillary nerve. Ulaş and colleagues (2020) employed the upper boundary of the humeral head as a reference and reported that the axillary nerve lies at an average distance of 48–58 mm from this landmark, designating this region as a "danger zone." Pediatric studies have likewise attempted to develop radiological and anatomical metrics to map the trajectories of nerve branches in the shoulder (Bozkurt et al., 2022).

Given these considerations, defining safe percutaneous entry zones that protect adjacent neurovascular structures during fixation of proximal humerus fractures is of utmost clinical importance. The aim of this study was to determine safe surgical zones for K-wire insertion by evaluating the anatomical relationships of shoulder region structures via magnetic resonance imaging (MRI) and thereby provide surgical guidance to reduce iatrogenic injury risk.

MATERIALS AND METHODS

This retrospective study evaluated shoulder MRI scans acquired at the Recep Tayyip Erdoğan University Training and Research Hospital Radiology Department. A 1.5 Tesla MRI unit (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) was used. Scans were performed with patients in the supine position, with the upper extremity in a neutral zero position. This positioning helps preserve the native anatomical relationships and standardize measurements.

The study cohort comprised 80 patients (43 male, 37 female) whose MRIs clearly visualized the axillary nerve, posterior circumflex humeral artery, and suprascapular nerve in both axial and coronal planes. In the coronal planes, two parallel horizontal reference lines were drawn from the upper and lower margins of the glenoid toward the ground. From these levels,

corresponding axial slices were selected, and a line parallel to the scapular axis was drawn. These reference lines served as baselines for spatial analyses.

Using these mapped reference lines in both axial and coronal planes, the shortest perpendicular distance (in mm) from the skin surface (i.e., projection of the reference line at the skin) to each neurovascular structure was measured. Additionally, the angles (in degrees) between the structures and the reference lines were determined using digital angle measurement tools. All measurements were standardized according to predefined anatomical landmarks and recorded for further analysis (Tables 1 & 2).

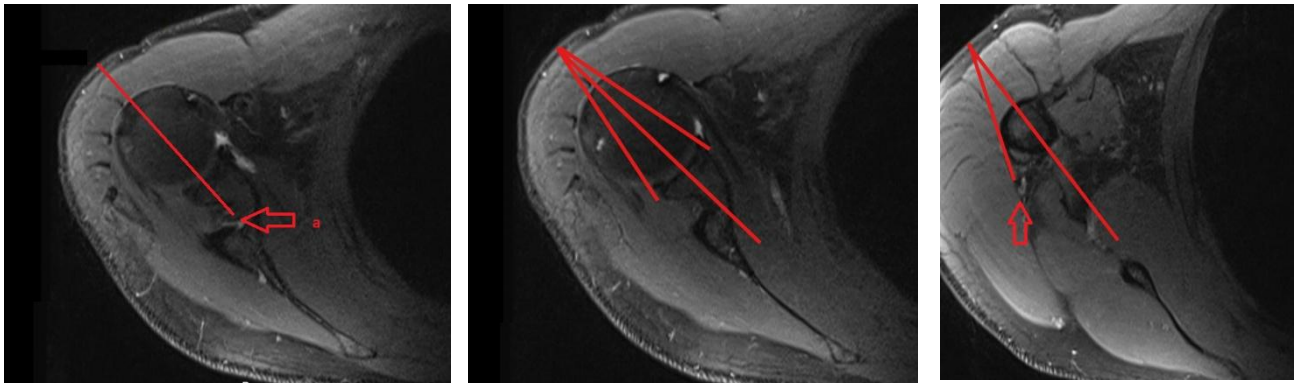
All measurements were carried out in randomized order to reduce observer bias. Inclusion criteria required participants to be aged ≥18 years. Exclusion criteria were prior shoulder surgery, presence of tumors or deformities, or MRI artifacts compromising image quality. This methodological framework is intended to allow planning of safe percutaneous entry zones in relation to critical structures around the shoulder (Figures 1 & 2).

Table 1. Axial-plane measurements: distances & angles from skin to anatomical structures (male vs. female)

Structure & Measurement	Male (Mean ± SD)	Female (Mean ± SD)
Axillary nerve + artery – distance (mm)	59 ± 3	73 ± 5
Axillary nerve + artery – angle (°)	18.7 ± 1.6	20.3 ± 1.9
Suprascapular nerve – distance (mm)	73 ± 3	89.9 ± 5
Glenoid rim – distance (mm)	62.5 ± 3	70.6 ± 5
Glenoid rim – angle (°)	31.8 ± 1.7	21.53 ± 1.9

Table 2. Coronal-plane measurements: distances & angles from skin to anatomical structures (male vs. female)

Structure & Measurement	Male (Mean ± SD)	Female (Mean ± SD)
Glenoid upper rim – distance (mm)	52 ± 3	57.4 ± 5
Glenoid lower rim – distance (mm)	62 ± 3	68.1 ± 6
Glenoid lower rim – axillary nerve angle (°)	17.2 ± 1.5	18.8 ± 1.9
Glenoid upper rim – axillary nerve distance (mm)	73 ± 3	44 ± 3
Glenoid upper rim – axillary nerve angle (°)	44 ± 1.3	42.6 ± 1.9



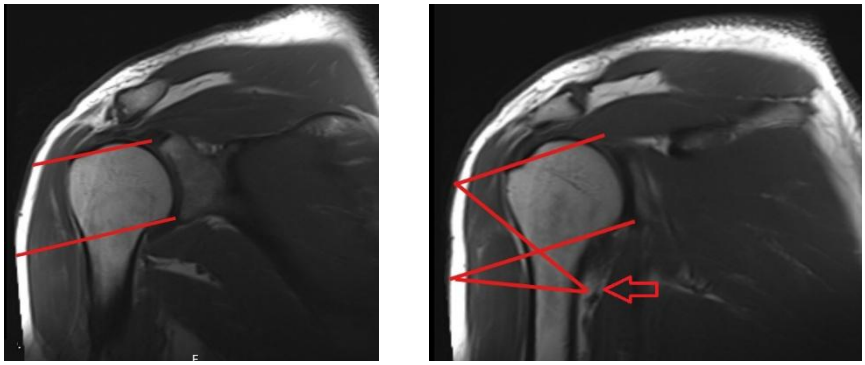
a **b** **c**

Figure 1.

(a) Axial section showing the distance from the skin surface to the suprascapular nerve (mm).

(b) Axial section demonstrating the glenoid corner angles measured from the skin level.

(c) Axial section showing the distance (mm) from the skin surface to the axillary nerve and posterior humeral circumflex artery, as well as their angular relationship with the glenoid axis.



a **b**

Figure 2.
(a) Coronal section showing the distance (mm) from the skin surface to the glenoid corner.
(b) Coronal section showing the distance (mm) from the skin surface to the axillary nerve and posterior humeral circumflex artery, as well as their angular relationship with the glenoid axis.

RESULTS

In this study, axial and coronal MRI slices were used to meticulously assess distances and angular relationships between skin-level entry points and critical shoulder neurovascular structures, stratified by sex.

On axial sections, the mean skin-to-axillary nerve + artery distance was 59 ± 3 mm in males and 73 ± 5 mm in females. The corresponding angles were 18.7° ± 1.6 for males and 20.3° ± 1.9 for females. The suprascapular nerve lay at 73 ± 3 mm (male) and 89.9 ± 5 mm (female) depth. The glenoid rim projected at 62.5 ± 3 mm in males and 70.6 ± 5 mm in females; the angle between the glenoid reference line and the structure was 31.8° ± 1.7 in males and 21.53° ± 1.9 in females.

In coronal sections, the skin-to-glenoid upper rim distances were 52 ± 3 mm (male) and 57.4 ± 5 mm (female), and to the lower rim 62 ± 3 mm (male) and 68.1 ± 6 mm (female). The angle from the glenoid lower rim to the axillary nerve averaged 17.2° ± 1.5 (male) and 18.8° ± 1.9 (female). The corresponding distances and angles between the glenoid upper rim and the axillary nerve were 73 ± 3 mm and 44° ± 1.3 in males, and 44 ± 3 mm and 42.6° ± 1.9 in females.

CONCLUSION AND DISCUSSION

These findings underscore several critical implications. First, the greater skin-to-neurovascular structure distances in females suggest that sex-based anatomical variations are not limited to soft tissue thickness but also extend to the relative positioning of anatomical structures. This should be taken into account in surgical planning. Court-Brown & Caesar (2006) have discussed

how age- and sex-related changes in bone density and tissue composition may contribute to anatomical variability.

Second, the deeper location of the suprascapular nerve in females (89.9 mm vs. 73 mm) hints at higher risk of injury in individuals with more superficial anatomy (e.g., leaner male subjects) during minimally invasive procedures. In their work, Bono et al. (2011) highlighted that suprascapular nerve injury, particularly in posterior approaches, can lead to significant functional compromise. Thus, preoperative mapping of nerve distances and angles is critical to tailor surgical trajectories to individual anatomy.

Third, the observed differences in glenoid-related angular measurements (31.8° male vs. 21.5° female) indicate distinct spatial geometry of shoulder structures across sexes. In interventions using fixed-angle guides or instrumentation, neglecting such differences may raise the risk of nerve impingement or malplacement. Pediatric studies, such as those by Bozkurt et al. (2022), reinforce the importance of defining safe zones relative to nerve paths.

Ulaş et al. (2020) employed the humeral head's superior margin as an anatomical reference to define axillary nerve safe corridors; our approach similarly uses glenoid boundaries as reference frames, and our data suggest its applicability in adult populations. A major strength of our study is the multi-planar approach (axial and coronal), enabling both linear and angular characterization of safe zones, which may be especially beneficial for deltoid-splitting or anterior minimally invasive approaches.

Nevertheless, limitations exist. Our sample size is modest and lacks stratification by anthropometric measures (e.g., height, weight, BMI) that could influence spatial relationships. Moreover, reliance solely on static MRI may not fully account for soft-tissue shifts during surgical positioning. Validation with cadaveric or intraoperative studies would strengthen the clinical applicability of the safe zones derived herein.

This work provides clinically relevant data on the distances and angles of key neurovascular structures relative to skin-level entry points in the shoulder. The observed sex-based differences emphasize the need for tailored surgical planning in percutaneous K-wire, screw, or plate fixation techniques. Preoperative MRI-based mapping of individual anatomy may enhance safety by reducing complications. Future advances in surgical simulation, navigation, and anatomical guidance systems can integrate these parameters to further improve procedural safety.

As one of the first MRI-based investigations in this domain, this study complements prior cadaveric research and offers more directly translatable data for clinical practice in percutaneous shoulder surgery.

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SEMANTIC INTEROPERABILITY AND ARTIFICIAL INTELLIGENCE INTEGRATION IN DIGITAL HEALTH SYSTEMS THROUGH STANDARD NURSING TERMINOLOGIES: TECHNICAL CHALLENGES AND ETHICAL DIMENSIONS

STANDART HEMŞIRELIK TERMINOLOJILERI ARACILIĞIYLA DIJITAL SAĞLIK SISTEMLERINDE ANLAMSAL BIRLIKTE ÇALIŞABILIRLIK VE YAPAY ZEKÂ ENTEGRASYONU: TEKNIK ZORLUKLAR VE ETIK BOYUTLAR

Lecturer Sinan İRTEGÜN

Ardahan University Health Services Vocational School, Ardahan, Türkiye

ORCID: 0000-0001-6828-9419

Assoc. Prof. Dr. Gönül GÖKÇAY

Kafkas University, Faculty of Health Sciences, Department of Public Health Nursing, Kars,Türkiye

ORCID: 0000-0003-0140-8668

ÖZET

Giriş: Hemşirelik mesleğinin kanıta dayalı bir bilim dalına evrimi, modern sağlık sistemlerinin dijitalleşmesi ve veri merkezli, akıllı sistemlere geçişi ile hızlanmıştır. Bu kapsamda, hemşirelik terminolojilerinin ulusal ve uluslararası referans sistemleriyle uyumlu olma gerekliliği, uluslararası bilgi paylaşımını ve veri analizini zorunlu kıldığı için artmıştır. Standartlaştırılmış Hemşirelik Dilleri (SNL'ler), bu çok disiplinli dijital ekosistemde kesintisiz veri alışverişi için kritik bir gereklilik olan, yapılandırılmış, anlamlı ve makine tarafından işlenebilir verinin kaynağını oluşturmaktadır. Bu yapılandırılmış veriler, Yapay Zekâ (YZ) ve öngörüsel analitik gibi ileri teknolojilere girdi sağlayarak geleceğin sağlık hizmetlerinin biçimlenmesine katkıda bulunma potansiyeline sahiptir.

Amaç: Bu çalışmanın amacı, Standart Hemşirelik Terminolojilerinin (NANDA-I, ICNP) Elektronik Sağlık Kayıtları (ESK), Referans Terminolojileri (SNOMED CT, LOINC), Klinik Karar Destek Sistemleri (KKDS) ve YZ ile entegrasyonunun teknik temellerini ve birlikte çalışabilirlik ilkelerini incelemektir. Aynı zamanda, bu teknolojik dönüşümün kaçınılmaz olarak ortaya çıkardığı algoritmik yanlılık, veri güvenliği ve KVKK çerçevesindeki etik ve pratik zorlukları irdelemektir.

Materyal ve metot: Bu bildiri taslağı, hemşirelik terminolojilerinin teknolojik entegrasyon süreçlerini ve bu süreçlerin getirdiği bilişimsel gereklilikleri değerlendiren Literatür temelli derleme çalışması formatında hazırlanmıştır. Çalışma için yapılan literatür taraması 01 Eylül – 15 Kasım 2025 tarihleri arasında gerçekleştirilmiştir. Çalışma sırasında "NANDA-I, ICNP" ve "ESK" veya "KKDS" ve YZ" ve "SNOMED CT, LOINC" anahtar kelimeleri ve bu kelimelerin ingilizce tercümeleri kullanılarak Google Akademik, PubMed, Sience Direct arama motorlarında taramalar yapılmıştır. Çalışmamızda, standart terminolojilerin yapısal

özelliklerini, kullanım alanlarını ve dijital sağlık ekosistemindeki teknik rollerini karşılaştırmalı olarak değerlendirmek için ilgili literatürden elde edilen sonuçlar kullanılmıştır.

Literatür Bulguları: SNL'ler ESK sistemleriyle entegrasyonu, hemşirelik verilerini serbest metin formatından, kurum genelinde analiz edilebilir ve anlamsal birlikte çalışabilir yapılandırılmış bir bilgi kaynağına dönüştürmektedir. Bu anlamsal bütünlük, uygulama terminolojilerinin (örneğin ICNP), SNOMED CT ve LOINC gibi evrensel referans terminolojilerine haritalanmasıyla (mapping) sağlanmakta, bu sayede hemşirelik verilerinin ulusal ve uluslararası düzeyde tutarlı ve sistematik paylaşımı mümkün kılınmaktadır. Yapılandırılmış ve standart kodlarla zenginleştirilmiş bu veriler, basit kural tabanlı KKDS'nin ve Makine Öğrenmesi (MÖ) tabanlı YZ algoritmalarına yüksek nitelikli girdi sağlayarak, bakım sürecini reaktif yaklaşımdan proaktif ve risk önleyici bir modele geçirmektedir. Ayrıca, Doğal Dil İşleme (NLP) ile serbest metin notlarındaki klinik gözlemlerin yapılandırılması ve giyilebilir teknolojilerden gelen gerçek zamanlı verilerin analitik sistemlere entegre edilmesi, hemşirenin rolünü "klinik veri yorumlayıcısı" ve "teknoloji destekli bakım koordinatörü" hâline getirerek mesleki otonomiyi ve hesap verebilirliği desteklemektedir.

Sonuç: SNL'ler, veriyi yapılandırılmış ve evrensel referans terminolojileri aracılığıyla anlamsal olarak birlikte çalışabilir bir kaynağa dönüştürerek dijital sağlık dönüşümünü kolaylaştırmıştır. Bu entegrasyon sayesinde üretilen yüksek nitelikli veriler, KKDS ve YZ uygulamalarına girdi sağlamakta, böylece bakım sürecini reaktif yerine proaktif ve risk önleyici bir yaklaşıma dönüştürmektedir. NLP ve giyilebilir teknolojiler gibi tamamlayıcı sistemlerin katkısıyla, hemşirenin rolü "klinik veri yorumlayıcısı" ve "teknoloji destekli bakım koordinatörü" olarak evrilmiştir. Ancak, algoritmik yanlılık ve veri mahremiyeti (KVKK) gibi etik ve yasal zorlukların Açıklanabilir YZ (XAI) ile aşılması, bu teknolojilerin güvenli ve adil kullanımının temel koşuludur. Bu dönüşüm, hemşirelik mesleğinin bilimsel görünürlüğünü ve klinik bakımın niteliğini önemli ölçüde artırma potansiyeli taşımayacaktır.

Anahtar Kelimeler: NANDA-I, ICNP, Yapay Zekâ, Karar Destek Sistemleri ve Hemşirelik.

ABSTRACT

Introduction: The evolution of the nursing profession into an evidence-based discipline has accelerated with the digitalization of modern healthcare systems and the transition to data-centric, intelligent systems. In this context, the need for compatibility with national and international reference systems for nursing terminology has increased, necessitating international information sharing and data analysis. Standardized Nursing Languages (SNLs) constitute the source of structured, meaningful, and machine-processable data, a critical requirement for seamless data exchange within this multidisciplinary digital ecosystem. This structured data has the potential to contribute to the shaping of the future of healthcare by providing input for advanced technologies such as Artificial Intelligence (AI) and predictive analytics.

Objective: The purpose of this study is to examine the technical foundations and interoperability principles of the integration of Standard Nursing Terminologies (NANDA-I, ICNP) with Electronic Health Records (EHRs), Reference Terminologies (SNOMED CT, LOINC), Clinical Decision Support Systems (CDSSs), and AI. It also explores the ethical and practical challenges inherent in this technological transformation, including algorithmic bias, data security, and the PDPL framework.

Materials and Methods: This paper was prepared as a literature-based review evaluating the technological integration processes of nursing terminologies and the informatics requirements of these processes. The literature search for the study was conducted between September 1 and

November 15, 2025. Search engines were searched using the keywords "NANDA-I, ICNP" and "ESK" or "KKDS" and "YZ" and "SNOMED CT, LOINC" and their English translations. In our study, results obtained from relevant literature were used to comparatively evaluate the structural features of standard terminologies, their areas of use, and their technical roles in the digital health ecosystem.

Literature Findings: Integration of SNLs with EHR systems transforms nursing data from free-text formats into a structured information source that can be analyzed and semantically interoperable across the organization. This semantic integrity is achieved by mapping application terminologies (e.g., ICNP) to universal reference terminologies such as SNOMED CT and LOINC, enabling consistent and systematic sharing of nursing data at national and international levels. These structured and standardized data, enriched with high-quality input for simple rule-based KKDS and Machine Learning (ML)-based AI algorithms, shifting the care process from a reactive approach to a proactive and risk-preventive model. Furthermore, structuring clinical observations in free-text notes with Natural Language Processing (NLP) and integrating real-time data from wearable technologies into analytical systems supports professional autonomy and accountability by transforming the nurse's role into a "clinical data interpreter" and "technology-assisted care coordinator."

Conclusion: SNLs have facilitated the digital health transformation by transforming data into a semantically interoperable resource using structured and universal reference terminologies. The high-quality data generated through this integration provides input to CRS and AI applications, thus transforming the care process from a reactive to a proactive and risk-preventive approach. With the contribution of complementary systems such as NLP and wearable technologies, the role of the nurse has evolved into that of a "clinical data interpreter" and "technology-enhanced care coordinator." However, overcoming ethical and legal challenges such as algorithmic bias and data privacy (DPL) through Explainable AI (XAI) is fundamental to the safe and fair use of these technologies. This transformation will not have the potential to significantly increase the scientific visibility of the nursing profession or the quality of clinical care.

Keywords: NANDA-I, ICNP, Artificial Intelligence, Decision Support Systems and Nursing.

GİRİŞ

Dijital sağlık sistemlerinin yaygınlaşması, hemşirelik dokümantasyonunda standart terminolojilerin kullanımını zorunlu hâle getirmiştir. NANDA-I ve ICNP gibi uygulama terminolojileri ile SNOMED CT ve LOINC gibi referans terminolojilerinin entegrasyonu, hemşirelik verisinin yapılandırılmış, makine tarafından işlenebilir ve kurumlar arası paylaşılabilir bir forma dönüşmesini sağlamaktadır (Eriş, 2016; Van Giersbergen & Pınarkaya Özpınar, 2025). Bu entegrasyon, ESK anlamsal birlikte çalışabilirlik düzeyini artırarak hem klinik karar süreçlerini hem de disiplinler arası veri akışını güçlendirmektedir (Yılmaz, Ergüner Özkoç & Öğütçü, 2021).

Standartlaştırılmış hemşirelik verileri, KKDS ve YZ uygulamaları için yüksek nitelikli veri altyapısı oluşturarak öngörüsel analitik, risk sınıflandırma ve kişiselleştirilmiş bakım modellerinin geliştirilmesine katkı sunmaktadır (Gür & Eşidir, 2025; Tüfekci & Çelik, 2025). Bununla birlikte, NLP teknikleri serbest metin hemşirelik notlarının yapılandırılmasını sağlayarak analitik süreçleri daha kapsamlı hâle getirmektedir (Cayır, 2025). Bu teknolojik dönüşümün hızlanması, algoritmik yanlılık, veri güvenliği ve etik sorumluluklara ilişkin yeni tartışma alanları yaratmaktadır. Özellikle YZ modellerinde veri temsiline bağlı yanlılıklar sağlık eşitsizliklerini artırma riski taşırken (Kaya, 2024), KVKK kapsamındaki düzenlemeler

sağlık verilerinin işlenmesinde yüksek düzeyde teknik ve idari güvenlik önlemlerini zorunlu kılmaktadır (Ceyhan, 2024). Bu bağlamda, hemşirelik terminolojilerinin ESK, referans terminolojileri, KKDS ve YZ ile entegrasyonu, hemşirelik pratiğinin dijital dönüşümünde kritik bir bileşen olup; teknik, etik ve hukuksal yönleriyle bütüncül olarak ele alınması gereken çok katmanlı bir süreçtir.

AMAÇ

Bu çalışmanın amacı, Standart Hemşirelik Terminolojilerinin (NANDA-I, ICNP) Elektronik Sağlık Kayıtları (ESK), Referans Terminolojileri (SNOMED CT, LOINC), Klinik Karar Destek Sistemleri (KKDS) ve YZ ile entegrasyonunun teknik temellerini ve birlikte çalışabilirlik ilkelerini incelemektir. Aynı zamanda, bu teknolojik dönüşümün kaçınılmaz olarak ortaya çıkardığı algoritmik yanlılık, veri güvenliği ve KVKK çerçevesindeki etik ve pratik zorlukları irdelemektir.

MATERYAL VE METOT

Bu bildiri taslağı, hemşirelik terminolojilerinin teknolojik entegrasyon süreçlerini ve bu süreçlerin getirdiği bilişimsel gereklilikleri değerlendiren Literatür temelli derleme çalışması formatında hazırlanmıştır. Çalışma için yapılan literatür taraması 01 Eylül – 15 Kasım 2025 tarihleri arasında gerçekleştirilmiştir. Çalışma sırasında "NANDA-I, ICNP" ve "ESK" veya "KKDS" ve YZ" ve "SNOMED CT, LOINC" anahtar kelimeleri ve bu kelimelerin ingilizce tercümeleri kullanılarak Google Akademik, PubMed, Sience Direct arama motorlarında taramalar yapılmıştır. Çalışmamızda, standart terminolojilerin yapısal özelliklerini, kullanım alanlarını ve dijital sağlık ekosistemindeki teknik rollerini karşılaştırmalı olarak değerlendirmek için ilgili literatürden elde edilen sonuçlar kullanılmıştır.

LİTERATÜR BULGULARI:

Teknik Entegrasyon, Birlikte Çalışabilirlik Ve Akıllı Sistemler

Standartlaştırılmış hemşirelik terminolojilerinin gerçek etkisi, ESK sistemleriyle bütünleştiğinde ortaya çıkmaktadır. Bu entegrasyon, hemşirelik verisini klinik dokümantasyondan kurum genelinde analiz edilebilir, paylaşılabilir ve karar destek süreçlerine entegre edilebilir bir bilgi kaynağına dönüştürür (Çiriş Yıldız, Başıbüyük & Yıldırım, 2020).

ESK Entegrasyonu ve Anlamsal Birlikte Çalışabilirlik

Hemşirelik tanılarının ESK'ya serbest metin yerine, standart kodlar ve yapılandırılmış veri öğeleri olarak kaydedilmesi, dijital sağlık dönüşümünün en kritik adımlarından biridir. Yapılandırılmış veri, her bir tanının benzersiz bir koda karşılık geldiği sistematik bir yapı ifade eder, böylece verilerin bilgisayarlar tarafından işlenebilir, karşılaştırılabilir ve analiz edilebilir hale gelmesini sağlar (Eriş, 2016; İskender ve Kaplan, 2020).

- **Birlikte Çalışabilirlik İlkesi:** Birlikte çalışabilirlik (interoperability), farklı sistemlerin hem teknik hem de anlamsal düzeyde veri alışverişi yapabilme yeteneğidir ve dijital hemşirelik uygulamalarının sürdürülebilirliği için kritik öneme sahiptir (Yılmaz, Ergüner Özkoç ve Öğütçü, 2021).

- **Anlamsal Birlik:** Bu hedefe ulaşmada en kritik boyut, anlamsal birlikte çalışabilirliktir. Bu birlikte çalışabilirlik, sistemlerin yalnızca veriyi aktarmakla kalmayıp, aktarılan bilginin anlamını da aynı şekilde yorumlayabilmesini ifade eder. Bu ortak anlam birliği, ulusal ve

uluslararası düzeyde veri entegrasyonunu mümkün kılan referans terminolojiler aracılığıyla sağlanır(Yılmaz, Ergüner Özkoç ve Öğütçü, 2021).

Etkili bir dijital hemşirelik bilgi ekosistemi, iki tamamlayıcı standardizasyon katmanına dayanmaktadır: Uygulama Terminolojileri (NANDA-I, ICNP gibi, klinisyenin düşünme sürecini yapılandıran) ve SNOMED CT, LOINC gibi, veriyi makine tarafından okunabilir formata çeviren). Bu çift katmanlı yapı zorunludur; çünkü uygulama terminolojisi klinik zenginliği sağlarken, referans terminolojileri bu zengin verinin anlamsal bütünlüğünü koruyarak küresel sistemler arasında paylaşılabilirliğini güvence altına alır(Van Gıersbergen ve Pınarkaya Özpınar, 2025).

Referans Terminolojiler ve Hemşirelik Verilerinin Haritalanması

Uygulama terminolojilerinde üretilen hemşirelik verilerinin, sağlık bilişim ekosisteminde farklı sistemler tarafından anlaşılabilmesi için evrensel referans terminolojilerine haritalanması (mapping) gereklidir (İskender ve Kaplan, 2020).

- **SNOMED CT (Systematized Nomenclature of Medicine – Clinical Terms):**Dünyanın en kapsamlı çok dilli klinik terminolojisi olup, klinik bilgilerin farklı yazılım altyapıları arasında anlamsal olarak tutarlı biçimde paylaşılmasını sağlamayı hedefler (Sezer, 2015). ICNP ile SNOMED International arasındaki iş birliği sonucunda, ICNP içeriği SNOMED CT sistemine Referans Set (Refset) biçiminde entegre edilmiş ve bu entegrasyon, ICNP'nin klinik zenginliği ile SNOMED CT'nin küresel teknik gücünü birleştirmiştir (Cubas & Nóbrega, 2022).

- **LOINC (Logical Observation Identifiers Names and Codes):** Laboratuvar testleri, ölçümler ve klinik gözlemleri tanımlamak için geliştirilmiş evrensel bir sistemdir (McDonald et al., 2003). LOINC, kapsamını hemşirelik tanıları ve değerlendirme ölçeklerini kapsayacak biçimde genişleterek (Legg & Swanepoel, 2012), Braden Skalası gibi hemşirelik değerlendirme araçlarının sonuçları için standart kodlar sağlar. Bu kodlar da hemşirelik tanılarının nesnel, karşılaştırılabilir ve uluslararası düzeyde paylaşılabilir olmasını sağlar (Vreeman et al., 2010).

KKDS ve YZ Entegrasyonu

Yapılandırılmış ve standart terminolojilerle kodlanmış hemşirelik verileri, basit kural tabanlı uyarı sistemlerinden, karmaşık öngörüsel YZ algoritmalarına kadar geniş bir yelpazede kullanılabilir. Bu veriler, YZ ve KKDS için yüksek nitelikli veri setleri oluşturmakta; öngörüsel ve kişiselleştirilmiş bakım modellerinin gelişimini desteklemektedir(Çetin, 2021).

Kural Tabanlı KKDS: Geleneksel KKDS'ler, "eğer–o zaman" mantığıyla çalışarak, ESK'dan alınan yapılandırılmış hemşirelik tanıları, vital bulgular ve risk skorlarını (örneğin Norton Risk Skalası) önceden tanımlanmış bilgi tabanı ile eşleştirir (Tüfekci ve Çelik, 2025). Örneğin, düşük risk skoru veya immobilite gibi bulgular varlığında, sistem otomatik olarak "Bozulmuş Deri Bütünlüğü Riski" tanısını önerir ve kanıta dayalı girişimleri listeler (Bulut ve Gözübüyük, 2024; Buçan Kırkbir ve Kurt, 2020).

- **YZ ve Öngörüsel Analitik:** MÖ tabanlı sistemler, büyük veri kümelerinden karmaşık örüntüleri öğrenme yeteneği sayesinde, düşme, hastane enfeksiyonu veya 30 gün içinde yeniden yatış gibi gelecekteki klinik olayları yüksek doğrulukla tahmin edebilir (Gür & Eşidir, 2025; Uncu & Yorulmaz, 2024). Bu dönüşüm, hemşirenin bakım sürecini reaktif yaklaşımdan proaktif, risk önleyici bir modele geçirmesini sağlar.

- **NLP:** Hemşirelik dokümantasyonlarındaki zengin klinik gözlemleri içeren serbest metin notları, NLP sayesinde bilgisayarların analiz edebileceği yapılandırılmış bilgiye dönüştürülür (Cayır, 2025). Adlandırılmış Varlık Tanıma (NER) ve Metin Sınıflandırma

teknikleri kullanılarak, notlardaki klinik bilgiler sistematik olarak yapılandırılarak analitik sistemlere entegre edilir (Açar, 2024; Purkuloğlu, Ün ve Yürürdurmaz, 2019).

- **Giyilebilir Teknolojiler:** Akıllı cihazlardan (saatler, sensörler) elde edilen gerçek zamanlı veriler (uyku döngüleri, aktivite), hemşirelik değerlendirmelerini daha kapsamlı hale getirir. Örneğin, bu verilerle "Uyku Örüntüsünde Bozulma" tanısına yönelik girişimlerin etkinliği objektif olarak ölçülebilir (Özen & Özen, 2023; Şirin & Yüksel Deniz 2021; Iskanderov ve Güvensan, 2019).

Bu teknolojik entegrasyon, hemşirenin rolünü yalnızca "veri toplayıcı" ve "girişim uygulayıcı" olmaktan çıkarıp; farklı kaynaklardan gelen karmaşık sinyalleri analiz eden, yapay zekânın önerilerini eleştirel bir süzgeçten geçiren ve teknoloji ile hasta arasındaki insani etkileşimi yöneten bir "klinik veri yorumlayıcısı" ve "teknoloji destekli bakım koordinatörü" hâline getirir (Şendir ve ark., 2019).

Teknolojik Entegrasyonun Zorlukları Ve Etik Boyutları

Standartlaştırılmış hemşirelik verilerinin ileri teknolojilerle bütünleşmesi büyük fırsatlar yaratmasına rağmen, bu vizyonun önünde pratik, etik ve yasal engeller mevcuttur(Aytur & Kantek, 2020).

Algoritmik Yanlılık (Algorithmic Bias) ve Etik İkilem

Algoritmik yanlılık, bir YZ sisteminin, eğitildiği veri setlerindeki toplumsal veya tarihsel önyargıları öğrenmesi ve belirli demografik veya sosyoekonomik gruplar aleyhine sistematik hatalı sonuçlar üretmesidir (Asıl, 2025).

- **Sağlık Eşitsizliği Riski:** Eğer bir YZ modeli, popülasyonun belirli kesimlerini yeterince temsil etmeyen verilerle eğitilmişse, bu gruplara ait hastalarda hatalı teşhisler veya yanlış risk skorları üreterek sağlık eşitsizliklerini pekiştirme riski taşır (Kaya, 2024).

YZ sistemleri karmaşıklaştıkça, bir önerinin hangi mantık çerçevesinde oluşturulduğunu anlamak zorlaşmaktadır. Hemşirelik mesleği otonomi ve hesap verebilirlik ilkelerine dayandığı için, hemşirenin bir YZ önerisini sorgulamadan uygulaması etik açıdan uygun değildir. Bu nedenle, YZ modelinin karar mantığını insan tarafından anlaşılır biçimde sunan Açıklanabilir YZ (Explainable AI) teknikleri, hemşirelerin klinik yargılarını ve mesleki otonomilerini koruyarak bu teknolojileri güvenli ve sorumlu bir şekilde entegre edebilmeleri için etik bir ön koşul olarak değerlendirilmelidir(Doğan Yüksekol,2010).

Veri Güvenliği, Mahremiyet ve KVKK Yükümlülükleri

Türkiye'de 6698 sayılı Kişisel Verilerin Korunması Kanunu (KVKK) kapsamında, bireylerin sağlık verileri özel nitelikli kişisel veri olarak sınıflandırılmakta ve bu verilerin işlenmesi ve korunması için en yüksek düzeyde yasal ve teknik önlemlerin alınması zorunlu kılınmaktadır (Ceyhan, 2024).

- Yasal Sorumluluklar: Sağlık kuruluşları, bu hassas verileri işlemek için hastalardan açık rıza almakla yükümlüdür. Ayrıca, verilerin yetkisiz erişim, sızıntı veya kötüye kullanım riskine karşı şifreleme ve erişim kontrolü gibi gerekli tüm teknik ve idari tedbirleri sağlamak zorundadır (Ceyhan, 2024; Yelmen, 2023).

- Risk Artışı: ESK, mobil sağlık uygulamaları ve bulut tabanlı YZ sistemlerinin yaygınlaşması, veri toplama, işleme ve saklama noktalarının sayısını artırmıştır. Bu durum, veri güvenliği ve mahremiyet risklerini karmaşık hale getirerek, kurumların KVKK kapsamındaki yasal yükümlülüklere tam uyumunu sağlama sürecini zorlaştırmaktadır (Mızrak & Aslan, 2023).

Teknik ve Organizasyonel Engeller

Teknolojinin etkinliği, teknik performansın yanı sıra kurumsal kültür ve klinik iş akışlarıyla uyum derecesine sıkı sıkıya bağlıdır (Çetin ve Eroğlu, 2020).

- **Birlikte Çalışabilirlik Sorunları:** Farklı üreticiler tarafından geliştirilen ESK sistemlerinin kullandığı çeşitli standartlar ve veri formatları, kurumlar arasında veri paylaşımını zorlaştırmaktadır. Merkezi bir veri tabanı altyapısının eksikliği, izole bilgi havuzları, yani "veri siloları" oluşturmakta ve entegrasyon sürecinde ciddi teknik zorluklar yaratmaktadır (Yazıcı & Özdemirci, 2019).
- **Kullanıcı Direnci:** İleri teknoloji donanım ve yazılımlarının yüksek başlangıç ve bakım maliyetleri önemli bir engel teşkil etmektedir. Ayrıca, yeni teknolojilerin mevcut klinik süreçlere uyum sağlayamaması, personelin iş yükünü artırabilir ve sosyo-teknik uyumsuzluk ortamı oluşturabilir(Kirchner-Krath at all., 2024).

SONUÇ VE ÖNERİLER

Standartlaştırılmış hemşirelik terminolojileri, yapılandırılmış ve makine tarafından işlenebilir veri üretme kapasitesi kazandırarak dijital sağlık dönüşümünü kolaylaştırmıştır. Bu veriler, KKDS ve YZ ile birleştiğinde, hemşirelik bakımını proaktif, kişiselleştirilmiş ve öngörüsel bir yaklaşıma dönüştürme potansiyeli taşımaktadır. Standart terminolojiler, bu sayede hem klinik bakımın niteliğini hem de mesleğin bilimsel görünürlüğünü önemli ölçüde artırmıştır.

Bu karmaşık dijital ekosistemde yetkin olabilmek için hemşirelik eğitim programlarının güncellenmesi zorunludur. Müfredatlar, temel bilişim becerilerinin ötesine geçerek; veri standartları (SNOMED CT, LOINC), YZ'nin etik boyutları (özellikle algoritmik yanlılık) ve veri mahremiyeti (KVKK gibi yasal çerçeveler) dahil olmak üzere ileri düzey bilişim yetkinliklerini kapsamalıdır. Bu eğitim, hemşirelerin yalnızca teknolojiyi kullanmalarını değil, aynı zamanda elde edilen veriyi eleştirel bir şekilde yorumlayabilmelerini ve etik sonuçlarını değerlendirebilmelerini sağlayacaktır.

Gelecekteki araştırmalar, hemşirelik süreçlerine özgü, şeffaflığı ve hesap verebilirliği artıran açıklanabilir YZ modellerinin geliştirilmesine odaklanmalıdır. Ayrıca, NLP tekniklerinin serbest metin notlarındaki örtük bilgiyi derinlemesine çözümlemesi, giyilebilir teknolojilerden elde edilen sürekli veri akışının klinik karar süreçlerine entegrasyonunun hasta sonuçlarına etkisinin ölçülmesi kritik araştırma alanlarıdır. Son olarak, bu teknolojilerin uygulanmasında adalet ve eşitliği sağlamak ve sosyo-teknik uyumsuzlukları en aza indirmek amacıyla uygulama ve değişim yönetimi stratejilerinin geliştirilmesi de önemlidir.

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TRANSFORMATIONAL EFFECTS OF STANDARDIZED NURSING TERMINOLOGIES ON CLINICAL PRACTICE, QUALITY OF CARE, AND PROFESSIONAL AUTONOMY: AN EVIDENCE-BASED LITERATURE REVIEW

STANDARTLAŞTIRILMIŞ HEMŞIRELIK TERMINOLOJILERININ KLINIK UYGULAMA, BAKIM KALITESI VE MESLEKI OTONOMI ÜZERINDEKI DÖNÜŞTÜRÜCÜ ETKILERI: KANITA DAYALI BIR LITERATÜR DERLEMESI

Lecturer Sinan İRTEGÜN

Ardahan University Health Services Vocational School, Ardahan, Türkiye

ORCID: 0000-0001-6828-9419

Assoc. Prof. Dr. Gönül GÖKÇAY

Kafkas University, Faculty of Health Sciences, Department of Public Health Nursing, Kars,Türkiye,

ORCID: 0000-0003-0140-8668

ÖZET

Giriş: Hemşirelik mesleği, Nightingale'in sistematik gözlemlerinden günümüze, sezgi temelli bir sanattan veri ve kanıta dayalı bilimsel bir disiplini hâline evrilmiştir. Dijitalleşen sağlık sistemlerinde bakımın görünür, ölçülebilir ve karşılaştırılabilir olması gerekliliği artmış; bu nedenle hemşirelik verilerinin standart terminolojilerle yapılandırılması, iletişim bütünlüğü, bakım sürekliliği ve kanıta dayalı karar süreçleri açısından kritik bir unsur olarak ortaya çıkmıştır. Standartlaştırılmış Hemşirelik Dilleri, hemşireliğin çok disiplinli dijital sağlık ekosistemi içindeki konumunu güçlendirerek mesleğin bilimsel katkısını belirginleştirmektedir.

Amaç: Bu çalışma, hemşirelik pratiğinde kullanılan standart terminolojilerin (NANDA-I, ICNP, Omaha Sistemi) bakım kalitesi, mesleki otonomi ve kanıta dayalı uygulamalar üzerindeki dönüştürücü etkilerini analiz etmeyi amaçlamaktadır. Çalışmanın temelini oluşturan sav, standartlaştırılmış hemşirelik tanılamasının yalnızca bir kayıt veya dokümantasyon aracı olmadığı; aksine, hemşirelik bakımını kanıta dayalı bir zeminde yapılandıran ve modern sağlık sistemlerinin yapıtaşını oluşturan anlamlı ve makine tarafından işlenebilir verinin kaynağı olduğudur.

Materyal ve metot: Bu bildiri taslağı, standardize edilmiş hemşirelik terminolojilerinin klinik ve mesleki pratik üzerindeki etkilerini inceleyen Literatür temelli derleme çalışması formatında hazırlanmıştır. Çalışma için yapılan literatür taraması 01 Eylül – 01 Kasım 2025 tarihleri arasında gerçekleştirilmiş olup bu çalışmada konu ile ilgili terimlerin arama motorları aracılığıyla elde edilen sonuçlar üzerinden, standart terminolojilerin yapısal özelliklerini, kullanım alanlarını ve dijital sağlık ekosistemindeki rollerini karşılaştırmalı olarak değerlendirilmiştir. Değerlendirme, hemşirelik uygulamaları üzerindeki doğrudan etkileri ve mesleki yeterliliğe sağlanan katkıları merkeze almaktadır.

Literatür Bulguları: Literatürde standartlaştırılmış hemşirelik terminolojilerinin, hemşirelik bakımının görünür, ölçülebilir ve karşılaştırılabilir hale gelmesinde kritik bir rol oynadığı

vurgulanmaktadır. Dijital sağlık sistemleriyle uyumlu hale gelen bu terminolojiler, bakım süreçlerini sistematikleştirmekte ve hemşirelerin klinik kararlarını yapılandırılmış bir çerçeveye oturtmaktadır. NANDA-I, ICNP ve Omaha Sistemi gibi sınıflandırmalar hem hemşireler arası hem de disiplinler arası iletişimi güçlendirerek bakımın sürekliliğini artırmakta, belirsizlikleri azaltmakta ve ortak bir profesyonel dil oluşturulmasına katkı sunmaktadır. Standart terimlerin kullanımı, bakım devri ve klinik belgelerde tutarlık sağlayarak hasta güvenliğini artırmakta; ayrıca verilerin makine tarafından işlenebilmesini mümkün kılarak dijital dönüşüm süreçlerine altyapı oluşturmaktadır. Literatür, hemşirelik tanılarının yapılandırılmış biçimde belirlenmesinin, kanıta dayalı uygulamaların geliştirilmesi için temel bir gereklilik olduğunu ve araştırmalar için karşılaştırılabilir veri setleri sağladığını göstermektedir. Bunun yanında, standart tanılama süreçleri hemşirelerin klinik yargılarını bilimsel temele oturtarak mesleki otonomiyi güçlendirmekte ve profesyonel kimliği pekiştirmektedir.

Sonuç: Genel olarak literatür, standartlaştırılmış hemşirelik terminolojilerinin modern hemşirelik uygulamalarının vazgeçilmez bir bileşeni haline geldiğini ortaya koymaktadır. Bu sistemler, bakım kalitesini artırmakta, iletişimi kolaylaştırmakta, mesleki otonomiyi güçlendirmekte ve kanıta dayalı uygulamalar için gerekli veri altyapısını oluşturmaktadır. Dijital sağlık teknolojilerinin hızla geliştiği günümüzde, hemşirelik eğitim müfredatlarının veri standartları, klinik bilişim, yapay zekâ ve veri etiği gibi alanlarla güçlendirilmesi gerekmektedir. Ayrıca gelecekteki çalışmaların, bu sistemlerin hasta sonuçlarına etkisini ölçmeye ve klinik entegrasyon süreçlerini değerlendirmeye odaklanması önerilmektedir.

Anahtar kelimeler: Hemşirelik tanısı, hemşirelik süreci, sınıflandırma, elektronik sağlık kayıtları, klinik karar verme, kanıta dayalı hemşirelik.

ABSTRACT

Introduction: From Nightingale's systematic observations to the present day, the nursing profession has evolved from an intuition-based art to a scientific discipline based on data and evidence. In digitalized healthcare systems, the need for care to be visible, measurable, and comparable has increased; therefore, structuring nursing data with standardized terminologies has emerged as a critical element for communication integrity, continuity of care, and evidence-based decision-making. Standardized Nursing Languages strengthen nursing's position within the multidisciplinary digital health ecosystem and highlight the profession's scientific contribution.

Objective: This study aims to analyze the transformative effects of standardized terminologies used in nursing practice (NANDA-I, ICNP, Omaha System) on quality of care, professional autonomy, and evidence-based practices. The underlying argument is that standardized nursing diagnostics are not merely a recording or documentation tool; rather, they are a source of meaningful, machine-processable data that structures nursing care on an evidence-based basis and constitutes the cornerstone of modern healthcare systems.

Materials and Methods: This paper was drafted as a literature-based review examining the impact of standardized nursing terminologies on clinical and professional practice. The literature search for this study was conducted between September 1 and November 1, 2025. This study compared the structural characteristics of standardized terminologies, their areas of use, and their role in the digital health ecosystem using search engine results for relevant terms. The evaluation focuses on the direct impact on nursing practice and the contributions to professional competence.

Literature Findings: The literature emphasizes that standardized nursing terminologies play a critical role in making nursing care visible, measurable, and comparable. These terminologies, compatible with digital health systems, systematize care processes and structure nurses' clinical decisions. Classifications such as NANDA-I, ICNP, and the Omaha System enhance both inter-nurse and interdisciplinary communication, increasing continuity of care, reducing uncertainty, and contributing to the creation of a common professional language. The use of standardized terminology enhances patient safety by ensuring consistency in care transfer and clinical documentation; it also facilitates machine-processed data, laying the groundwork for digital transformation processes. The literature demonstrates that structured nursing diagnosis is essential for developing evidence-based practice and provides comparable data sets for research. Furthermore, standardized diagnostic processes strengthen professional autonomy and reinforce professional identity by grounding nurses' clinical judgments in scientific evidence.

Conclusion: Overall, the literature demonstrates that standardized nursing terminologies have become an essential component of modern nursing practice. These systems improve the quality of care, facilitate communication, strengthen professional autonomy, and establish the data infrastructure necessary for evidence-based practice. Given the rapid development of digital health technologies, nursing education curricula need to be strengthened with data standards, clinical informatics, artificial intelligence, and data ethics. Furthermore, it is recommended that future studies focus on measuring the impact of these systems on patient outcomes and evaluating clinical integration processes.

Key words: Nursing diagnosis, nursing process, classification, electronic health records, clinical decision making, evidence-based nursing.

GİRİŞ

Hemşirelik mesleği, kökenleri Florence Nightingale'in Kırım Savaşı döneminde yaptığı sistematik gözlemlere dayanan (Ökten ve Öztekin, 2024), sezgi ve deneyime dayalı sanatsal bir uygulama alanından, veri temelli ve kanıta dayalı bir bilim dalına evrilmiştir. Bu tarihsel dönüşümün dijitalleşme ile birleştiği günümüz küresel sağlık sistemlerinde, sunulan hemşirelik bakımının görünür, ölçülebilir ve farklı kurumlar arasında karşılaştırılabilir hale gelmesi, mesleğin ilerlemesi açısından kritik bir gereklilik olarak değerlendirilmektedir (Çobanoğlu ve Oğuzhan, 2023).

Hemşirelik verilerinin standardizasyonu, bu bağlamda iletişim bütünlüğü, bakım sürekliliği, sonuçların ölçülebilirliği ve kanıta dayalı karar verme süreçlerinin yapılandırılması açısından kritik öneme sahiptir. Dijitalleşme ivmesiyle birlikte, hemşirelik terminolojilerinin ulusal ve uluslararası referans sistemleriyle uyumlu olması gerekliliği artmıştır. Standartlaştırılmış Hemşirelik Dilleri (SNL'ler), mesleğin ortak iletişim dilini oluşturarak, hemşireliğin çok disiplinli sağlık bilgi sistemleri içindeki yerini güçlendirmekte ve mesleğin bilimsel katkısını somutlaştırmaktadır (Monsen ve ark., 2023).

AMAÇ

Bu çalışma, hemşirelik pratiğinde kullanılan standart terminolojilerin (NANDA-I, ICNP, Omaha Sistemi) bakım kalitesi, mesleki otonomi ve kanıta dayalı uygulamalar üzerindeki dönüştürücü etkilerini analiz etmeyi amaçlamaktadır. Çalışmanın temelini oluşturan sav, standartlaştırılmış hemşirelik tanılamasının yalnızca bir kayıt veya dokümantasyon aracı olmadığı; aksine, hemşirelik bakımını kanıta dayalı bir zeminde yapılandıran ve modern sağlık

sistemlerinin yapıtaşını oluşturan anlamlı ve makine tarafından işlenebilir verinin kaynağı olduğudur.

MATERYAL VE METOT

Bu bildiri taslağı, standardize edilmiş hemşirelik terminolojilerinin klinik ve mesleki pratik üzerindeki etkilerini inceleyen Literatür temelli derleme çalışması formatında hazırlanmıştır. Çalışma için yapılan literatür taraması 01 Eylül – 01 Kasım 2025 tarihleri arasında gerçekleştirilmiş olup bu çalışmada konu ile ilgili terimlerin arama motorları aracılığıyla elde edilen sonuçlar üzerinden, standart terminolojilerin yapısal özelliklerini, kullanım alanlarını ve dijital sağlık ekosistemindeki rollerini karşılaştırmalı olarak değerlendirilmiştir. Değerlendirme, hemşirelik uygulamaları üzerindeki doğrudan etkileri ve mesleki yeterliliğe sağlanan katkıları merkeze almaktadır.

LİTERATÜR BULGULARI

Standartlaşmanın Klinik Ve Mesleki Pratik Üzerindeki Etkileri

Standartlaştırılmış Hemşirelik Dilleri (SNL'ler), hemşirelik bilgisini düzenleme amacının ötesine geçerek, klinik uygulamaların her aşamasını sistematik biçimde yönlendiren, bakım kalitesini değerlendirilebilir kılan ve mesleki özerkliği güçlendiren dinamik bir yapıya evrilmiştir (İskender ve Kaplan, 2020). Bu sistemlerin kullanımı, hemşirelik bakımının niteliğini, sürekliliğini ve profesyonel standartlarını çok yönlü biçimde etkilemektedir (Uslu ve Yavuz, 2019).

Bakım Kalitesi ve Sürekliliği Üzerindeki Etkileri

Standartlaştırılmış terminolojilerin benimsenmesi, bakımın planlanmasından değerlendirilmesine kadar yapılandırılmış bir yaklaşım sağlar ve bu da hasta güvenliği ile mesleki gelişimi destekler(Demirtaş, 2024).

- **Sistematik Yaklaşım:** SNL'ler, hemşirelerin bakım sürecini planlama, uygulama ve değerlendirme aşamalarında sistematik bir yöntem izlemesine olanak tanır (Zaybak, 2023).
- **Tutarlılık** Garantisi: Ortak bir terminolojinin kullanılması, bakımın vardiyalar veya farklı hemşireler arasında devredilirken tutarlılığının korunmasını sağlar. Bu sayede bakımda süreklilik ve bütünlük güvence altına alınır. Bu yapısal tutarlılık, hizmet kalitesini artırarak aynı zamanda hasta güvenliği ve memnuniyetini de güçlendirir (Kaya, 2021).

Bakımın standardize edilmesi, kritik bilgilerin yoruma açık olmadan, kodlanmış ve tutarlı bir formatta aktarılmasını mümkün kılar. Bu özellik, özellikle bakım devirleri sırasında yanlış anlaşılmalardan kaynaklanan klinik hataların önlenmesinde hayati bir rol üstlenir. Bu açıdan SNL'ler, yalnızca bir ortak iletişim aracı olmanın ötesinde, disiplinler arası ve zaman içindeki süreçlerde hasta güvenliğini garanti altına alan bir kalite kontrol ve risk azaltma katmanı işlevi görmektedir(Demirtaş, 2024).

İletişim, İş Birliği ve Multidisipliner Entegrasyon

Standartlaştırılmış terimlerin kullanılması, sadece hemşireler arasındaki profesyonel iletişimi değil, aynı zamanda diğer sağlık ekibi üyeleriyle olan bilgi paylaşımını da kolaylaştırır (Kıyıcı ve Koç, 2025).

- **Belirsizliğin Giderilmesi:** Ortak bir dil kullanımı, klinik belgelerdeki belirsizlikleri ortadan kaldırarak daha net, anlaşılır ve bütüncül bir iletişim ortamı yaratır(Usta, 2024).

- **Koordinasyon:** Bu durum, disiplinler arası etkileşimi önemli ölçüde artırır ve hasta bakımında bütüncül, koordineli bir yaklaşımın benimsenmesini destekler (Khatri et al., 2023). Uluslararası Hemşirelik Uygulamaları Sınıflandırması (ICNP) gibi sistemler, farklı diller ve sınıflandırmalar arasında bağlantı kurmayı amaçlayan bir "birleştirici dil" niteliği taşıyarak küresel düzeyde veri karşılaştırılabilirliğini hedefler (Ay, 2008; Kaya, 2021).

Mesleki Otonomi ve Bilimsel Kimlik

SNL'ler, hemşirelik uygulamalarında bağımsız karar verme süreçlerinin bilimsel temele dayandırılmasını sağlayarak mesleki otonomiye doğrudan katkıda bulunur (Erikmen ve Vatan, 2019).

- **Klinik Yargının Temellendirilmesi:** Hemşire, hastaya ait verileri analiz eder, klinik yargısını kullanır ve bu yargıya dayalı olarak hemşirelik tanısını belirler. Tanı süreci, hemşirenin uygulayacağı girişimlerin ve beklenen sonuçların bilimsel temele dayandırılmasını sağlar (Urhan ve Harmancı Seren, 2019).
- **Profesyonel Kimliğin Güçlenmesi:** NANDA-I gibi uluslararası sistemler, hemşirelik bilgisinin sınıflandırılmasını ve yapılandırılmasını sağlayarak mesleğin profesyonel kimliğini pekiştirir (Gençbaş et al., 2023).

Otonominin güçlenmesi, sadece bağımsız hareket etme hakkını değil, aynı zamanda bu kararların gerekçelerini standart bir terminolojiyle (örneğin Sorun Odaklı tanılarda kullanılan P (Problem), E (Etiyoloji), S (Semptomlar) (PES) formatı açıkça sunma yeteneğini de içerir. SNL'ler, hemşirenin eleştirel düşünme becerisini yapılandırılmış bir taksonomiye dönüştürerek, mesleki kararların üçüncü taraflarca sorgulanabilir ve doğrulanabilir olmasını sağlar. Bu yaklaşım, otonominin bilimsel ve etik açıdan hesap verebilirliğini artırmaktadır(Urhan ve Harmancı Seren, 2019; Akgül Gündoğdu et al., 2016).

Kanıta Dayalı Uygulama (KDU) için Temel

Standart tanı sistemleri, kanıta dayalı hemşirelik uygulamalarının (KDU) temelini oluşturmaktadır.

- **Sistematik Tanımlama:** Klinik bir problemin açık ve standart bir biçimde tanımlanması, kanıt temelli araştırmaların yürütülmesi için ilk ve en kritik adımdır (Çakmakkaya, 2021).
- **Araştırma Altyapısı:** Örneğin PICO (Hasta/Problem, Girişim, Karşılaştırma, Sonuç) yaklaşımında "P – Hasta/Problem" bileşeni, SNL'ler aracılığıyla sistematik biçimde tanımlanabilir. Bu yapı, hemşirelik uygulamalarının bilimsel kanıtlara dayalı, tekrarlanabilir ve ölçülebilir bir biçimde yürütülmesine olanak sağlar (Şirin, 2025).

Eğer hemşirelik tanıları küresel düzeyde standardize edilirse, farklı ülkelerde veya kurumlarda çalışan araştırmacılar aynı klinik problemi aynı terminolojiyle inceleyebilir. Bu ortak terminoloji sayesinde hemşirelik araştırmalarının sonuçları birleştirilebilir, meta-analizler yapılabilir ve böylece küresel düzeyde geçerli bilimsel kanıt setlerinin oluşturulması mümkün kılınabilir. Standardizasyon, hemşirelik biliminin uluslararası arenadaki ilerlemesi için temel bir katalizör görevi üstlenmektedir (Köse & Sis Çelik, 2020).

SONUÇ VE ÖNERİLER

Standartlaştırılmış hemşirelik terminolojileri, NANDA-I, ICNP ve Omaha Sistemi dahil olmak üzere, modern hemşirelik uygulamalarının temel bileşenleri haline gelmiştir. Bu diller, klinik bakımın doğruluğunu, veri kalitesini ve mesleki görünürlüğü artırmaktadır. Standart

terminolojilerin kullanılması, mesleğin bilimsel görünürlüğünü önemli ölçüde artırmış ve aynı zamanda dijital sağlık dönüşümünü kolaylaştırmıştır. Bu dijital dönüşüm ortamında etkili olabilmek için, geleceğin hemşirelerinin gelişmiş bilişim yetkinlikleri ile donatılması gerekmektedir. Hemşirelik lisans ve lisansüstü eğitim programları, temel bilgisayar becerilerinin ötesine geçmelidir. Müfredatlar; veri standartları (SNOMED CT, LOINC), klinik karar destek sistemlerinin işleyişi, temel veri analitiği, yapay zekânın etik boyutları (özellikle algoritmik yanlılık) ve veri mahremiyeti (KVKK gibi yasal çerçeveler) gibi ileri düzey bilişim yetkinliklerini kapsayacak şekilde güncellenmelidir. Bu sayede hemşireler, yalnızca teknolojiyi kullanan değil, aynı zamanda elde edilen veriyi eleştirel bir şekilde yorumlayabilen ve etik sonuçlarını değerlendirebilen profesyoneller hâline gelecektir.

Gelecekteki araştırmalar, standartlaştırılmış terminolojilerin klinik uygulamalara entegrasyonunun, spesifik hasta sonuçlarına (örneğin düşme insidansı, hastane enfeksiyon oranları) olan etkisini nicel olarak ölçmeye odaklanmalıdır. Son olarak, teknolojik sistemlerin başarılı bir şekilde uygulanabilmesi ve sosyo-teknik uyumsuzlukların en aza indirilmesi amacıyla, uygulama ve değişim yönetimi stratejilerinin geliştirilmesi önem arz etmektedir.

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EVALUATION OF TIME-DEPENDENT COLOR DIFFERENCES IN RESIN COMPOSITES: A COMPARATIVE STUDY USING SPECTROPHOTOMETER, MOBILE APPLICATION, AND ARTIFICIAL INTELLIGENCE-BASED METHODS

REZİN KOMPOZİTLERDE ZAMANA BAĞLI RENK FARKLILIKLARININ DEĞERLENDİRİLMESİ: SPEKTROFOTOMETRE, MOBİL UYGULAMA ve YAPAY ZEKA TABANLI KARŞILAŞTIRMALI BİR ÇALIŞMA

Arş. Gör. İbrahim Elgin OLGAR

Uşak Üniversitesi, Diş Hekimliği Fakültesi, Restoratif Diş Tedavisi, Uşak, Türkiye

Doç. Dr. Muhammet FİDAN

Uşak Üniversitesi, Diş Hekimliği Fakültesi, Restoratif Diş Tedavisi, Uşak, Türkiye

Öğr. Gör. Özhan YAĞCI

Uşak Üniversitesi, Diş Hekimliği Fakültesi, Restoratif Diş Tedavisi, Uşak, Türkiye

ÖZET

Bu çalışmanın amacı, rezin kompozit materyallerin kısa ve uzun dönem renk farklılıklarının farklı dijital renk ölçüm yöntemleri aracılığıyla değerlendirilmesidir. Çalışmaya altı farklı rezin kompozit materyal [Charisma Smart (A2), Charisma Diamond One, Opallis (E2), Vittra APS Unique, Estelite Sigma Quick (A2) ve Omnichroma] dahil edildi. Her bir materyalden 10 mm çapında ve 2 mm kalınlığında disk formunda numuneler hazırlandı. Her alt grup için 8 numune olmak üzere toplam 144 numune hazırlandı. Renk ölçümleri üç farklı yöntem ile gerçekleştirildi: spektrofotometre (Vita Easyshade V), mobil tabanlı renk ölçüm uygulaması (ColorMeter RGB) ve yapay zeka tabanlı dil modeli (ChatGPT-4o). Renk ölçümleri üç farklı zamanda yapıldı: gün 0 (T_0), gün 1 (T_1) ve gün 7 (T_2). Renk farklılıkları, CIEDE2000 formülüne göre (ΔE_{00}) ve ortalama renkten olan ortalama renk farkı ($MCDM_{00}$) değerleri ile hesaplandı. Verilerin istatistiksel analizi Robust ANOVA testi ile yapıldı ($p < 0,05$). ChatGPT-4o ile elde edilen $MCDM_{00}$ değerleri, spektrofotometre ve mobil uygulama yöntemlerine kıyasla anlamlı düzeyde yüksek bulundu ($p < 0,001$). Materyal ve renk ölçüm yöntemi kombinasyonu değerlendirildiğinde, ChatGPT-4o × Vittra APS Unique ve ChatGPT-4o × Omnichroma ve ChatGPT-4o × Charisma Smart (A2) kombinasyonları en yüksek $MCDM_{00}$ değerlerini gösterdi ($p < 0,05$). T_0–T_1 aralığında Vittra APS Unique ve Omnichroma daha yüksek renk değişimi sergilerken, Charisma Smart (A2) ve Opallis (E2) daha düşük renk değişimi gösterdi ($p < 0,05$). Rezin kompozit materyallerin renk stabilitesi; materyal türüne, zaman faktörüne ve kullanılan renk ölçüm yöntemine bağlı olarak anlamlı düzeyde değişiklik göstermektedir. Spektrofotometre, test edilen süreler boyunca en düşük renk değişimini gösterdi. Yapay zeka tabanlı ölçüm yöntemi ise spektrofotometre ve mobil-tabanlı renk ölçüm yöntemlerine göre en yüksek renk değişimini gösterdi.

Anahtar Kelimeler: Rezin Kompozitler, Renk Farklılıkları, Spektrofotometre, Yapay Zeka

ABSTRACT

The aim of this study is to evaluate the short- and long-term color differences of resin composite materials using different digital color measurement methods. Six different resin composite materials were included in the study [Charisma Smart (A2), Charisma Diamond One, Opallis (E2), Vittra APS Unique, Estelite Sigma Quick (A2), and Omnichroma]. Disc-shaped samples were prepared from each material (10 mm diameter and 2 mm thickness). A total of 144 samples were prepared, with 8 samples for each subgroup. Color measurements were performed using three different methods: a spectrophotometer (Vita Easyshade V), a mobile-based color measurement application (ColorMeter RGB), and an artificial intelligence-based large language model (ChatGPT-4o). Measurements were taken at three times: day 0 (T_0), day 1 (T_1), and day 7 (T_2). Color differences were calculated using the CIEDE2000 formula, and both (ΔE_{00}) and the mean color difference from the mean ($MCDM_{00}$) values were obtained. Statistical analysis was performed using Robust ANOVA ($p < 0.05$). The $MCDM_{00}$ values obtained with the ChatGPT-4o method were significantly higher compared to the spectrophotometer and mobile application methods ($p < 0.001$). When evaluating the combination of material and color measurement methods, the ChatGPT-4o × Vittra APS Unique and ChatGPT-4o × Omnichroma, and ChatGPT-4o × Charisma Smart (A2) combinations showed the highest $MCDM_{00}$ values ($p < 0.05$). In the T_0–T_1 interval, Vittra APS Unique and Omnichroma exhibited higher color change, while Charisma Smart (A2) and Opallis (E2) exhibited lower color change ($p < 0.05$). The color stability of resin composite materials varies significantly depending on the type of material, time factor, and color measurement method used. The spectrophotometer showed the lowest color change throughout the test intervals. The artificial intelligence-based measurement method showed the highest color change compared to spectrophotometer and mobile-based color measurement.

Keywords: Resin Composites, Color Differences, Spectrophotometer, Artificial Intelligence

GİRİŞ

Rezin kompozit materyaller daha konservatif bir tedavi yaklaşımı sundukları için hastalar arasında giderek daha fazla tercih edilmektedir (Al-Taie, 2025). Uygun restoratif materyalin seçimi kadar, doğru rengin belirlenmesi de estetik sonuç için son derece önemlidir (Hajdu et al., 2024). Bu süreçte amaç, restorasyon materyallerinin renklerini doğal dişlerle uyumlu hale getirmek, olası farklılıkları belirlemek ve bu farkların klinik olarak kabul edilebilir sınırlar içinde olup olmadığını değerlendirmektir (Makhloota et al., 2021).

Görsel olarak tatmin edici bir restorasyon için, kompozit ve diş arasındaki renk farkı insan gözüyle algılanamayacak düzeyde olmalıdır. Bu nedenle, diş yüzeyinin yapısı ve ışığın rezin kompozit ile etkileşimi hakkında derin bilgi sahibi olunması gerekir (Makhloota et al., 2021). Benzer renk özelliklerine sahip materyaller arasında dahi renk değişkenliği, renk stabilitesinin yetersizliği ve doğal dişlerin sınırlı renk skalası önemli zorluklar yaratmaktadır. Klinisyenler, restorasyon ile diş arasındaki renk farkını en aza indirmeyi hedefler. Bu amaçla, kompozitin çevresindeki rengi yansıtma özelliği olarak bilinen “bukalemun etkisi (chameleon effect)”, renk uyumunu artıran önemli bir avantaj olarak kabul edilir (Oivanen et al., 2021). Renk seçimi süreci, özellikle renk görme bozukluğu olan bireylerde daha da karmaşık hale gelir. Araştırmalar, renk görme problemi olan diş hekimlerinin renk eşleştirmede daha fazla hata yaptığını göstermektedir (Khosla et al., 2017).

Renk ölçümünde yüksek doğruluk sunan kolorimetre ve spektrofotometre cihazları mevcut olsa da yüksek maliyetleri nedeniyle kliniklerde yaygın kullanılmamaktadır (Chu et al., 2010a). Son yıllarda akıllı telefonların gelişmiş kamera ve sensör özellikleri, bu cihazları taşınabilir renk

ölçüm araçları haline getirdi. Önceki bir çalışmada mobil kolorimetre uygulamalarının cilt üzerinden renk seçimi ile yüz protezleri yapımında kullanımının başarılı olduğunu rapor edilmiştir (Niakan et al., 2025). Bir kolorimetrenin performansı; doğruluk, tekrarlanabilirlik, yeniden üretilebilirlik ve tekrar ölçüm tutarlılığı gibi kriterlerle değerlendirilir (Lehmann et al., 2011). Ortalama renk farkı (MCDM) değeri bu tutarlılığı ölçmek için kullanılır; düşük MCDM, yüksek tekrarlanabilirlik anlamına gelir (Centore, 2016).

Mevcut renk ölçüm teknolojilerinin sınırlılıkları tartışılırken, diş hekimliğinde genel olarak dijitalleşmenin ve özellikle yapay zekâ temelli yaklaşımların hızla ilerlediği de dikkat çekmektedir. Yapay zeka, günümüzün hızla gelişen ve her alanda etkisini gösteren bir teknolojisidir. Yapılan bir bibliyometrik derlemede, son beş yılda diş hekimliği alanında yapay zekâ yöntemlerinin kullanımına yönelik çalışmaların belirgin bir artış gösterdiğini ortaya koymaktadır (Zatt et al., 2024). Diş hekimliği perspektifinden bakıldığında yapay zekâ uygulamaları; tanı, karar verme, tedavi planlaması ve tedavi sonuçlarının öngörülmesi alanlarında sınıflandırılmaktadır. Yapay zeka, tanısal doğruluğu artırarak, tedavi süreçlerini kişiselleştirerek ve veri yönetimini daha etkin hâle getirerek diş hekimliğini dönüştürmektedir (Mallineni et al., 2024).

Sonuç olarak, renk değerlendirme estetik diş hekimliğinde kritik bir unsurdur. Mobil uygulama ve yapay zekâ teknolojilerindeki gelişmeler, diş rengi ölçümünde daha objektif, pratik ve düşük maliyetli alternatifler sunabilir. Ancak bu araçların farklı koşullarda güvenilirliği ve tekrarlanabilirliği klinik kullanım öncesinde doğrulanmalıdır. Eğer etkinlikleri kanıtlanırsa, mobil uygulamalar ve yapay zekanın renk değerlendirmesi, iletişim ve reprodüksiyon süreçlerinde destekleyici bir araç olarak değerlendirilebilir.

Bu çalışmanın amacı, rezin kompozit materyallerin kısa ve uzun dönem renk farklılıklarının farklı dijital renk ölçüm yöntemleri aracılığıyla değerlendirilmesidir. Bu kapsamda, bir spektrofotometre ile iOS tabanlı bir mobil renk ölçüm uygulaması ve yapay zeka tabanlı bir dil modelinin performansları karşılaştırıldı. Araştırmanın hipotezi, renk ölçüm tekrarlanabilirliğinin kısa ve uzun dönem zaman aralıklarında, kullanılan ölçüm yöntemine ve materyal türlerine bağlı olarak farklılık gösterebileceği yönündedir.

ARAŞTIRMA ve BULGULAR

Çalışmada kullanılan materyaller ve cihazlar

Güç analizi G*Power 3.1.9.4 programı kullanılarak yapıldı. Bu çalışmada dikkate alınan değişkenler materyal türü, ölçüm yöntemi ve ışık kaynağıdır. Literatüre dayanarak büyük etki büyüklüğü (f = 0.4), %95 güven düzeyi ve %80 güç kullanılarak her alt grup için minimum n = 6 örnek hesaplandı. Her alt grup için hedeflenen örnek sayısı 6 olmakla birlikte, çalışma sırasında oluşabilecek olası sorunlara karşı her grupta 8 örnek hazırlandı.

Çalışmada toplam altı farklı rezin kompozit materyal kullanıldı. Bunların üçü single-shade (tek-renk), üçü ise multi-shade (çoklu-renk) özellik göstermektedir. Araştırmada değerlendirilen kompozit materyaller Charisma Smart (A2), Opallis (E2), Estelite Sigma Quick (A2), Vittra APS Unique, Omnichroma ve Charisma Diamond One'dır. Kompozitlerin üretici firmalarına ve materyal içeriklerine ilişkin ayrıntılı bilgiler Tablo 1'de sunuldu.

Bu çalışmada renk ölçümleri için standart referans cihaz olarak spektrofotometre (VitaEasyshade V; Vita Zahnfabrik, Bad Sackingen, Almanya) kullanıldı. Rezin kompozit örneklerin değerlendirilmesine geçilmeden önce cihaz, üreticinin sağladığı kalibrasyon plağı kullanılarak kalibre edildi. Renk ölçümünde kullanılan bir diğer yöntem, ColorMeter RGB uygulamasıdır (Baden-Württemberg, Almanya). Uygulama, iOS işletim sistemine sahip iPhone

15 Pro cihazı ile çalıştırıldı (6.1'' ekran, 2556 × 1179 piksel çözünürlük; 48 MP/12 MP/12 MP/12 MP dörtlü kamera; Apple, Cupertino, CA, ABD). Son ölçüm yöntemi olarak ChatGPT-4o isimli yapay zekâ tabanlı dil modeli kullanıldı. Çalışmanın yürütüldüğü dönemde ChatGPT-4o, piyasada erişilebilir olan en güncel model niteliğini taşımaktadır.

Tablo 1. Çalışmada kullanılan materyallerin listesi

Rezin Kompozitler	Üretici Firma	İçerik	Lot No.
Charisma Smart (CS/multi-shade)	Kulzer, Almanya	Bis-GMA, baryum-alüminyum-florür camı, silicon dioksit, 0.005– 10 μm	A2:N010534
Opallis (OP/multi-shade)	FGM, Brezilya	Bis-GMA, Bis-EMA, TEGDMA, üretan dimetakrilat ve baryum alüminyum silikat, silikon oksit nanoparçacıkları, kamforokinon, hızlandırıcılar, stabilize ediciler ve pigmentler	EA2:220623
Estelite Σ Quick (ES/multi-shade)	Tokuyama, Japonya	Küresel submikron dolgu (0.1–0.3 μm) Bis-GMA, TEGDMA, silika- zirkonya	A2:284EY3
Vittra APS Unique(V/single-shade)	FGM, Brezilya	UDMA, TEGDMA, foto başlatıcı bileşimi (APS), yardımcı başlatıcılar, silan, bor-alüminyum-silikat camı	040723
Omnichroma (O/single-shade)	Tokuyama, Japonya	UDMA, TEGDMA, üniform boyutlu süper-nano küresel doldurucu (260 nm küresel SiO_2-ZrO_2) ve doldurucu	156E84
Charisma Diamond One (C/single-shade)	Kulzer, Almanya	B2O3-F-Al2O3-SiO2, silika, TiO2, floresan pigmentler, metal oksit pigmentleri, organik pigmentler, 5–20 μm	NOI0209

Bis-GMA: Bisfenol A glikol dimetakrilat; Bis-EMA: Bisfenol A etoksil dimetakrilat; TEGDMA: Trietilen glikol dimetakrilat; UDMA: Üretan dimetakrilat; SiO_2: Silikon oksit (silika); ZrO_2: Zirkonyum oksit. Veriler üreticiler tarafından sağlandı.

Disklerin hazırlanışı ve ölçüm düzeneği

Diskler, 10 mm çapında ve 2 mm kalınlığında olacak şekilde teflon kalıp kullanılarak hazırlandı. Rezin kompozitler kalıplara yerleştirildikten sonra, yüzeyde düzgünlük sağlamak amacıyla örneklerin üzerine şeffaf Mylar şeridi ve cam lam yerleştirildi, fazla materyalin uzaklaştırılması için hafif baskı uygulandı. Polimerizasyon işlemi, LED ışık cihazı (Elipar DeepCure-S, 3M ESPE, ABD) kullanılarak 1.200 mW/cm² ışık yoğunluğunda 20 saniye uygulanarak gerçekleştirildi.

Polimerizasyon sonrası örnek yüzeyleri, önce 1000-grit silikon karbür zımpara diskleri ile düzleştirildi; ardından kuru ortamda, 10.000 rpm hızla çalışan düşük devirli anguldurva ve Zenit Flex Pop On polisaj diskleri ile cilalandı. Her basamak arasında örnekler yıkanıp kurutularak olası artıkların ölçüm sonuçlarını etkilemesi önlendi, ayrıca her örnek için yeni polisaj diskleri kullanıldı. Tüm rezin kompozit örneklerinin kalınlıkları dijital kumpas (Insize 1110; Çin) ile ölçüldü ve ± 0.05 mm tolerans aralığında olanlar çalışmaya dâhil edildi (Dietschi & Fahl, 2016; Vichi et al., 2007). Her bir kompozit materyal için sekiz adet disk hazırlanmış olup toplam 144 örnek, ölçümler arasında 37 °C (±1 °C) distile su içinde, karanlık bir kapta ve inkübatörde 24 saat bekletildi.

Renk ölçümleri üç farklı yöntemle gerçekleştirildi: spektrofotometre (Vita Easyshade V), mobil tabanlı renk ölçüm uygulaması (ColorMeter RGB) ve yapay zekâ tabanlı dil modeli (ChatGPT-4o). Ölçümler, başlangıç (T_0), birinci gün (T_1, 24 saat sonra) ve 7. gün (T_2) olmak üzere üç

zaman noktasında yapıldı. Her yöntem için her diskten üç kere ölçüm alınmış ve analizlerde her disk için bu ölçümlerin ortalama değerleri kullanıldı.

Kompozit disklerin renk ölçümleri için özel bir ölçüm düzeneği oluşturuldu. Düzeneğin standardizasyonunu sağlamak amacıyla CIE Standard Illuminant D65, 1.000 lx özelliklerine sahip bir ışık kaynağı kullanıldı. Ölçüm kabininin iç yüzeyleri, ışığın yansımasını minimize etmek için nötr gri renkte tasarlandı. Ölçümler karanlık bir odada yapıldı. Numunelerin yerden 45° açıyla duracağı şekilde özel bir düzenek üretildi. Cep telefonu tutucusu, telefon kamerasının RC örneğine 0° açıyla bakacağı şekilde ayarlandı. Işık örnekten 45° uzaklıktaydı ve böylece 45°/0° optik geometri sağlandı. Cep telefonu tutucusu örnekten 30 cm uzağa yerleştirildi (Paravina et al., 2015). Belirtilen açıların doğruluğu dijital bir inklinometre (Kagen, Çin) ile kontrol edildi. Tüm gruplarda standardizasyon sağlamak için tüm rezin kompozit örneklerinin ölçümünde beyaz bir arka plan (L = 96, a = 0, b = 1) (GC3; Danes Picta) kullanıldı (Yılmaz Savaş & Akın, 2022). Tüm ölçümler tek bir araştırmacı tarafından gerçekleştirildi. Bu yaklaşım, ölçüm sürecindeki tutarlılığı sağladı ve değişkenliği azalttı.

ColorMeter RGB uygulamasında, ekrandaki hedef işareti örneğin merkezine hizalandı. Her ölçüm, uygulamaya özgü kayıt butonuna dokunularak veya hedef işaretine odaklanarak gerçekleştirildi. Ölçüm tamamlandıktan hemen sonra L*a*b* değerleri ekranda görüntülendi ve kayıt altına alındı. Ölçümler, ortam ışığından etkilenmemesi amacıyla kamera flaşı kapalı şekilde yapıldı.

ChatGPT ile gerçekleştirilen ölçümlerden önce, her örneğin fotoğrafı düzenek içinde iPhone 15 Pro kullanılarak çekildi (24 MP kamera, 3× optik zoom; iOS). Fotoğraf çekimi öncesinde odaklama kararlılığını sağlamak amacıyla AF kilidi aktive edildi. Ardından ChatGPT-4o modeline, dört fotoğraftan oluşan gruplar halinde şu komut verilerek ölçümler yaptırıldı: *"Yüklediğim fotoğrafların ortasındaki diskin tam merkezinden aldığın piksellerin CIELAB değerlerini ölçmeni istiyorum."* ChatGPT-4o, diskin merkez bölgesindeki belirli sayıdaki pikselin renk bilgilerini önce RGB renk uzayında analiz etmiş, ardından bu değerleri CIELAB renk sistemine dönüştürerek L*, a*, b* değerlerini hesapladı.

Renk farklılığı ölçümleri

Renk farklılıkları $T_0 - T_1$ ve $T_0 - T_2$ (kısa ve uzun dönem) aralıklarında CIEDE2000 formülü kullanılarak hesaplanan ΔE_{00} değerleri üzerinden değerlendirildi. Formül şu şekildedir:

$$\Delta E_{00} = \sqrt{(\frac{\Delta L'}{K_L S_L})^2 + (\frac{\Delta C'}{K_C S_C})^2 + (\frac{\Delta H'}{K_H S_H})^2 + R_T(\frac{\Delta C'}{K_C S_C})(\frac{\Delta H'}{K_H S_H})}$$

Burada ΔL', ΔC' ve ΔH', iki ölçüm arasındaki açıklık, kroma ve ton farklarını ifade eder. S_L, S_C ve S_H ağırlık fonksiyonları renk uzayındaki konuma göre düzeltme yaparken, K_L, K_C ve K_H parametrik faktörleri bu çalışmada 1:1:1 olarak kullanıldı. R_T ise özellikle mavi bölgede ton–kroma etkileşimini tanımlar (Emídio et al., 2023). ΔE_{00} değerlerinin klinik yorumu, algılanabilirlik (PT = 0.8) ve kabul edilebilirlik (AT = 1.8) eşiklerine göre yapıldı (Paravina et al., 2015). Hesaplamalarda Sharma ve arkadaşlarının formülasyonu kullanıldı (Sharma et al., 2005).

Her yöntem için $T_0 - T_1$, $T_0 - T_2$ ve $T_1 - T_2$ aralıklarında elde edilen ΔE_{00} değerleri kullanılarak ortalama renk değişiminden sapmayı gösteren $MCDM_{00}$ hesaplandı:

$$MCDM_{00} = \frac{\sum \Delta E_{00}}{n}$$

$MCDM_{00}$ değerleri PT ve AT eşikleri ile karşılaştırılarak klinik önemi değerlendirildi (Paravina et al., 2015).

İstatistiksel analiz

Veriler Jamovi 2.7.9 (Jamovi Project, ABD) istatistik yazılımı kullanılarak analiz edildi. Normal dağılım varsayımı Kolmogorov–Smirnov testi ile değerlendirildi. Materyal tipi ve ölçüm yöntemi tipi ana etkileri ile etkileşimlerini incelemek amacıyla Robust ANOVA analizleri yürütüldü. Bu analizler, Jamovi yazılımına entegre bir eklenti olan Walrus paketi kullanılarak gerçekleştirildi. Walrus paketi; normallik varsayımının sağlanmadığı, varyans homojenliğinin ihlal edildiği veya aykırı değerlerin bulunduğu durumlarda, kırpılmış (trimmed) ortalamalar ve bootstrap tabanlı yöntemler kullanarak daha sağlam (robust) sonuçlar elde etmeyi amaçlayan bir istatistiksel çerçeve sunmaktadır. Nicel veriler kırpılmış (trimmed) ortalama ± standart hata şeklinde raporlandı. İstatistiksel anlamlılık düzeyi $p < 0,05$ olarak kabul edildi.

MCDM değerleri ile ilgili bulgular

Tablo 2 incelendiğinde, materyal tipinin MCDM değerleri üzerinde tek başına anlamlı bir etkisinin olmadığı görülmektedir. Buna karşın, kullanılan renk ölçüm yöntemleri arasında istatistiksel olarak anlamlı farklar saptandı. MCDM değerinin düşük olması ölçümün yüksek tutarlılığını ifade etmektedir. Bu doğrultuda Tablo 3'te en düşük MCDM değerinin spektrofotometre yöntemine ait olduğu ($p < 0,05$) ve bu yöntemin en yüksek tekrarlanabilirliği gösterdiği belirlendi. En yüksek MCDM değerinin ise ChatGPT ölçümlerinde ortaya çıkması, bu yöntemin tekrarlanabilirliğinin en düşük olduğunu göstermektedir ($p < 0,05$).

Materyal ve ölçüm yönteminin birlikte değerlendirildiği analizlerde, ChatGPT-4o ile yapılan ölçümlerde özellikle Vittra APS Unique, Omnichroma ve Charisma Smart materyallerinin en yüksek $MCDM_{00}$ değerlerini verdiği tespit edildi.

Tablo 2. $MCDM_{00}$ değişkenlere ait Robust ANOVA ana etki ve etkileşim bulguları

	Q	*p*	Adj *p*
Materyal	50,4	0,001	0,564
Ölçüm Yöntemi	518,1	0,001	0,001
Materyal ✻ Ölçüm Yöntemi	108,9	0,001	0,001

Kırpılmış (trimmed) anlam değeri 0,2'dir.

Tablo 3. Rezin kompozitlerde renk ölçüm yöntemine göre $MCDM_{00}$ değerlerinin karşılaştırmasına ilişkin tanımlayıcı istatistikler

	Spektrofotometre	**ColorMeter**	**ChatGPT-4o**	**Toplam**
Charisma Smart/A2	$0,30 \pm 0,06^{a}$	$0,94 \pm 0,07^{b}$	$2,57 \pm 0,18^{e}$	$1,15 \pm 0,30$
Estelite Smart/A2	$0,36 \pm 0,05^{a}$	$1,16 \pm 0,07^{b}$	$1,58 \pm 0,34^{dc}$	$0,97 \pm 0,14$
Opallis/A2	$0,28 \pm 0,04^{a}$	$1,28 \pm 0,06^{bc}$	$1,11 \pm 0,23^{b}$	$0,90 \pm 0,16$
Charisma Diamond One	$0,94 \pm 0,14^{b}$	$0,86 \pm 0,15^{b}$	$1,62 \pm 0,24^{dc}$	$1,06 \pm 0,10$
Omnichroma	$0,36 \pm 0,02^{a}$	$1,15 \pm 0,04^{b}$	$2,60 \pm 0,36^{e}$	$1,20 \pm 0,25$
Vittra APS Unique	$0,44 \pm 0,04^{a}$	$1,39 \pm 0,12^{c}$	$2,63 \pm 0,19^{e}$	$1,43 \pm 0,28$
Toplam	$0,39 \pm 0,02^{A}$	$1,15 \pm 0,04^{B}$	$2,07 \pm 0,14^{C}$	

[a-e] Tabloda aynı harfe sahip değerler arasında anlamlı fark yoktur (materyal ⁎ ölçüm yöntemi etkileşimi). [A-C] Satırda aynı harfe sahip değerler arasında anlamlı fark yoktur (ölçüm yöntemi ana etki).

$T_0 – T_1$ zaman aralığı ile ilgili bulgular

Tablo 4 incelendiğinde, ilk 24 saat sonraki renk değişiminin hem kompozit materyalin tipinin hem de kullanılan ölçüm yöntemin tipinden etkilendiği ve bu faktörler arasında istatistiksel olarak anlamlı farklılıklar bulunduğu görülmektedir. Tablo 5'e göre kısa dönem renk değişiminin değerlendirilmesinde spektrofotometre, en tutarlı sonuçları veren yöntem oldu ($p < 0,05$). Ayrıca 24 saatlik süreçte renk stabilitesi açısından Opallis ve Charisma Smart en az değişim gösteren materyaller olurken, Omnichroma ve Vittra APS Unique daha belirgin renk değişimi eğilimi sergiledi.

Tablo 4. *$T_0 – T_1$* zaman aralığında değişkenlere ait Robust ANOVA ana etki ve etkileşim bulguları

	Q	*p*	Adj *p*
Materyal	124	0,001	0,001
Ölçüm Yöntemi	318	0,001	0,001
Materyal ⁎ Ölçüm Yöntemi	284	0,001	0,001

Kırpılmış (trimmed) anlam değeri 0,2'dir.

Tablo 5. Rezin kompozitlerde, *$T_0 – T_1$* zaman aralığında renk ölçüm yöntemine göre renk değişim değerlerinin karşılaştırmasına ilişkin tanımlayıcı istatistikler

	Spektrofotometre	**ColorMeter**	**ChatGPT-4o**	**Toplam**
Charisma Smart/A2	0,36 ± 0,06[a]	0,67 ± 0,17[g]	1,29 ± 0,06[bc]	0,66 ± 0,11[AB]
Estelite Smart/A2	0,41 ± 0,04[a]	1,06 ± 0,05[b]	1,13 ± 0,29[b]	0,83 ± 0,11[B]
Opallis/A2	0,36 ± 0,07[a]	0,48 ± 0,10[a]	1,05 ± 0,10[b]	0,57 ± 0,09[A]
Charisma Diamond One	0,45 ± 0,08[a]	1,20 ± 0,20[bc]	1,54 ± 0,42[bc]	0,99 ± 0,15[D]
Omnichroma	0,34 ± 0,02[a]	1,64 ± 0,01[cd]	3,76 ± 0,51[e]	1,64 ± 0,39[C]
Vittra APS Unique	0,42 ± 0,06[a]	1,83 ± 0,22[d]	2,44 ± 0,33[f]	1,58 ± 0,27[C]
Toplam	0,39 ± 0,01[X]	1,14 ± 0,09[Y]	1,67 ± 0,16[Z]	

[a-g]Tabloda aynı harfe sahip değerler arasında anlamlı fark yoktur (materyal ⁎ ölçüm yöntemi etkileşimi). [X-Z] Satırda aynı harfe sahip değerler arasında anlamlı fark yoktur (ölçüm yöntemi ana etki). [A-C] Sütunda aynı harfe sahip değerler arasında anlamlı fark yoktur (materyal ana etki).

$T_0 – T_2$ zaman aralığı ile ilgili bulgular

Tablo 6 incelendiğinde, bir haftalık periyotta meydana gelen renk değişiminin yalnızca kullanılan ölçüm yöntemine bağlı olarak anlamlı farklılık gösterdiği görülmektedir. Tablo 7'de spektrofotometrenin bir haftalık süreçte de en stabil ve en güvenilir ölçüm yöntemi olmayı sürdürdüğü, ColorMeter uygulamasının ise kabul edilebilir düzeyde tutarlılık sergilediği görülmektedir. Estelite Smart⁎Spektrofotometre etkileşiminde en düşük renk değişim değeri gözlendi ($p < 0,05$).

Tablo 6. *$T_0 – T_2$* zaman aralığında değişkenlere ait Robust ANOVA ana etki ve etkileşim bulguları

	Q	*p*	Adj *p*
Materyal	49,7	0,001	0,968
Ölçüm Yöntemi	246,7	0,001	0,001
Materyal ⁎ Ölçüm Yöntemi	253,7	0,001	0,001

Kırpılmış (trimmed) anlam değeri 0,2'dir.

Tablo 7. Rezin kompozitlerde, $T_0 - T_2$ zaman aralığında renk ölçüm yöntemine göre renk değişim değerlerinin karşılaştırmasına ilişkin tanımlayıcı istatistikler

	Spektrofotometre	**ColorMeter**	**ChatGPT-4o**	**Toplam**
Charisma Smart/A2	0,24 ± 0,04[a]	1,04 ± 0,06[b]	3,63 ± 0,22[f]	1,41 ± 0,45
Estelite Smart/A2	0,18 ± 0,06[a]	1,53 ± 0,19[d]	2,06 ± 0,66[c]	1,16 ± 0,24
Opallis/A2	0,21 ± 0,02[a]	1,61 ± 0,06[ed]	1,36 ± 0,24[b]	1,10 ± 0,21
Charisma Diamond One	0,35 ± 0,25[a]	0,43 ± 0,24[g]	1,75 ± 0,22[e]	1,17 ± 0,16
Omnichroma	0,43 ± 0,02[g]	0,44 ± 0,25[g]	3,43 ± 0,52[f]	1,14 ± 0,38
Vittra APS Unique	0,63 ± 0,06[g]	1,01 ± 0,16[b]	3,40 ± 0,34[f]	1,43 ± 0,40
Toplam	0,41 ± 0,04[X]	1,07 ± 0,10[Y]	2,63 ± 0,27[Z]	

[a-f] Tabloda aynı harfe sahip değerler arasında anlamlı fark yoktur (materyal ✻ ölçüm yöntemi etkileşimi). [X-Z] Satırda aynı harfe sahip değerler arasında anlamlı fark yoktur (ölçüm yöntemi ana etki).

SONUÇ VE TARTIŞMA

Önceki bir çalışmada beyaz arka plan kullanılarak yapılan ölçümlerin siyah arka plana kıyasla daha yüksek doğruluk gösterdiği bildirildi; ayrıca nötr bir arka planın ve kalibre bir referans hedefinin eşlik etmesinin yapılan görüntü düzeltme işlemlerini kolaylaştırarak ölçüm hassasiyetini artırabileceği belirtildi (Mulcare & Coward, 2019). Renk ölçüm doğruluğu, ışığın homojenliği, arka plan gürültüsü, kamera–örnek mesafesi ve odak uzaklığı gibi çok sayıda çevresel değişkenden etkilenmektedir. Kamera örneğe yaklaştıkça çevresel etkileşimler azalırken; cihazın ölçülen yüzeye düşen ışığı engellemesi nedeniyle çok yakın mesafede ölçüm hataları artabilir. Ayrıca, mobil telefon tabanlı renk ölçümlerinde 25 mm mesafede alınan değerlerin diğer mesafelere göre anlamlı biçimde farklılık gösterdiğini, ancak 30 mm ile 35 mm mesafeleri arasında anlamlı bir fark saptanmadığını rapor etti; bu nedenle doğru sonuç elde etmek için cihazın örnekten en az 25 mm uzaklıkta tutulması önerilmektedir (Mulcare & Coward, 2019).

Literatürde bildirilen klinik eşik değerlerine göre ΔE_{00} değerlerinin 0,8'in altında olması farkın algılanamaz, 0,8–1,8 aralığında olması kabul edilebilir ve 1,8'in üzerinde olması ise klinik olarak kabul edilemez düzeyde renk farkını temsil etmektedir. Bu eşikler dikkate alındığında çalışmamızda spektrofotometre, tüm zaman aralıklarında en yüksek tekrarlanabilirlik ve stabiliteyi gösterdi. Literatürde de spektrofotometrenin renk ölçümünde en güvenilir ve en hassas yöntem olduğu birçok çalışma tarafından desteklenmektedir (Akl et al., 2023; Chu et al., 2010b). ColorMeter uygulaması, ΔE_{00} değerlerinin klinik kabul edilebilirlik sınırlarının altında kalması nedeniyle pratik ve ulaşılabilir bir renk ölçüm yöntemi olarak değerlendirilebilir. Ancak ölçüm hassasiyetinin spektrofotometreye kıyasla daha düşük olduğu görüldü. Literatürde de benzer şekilde ColorMeter'ın kabul edilebilir, ancak hassasiyet açısından orta düzeyde performans gösterdiği bildirildi (Dang et al., 2024).

ChatGPT-4o ise renk analizi konusunda potansiyel gösterse de ölçüm varyansının yüksek olması nedeniyle özellikle uzun dönem ölçümlerde daha az güvenilir sonuçlar verdi. Kısa dönemde kabul edilebilir MCDM değerleri üretse de uzun dönem performansının dikkatle değerlendirilmesi gerekmektedir. CIEDE2000 renk farkı formülü, klinik yorumlamalarda ve renk farklarının değerlendirilmesinde daha iyi görsel uyum sağladığı için tercih edilen ölçüm yöntemidir (Güven et al., 2023). Ardışık ölçümler (kısa dönem), saatler içinde yapılan ölçümler (orta dönem) ve günler, haftalar veya daha uzun sürelerde yapılan ölçümler (uzun dönem) için alınan sonuçların birbirine yakınlığı "tekrarlanabilirlik" olarak tanımlanır. Bu çalışmada önceki çalışmada belirtildiği gibi tekrarlanabilirliği değerlendirmek için MCDM hesaplanmış ve düşük değerler daha yüksek tekrarlanabilirlik gösterdi (Olgar et al., 2025).

Rezin kompozit materyallerin renk stabilitesi; materyal türü, zaman faktörü ve kullanılan renk ölçüm yöntemine bağlı olarak anlamlı düzeyde farklılık göstermektedir. Genel olarak ilk 24 saatlik periyodun ardından single-shade kompozitlerin, multi-shade kompozitlere kıyasla daha fazla renk değişimi sergilediği belirlendi. Ancak uzun dönem değerlendirmelerinde materyaller arasındaki bu farklılıkların azalması, renk değişiminin zaman içerisinde daha benzer bir düzeye yaklaştığını göstermektedir. Bizim çalışmamızda renk değişimi yönünden değerlendirildiğinde, Opallis ve Estelite Sigma Quick en stabil materyaller olurken; Vittra APS Unique ve Omnichroma renk değişimine karşı en duyarlı materyaller olarak belirlendi. Benzer şekilde Checchi ve ark. tarafından yapılan bir çalışmada kompozit materyallerde erken dönemde daha yüksek renk değişimi görüldüğü, zaman geçtikçe ise renk stabilitesinin arttığı ve materyaller arasındaki farkların azaldığı bildirilmektedir (Checchi et al., 2024).

Spektrofotometre, test edilen süreler boyunca en düşük renk farklılığını gösterdi. Yapay zeka tabanlı ölçüm yöntemi ise spektrofotometre ve mobil-tabanlı renk ölçüm yöntemlerine göre en yüksek renk farkını gösterdi. ChatGPT-4o, renk değişimi değerlendirmelerinde beklenen ölçüde doğruluk ve tekrarlanabilirlik sunmadı. Bu nedenle, renk ölçümünde güvenilir bir alternatif olabilmesi için modelin daha da geliştirilmesine ihtiyaç olduğu sonucuna varıldı. Gelecekte yapılacak çalışmalar ve geliştirilecek yeni sürümlerin bu konuda daha iyi sonuçlar sağlayabileceği düşünülmektedir.

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MODERN APPROACHES TO THE SURGICAL MANAGEMENT OF CONGENITAL DIAPHRAGMATIC HERNIA IN NEWBORNS

F. R. Huseynov

Azerbaijan State Advanced Training Institute for Doctors, Department of "General and Plastic Surgery", Baku, Azerbaijan

https://orcid.org/0009-0008-3621-084X

ABSTRACT

Considering all these factors, research aimed at improving the management strategies for congenital diaphragmatic hernia is an important and timely scientific topic. In this study, the treatment methods and surgical techniques used for 98 newborns and older pediatric patients diagnosed with congenital diaphragmatic hernia will be evaluated from the moment of diagnosis—both in the neonatal intensive care unit and in the operating room—as well as during postoperative intensive care, and will serve as the basis for this scientific work.

Among the 98 patients included (75 left-sided, 11 right-sided, 11 Morgagni hernias, and 1 eventration; 3 recurrences), the following procedures was reviewed: 69 laparotomies, 10 thoracoscopies, 12 thoracotomies, 2 laparoscopy/laparotomy combinations, 4 thoracoscopy/thoracotomy combinations, 1 re-thoracotomy, and 1 thoracotomy performed for recurrence after thoracoscopy.

Laparotomy was performed through a subcostal incision on the side of the hernia. Herniated organs was reduced into the abdominal cavity, and the diaphragmatic defect was repaired using 7–9 interrupted non-absorbable 2-0 silk or Ethibond sutures.

The findings of the present study show that male infants predominate among newborns diagnosed with congenital diaphragmatic hernia. Cases of pulmonary infection, pulmonary hypertension, and scleroderma were more frequently observed in the comparison group. In this group, a greater number of infants presented with critical oxygen saturation levels and required mechanical ventilation.

The newly introduced minimally invasive surgical technique (endoscopic approach) proposed for the treatment of diaphragmatic hernias proved to be more effective compared to conventional surgical methods. This superiority was demonstrated by significantly lower intraoperative blood loss, shorter incision length, and a statistically shorter duration of postoperative antibiotic therapy.

Introduction. Congenital diaphragmatic hernia (CDH) is a life-threatening developmental defect of the diaphragm that allows abdominal viscera to herniate into the thoracic cavity, leading to pulmonary hypoplasia and persistent pulmonary hypertension of the newborn. Despite advances in perinatal and surgical care, CDH remains a major challenge in neonatal surgery, with mortality and long-term morbidity still substantial, particularly in infants with severe lung hypoplasia and complex associated anomalies.

Over the past three decades, the management paradigm for CDH has shifted from emergent surgical repair in the delivery room to a strategy of delayed repair after cardiorespiratory stabilization in a neonatal intensive care unit. Modern protocols emphasize “gentle ventilation,” permissive hypercapnia, targeted management of pulmonary hypertension (including inhaled nitric oxide and in selected cases extracorporeal membrane oxygenation, ECMO), and strict hemodynamic monitoring before proceeding to surgery. Timing of repair is now individualized, typically within the first 24–72 hours after birth once adequate stabilization has been achieved, as very early or excessively delayed repair has been associated with worse respiratory and nutritional outcomes.

The embryologic basis of CDH remains controversial. It was thought initially that the defect happened secondary to failure of different parts of the diaphragm to fuse resulting in a patent pleuroperitoneal canal [19, 20]. Rat models have shown a defect in the primordial diaphragm called the pleuroperitoneal fold [16]. This, in turn, allows the gut to enter the thoracic cavity when it returns from the extraembryonic coelom of the umbilicus. Another speculation is that lung hypoplasia may be the primary causal factor in the pathophysiology of diaphragmatic hernia [21]. If the development of lung bud is disturbed, there is an impaired development of a post hepatic mesenchymal plate (PHMP) that is closely related to the development of lung, resulting in a defective diaphragm [21]. Evidence from electron microscopy in a rat model [22] of CDH further supports the fact that when the development of the PHMP is impaired, a diaphragmatic defect occurs.

A weakness in the diaphragm can cause diaphragmatic eventration and may be mistaken for a diaphragmatic hernia. Diaphragmatic eventration is more common on the right side and is not associated with severe lung hypoplasia. While a complete absence of the diaphragm may occur resulting in diaphragmatic agenesis and severe lung hypoplasia. Irrespective of the basis, a defect in the diaphragm causes the abdominal viscera to herniate into the thoracic cavity resulting in abnormal lung development. The defect also leads to abnormal fetal breathing movements resulting in the void of stretch-induced lung maturation [1]. Thus the major underlying pathophysiology of CDH appears to be a combination of lung immaturity and hypoplasia that leads to PPHN. This may be further aggravated by left ventricular underdevelopment and right ventricular hypertrophy resulting in ventricular dysfunction.

Lung hypoplasia occurs on the ipsilateral side of herniation, with the contralateral side being affected to a variable extent . Hypoplasia was initially thought to be secondary to physical compression of the lung by abdominal contents arresting lung development. Recently, a two-hit hypothesis has been proposed based on rat model explaining the lung injury in CDH. According to this hypothesis, the initial insult occurs during the stages of organogenesis resulting in bilateral hypoplasia, followed by compression of the ipsilateral lung secondary to the herniation of the abdominal viscera at later stages. This theory explains the variability of lung hypoplasia on the contralateral side. The interference results in decreased branching of the bronchioles and pulmonary vessels leading to acinar hypoplasia [3]. The terminal bronchioles are decreased with thickening of alveolar septa. The lung is relatively immature [4] and hypoplasia of pulmonary vasculature leads to PPHN.

Surgically, open abdominal repair via laparotomy remains the gold standard, particularly for large defects and in unstable infants, allowing optimal exposure, assessment of lung size, and secure primary or patch repair of the diaphragmatic defect.PM For carefully selected, hemodynamically stable neonates with smaller defects, minimally invasive approaches (thoracoscopic or laparoscopic repair) are increasingly employed, offering reduced postoperative pain and shorter recovery, although at the cost of a higher reported recurrence rate and a steep learning curve. In parallel, prenatal interventions, particularly fetoscopic endoluminal tracheal occlusion (FETO), have emerged as a promising option for fetuses with

severe CDH, aiming to stimulate lung growth and improve postnatal operability and survival [5]. Current evidence supports a multidisciplinary, protocol-driven approach, integrating prenatal risk stratification, standardized preoperative stabilization, individualized choice of surgical technique, and structured long-term follow-up for respiratory, nutritional, and neurodevelopmental outcomes. Recent international guidelines and collaborative registries continue to refine these strategies, with the goal of improving both survival and quality of life in infants born with CDH [6].

Congenital diaphragmatic hernia refers to the presence of a defect in the diaphragm, a thin muscular layer separating the thoracic and abdominal cavities. As a result of abnormal intrauterine development, a portion of the abdominal organs—such as segments of the intestine, the stomach, and in some cases even the liver—may herniate through this diaphragmatic defect into the thoracic cavity. Herniation of abdominal viscera into the chest reduces the available space for lung development, leading to significant respiratory compromise after birth. Because the lungs develop in a compressed state in congenital diaphragmatic hernia, pulmonary function may be impaired even before delivery. Infants with this condition frequently develop pulmonary hypoplasia**,** characterized by a reduced number of alveoli and an increased diffusion distance for oxygen to reach the bloodstream. In addition, pulmonary hypertension commonly develops [7].

During fetal life, most respiratory functions are supported by the placenta; therefore, signs of fetal hypoxia typically do not appear. However, after birth, adequate oxygenation depends entirely on functional lungs, making respiratory insufficiency a critical concern. Congenital diaphragmatic hernia occurs in approximately 1 in 2,500 live births, with defects recorded on the left, right, or – rarely - bilaterally.

In normal fetal development, the diaphragm completes its formation by the 10th gestational week. In cases of diaphragmatic hernia, this developmental process is disrupted, resulting in a defect that allows abdominal organs to migrate into the thoracic cavity during fetal respiratory movements. Several studies have associated the development of diaphragmatic hernia with chromosomal abnormalities and genetic factors. In such cases, various structural anomalies in other organs may also be detected, prompting many specialists to recommend genetic evaluation for affected patients.

Prenatally, diaphragmatic hernia may be incidentally identified on ultrasound, either by the presence of excess amniotic fluid in the thoracic cavity or by the detection of abdominal organs and tissues within the chest. Advanced ultrasound techniques can identify which abdominal organs have herniated into the thorax and assess lung size. During such assessments, clinicians focus on features associated with the presence of the syndrome. Lung size may be evaluated by calculating the lung-to-head ratio (LHR)**.** Additionally, determining whether the liver has herniated into the chest is crucial. Based on these prognostic findings, diaphragmatic hernias are classified as mild, moderate, or severe.

In some cases, the hernia is diagnosed after birth or during infancy when the child presents with respiratory distress. These infants require surgical repair of the defect. However, closing the diaphragmatic defect surgically does not reverse the irreversible lung changes that have already occurred. Therefore, when detected prenatally, certain fetal interventions may be required with the primary goal of preventing progressive pulmonary damage. For example, during fetal life, the lungs secrete fluid that is normally expelled through the mouth. If the outflow of this fluid is blocked, it accumulates and exerts pressure on the lungs, causing them to expand. This procedure, known as fetoscopic tracheal occlusion (FETO)**,** has been used as a fetal therapy aimed at promoting lung growth.

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SERUM LIPID PROFILE PREVALENCE IN MALE AND FEMALE ADOLESCENTS IN KATSINA STATE, NORTH WEST NIGERIA

A. I. Yaradua
Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

A. J. Alhassan
Department of Biochemistry, Faculty of Basic Medical Sciences, Bayero University Kano, Kano, Nigeria.

M. K. Atiku
Department of Biochemistry, Faculty of Basic Medical Sciences, Bayero University Kano, Kano, Nigeria.

K. I. Matazu
Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

A. Nasir
Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

L. Shuaibu
Department of Pure and Industrial Chemistry, Faculty of Sciences Federal University Birnin Kebbi, Birnin Kebbi, Nigeria.

Y.Y. Riko
Department of Microbiology, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

Z. A. Suleman
Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

I. Muhammad
Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, Katsina, Nigeria.

ABSTRACT

Modifiable unhealthy behaviors with consequential adverse health outcomes are usually established and nurtured during the adolescent stage with the resulting effects, usually presenting as chronic degenerative diseases seen in adulthood. Studies have associated Lipid levels in adolescence with cardiovascular events risk in adulthood, but there is paucity of recent data for lipid levels for Katsina state adolescents lipid levels. A descriptive cross-sectional study was conducted among male and female adolescent subjects attending the General Out-

Patient Department of the Federal Medical centre in Katsina metropolis Katsina State- Nigeria in the year 2017. A total of 296 (male 150; female 146) adolescents aged 11 to 19 years were selected for the study. The adolescents were subjected to anthropometric measurement, social classification of each participant was determined based on the occupational status and highest educational attainment of the parents, serum lipid levels were measured enzymatically. From the result, 39% of the respondents falls within the upper social class and 31% falls within the lower class; 21% male and 18% female were under weight, 10% male and 9% female were overweight, and 5% male and 2% female were obese, there exist an age trend for increasing weight in both groups. For both sexes, body mass index (BMI) and age were positively correlated to total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C). There were no significant differences in the measured parameters between the sexes. The positive correlation of BMI/age with serum TC and LDL-C and the low HDL-C values in the subjects is a cause for concern as it may likely predispose them to cardiovascular complications

in adulthood.

Keywords: *Lifestyle; non-communicable diseases; modifiable behaviors; social status; Africans*

INTRODUCTION

The onset of chronic degenerative diseases whose major consequences usually appear during adulthood has been linked to the childhood and adolescent stages [1]. Despite the high prevalence of under nutrition, the combine effect of globalization, emergence of a middle class coupled with urbanization and the craving for cheap, high energy dense food and sedentary life style due to the ongoing economic transition in Nigeria may likely predispose the younger population to obesity with the likely consequential development of dyslipidemia that may possibly lead to insulin resistance and cardiovascular complications in adulthood [2]. The modifiable unhealthy lifestyle behaviors leading to such chronic disease conditions are usually established during the adolescence stage [3]. More so with association of Lipid levels with cardiovascular events risk [4,5,6] there is a need to monitor the lipid profile trend of adolescents.

Earlier studies conducted in Katsina State, North-west Nigeria on lipid profiles in adolescents mainly targeted apparent healthy subjects in school settings [7,8,9]. This work therefore seek to contribute to the monitoring of cardio vascular risk factors in adolescents from Katsina State, Nigeria, by investigating the lipid profile of adolescents presenting with mild ailments at the General Out Patient Department of the Federal Medical Centre Katsina State, Nigeria.

MATERIALS AND METHODS

Study Population

A descriptive cross-sectional study was conducted among male and female adolescent subjects attending the general Out-Patient Department of the Federal Medical Centre in Katsina metropolis Katsina State- Nigeria in the year 2017. The global location of the state is between latitude 12º 15′ north of the equator and longitude 07º 30′ east of the Greenwich Meridian with a total area of 24, 192 km^2 [10]. This study was approved by the Ethical Committee of the Ministry of health, Katsina State. A total of 296 adolescents aged 11 to 18 years attending the General Out-Patient Department (GOPD) clinic drawn from the three senatorial zones that constitute to make Katsina State were consecutively recruited. These were selected from the

population of adolescents presenting with mild ailments such as colds and fever, which are not known to affect serum lipid concentrations.

All out patients within the study age groups were considered. However, in each age group, systematic sampling method was employed in which the patients in each age group were given numbers serially according to their age grouping, thereby giving each patient an equal chance. The random number table was used to select the first number and thereafter patients were picked at regular interval (sample interval) so as to meet the sample size requirement in each group. The sample interval was determined by dividing the total number of patients in the age groups by the sample size:

3100/316=9.81=10.

A total of 316 out patients were selected for the study, out of which 296 have complete data.

Only those with complete data taken were included in the study analysis.

Anthropometric Measurements

The weight of each adolescent subject was measured, with the subject bare footed and with light clothing, using WEYLUX weighing scale, model 424J; Sliding Beam Column Scale, (Short Pillar with height of 560mm). The measurements were recorded to the nearest one (1) kilogram (Kg). Their height was measured using ACCUSTAT Ross Stadiometer, 44817, manufactured by Genentech Incorporated. The measurements were recorded to the nearest 1cm.The BMI (for age groups 11-18 years) was then computed using the standard formula [BMI=weight (kg)/height (m^2)] [11].

Social Class of Participants

The participating adolescent's social classification was derived following the method of Oyedeji *et al.* [12], the social classification of each participating adolescent was determined based on the occupational status and highest educational attainment of the parents. The scores were summed and the mean (approximated to the nearest whole number) obtained. The mean score was used to assign the child to one of the socio-economic classes (I to V). The social classes of the subjects were further stratified into upper (social classes I and II), middle (social class III) and lower (social classes IV and V).

Lipid Profile

Blood samples were obtained from each subject by veni puncture and the samples were allowed to clot at room temperature before being centrifuged to separate the serum and frozen prior to analysis.

Serum TC concentration was measured by the end point colorimetric] with the use of T60 spectrophotometer and test kits obtainable from Spectrum diagnostic Limited. In this method, the cholesterol was determined after enzymatic hydrolysis and oxidation. The indicator quinoneimine was formed from the reaction between hydrogen peroxide and 4-aminoantipyrine in the presence of phenol and peroxidase.

Serum HDL-Cholesterol was measured with a T60 spectrophotometer with test kits obtainable from Spectrum diagnostic Limited. In this method, low density lipoprotein and chylomicron fractions are precipitated quantitatively by addition of phosphotungstic acid in the presence of

Mg_2^+ ions. After centrifugation, the cholesterol concentration in the HDL fraction which remained in the supernatant was then determined [14].

Serum LDL-Cholesterol concentration was measured with a T60 spectrophotometer with test kits obtainable from Spectrum diagnostic limited. In this method, low density lipoproteins are precipitated by heparin at their iso-electric point (pH=5.04). After centrifugation, the HDLsCholesterol and VLDL remained in the supernatant. The cholesterol concentration in the LDL fraction was determined by enzymatic method [15]. Serum Triacyl glycerol concentration was measured with a T60 spectrophotometer with test kits obtainable from Spectrum diagnostic limited. In this method, the triglycerides are determined after enzymatic hydrolysis with lipases. The indicator is a quinoneimine formed from hydrogen peroxide, 4-amino phenazone and 4-chlorophenol under the catalytic influence of peroxidase [16].

Data Analysis

The results were expressed as mean ± standard error of mean. The student- t test was used to test for significant differences. Pearson's correlation coefficients between Age, BMI and serum lipids of the subjects were computed to establish whether there is a linear relationship between the measured variables. Statistical variations were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

Results

Tables 1-3 represent the socio demographic characteristics, anthropometry and lipid profile of the adolescent subjects. From Table 1, the social class distribution of the subjects was 54(18%), 62(21%), 88(30%), 48(16%) and 44(15%) respectively for socio economic classes 1, 2, 3, 4 and 5. BMI provides the most useful population-level measure of overweight and obesity as it is the same for both sexes and for all ages [17]. From Tables 2 and 3 the mean anthropometric parameters of the male and female adolescent subjects has revealed that except for the age groups 11-12 years and 13-14 years, the female have higher though not statistically different ($p>0.05$) mean anthropometric values compared to the male adolescents. Likewise from Tables 2 and 3 with the exception of TRIGs, the female adolescents have higher though not statistically significant ($p>0.05$) serum lipid profile compared to the male adolescents.

Table 1. Socio-demographic characteristics of study subjects

Variables Age (Years)	Total (n=296)	Percentage (%)
11-12	24	8
12-13	36	12
13-14	29	10
14-15	43	15
15-16	57	19
16-17	32	11
17-18	39	13
18-19	36	12
Sex		
Male	150	51
Female	146	49
Social class		
1	54	18
2	62	21
3	88	30
4	48	16
5	44	15

All serum lipids measurements in the male and female adolescent subjects correlated positively with BMI (Fig. 1). With the highest correlation exhibited by TC (0.9485) for male adolescents and the lowest correlation exhibited by HDL-C (0.2713) for the female adolescents.

The BMI classification of the male and female adolescent subjects is presented in Fig. 2 From the figure the female adolescents have a more favorable BMI compared to the male adolescents, 18% (frequency = 26) of the female subjects were under weight, 71% (frequency = 104) were within the normal range, 9% (frequency = 13) of the study female population was found to be overweight and 2% (frequency = 3) were obese. But the difference between the adolescents is not statistically significant ($p>0.05$).

The most common form of Dyslipidemia in the adolescent subjects is low HDL-C (Table 4), with the male subjects exhibiting the highest percentage decrease (70.67%) and the female subjects the least (66.44%). The male subjects have the highest percentage elevated triglyceride (13.33%), while the female subjects have the least (10.96%). The percentage elevated LDL-C is highest in female subjects (7.53%) and lowest in male subjects (4.67%). Elevated TC was highest in female subjects (15.07%) and lowest in the male subjects (11.33%).

Discussion

The mean BMI for both the male and female adolescents in this study is in accordance with studies carried out earlier on adolescents in Katsina State Nigeria [7,8,9]. Anthropometry has been observed to vary significantly worldwide [18], but the trend of low anthropometric parameters observed in the adolescents compared to global standard is similar to what was reported in some studies conducted on adolescents anthropometry in Nigeria [19,7,8,9]. BMI as a measure of weight relative to height is a clinical diagnostic tool used to classify underweight, overweight and obesity in adults. BMI has also been demonstrated to be directly related to total cholesterol and LDL-CH [20,9,21].

The results of the prevalence of anthropometry (Underweight, normal weight, overweight and obesity) in the male and female subjects is different from the prevalence reported for adolescents from Vicosa Brazil [22] with the subjects in the present study having a comparatively lower overweight and obese but a higher normal weight values. The prevalence is also lower than the prevalence reported for adolescents from Nuevo Leon State of Mexico [21]. The prevalence of obesity in the present study is similar to the world prevalence values for adults as reported by Planchart et al., [23]. The values are also lower than the reported obesity prevalence for adolescents from Saudi Arabia [24]. But the prevalence is similar to the prevalence reported for adolescents in a study conducted in Enugu, Nigeria [2].

The low serum lipid profile observed in this study is similar to what was reported in studies on lipid profile trend in adolescents conducted in Northern Nigeria [25,19,7,8,9] and from south-western Uganda [26]. But lower than that reported in the Tehran lipid and glucose study [27].

Table 2. Mean anthropometric and serum lipid parameters in male adolescent subjects

Age (Years)	Height (m)		Weight (kg)		BMI (kg/m^2)		TC mmol/l		LDL-C mmol/l		HDL-C mmol/l		TRIG mmol/l	
11-12$_{n=12}$	1.365	±	29.418	±	15.838±		2.525	±	0.953±		0.963	±	0.843±	
	0.0107		0.4587		0.526		0.1320		0.0095		0.0176		0.0152	
12-13$_{n=18}$	1.438	±	38.008	±	16.035±		3.133	±	1.160	±	0.895	±	0.958	±
	0.0127		1.0000		0.6069		0.2175		0.0327		0.0170		0.0459	
13-14$_{n=15}$	1.495	±	38.603	±	17.315	±	2.963	±	1.108	±	0.898	±	1.098	±
	0.0099		0.8102		0.4908		0.0296		0.0216		0.1541		0.0270	
14-15$_{n=22}$	1.517	±	39.587	±	17.243	±	2.930	±	1.193	±	1.007	±	1.123	±
	0.0049		0.7110		0.4140		0.0356		0.0181		0.0109		0.0161	
15-15$_{n=29}$	1.575	±	41.628	±	16.808	±	2.965	±	1.193	±	0.978	±	1,120	±
	0.0058		0.1640		0.1948		0.0328		0.0111		0.0065		0.0154	
16-17$_{n=16}$	1.608	±	46.278	±	17.933	±	3.133	±	1.265	±	0.965	±	1.165	±
	0.0052		0.6595		0.3715		0.0999		0.0349		0.0034		0.0363	
1718n$_{=20}$	1.635	±	49.908	±	18.685	±	3.185	±	1.288	±	0.960	±	1.260	±
	0.0043		0.3801		0.2268		0.0605		0.0339		0.0037		0.1128	
18-19$_{n=18}$	1.618	±	51.610	±	19.785	±	3.355	±	1.528	±	0.950	±	1.323	±
	0.0804		0.9892		0.5765		0.0657		0.0492		0.0058		0.1155	

Values are given as Mean ± Standard Error of Mean. KEY: BMI= Body Mass Index, TC =Total Cholesterol, LDL-C= Low Density Lipoprotein Cholesterol, HDL-C=High Density Lipoprotein Cholesterol, TRIG= Triglyceride

Table 3. Mean anthropometric and serum lipid parameters in female adolescent subjects

Age (years)	Height (m)		Weight (kg)		BMI (kg/m^2)		TC mmol/l		LDL-C mmol/l		HDL-C mmol/l		TRIG mmol/l	
1112$_{n=12}$	1.363	±	23.780	±	12.793	±	2.693	±	1.310	±	0.990	±	1.153	±
	0.0060		0.1182		0.0497		0.0935		0.0247		0.0077		0.0637	
12-13$_{n=18}$	1.430	±	31.423	±	17.187	±	2.927	±	1.200	±	1.007	±	1.370	±
	0.0187		0.6425		0.8763		0.0295		0.0363		0.0059		0.0785	
13-14$_{n=14}$	1.470	±	38.182	±	16.864	±	3.156	±	1.416	±	1.070	±	1.150	±
	0.0087		1.3540		0.1764		0.0906		0.0886		0.0161		0.0374	
14-15$_{n=21}$	1.536	±	41.733	±	17.730	±	3.458	±	1.483	±	0.993	±	1.170	±
	0.0052		0.8698		0.3609		0.0739		0.1286		0.0105		0.0279	
15-16$_{n=28}$	1.550	±	44.093	±	18.845	±	3.223	±	1.243	±	1.043	±	1.013	±
	0.0057		0.9387		0.4356		0.1414		0.0683		0.0184		0.0295	
16-17$_{n=16}$	1.575	±	49.238	±	19.992	±	3.308	±	1.310	±	0.945	±	0.973	±
	0.0066		0.0625		0.3347		0.0457		0.0361		0.0083		0.0099	
17-18$_{n=19}$	1.565	±	48.450	±	19.808	±	3.335	±	1.300	±	1.028	±	1.063	±
	0.0060		0.6451		0.3737		0.0481		0.0490		0.0154		0.2637	
18-19$_{n=18}$	1.566	±	49.113	±	20.130	±	3.363	±	1.467	±	0.950	±	1.077	±
	0.0361		0.4917		0.2199		0.0368		0.0232		0.01024		0.2023	

Values are given as Mean ± Standard Error of Mean. KEY: BMI= Body Mass Index, TC =Total Cholesterol, LDL-C= Low Density Lipoprotein Cholesterol, HDL-C=High Density Lipoprotein Cholesterol, TRIG= Triglyceride

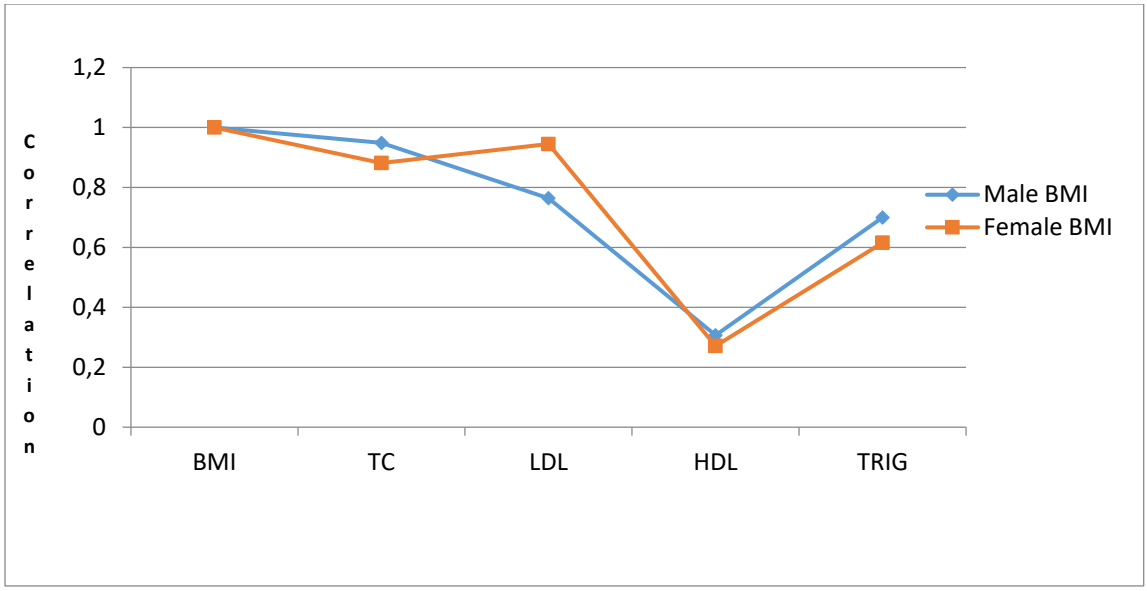


Fig. 1. Correlation between serum lipid profiles in male and female adolescent subjects with BMI

KEY: BMI= Body Mass Index, TC =Total Cholesterol, LDL-C= Low Density Lipoprotein Cholesterol, HDL-C=High Density Lipoprotein Cholesterol, TRIG= Triglyceride

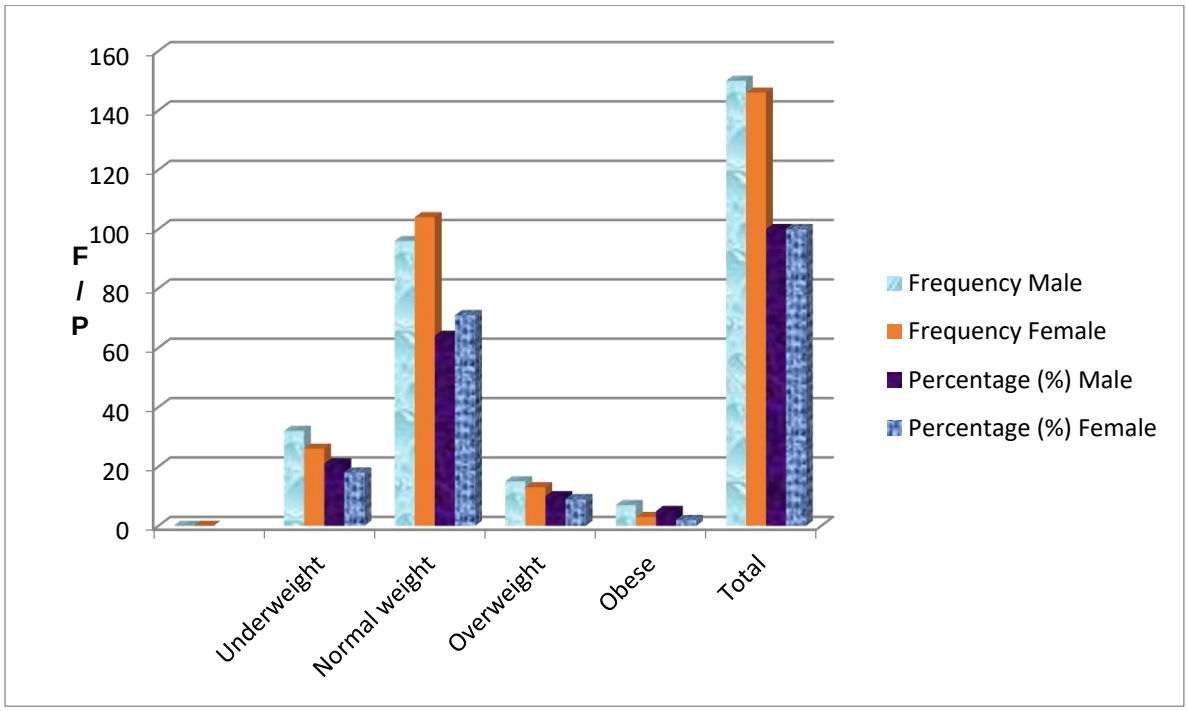


Fig. 2. Body Mass Index (BMI) classification of the male and female adolescent subjects

BMI Classification

Key= F= Frequency, P= Percentage

Table 4. Dyslipidemia (%) in the male and female adolescent subjects

Dyslipidemia	Number (%) Male (n=150)	Number (%) Female (n=146)
↑TC	17(11.33)	22(15.07)
↑LDL-C	7(4.67)	11(7.53)
↑TRIG	20(13.33)	16(10.96)
↓HDL-C	106(70.67)	97(66.44)

All serum lipids measurements with the exception of serum HDL-C concentration correlated positively with BMI, which is in line with the Bogalusa heart study [28,29,30] and the Framingham Offspring Study [31], the study of Sairam *et al.*, [32] and earlier studies conducted on lipid profile in adolescents in the Northern parts of Nigeria [25,19,7,8,9].

Elevated serum HDL-C as the most common dyslipidemia recorded in the present study is similar to findings reported in some studies [21,2,1], but differ from the studies of *Pereira et al.*, [22] and Pelegrini *et al.*, [20] that reported elevated TC as the most common dyslipidemia.

The prevalence of low HDL-C exhibited by the male and female adolescents is higher to what was reported for adolescents from Enugu, Nigeria [2] and from Sokoto, Nigeria [33] and in a Nigerian population with impaired fasting blood glucose level and diabetes mellitus [34]. But the prevalence is higher than the prevalence of low HDL-C (16.6%) reported for African-Americans [35], but falls within the range of prevalence (71.3%) reported in a rural population in South-western Uganda [26].

Prevalence of elevated TRIG in the male and female subjects in the present study is lower than the prevalence of 35% reported for female adolescents from Vicosa, and 26% for male and 33% for female adolescents from Araucaria Municipal laboratory, all in Brazil [22,1].

This study has limitation because of its cross sectional nature hence no causal relationship could be established. But the findings can be extended to populations with similar characteristics.

CONCLUSION

In a cross sectional study we demonstrated that of the total adolescent that took part in the study more than 60% have some form of dyslipidemia, with low HDL-C being the most common component. There is a need to carry out an Epidemiological study to establish a causal relationship as low HDL-C in childhood and adolescence has been linked to adverse cardio vascular events in adulthood.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee (Katsina HREC assigned number: MOH/ADM/SUB/1174/1/190) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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INFANTILE HYPERCALCEMIA TYPE 2

Doctor of Philosophy in Medicine Salehova Gunay

Scientific Research University of Pediatrics named after KY Farajova, Baku, 2025

ORCID ID: 0000-0002-2434-2377

Dr. Isgenderova Qemer

Scientific Research University of Pediatrics named after KY Farajova, Baku, 2025

ORCID ID: 0009-0004-9481-8280

ABSTRACT

Infantile hypercalcemia type 2 (IH2) is a rare inherited disorder in children caused by mutations in the CYP24A1 gene, which disrupts the proper inactivation of vitamin D, leading to excess vitamin D and high blood calcium levels (hypercalcemia). This condition manifests itself in gastrointestinal, renal, and nervous system dysfunction, requiring early diagnosis and treatment to prevent serious complications. The calcium and phosphorus balance in babies, especially newborns, is much more dynamic and sensitive than in adults. Because these minerals are vital for rapid growth and bone development. When the balance is disrupted, bone development, kidney function, and metabolism can be severely affected. This balance is regulated by parathyroid hormone, calcitonin, and vitamin D. Infantile hypercalcemia type 2 is a rare metabolic disease characterized by high calcium levels in early childhood, caused by mutations in the SLC34A1 gene. These conditions usually manifest in the first few months or years of life. The main symptoms include anorexia, vomiting, constipation, growth retardation, failure to gain weight, muscle weakness, delayed walking or gait disturbances, nephrocalcinosis, and nephrolithiasis. Our patient was admitted with complaints of physical developmental delay, weight loss, muscle weakness and vomiting. Laboratory findings include hypercalcemia, hypercalciuria, hypophosphatemia, low PTH levels, high 1.25(OH)2D vitamin, and high Calcitonin levels.

Keywords: Hypercalcemia, İnfantile, SLC34A1 gene, Nephrolithiasis.

INTRADUCTION

Hereditary hypophosphatemic rickets with hypercalciuria is an autosomal recessive form of hypophosphatemia with hyperphosphaturia, hypercalciuria, and hypercalcemia. The disease is inherited as an autosomal recessive trait. The SLC34A1 gene (Soluture Carrier Family 34 Member 1) encodes the NaPi-IIa (Sodium-Phosphate Contransporter Type IIa) protein. This protein is found in the proximal tubules of the kidneys. Its primary function is to reabsorb a portion (70-80%) of the phosphate filtered into the urine to be excreted. During infancy, hyperechoic kidneys and hypercalcemia were detected, and a patient was admitted to our clinic. The patient had hypercalciuria and nephrocalcinosis, as well as a new mutation in the SLC34A1 gene. A mutation in this gene prevents the kidneys from reabsorbing phosphate, leading to excessive phosphate loss in the urine. This leads to a decrease in blood phosphate levels. Low

phosphate levels activate vitamin D, which in turn increases calcium absorption from the intestines and raises blood calcium levels. As a result, hypophosphatemia, hypercalcemia, and hypercalciuria develop.

The patient is a 3-month-old female baby girl who was admitted to our hospital with complaints of decreased urine output, failure to gain weight, and muscle weakness. It was learned that she was the first child of the family, she was born by normal vaginal delivery with a weight of 3200 qr and the parents were consanguineous. Her body weight was 3700 qr, height – 53 cm when she was admitted to the hospital. The patient was admitted to the ward and blood samples were taken. The patient's hemogram was WBC-15.36 103/µL, RBC-3.93 103/µL, HBC-10.7g/dL, HCT-33.3%, PLT-785 103/µL. CRP-9.52mg/L, ALT-74U/L, AST-77U/L, Urine-microscopy-35-40 leukocytes, oxalate salts++; urine Calcium-38.7mg/dL, electrolytes in the blood Calcium-14.3mg/dL, Potassium-3.6mmol/L, Sodium-134mmol/L, Phosphate-1.06mmol/L, Cholecalciferol (1.25(OH)2D vitamin -100ng/mL, Parathormone-3pg/ml, Calcitonin-36.2pg/mg, Aldosterone-557ng/dL, Renal ultrasonography reveals increased exogenous kidneys, nephrocalcinosis and 2-3 mm stones.

Considering all the findings, the patient was considered to have Infantile Hypercalcemia type 2. Genetic analysis was performed in order to reach the correct diagnosis. A homozygous variant of uncertain significance was identified in SLC34A1. SLC34A1 is associated with autosomal recessive 'Hypercalcemia, infantile, 2 (OMIM: 616963). As a result, a mutation was detected in the SLC34A1 NM_003052.5:c.568G>C (NP_003043.3:p.Gly190Arg) gene and it was associated with Infantile Hypercalcemia Type 2. The patient was prescribed intravenous and oral hydration, as well as furosemide therapy. Oral administration of a phosphorus-containing solution was started. Treatment is directed at managing symptoms and preventing complications.

METHODOLOGY

Genomic DNA was extracted from EDTA blood specimen using standard protocol. Exome capture was performed using xGen Exome Research Panel v2, supplemented with xGen human mtDNA panel and xGen Custom Hyb Panel v1 (Integrated DNA Technologies, Coralville, Iowa, USA). To determine the clinical and molecular genetic characteristics of IH2 in children with biallelic variants in the SLC34A1 gene, identifying phenotypic features of the disease course and potential genotype-phenotypic associations. A retrospective analysis of the medical records of a 3-month-old girl with genetically confirmed IIH2 was performed. The child underwent molecular genetic analysis using analysis technology - whole genome and exome sequencing. The main pathogenesis is hypercalcemia due to renal phosphate loss and increased levels of active vitamin D.

CONCLUSION AND DISCUSSION

Genetic evaluation of patients with familial hypercalciuria, hypophosphatemia and nephrolithiasis is needed for further information on the prevalence and management of this rare disorder. Hereditary hypophosphatemia is a group of rare renal phosphate wasting disorders. The diagnosis is based on clinical, radiological, and biochemical features and may require genetic testing to be confirmed. Infantile Hypercalcemia Type 2 (HCINF2) is a rare genetic disorder caused by **mutations in the** SLC34A1 **gene,** which disrupts the normal breakdown of active vitamin D. As a result, infants develop **excessive levels of calcium in the blood,** leading to symptoms such as vomiting, dehydration, poor weight gain, irritability, nephrocalcinosis, and kidney dysfunction. Early recognition is essential because untreated hypercalcemia can

lead to long-term renal complications. Genetic testing and careful monitoring of calcium, vitamin D metabolites, and kidney function are key for confirming diagnosis and guiding treatment.The presence of renal crystalloids alone indicates that mutations in this gene can cause a wide range of diseases. This mutation should be considered in children with hypercalcemia accompanied by high phosphorus levels. Management focuses **on reducing calcium and vitamin D intake,** promoting hydration, and using medications that decrease vitamin D activation or calcium reabsorption. However, treatment must be individualized because infants are highly sensitive to changes in mineral metabolism. Long-term follow-up is particularly important since some children may develop chronic kidney issues despite early treatment. SLC34A1 gene also highlights the delicate balance of vitamin D metabolism in infants. While vitamin D supplementation is widely recommended for children, genetically susceptible individuals can develop severe toxicity even with standard doses. This raises the importance of assessing family history, monitoring symptoms of hypercalcemia and considering genetic causes when hypercalcemia appears without an obvious environmental explanation. Overall, increased awareness among clinicians can lead to earlier diagnosis, prevention of unnecessary complications, and improved outcomes for affected infants.

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ALLOSTERIC MODULATION OF ENZYMES AND ITS FUNCTIONAL SIGNIFICANCE IN CELLULAR METABOLISM

Sabina GULIYEVA

Biochemistry Department, Azerbaijan Medical University

Khayala MAMMADOVA

Medical and Biological Physics Department, Azerbaijan Medical University

Abstract

Allosteric regulation enables metabolic enzymes to modulate their catalytic properties in response to fluctuations in intracellular metabolites, energy status, and environmental conditions. This regulatory system relies on effector molecules that bind to non-catalytic regions of an enzyme and induce structural transitions that alter activity. Because many key enzymes of glycolysis, fatty acid biosynthesis, nucleotide metabolism, and amino acid catabolism are allosteric proteins, their modulation forms one of the central strategies by which cells maintain metabolic homeostasis. Recent structural and computational studies have broadened understanding of how conformational landscapes, dynamic residue networks, and cryptic allosteric sites contribute to regulation. These insights have simultaneously expanded opportunities for therapeutic intervention in diseases where allosteric control is impaired, including cancer, inherited metabolic disorders, and disturbances of energy balance. This paper synthesizes current knowledge of the structural principles, metabolic functions, and clinical implications of allosteric modulation, integrating classical theories with contemporary molecular findings.

Introduction

Allosteric regulation is one of the most fundamental mechanisms by which enzymes adjust their catalytic behavior to meet the changing metabolic needs of the cell. Unlike enzymes that strictly follow Michaelis–Menten kinetics, allosteric enzymes shift between different conformations that exhibit distinct affinities and activities. The binding of small regulatory molecules to sites that are spatially separate from the catalytic center triggers structural changes that propagate through the protein and modulate its catalytic efficiency. These structural transitions allow enzymes to act as metabolic sensors that interpret subtle shifts in the cellular biochemical environment. For pathways such as glycolysis, the tricarboxylic acid cycle, fatty acid synthesis, and nucleotide biosynthesis, the ability to rapidly adjust the flow of metabolites is crucial for maintaining homeostasis. Classic theoretical descriptions of these behaviors, particularly the concerted Monod–Wyman–Changeux (MWC) model and the sequential Koshland–Némethy–Filmer (KNF) model, provided the earliest explanation for cooperative binding and long-range communication within multimeric enzymes. Modern research, supported by cryo-electron microscopy and molecular dynamics simulations, now demonstrates that allosteric transitions involve a wide spectrum of structural fluctuations rather than a simple switch between two rigid states. This expanded view has transformed allostery into a broader concept encompassing

dynamic networks and energetic communication pathways distributed throughout the protein structure.

Materials and Methods

The present study was developed through an integrative literature review of peer-reviewed biochemical research published predominantly from 2020 to 2024. Relevant articles were identified using electronic databases including PubMed, Scopus, and Web of Science, with emphasis on primary experimental work involving structural analyses, enzymatic kinetics, and computational modeling of allosteric transitions. Search terms included “metabolic allostery,” “enzyme regulation,” “conformational dynamics,” and “allosteric modulation in disease.” Studies without structural or mechanistic relevance or those lacking peer review were excluded. Sources that provided detailed descriptions of regulatory interactions, cooperative effects, and clinical consequences of allosteric dysregulation were incorporated to construct a coherent conceptual narrative. Extracted information was organized thematically and synthesized to produce a continuous discussion without quantitative meta-analysis, given the variability of experimental approaches across studies.

Discussion

Allosteric modulation arises from the intrinsic capacity of enzymes to adopt energetically distinct conformations and to interconvert between them in response to environmental and metabolic signals. These transitions typically involve cooperative interactions among subunits of multimeric enzymes, enabling small fluctuations in effector concentrations to produce disproportionately large changes in catalytic activity. A clear illustration is found in phosphofructokinase-1, a central regulator of glycolysis whose activity decreases when ATP binds to its allosteric site, signaling that the cell has sufficient energy. When ATP levels drop and AMP accumulates, the enzyme shifts toward a more active conformation, accelerating glycolytic flux. The potent activation by fructose-2,6-bisphosphate overlays hormonal regulation onto this metabolic control, connecting glycolysis to systemic glucose homeostasis. At the end of glycolysis, pyruvate kinase demonstrates an equally sophisticated form of allosteric modulation by responding not only to energetic indicators but also to amino acid and lipid metabolism. Inhibition by alanine and ATP preserves carbon skeletons for gluconeogenesis during fasting, whereas activation by fructose-1,6-bisphosphate provides feed-forward coordination between sequential glycolytic steps. Similar regulatory logic appears in fatty acid biosynthesis, where acetyl-CoA carboxylase becomes highly active in the presence of citrate but is suppressed by long-chain acyl-CoAs, thereby balancing lipogenesis with nutrient availability. In amino acid catabolism, glutamate dehydrogenase integrates mitochondrial redox and energy states, with its activation by ADP promoting flux during low-energy conditions and its inhibition by GTP dampening oxidative deamination when energy is sufficient. Mutations that disrupt this inhibition can trigger persistent hyperinsulinism and hyperammonemia, emphasizing how sensitive metabolic homeostasis is to disturbances in allosteric control. Nucleotide biosynthesis also depends on allosteric sensing, particularly through carbamoyl-phosphate synthetase II, which responds to ATP, PRPP, and UTP in a manner that precisely matches nucleotide production with cellular demand. Excessive activation of this enzyme in proliferating cells enhances pyrimidine synthesis and supports pathological growth, offering a rationale for targeting CPS-II and related enzymes in anticancer therapy.

Contemporary structural biology has greatly refined the understanding of how allosteric signals propagate. Rather than functioning as rigid switches, allosteric enzymes appear to operate through networks of flexible residues linked by energetic coupling, enabling subtle movements at distal sites to influence catalytic geometry. Molecular dynamics simulations demonstrate that

these networks can include residues far from both effector and catalytic sites, indicating that allostery is distributed across the protein. A particularly important recent discovery is the presence of cryptic allosteric sites—transient pockets that emerge only in specific conformations and are invisible in static crystal structures. These regions have become attractive targets for drug development because they provide opportunities to design highly selective modulators capable of fine-tuning enzyme activity rather than completely inhibiting it. Such precision is especially valuable in cancer therapy, where mutant metabolic enzymes such as isocitrate dehydrogenase produce pathological metabolites that contribute to malignancy. Allosteric inhibitors that stabilize non-pathogenic conformations of mutant IDH have already achieved clinical success, demonstrating the therapeutic promise of targeting structural dynamics rather than active sites. Similarly, pharmacologic activation of pyruvate kinase M2 can shift cancer cells away from aerobic glycolysis and limit their proliferative capacity.

Conclusion

Allosteric regulation constitutes one of the most versatile and finely tuned mechanisms of metabolic control in living cells. Its reliance on cooperative conformational transitions allows enzymes to rapidly adapt catalytic behavior to fluctuating physiological conditions and to integrate complex biochemical signals into coherent metabolic responses. Modern structural and computational research has deepened insight into the mechanisms governing allostery, revealing dynamic residue networks and previously unrecognized regulatory pockets that extend far beyond classical allosteric descriptions. These discoveries have enriched the biochemical understanding of metabolic homeostasis and opened new avenues for drug development, especially in disorders where enzymatic regulation is disrupted. Continued exploration of conformational landscapes and long-range communication within proteins will be essential for developing the next generation of allosteric therapeutics and for advancing comprehension of how cells achieve such remarkable precision in regulating metabolism.

Keywords: allosteric modulation, enzymes, cellular metabolism

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INTEGRATED RENAL MECHANISMS OF FLUID AND ELECTROLYTE HOMEOSTASIS

Dilara ALIYEVA

Normal Physiology Department, Azerbaijan Medical University

Tariyel ISMAYILOV

Normal Physiology Department, Azerbaijan Medical University

Asiya AGHAYEVA

Normal Physiology Department, Azerbaijan Medical University

Mehriban KAZIMOVA

Normal Physiology Department, Azerbaijan Medical University

Khayala MAMMADOVA

Medical and Biological Physics Department, Azerbaijan Medical University

Abstract

The kidneys maintain internal constancy through the regulation of fluid volume, osmolarity, and electrolyte concentrations. These functions rely on tightly coordinated mechanisms of glomerular filtration, tubular reabsorption and secretion, and hormonal regulation. Advances in renal physiology have clarified the roles of segment-specific transporters, including NKCC2, NCC, and ENaC, and expanded understanding of neurohormonal systems such as the renin–angiotensin–aldosterone system (RAAS), vasopressin–aquaporin pathways, and natriuretic peptides. This article summarizes the integrated processes that sustain normal fluid and electrolyte homeostasis and highlights their relevance for blood pressure regulation, potassium balance, and clinical disorders such as hypertension and chronic kidney disease.

Introduction

Renal control of body fluid and electrolyte balance depends on the highly specialized structure of the nephron and the precise regulation of tubular transport processes. Although glomerular filtration rate (GFR) remains a key index of kidney function, modern physiology emphasizes that tubular transport mechanisms—particularly in the proximal tubule, loop of Henle, distal convoluted tubule, and collecting duct—are the critical determinants of daily sodium, water, and potassium balance [1].

The proximal tubule reabsorbs approximately two-thirds of filtered sodium and water using apical transporters such as the Na^+/H^+ exchanger and sodium-dependent cotransport systems. These processes are coupled to basolateral Na^+/K^+-ATPase, creating the electrochemical

gradient that drives reabsorption [1,2]. Proximal reabsorption is influenced by peritubular capillary forces and plays a central role in glomerulotubular balance, enabling stability even under fluctuating GFR.

The loop of Henle contributes to the establishment of the corticomedullary osmotic gradient, essential for the concentration of urine. The thick ascending limb reabsorbs sodium, potassium, and chloride via the NKCC2 cotransporter while remaining impermeable to water, producing progressive dilution of tubular fluid [3]. This countercurrent multiplication system enables vasopressin-dependent water reabsorption in downstream segments.

Fine control of sodium excretion occurs in the distal convoluted tubule and collecting duct, where the Na^+–Cl^- cotransporter (NCC) and epithelial sodium channel (ENaC) are tightly regulated by aldosterone and other hormonal signals [4]. Aldosterone increases ENaC activity and Na^+/K^+-ATPase expression, promoting sodium retention and potassium secretion. Small modifications in this segment can produce large cumulative effects on extracellular fluid volume and blood pressure.

The RAAS system is central to long-term blood pressure and volume regulation. Renin release leads to angiotensin II formation, which stimulates aldosterone secretion, enhances proximal sodium reabsorption, induces vasoconstriction, and increases thirst [5]. Opposing this, natriuretic peptides promote vasodilation, suppress renin release, and increase natriuresis, thereby reducing extracellular volume.

Water balance is primarily controlled by the vasopressin–aquaporin-2 pathway. Vasopressin, released in response to increased plasma osmolarity, binds to V_2 receptors in the collecting duct, stimulating the insertion of aquaporin-2 channels and increasing water permeability [6]. This system allows rapid adjustments in urine concentration and prevents significant fluctuations in plasma osmolarity.

Potassium homeostasis depends on secretion by principal cells in the distal nephron. Aldosterone plays a key role by enhancing ENaC activity and increasing the electrochemical gradient that favors potassium secretion [4,7). Intercalated cells reabsorb potassium during deficiency, demonstrating the kidney's bidirectional regulatory capacity.

Calcium and phosphate balance are maintained through distinct tubular pathways. Calcium reabsorption in the distal tubule is tightly regulated by parathyroid hormone and vitamin D, while phosphate reabsorption in the proximal tubule is controlled by sodium–phosphate cotransporters modulated by fibroblast growth factor-23 [8].

Interactions between renal and cardiovascular systems are central for maintaining blood pressure. The pressure-natriuresis mechanism increases sodium excretion during elevated arterial pressure and is impaired in salt-sensitive hypertension [5,9]. In states such as heart failure, enhanced RAAS and vasopressin activity lead to pathologic sodium and water retention.

Pharmacologic agents targeting renal transporters have provided insights into physiology. Loop diuretics inhibit NKCC2, thiazides inhibit NCC, and mineralocorticoid receptor antagonists block aldosterone effects. SGLT2 inhibitors, originally developed for diabetes, reduce sodium and glucose reabsorption in the proximal tubule and improve outcomes in heart failure and chronic kidney disease [10].

Conclusion

Renal fluid and electrolyte homeostasis is achieved through precise interactions among tubular transport mechanisms, hormonal systems, and hemodynamic forces. The proximal tubule

performs bulk reabsorption, while the loop of Henle generates osmotic gradients essential for concentration. Distal nephron segments fine-tune sodium, potassium, and water excretion under the influence of aldosterone and vasopressin. Dysfunction in these systems contributes to major clinical disorders such as hypertension, heart failure, and renal disease. Understanding these physiological principles provides a strong foundation for interpreting electrolyte abnormalities and optimizing therapeutic strategies.

Keywords: renal mechanisms of fluid, electrolyte homeostasis, clinical disorders

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TELE-NURSING INTERVENTIONS IN CHRONIC DISEASE MANAGEMENT: IMPACTS ON PATIENT SAFETY, DIGITAL HEALTH LITERACY, AND HEALTH INEQUITIES

Dr. Öğr. Üyesi Esin KAVURAN

Atatürk Üniversitesi Hemşirelik Fakültesi, Hemşirelik Esasları ABD

0000-0003-3791-102X

Dr. Öğrencisi, Hasan SAĞLAM

Atatürk Üniversitesi Hemşirelik Fakültesi, Hemşirelik Esasları ABD

0000-0002-8307-6996

Abtract

Introduction: The increasing prevalence of chronic diseases has highlighted the need for continuous and sustainable care models. Tele-nursing, through information and communication technologies (ICT), provides remote care, monitoring, counseling, and education, and is increasingly utilized in chronic disease management. The literature indicates that tele-nursing interventions have significant impacts on patient safety, digital health literacy, and access-related health inequities. In this context, tele-nursing has the potential to support early detection of symptoms, continuity of care, and improved accessibility.

Objective: This review aims to examine the effects of tele-nursing interventions on patient safety, digital health literacy, and health inequities in chronic disease management, based on current literature.

Methods: This study is a comprehensive literature review of recent research and review articles published between 2020 and 2025. Searches were conducted in PubMed, Scopus, and Web of Science using the keywords “tele-nursing,” “chronic disease management,” “digital health literacy,” and “health inequities.” Included studies evaluated the impact of tele-nursing interventions on chronic disease management using qualitative, quantitative, and mixed-method approaches.

Results: Tele-nursing interventions were found to enhance patient safety in chronic disease management. Nurse-led tele-home care programs facilitate early detection of clinical changes, reducing emergency visits and mortality. During pandemic periods, tele-nursing minimized infection risks, protecting both patients and healthcare personnel. Regarding digital health literacy, tele-nursing applications provide counseling and educational services via digital platforms, improving patients’ ability to use digital tools for self-management. In terms of health inequities, tele-nursing has the potential to improve care access by overcoming geographical barriers. However, socio-economic factors, limited digital access, and low digital literacy continue to create disparities among certain patient groups.

Conclusion: Tele-nursing offers significant contributions to patient safety and continuity of care in chronic disease management. Educational interventions supporting digital health

literacy enhance patients' engagement in their own care. Nevertheless, fully leveraging tele-nursing to reduce health inequities requires addressing digital access, technological infrastructure, and training needs. Further research in these areas can help make tele-nursing applications more inclusive and effective.

Keywords: Tele-nursing, Chronic disease management, Patient safety, Digital health literacy, Health inequities, Remote care

Introduction

The rapid advancement of digital health technologies has led to profound transformations in the delivery of healthcare services and has expanded the scope of nursing practice. One of the key components of this transformation is tele-nursing, which has become a fundamental pillar of modern healthcare systems by enabling the remote delivery of nursing care through information and communication technologies. In particular, the global increase in chronic diseases, an ageing population, shortages of healthcare professionals, and barriers to access have further intensified the necessity and importance of remote care models. Tele-nursing contributes to the development of patients' self-management skills, ensures continuity of care, and facilitates the early identification of complications, thereby offering significant health benefits at both individual and societal levels. Tele-nursing practices encompass a wide range of services, including digital education, remote monitoring, post-discharge care, chronic disease management, and psychosocial support, and play a supportive role in clinical decision-making processes. However, issues such as data security, ethical responsibilities, and digital health literacy are of critical importance for the effective and safe delivery of these services. As technological advancements continue to accelerate the integration of nursing practice into digital environments, an in-depth examination of the scope, models, and application areas of tele-nursing has become an academic and clinical necessity.

Tele-Nursing in Chronic Disease Management

Tele-nursing is a model that utilises digital health tools to deliver nursing services remotely (Zhou, 2025). Its core components include the provision of remote care, the use of information and communication technologies, interdisciplinary collaboration, and support for patients' self-management (Asbath, 2025).

Tele-Nursing Models and Areas of Application

Tele-nursing is implemented through various models in order to ensure continuity of care, support self-management, and improve clinical outcomes in individuals with chronic illnesses. Within the scope of digital education models, nurse-led tele-education programmes for individuals with chronic obstructive pulmonary disease (COPD), type 2 diabetes, and cardiovascular diseases aim to enhance patients' self-care skills through individualised educational content, asynchronous reinforcement, and structured follow-up processes (Cianciulli, 2025). Tele-nursing interventions developed to ensure continuity of post-discharge care particularly support home-care processes among older adults, strengthening caregivers' knowledge and practices and increasing patients' levels of self-efficacy (Mohamed, 2022). In the management of chronic pain, web-based interventions and telemedicine applications are widely utilised by nurses; these digital approaches provide psychosocial interventions and have been shown to yield effective outcomes (Lee, 2025). In rheumatic musculoskeletal diseases, tele-nursing is considered a model that contributes to the strengthening of patient-centred care,

particularly among patients receiving biological therapies, and its potential in this field is being increasingly investigated (Melis, 2022).

Monitoring, Education, and Counselling Roles in Chronic Diseases

In chronic disease management, tele-nursing is defined as an innovative model that enables the remote delivery of nursing care through information and communication technologies (Asbath, 2025). The increasing demand for healthcare services, an ageing population, and the global shortage of healthcare professionals have positioned tele-nursing as a key practice that both enhances care efficiency and expands access to healthcare services (Asbath, 2025). This model facilitates the support of remote monitoring, assessment, and clinical decision-making processes through digital tools, enabling nurses to follow patients continuously and systematically. Information sharing, bidirectional communication, and interdisciplinary collaboration are fundamental components that enhance the quality of care in tele-nursing practices.

Within tele-nursing, education, monitoring, and counselling constitute central roles. In the educational dimension, nurses deliver structured educational programmes via digital platforms on topics such as self-care, dietary management, blood glucose monitoring, and medication reminders for individuals with chronic illnesses (Cianciulli, 2025; Zhou, 2025). In addition, psychosocial interventions—including exercise, cognitive-behavioural therapy, and self-management techniques—are implemented digitally in chronic pain management, while rheumatology nurses conduct planned interventions focused on accurate data collection and patient education (Lee, 2025; Melis, 2022). With regard to the monitoring role, tele-nursing enables continuous remote assessment of patients' health status. Blood glucose monitoring is identified as a prominent need within tele-nursing services for patients with diabetes. In the counselling role, patients actively use tele-nursing applications as a source of guidance on health education, lifestyle modifications, and dietary counselling (Zhou, 2025).

Digital Tools Used in Tele-Nursing

A variety of digital tools are used in tele-nursing:

Telehealth and Web-Based Interventions: These are digital nursing practices that incorporate technologies such as internet-based video consultations, live chat, mobile health applications, and telephone-based counselling (Lee, 2025). These tools aim to improve patient outcomes, enhance accessibility, and ensure continuity of care across different healthcare settings (Asiri, 2025). While nurses use digital interventions such as exercise training, cognitive–behavioural therapy, and self-management techniques in the management of chronic pain (Lee, 2025), they utilise remote monitoring, virtual consultations, and mobile health tools in primary cardiac care (Asiri, 2025). Telehealth systems also increase access and convenience in mental health services by providing telephone- and internet-based social support (Bright, 2023). Digital tools designed for family caregivers offer functions such as education, counselling, psychosocial support, and data monitoring (Chi, 2015), while telehealth applications in school health services play an important role in health education, mental health monitoring, and early detection processes (Margañon, 2023). In addition, the combination of web-based eHealth and telephone nurse case management in paediatric asthma management represents an effective digital approach to improving asthma control in children (Gustafson, 2012).

Mobile Health (mHealth) Technologies: mHealth technologies are widely used in nursing practice and make significant contributions to disease prevention, reduction of risk factors, and improvement of quality of life. Mobile health applications support nurses in clinical processes such as diagnosis, treatment, feedback provision, and patient monitoring, thereby enhancing the effectiveness of care. Moreover, mHealth strengthens patients' self-care skills, enabling them

to monitor and manage their health status more closely, and thus contributes to the updating of self-care models in modern nursing (Choi, 2023). Mobile applications developed for nursing students are also used as effective tools to improve physical and mental health habits, supporting students' wellbeing and professional resilience (Sittig, 2022).

Digital Medication Management Tools: Digital medication management tools encompass a range of technological solutions developed to improve medication adherence and strengthen medication safety (Mason, 2021). These tools aim to enhance treatment effectiveness by supporting patients in taking their medications at the correct dose and at the correct time (Galhardi, 2024). Electronic pill boxes and bottles monitor medication intake, while ingestible sensors can directly track medication ingestion within the body (Mason, 2021). Electronic medication management systems and blister packaging technologies contribute to monitoring adherence by evaluating medication-use processes more comprehensively. Technologies based on patient self-reporting, video-based or motion-sensor monitoring systems, and mHealth applications also provide reminders, educational content, and monitoring features related to medication intake (Galhardi, 2024). Digital tools such as smart pill dispensers, wearable devices, digital inhalers, e-injection pens, and e-prescription systems make medication use more reliable in both chronic disease management and treatments requiring injections or inhalers (Zhamharyan, 2025).

These technologies support patients' treatment processes by providing features such as real-time monitoring, audiovisual reminders, digital displays, and feedback on adherence performance. However, usability of the products and their impact on healthcare professionals' workload emerge as key determinants of the adoption and effectiveness of digital medication management tools.

Remote Monitoring: Remote patient monitoring (RPM) is an approach that enables the monitoring of patients' health status and vital signs outside traditional healthcare settings through the use of technological tools. By providing healthcare professionals with real-time patient data, this approach facilitates faster and more effective clinical decision-making, while aiming to improve quality of care by saving time and costs for patients (Hathaliya, 2019). Key technologies used in RPM include wearable sensors that monitor physiological parameters and medication adherence (Ghavghave, 2025), mobile applications that facilitate health data tracking and interaction with healthcare professionals (Carlson, 2021), home monitoring systems that measure critical indicators such as SpO_2, temperature, and heart rate (Bhise, 2025), wireless communication infrastructures that ensure secure data transmission, and Internet of Things (IoT) technologies that enable real-time data collection from multiple devices (Ghavghave, 2025). The use of remote monitoring technologies increased rapidly during the COVID-19 pandemic, particularly enabling effective monitoring of physiological parameters in pulmonary medicine; moreover, in neurological conditions such as Parkinson's disease, remote visits and follow-up applications have demonstrated significant potential to improve access to care (Ilowite, 2021).

Examples of Evidence-Based Tele-Nursing Practices

Evidence-based tele-nursing practices demonstrate effective outcomes across a wide range of areas, from chronic disease management and intensive care processes to educational models and paediatric oncology. The PROSELF study showed that a 12-month nurse-led digital education programme for individuals with COPD, diabetes, and cardiovascular disease significantly improved treatment adherence and self-care behaviours (Cianciulli, 2025). During the COVID-19 pandemic, tele-nursing strategies used to support continuity of post-discharge care among older adults were found to enhance caregivers' knowledge and practices and to increase patients' levels of self-efficacy (Mohamed, 2022). In chronic pain management,

telemedicine and web-based interventions provide effective psychosocial support and make substantial contributions to the treatment process (Lee, 2025). The literature also highlights the potential of tele-nursing to reduce hospital readmission rates, increase patient satisfaction, and support chronic disease management (Asbath, 2025).

Tele-nursing models implemented in Tele-Intensive Care Units (Tele-ICUs) integrate information systems, telecommunications, and telemedicine technologies to deliver expert, evidence-based care to critically ill patients, contributing to improvements such as enhanced ventilator weaning practices, reduced mortality, and shorter lengths of hospital stay. In paediatric oncology, tele-practice guidelines are based on evidence derived from case reports and clinical examples in symptom management and serve as a useful resource for healthcare professionals providing telephone-based counselling. In school health services, telemedicine-supported nursing practices are effective in areas such as health education, mental health management, and early diagnosis, strengthening school nurses' roles in remote monitoring and management (Margañon, 2023). In addition, the integration of telemedicine simulations into nurse practitioner education curricula supports students' preparation for digital care delivery and fosters positive perceptions of robot-assisted telemedicine technologies (LaManna, 2021).

Tele-Nursing and Patient Safety

The Concept of Patient Safety and Risks in the Telehealth Context

Patient safety refers to the prevention of harm to patients during the delivery of healthcare services. In the context of telehealth, patient safety may be influenced by factors such as quality of care and the patient–healthcare professional relationship (Keenan, 2022). Risk factors identified in telehealth practices include environmental factors (lack of private spaces for vulnerable populations, difficulties in sharing sensitive health information remotely), technological factors (data security issues, limited access to the internet and technology), and operational factors (reimbursement, accessibility of technology, and training) (Houser, 2023). Both patients and practitioners perceive telehealth as potentially more harmful when it creates new or increased risks of harm compared with face-to-face care (Keenan, 2022).

Safe Monitoring and Intervention Strategies in Tele-Nursing

Safe monitoring and intervention strategies in tele-nursing are particularly important for patients with chronic illnesses. In patients with rheumatic diseases, a tele-monitoring programme aimed at strict control of treatment safety has been evaluated using an app-based, nurse-supported approach. In this programme, treatment effectiveness was assessed through patient-reported outcomes (PROs) and wearable devices, while safety was enhanced through remote vital sign measurement and tele-nursing. Deterioration in vital signs triggered automated alerts, enabling timely corrective actions (Fedeli, 2023). Tele–Intensive Care Unit (Tele-ICU) systems improve nursing care by providing real-time monitoring and consultation for critically ill patients. By ensuring continuous surveillance, these systems enhance adherence to best practices and allow nurses to offer real-time support as a "second set of eyes" (Alruqi, 2024).

The Contribution of Tele-Nursing to the Prevention of Clinical Errors

Tele-nursing can contribute to the prevention of clinical errors in several ways. Tele-ICU programmes may reduce patient safety incidents by supporting continuous monitoring and increasing compliance with best practices (Alruqi, 2024). Tele-monitoring programmes have also been found beneficial in cases where a patient with rheumatic disease experienced infection in the presence of high levels of comorbidity, as well as in another case involving a dosage error following the initiation of a new treatment (Fedeli, 2023).

Remote Monitoring of Vital Signs and Early Detection of Potential Complications

Remote monitoring of vital signs is a key component of tele-nursing and plays a critical role in the early detection of potential complications. In a tele-monitoring programme developed for patients with rheumatic diseases, contactless optical vital sign measurement was utilised (Fedeli, 2023). Deterioration in vital signs triggered automated alerts—categorised as green, yellow, and red—allowing for timely corrective interventions (Fedeli, 2023). Tele-ICU systems also enable continuous monitoring of critically ill patients, facilitating early identification of complications and prompt intervention (Alruqi, 2024).

Data Security, Privacy, and Ethical Responsibilities

Data security and privacy are of critical importance in telehealth services due to risks inherent in technological infrastructures. When combined with factors such as limited internet access, data security challenges threaten the confidentiality of patient information and hinder the effective delivery of services (Houser, 2023). With the increasing use of electronic health records, connected medical devices, and artificial intelligence–supported tools, healthcare organisations must balance the need to protect sensitive data with the requirement to share information for clinical care, research, and public health purposes. Overly restrictive security measures may disrupt urgent care processes or slow research, whereas inadequate data protection practices can seriously undermine patient privacy and trust.

Ethical responsibilities also constitute a significant dimension of telehealth services. Differences in how ethical principles are perceived by practitioners and patients may directly affect the quality and safety of care (Keenan, 2022). While existing ethical guidelines tend to focus on macro-level issues such as technological processes and data security, healthcare professionals often face challenges in adapting these guidelines to the micro-level contexts of patient interactions (Kuziemsky, 2020). Ethical issues and patient safety concerns in tele-palliative care, particularly from the caregiver perspective, require further investigation (Schuessler, 2023). Therefore, the development of standardised and context-specific practice guidelines that ensure equitable access, quality of care, financial sustainability, professional accountability, respect for patient privacy, and robust data protection is of paramount importance in telehealth services (Solimini, 2021).

The Impact of Tele-Nursing Interventions on Digital Health Literacy

Definition and Importance of Digital Health Literacy

Digital health literacy (DHL) refers to individuals' ability to locate, understand, evaluate, and apply digital health information (Turchioe, 2023). With the digitalisation of healthcare services, this concept has attracted increasing attention within the academic community. DHL has significant potential to improve health outcomes, bridge the digital divide, and reduce health inequalities (Yang, 2021). The importance of DHL is emphasised as individuals' capacity to critically appraise and wisely use online health information (Azahra, 2024). Healthcare providers are required to take consumers' eHealth literacy into account when using digital health technologies (Lee, 2025). DHL is also crucial for understanding the potential challenges of digital health technologies—such as telehealth, wearable sensors, and smartphone applications—among individuals with chronic conditions, including Parkinson's disease (Esper, 2024). Within the context of organisational health literacy, the importance of digital health is likewise increasing; organisations must ensure equitable support for individuals to understand and use digital information and services.

Levels of Digital Health Literacy in Individuals with Chronic Conditions

Levels of digital health literacy among individuals with chronic conditions are generally low. In particular, older adults with chronic illnesses face constraining factors such as cognitive blind spots and fundamental skill deficits in digital adaptation. However, drivers influencing DHL include the accessibility of digital health resources, perceived value, and management needs (Shao, 2025). A meta-analysis reported a mean perceived eHealth literacy (eHEALS) score of 27.03 among patients with diabetes, hypertension, and rheumatoid arthritis, suggesting an overall high level of DHL; nevertheless, the limited number of studies restricts comprehensive analysis. Factors such as age, education, employment status, and perceiving the internet as a health resource influence DHL levels (Zaghloul, 2025). Among individuals with multiple chronic conditions, higher health literacy increases the likelihood of using digital media to seek health information (Kim, 2025). DHL has been reported to have a positive impact on chronic disease management and health outcomes (Yuen, 2023). However, among migrant populations with chronic conditions, DHL levels have been observed to be low, with persistent barriers to the effective use of digital health tools (Garcia, 2025).

Effects of Tele-Nursing Education on Knowledge, Skills, and Self-Efficacy

Tele-nursing education has been shown to have positive effects on patients' knowledge, skills, and self-efficacy. For example, following tele-nursing-supported discharge, a significant reduction in maternal anxiety and an increase in mothers' self-efficacy in caring for their children were observed (Seif, 2025). Education and monitoring delivered via tele-nursing for older cancer patients using oral anticancer agents were found to positively influence patients' self-efficacy and medication adherence (Başoğlu, 2024). A study examining the effect of tele-nursing on self-efficacy among patients with myocardial infarction demonstrated a statistically significant increase in self-efficacy scores in the group receiving tele-nursing interventions (Keshavaraz, 2020). Similarly, a tele-nursing educational intervention in haemodialysis patients resulted in significant improvements in self-efficacy and quality of life. Moreover, tele-nursing education was reported to be effective in increasing haemodialysis patients' knowledge levels and adherence to treatment regimens (Selima, 2023).

The Relationship Between Digital Health Literacy and Technology Acceptance Models

Digital health literacy is closely associated with technology acceptance models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT). These models are widely used to predict the adoption of mobile health applications (mHealth apps) and other digital health technologies (Adnan, 2025; Fauzi, 2025). Relationships among the core constructs of TAM—perceived usefulness, perceived ease of use, and behavioural intention—have been validated. Among extended TAM constructs, digital literacy, trust, and application-related factors demonstrate significant predictive capacity (Adnan, 2025). In particular, digital literacy has been examined within the UTAUT2 framework as an important factor influencing older adults' willingness to adopt wearable devices (Wu, 2024).

At the individual level, digital determinants of health (DDoH), including access to technological tools and digital health literacy, influence patient portal enrolment and use. Alongside perceived ease of use and perceived usefulness, digital health literacy has been found to be significantly associated with patient portal registration.

While health literacy dimensions positively affect the perceived ease of use of teleconsultation, the comprehension and access dimensions have been shown to have a surprisingly negative effect on perceived usefulness. Trust has emerged as a significant mediating factor between literacy and the adoption of teleconsultation (Lebrument, 2025).

A study examining the acceptance of virtual coaching systems among an ageing population extended TAM with new external determinants, including subjective norms, health literacy, and information technology literacy. Health literacy was found to have a significant but negative effect on the perceived usefulness of virtual coaching systems, while exerting a positive and significant influence on perceived ease of use (Pinzone, 2025).

The ways in which high and low levels of eHealth literacy influence the relationships between the Technology Readiness and Acceptance Model (TRAM) and attitudes towards, and intentions to use, digital health technologies have also been investigated. Findings partially support the role of eHealth literacy in encouraging older adults to use digital health technologies and to derive health benefits from them (Kim, 2025).

Overall, TAM and UTAUT provide important frameworks for understanding the role of digital health literacy in the adoption of digital health technologies. These models are increasingly applied alongside extended constructs such as psychological factors, health literacy, regulatory readiness, security concerns, and infrastructural constraints (Fauzi, 2025).

Tele-Nursing and Health Inequalities

Inequalities in Access to Telehealth

Health inequalities refer to differences in individuals' access to healthcare services that arise from social determinants such as socioeconomic status, geographical location, age, level of education, and ethnicity. These inequalities have significant implications for the management of chronic diseases (Feng, 2025). The primary driver of inequalities in access to telehealth is the *digital divide*, which describes disparities in access to and use of technology (Nakayama, 2023). The digital divide is particularly pronounced among socioeconomically disadvantaged groups, older adults, individuals living in rural areas, and minority populations (Medero, 2021).

Limited internet access among rural and low-income populations reduces the likelihood of using telehealth services (Ko, 2023). Studies conducted in Brazil and the United States have shown lower telehealth utilisation among older adults, rural residents, individuals with low income, and Hispanic communities (Nakayama, 2023). Although overall telehealth use increased during the COVID-19 pandemic, this increase was not observed to the same extent among minority groups and low-income communities (Ko, 2023). Medicare data indicate that telehealth utilisation is lower among African Americans, Hispanics, and Indigenous populations compared with non-Hispanic White individuals (Bhagavathula, 2024). In addition, older adults and individuals living in underserved areas are less likely to use video-based consultations (Cousins, 2022).

Socioeconomic disadvantage, low health literacy, limited language proficiency, and lower educational attainment are additional factors that negatively affect the telehealth experience (Yoon, 2024). For example, higher mortality rates have been reported among minority groups with breast cancer due to unequal access to the internet and telehealth services (Bayard, 2022). The digital divide not only affects telehealth utilisation but also influences online health information-seeking behaviour, with home computer and mobile access playing a decisive role in this process (Medero, 2021).

Similar inequalities are observed in tele-nursing practice. Lack of technological skills, insufficient access to devices, and challenges related to digital literacy hinder the effective use of tele-nursing among disadvantaged groups. Infrastructure deficiencies and digital exclusion in rural areas further limit the potential of telehealth innovations. Moreover, the increasing use

of artificial intelligence in nursing carries the risk of exacerbating inequalities due to algorithmic bias (Asbath, 2025).

Among vulnerable populations, such as individuals living with HIV, limited familiarity with technology and technical barriers impede the adoption of telehealth (Auchus, 2021). Although nurse-led mobile health clinics have the potential to reduce these inequalities, various structural barriers constrain the large-scale implementation of such models (Nadeau, 2025).

The Potential of Tele-Nursing to Reduce Inequalities

Tele-nursing is regarded as an important tool for reducing health inequalities due to its capacity to enhance access to healthcare services and overcome geographical barriers (Asbath, 2025; Ajayi, 2025). Evidence indicates that tele-nursing interventions improve care delivery and expand access to services, particularly in communities with limited access to healthcare, including those living in rural and remote areas (Asbath, 2025). By mitigating barriers related to geographical distance, transportation difficulties, and shortages of healthcare professionals, tele-nursing systems enable patients to receive timely care and contribute to the reduction of inequalities (Ajayi, 2025). For instance, telehealth applications have been reported to facilitate access to specialist care and support equity in care among individuals with breast cancer (Bayard, 2022). In addition, nurse-led digital health interventions have been shown to improve cardiovascular health in patients who have experienced stroke, with greater effectiveness observed among individuals with higher levels of digital health literacy (Asiri, 2025). The emergence of nurse-managed mobile health clinics as a scalable model that increases access to care in disadvantaged communities further reinforces the potential of tele-nursing to reduce inequalities (Nadeau, 2025).

However, declining trends in telehealth use and widening digital access disparities among older adults, low-income individuals, rural populations, and patients with lower educational attainment indicate that the inequality-reducing impact of tele-nursing is not experienced equally by all individuals (Shilane, 2023). Strengthening nursing capacity, fostering a culture of health, and adopting holistic approaches that take social determinants into account are critical to reducing health inequalities (Sedlak, 2022).

To fully realise the potential of tele-nursing in reducing inequalities, it is essential to strengthen practices grounded in accessibility, cultural appropriateness, and ethical principles. From an accessibility perspective, disparities in digital literacy and reliable internet infrastructure constitute significant barriers, particularly for low-income individuals, older adults, and those living in rural areas (Alrebh, 2024). Consequently, investment in digital infrastructure, support for access to technology, and the development of user-friendly telehealth platforms are required. In terms of cultural appropriateness, digital empathy and cultural sensitivity are identified as core elements of effective tele-nursing practice; enhancing nurses' cultural competence has been shown to improve the quality of patient care and mitigate the negative effects of social determinants. Within an ethical framework, issues such as patient privacy, data security, informed consent, and digital competence are of central importance in telehealth practice. Strengthening ethical practice in telehealth requires trust-based communication, enhancement of professionals' digital competencies, and the development of telehealth-related competencies within nursing education. It has been emphasised that the accurate assessment of ethical sensitivity plays an important role in preventing ethical discordance in telehealth practice (Zhou, 2025).

Effectiveness of Tele-Nursing Interventions

Tele-nursing interventions provide substantial benefits across multiple domains, including clinical outcomes, patient satisfaction and quality of life, medication and treatment adherence, impacts on healthcare professionals, and cost-effectiveness (Asbath, 2025; Ajalli, 2015). Evidence indicates that tele-nursing has the potential to reduce hospital readmission rates, prevent complications, and decrease mortality among patients with chronic conditions. Tele–Intensive Care Unit (Tele-ICU) nursing surveillance can enhance patient safety by enabling the early detection of potential harm in critically ill patients (Goran, 2012). Significant improvements have been reported in functional capacity, pain, joint findings, and overall disease status among children with rheumatoid arthritis, as well as reductions in readmission rates and length of hospital stay among patients with schizophrenia (Amer, 2022).

The impact of tele-nursing on patient satisfaction and quality of life is also noteworthy. Among patients with pulmonary fibrosis, a 28% increase in patient satisfaction and a 30% increase in caregiver satisfaction have been reported (Baiges, 2025). Improvements in physical and psychological quality of life have been observed in children with rheumatoid arthritis, while positive effects across multiple dimensions of quality of life have also been demonstrated in patients with cancer. An enhanced patient experience strengthens psychological well-being and contributes to improved quality of care and greater adherence to treatment. Tele-nursing interventions further support medication and treatment adherence, thereby increasing the effectiveness of chronic disease management. Increased medication adherence has been reported among children with rheumatoid arthritis and patients with schizophrenia following tele-nursing interventions (Amer, 2022). Higher patient satisfaction has also been identified as a mediating mechanism that positively influences adherence to pharmacological treatment (AlOmari, 2022).

From the perspective of healthcare professionals, tele-nursing enhances care efficiency and offers a potential response to the growing demand for healthcare services and the global shortage of healthcare professionals. Tele-ICUs contribute to improved quality of care by providing real-time support to nurses in institutions where access to critical care specialists is limited. Support from nurse managers for the integration of tele–intensive care further strengthens the effectiveness of these systems. In terms of cost-effectiveness, tele-nursing has the potential to reduce patients' costs associated with accessing healthcare services. Given the high costs involved in chronic disease management, tele-nursing interventions play an important role in alleviating this burden (Ajalli, 2015). Although demonstrating cost savings in Tele-ICU applications can be challenging, these systems are recognised as valuable in enhancing the quality of care (Goran, 2012). In addition, medication reviews conducted through tele-consultation have been reported to improve cost-effectiveness ratios compared with standard care.

Challenges and Limitations in Tele-Nursing

Tele-nursing involves multifaceted challenges and limitations encompassing technological, human, ethical, and regulatory dimensions (Yustikasari, 2025; Febrianti, 2025; Leo, 2024). Limited access to technological infrastructure, low levels of digital literacy, and infrastructural deficiencies—particularly in remote areas—constitute major barriers. Nurses, in turn, perceive resource constraints, integration difficulties, and the complexity of tele-nursing tools as significant limitations (Yustikasari, 2025; Febrianti, 2025; Leo, 2024). From the perspective of healthcare professionals, insufficient digital literacy is a prominent concern. Many nurses lack formal academic training in tele-nursing, and a substantial proportion require advanced education programmes due to inadequate knowledge (Leo, 2024). Indeed, studies reveal that a

considerable number of nurses possess only average or poor levels of knowledge regarding tele-nursing, underscoring the need for comprehensive and structured training programmes. Although tele-nursing has the potential to reduce the workload of bedside nursing staff, current implementations do not consistently demonstrate sustainable effects in reducing workload or improving nurse-to-patient ratios.

From the patient perspective, low digital literacy, difficulties in using technological tools, and a lack of trust in tele-nursing represent key barriers (Leo, 2024). Building trust and motivation among patients regarding telemedicine applications requires effective communication strategies, promotional activities, and the use of therapeutic communication skills (Yustikasari, 2025). While digital interventions can enhance patient adherence, the absence of such supportive measures may render non-adherence inevitable (Febrianti, 2025).

Data security and privacy also represent significant ethical limitations in tele-nursing. The integration of digital technologies into healthcare increases risks related to data confidentiality and ethics, thereby necessitating stringent regulatory oversight (Yustikasari, 2025). Moreover, the inability of existing legislation to keep pace with the rapid developments in digital health applications constrains the expansion and sustainability of tele-nursing. Inadequate government policies, lack of funding, regulatory uncertainty, and compliance challenges are identified as major barriers to progress in the fields of digital health and tele-nursing (Yustikasari, 2025).

Future Perspectives of Tele-Nursing

The future of tele-nursing is addressed within a broad framework encompassing the integration of technological innovations, the development of personalised digital care models, and the strengthening of telehealth competencies in nursing education. Artificial intelligence and big data are becoming increasingly prominent in contemporary healthcare, and tele-nursing practices are expected to integrate with these technologies in the future; however, current sources do not provide clear or detailed evidence regarding their specific applications within tele-nursing. Similarly, there is limited direct evidence or explanation concerning the potential role of wearable technologies and smart home systems in tele-nursing practices. Although digital care models are discussed in general terms, the existing literature does not offer sufficient data on future, tele-nursing-specific developments related to personalised digital care approaches.

The most concrete and robust future perspective for tele-nursing lies in the development of telehealth competencies within nursing education. Current studies indicate that nursing students have limited awareness of tele-nursing, that formal education in this area remains insufficient, yet that students demonstrate positive attitudes towards tele-nursing (Mun, 2024). Technological advancements necessitate that future nurses be equipped to deliver effective care within highly digital, technology-driven healthcare environments (Khraisat, 2023). Therefore, the integration of tele-nursing content into nursing curricula at both theoretical and practical levels is of critical importance (Bdair, 2024). Simulation-based tele-nursing education programmes have been shown to significantly enhance students' knowledge, skills, attitudes, and self-efficacy in remote care. Moreover, the COVID-19 pandemic has unequivocally demonstrated that tele-nursing will occupy a central role in future healthcare delivery, while simultaneously highlighting the urgency of preparing nursing students for digital health paradigms. In addition, a review conducted in Canada revealed that telehealth practice guidance was expanded during the pandemic and emphasised the need for a standardised telehealth competency framework to guide nursing practice and education. In this context, it is recommended that policymakers and higher education institutions work collaboratively to strengthen nurses' attitudes towards tele-nursing (Butta, 2025).

Conclusion

Tele-nursing has emerged, alongside the advancement of digital health technologies, as a patient-centred, accessible, and sustainable model of care that transcends temporal and geographical boundaries in nursing practice. The existing literature demonstrates that tele-nursing is an effective tool in the management of chronic diseases, the continuation of post-discharge care, the enhancement of self-care skills, and the provision of psychosocial support. Digital educational interventions, web-based programmes, remote monitoring systems, and home-based care models not only improve patient outcomes but also reduce the burden on healthcare systems. Nevertheless, data security, privacy, ethical responsibilities, and digital inequalities remain critical issues for the safe and effective implementation of tele-nursing practices. Current evidence indicates that tele-nursing is not merely a technological innovation but a strategic approach that strengthens the roles and responsibilities of nursing professionals while enhancing the quality of care. The successful outcomes of tele-nursing models across diverse clinical settings necessitate the further expansion of their integration into healthcare services.

Recommendations

- Nationally standardised guidelines encompassing data protection, privacy, professional accountability, and ethical principles should be developed to ensure the safe delivery of tele-nursing practices.
- Continuous professional development programmes covering digital health literacy, remote assessment techniques, and digital communication skills should be implemented to enhance the quality of tele-nursing services.
- To ensure the effectiveness of chronic disease management, post-discharge care, and home-based care processes, patients and caregivers should be supported in accessing and developing the skills required to use telehealth tools.
- Issues related to data security, privacy, transparency in the use of artificial intelligence-supported systems, and equitable access to services should be monitored regularly, and protective mechanisms should be developed in response to emerging risks.

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EFFECTS OF SHORT-TERM MELOXICAM ADMINISTRATION ON OXIDATIVE STRESS IN THE RAT HIPPOCAMPUS: A PRELIMINARY STUDY

KISA SÜRELİ MELOKSİKAM UYGULAMASININ SIÇAN HİPOKAMPUSUNDA OKSİDATİF STRES ÜZERİNE ETKİLERİ: ÖN ARAŞTIRMA

Erkan ÖZKAN

Aksaray University, Faculty of Veterinary Medicine, Department of Parasitology, Aksaray-Türkiye

ORCID: 0000-0002-5251-2302

Neşe Hayat AKSOY

Aksaray University Faculty of Veterinary Medicine, Department of Biochemistry, Aksaray-Türkiye

ORCID: 0000-0001-9039-555X

Caner ÖZTÜRK

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray-Türkiye

ORCID: 0000-0003-0566-0684

Ramazan ARSLAN

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray-Türkiye

ORCID: 0009-0000-6275-5861

ABSTRACT

Nonsteroidal anti-inflammatory drugs (NSAIDs) are widely used to relieve pain and inflammation. However, they may also exert direct or indirect effects on the central nervous system (CNS). Meloxicam is a nonsteroidal anti-inflammatory agent. It exerts its anti-inflammatory activity through the selective inhibition of the cyclooxygenase-2 (COX-2) enzyme. The effects of short-term meloxicam administration on oxidative stress response and antioxidant balance in the brain have been investigated to a limited extent. The hippocampus is one of the brain regions most vulnerable to oxidative processes. In addition to its role in neuroplasticity, learning, and memory, it is highly sensitive to changes in oxidative load. This study aimed to evaluate the effects of short-term meloxicam administration on oxidative balance parameters in the rat hippocampus.

In the experimental design, two groups were included: a control group and a meloxicam group, each consisting of 3 rats. The meloxicam group received intraperitoneal meloxicam at a dose of 2 mg/kg for 5 consecutive days, while the control group was given physiological saline for the same period. At the end of the experiment, hippocampal tissues were collected and homogenized. Total antioxidant capacity (TAS) and total oxidant status (TOS) were determined using colorimetric methods, and the oxidative stress index (OSI) was calculated as the TOS/TAS ratio. Since the data showed a normal distribution, Student's *t*-test was used for statistical analysis.

The findings showed a significant increase in TAS levels in the meloxicam group ($p<0.05$) while TOS ($p<0.05$) and OSI ($p<0.05$) values were markedly decreased. In conclusion, short-term meloxicam administration was found to improve oxidative balance in the hippocampus by increasing antioxidant capacity and reducing oxidative load. These findings suggest that meloxicam may exhibit potential neuroprotective effects at the central nervous system (CNS) level.

Keywords: Brain, hippocampus, meloxicam, neuroprotective, TAS, TOS

ÖZET

Nonsteroidal antiinflamatuvar ilaçlar (NSAİİ), ağrı ve inflamasyonun giderilmesinde yaygın biçimde kullanılmakla birlikte, merkezi sinir sistemi (MSS) üzerinde de doğrudan ya da dolaylı etkiler oluşturabilmektedir. Meloksikam antiinflamatuvar etkinliğini siklooksijenaz-2 (COX-2) enziminin selektif inhibisyonu yoluyla gösteren bir nonsteroidal antiinflamatuvar ajandır. Kısa süreli uygulamalarında beyinde oksidatif stres yanıtı ve antioksidan savunma dengesi üzerindeki etkileri sınırlı düzeyde araştırılmıştır. Beyin dokusu içinde oksidatif süreçlere en duyarlı yapılardan biri olan hipokampus, nöroplastisite, öğrenme ve hafıza gibi işlevlerde görev almasının yanı sıra oksidatif yük değişimlerine oldukça hassastır. Bu çalışmada, meloksikamın kısa süreli uygulanmasının sıçan hipokampus dokusundaki oksidatif denge parametrelerine olan etkilerinin değerlendirilmesi amaçlanmıştır.

Deneysel tasarımda her grup 3 hayvandan olacak şekilde kontrol ve meloksikam grupları yer almıştır. Meloksikam grubuna 2 mg/kg dozunda meloksikam intraperitoneal olarak 5 gün boyunca uygulanmış, kontrol grubuna aynı sürede serum fizyolojik verilmiştir. Deney sonunda alınan hipokampus dokuları homojenize edilerek toplam antioksidan kapasite (TAS) ve toplam oksidan seviye (TOS) kolorimetrik yöntemlerle belirlenmiş, oksidatif stres indeksi (OSI) ise TOS/TAS oranı üzerinden hesaplanmıştır. Verilerin normal dağılım göstermesi nedeniyle Student's *t*-testi kullanılmıştır.

Elde edilen bulgular, meloksikam grubunda TAS düzeyinin anlamlı biçimde arttığını ($p<0.05$), buna karşın TOS ($p<0.05$) ve OSI ($p<0.05$) değerlerinde belirgin azalma meydana geldiğini göstermiştir. Sonuç olarak, kısa süreli meloksikam uygulamasının hipokampusta oksidatif dengeyi olumlu yönde düzenlediği, antioksidan kapasiteyi artırarak oksidan yükü azalttığı belirlenmiştir. Bu bulgular, meloksikamın MSS düzeyinde potansiyel nöroprotektif etkiler ortaya koyabileceğini göstermektedir.

Anahtar Kelimeler: Beyin, hipokampus, meloksikam, nöroprotektif, TAS, TOS

INTRODUCTION

Nonsteroidal anti-inflammatory drugs (NSAIDs) are widely used for the management of pain and inflammation. The selectivity of cyclooxygenase (COX) enzymes is considered critical for

the regulation of central nervous system (CNS) physiology and pathophysiology. Meloxicam has been defined as an NSAID with relatively selective activity toward COX-2. Pharmacological studies report that meloxicam has a strong inhibitory effect on COX-2, while its weaker interaction with COX-1 contributes to a reduction in gastrointestinal side effects. This selectivity enables meloxicam to elicit a potent anti-inflammatory response while minimizing the occurrence of gastrointestinal adverse effects (Engelhardt, 1996; Furst, 1997).

In the central nervous system (CNS), the interplay between oxidative stress and neuroinflammation plays a crucial role in maintaining neuronal integrity and regulating neural network function. The hippocampus plays a central role in learning and memory and is highly responsive to alterations in synaptic plasticity, energy metabolism, and cellular redox balance. The excessive generation of reactive oxygen species, exhaustion of antioxidant defenses, and mitochondrial dysfunction operate as interconnected mechanisms that collectively drive the progression of oxidative injury. Recent evidence indicates that oxidative stress can induce structural alterations in hippocampal regions involved in learning and memory. As a result, the hippocampus has emerged as a key biomarker of oxidative imbalance in the brain (Blossom vd., 2025; Jia vd., 2023; Kandlur vd., 2020).

In this context, assessing the overall redox state provides a broader understanding of both the magnitude and direction of oxidative stress than analyses based solely on individual biomarkers. Total antioxidant capacity (TAS) and total oxidant status (TOS) are widely recognized in both clinical and experimental research, as they are measured using Erel's well-established automated colorimetric assays. These methods offer a sensitive and reproducible analytical approach that is also cost-effective. Assessing TAS and TOS together enables the calculation of the oxidative stress index (OSI = TOS/TAS), which represents both the magnitude and the direction of the redox balance within a single scale (Erel, 2004; Erel, 2005).

Evidence from animal models indicates that meloxicam exerts neuroprotective effects within the CNS. However, the extent of this protection appears to depend on both the administered dose and the duration of exposure. For example, research using a transient focal cerebral ischemia model has shown that meloxicam decreases infarct size and facilitates neurological recovery. It also modulates glial scar formation, thereby exerting a favorable effect on regenerative mechanisms. These observations suggest that while anti-inflammatory therapies provide beneficial effects, their impact on neuronal regeneration and repair processes can fluctuate according to the administered dose and treatment duration (Ugidos vd., 2023).

However, there is a limited number of studies that have systematically evaluated the impact of short-term meloxicam treatment on hippocampal redox balance in healthy rats, focusing solely on global parameters such as TAS, TOS, and OSI. Understanding the pharmacodynamic responses of meloxicam across different brain regions is essential. It is equally important to minimize the potential influence of solvents or analgesics used in experimental settings on behavioral and biochemical results. The present study employs a short-term, two-group experimental design focusing on hippocampal tissue, using the TAS/TOS measurement approach originally developed by Erel. The primary objective was to determine clearly whether meloxicam decreases oxidative burden while increasing antioxidant capacity.

Based on this context, we hypothesized that short-term meloxicam administration would enhance antioxidant defense by elevating TAS levels in the hippocampus, decrease oxidative burden by lowering TOS levels, and consequently lead to a reduction in OSI values. From a methodological perspective, the use of standardized colorimetric protocols enables the redox balance to be assessed in an integrated and comparable way (Erel, 2004; Erel, 2005).

MATERIALS AND METHODS

Experimental Design

The study was carried out at the Experimental Animals Application and Research Center of Aksaray University. Healthy male Wistar rats (n = 3), aged 3 months and weighing 220 ± 20 g, were used in the experiments. Animals were maintained under controlled laboratory conditions (22 ± 2 °C, 50–60% humidity, 12 h light/dark cycle) with unrestricted access to standard pellet diet and water.

The rats were randomly assigned to two groups.

Control Group (n = 3): Administered intraperitoneal (i.p.) physiological saline once daily for five days.

Meloxicam Group (n = 3): Treated with meloxicam at a dose of 2 mg/kg via the i.p. route for 5 consecutive days.

The selected dose was determined according to previous studies that established short-term safety profiles for meloxicam administration (Alemán-Laporte vd., 2022; Hiskens vd., 2024). Throughout the administration period, all animals were monitored on a daily basis for both behavioral alterations and clinical signs.

Rats were anesthetized 24 hours after the final administration using a combination of ketamine (90 mg/kg) and xylazine (10 mg/kg). Euthanasia was performed using the cervical dislocation method. After the brain tissue was removed, the hippocampal region was rapidly dissected and separated on ice. Each tissue sample was stored at –80 °C for subsequent biochemical analyses.

Biochemical Analyses

Frozen hippocampal tissues were homogenized in 1% phosphate buffer (pH 7.4). The homogenates were centrifuged at 10,000 g for 15 minutes, and the supernatant was used for subsequent analyses.

Based on the Total Antioxidant Capacity (TAS) assay developed by (Erel, 2004),

Total Oxidant Status (TOS) was measured through the colorimetric assay developed by (Erel, 2005).

Each measurement was performed using commercial ELISA-based kits in accordance with the manufacturer's protocol. The absorbance was read on a microplate reader at the wavelength specified by the manufacturer.

The Oxidative Stress Index (OSI) was calculated by multiplying the TOS/TAS ratio by 100:

$$\mathrm{OSI} = \frac{\mathrm{TOS}\left(\frac{\mu\mathrm{molH2O2eq}}{\mathrm{L}}\right)}{\mathrm{TAS}\left(\frac{\mu\mathrm{molTroloxeq}}{\mathrm{L}}\right)} \times 100$$

RESULTS

The study evaluated the effects of short-term meloxicam administration on oxidative balance parameters in hippocampal tissue. The obtained data revealed significant changes, indicating an increase in antioxidant capacity and a decrease in oxidative load.

TAS levels were significantly higher in the meloxicam group compared to the control group ($p<0.05$). The mean TAS value was 1251.45 ± 416.44 µmol/L in the control group and 2296.38 ± 121.36 µmol/L in the meloxicam group. This increase indicates that short-term meloxicam administration enhances the antioxidant defense in the hippocampus.

In the analysis of TOS, a significant decrease in values was observed in rats treated with meloxicam ($p<0.05$). The TOS level measured in the control group was 1241.75 ± 48.30 µmol/L, whereas it was 730.18 ± 194.22 µmol/L in the meloxicam group. These findings indicate that meloxicam exerts a reducing effect on oxidant production and overall oxidative burden.

A significant decrease was also observed in OSI values ($p<0.05$). The mean OSI was 106.40 ± 32.65 in the control group and 31.88 ± 8.52 in the meloxicam group. The increase in TAS levels, together with the reduction in TOS and OSI, indicates that meloxicam exerts suppressive effects on oxidative stress in the hippocampus.

These findings demonstrate that short-term meloxicam administration exerts a protective effect on redox balance at the hippocampal tissue level and enhances the antioxidant defense capacity.

Table 1. TAS, TOS and OSI Values in the Hippocampus

Group	TAS (µmol/L) (Ort ± SD)	TOS (µmol/L) (Ort ± SD)	OSI (Ort ± SD)
Control	1251,45± 416,44[a]	1241,75 ± 48,30[a]	106,40 ± 32,65[a]
Meloxicam	2296,38 ± 121,36[b]	730,18 ± 194,22[b]	31,88 ± 8,52[b]

Table 1. TAS, TOS, and OSI parameters of rats. The results are expressed as mean ± standard deviation (SD). Groups that do not share the same superscript letter (a, b) were considered statistically different at the ($p<0.05$) level. In the meloxicam group, TAS levels increased significantly, whereas TOS and OSI values showed a marked decrease.

DISCUSSION

This study investigated the effects of short-term meloxicam administration on oxidative balance in rat hippocampal tissue. The obtained results revealed that meloxicam induced protective alterations in the redox system. A marked increase in TAS levels was observed in the meloxicam-treated group. A significant decrease was observed in TOS and OSI values. These findings indicate that short-term meloxicam administration strengthens the antioxidant defense system and reduces oxidative burden.

The effects of NSAIDs on the brain are not limited to the inhibition of prostaglandin synthesis. Recent studies have shown that these drugs may also exert indirect effects on redox homeostasis and glial cell activity (Hiskens vd., 2024). It has been reported that agents selectively targeting the COX-2 enzyme not only suppress the inflammatory response but also reduce the production of reactive oxygen species (ROS), thereby preserving cellular antioxidant capacity. (Sheverini vd., 2024). Another study reported that meloxicam reduced neuronal damage, suppressed microglial activation, and promoted behavioral recovery in a transient focal brain ischemia model (Ugidos vd., 2023). In our study, the decrease in TOS and the increase in TAS observed after short-term meloxicam administration support the notion that these antioxidant effects are specific to the hippocampus.

The hippocampus is a brain region with high oxygen consumption and metabolic activity. Due to its involvement in neuroplasticity, it is highly sensitive to oxidative imbalances. Therefore, even minor alterations in the redox system have been reported to exert significant effects on learning, memory, and synaptic plasticity processes (Kandlur vd., 2020). Increased oxidative stress leads to a reduction in BDNF levels and consequently weakens neuroplasticity. Enhancing antioxidant capacity contributes to the maintenance of synaptic integrity (Jia vd., 2023). In our results, the increase in TAS levels induced by meloxicam suggests that the drug may have indirectly prevented oxidative stress–related damage in the hippocampus.

The regulatory effect of meloxicam on oxidative processes is primarily based on COX-2 inhibition. The reduction in PGE2 levels decreases intracellular calcium influx, microglial activation, and nitric oxide production (Hiskens vd., 2024). This mechanism contributes to the preservation of neuronal membrane integrity by suppressing the excessive production of reactive oxygen and nitrogen species. The inhibition of the NF-κB signaling pathway by meloxicam reduces TNF-α and IL-1β levels, thereby decreasing inflammation-associated oxidative burden. (Sallam vd., 2024). TAS and TOS parameters are considered indicators of the total antioxidant and oxidant capacity in tissues. The OSI calculated using both parameters, reflects the direction of the redox balance. (Erel, 2004; Erel, 2005) In our study, the OSI value decreased in the meloxicam group. The short-term administration of the drug revealed a marked reduction in oxidative load. Similarly, it has been reported that co-administration of meloxicam with hesperetin regulates hippocampal redox balance, increases the TAS/TOS ratio, and reduces oxidative damage. This finding supports the notion that meloxicam alone may play an active role in the modulation of oxidative stress (Yadav vd., 2023).

The neuroprotective effects of meloxicam extend beyond its antioxidant mechanisms. After ischemia, it has been demonstrated to inhibit glial scar formation and promote axonal regeneration (Ugidos vd., 2023). Another study reported that meloxicam reduced lipid peroxidation in oxidative stress models (Sheverini vd., 2024).

These results demonstrate that meloxicam can exert a regulatory effect on both inflammatory and oxidative processes. Our study is limited to the evaluation of TAS and TOS levels in hippocampal tissue. However, the marked changes in these parameters suggest that meloxicam may play a protective role in synaptic regions sensitive to redox balance.

The present study has certain limitations and recommendations for future research,

It was conducted with a small sample size (n = 3) and short-term drug administration.

To improve the generalizability of the results, further studies with larger sample sizes supported by behavioral and molecular analyses are required.

Future studies should examine the dose–time relationship of meloxicam.

The differences among hippocampal subregions (CA1, CA2, CA3, and DG) should be further investigated.

The effects of meloxicam on signaling pathways such as BDNF, Nrf2, and NF-κB need to be explored in more detail.

In addition, long-term use of meloxicam has been reported to cause inverse changes in oxidative stress parameters (Ugidos vd., 2023). This highlights the importance of determining the optimal duration of action and effective dose range of the drug.

CONCLUSION

The obtained data indicate that short-term systemic administration of meloxicam positively regulates oxidative balance in hippocampal tissue. The increased TAS and decreased TOS and OSI levels demonstrate that the drug enhances antioxidant defense and suppresses oxidative burden. These findings suggest that meloxicam may be considered a potential neuroprotective agent at the CNS level. It also indicates that meloxicam should be re-evaluated as a pharmacological protective agent, particularly in experimental models based on neuroinflammation, neurodegeneration, and oxidative injury.

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CHARLSON COMORBIDITY INDEX IN ENDOMETRIAL LESIONS

Loichita Mihai

“Victor Babes” University of Medicine and Pharmacy Timisoara, (ROMANIA)

Petre Ion

“Victor Babes” University of Medicine and Pharmacy Timisoara, (ROMANIA)

Suciu Oana

“Victor Babes” University of Medicine and Pharmacy Timisoara, (ROMANIA)

Bobora Razvan

“Victor Babes” University of Medicine and Pharmacy Timisoara, (ROMANIA)

Furau Alexandru-Marius

"Vasile Goldiș" Western University of Arad, (ROMANIA)

Petre Izabella

“Victor Babes” University of Medicine and Pharmacy Timisoara, (ROMANIA)

Abstract

***Introduction**:*The Charlson Comorbidity Index classifies comorbidities based on the International Classification of Diseases that hospitals use administratively. Each comorbidity category is assigned a value between 1-6, depending on the adjusted mortality risk, the sum of these values creates a unique score for each patient; a score of zero indicates the absence of a comorbidity, and the higher the score, the higher the probability of death.

Methods and Materials: In endometrial cancer, the Charlson Comorbidity Index analyzes patients' secondary diagnoses and can predict mortality by assigning a weight to each comorbidity, a procedure used by medical research to assess the burden of the disease and especially for case mix characteristics.

Results and discussions:After cohorting the 594 patients by age decade, to calculate the chances of survival at 10 years, in order to identify the most common associated diseases involved, we obtained: the most common comorbidities were hypertension (62.28%), obesity (35.01%) and diabetes mellitus (22.89%), all of which are risk factors for tumor disease in general, with cardiovascular diseases in fourth place. These results are also present in the specialized literature. The study in this dissertation emphasizes the need for extensive screening of diabetes mellitus (for every woman with diabetes mellitus, there are at least 9 who may develop endometrial cancer or atypical endometrial hyperplasia), obesity (there may be at least 8 obese women who may develop endometrial cancer or atypical endometrial hyperplasia), and

hypertension (for every woman with hypertension, there may be at least 3 other women with hypertension who may develop endometrial cancer or atypical endometrial hyperplasia).

High blood pressure increases the risk of endometrial cancer compared to typical endometrial hyperplasia (for every hypertensive woman, there may be at least 3 women who may develop endometrial cancer or atypical endometrial hyperplasia), which demonstrates the role of high blood pressure in endometrial cancer, which is also emphasized by other research.

Conclusions:The 10-year survival rate is 95.8571% for women under 50 years of age, decreases to 82.3125% for the 50-59 decade, decreases to 62.9061% for the 60-69 decade, decreases to 35.9833% for the 70-79 decade, and 1.3846% over 80 years of age. This study also documents that the prevalence of diabetes mellitus among the 594 women exceeds that of the general population by at least 10 percent (22.39%) and confirms the working hypothesis that the presence of comorbidities (high blood pressure and obesity) is strongly positively correlated with endometrial cancer.

THE CONTRIBUTION OF TELE-NURSING INTERVENTIONS TO ADOLESCENT NUTRITIONAL HABITS IN THE CONTEXT OF DIGITAL HEALTH LITERACY: CURRENT EVIDENCE

Dr. Öğr. Üyesi Esin KAVURAN

Atatürk Üniversitesi Hemşirelik Fakültesi, Hemşirelik Esasları ABD

0000-0003-3791-102X

Dr. Öğrencisi Hasan SAĞLAM

Atatürk Üniversitesi Hemşirelik Fakültesi, Hemşirelik Esasları ABD

0000-0002-8307-6996

Abstract

Introduction: Current literature increasingly highlights the importance of digital health literacy in promoting health among children and adolescents. Digital tools offer innovative strategies to strengthen health behaviors and provide effective intervention opportunities that support healthy lifestyle habits, particularly within young populations. Digital and audiovisual tools have been reported to be effective in enhancing health literacy and promoting healthy behaviors. However, interventions targeting adolescents must consider cultural, linguistic, and psychosocial characteristics. Schools are recognized as key settings for fostering digital health literacy, as they contribute to developing students' responsibility for their own health behaviors. Despite this, existing studies do not directly address the influence of tele-nursing practices on adolescents' nutritional habits.

Aim: The aim of this presentation is to summarize the current literature on digital health literacy and to discuss the potential contributions of tele-nursing practices to improving adolescents' nutritional behaviors, while identifying gaps within the existing body of research.

Method: This presentation is based on a literature review of studies published between 2019 and 2024 on digital health literacy, digital interventions, adolescent health, health promotion, and tele-nursing. PubMed, Scopus, and Google Scholar databases were searched, and studies examining digital health interventions targeting children and adolescents were included. Studies lacking direct evidence on tele-nursing and adolescent nutritional behaviors were analyzed for comparative purposes.

Findings: The reviewed studies demonstrate that digital interventions are effective in enhancing health literacy, promoting healthy behaviors, and fostering health responsibility among children and adolescents within educational settings. Digital and audiovisual tools were found to be particularly impactful. However, the number of studies directly investigating the specific effects of tele-nursing on adolescents' nutritional behaviors is limited. While current literature provides strong evidence on digital interventions, the influence of tele-nursing–based nutritional approaches in this age group remains insufficiently explored.

Conclusion: The literature indicates that digital health literacy is a valuable tool for improving adolescent health. However, research on the impact of tele-nursing practices on adolescents' nutritional habits is notably limited. Future studies should evaluate the effectiveness of tele-nursing–based nutritional interventions and address the existing knowledge gap in this field.

Keywords: Digital health literacy, tele-nursing, adolescent, nutritional behaviors, health promotion.

Introduction

Adolescence is a critical developmental period characterised by rapid physical, cognitive, and intellectual growth, during which the foundations of lifelong health behaviours are established. Dietary habits acquired in this phase not only influence current health status but also significantly affect the risk of developing chronic diseases in adulthood (Pico, 2024). Unhealthy and inadequate dietary practices are associated with weakened immune function, impaired muscle development, adverse effects on cognitive performance, and—through obesity—an increased prevalence of serious health conditions such as cardiovascular disease, coronary heart disease, stroke, and cancer (Faridi, 2023). Nevertheless, insufficient nutritional knowledge among adolescents underscores the urgency of implementing nutrition-focused interventions in this age group (Pico, 2024).

Adolescents are regarded as a particularly high-risk population in terms of nutritional problems (Riwu, 2024). The most prevalent nutrition-related issues during adolescence include stunting, anaemia, chronic energy deficiency (CED), obesity, and foetal growth restriction in adolescent pregnancies. These problems are largely attributed to inappropriate and irregular dietary behaviours (Puspita, 2025). Adolescents frequently engage in unhealthy practices such as skipping meals, eating at inappropriate times, consuming energy-dense but nutrient-poor foods, and maintaining insufficient levels of physical activity (Pico, 2024). In particular, the increasing reliance on online food delivery services and convenience foods has been reported to heighten the risk of nutritional inadequacy and imbalanced diets among adolescents (Sandy, 2023).

Digitalisation has brought about a substantial transformation in healthcare, creating new opportunities for behavioural interventions and health promotion (Corrêa, 2025). However, the impact of digital technologies on adolescents' health behaviours is inherently bidirectional. While social media and digital platforms facilitate social interaction and self-expression among young people, they also entail significant risks, including compulsive social media use, cyberbullying, exposure to unrealistic body and beauty ideals, and the normalisation of unhealthy eating behaviours and substance use (Masri-zada, 2025). Within this context, the reliability of health and nutrition information disseminated through digital media, as well as individuals' capacity to critically appraise such information, has become increasingly important (Ahraz, 2025).

Digital tools and telehealth applications offer promising approaches to nutritional management and health promotion in children and adolescents. Mobile applications, digital games, telehealth platforms, and remote counselling services are widely utilised to prevent and manage childhood obesity, deliver nutrition education, and support healthy lifestyle behaviours. These interventions have the potential to provide personalised support, monitor dietary intake and physical activity, and enhance self-efficacy (Ahraz, 2025). Nevertheless, challenges such as inequalities in digital access, lack of scientific validation, and concerns regarding data privacy and security may limit the effectiveness of these interventions (Corrêa, 2025).

This review aims to comprehensively examine, in light of current scientific evidence, the importance of dietary habits during adolescence, the common nutritional problems and associated risk factors in this age group, the effects of digitalisation on adolescent health behaviours, and the role of telehealth and telenursing practices in health promotion.

Conceptual Framework

Digital Health Literacy

Definition and Components

Digital health literacy is defined as the ability to search for, locate, comprehend, and utilise health-related information from electronic sources in order to address a health issue (Tümer, 2021). This concept encompasses individual competencies such as literacy, analytical skills, and self-efficacy. Critical health literacy is essential for evaluating the reliability and relevance of online health information (Taba, 2022). The Digital Health Literacy Instrument (DHLI) assesses seven subdomains: operational skills, navigation skills, information searching, evaluating reliability, determining relevance, adding self-generated content, and protecting privacy (Vaart, 2017). Definitions of health literacy in adolescents extend beyond basic numeracy and reading skills, reflecting a multidimensional construct.

Levels of Digital Health Literacy Among Adolescents

Although adolescents generally report high self-efficacy in using online health information, their perceived digital health literacy may exceed their actual competencies. They access health information both intentionally via search engines and unintentionally through social media. While information obtained from social media is perceived as less reliable than that from websites, similar evaluation strategies are often applied to both sources (Taba, 2022). A study conducted in Germany found that 30.76% of children and adolescents had problematic and 4.63% had inadequate levels of digital health literacy. The least difficulty was observed in operational skills and determining relevance, whereas the greatest challenges were related to privacy protection and navigation skills. Age was significantly associated with digital health literacy, with younger children (9–11 years) being at greater risk of limited competencies (Stauch, 2025). In Türkiye, the mean eHealth Literacy Scale (eHEALS) score among high school students was 27.52 ± 6.76, corresponding to a high level of digital health literacy (Tümer, 2021). More than half of Lithuanian adolescents (55.7%) demonstrated excellent digital health literacy (Motiejunaite, 2025). Furthermore, 79.6% of adolescents reported that online health information influenced their health-related decisions to some extent. Factors associated with a stronger influence included being male, initiating internet use at a younger age, higher perceived eHealth literacy, and the use of health applications, Google, health forums, health institution websites, social media, and YouTube, as well as an interest in specific health topics such as diet and nutrition (Gazibara, 2022). Nonetheless, there remains a clear need to enhance adolescents' critical health literacy skills (Taba, 2022).

The Relationship Between Digital Health Literacy and Dietary Behaviours

A web-based educational programme grounded in health literacy has been shown to improve adolescents' health literacy levels and positively influence their dietary behaviours (Dülger, 2024). A comprehensive food literacy intervention increased adolescents' nutritional knowledge, enhanced self-regulation skills, and favourably affected dietary habits and body mass index (BMI). This intervention integrated theoretical learning with practical activities and digital tools (Mancone, 2024). Interest in diet and nutrition has also been associated with a stronger impact of online health information on health-related decision-making (Gazibara, 2022). However, one study reported no association between digital health literacy and eating behaviours among adolescent girls (Sjamsuddin, 2023).

Telenursing

Definition and Scope of Telenursing

Telenursing refers to the use of telecommunications and information technologies to deliver nursing services when there is a substantial physical distance between the patient and the nurse or nursing team (Qadir, 2022). It represents a clinical method for providing high-quality nursing care and played a critical role in preventing infection transmission by reducing face-to-face interactions during situations such as the COVID-19 pandemic (Danesh, 2022; Ravindranadhan, 2025). Telenursing encompasses the planning, implementation, and evaluation of nursing care through information and communication technologies. As a component of telehealth, it interfaces with other medical and non-medical applications, including tele-diagnosis, tele-consultation, and tele-monitoring (Qadir, 2022). Its primary objectives are to overcome physical distance barriers, facilitate access to information, monitor chronic conditions, reduce hospital admissions, and deliver cost-effective healthcare services within shorter timeframes. By enabling remote monitoring, follow-up, and clinical decision-making through information exchange and interprofessional collaboration, telenursing enhances access to care and improves its quality.

Models of Telenursing Practice

Telenursing practices facilitate patient monitoring, increase the accessibility of education and counselling services, and ensure continuity of care (Bayrak, 2025). They have the potential to reduce hospital readmissions, enhance patient satisfaction, and improve chronic disease management. Telenursing is particularly effective in delivering care to underserved populations in rural and remote areas. In psychiatric care, telenursing is commonly utilised for post-discharge follow-up (Çam, 2018). Services provided through telenursing may include health education, dietary counselling, blood glucose monitoring, and medication reminders (Zhou, 2025). Rozzano Locsin's Theory of Technological Competency as Caring in Nursing emphasises that nurses can enhance their caregiving capacity by using technology consciously and competently; telenursing initiatives such as remote monitoring systems, digital education platforms, and tele-consultations exemplify the practical application of this theory (Bayrak, 2025).

Telenursing Approaches in Adolescent Health

Digital tools demonstrate considerable potential for nutritional management and health promotion among children and adolescents. Mobile applications, digital games, and telehealth platforms are utilised in the prevention and treatment of childhood obesity, the promotion of breastfeeding, diet therapy for specific clinical conditions, and nutrition education. Remote education delivered by nurses is particularly important for improving the mental health and overall well-being of families and children. Telenursing enables the provision of personalised interventions for adolescents, supports the monitoring of dietary intake and physical activity, and facilitates clinical decision-making processes (Corrêa, 2025).

Health Promotion Model

Pender's Health Promotion Model (HPM) provides a conceptual framework for understanding and encouraging health-promoting behaviours. The model conceptualises health as a dynamic process and emphasises that individuals play an active role in constructing and maintaining their own well-being.

Core Assumptions of the Model

Pender's Health Promotion Model assumes that health behaviours are influenced by a combination of personal, social, and environmental factors (Landívar, 2024). The model seeks to explain the complex interactions that affect individuals' adoption and maintenance of health-promoting behaviours (Srof, 2006). It is grounded in the premise that individuals are proactive in their efforts to protect and enhance their health (Landívar, 2024).

Individual Characteristics and Experiences

Within the model, individual characteristics and experiences are key determinants of health behaviours. These include biological, psychological, and sociocultural attributes (Penwell-Waines, 2017). Prior related behaviours are also considered part of individual experiences and may exert a strong influence on current and future health behaviours. For example, previous behaviours have been identified as a significant factor shaping individuals' subsequent behavioural choices (Imani-Nasab, 2022).

Behaviour-Specific Cognitive and Affective Factors

Behaviour-specific cognitive and affective factors constitute the core components of Pender's Health Promotion Model and exert a direct influence on health behaviours. These factors include:

- **Perceived Benefits:** Beliefs regarding the potential positive outcomes of engaging in a health-promoting behaviour (Shahroodi, 2021).
- **Perceived Barriers:** Beliefs about the costs, difficulties, or negative consequences associated with performing a particular behaviour (Shahroodi, 2021).
- **Perceived Self-Efficacy:** An individual's belief in their capacity to successfully perform a specific behaviour (Shahroodi, 2021; Penwell-Waines, 2017).
- **Activity-Related Affect (Positive and Negative):** Emotions experienced in relation to the behaviour itself (Imani-Nasab, 2022).
- **Interpersonal Influences:** The impact of significant others, such as family members, peers, and healthcare professionals, on an individual's behaviours (Shahroodi, 2021).
- **Situational Influences:** Perceived characteristics of the environment in which the behaviour occurs.
- **Immediate Competing Demands and Preferences:** Alternative actions or desires that may compete with engagement in a health-promoting behaviour.

These factors influence individuals' commitment to a plan of action and, ultimately, their health behaviours (Dehdari, 2013; Imani-Nasab, 2022).

Behavioural Outcomes

The behavioural outcomes of the model refer to the adoption and maintenance of health-promoting behaviours by the individual. These outcomes emerge through commitment to a plan of action and the subsequent implementation of that plan. For example, nutrition education interventions have been associated with significant increases in breakfast consumption frequency and overall nutrient intake (Dehdari, 2013). It has been reported that the constructs of the model explain approximately 47% of the variance in breakfast consumption behaviour (Imani-Nasab, 2022).

Adaptation of the Health Promotion Model to Adolescent Nutrition

Pender's Health Promotion Model provides an appropriate and robust framework for explaining and improving adolescents' dietary behaviours (Srof, 2006; Dehdari, 2013; Imani-Nasab, 2022). Adolescence represents a critical transitional period during which personal responsibility for health behaviours is progressively established (Srof, 2006).

The adaptation of the model to adolescent nutrition has proven particularly effective in understanding and promoting specific behaviours, such as breakfast consumption (Dehdari, 2013; Imani-Nasab, 2022). Nutrition education interventions can improve adolescents' dietary habits by reducing perceived barriers and negative activity-related affect, while simultaneously enhancing perceived benefits, self-efficacy, and positive activity-related affect (Dehdari, 2013).

Research indicates that the constructs of Pender's Health Promotion Model constitute an appropriate theoretical basis for predicting planning and behaviour related to breakfast consumption among adolescent girls. In particular, the influence of affect and behavioural perceptions on commitment to breakfast consumption plans should be taken into account when designing nutrition interventions for this population. Educational interventions that create pleasant experiences and positively influence individual perceptions and determinants related to the target behaviour may strengthen adolescents' commitment to regular breakfast consumption (Imani-Nasab, 2022).

Evaluation of Telenursing Interventions within the Health Promotion Model Framework

Pender's Health Promotion Model (HPM) offers a comprehensive framework for evaluating the effectiveness of telenursing interventions. Telenursing refers to the provision of nursing care at a distance through the use of telecommunications and information technologies. Such interventions can influence health behaviours through the key components of the HPM, including perceived benefits, perceived barriers, self-efficacy, activity-related affect, interpersonal influences, and situational influences.

Perceived Benefits and Barriers

Telenursing interventions have the potential to enhance individuals' perceived benefits of health behaviours while reducing perceived barriers. Educational interventions grounded in the HPM have been shown to be effective in improving healthy dietary behaviours by increasing perceived benefits and decreasing perceived barriers (Naserpoor, 2018). Among individuals with cardiovascular disease, perceived barriers and facilitators to adopting healthy lifestyles have been found to align with the assumptions of the HPM (Espinosa, 2021). Similarly, perceived benefits and barriers have been identified as influential factors in fruit and vegetable consumption among individuals with diabetes (Tabatabai, 2022; Zeidabadi, 2024). Nursing care delivered through information and communication technologies may therefore significantly influence individuals' perceptions of benefits and barriers (Estrada, 2017).

Perceived Self-Efficacy

Perceived self-efficacy, defined as an individual's belief in their ability to successfully perform a specific health behaviour, is a key construct of the HPM (Jalali, 2023; Estrada, 2017). Telenursing interventions have demonstrated effectiveness in enhancing self-efficacy. For instance, among individuals with diabetes, telephone-based follow-up (telenursing) has been associated with significant improvements in self-efficacy and healthy lifestyle behaviours (Elgaphar, 2017). In women with gestational diabetes, telenursing services have been shown to significantly increase healthy lifestyle and self-efficacy scores (Metwaly, 2016). Evidence from a systematic review and meta-analysis further supports that educational interventions based on

Pender's HPM lead to significant improvements in self-efficacy (Jalali, 2023). Additionally, self-efficacy has been identified as the strongest predictor of fruit and vegetable consumption among individuals with diabetes (Tabatabai, 2022).

Activity-Related Affect

Activity-related affect refers to the positive or negative emotions experienced while engaging in a health-related behaviour. Telenursing interventions have the potential to influence these emotions in a positive manner. Nutrition education interventions have been shown to reduce negative activity-related affect while enhancing positive affect associated with the behaviour (Dehdari, 2013). Among obese middle-aged women, activity-related affect has been found to exert a direct effect on health-promoting behaviours (Bae, 2022). Similarly, interventions based on the Health Promotion Model have demonstrated positive effects on activity-related affect among employees with hypertension (Abbas, 2022).

Interpersonal Influences

Interpersonal influences encompass the effects of significant others—such as family members, friends, and healthcare professionals—on health behaviours (Fraile, 2013). Telenursing can support and strengthen these interpersonal interactions. For instance, nursing care delivered through the use of information and communication technologies has been shown to influence interpersonal factors (Estrada, 2017). Among older women, social support has been reported to directly affect health-promoting behaviours (Oh, 2020). In farmers, interpersonal support has been identified as a statistically significant predictor of hearing protection device use (McCullagh, 2002). Likewise, interpersonal influences have been shown to affect vegetable and salad consumption among individuals with diabetes (Zeidabadi, 2024).

Situational Influences and the Digital Environment

Situational influences refer to the perceived characteristics of the environment in which a behaviour occurs (Dehdari, 2013). Telenursing interventions shape these situational influences through the use of digital environments. Web- and software-based interventions have significantly increased students' levels of physical activity, highlighting the role of the digital environment as a situational influence (Sabooteh, 2020). Nursing care delivered via information and communication technologies may also affect situational factors (Estrada, 2017). Situational influences have been identified as important predictors of health behaviours, such as the use of hearing protection among farmers (McCullagh, 2002). Similarly, situational influences have been shown to affect fruit and vegetable consumption among individuals with diabetes (Zeidabadi, 2024).

Synthesis of Current Evidence

The evaluation of telenursing interventions within the framework of Pender's Health Promotion Model (HPM) highlights their potential to influence individuals' health behaviours.

Telenursing-Based Nutritional Interventions in Adolescents

Adolescents are frequently targeted in research grounded in Pender's Health Promotion Model, which addresses issues such as healthy lifestyles and the prevention of chronic diseases (Hoyos, 2018). Educational interventions based on the HPM have been found to be effective in improving dietary behaviours among adolescent girls. Such interventions may enhance perceived benefits and self-efficacy while reducing perceived barriers to healthy eating (Naserpoor, 2018). Although digital tools—such as chatbots—hold promise for promoting

nutrition and physical activity among adolescents, research in this area remains limited, and feasibility and acceptability vary across contexts (Han, 2022).

Interventions Targeting Digital Health Literacy

Digital health literacy refers to individuals' ability to search for, locate, understand, appraise, and apply health information from electronic sources in order to address health-related problems (Norman, 2006). Telenursing interventions may positively influence health behaviours by enhancing digital health literacy (Mitsutake, 2016). E-health interventions are implemented using a range of technologies, including mobile-based, web-based, and telemedicine applications (Benny, 2020). Systematic reviews indicate that mobile health (mHealth)-based interventions can improve health literacy and that mobile applications are effective in enhancing patients' health literacy (Lin, 2020). However, most existing digital health interventions do not comprehensively address all domains of the eHealth literacy model (Benny, 2020). Studies conducted among nursing students emphasise that digital literacy and self-efficacy in online learning influence eHealth literacy levels, underscoring the need to strengthen digital literacy within nursing education (Kim, 2020; Lekalakala-Mokgele, 2023).

Effects of Telenursing Interventions on Dietary Behaviours

Telenursing interventions have demonstrated effectiveness in improving dietary behaviours across diverse populations. A three-tier enteral nutrition nursing system implemented under an "Internet + medical" model improved nurses' knowledge and practices related to nutritional safety, as well as patients' nutritional status (Hu, 2022). In the management of paediatric obesity, telemedicine has been identified as a useful tool for delivering nutritional support and exercise programmes (Calcaterra, 2021). A nurse-led telemedicine intervention (Care4US+) increased adherence to healthy eating and physical activity behaviours among overweight or obese young adults, resulting in significant reductions in body weight, body mass index (BMI), and waist circumference (García-Rodríguez, 2024). Among individuals with spinal cord injury, telenutrition counselling has provided preliminary evidence of improvements in diet quality (Wood, 2021). In addition, studies are being conducted on the effects of telephone follow-up (telenursing)-based, family-centred multimedia education in enhancing quality of life and self-efficacy among patients with myocardial infarction (Dehkordi, 2021).

Effectiveness According to Intervention Type

Digital nutrition interventions are delivered in a variety of formats and demonstrate differing levels of effectiveness:

Mobile Applications: A review of digital interventions aimed at promoting healthy eating in children reported that the effects of various digital tools, including mobile applications, were generally small and inconsistent; however, these tools may show promise in improving fruit and vegetable intake (Prowse, 2021). The FIT4PEDON mobile nutrition counselling application, developed for survivors of childhood cancer, has shown potential in promoting healthy dietary behaviours (Bavatharani, 2025). Conversely, among patients with upper gastrointestinal cancer, asynchronous mobile application–based nutrition counselling was associated with lower acceptability and higher dropout rates compared with telephone-based counselling (Huggins, 2022).

SMS and Telephone Messaging: In a comparison of video drama and short message service (SMS) interventions aimed at improving nutrition knowledge and dietary diversity among parents of undernourished children, video drama improved dietary diversity and parental knowledge, whereas SMS did not provide additional benefits (Mutai, 2025). Among caregivers of patients with end-stage renal disease, the combination of tele-counselling delivered via the

Line messaging application and traditional support significantly improved nutrition knowledge and dietary behaviours (Saengyo, 2023).

Video Counselling: Real-time video counselling has been found to be potentially more effective than control conditions or other support modalities in addressing risk factors such as physical inactivity and obesity (Amalia, 2025). In paediatric telenutrition services, synchronous video consultations are the most commonly used modality (60–85%) and yield clinical outcomes comparable to those of traditional face-to-face care (Haimi, 2025).

Hybrid Models and Other Digital Interventions: Digital micro-interventions—including virtual culinary medicine programmes, web-based nutrition coaching, SMS and email reminders, mobile application–based self-management, and hybrid community programmes—have been identified as effective tools for promoting plant-based diets. These interventions have led to improvements in diet quality, cooking skills, and nutrition knowledge (Zábó, 2025).

The Role of Digital Health Literacy in Intervention Effectiveness

Digital health literacy (DHL) refers to individuals' ability to access, understand, appraise, and use reliable health information in digital environments to make informed health decisions (Causio, 2025; Yani, 2022). It plays a critical role in the effectiveness of telenursing interventions, as it directly influences how efficiently individuals can utilise digital health tools and services (Asiri, 2025; Margañon, 2023).

Digital health interventions (DHIs) can enhance health literacy and improve health behaviours across diverse populations (Causio, 2025; Yani, 2022). For example, mobile-based, family-centred educational interventions have been shown to significantly improve both health literacy and self-care behaviours among patients with heart failure (Badiyepeymaiejahromi, 2025). However, the effectiveness of DHIs may vary due to the digital divide, which is influenced by factors such as age and socioeconomic status. Inequalities in digital health literacy may exacerbate disparities in access to telemedicine, highlighting the importance of addressing these gaps to promote health equity (Ch, 2025).

Digital health literacy is also crucial for nurses. Studies indicate that nursing students' levels of digital health literacy are associated with their healthy lifestyle behaviours and psychological resilience (Liu, 2024). In telenursing services, communication strategies such as the "teach-back" method can be particularly beneficial for users with limited health literacy, helping patients feel heard, enhancing their confidence to take action, and ensuring clarity regarding next steps (Morony, 2018). Such approaches represent effective strategies for increasing intervention effectiveness among individuals with lower levels of digital health literacy.

Strengths and Limitations of Telenursing Practices

While telenursing practices offer significant advantages in healthcare delivery, they also entail certain limitations.

Strengths

Accessibility and Continuity: Telenursing enhances access to healthcare services and ensures continuity of care, particularly for individuals facing geographical barriers or mobility limitations (Ch, 2025; Asiri, 2025).

Improved Patient Outcomes: Technology-based nursing interventions can increase patient adherence, reduce hospital admissions, and improve nursing efficiency (Asiri, 2025). Among

patients with heart failure, such interventions have been shown to improve health literacy and self-care behaviours (Badiyepeymaiejahromi, 2025).

Cost-Effectiveness: Telenursing has the potential to reduce healthcare costs (Margañon, 2023).

Flexibility and Convenience: It offers appointment flexibility and enables patients to receive care in the comfort of their own homes (Ch, 2025).

Health Equity: Telenursing can be effective in delivering healthcare services to disadvantaged populations (Asiri, 2025).

Limitations

Digital Divide and Limited Literacy: Insufficient digital literacy, infrastructural limitations, and socioeconomic factors may restrict access to and use of telenursing services (Asiri, 2025; Ch, 2025; Margañon, 2023).

Technological Challenges: Limited access to devices, internet connectivity issues, and technical failures may disrupt service delivery (Margañon, 2023).

Lack of Personal Contact: For some patients, telenursing may not fully replace face-to-face interactions, potentially limiting the development of therapeutic relationships.

Data Security and Privacy Concerns: Ensuring the security and confidentiality of health data on digital platforms remains a major concern (Yani, 2022).

Nursing Workload and Training Requirements: Telenursing may require nurses to acquire new competencies and undergo additional training, potentially affecting workload (Asiri, 2025).

Legal and Regulatory Frameworks: The absence of clear legal and regulatory frameworks for telenursing practices may hinder their widespread implementation.

School Health and Digital Intervention Programmes

The adoption of telehealth within school health services has accelerated markedly, particularly in the wake of the COVID-19 pandemic, thereby highlighting the pivotal role of nurses in this field (Margañon, 2023). Digital intervention programmes are increasingly utilised in schools for a range of purposes, including health promotion, mental health management, and early detection of health problems (Margañon, 2023).

These programmes may employ mobile applications, online platforms, and other digital tools to improve students' health behaviours and outcomes. For instance, the potential of digital tools such as chatbots to promote nutrition and physical activity among adolescents has been explored. However, the feasibility and acceptability of such programmes may vary across contexts and populations.

School nurses assume multifaceted roles in school-based telehealth initiatives, encompassing management, education, and remote monitoring. Although telehealth offers clear advantages for enhancing the delivery of health services in schools, challenges related to digital literacy, access to devices, and associated costs remain. Consequently, there is a need for more robust empirical evidence and stronger stakeholder collaboration to enhance the effectiveness of digital interventions in the field of school health (Margañon, 2023).

Conclusion and Recommendations

This review has examined, from a holistic perspective, the decisive role of dietary habits during adolescence in shaping lifelong health, the bidirectional effects of digitalisation on adolescent health behaviours, and the potential contributions of tele-nursing practices to health promotion. The findings indicate that adolescents are at high risk of unhealthy dietary behaviours, while the abundance of information available in digital environments may lead to misinformation in the absence of adequate digital health literacy.

Digital health literacy emerges as a critical determinant of adolescents' ability to accurately evaluate online health and nutrition information and to translate this knowledge into healthy behaviours. The studies reviewed demonstrate that individuals with higher levels of digital health literacy make more informed health decisions and exhibit more positive dietary habits. Conversely, the digital divide, socioeconomic inequalities, and insufficient critical appraisal skills constitute significant factors limiting the effectiveness of digital interventions.

When evaluated within the framework of Pender's Health Promotion Model, tele-nursing practices are considered effective tools for increasing perceived benefits, reducing perceived barriers, strengthening self-efficacy, and supporting positive behavioural affect. Although mobile applications, video counselling, SMS-based support, and hybrid digital models appear to hold potential for improving dietary behaviours among adolescents, the evidence regarding their effectiveness remains inconsistent, underscoring the need for more robust research.

In light of these findings, the following recommendations may be proposed:

- Nutrition interventions targeting adolescents should move beyond mere information provision and focus on enhancing digital health literacy and critical appraisal skills.
- Tele-nursing-based nutrition programmes should be structured around theoretical frameworks such as Pender's Health Promotion Model and incorporate personalised approaches.
- The integration of digital and telehealth applications within school health services should be supported, and the roles of school nurses in this area should be strengthened.
- The design of digital interventions should prioritise data privacy, ethical principles, and equity of access, alongside the development of policies aimed at reducing the digital divide.
- Future research should prioritise randomised controlled and culturally sensitive studies that assess the long-term effects of tele-nursing and digital nutrition interventions for adolescents.

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SIGMOID VOLVULUS IN A 13-YEAR-OLD GIRL: CASE REPORT

Dr. Muhammed Burhan TEKIN
Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

Dr. Sabit DERE
Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

Doç. Dr. İbrahim AKKOYUN
Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

ÖZET

Sigmoid volvulus (SV), çocukluk çağında oldukça nadir görülen ancak tanıda gecikildiğinde kolonik iskemi, nekroz ve perforasyon gibi hayatı tehdit edici komplikasyonlara yol açabilen bir klinik tablodur. Çocuklar çoğunlukla karın ağrısı, abdominal distansiyon, kusma gibi nonspesifik semptomlarla başvurduklarından tanı kolayca gecikebilir. Bu nedenle, akut veya tekrarlayan karın ağrısı ile başvuran pediatrik hastalarda Sigmoid Volvulus ayırıcı tanıda mutlaka göz önünde bulundurulmalıdır.

Bu olgumuzda 13 yaşındaki kız hasta, bir gün önce başlayan karın ağrısı ve iki gün önceki kısa süreli ishal öyküsü ile başvurdu. Kontrastlı batın BT'de sigmoid kolona ait 9 cm'ye ulaşan belirgin dilatasyon ile mezenterde volvulus lehine torsiyon "girdap" bulgusu ve serbest sıvı saptandı. Laparoskopik girişim sonrası ciddi dilate kolon ansları ,manevra ve görüş kabiliyetini sınırlaması nedeniyle laparotomiye geçildi ve sigmoid kolonun kendi etrafında 360° döndüğü görüldü. Detorsiyon sonrası barsak dolaşımı doğal olarak değerlendirildi. Postoperatif dönemi sorunsuz seyreden hasta beşinci günde oral alımı tolere ederek gaz-gaita çıkışı ile taburcu edildi.

Bu olgu, çocukluk çağında nadir görülen sigmoid volvulusun nonspesifik semptomlarla prezente olabileceğini ve erken radyolojik değerlendirme ile zamanında cerrahi müdahalenin morbiditeyi azalttığını göstermektedir. Sigmoid volvulusun çocukluk çağında nadir görülmesine rağmen erken tanı ve uygun cerrahi yönetim ile başarılı şekilde tedavi edilebildiği vurgulanmaktadır.

ABSTRACT

Sigmoid volvulus (SV) is a rare clinical entity in the pediatric population, which can lead to life-threatening complications such as colonic ischemia, necrosis, and perforation if diagnosis is delayed. Children often present with nonspecific symptoms, including abdominal pain, distension, and vomiting, which can easily delay recognition. Therefore, SV should be considered in the differential diagnosis of pediatric patients presenting with acute or recurrent abdominal pain.

We report a case of a 13-year-old girl who presented with abdominal pain of one-day duration and a brief episode of diarrhea two days prior. Contrast-enhanced abdominal computed tomography revealed significant dilation of the sigmoid colon measuring up to 9 cm, with twisting of the mesentery consistent with volvulus and associated free fluid. Laparoscopic exploration was initially performed; however, due to severely dilated colonic loops limiting visualization and manipulation, conversion to laparotomy was necessary. Intraoperatively, the

sigmoid colon was found to have rotated 360° around its mesentery. Bowel perfusion was assessed as normal following detorsion. The postoperative course was uneventful, and the patient was discharged on the fifth day with adequate oral intake and regular bowel function.

This case highlights that pediatric SV, although rare, may present with nonspecific clinical features. Early radiologic evaluation and timely surgical intervention are crucial to reduce morbidity. Despite its rarity in children, prompt diagnosis and appropriate surgical management can lead to successful outcomes.

GİRİŞ

Sigmoid volvulus (SV), çocuklarda nadir görülen bir kolon tıkanıklığıdır ve tanıdaki gecikmeler kolonik iskemi, nekroz veya perforasyon gibi ciddi komplikasyonlara yol açabilir [1]. Pediatrik hastalarda karın ağrısı, abdominal şişlik ve kusma gibi spesifik olmayan belirtiler ön planda olduğundan, hastalığın tanısı sıklıkla zor konulur ve yüksek klinik şüphe gerektirir [1,2]. Bu nedenle, tekrarlayan veya ani karın ağrısı ile başvuran çocuklarda SV, nadir görülmesine rağmen mutlaka ayırıcı tanıda düşünülmelidir [2].

Çocukluk çağındaki volvuluslar genellikle bağırsaklarda malrotasyon veya internal herniasyon ile ilişkilidir; buna karşın SV, bu yaş grubunda oldukça nadirdir [1]. Erken tanı konulmazsa, hastalık kolonik iskemi ve perforasyona ilerleyebilir; bu nedenle hızlı radyolojik değerlendirme ve uygun cerrahi yaklaşım morbidite ve mortalitenin azaltılmasında hayati öneme sahiptir [2].

Bu rapor, fonksiyonel konstipasyon nedeniyle SV tanısı alan bir pediatrik olguyu sunmakta ve çocuklarda nadir görülen bu durumun erken tanı ve cerrahi yönetim açısından önemini ortaya koymaktadır [2].

ARAŞTIRMA VE BULGULAR

OLGU SUNUMU

13 yaşında kız hasta, bir gün önce başlayan karın ağrısı ve iki gün önce kısa süreli ishal öyküsü ile acil servise başvurdu. Hastada kusma yoktu hafif düzeyde bulantı mevcuttu; son 24 saatte gaz ve gaita çıkışı mevcuttu. Fizik muayenede batında yaygın hassasiyet saptandı; rebound ve defans bulgusu yoktu . Alt kadranlarda muhtemel dilate bağırsak anslarına bağlı olarak hafif distansiyon bulgusu mevcuttu. Hastanın birkaç yıldır kabızlık bulgularına bağlı olarak tedavi aldığı dönemler olduğu öğrenildi.

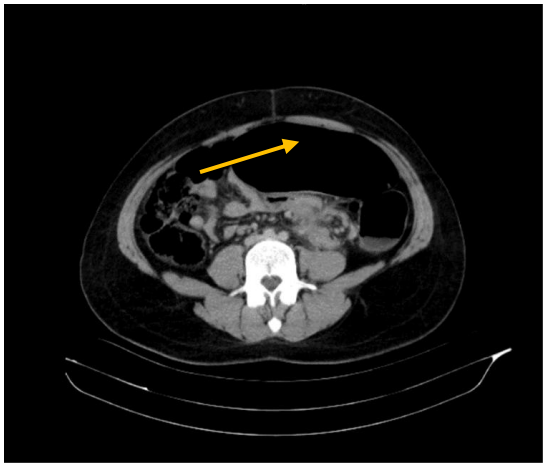
Hastaya öncelikle çekilen grafilerde kahve çekirdeği görünümünü andıran muhtemel sigmoid kolona ait olan belirgin dilate kolonik ans görüntüsü mevcuttu.(Resim 1) Başlangıçta abdominal ultrasonografi planlansa da, hastanın fazla kilolu olması nedeniyle kontrastlı tüm batın bilgisayarlı tomografi (BT) çekilmesi uygun görüldü. BT incelemesinde sol üst kadranda çapı yaklaşık 9 cm'ye ulaşan sigmoid kolon dilatasyonu(Resim 2), mezenterde torsiyon görüntüsü (girdap bulgusu)(Resim 3) ve perisplenik alanda serbes t sıvı izlendi.



(Resim 1): Kahve çekirdeği görünümünü andıran muhtemel sigmoid kolona ait olan belirgin dilate kolonik ans görüntüsü



(Resim 2):Dilate Sigmoid kolon ansı Bt de çapı en geniş yerinde 9 cm e ulaşmakta



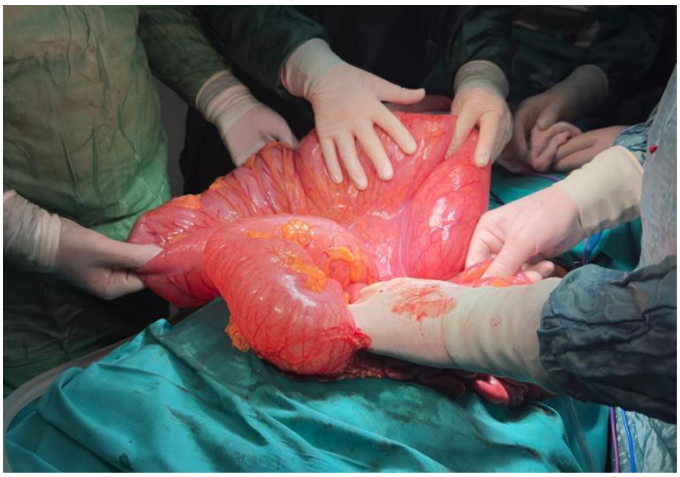
(Resim 3): mezenterde torsiyon görüntüsü (ok ile gösterilen:girdap bulgusu)

Ardından hastanın oral alımı durdurularak çocuk cerrahisi servisinde takip ve tedaviye alındı. Nazogastrik tüp takıldı ve antibiyoterapi başlandı. Operasyon planlandı.

Ameliyat sırasında infraumbilikal insizyon ve 10 mm trokar ile laparoskopik olarak batın değerlendirildi. Sağ üst ve alt kadranlardan ek trokarlarla eksplorasyon yapıldı. Sigmoid kolon, inen kolon ve transvers kolon belirgin şekilde dilateydi ve sigmoid kolon mezosunda "girdap" bulgusu gözlendi. İnce bağırsak segmentlerinin dolaşımı doğaldı. Laparoskopik girişim sonrası ciddi dilate kolon ansları ,manevra ve görüş kabiliyetini sınırlaması nedeniyle laparotomiye geçildi ve göbek üstü altı orta hat insizyonuyla batın eksplore edildi. Operasyonda sigmoid kolonun kendi etrafında 360° dönmüş olduğu ve detorsiyon sonrası barsak perfüzyonunun doğal olduğu görüldü.(Resim 4) Sigmoid kolonun en geniş segmenti yaklaşık 15 cm çapındaydı;(Resim 5) transvers, inen ve çıkan kolon segmentlerinde de belirgin dilatasyon mevcuttu. İnce bağırsaklar Treitz'e kadar izlendi ve doğal yapıda gözlendi. Ek cerrahi patolojik bulguya rastlanılmadı. Operasyon sırasında komplikasyon gözlenmedi.

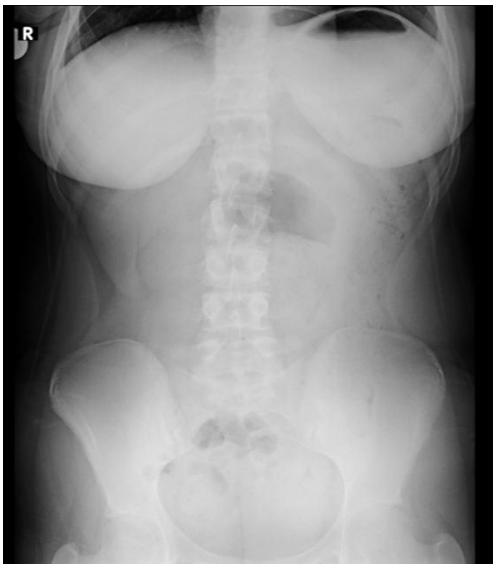


(Resim 4): Sigmoid kolonun kendi etrafında 360° dönmüş olduğu görüldü. Ok işaretiyle gösterilmiştir.



(Resim 5): Sigmoid kolonun en geniş segmenti yaklaşık 15 cm çapındaydı

Postoperatif dönemde hasta 5. günde normal beslenmeye başladı, gaz ve gaita çıkışı olduğu görüldü, kusma veya aktif şikayeti yoktu ve komplikasyonsuz şekilde taburcu edildi. Postop poliklinik kontrollerinde hastanın aktif şikayeti olmadığı görüldü ve kontrol grafilerinde dilate bağırsak anslarının normale döndüğü görüldü.(Resim 5)



(Resim 5): Postop 2. Ayda çekilen adbg görüntüsü. Dilate bağırsak anslarının normale döndüğü görüldü

TARTIŞMA

Sigmoid volvulus (SV), redundant bir kolon segmentinin mezenteri etrafında dönmesi ile ortaya çıkan nadir bir pediatrik gastrointestinal acil durumdur [3]. Torsiyonun 180°'yi aşması bağırsak lümeninde tıkanıklığa, 360°'yi aşması ise vasküler perfüzyon bozukluğuna yol açar [3]. Çocukluk çağında SV nadir görülmekle birlikte, tanı gecikirse kolonik iskemi, nekroz ve perforasyon gibi ciddi komplikasyonlar gelişebilir [1,2]. Olgumuzda, hastanın nonspesifik semptomlarla başvurması, bu durumun tanısal zorluğunu yansıtmaktadır [2].

Pediatrik SV olguları genellikle erkeklerde daha sık görülür; literatürde erkek/kız oranı yaklaşık 3.5:1 olarak bildirilmiştir [2,4]. Bununla birlikte olgumuz bir kız hastada gerçekleşmiştir; bu durum, SV'nin pediatrik popülasyonda her iki cinsiyeti de etkileyebileceğini göstermektedir.

Pediatrik hastalarda SV, akut veya tekrarlayan karın ağrısı atakları ile prezente olabilir [2]. Spontan detorsiyon sonrası gaz veya gaita çıkışı görülebilir ve bu durum SV'nin konstipasyon ile karıştırılmasına neden olabilir [5]. Olgumuzda da başlangıçta bulantı ve ishal öyküsü mevcuttu, bu da tanıyı geciktirebilecek bir klinik tablodur.

Tanıda görüntüleme yöntemleri büyük önem taşır. Düz batın grafilerinde kolon dilatasyonu ve "coffee bean" işareti görülebilir; ancak pediatrik olgularda bu bulgular erişkinlere kıyasla daha az tanısaldır [6,7]. Baryum lavman ve kontrastlı BT, hem tanısal hem de tedavi planlaması açısından değerli bilgiler sağlar [6]. Olgumuzda, kontrastlı BT ile sigmoid kolon dilatasyonu, mezenterde girdap bulgusu ve serbest sıvı saptanmış, cerrahi yaklaşımın planlanmasında yol gösterici olmuştur.

SV'nin tedavisinde stabil hastalarda non-operatif redüksiyon yöntemleri (baryum lavman veya sigmoidoskopi) ilk seçenek olabilir [2,6]. Ancak, redüksiyon başarısız olursa veya barsakta iskemik değişiklikler gelişirse acil cerrahi gereklidir [7,8]. Olgumuzda, laparoskopik girişim sonrası ciddi dilate kolon ansları ve görüş kısıtlılığı nedeniyle laparotomiye geçilmiş ve sigmoid kolonun kendi etrafında 360° dönmüş olduğu görülmüştür. Detorsiyon sonrası perfüzyonun normal olması, erken cerrahi müdahalenin morbiditeyi azaltmada kritik rol oynadığını göstermektedir [2].

Kesin tedavi, sigmoid kolon rezeksiyonu ile sağlanır; sadece detorsiyon yapılan olgularda nüks riski yüksektir [2,4]. Olgumuzda herhangi bir rezeksiyon yapılmamış ve postoperatif takipte komplikasyon veya nüks gözlenmemiştir. Hirschsprung hastalığı ve diğer konjenital anomalilerin dışlanması için dikkatli değerlendirme yapılması önerilmektedir [2,6,9,10].

Sonuç olarak, pediatrik SV olguları nadir ve tanısı zor olabilir; nonspesifik semptomlar ve erken radyolojik bulguların dikkatle yorumlanması, zamanında cerrahi müdahale ile morbiditeyi azaltmada kritik öneme sahiptir [2]. Olgumuz, çocukluk çağında SV'nin nadir görüldüğünü, ancak erken tanı ve uygun cerrahi yönetimle başarılı şekilde tedavi edilebildiğini göstermektedir [2].

SONUÇ

Sonuç olarak, çocukluk çağında SV nadir olmakla birlikte, akut veya tekrarlayan karın ağrısı ve bağırsak obstrüksiyonu ile başvuran hastalarda mutlaka ayırıcı tanıda düşünülmelidir [2]. Standardize edilmiş bir tanı ve tedavi algoritmasının uygulanması, morbidite ve mortaliteyi azaltmada ve başarılı cerrahi sonuçlar elde etmede önemli bir strateji olarak öne çıkmaktadır [2].

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THE GUT-BRAIN-SKIN AXIS IN ACNE: IMPACT OF POLENODERM

Prof dr med Manole COJOCARU

Academy of Romanian Scientists

Titu Maiorescu University, Faculty of Medicine, Bucharest, Romania

https://orcid.org/0000-0002-7192-7490

Major Gheorghe GIURGIU

Deniplant-Aide Sante Medical Center, Biomedicine, Bucharest, Romania

https://orcid.org/0000-0002-5449-2712

ABSTRACT

Background It is increasingly believed that the interaction between skin microbes and host immunity plays an important role in acne. Acne also has close connections with the gastrointestinal tract, and many argue that the gut microbiota could be involved in the pathogenic process of acne. The emotions of stress, have been hypothesized to aggravate acne by altering the gut microbiota. The presence of a gut-brain-skin axis that connects gut microbes, oral probiotics, and diet, currently an area of intense scrutiny, to acne severity. This study concentrates on the skin and gut microbes in acne, the role that the gut-brain-skin axis plays in the immunobiology of acne, and newly emerging microbiome-based therapies that can be applied to treat acne.

Obiective The purpose of this study was to compare the diversity of the skin microbiota in acne patients before and after taking Polenoderm.

Materials and methods A longitudinal cohort study was performed on 20 participants with moderate to severe facial acne with no recent use of oral and topical antibiotics/retinoids.

Results Hence, it is crucial to understand Polenoderm impact on the acne skin microbiota which is thought to be perturbed, our study provides insight into the skin microbiota in acne and how it is modulated by Polenoderm and diet.

Conclusion Acne also has close connections with the gastrointestinal tract, and many argue that the gut microbiota could be involved in the pathogenic process of acne. As understanding of the microbiome in healthy skin and the pathophysiology of acne continues to develop, new therapeutic targets are arising.

Keywords: acne, gut-brain-skin axis microbiota, diet, Polenoderm

H-TYPE TRACHEOESOPHAGEAL FISTULA IN AN INFANT: CASE REPORT

Dr. Muhammed Burhan TEKIN

Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

Dr. Sabit DERE

Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

Doç. Dr. İbrahim AKKOYUN

Konya City Hospital, Department of Pediatric Surgery, Konya, Türkiye

ÖZET

H-tipi trakeoözofageal fistül (TÖF), tüm konjenital özofagus anomalileri içinde oldukça nadir görülen ve klinik seyri çoğu zaman belirgin olmayan bir malformasyondur. Aspirasyon ataklarının aralıklı seyretmesi ve özofagus lümeninin devamlı olması nedeniyle tanı neonatal dönemde çoğunlukla gözden kaçabilmektedir. Bu olgu sunumunda, tekrarlayan solunum sistemi yakınmaları ile başvuran Down sendromlu bir infantta tanı alan H-tipi TÖF'ün klinik özellikleri ve cerrahi yönetimi aktarılmıştır.

5 aylık, 4 kg ağırlığındaki erkek hasta; doğum sonrası dönemde 22 gün yenidoğan yoğun bakım yatış öyküsü olan bir olgudur. Hastanın beslenme sırasında ortaya çıkan öksürük, siyanoz ve hırıltılı solunum atakları nedeniyle yapılan değerlendirmesinde, tekrarlayan alt solunum yolu enfeksiyonlarına ait radyolojik bulgular mevcuttu. Hastamıza yapılan fleksible bronkoskopide yaklaşık C7-T1 vertebra hizasında trakeada sekresyon akışının izlendiği H-tipi fistül orifisi görüldü. Bunun üzerine tarafımızca cerrahi onarım planlandı. Peroperatif ve Postoperatif dönemde komplikasyon izlenmedi. Hasta halen tarafımızca sorunsuz takip edilmektedir.

H-tipi TÖF'de klinik bulgular çoğu kez nonspesifiktir ve tekrarlayan aspirasyon pnömonisi ile büyüme geriliğine yol açabileceğinden, özellikle açıklanamayan öksürük, beslenme zorluğu ve akciğer infiltrasyonlarının varlığında bu nadir anomalinin akılda tutulması önemlidir. Bronkoskopi tanıda belirleyici yöntem olup, erken tanı cerrahi tedavi başarısını artırmakta ve morbiditeyi azaltmaktadır.

ABSTRACT

H-type tracheoesophageal fistula (TEF) is a rare congenital malformation among esophageal anomalies, and its clinical course is often subtle. Because aspiration episodes may occur intermittently and esophageal continuity is preserved, the diagnosis is frequently missed during the neonatal period. In this case report, we describe the clinical features and surgical management of an H-type TEF diagnosed in a Down syndrome infant presenting with recurrent respiratory symptoms.

The patient was a 5-month-old, 4-kg male infant with a history of 22 days of neonatal intensive care unit stay after birth. Evaluation for cough, cyanosis, and wheezing episodes occurring during feeding revealed radiologic findings consistent with recurrent lower respiratory tract

infections. Flexible bronchoscopy demonstrated an H-type fistulous orifice at approximately the C7–T1 vertebral level, with visible secretion flow into the trachea. Surgical repair was subsequently planned. No perioperative or postoperative complications were observed, and the patient continues to be followed uneventfully.

Clinical manifestations of H-type TEF are often nonspecific, and the condition may lead to recurrent aspiration pneumonia and growth retardation. Therefore, this rare anomaly should be considered in infants with unexplained cough, feeding difficulties, or persistent pulmonary infiltrates. Bronchoscopy is the key diagnostic tool, and early diagnosis improves surgical outcomes and reduces morbidity.

GİRİŞ

Trakeoözofageal fistül (TÖF), özofagus ve trakea arasında anormal bir fistül gelişimi ile karakterize, nadir görülen konjenital bir anomalidir. Embriyolojik dönemde trakeoözofageal septumun ayrışmasındaki yetersizlik sonucu oluştuğu kabul edilmektedir.(1) TÖF'lerin büyük çoğunluğu özofagus atrezisi ile birlikte izlenirken, izole TÖF olguları tüm trakeoözofageal malformasyonların küçük bir bölümünü oluşturmakta ve bu nedenle tanı süreci sıklıkla gecikebilmektedir.(2) İlk tanımlamalar 19. yüzyıla uzanmakta olup,(3) izole TÖF'ün cerrahi onarımı 20. yüzyılın ortalarında standart bir tedavi yaklaşımı olarak literatüre girmiştir.(4)

İzole, özellikle H-tipi TÖF, anatomik yapısı nedeniyle neonatal dönemde gözden kaçabilmekte ve olguların önemli bir kısmı süt çocukluğu döneminde, hatta bazı durumlarda adölesan ya da erişkin yaşlarda tanı almaktadır.(5).

Klinik bulgular çoğu zaman nonspesifiktir; ancak beslenme sırasında ortaya çıkan ani öksürük, hışıltı, siyanoz atakları ve tekrarlayan pnömoniler önemli ipuçlarıdır. (6) Özellikle açıklanamayan, üst lob yerleşimli tekrarlayan infiltrasyonlar ile başvuran süt çocuklarında gastroözofageal reflü düşünüldüğünde ayırıcı tanıda mutlaka TÖF de göz önünde bulundurulmalıdır.(7) H-tipi TÖF'de özofagus lümeninin devamlı olması nedeniyle yiyecek ya da sıvıların aspire edilmesi daha seyrek olsa da basınç değişikliklerine bağlı olarak trakeaya yemek içerikleri veya özofagusa hava geçişi görülebilir.(8) Bu durum, tekrarlayan solunum yolu enfeksiyonlarına, balgamlı öksürüğe ve daha nadiren göğüs ağrısı ya da hemoptiziye yol açabilir.(9)

Bu çalışmamızda, beslenme sırasında ortaya çıkan öksürük, siyanoz ve hırıltılı solunum atakları nedeniyle yapılan değerlendirmeler sonucunda izole H tipi trakeo-özofageal fistüllü, 5 aylık down sendromlu bir erkek hasta literatür eşliğinde sunulmuştur.

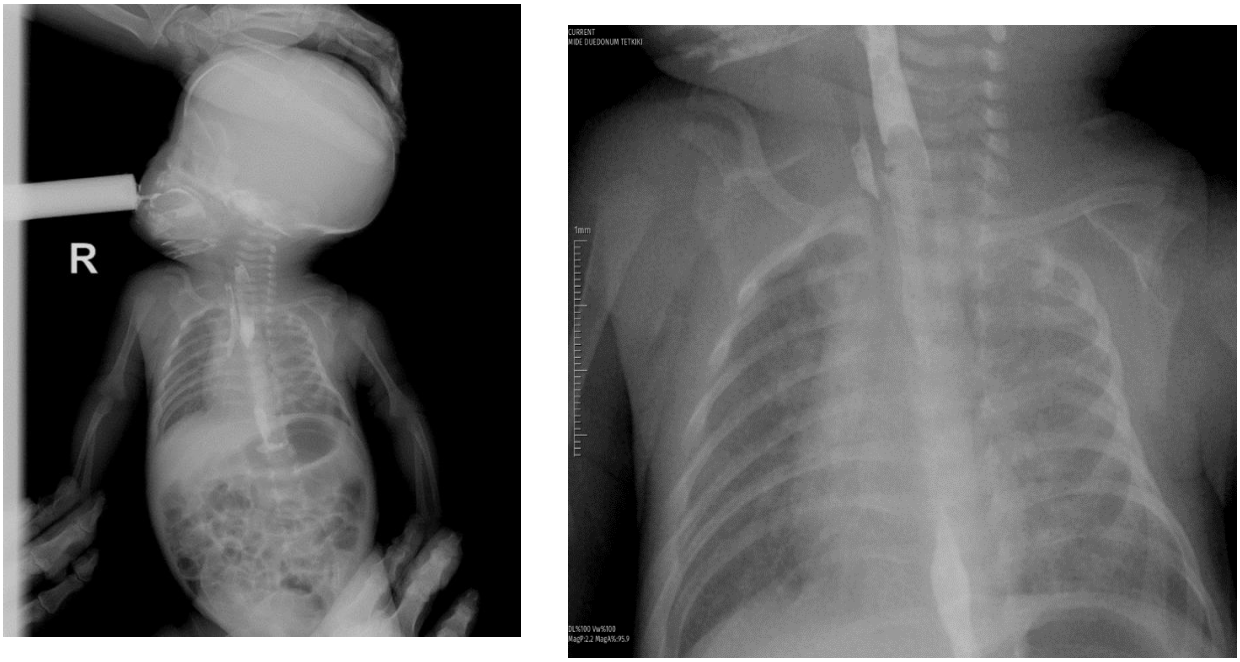
ARAŞTIRMA VE BULGULAR

OLGU SUNUMU

5 aylık erkek hasta, bilinen Trizomi 21 tanısı olan, 37. gebelik haftasında sezaryen ile 2520 g olarak dünyaya gelmiş. Doğum sonrası 22 gün yenidoğan yoğun bakım ünitesinde takip edilmiş. Son üç ay içinde COVID-19 enfeksiyonu nedeniyle hem servis hem de yoğun bakım yatışları bulunan hastanın, tekrarlayan öksürük, siyanoz ve hırıltılı solunum atakları nedeniyle tekrar hastanemize başvurduğu öğrenildi.

Başvuru sırasında solunum sıkıntısı belirgin olan hasta, mevcut klinik bulguları açısından ve tanısal amaçlı olarak ilk aşamada sineözofagografi çekildi. Çekilen özofagografi Radyoloji bölümü tarafından 'Özofagus lümenini dolduran oral kontrast maddenin C7-T1 vertebra

seviyesinde trakea lümenine kaçış olup öncelikle trakeo-özofageal fistül lehine değerlendirilmiştir.' Şeklinde raporlanmıştır.**(Resim 1)**



(Resim 1): Özofagus lümenini dolduran oral kontrast maddenin C7-T1 vertebra seviyesinde trakea lümenine kaçışı görüntülenmektedir.

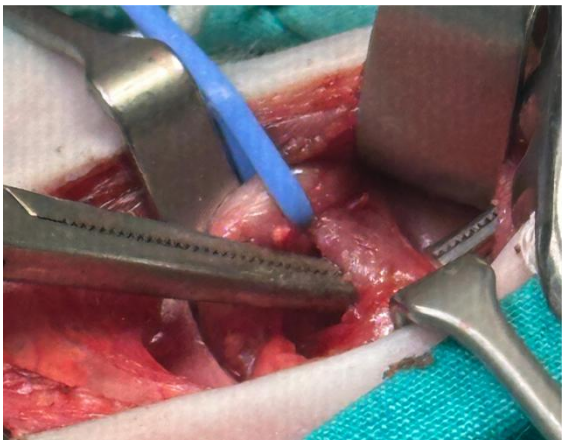
Bunun üzerine hastaya fleksible bronkoskopi yapıldı. Bronkoskopi, vokal kordların doğal olduğu; trakeanın üst, servikal bölgeye yakın kısmında fistül ağzı izlendiği ve fistül açıklığından sekresyon geldiği görüldü. Ek anomalilere rastlanmadı**. (Resim 2)**



(Resim 2): Bronkoskopide trakeanın üst, servikal bölgeye yakın kısmında **fistül ağzı** görülmektedir.

Hastaya çocuk cerrahisi kliniğimizce H tipi trakeoözofageal fistül (Tip E özofagus atrezisi) ön tanısıyla operasyon planlandı. Genel anestezi altında, hasta supin ve baş ekstansiyon pozisyonunda yatırılarak sağ klavikula üzerinden transvers servikal kesi ile giriş yapıldı. Sternokleidomastoid kas ekarte edilerek sağ a. carotis communis **ve** v. jugularis externa güvenli şekilde ortaya kondu ve ekarte edildi.

Preoperatif dönemde özofagusa yerleştirilen buji rehberliğinde özofagus lokalize edilerek askıya alındı. Trakea palpasyonla belirgin hale getirildi. C6–C7seviyesinde, trakea ve özofagus arasında seyreden fistül yapısı izlendi ve askıya alındı. Önce fistülün trakeal bileşeni 4/0 Vicryl ile ilki transfiks geçilerek çift bağlandı ve fistül trakeadan ayrıştırıldı. Ardından özofagus tarafı serbestleştirilerek fistül eksize edildi; lümen kontrolü sağlandı. Özofageal defekt 4/0 Vicryl sütürlerle primer olarak kapatıldı. Boyun derin fasyası anatomik olarak kapatıldı. Kanama kontrolü sonrası cilt altı ve cilt kapatıldı. İşlem sırasında komplikasyon gelişmedi**.(Resim 3 ve** 4)



(Resim 3): Servikal yolla “H tipindeki” trakeoözofageal fistül right angle klemp ile askıya alınmış olarak görülmektedir.



(Resim 4): Askı süturlara alındıktan sonra eksize edilen TÖF ün lümen görüntüsü

Postoperatif dönemde hasta stabil seyir gösterdi. **9. gününde** solunum sıkıntısı olmaması üzerine **nazogastrik tüp** çıkarıldı ve oral beslenmeye başlandı. Hastanın cerrahi sonrası takiplerinde komplikasyon gelişmediği görüldü.

TARTIŞMA

İzole H-tipi trakeoözofageal fistül (TÖF), tüm trakeoözofageal malformasyonlar içinde oldukça düşük prevalansa sahip olup, özofagus lümeninin tamamen açık olması ve aspirasyon ataklarının aralıklı görülmesi nedeniyle neonatal dönemde sıklıkla tanıdan kaçabilmektedir. Anatomik olarak fistül traktusunun çoğu olguda oblik seyir göstermesi, trakeal açıklığın genellikle daha kraniyal yerleşimli olması ve fistülün fonksiyonel olarak “tek yönlü valf” benzeri davranması tanı sürecini zorlaştıran faktörler arasındadır. Bu nedenle H-tipi TÖF’lü hastalarda tanı çoğu kez süt çocukluğu dönemine, hatta bazı bildirilerde adölesan ve erişkin yaşlara kadar gecikebilmektedir.(10)

Bizim olgumuzda da literatürle uyumlu şekilde klinik tablo nonspesifik olup, beslenme sırasında öksürük, siyanoz ve hışıltılı solunum atakları ön plandaydı. Hastanın tekrarlayan solunum yolu enfeksiyonları ve radyolojik olarak belirgin infiltrasyon odaklarının görülmesi, aspirasyon etiyolojisini düşündürmüş; ancak sıklıkla ilk akla gelen patolojiler arasında yer alan gastroözofageal reflü ile açıklanamayan bu bulgular, TÖF'ün mutlaka ayırıcı tanıda değerlendirilmesi gerektiğini göstermiştir.(7) Özellikle Down sendromu gibi eşlik eden genetik anomalilerde solunum sistemi enfeksiyonlarına yatkınlık artmakla birlikte, aspirasyon öyküsü ile birlikte sebat eden klinik tablo varlığında yapısal anomalilerin dışlanması önem kazanmaktadır.

Tanısal değerlendirmede fleksible bronkoskopi, H-tipi TÖF için en güvenilir yöntemlerden biridir ve fistül ağzının doğrudan görüntülenebilmesi nedeniyle tanıda belirleyici rol oynamaktadır.(4) Olgumuzda da kontrastlı özofagografi fistül lehine bulgular sağlamış; ancak kesin tanı bronkoskopide C7–T1 düzeyinde fistül orifisinin izlenmesi ile konulmuştur. Literatürde baryumlu özofagografilerde fistülün çoğu zaman saptanamayabileceği, bu nedenle bronkoskopinin tanısal doğruluğu artırdığı bildirilmiştir.(7) Bizim olgumuzda her iki yöntemden de yararlanılmış olup, bu yaklaşım tanısal süreci hızlandırmıştır.

H-tipi fistüllerin cerrahi tedavisinde amaç fistül traktusunun tamamen eksize edilmesi ve trakeal ile özofageal açıklıkların güvenli şekilde kapatılmasıdır. Servikal yaklaşım, özellikle kraniyal yerleşimli fistüllerde sıklıkla tercih edilen ve düşük morbiditeye sahip bir yöntemdir. Cerrahi sırasında rekürren laringeal sinir başta olmak üzere bölgedeki nörovasküler yapılar dikkatle korunmalı, trakea ve özofagus dikkatli diseksiyonla ayrılmalıdır. Olgumuzda sağ transvers servikal kesi ile fistül başarılı şekilde eksize edilmiş, trakeal ve özofageal komponentler primer sütürasyon ile onarılmış ve işlem sırasında komplikasyon izlenmemiştir. Postoperatif dönemin sorunsuz seyretmesi, erken tanı ve uygun cerrahi teknikle ilişkilendirilebilir.

H-tipi TÖF onarımının en önemli geç dönem komplikasyonları arasında fistül nüksü, striktür ve trakeomalazi yer almaktadır.(10,11) Literatürde özellikle nüks oranlarının düşük olmakla birlikte varlığını sürdüğü; bu nedenle cerrahi onarım sonrası uzun dönem izlemin gereklilik olduğu belirtilmiştir. Olgumuzun mevcut takiplerinde herhangi bir solunumsal komplikasyon veya nüks fistül bulgusunun izlenmemesi olumlu bir prognoza işaret etmektedir. Bununla birlikte Down sendromuna bağlı sistemik yatkınlıklar nedeniyle uzun dönem izlem planlanmaktadır.

SONUÇ

İzole H-tipi trakeoözofageal fistül, klinik bulguları çoğu zaman belirgin olmayan ve tanıda gecikmeye yol açabilen nadir bir konjenital anomalidir.(1) Özellikle beslenme sırasında ortaya çıkan öksürük, siyanoz, hışıltı atakları ve açıklanamayan tekrarlayan pnömonilerde bu patoloji mutlaka ayırıcı tanıda düşünülmelidir.(6) Bronkoskopi, fistülün doğrudan görüntülenmesine olanak sağlayarak tanıda en değerli yöntemdir.(4) Erken tanı ve uygun cerrahi yaklaşım, morbiditeyi azaltmakta ve prognozu belirgin şekilde iyileştirmektedir. Bizim olgumuzda olduğu gibi Down sendromu gibi eşlik eden durumlarda bile zamanında yapılan cerrahi onarım ile başarılı ve sorunsuz bir takip dönemi sağlanabilmektedir.

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GUT DYSBIOSIS IN DOGS WITH SPINAL CORD INJURY: IMPACT OF POLENOPLASMIN

Major Gheorghe GIURGIU
Deniplant-Aide Sante Medical Center, Biomedicine, Bucharest, Romania
https://orcid.org/0000-0002-5449-2712

Dr. Cristina FERNOAGA
Head of Works at the University of Agronomic Sciences and Veterinary Medicine, Faculty of Veterinary Medicine. Bucharest, Romania
University Veterinary Emergency Hospital Prof. Univ.Dr. Alin Bîrțoiu, Bucharest, Romania

Prof dr med Manole COJOCARU
Academy of Romanian Scientists
Titu Maiorescu University, Faculty of Medicine, Bucharest, Romania
https://orcid.org/0000-0002-7192-7490

Abstract

Background Studies have demonstrated the presence of gut dysbiosis (alterations in gut bacterial homeostasis) secondary to spinal cord injury in dogs. The dysbiosis is thought to impair recovery by decreasing the production of short-chain fatty acids which play a role in suppressing inflammation within the central nervous system.

Obiective Therefore, targeting gut dysbiosis could have significant therapeutic value in the management of spinal cord injury. The purpose of this study is to determine if gut dysbiosis occurs in dogs with spinal cord injury. Another area of potential intervention interest is in situations of spinal injury where there is an urgent need to generate new neurons. To arrive at these observations, the authors examined how Polenoplasmin and diet solve paralysis in dogs.

Materials and methods The most common cause of spinal problems in dogs is trauma. We are currently assessing whether indoles can also stimulate formation of neurons in dogs with paralysis.

Results We found that gut microbes that metabolize tryptophan-an essential amino acid-secrete small molecules called indoles, which stimulate the development of new brain cells in dogs, also demonstrated that the indole-mediated signals elicit key regulatory factors known to be important for the formation of new neurons.

Conclusion This study is another intriguing piece of the puzzle highlighting the importance of lifestyle factors and diet.

In conclusion, the link between the health of the microbiome and the health of the brain shows how microorganisms in the gut solve paralysis. Gut microbe secreted molecule linked to formation of new nerve cells in paralysed dogs.

Keywords: intestinal dysbiosis, indoles, paralysed dog, Polenoplasmin.

CERVICAL DISABILITY INDEX (NDI): THE VALIDITY AND RELIABILITY FOR USE IN THE ALBANIAN-SPEAKING POPULATION

Elda Zeqiri

Health Science PhD Program, UCAM Universidad Católica San Antonio de Murcia, Campus de los Jerónimos, Murcia, Spain

Orges Lena

ÍTEM – Innovation in Manual and Physical Therapies, Research Group, Physiotherapy, Department, UCAM Universidad Católica San Antonio de Murcia, Murcia, Spain

Jasemin Todri

ÍTEM – Innovation in Manual and Physical Therapies, Research Group, Physiotherapy, Department, UCAM Universidad Católica San Antonio de Murcia, Murcia, Spain

Abstract*:*

Background: “Cross-cultural adaptation procedures” are usually used to convert the self-reported questionnaires to other languages and to ensure that the content is culturally appropriate.

Objective: To translate and validate in Albanian language the Neck Disability Index (NDI).

Design: An observation cross-cultural study.

Setting: The Cervical Disability Index will be taught individually online through the Google questionnaire.

Methodology: The cross-cultural adaptation will be performed according to the internationally recommended methodology, using the following guidelines: translation, back-translation; questionnaire diffusion and data collection and analysis.

The psychometric properties will be evaluated by administering the questionnaire to approximately 400 participants. Reliability will be estimated through stability and homogeneity assessment.

Results: This study is waiting for the committee’s approval, so there are no results to report.

Conclusion: We expect positive feedback from the Albanian version of the Neck Disability Index (NDI).

Keywords: Cross-cultural adaptation; Reliability; Validity, Neck Disability Index, Albanian translation

Introduction

Cross-cultural translation and validation of clinical instruments are essential processes to ensure that assessment tools are culturally relevant and linguistically accurate in different contexts. The Neck Disability Index (NDI) is one of the most widely used questionnaires to evaluate the

impact of cervical disorders on daily functioning and patients' quality of life (1–4). Originally designed in English by Vernon and Mior in 1991, the NDI has proven to be a valid and reliable tool across multiple languages, provided that appropriate methodological principles of translation and cross-cultural adaptation are followed (1–5).

The process of cross-cultural translation requires more than a literal translation; it involves adapting the content to ensure that it reflects the cultural nuances and linguistic practices of the target language. This includes semantic, idiomatic, conceptual, and experiential equivalence. An inappropriate translation may compromise the validity and sensitivity of the instrument, affecting its ability to accurately measure functional limitations and symptoms related to neck pain (2).

Validating the NDI in specific populations is crucial to confirm that the instrument preserves its psychometric properties, such as reliability, content and construct validity, and sensitivity to clinical change. Recent studies have highlighted the importance of using validated versions of the NDI to obtain comparable data across different cultures and to ensure the effectiveness of therapeutic interventions in multicultural contexts (2–6).

The clinical importance of the NDI lies in its ability to quantify cervical disability and monitor treatment outcomes. Proper use of the instrument enables healthcare professionals to make informed decisions regarding patient management and facilitates research in diverse populations. Therefore, translating and validating the NDI are fundamental steps toward expanding its applicability and global usefulness in clinical practice and research.

In Spanish-speaking contexts, significant efforts have been made to adapt and validate the NDI. For example, Andrade Ortega et al. conducted the validation of the Spanish version of the NDI, confirming that it is a reliable and valid tool for evaluating disability in patients with neck pain (7).

It is important to emphasize that cross-cultural adaptation not only involves language translation but also the consideration of cultural factors that may influence understanding and relevance of questionnaire items.

However, to date, there is no validated Albanian version of the NDI, which limits its applicability in Albanian-speaking countries and communities, such as Albania, Kosovo, North Macedonia, and the Albanian diaspora across Europe and beyond.

Validating the Albanian version of the NDI also provides a unique opportunity to address potential cultural and linguistic differences that may influence the perception of pain and disability in this population. For example, cultural norms, differences in healthcare access, and expectations regarding treatment outcomes may affect how Albanian patients interpret and respond to questionnaire items.

Translating and validating the NDI into Albanian for the first time is an essential step to improving healthcare and research in Albanian-speaking countries and communities. This effort will not only increase access to standardized clinical tools but also contribute to the development of international comparative data, strengthening global understanding of cervical disorders and their functional and social implications.

Objective

To adapt, validate, and assess the test–retest reliability of the Neck Disability Index (NDI) in an Albanian-speaking population.

Methods

This study protocol fully adheres to the ethical standards of the 1975 Declaration of Helsinki and was prospectively registered at the U.S. National Library of Medicine with a clinical trial protocol number: NCT06685094. Approval from the UCAM Research Ethics Committee is pending.

3.1. Study Design

A cross-cultural observational study will be applied.

3.2. Participants

Data collection will be launched online using a Google questionnaire in Albania, with a total of 400 voluntary participants aged between 18 and 80 years, after approval from the UCAM Ethics Committee.

The prerecorded training session will include instructions on administrative aspects of the study (e.g., informed consent, participant recruitment). The questionnaires will be completed individually and voluntarily.

3.2.1. Eligibility Criteria

Participants with joint and muscle pain, musculoskeletal disorders, rheumatism, or myofascial pain syndrome will be informed about the study. If they are interested and available, they will complete the online questionnaire. Each online participant must be over 18 years old. Patients with contraindications for manual therapy, severe trauma of the lumbar spine or hip, tumour, or metabolic disease will be excluded.

3.3. Study Phases

Phase 1. Preparation for Translation

A careful translation methodology will be followed to avoid linguistic and cultural distortions that may produce a version with different psychometric properties.

Two independent translators will prepare the Albanian translation of the NDI. One translator will be a physiotherapist working in academia who will be informed about the concept of the questionnaire, and the other will be a professional translator who will not be informed about the project. The translators and one of the study investigators will compare both translations and reach consensus.

Next, two independent bilingual translators (English and Albanian), unfamiliar with the original English versions and the questionnaire application, will perform a back-translation. The final Albanian versions will be produced by the professional translators and two study investigators.

Phase 2. Data Collection, Management, and Confidentiality

One investigator will check the online questionnaire before data collection. This training will include discussion on data safety monitoring and participant confidentiality. Once data collection begins, the principal investigator will follow the progress of the questionnaire weekly online.

All records related to participant involvement will be stored in a password-protected online folder accessible only to researchers, study personnel, and physiotherapists involved in providing data. Each participant will receive a Study Identification Number (SIN).

Phase 3. Validation to Determine Psychometric Properties

This includes data analysis and interpretation.

Phase 4. Publication of Results

Participants will not be individually identified in any publication or presentation of research results. However, in unusual cases, online research records may be inspected by appropriate government agencies or disclosed in response to a court order. (Appendix 1: Timeline and Work Plan).

3.4. Translated Questionnaires for Outcome Measures (Neck Disability Index)

The Neck Disability Index (NDI) is a widely used self-administered questionnaire designed to assess the impact of neck pain on daily living activities and patient quality of life. Originally designed by Vernon and Mior (1991), the NDI consists of 10 items, each addressing a specific functional or symptom-related dimension of cervical disorders (1). These items include:

Pain: Intensity of neck pain; Personal care: Difficulty performing activities such as dressing or bathing; Lifting: Problems lifting objects of various weights. Reading: Limitations in reading due to neck pain. Headaches: Frequency and intensity of associated headaches. Concentration: Difficulties concentrating due to pain. Work: Impact of neck pain on work tasks. Driving: Problems operating vehicles. Sleep: Sleep disruptions due to pain. Recreation: Restrictions in leisure activities.

Each item includes five response options ranging from 0 to 5 points, where 0 indicates no problem or limitation and 5 represents maximum disability or restriction in performing the activity. The total score is obtained by summing the 10 items, with a maximum of 50 points. This score can also be expressed as a percentage, where 0% indicates no disability and 100% indicates maximum disability (1).

Completion Process

The NDI is designed to be easy to complete and takes approximately 5 to 10 minutes. Patients should read each item and select the response that best reflects their condition in the past few days. Ensuring that patients understand the instructions is fundamental, highlighting the importance of culturally and linguistically adapted versions in different languages, such as Albanian, to ensure validity of responses (8).

Clinical Utility

The NDI is a key tool in clinical practice and research because it allows healthcare professionals to:

- Assess severity of cervical disability.
- Monitor the effectiveness of treatments such as physiotherapy, medications, or surgery.
- Compare data across populations and international studies.

Additionally, due to its simple structure and focus on relevant daily activities, it is highly valued for its sensitivity to clinical change, making it an effective tool for measuring patient progress (9).

3.5. Statistical Method

SPSS version 25 (Chicago, IL) will be used to analyze the data. Normality of data distribution will be assessed (Shapiro–Wilk test). Descriptive data will be presented as mean ± standard deviation. Inter-rater reliability will be estimated using kappa statistics at the item level, and Cronbach’s alpha will be used to estimate internal consistency of the original and Albanian versions.

Results

This study is awaiting approval from the UCAM Research Ethics Committee; therefore, no results are available to report.

Discussion

The need for an Albanian version of the NDI is evident, given the increasing prevalence of musculoskeletal disorders, including cervical conditions, in this population. Recent reports indicate that cervical problems are a major global cause of disability, and their accurate assessment is fundamental for planning and monitoring clinical and rehabilitation interventions (10–13). Without a culturally and linguistically validated instrument, there is a significant risk of obtaining inaccurate or unrepresentative clinical data, which may negatively affect patient care and scientific research in this demographic group.

The process of translating and validating the NDI into Albanian will not only improve the accuracy and reliability of assessments in this population but also facilitate comparison of clinical and research data across international contexts. Furthermore, it will allow Albanian-speaking healthcare professionals to use a standardized tool to measure cervical disability severity and evaluate the effects of therapeutic interventions. This process requires rigorous cross-cultural translation to ensure semantic, idiomatic, cultural, and conceptual equivalence with the original instrument.

Conclusions

We expect a positive outcome for the Albanian version of the NDI.

Competing Interests Statement

The investigators declare no conflicts of interest.

Authorship

Individuals contributing substantially to the design, execution, analysis, and reporting of this study will be acknowledged as authors in the final publication.

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A CHILD PRESENTING WITH SUBGLOTTIC STENOSIS: A CASE OF RECURRENT STRIDOR

Fırat Bedir, MD

Department of Pediatrics, Bahçelievler Medipol Hospital, Istanbul, Türkiye

Abstract

Subglottic stenosis (SGS) is an uncommon but potentially life-threatening cause of upper airway obstruction in children. While congenital cases exist, most are acquired following intubation or infection. We present a pediatric patient with recurrent stridor due to SGS, successfully managed with endoscopic balloon dilation and corticosteroid therapy. This case emphasizes the importance of early recognition, multidisciplinary management, and long-term follow-up to prevent recurrence.

Keywords: Subglottic stenosis, stridor, balloon dilation, airway obstruction, pediatrics

Introduction

Subglottic stenosis (SGS) refers to airway narrowing below the vocal cords, typically at the level of the cricoid cartilage. It represents one of the most challenging causes of upper airway obstruction in children. The majority of cases are acquired, often resulting from mucosal injury following prolonged intubation, trauma, or infection. Congenital stenosis accounts for less than 10% of cases.

The widespread use of mechanical ventilation in neonatal and pediatric intensive care units has increased the prevalence of acquired SGS. Risk factors include prolonged intubation duration, large tube size, local infection, and gastroesophageal reflux. Recent studies suggest that post-intubation inflammation, ischemic injury, and subsequent fibrosis play key roles in the development of this condition.

Advances in endoscopic technology have enabled early diagnosis and minimally invasive management. Balloon dilation has emerged as a preferred first-line treatment for low- to moderate-grade SGS, reducing the need for open reconstructive surgery.

Case Presentation

A two-year-old girl was admitted to the pediatric emergency department with inspiratory stridor and respiratory distress persisting for two weeks. She had a history of intubation at six months of age for bronchiolitis, lasting ten days. Since then, she experienced recurrent episodes of stridor and noisy breathing.

On admission, she was alert, afebrile, and exhibited mild respiratory distress with suprasternal retractions. Her oxygen saturation was 96% on room air. Physical examination was unremarkable except for inspiratory stridor. Laboratory findings were within normal limits. A chest X-ray revealed normal lung fields without acute pathology.

Figure 1. Normal posteroanterior chest radiograph showing clear lung fields



Flexible laryngoscopy demonstrated a circumferential narrowing just below the vocal cords, consistent with Grade II subglottic stenosis according to the Cotton–Myer classification. A multidisciplinary team including pediatric otolaryngology and anesthesiology was consulted.

Under general anesthesia, direct laryngoscopy confirmed a 4-mm subglottic lumen. Endoscopic balloon dilation was performed using a 5-mm balloon catheter inflated to 8 atmospheres for 30 seconds, repeated three times. Following the procedure, intravenous dexamethasone (0.5 mg/kg/day) and nebulized budesonide were administered.

Postoperatively, the patient showed marked improvement. Stridor resolved within 24 hours, and she was discharged on oral corticosteroids for seven days with a proton pump inhibitor to prevent reflux.

At three-month and six-month follow-ups, the child remained asymptomatic. A repeat endoscopic evaluation at two years revealed a patent airway with minimal residual narrowing.

Figure 2. Endoscopic view showing circumferential subglottic narrowing consistent with Grade IIIsubglottic stenosis



Discussion

Subglottic stenosis remains a complex disorder requiring individualized management. In children, acquired SGS is far more common than congenital forms and is predominantly iatrogenic. The incidence is estimated at 1–4% among intubated neonates and infants. Prolonged intubation, excessive cuff pressure, and infection are key risk factors.

Endoscopic balloon dilation has become the preferred initial therapy for mild to moderate SGS (Grades I–II). It offers the advantages of airway preservation, minimal scarring, and short recovery time. Multiple studies report success rates of 70–90% after one or more dilation sessions. In severe cases (Grades III–IV), open reconstruction or cricotracheal resection may be necessary.

A 2023 multicenter study by Patel et al. showed that 84% of pediatric SGS patients treated with balloon dilation remained asymptomatic over two years. Similarly, Gupta et al. (2024) found that combining balloon dilation with topical corticosteroid therapy reduced recurrence rates and improved airway patency.

Adjunctive medical therapy with systemic or intralesional steroids helps suppress inflammation and fibroblast proliferation. Proton pump inhibitors are recommended to minimize reflux-induced mucosal irritation. Serial endoscopic evaluation at three- to six-month intervals ensures timely detection of restenosis.

Our case supports the literature emphasizing early endoscopic management and regular follow-up. Balloon dilation combined with corticosteroid therapy provided excellent long-term outcomes without the need for tracheostomy or open surgery.

Conclusion

Subglottic stenosis should always be considered in infants and children presenting with recurrent stridor, particularly in those with a history of previous intubation. Early diagnosis, appropriate grading, and minimally invasive management such as endoscopic balloon dilation significantly reduce morbidity. Combined corticosteroid and reflux prophylaxis further enhance long-term success. Regular follow-up remains essential for ensuring airway stability and detecting recurrence.

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EXPOSURE TO PEER BULLYING AMONG HEALTHY AND CHRONICALLY ILL SCHOOL-AGE CHILDREN: A COMPARATIVE PILOT STUDY

SAĞLIKLI VE KRONİK HASTALIĞA SAHİP OKUL ÇAĞI ÇOCUKLARININ AKRAN ZORBALIĞINA MARUZ KALMA DURUMLARI: KARŞILAŞTIRMALI BİR PİLOT ÇALIŞMA

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Ümmü Gül Aksu

Kastamonu Üniversitesi, Sağlık Bilimleri Fakültesi Hemşirelik Bölümü

Arş. Gör. Dr. Gamze Kaş Alay

Kastamonu Üniversitesi, Sağlık Bilimleri Fakültesi Hemşirelik Bölümü

Çocuk Sağlığı ve Hastalıkları Hemşireliği Anabilim Dalı

Mehmet Emre Usta

Kastamonu Üniversitesi, Sağlık Bilimleri Fakültesi Hemşirelik Bölümü

ÖZET

Amaç: Akran zorbalığı dünya genelinde çocuklar ve ergenler arasında yaygın olarak görülen bir şiddet türüdür. Bu çalışmanın amacı sağlıklı ve kronik hastalığa sahip okul çağı çocuklarının akran zorbalığına maruz kalma durumlarını belirlemektir.

Metod: Kesitsel, karşılaştırmalı ve tanımlayıcı çalışma, Mayıs 2025-Eylül 2025 tarihleri arasında Türkiye genelinde 7-14 yaş arası 204 çocukla yürütülmüştür. Araştırma verileri "Demografik Veriler Formu" ve "Akran Zorbalığı Ölçeği" kullanılarak çevrimiçi toplanmıştır. Veriler SPSS 22.0 programında analiz edilmiştir. Katılımcıların özellikleri frekans ve yüzde dağılımlarıyla, ölçek puanları ise ortalama ve standart sapma değerleriyle değerlendirilmiştir. Kategorik değişkenler arasındaki farklar Ki-Kare testi, ölçek puanlarındaki farklılıklar ise t-testi, ANOVA ve post hoc (Tukey, LSD) analizleriyle incelenmiştir. Anlamlılık düzeyi $p<0.05$ alınmıştır.

Bulgular: Araştırmaya katılan çocukların yaş ortalaması 10,75±1,81, olup %54,4'ünün kadın, %57,8'inin ortaokul düzeyinde eğitim gördüğü, %73,5'inin Akdeniz Bölgesi'nde yaşadığı, %17,6'sının kronik hastalığa sahip olduğu, %92,2'sinin ebeveynlerinin evli ve eğitim durumlarının lise olduğu (anne=%30,4, baba=%35,3) belirlenmiştir. Araştırmaya katılan çocukların hem zorbalığa maruz kalma (1.921±0.686) hem de zorba olma (1.501±0.652) düzeylerinin düşük olduğu belirlenmiştir. Katılımcıların %82,4'ünün akran zorbalığına karışmadığı ancak zorba ve kurban puanları arasında pozitif yönde ve yüksek düzeyde anlamlı bir ilişki olduğu bulunmuştur ($r=0.684$, $p<0.01$). Erkek öğrencilerin kurban ve zorba puan ortalamalarının, kız öğrencilere kıyasla daha yüksek olduğu ($p=0.010$, $p=0.017$), üniversite ve yüksek lisans mezunu ebeveyne sahip çocukların daha yüksek kurban ve zorba puanlarına sahip

olduğu ($p<0.05$), yaş arttıkça zorbalık davranışlarının azaldığı ($r=-0.151$; $p=0.031$) ve kronik hastalığı olan çocuklar arasında kurban, zorba ve hem zorba hem kurban oranlarının kronik hastalığı olmayanlara göre daha yüksek olduğu ($\chi^2=53.930$; $p=0.000$) belirlenmiştir.

Sonuç: Bulgular erkek cinsiyetin, kronik hastalık varlığının, yüksek ebeveyn eğitim düzeyinin akran zorbalığı riskini artırdığını ve yaş artışının zorbalık eğilimlerini azalttığını göstermektedir. Ayrıca kurban ve zorba rollerinin bir döngü içinde olduğu ve birbirinin risk faktörü olabileceği belirlenmiştir. Akran zorbalığının en fazla görüldüğü okul ortamlarında kronik hastalığı olan dezavantajlı çocuklar dikkatle izlenmeli, mağdur ya da zorba olma açısından riskli oldukları unutulmamalıdır. Bu kapsamda okul hemşireleri ve pediatri hemşireleri riskli çocukları merkeze alarak ebeveynler, öğretmenler, akranlar ve okul yönetimi dahil olmak üzere bütüncül eğitim ve tarama programları düzenlemelidir.

Anahtar Kelimeler: Akran Zorbalığı, Kurban, Zorba, Okul Çocuğu, Kronik Hastalık.

ABSTRACT

Objective: Peer bullying is a common form of violence among children and adolescents worldwide. The aim of this study was to determine the exposure of healthy and chronically ill school-aged children to peer bullying.

Method: A cross-sectional, comparative, and descriptive study was conducted with 204 children aged 7-14 across Turkey between May 2025 and September 2025. Data were collected online using the "Demographic Data Form" and the "Peer Bullying Scale." Data were analyzed using SPSS 22.0. Participant characteristics were evaluated using frequency and percentage distributions, and scale scores were evaluated using mean and standard deviation values. Differences between categorical variables were analyzed using the chi-square test, and differences in scale scores were analyzed using t-tests, ANOVA, and post hoc analyses (Tukey, LSD). A significance level of $p<0.05$ was set at 0.05.

Findings: The mean age of the children participating in the study was 10.75±1.81. 54.4% were female, 57.8% had a secondary school education, 73.5% lived in the Mediterranean Region, 17.6% had a chronic disease, and 92.2% of their parents were married and had a high school education (mothers=30.4%, fathers=35.3%). The participating children were found to have low levels of both bullying victimization (1.921±0.686) and bullying (1.501±0.652). While 82.4% of the participants did not engage in peer bullying, a positive and highly significant correlation was found between bully and victim scores ($r=0.684$, $p<0.01$). It was determined that male students had higher mean victim and bully scores than female students ($p=0.010$, $p=0.017$), children with parents who were university or graduate graduates had higher victim and bully scores ($p<0.05$), bullying behavior decreased with age ($r=-0.151$; $p=0.031$), and the rates of victims, bullies, and both bullies and victims were higher among children with chronic illnesses than among those without chronic illnesses ($\chi^2=53.930$; $p=0.000$).

Conclusion: The findings indicate that male gender, the presence of a chronic illness, and a higher level of parental education increase the risk of peer bullying, while increasing age decreases bullying tendencies. Furthermore, it was determined that the roles of victim and bully are cyclical and can be risk factors for each other. In school environments where peer bullying is most common, disadvantaged children with chronic illnesses should be carefully monitored, and it should be remembered that they are at risk for becoming victims or bullies. In this context, school nurses and pediatric nurses should organize holistic education and screening programs centered on at-risk children, including parents, teachers, peers, and school administration.

Keywords: Peer Bullying, Victim, Bully, School Child, Chronic Illness

GİRİŞ

Akran zorbalığı çocukluktan ergenliğe kadar yaygın olarak rastlanan, kısa ve uzun vadede biyopsikososyal, duygusal, akademik ve fiziksel gelişimi olumsuz etkileyen çok boyutlu bir sorun olarak tanımlanmaktadır (Ajibewa vd., 2025). Akran zorbalığı genellikle okul ortamlarında gerçekleşir (Christ vd., 2025). Öte yandan kronik hastalıklar, çocukların özgüvenlerini etkileyerek kendilerini dışlanmış hissetmelerine yol açabilir (Pinquart, 2013). Kronik hastalıklar, fiziksel ve psikolojik açıdan zorluklar yaratmakla kalmaz, aynı zamanda çocukların okulda ve sosyal çevrelerinde başkalarıyla olan etkileşimlerini de etkileyebilir (Sentenac vd., 2012). Kalp hastalıkları, diyabet, astım, obezite, metabolik, fiziksel ya da nörolojik durumlar başta olmak üzere kronik hastalığı olan çocuklar hem hastalık nedeniyle görünen farklılıklar hem de okul ve arkadaş aktivitelerinden kısıtlanma yüzünden sağlıklı akranlarına göre daha sık hedef alınma riski taşımaktadır (Sentenac vd., 2012; Pinquart, 2017; Abregú-Crespo vd., 2024). Hatta diyabet, astım gibi hastalıklarda okulda ilaç kullanmak ya da çeşitli aletlerle ölçüm yapmak (örneğin kan şekeri ölçümü, insülin uygulamak, astım spreyi kullanmak vb.) onları akranları tarafından dışlanmaya ve zorbalığa daha açık hale getirebilir (Andrade & Cresio Alves, 2019; Ancheta vd., 2023).

Yapılan çalışmalarda zorbalık; anksiyete, depresyon, sosyal izolasyon, düşük özsaygı, intihar düşünceleri, okula devamsızlık ve düşük akademik başarı ile ilişkili bulunmuştur (Sentenac vd., 2012; Christ vd., 2025; Ajibewa vd., 2025). Bu nedenle, zorbalığa karşı müdahaleler gerekli olmakla kalmayıp aynı zamanda zorbalık oranlarını azaltmada ve öğrencilerin ruh sağlığı sorunlarını iyileştirmede de etkili olacaktır (Brandão Neto vd., 2024). Hemşireler, çocukların sağlık ihtiyaçlarını karşılamada kritik bir rol oynarken aynı zamanda onların psikolojik, duygusal ve sosyal iyilik hallerini de izleyen ve destekleyen sağlık profesyonelleridir. Bu bağlamda, kronik hastalığı olan okul çağı çocuklarının akran zorbalığına maruz kalma durumu, çocuklarla çalışan okul hemşireleri ve pediatri hemşireleri açısından önemli bir konudur, çünkü zorbalık çocukların sağlıkları üzerinde uzun vadeli olumsuz etkiler yaratabilmektedir (Celdrán-Navarro vd., 2023; Brandão Neto vd., 2024). Hemşirelerin eğitim ortamındaki varlığı, bu ciddi okul sağlığı sorununun erken teşhisine ve önlenmesine katkıda bulunabilir (Brandão Neto vd., 2024).

Uluslararası literatürde sağlıklı ve kronik hastalığı olan çocukların akran zorbalığına maruz kalma durumlarını karşılaştıran çeşitli çalışmalar bulunmakla birlikte (Pinquart, 2017; Sentenac vd., 2012; Abregú-Crespo vd., 2024) bildiğimiz kadarıyla Türkiye'de bu konuyu ele alan bir çalışma bulunmamaktadır. Bu bağlamda çalışma, kronik hastalığı olan çocukların akran zorbalığına maruz kalma durumlarını incelemeyi, sağlıklı çocuklarla karşılaştırmayı ve mevcut literatürdeki boşluğu doldurmayı amaçlamaktadır.

Araştırma Sorusu

Türkiye'de sağlıklı çocuklar ile kronik hastalığı olan çocuklar arasında akran zorbalığı açısından anlamlı bir fark var mıdır?

YÖNTEM

Araştırmanın tipi, evren ve örneklem

Araştırma kesitsel, karşılaştırmalı ve tanımlayıcı tipte olup Mayıs 2025-Eylül 2025 tarihleri arasında Türkiye genelinde çevrimiçi olarak gerçekleştirildi. Araştırmanın evrenini, Türkiye genelinde çeşitli bölgelerde yaşayan sağlıklı veya kronik hastalığa sahip çocuklar oluşturmaktadır. Araştırmanın örneklemini örneklem seçim kriterlerini sağlayan, veri toplama süreci boyunca ulaşılabilen, çalışmaya katılmayı kabul eden 216 çocuk oluşturdu. Anket

sorularını eksik dolduran ve/veya dahil etme kriterlerini sağlamayan 12 çocuk çalışmadan çıkarılmış olup toplamda 204 çocuğun (kronik hastalık=36, sağlıklı=168) verileri analiz edilmiştir. Çalışmaya dahil edilme kriterleri; çocuğun 7-14 yaş arasında olması, tanı almış psikiyatrik bir hastalığının olmaması, okuma yazma bilmesi, zihinsel/mental yetersizliğinin olmamasıdır.

Veri toplama formları ve verilerin toplanması

Araştırmanın verileri "Demografik veriler formu" ve "Akran zorbalığı ölçeği" ile toplanmıştır. Demografik veriler formu; çocuğun yaş, cinsiyet, kronik hastalık varlığı, kardeş sayısı, eğitim durumu ile anne ve babanın sosyodemografik özelliklerini içeren 9 sorudan oluşmaktadır. Akran zorbalığı ölçeği; Kutlu ve Aydın (2010) tarafından ilkokul ve ortaokul düzeyindeki öğrencilerin okul ortamında yaşadıkları zorbalık davranışlarını hem kurban hem zorba rolleri açısından değerlendirmek amacıyla geliştirilmiştir. 5'li Likert tipindeki ölçek 19 maddeden oluşmaktadır ve ölçek puanlaması 1-5 arasında değişmektedir. Yüksek puanlar zorbalığa maruz kalma ya da zorbalık yapma düzeyinin yüksek olduğunu gösterir. "Kurban", "Zorba" ve "Dolgu" olmak üzere üç alt boyuttan oluşan ölçekte, kurban alt boyutu, öğrencinin arkadaşları tarafından dışlanma, alay edilme, tehdit edilme ya da fiziksel zarar görme gibi davranışlara maruz kalma düzeyini ölçer. Zorba alt boyutu, öğrencinin başkalarına yönelik fiziksel, sözel veya sosyal zorbalık davranışlarına yönelme eğilimini değerlendirir. Dolgu alt boyutu ise ölçekteki yanıt dengesini sağlamak amacıyla yer almakta olup doğrudan zorbalık ya da kurbanlıkla ilişkili değildir. Nötr Maddeler: 2, 4, 7, 15; Kurban olma maddeleri: 1, 3, 6, 8, 9, 10, 13, 16; Zorbalık maddeleri: 5, 12,14, 17, 18, 19'dur. Alt ölçeklerin Cronbach α güvenirlik katsayıları zorba, kurban ve dolgu için sırasıyla .83, .86, ve .70'dir (Kutlu & Aydın, 2010). Bizim çalışmamızda Kurban alt boyutu için Cronbach α katsayısı 0,767, Zorba alt boyutu için 0,848 ve Dolgu alt boyutu için 0,721 olarak bulunmuştur. Ölçeğin kullanılması için yazarlardan mail yolu ile izin alınmıştır.

Araştırmanın verileri, Mayıs 2025 – Eylül 2025 tarihleri arasında sosyal medya platformları (Instagram, Facebook, WhatsApp vb.) aracılığıyla çevrimiçi olarak toplanmıştır. Veri toplama araçları Google Form formatına dönüştürülerek dijital ortamda erişime açılmıştır. Araştırmacıların sosyal medya hesaplarında araştırmaya katılım çağrısı içeren bir afiş ve Google Form bağlantısı paylaşılmış; böylece erişim sağlayan çocukların/ebeveynlerinin forma erişip yanıtlamaları sağlanmıştır.

İstatistiksel analiz

Veriler SPSS 22.0 istatistik yazılımı kullanılarak analiz edilmiştir. Katılımcıların tanımlayıcı özelliklerini belirlemek için frekans ve yüzde dağılımları, ölçek puanlarını değerlendirmek için ise ortalama ve standart sapma istatistiklerinden yararlanılmıştır. Araştırma değişkenlerinin normal dağılıma uygunluğu, çarpıklık (Skewness) ve basıklık (Kurtosis) değerleri incelenerek test edilmiştir. Literatürde, bu değerlerin -1.5 ile +1.5 aralığında olması durumunda normal dağılım varsayımı kabul edilmektedir (Tabachnick & Fidell, 2013). Analiz sonuçlarına göre değişkenler normal dağılım göstermiştir ve bu nedenle parametrik testler uygulanmıştır. Kategorik değişkenler arasındaki oran farklarını incelemek için Ki-Kare testi, tanımlayıcı özelliklere göre ölçek puanlarındaki farklılıkları belirlemek amacıyla bağımsız gruplarda t-testi, tek yönlü varyans analizi (ANOVA) ve post hoc (Tukey, LSD) testleri kullanılmıştır. Tüm analizlerde anlamlılık düzeyi $p < 0.05$ olarak kabul edilmiştir.

Çalışmanın etik yönü

Araştırmanın yapılabilmesi için gerekli olan etik kurul izni, Kastamonu Üniversitesi Sosyal ve Beşeri Etik Kurul'undan (4/55-10.04.2025) alınmıştır. Katılımcı çocuklar ve ebeveynleri çevrimiçi olarak bilgilendirilmiş gönüllü onam formu aracılığı ile bilgilendirilmiş ve ölçeği doldurmaya başlamadan önce yazılı onam formunu işaretlemiştir.

BULGULAR

Araştırmaya katılan çocukların tanımlayıcı özelliklerine ilişkin bulgular incelendiğinde; yaş ortalaması 10,75±1,81 olup yaş aralığı 7-14 arasında değişmektedir. Katılımcıların %54,4'ü kadın, %45,6'sı erkek ve %57,8'inin ortaokul, %42,2'sinin ilkokul düzeyinde eğitim gördüğü belirlenmiştir. Katılımcıların %17,6'sı kronik hastalığa sahip olduğunu ve %82,4'ü herhangi bir kronik hastalığa sahip olmadığını belirtmiştir. Çalışmada Türkiye'nin yedi bölgesinden katılımcılar yer almakta olup büyük çoğunluğunun Akdeniz Bölgesi'nde (%73,5) yaşadığı belirlenmiştir. Büyük çoğunluğunun ebeveynleri evli (%92,2) ve yine büyük çoğunluğunun anne (%30,4) ve baba (%35,3) eğitim düzeyi liseydi.

Ölçekten elde edilen puan ortalamaları Tablo 1'de sunulmuş olup araştırmaya katılan çocukların hem zorbalığa maruz kalma hem de zorba olma düzeylerinin düşük olduğu, yani akran ilişkilerinde zorbalığın yaygın olmadığı görülmektedir.

Tablo 1. Akran Zorbalığı Ölçeği Puan Ortalamaları (n=204)

	Ort ± SS	Min - Maks	Ölçek Ranjı
Kurban	1.921±0.686	1.000-4.430	1-5
Zorba	1.501±0.652	1.000-5.000	1-5

Katılımcıların akran zorbalığına ilişkin rollerine göre dağılımları incelendiğinde bulgular, örneklem grubunda akran zorbalığına karışma oranlarının oldukça düşük olduğunu ve öğrencilerin büyük çoğunluğunun akran ilişkilerinde sağlıklı bir dengeye sahip olduğunu ortaya koymaktadır (Tablo 2).

Tablo 2. Katılımcıların Zorba Kurban Durumu Dağılımı (n=204)

Gruplar	Frekans (n)	Yüzde (%)
Kurban	12	5.9
Zorba	12	5.9
Zorba ve Kurban	12	5.9
Nötr	168	82.4

Tablo 3'de ölçek alt boyutları arasındaki ilişki incelendiğinde, zorba ve kurban puanları arasında pozitif yönde ve yüksek düzeyde anlamlı bir ilişki bulunmuştur ($r=0.684$, $p<0.01$). Pearson korelasyon analizine göre bu ilişkinin istatistiksel olarak oldukça anlamlı ($p<0.01$) olması, iki boyutun birbirini önemli ölçüde yordadığını göstermektedir.

Tablo 3. Akran Zorbalığı Ölçek Puanları Arasında Korelasyon Analizi

		Kurban
Zorba	r	0.684**
	p	0.000

**<0,01; Pearson Korelasyon Analizi

Tablo 4'de ölçek puanlarının katılımcıların tanımlayıcı özelliklerine göre farklılaşma durumuna ilişkin bulgular gösterilmiştir. Erkek öğrencilerin kurban (Ort.=2.06±0.76) ve zorba (Ort.=1.63±0.81) puan ortalamalarının, kız öğrencilere kıyasla (Ort.=1.81±0.60; Ort.=1.40±0.47) daha yüksek olduğu görülmektedir. Kronik hastalığı olan çocukların kurban (Ort.=2.73±0.85) ve zorba (Ort.=2.23±0.91) puan ortalamalarının, hastalığı olmayanlara göre (Ort.=1.75±0.50; Ort.=1.34±0.45) belirgin şekilde yüksek olması, sağlık sorunları yaşayan öğrencilerin hem zorbalığa maruz kalma hem de zorbalığa karışma eğilimlerinin daha yüksek olduğunu göstermektedir. Post hoc analiz sonuçlarına göre, üniversite ve yüksek lisans mezunu anne ve babaya sahip çocuklar daha yüksek kurban ve zorba puanlarına sahiptir. Bu bulgu, ebeveyn eğitim düzeyinin çocukların akran ilişkileri üzerindeki etkisine işaret etmektedir. Korelasyon analizine göre, yaş ile zorba puanları arasında negatif yönde anlamlı bir ilişki saptanmıştır (r=-0.151; p=0.031). Bu sonuç, yaş arttıkça zorbalık davranışlarının azaldığını göstermektedir.

Tablo 4. Akran Zorbalığı Ölçek Puanlarının Tanımlayıcı Özelliklere Göre Farklılaşma Durumu

Demografik Özellikler	**n**	**Kurban**	**Zorba**
Cinsiyet		Ort ± SS	Ort ± SS
Erkek	93	2.06±0.76	1.63±0.81
Kadın	111	1.81±0.60	1.40±0.47
t; p		2.658; **0.010**	2.513; **0.017**
Kronik Hastalık Varlığı		Ort ± SS	Ort ± SS
Var	36	2.73±0.85	2.23±0.91
Yok	168	1.75±0.50	1.34±0.45
t; p		9.225; **0.000**	8.660; **0.000**
Eğitim Durumu		Ort ± SS	Ort ± SS
İlkokul	86	2.01±0.73	1.59±0.69
Ortaokul	118	1.86±0.65	1.44±0.62
t; p		1.559; 0.121	1.697; 0.097
Ebeveyn Medeni Durumu		Ort ± SS	Ort ± SS
Evli	188	1.91±0.69	1.49±0.65
Ayrı	16	2.11±0.67	1.62±0.63
t; p		-1.132; 0.259	-0.740; 0.460
Anne Eğitim Durumu		Ort ± SS	Ort ± SS
İlkokul	41	1.64±0.48	1.39±0.54
Ortaokul	45	1.76±0.54	1.36±0.42

Lise	62	1.85±0.67	1.41±0.66
Üniversite	42	2.34±0.75	1.85±0.84
Yüksek Lisans	14	2.30±0.81	1.65±0.59
F; p		8.400; **0.000**	4.537; **0.002**
PostHoc=		4>1, 5>1, 4>2, 5>2, 4>3, 5>3 (p<0.05)	4>1, 4>2, 4>3 (p<0.05)
Baba Eğitim Durumu		Ort ± SS	Ort ± SS
İlkokul	31	1.83±0.64	1.55±0.70
Ortaokul	43	1.66±0.46	1.24±0.29
Lise	72	1.91±0.72	1.48±0.65
Üniversite	46	2.20±0.73	1.71±0.78
Yüksek Lisans	12	2.05±0.75	1.68±0.68
F; p		3.951; **0.004**	3.311; **0.012**
PostHoc=		4>1, 3>2, 4>2, 4>3 (p<0.05)	1>2, 4>2, 5>2 (p<0.05)
		r/p	r/p
Yaş		-0.098 / 0.162	**-0.151 / 0.031***

F: Anova Testi; t: Bağımsız Gruplar T-Testi; PostHoc:Tukey, LSD; Pearson Korelasyon Analizi. Kronik hastalıkların dağılımı: Ailevi Akdeniz ateşi, tip 1 diyabet, astım, çölyak, obezite, epilepsi, hipotiroidi, işitme kaybı, kalp hastalıkları, bronşit, egzama.

Tablo 5'de kronik hastalığı olan çocuklar arasında kurban, zorba ve hem zorba hem kurban oranlarının kronik hastalığı olmayanlara göre daha yüksek olduğu saptanmıştır (χ^2=53.930; p=0.000). Buna karşılık, kronik hastalığı olmayan grubun büyük çoğunluğunun nötr konumda olduğu, yani zorbalık davranışlarına karışmadığı görülmektedir.

Tablo 5. Kronik Hastalık Varlığına Göre Zorba Kurban Durumu Dağılımı

		Kronik Hastalık Var (n=36)		**Kronik Hastalık Yok (n=168)**		**p**
		n	**%**	**n**	**%**	
Zorba Kurban Durumu	Kurban	6	%16.7	6	%3.6	X^2=53.930 **p=0.000**
	Zorba	4	%11.1	8	%4.8	
	Zorba ve Kurban	10	%27.8	2	%1.2	
	Nötr	16	%44.4	152	%90.5	

Ki-Kare Analizi

TARTIŞMA

Akran zorbalığı, dünya genelinde okul çağındaki çocukların ve ergenlerin yaşadığı başlıca şiddet türlerinden biridir (Brandão Neto vd., 2024). Çalışmamızda zorbalığa maruz kalan çocukların aynı zamanda zorbalık davranışlarına da eğilim gösterdikleri belirlenmiştir. Başka bir ifadeyle, akranları tarafından zorbalığa uğrayan çocukların, benzer davranışları başka çocuklara yöneltebildiği görülmektedir. Bu sonuç, literatürde yer alan "zorba/kurban" döngüsünü desteklemekte ve akran zorbalığının yalnızca tek yönlü bir süreç olmadığını, etkileşimsel bir dinamik içerdiğini göstermektedir (Olweus, 1993; Salmivalli, 2010; Lereya vd., 2015).

Tanımlayıcı ve demografik değişkenler incelendiğinde, çalışmamızda erkek çocukların zorba ve kurban puan ortalamalarının kızlara kıyasla daha yüksek olması literatürle uyumludur. Çalışkan vd. (2019)'nin çalışmasında erkeklerin kızlardan 1,5 kat daha fazla zorbalığa uğradığı belirlenmiştir. Benzer bir çalışmada yine farklı zorbalık türleri dikkate alındığında erkek

çocuklarının, özellikle fiziksel zorbalık için, daha sık mağdur olduğu bulunmuştur (Iossi Silva vd., 2013). Korelasyon analizine göre, yaş ile zorba puanları arasında negatif yönde anlamlı bir ilişki saptanmıştır. Bu sonuç, yaş arttıkça zorbalık davranışlarının azaldığını göstermektedir. Gelişimsel olarak, yaşla birlikte empati ve sosyal farkındalığın artması bu durumu açıklayabilir. Amerika'da yapılan geniş kapsamlı bir çalışmada 6. sınıf öğrencileriyle karşılaştırıldığında 9 ve 10. Sınıf öğrencileri zorbalık biçimlerine daha az dahil oldukları belirlenmiştir (Wang vd., 2009). Ancak literatürdeki çalışmaların çoğu bu bulgudan farklı sonuçlar ortaya koymaktadır. Çalışkan vd. (2019), öğrencilerin yaşı bir yıl arttıkça zorbalığa uğrama olasılığının 1,2 kat arttığını saptamışlardır. Benzer olarak Yurtal ve Cenkseven (2007)'in çalışmasında okulda zorbaca davranışlarda bulunan öğrencilerin daha çok erkek olduğu ve yaşça daha büyük oldukları belirtilmiştir. Bu nedenle, araştırmamızda elde edilen bulgu literatürdeki genel eğilimden farklılık göstermekte olup kültürel özellikler, örneklem ve veri toplama aracı farklılıklarından kaynaklanabileceği düşünülmektedir. Çalışmamızda, üniversite ve yüksek lisans mezunu anne ve babaya sahip çocuklar daha yüksek kurban ve zorba puanlarına sahipti. Bu bulgu, ebeveyn eğitim düzeyinin çocukların akran ilişkileri üzerindeki etkisini göstermekte olup literatür ile paralellik göstermemektedir. Yapılan çalışmalarda ebeveyn eğitim seviyesi yüksek olan öğrencilerin, eğitim seviyesi düşük olanlara göre zorbalığa uğrama riskinin daha az olduğu bulunmuştur (Çalışkan vd., 2019; Magklara vd., 2012). Yüksek eğitim düzeyine sahip ebeveynlerin çocuklarının genellikle rekabetçi okul ortamlarında yer alması, çocukların sosyal ilişkilerinde daha fazla başarı mücadelesi ve sosyal baskı yaşamalarına neden olabilir. Bu tür ortamlarda akran ilişkileri daha karmaşık hale gelebilir ve hem zorbalık davranışları hem de kurban olma riski artabilir (Espelage & Swearer, 2010). Sonuç olarak, bu bulgu literatürdeki "yüksek sosyoekonomik düzeyde zorbalığın azaldığı" yönündeki klasik yaklaşımın aksine, modern okul ortamlarında zorbalığın sosyoekonomik ve kültürel düzeyden bağımsız, daha karmaşık bir sosyal etkileşim sorunu olduğunu göstermektedir.

Çalışmamızda kronik hastalığı olan çocukların kurban, zorba ve hem zorba hem kurban puanlarının kronik sağlıklı çocuklara göre daha yüksek olduğu saptanmıştır. Bu bulgu, kronik hastalığa sahip çocukların akran ilişkilerinde daha kırılgan bir konumda olduklarını, hem zorbalığa maruz kalma hem de zorbalık davranışlarında bulunma olasılıklarının arttığını göstermektedir. Sonuçlarımız, kronik fiziksel hastalık veya engeli olan çocukların, sağlıklı akranlarına kıyasla daha yüksek mağduriyet ve saldırganlığa maruz kaldığını bildiren bir meta-analiz sonuçlarıyla benzerdir (Pinquart, 2017). Benzer şekilde Sentenac vd. (2012)'nin çalışmasında psikiyatrik tanılar, öğrenme güçlükleri, fiziksel ve motor bozukluklar, kronik hastalıklar ve obezite gibi kronik rahatsızlığı olan çocuklarda daha yüksek düzeyde akran zorbalığı gösterilmiştir. Öte yandan zorbalığın önde gelen nedenlerinden biri, faillerin kurbanlarını farklı olarak algılamasıdır. Fiziksel rahatsızlığı, engelliliği veya kronik hastalığı olan gençler ve LGBT'li gençler için akran zorbalığı riskinin arttığı bildirilmiştir (Abregú-Crespo vd., 2024). Sağlık sorunlarının hem fiziksel hem de psikososyal etkilerinin bu çocukların akran gruplarında dışlanma, etiketlenme veya kendini savunma amaçlı saldırgan tepkiler verme gibi durumları tetikleyebileceği düşünülmekte olup çalışma sonuçlarımızın da bu hipotezi yansıttığı görülmektedir.

SONUÇ VE ÖNERİLER

Sonuç olarak bu çalışmanın bulguları erkek cinsiyetin ve yüksek ebeveyn eğitim düzeyinin akran zorbalığıyla ilişkili olduğunu, yaş artışının zorbalık eğilimlerini azalttığını ve kronik hastalık varlığının akran zorbalığını önemli derecede etkilediğini göstermektedir. Kronik hastalığın görünür semptomları, okul devamsızlıkları veya fiziksel zorluklar, sosyal farklılıkları belirginleştirerek damgalanmayı ve hedef alınmayı kolaylaştırabilir. Ayrıca hastalıkla ilişkili stres, düşük benlik algısı ve sosyal izolasyon riski de zorbalık etkilerini güçlendirebilir.

Zorbalık, kronik hastalık yönetimini zorlaştırarak tedavi uyumunu ve yaşam kalitesini olumsuz etkileyebilir. Bu nedenle akran zorbalığının erken dönemde tespit edilmesi ve önleme stratejilerinin geliştirilmesi, özellikle kronik sağlık sorunu olan çocuklar için, elzemdir. Hemşireler, bu çocukları izleyen ve onlara sağlık hizmeti sunan profesyoneller olarak zorbalıkla ilişkili psikolojik etkilerin erken dönemde fark edilmesini sağlayabilirler. Hemşireler erken tanı için sistematik tarama araçları ve anketlerle, okul ortamında veya polikliniklerde risk altındaki çocukları belirleyebilir; bireyselleştirilmiş destek, akran eğitimi ve aile danışmanlıkları sunabilirler. Ayrıca, zorbalığın etkilerinin yalnızca okul ortamında değil, evde de hissedildiği göz önünde bulundurulduğunda, aile desteği sağlamak, hemşirelerin hemşirelik pratiği içinde yer alan kritik bir alan olmalıdır. Hemşirelik uygulamalarının güçlendirilmesi ve kronik hastalığa özgü müdahalelerin geliştirilmesi, hem zorbalık maruziyetini azaltmaya hem de bu çocukların sağlık sonuçlarını iyileştirmeye katkı sağlayacaktır.

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THE CARE BURDEN EXPERIENCED BY PARENTS OF CHILDREN WITH SPECIAL NEEDS AND NURSING INTERVENTIONS

ÖZEL GEREKSİNİMLİ ÇOCUKLARA SAHİP EBEVEYNLERİN YAŞADIĞI BAKIM YÜKÜ VE HEMŞİRELİK MÜDAHALELERİ

Hayriye Ecem BABAOĞLU

Lisansüstü Öğrencisi, Selçuk Üniversitesi, Sağlık Bilimleri Enstitüsü, Psikiyatri Hemşireliği Anabilim Dalı

Graduate Student, Selcuk University, Institute of Health Sciences, Department of Psychiatric Nursing

ORCID ID: 0009-0003-0193-0832

Arzu KOÇAK UYAROĞLU

Doç. Dr., Selçuk Üniversitesi, Hemşirelik Fakültesi, Psikiyatri Hemşireliği Anabilim Dalı

Assoc. Prof. Dr,. Selçuk University, Faculty of Nursing, Department of Psychiatric Nursing

ORCID ID: 0000-0002-6581-4617

ÖZET

Özel gereksinimli bireyler, toplum içinde kendilerinden beklenen rolleri sınırlı düzeyde yerine getirebilen veya bu rolleri gerektiği gibi gerçekleştiremeyebilen bireylerdir. Özel gereksinimin türü ve derecesi; bireyin yaşam kalitesini düşürebilmekte, sosyal hayatını olumsuz etkileyebilmekte ve sahip olunan yetersizlik, çevresel faktörlerle birleştiğinde engele dönüşebilmektedir. Bu süreç yalnızca bireyin fizyolojik işlevlerini değil, içinde yaşadığı toplumun sosyal ve kültürel dinamikleriyle olan etkileşimini de şekillendirmektedir. Normal gelişim gösteren bir çocuğa sahip olma arzusu tüm ebeveynlerde ortak bir beklentidir. Ancak aileye özel gereksinimli bir çocuğun katılması; şok, inkâr, üzüntü, öfke, suçluluk ve kaygı gibi yoğun duygusal tepkilere yol açabilmekte olup ebeveynin bu sürece verdiği tepki bireyselleşmektedir. Bu bağlamda, özel gereksinimli bir çocuğun dünyaya gelmesi, ailelerin yaşamlarına dair beklentilerini köklü biçimde değiştirerek fiziksel, psikolojik, ekonomik ve sosyal açıdan çok yönlü sorunları beraberinde getirmekte; ailenin hem subjektif hem de objektif yük yaşamasına neden olmaktadır. Ailede özel gereksinimli bir bireyin bulunması, ailenin tüm üyelerini işlevsel ve gelişimsel boyutlarıyla etkilemekte ayrıca bu durum aile üyelerinin inançlarını, rollerini ve ilişkilerini yeniden şekillendirirken ailedeki her bir bireyin ihtiyaçlarının, taleplerinin ve sorunlarının kendi perspektifinden değerlendirilmesi ve desteklenmesini gerekli kılmaktadır. Hemşireler, özel gereksinimli bireye ve ailesine bütüncül bir yaklaşımla bakım sunarak sürecin yönetiminde önemli bir rol üstlenmektedir. Psikiyatri hemşireleri; ebeveynlerin yaşadığı rol değişimi, stres, tükenmişlik ve psikososyal zorluklarla başa çıkmalarına yardımcı olurken güçlü yönlerini fark etmelerini ve etkili baş etme stratejileri geliştirmelerini de sağlamaktadır. Psikiyatri hemşireleri, ebeveynlerin psikolojik iyilik hâlini desteklemek, yaşam kalitesini artırmak ve bilinçli farkındalık becerileri kazandırmak amacıyla

bağımsız olarak uygulayabilecekleri müdahalelere yönelmelidir. Bu derlemede, özel gereksinimli çocuklara sahip ebeveynlerin yaşadığı bakım yükü ve hemşirelik müdahalelerine güncel kaynaklarla dikkat çekilmesi amaçlanmıştır.

Anahtar Kelimeler: Bakım Yükü, Özel Gereksinim, Hemşirelik Müdahaleleri, Psikiyatri Hemşireliği.

ABSTRACT

Individuals with special needs are those who can fulfill the roles expected of them in society to a limited extent or who may not be able to fulfill these roles as required. The type and degree of special needs can reduce an individual's quality of life, negatively affect their social life, and, when combined with environmental factors, can become a barrier. This process shapes not only the individual's physiological functions but also their interaction with the social and cultural dynamics of the society in which they live. The desire to have a child who develops normally is a common expectation among all parents. However, the arrival of a child with special needs in the family can trigger intense emotional reactions such as shock, denial, sadness, anger, guilt, and anxiety, and the parent's response to this process is individualized. In this context, the birth of a child with special needs fundamentally changes families' expectations about their lives, bringing with it multifaceted problems in physical, psychological, economic, and social terms; causing the family to experience both subjective and objective burdens. The presence of a person with special needs in the family affects all family members in functional and developmental terms. Furthermore, this situation reshapes the beliefs, roles, and relationships of family members, requiring the needs, demands, and problems of each individual in the family to be evaluated and supported from their own perspective. Nurses play an important role in managing the process by providing holistic care to the individual with special needs and their family. Psychiatric nurses help parents cope with role changes, stress, burnout, and psychosocial difficulties, while also helping them recognize their strengths and develop effective coping strategies. Psychiatric nurses should focus on interventions that parents can implement independently to support their psychological well-being, improve their quality of life, and develop mindful awareness skills. This review aims to highlight the caregiving burden experienced by parents of children with special needs and nursing interventions using current resources.

Keywords: Care Burden, Special Needs, Nursing Interventions, Psychiatric Nursing.

THE EFFECTS OF MANUAL THERAPY ON VAGAL ACTIVITY AND EMOTIONAL REGULATION

Nilsu AKAR

Bahcesehir University, Graduate Institute, Physiotherapy and Rehabilitation, Doctorate Programme, Istanbul, Turkey

Ceren KARADUMAN

Bahcesehir University, Graduate Institute, Physiotherapy and Rehabilitation, Doctorate Programme, Istanbul, Turkey

Berkay Eren PEHLİVANOĞLU

Bahcesehir University, Faculty of Health Sciences, Physiotherapy and Rehabilitation, Istanbul, Turkey

ABSTRACT

Manual therapy (MT) is not merely a treatment modality targeting musculoskeletal disorders; it is also a neurophysiological approach capable of exerting modulatory effects on the autonomic nervous system (ANS), particularly on vagal activity (Bialosky et al., 2009). Vagal activity is one of the most reliable indicators of the parasympathetic branch of the ANS and is commonly assessed through heart rate variability (HRV) (Porges, 2007). HRV provides critical information regarding an individual's stress tolerance, emotional regulation capacity, and ability to maintain homeostatic balance (Thayer & Lane, 2000). The literature indicates that the effects of manual therapy cannot be fully explained by local biomechanical changes alone; rather, MT can induce systemic effects via physiological mechanisms such as mechanoreceptor activation, modulation of the hypothalamic–pituitary–adrenal (HPA) axis, and the cholinergic anti-inflammatory pathway (Budgell & Hirano, 2001; Plaza-Manzano et al., 2014). In particular, manual therapy techniques applied to the cervical and thoracic regions have been shown to increase HRV, reduce cortisol levels, and promote parasympathetic predominance (Roy et al., 2009). These findings suggest that manual therapy may attenuate the neurophysiological impact of stress, support emotional balance, and contribute to overall psychophysiological well-being by enhancing vagal tone (Koenig et al., 2016). This paper provides a holistic examination of the effects of manual therapy on vagal activity, integrating neurophysiological, endocrine, immunological, and mood-regulatory mechanisms.

Keywords: Manual therapy; Autonomic nervous system; Emotional regulation; Vagal activity.

INTRODUCTION

Vagal activity is one of the most commonly used indicators of the parasympathetic branch of the autonomic nervous system and is predominantly assessed via heart rate variability (HRV) (Porges, 2007). HRV reflects the variability in the intervals between consecutive heartbeats, thereby representing autonomic balance and serving as an important biomarker for assessing the functional capacity of the vagus nerve (Thayer & Lane, 2000). The vagus nerve plays a

pivotal role not only in cardiovascular regulation but also in the modulation of emotional processes, stress responses, and the maintenance of psychological well-being (Porges, 2007).According to polyvagal theory, vagal tone constitutes a central regulator of the integrated physiological and behavioral responses that individuals exhibit in relation to environmental stimuli (Porges, 2007).

Empirical evidence indicates that high vagal tone is associated with positive affect, resilience, and effective coping with stress, whereas low vagal activity is frequently observed in psychiatric conditions such as depression, anxiety disorders, and post-traumatic stress disorder (Thayer & Lane, 2000; Kemp et al., 2010). Meta-analytic findings confirm that reduced HRV is a robust marker of vulnerability in chronic stress and mood disorders (Chalmers et al., 2014; Koch et al., 2019). Consequently, therapeutic approaches that support vagal modulation are considered important not only for restoring physiological balance but also for enhancing psychological well-being (Koenig et al., 2016).

In light of these physiological and psychosocial processes, the investigation of interventions that can positively influence vagal activity is of considerable clinical relevance. Within this context, manual therapy has emerged as a particularly noteworthy approach in recent years. Manual therapy is a comprehensive treatment modality administered by physiotherapists that includes mobilization, manipulation, soft tissue techniques, and stretching methods (Kaltenborn, 2009). Although it has traditionally been used for pain control, reduction of muscle tension, and improvement of joint range of motion, contemporary literature indicates that the effects of manual therapy are mediated not only by mechanical but also by neurophysiological and psychosocial mechanisms (Bialosky et al., 2009).

Recent research suggests that manual therapy can shape systemic autonomic responses beyond its local effects. In particular, techniques applied to the cervical and thoracic regions have been reported to induce significant increases in HRV, changes that are associated with enhanced parasympathetic (vagal) activity (Budgell & Hirano, 2001; Roy et al., 2009). This neurological influence is thought to arise through neuromodulatory adaptations within spinal and supraspinal centers triggered by sensory input from peripheral receptors (Pickar, 2002). Furthermore, manual therapy has been reported to modulate the HPA axis, a key regulator of stress physiology, by reducing cortisol levels, altering β-endorphin release, and supporting emotional regulation (Plaza-Manzano et al., 2014; Teodorczyk-Injeyan et al., 2006).

In sum, manual therapy should not be conceptualized solely as a treatment for musculoskeletal disorders; it also represents a holistic intervention with the potential to enhance vagal activity, regulate stress responses, and exert beneficial effects on mood (Bialosky et al., 2009).

GENERAL BACKGROUND

Interaction Between Vagal Activity And Manual Therapy Applications

Overview of the Effects of Manual Therapy on Vagal Activity

The International Federation of Orthopaedic Manipulative Physical Therapists (IFOMPT) defines manipulations as “a passive, high-velocity, low-amplitude thrust applied to a joint complex within its anatomical limits; active and passive movement occurs within the joint complex’s range of motion and does not exceed the anatomical boundary of the joint.” The primary aim of such interventions is to restore optimal movement and function or to reduce pain (IFOMPT, 2019). For many years, theories explaining the analgesic effects of spinal manipulative therapy (SMT) were based almost exclusively on mechanical mechanisms. A substantial body of literature has focused on proposed mechanical effects of SMT, such as

realignment of joint “subluxations,” restoration of dysfunctional vertebral segments, or “unlocking” of zygapophyseal joints (Evans, 2022).

However, accumulating evidence over the past two decades has demonstrated that these mechanical explanations are insufficient on their own. Current literature suggests that the effects of manual therapy are not limited to local biomechanical alterations; instead, the neuro–immune–endocrine system and various nonspecific (contextual and psychological) factors play critical roles in this process (Bialosky et al., 2018; Gyer et al., 2019). High-quality systematic reviews have reported that SMT provides short-term but limited improvements in pain reduction and functional status in low back pain (Rubinstein et al., 2011) and neck pain (Gross et al., 2010). These findings imply that biological and neurophysiological factors may be more decisive in accounting for the clinical outcomes of manual therapy (Kovanur-Sampath et al., 2017).

Within this framework, the neurophysiological effects of manual therapy are explained through complex interactions within the autonomic nervous system. The impact of manual therapy on vagal activity has increasingly attracted attention in the fields of physiotherapy, neurophysiology, and neuromodulation. This interaction is a highly multidimensional neurophysiological process that cannot be fully explained by local mechanical effects on the musculoskeletal system alone. Contemporary evidence suggests that manual therapy may exert a regulatory effect on the ANS at the organismic level (Porges, 2007).

The vagus nerve, which constitutes the parasympathetic branch of the autonomic system, plays an integrative role in the regulation of homeostatic processes such as HRV, respiratory patterns, endocrine responses, and emotional balance (Thayer & Lane, 2000; Kemp et al., 2010). Accordingly, the potential effects of manual therapy on vagal tone are clinically relevant not only for physiological balance but also for stress management and mood regulation (Koenig et al., 2016).

Neurophysiological Mechanisms: Mechanoreceptor Activation and Vagal Reflexes

The neurophysiological mechanisms proposed to explain the relationship between manual therapy and vagal activity include mechanoreceptor activation, the integration of proprioceptive input within the central nervous system, alterations in baroreflex sensitivity, and modulation of the HPA axis (Pickar, 2002; Budgell & Polus, 2006; Bialosky et al., 2009). During manipulation or mobilization, afferent signals arising from muscle spindles, Golgi tendon organs, and joint capsule receptors ascend from the dorsal horn of the spinal cord to brainstem centers (Budgell, 2000). These signals are processed in the nucleus tractus solitarius (NTS) located in the medulla oblongata, which in turn projects to vagal nuclei such as the nucleus ambiguus and the dorsal motor nucleus of the vagus (Budgell & Hirano, 2001). Through this pathway, manual therapy may lead to a transient increase in parasympathetic activity as a consequence of centrally mediated evaluation of peripheral mechanical stimuli (Roy et al., 2009; Martínez-Segura et al., 2006).

The NTS is one of the brainstem centers involved in the integrated control of cardiovascular, respiratory, and visceral functions and serves as a key regulator of vagal tone. Afferent mechanical stimuli generated during manual therapy can modulate neuronal networks within this region and facilitate vagal reflexes in the short term. In HRV recordings, increases particularly in the high-frequency (HF) component reflect transient elevations in parasympathetic activity (Roy et al., 2009; Martínez-Segura et al., 2006).

Endocrine and Neuroimmune Regulatory Mechanisms

The effects of manual therapy are not confined to neurophysiological pathways; they also manifest through endocrine and immune mechanisms. The HPA axis, which is central to the

regulation of the stress response, is closely associated with cortisol levels. Excessive activation of the HPA axis leads to increased cortisol secretion and a shift of the autonomic nervous system toward sympathetic predominance, whereas post-manipulative reductions in cortisol and increases in β-endorphin indicate modulation of stress at a neuroendocrine level (Plaza-Manzano et al., 2014).

Studies investigating the effects of manual therapy on the HPA axis have reported short-term changes in cortisol levels. Plaza-Manzano et al. observed a transient increase in cortisol following cervical and thoracic manipulation, followed by a decline within two hours. Similarly, Kovanur-Sampath et al. reported a significant reduction in salivary cortisol levels five minutes after thoracic manipulation, although this effect had dissipated by 30 minutes.

Conversely, Christian et al. and Lohman et al. found no significant changes in cortisol following manipulation. These inconsistent findings are thought to arise from variability in intervention types, timing of cortisol measurements, and differences in sham manipulation protocols. Overall, current evidence suggests that manual therapy may induce short-lived physiological changes in endocrine responses, while the long-term clinical significance of these effects remains uncertain (Phul et al., 2017; Vernon et al., 2012).

Recent systematic reviews have demonstrated that manual therapy may exert systemic effects not only on local tissues but also via the neuro–immune–endocrine system. A recent meta-analytic study (Kovanur-Sampath et al., 2017) quantitatively synthesized existing evidence regarding the effects of spinal manipulation on these systems. The investigators examined changes in concentrations of neuropeptides, inflammatory markers, and endocrine hormones in biological samples such as blood, urine, or saliva.

These findings suggest that dysfunctions within the neuro–immune–endocrine system may play a central role in musculoskeletal pain (Generaal et al., 2014; Kadow et al., 2015). In particular, low-grade inflammation has been associated with pain severity in chronic conditions such as low back and neck pain, supported by elevated levels of pro-inflammatory cytokines and chemokines in these patients (Heffner et al., 2011; Teodorczyk-Injeyan et al., 2006).

Moreover, biomarkers such as tumor necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), interleukin-6 (IL-6), and interleukin-8 (IL-8) have been reported to be significantly elevated in individuals with spinal joint degeneration (Risbud & Shapiro, 2013; Sadowska et al., 2018; Wang et al., 2017). These structural changes are thought to arise from immune cell infiltration into cartilaginous endplates and vertebral bodies rather than being a mere consequence of aging (Buckley et al., 2018).

Nevertheless, it remains unclear whether such biochemical and cellular alterations are the cause or the consequence of structural abnormalities. Additionally, low-grade inflammation has been proposed to be associated with cortisol dysregulation in clinical conditions such as chronic low back pain (Muhtz et al., 2013), fibromyalgia (McEwen & Kalia, 2010), and temporomandibular dysfunction (Quartana et al., 2010) (Abdallah et al., 2017; Paananen et al., 2015).

The immunomodulatory effects of manual therapy are also supported in the literature. Teodorczyk-Injeyan et al. (2006) reported significant post-manipulative increases in anti-inflammatory cytokines such as IL-2 and IL-10 in healthy individuals. These changes have been linked to immune modulation mediated by the vagus nerve's cholinergic anti-inflammatory pathway. Accordingly, manual therapy may influence vagal activity not only through cardiovascular parameters but also via neurovegetative control of the immune system, thereby contributing to an integrated psychophysiological balance (Teodorczyk-Injeyan et al., 2006).

Thus, the effects of manual therapy on the endocrine and immune systems may involve not only attenuation of inflammatory responses but also restoration of homeostatic equilibrium.

Clinical Findings and Outcomes on Autonomic Balance

Clinical studies have demonstrated that manual therapy can lead to significant increases in HRV, decreases in heart rate, and heightened subjective reports of relaxation (Roy et al., 2009; Budgell & Hirano, 2001). These post-intervention changes, particularly noted following cervical manipulations, have been associated with transient elevations in vagal tone and improvements in emotional stability. Roy et al. (2009) reported a significant increase in the HF component of HRV after spinal manipulation, indicating a shift toward parasympathetic dominance.

These findings underscore that the capacity of manual therapy to influence vagal activity represents not merely a mechanical effect confined to peripheral tissues but a multisystem neurophysiological process (Bialosky et al., 2009). Peripheral receptor activation, central nervous system integration, baroreflex sensitivity, HPA axis responses, and neurovegetative anti-inflammatory mechanisms constitute the principal components of this interaction (Pickar, 2002; Plaza-Manzano et al., 2014).

Nonetheless, methodological heterogeneity is evident among studies evaluating the physiological effects of manual therapy. In particular, variations in the definition of placebo or sham manipulation protocols, timing of cortisol assessments, and the nature of the techniques employed contribute to inconsistencies across studies (Phul et al., 2017; Vernon et al., 2012). Vernon and colleagues emphasized that an ideal placebo manipulation should be both inert and indistinguishable from the active intervention; otherwise, contextual effects may be confounded with specific physiological responses. Consequently, while some studies have reported significant changes in vagal or endocrine responses following manual therapy, others have observed only short-lived or negligible effects. This variability suggests that the influence of manual therapy on the ANS is strongly shaped by individual differences and intervention parameters.

Therefore, manual therapy is increasingly regarded as a neurovegetative regulatory intervention that can enhance vagal tone beyond the treatment of musculoskeletal dysfunction (Roy et al., 2009).

Manual Therapy and Emotional Regulation

The effects of manual therapy on the ANS are not restricted to physiological balance; they also play a decisive role in stress management and emotional regulation. According to polyvagal theory, the vagus nerve lies at the core of brain–heart communication and orchestrates the integrated emotional and behavioral responses to environmental stressors (Porges, 2007).

High vagal tone is associated with greater emotional flexibility, social engagement, and stress tolerance, whereas low vagal tone has been linked to depression, anxiety, and emotional instability (Thayer & Lane, 2000; Kemp et al., 2010). According to the Neurovisceral Integration Model, the strength of neural interactions among the prefrontal cortex, amygdala, and brainstem structures determines both HRV levels and emotional regulation capacity (Thayer & Lane, 2009). Research has shown that individuals with higher HRV exhibit more rapid physiological recovery from stress and maintain positive affect for longer periods (Koenig et al., 2014).

Previous studies have demonstrated that psychosocial factors play a critical role in the emergence and persistence of pain (Groeneweg et al., 2017). Depression and fear have been reported to be associated with perceived recovery, pain severity, and functional capacity in patients with low back pain (Ailliet et al., 2016). Martí-Salvador et al. observed significant improvements in Hospital Anxiety and Depression Scale (HADS), Pain Catastrophizing Scale (PCS), and Fear-Avoidance Beliefs Questionnaire scores following a three-month manual

therapy program. Similarly, in another randomized clinical trial, ten sessions of manual therapy led to statistically significant reductions in depression and kinesiophobia (de Oliveira Meirelles et al., 2020). Manual therapy has also been shown to induce notable changes in fear-avoidance beliefs in individuals with chronic low back pain (Arguisuelas et al., 2017).

By contrast, Sung et al. reported no significant effects of manual therapy and exercise on Fear-Avoidance Beliefs Questionnaire scores. These discrepancies may stem from differences in the anatomical region targeted and the specific techniques employed—such as thoracic versus lumbar application or use of single-plane versus multiplanar techniques. Collectively, these findings indicate that the type and location of manual therapy procedures may influence treatment outcomes.

Pain catastrophizing is defined as a negative cognitive–emotional response to an actual or anticipated painful experience (Quartana et al., 2009). Studies conducted in patients with chronic neck pain have shown that manual therapy can significantly reduce pain catastrophizing scores (Sobhani et al., 2017). Similarly, research in individuals with fibromyalgia has demonstrated that mobilization and manipulation techniques can decrease PCS scores and that this effect may be sustained over time. Systematic reviews confirm that manual therapy has a therapeutic impact on fear-avoidance, kinesiophobia, and catastrophizing in chronic musculoskeletal disorders (Kamonseki et al., 2021).

Accordingly, manual therapy is increasingly regarded not merely as a mechanical intervention that reduces pain but also as a modality that can positively influence psychological processes related to pain, including anxiety, depression, kinesiophobia, and catastrophizing.

The frequently reported post-treatment sensations of relaxation and well-being following manual therapy are likely to reflect not only musculoskeletal relief but also restoration of neurovegetative balance (Bialosky et al., 2009). Moreover, reductions in cortisol and increases in β-endorphin indicate that the HPA axis may suppress the stress response and thereby support emotional stability (Plaza-Manzano et al., 2014). The observed increases in anti-inflammatory cytokines such as IL-2 and IL-10 may, in turn, be associated with vagally mediated anti-inflammatory responses (Teodorczyk-Injeyan et al., 2006).

CONCLUSION

Manual therapy is more than a peripheral tissue-focused treatment approach; it is a holistic modality that supports psychophysiological balance through the dynamic interplay of brain, heart, and emotion (Bialosky et al., 2009). Enhanced parasympathetic activity mitigates the physiological effects of stress, strengthens emotional control via the prefrontal cortex, and increases an individual's capacity to cope with stress (Thayer & Lane, 2009). These mechanisms collectively demonstrate that manual therapy contributes to both physiological and emotional well-being by augmenting vagal tone (Koenig et al., 2016).

Current literature indicates that the effects of manual therapy extend beyond the musculoskeletal system and can influence the organism's biopsychosocial integrity via autonomic, endocrine, and immune mechanisms (Plaza-Manzano et al., 2014; Teodorczyk-Injeyan et al., 2006). The analgesic effects of manual therapy promote a shift of autonomic balance toward parasympathetic dominance by inhibiting sympathetic activity (Bialosky et al., 2009). This response appears particularly pronounced in individuals with chronic pain, in whom heightened sympathetic tone may render vagal modulation more readily inducible (Martínez-Segura et al., 2006).

Reductions in pain perception also play a decisive role in the impact of manual therapy on the ANS. As pain diminishes, excessive sympathetic activation is suppressed, vagal tone increases, and autonomic balance is re-established in favor of parasympathetic activity (Bialosky et al., 2009). When considered within the pain–stress–autonomic system loop, this neurophysiological interaction suggests that manual therapy is not simply a mechanically acting intervention; rather, it is a multidimensional approach that contributes to emotional regulation, stress adaptation, and restoration of neurovegetative stability (Thayer & Lane, 2009).

Increases in parasympathetic activity manifest as elevated HRV, reduced cortisol levels, and suppression of the stress response (Roy et al., 2009; Plaza-Manzano et al., 2014). These adjustments yield a more balanced emotional response profile and diminished perceived stress (Koenig et al., 2014). Thus, manual therapy may be conceptualized as a neuromodulatory method capable of restoring autonomic balance by enhancing vagal activity.

In light of these findings, further clinical research is warranted to clarify the long-term effects of manual therapy on the neurovegetative system, the specific neurophysiological responses elicited by different techniques, and its relationship with mood disorders (Budgell & Polus, 2006; Porges, 2007).

The present review suggests that the effects of manual therapy should not be confined to peripheral tissue mobilization but rather be evaluated within a broad neurophysiological framework encompassing autonomic, endocrine, and neuroimmune systems. Accumulating evidence indicates that manual therapy can enhance parasympathetic responses via vagal activity, thereby exerting regulatory influences on both physiological and psychological processes. These findings highlight that the clinical effects of manual therapy cannot be adequately explained by mechanical mechanisms alone and that the intervention elicits integrative systemic responses.

Furthermore, the available data show that the effectiveness of manual therapy is closely related to the patient’s psychosocial profile. Given that depression, anxiety, pain beliefs, and kinesiophobia shape the pain experience and treatment response, it becomes increasingly evident that manual therapy applications should be embedded within a biopsychosocial model. In this context, it is of great importance that clinicians conceptualize treatment not solely as a biomechanical intervention but also as a multidimensional procedure influencing central nervous system and emotional regulation processes.

It is also apparent that the effects of manual therapy on vagal activity and the ANS cannot be attributed to a single mechanism; rather, they depend on factors such as the type of technique used, the targeted anatomical region, the biomechanical characteristics of the tissues, and the patient’s autonomic profile. Therefore, there is a clear need for high-quality clinical studies designed to differentiate the specific effects of various manual therapy techniques. In particular, the scarcity of long-term follow-up studies underscores the importance of elucidating the sustainability of the neurovegetative effects of manual therapy in future research.

In conclusion, contemporary evidence suggests that manual therapy should not be regarded solely as a mechanically acting analgesic intervention; it may also represent a potential neuromodulation tool for supporting vagal tone, stress regulation, and psychophysiological integrity. This multidimensional perspective calls for the development of more comprehensive and systematic approaches in both clinical practice and research design. Accordingly, advanced studies that examine the neurophysiological, endocrine, and psychosocial effects of manual therapy from an integrative perspective are expected to make substantial contributions to the literature.

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A CASE OF ADENOSQUAMOUS CARCINOMA IN AN 8-YEAR-OLD FEMALE GERMAN SHEPHERD DOG

Res. Assist. Dr. Zeynep ÇELİK KENAR,

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Prof. Dr. Özgür ÖZDEMİR

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Prof. Dr. Fatih HATİPOĞLU

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Vet. Dr. Cennet YAKA

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

ABSTRACT

Mammary tumors are the most common neoplasms in female dogs, while mammary adenosquamous carcinoma (ASC) is a rare but highly aggressive malignant epithelial tumor characterized by the coexistence of glandular and squamous differentiation within the same neoplasm. ASC is reported to occur more frequently in intact female dogs and is associated with rapid growth, high recurrence rates, and poor prognosis. An 8-year-old intact female German Shepherd dog was presented with recurrent mammary masses that had first been noticed five months earlier and had recurred two months after surgical removal. Clinical examination revealed masses in the left fourth and fifth mammary glands, and a total left-chain mastectomy was performed. The excised tissues were submitted for pathological evaluation. Samples were fixed in 10% neutral buffered formalin, routinely processed, embedded in paraffin, sectioned at 5 µm, and stained with hematoxylin–eosin. Macroscopically, the mass measured 20 × 11.5 × 7 cm, had a whitish, lobulated cut surface with hemorrhagic and necrotic areas, and was moderately firm in consistency. Histopathological examination revealed irregular tubular and tubulopapillary glandular proliferations composed of cuboidal to columnar epithelial cells, accompanied by distinct areas of squamous differentiation with prominent keratin pearl formation. Tumor cells exhibited marked nuclear pleomorphism, hyperchromasia, high mitotic activity, and extensive necrosis. An infiltrative growth pattern into the surrounding mammary tissue was observed, along with both lymphatic and hematogenous vascular invasion. Based on these findings, the tumor was diagnosed as mammary adenosquamous carcinoma. The rapid postoperative recurrence history and the death of the patient shortly after mastectomy further supported the aggressive biological behavior of this tumor. This case emphasizes the

importance of early diagnosis, accurate histopathological classification, and close clinical follow-up in canine mammary tumors, particularly in rare and aggressive subtypes such as adenosquamous carcinoma.

Key Words: Adenosquamous carcinoma; Dog; Histopathology; Mammary gland; Neoplasia

INTRODUCTION

Mammary tumors are the most frequently diagnosed neoplasms in female dogs (Misdorp, 2002; Rasotto et al., 2017). Canine mammary adenosquamous carcinoma (ASC) is a rare but aggressive malignant epithelial tumor classified under malignant epithelial neoplasms and characterized by the coexistence of both glandular and squamous differentiation within the same tumor (Goldschmidt et al., 2011). ASC has been reported to occur more frequently in intact female dogs and is characterized by rapid growth, irregularly bordered masses, and a high tendency for local recurrence (Canadas et al., 2019; Pastor et al., 2020). Rasotto et al. (2017), based on the classification proposed by Goldschmidt et al. (2011), investigated mammary carcinomas in 229 female dogs and reported that only 10 of these tumors were diagnosed as ASC. In the same study, ASC was identified as the tumor type with the highest rates of local metastasis (50%) and distant metastasis (60%), and the mean survival time of dogs with ASC was reported to be 12.6 months (Rasotto et al., 2017). Similarly, Seung et al. (2021), in a study conducted between 2007 and 2018, found that only 1 out of 155 canine mammary tumors was ASC and concluded that ASC, together with carcinosarcoma and anaplastic carcinoma, exhibited the poorest prognosis among mammary tumor types. In a case reported in 2022, bone marrow and lung metastases were documented in a dog with mammary ASC (Neto et al., 2022). Histopathological examinations have demonstrated the presence of tubular/tubulopapillary glandular structures coexisting with areas of squamous differentiation within the same tumor, with finger-like projections extending into the glandular lumina and prominent keratin pearls and intercellular bridges observed in the squamous areas (Goldschmidt et al., 2011; Peña et al., 2012). Treatment of ASC, as with other mammary tumors, consists of surgical excision of the tumor and the associated mammary lymph nodes, often combined with chemotherapy (Rueda et al., 2024).

MATERIALS AND METHODS

An 8-year-old intact female German Shepherd dog was presented to the Selçuk University Faculty of Veterinary Medicine Animal Hospital with a complaint of mammary masses. According to the anamnesis, the masses had been noticed five months earlier; they had been surgically removed two months prior but subsequently recurred. Clinical examination revealed masses in the left fourth and fifth mammary glands. Consequently, a total left mammary chain mastectomy was performed, and the excised tissues were submitted to the Department of Pathology, Faculty of Veterinary Medicine, Selçuk University. The collected specimens were examined macroscopically, and photographic documentation was obtained.

Histopathological Examination

Samples obtained from the excised masses and mammary tissues were fixed in 10% neutral buffered formalin for 24 hours. Following fixation, the tissues were processed using an automatic tissue processor (Leica TP 1020) and embedded in paraffin. Sections of 5 µm thickness were cut from the paraffin blocks using a microtome (Leica RM 2125RT) and stained with Hematoxylin–Eosin (Luna, 1968). The prepared slides were examined under a light microscope (Olympus BX51, Tokyo, Japan) and photographed (Olympus EP50).

RESULTS

Macroscobic results

On macroscopic examination, the mass measured 20 × 11.5 × 7 cm (Figure 1). The cut surface was whitish, lobulated, and exhibited focal hemorrhagic and necrotic areas, with a moderately firm consistency (Figure 2).



Figure 1. General view of the mass.

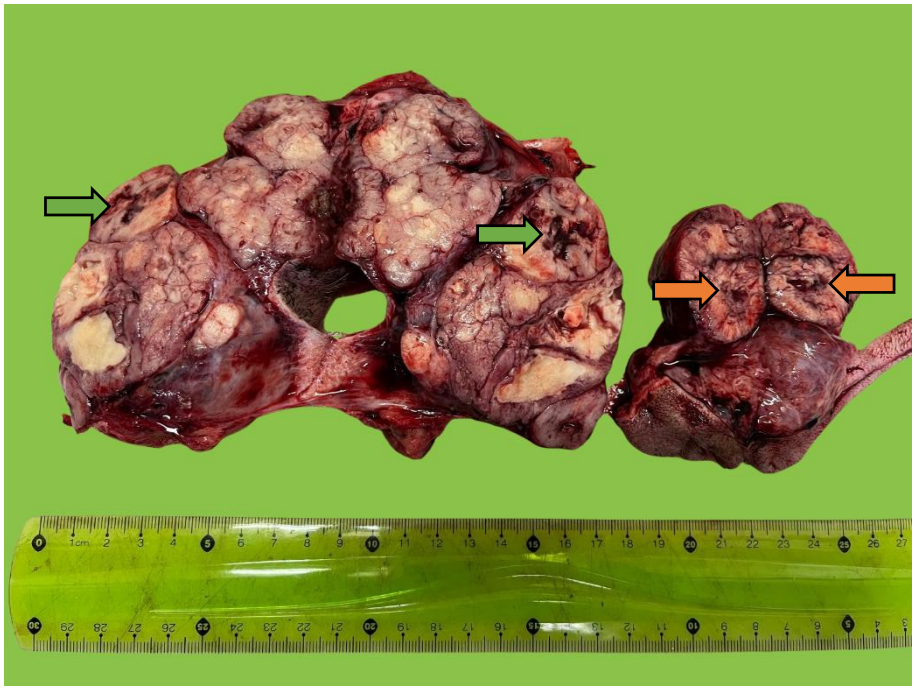


Figure 2. Cut surface of the lobulated mass showing areas of necrosis (orange arrow) and hemorrhage (green arrow).

Histopathologic results

Microscopic examination revealed irregular proliferations composed of cuboidal to columnar epithelial cells forming papillary projections toward the glandular lumina, accompanied by newly formed glandular structures (Figures 1-4). In some areas, foci of squamous differentiation were observed, and keratin pearls were present in the centers of these regions (Figures 3-6). Tumor cells exhibited marked nuclear pleomorphism, hyperchromasia, and high mitotic activity (Figure 9). In addition, extensive areas of necrosis were noted both within the tumor cells and throughout the tumor tissue (Figures 7, 8). The tumor demonstrated an invasive growth pattern extending into the surrounding mammary tissue, with foci of both lymphovascular and hematovascular invasion observed in certain areas (Figures 10, 11). Based on these findings, the tumor tissue exhibited histomorphological features consistent with adenosquamous carcinoma, characterized by the coexistence of adenocarcinoma and squamous cell carcinoma components.

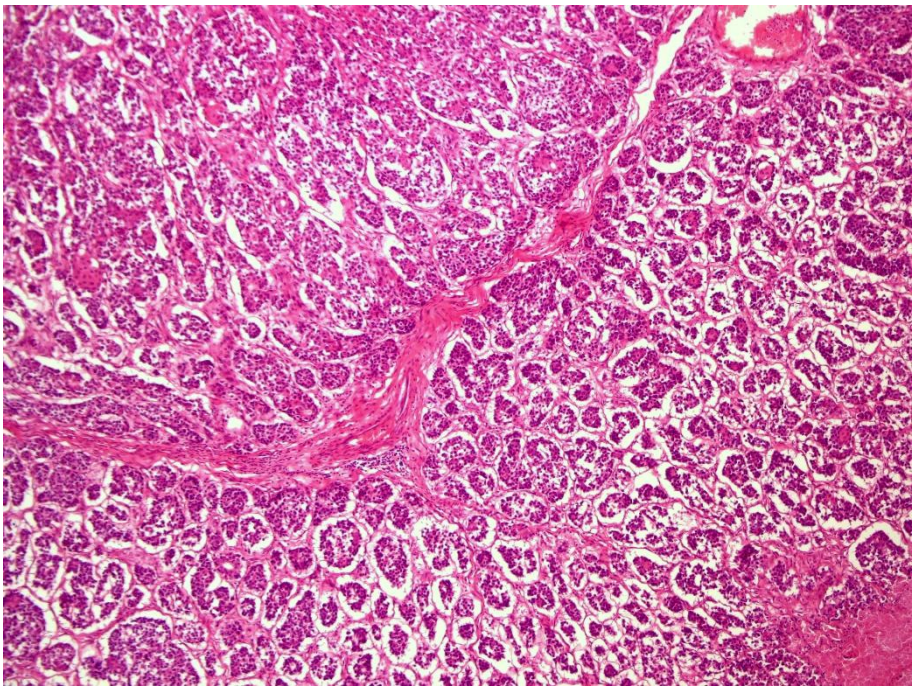


Figure 3. General view of the microscopic section of the tumor, X10, HE.

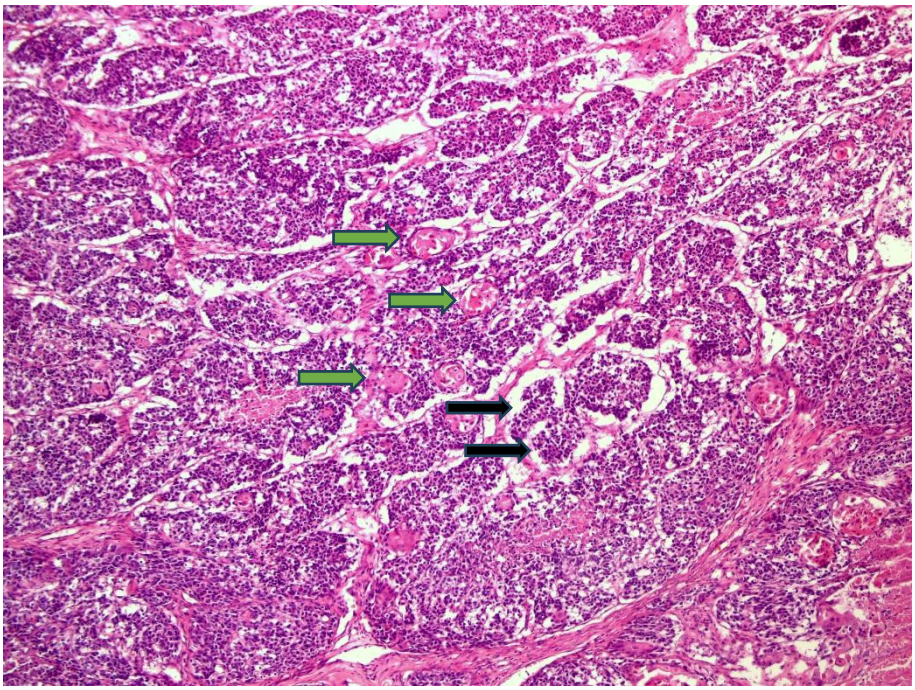


Figure 4. Papillary projections into the glandular lumina (black arrows) and keratin pearls (green arrows), X10, HE.

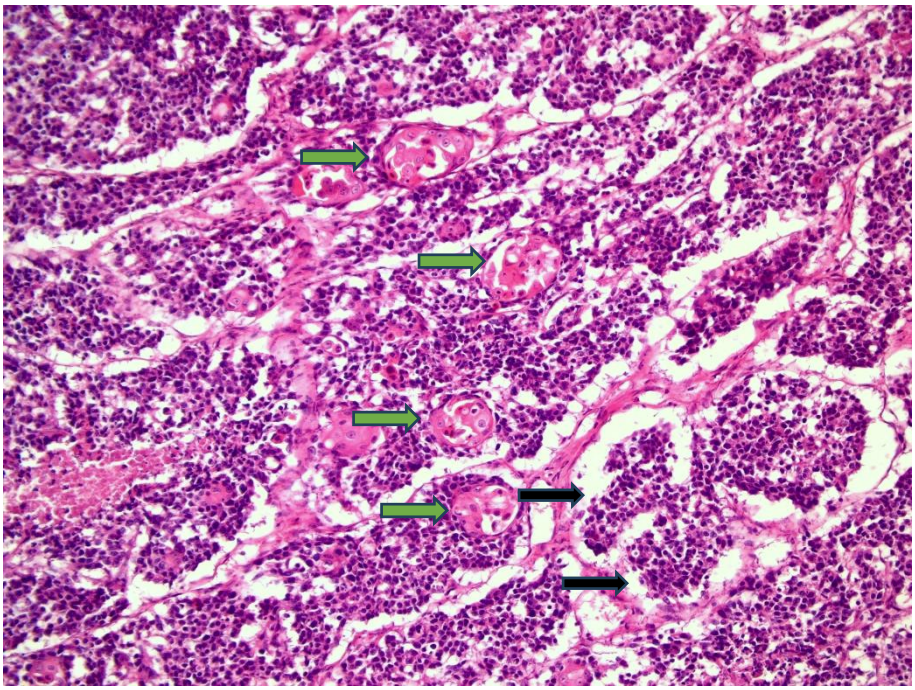


Figure 5. Papillary projections into the glandular lumina (black arrows) and keratin pearls (green arrows), X20, HE.

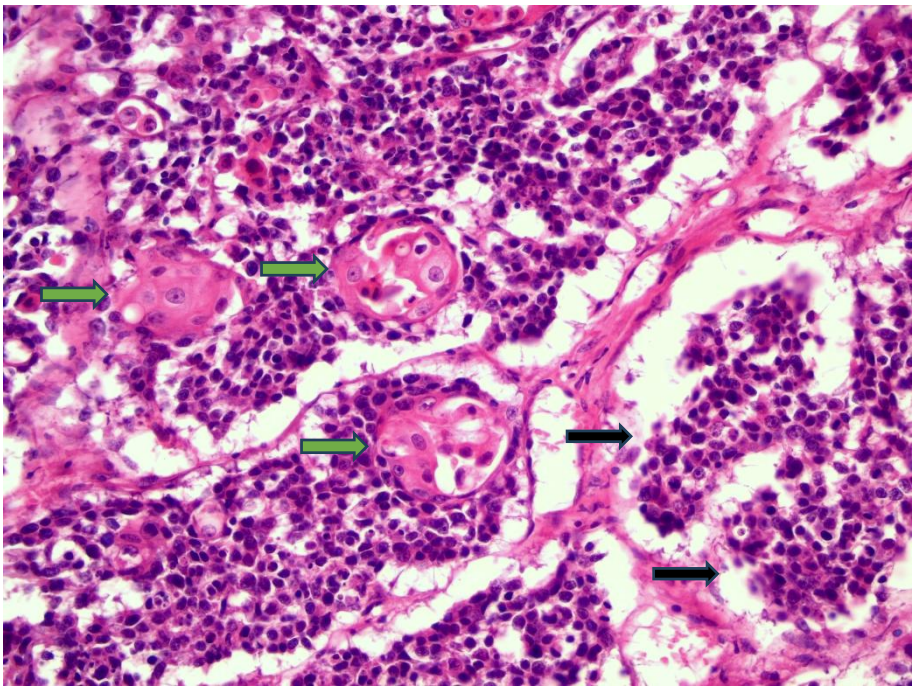


Figure 6. Papillary projections into the glandular lumina (black arrows) and keratin pearls (green arrows), X40, HE.

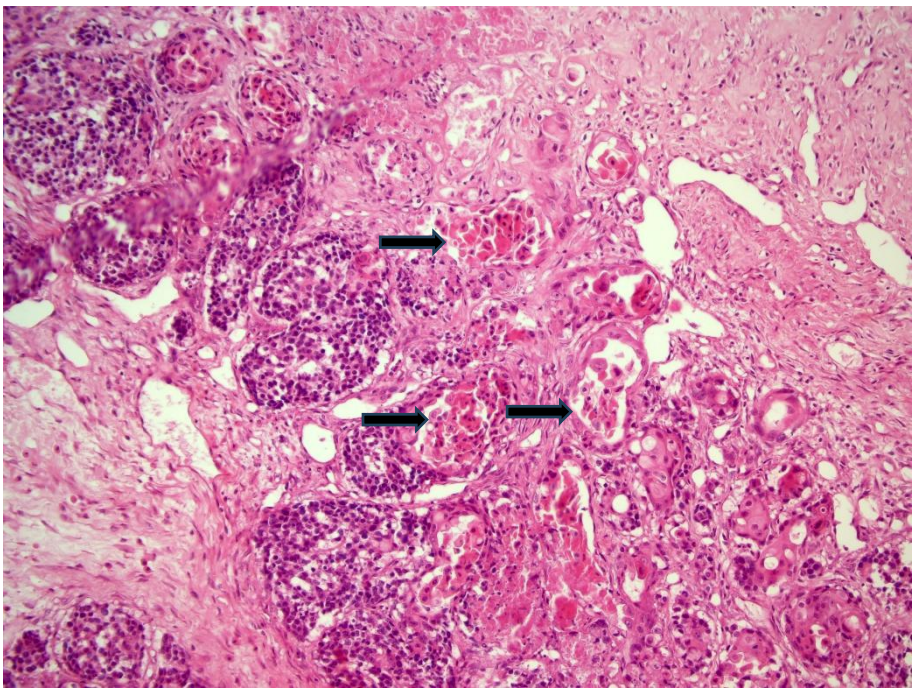


Figure 7. Marked necrotic changes in atypical tumor cells (black arrows), X40, HE.

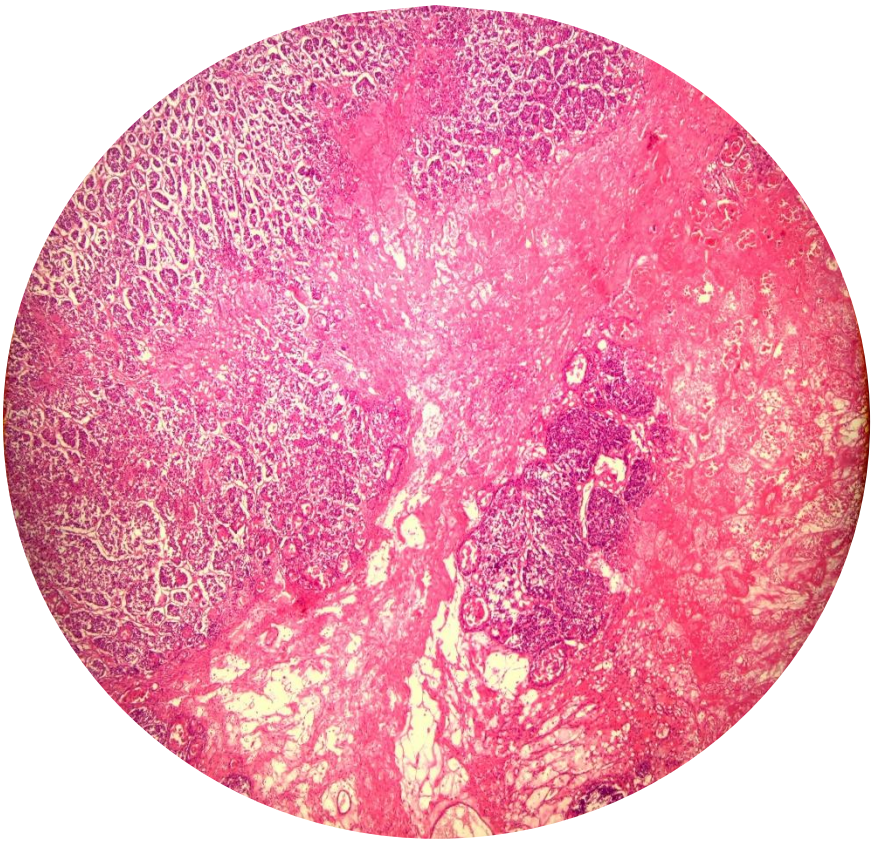


Figure 8. Prominent necrosis in the microscopic section of the tumor, X4, HE.

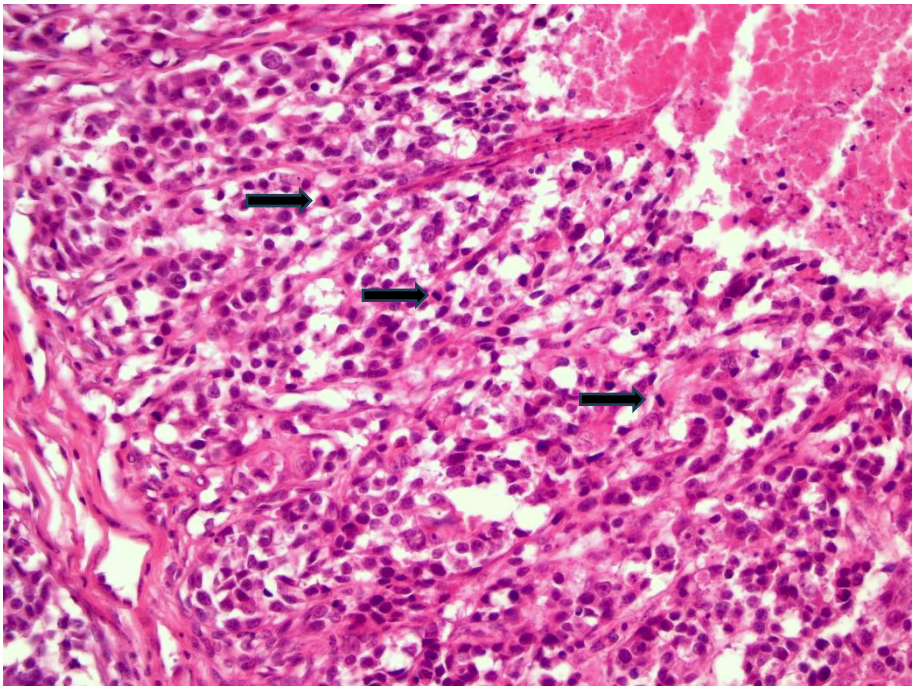


Figure 9. Mitotic figures in tumor cells (black arrows), X40, HE.

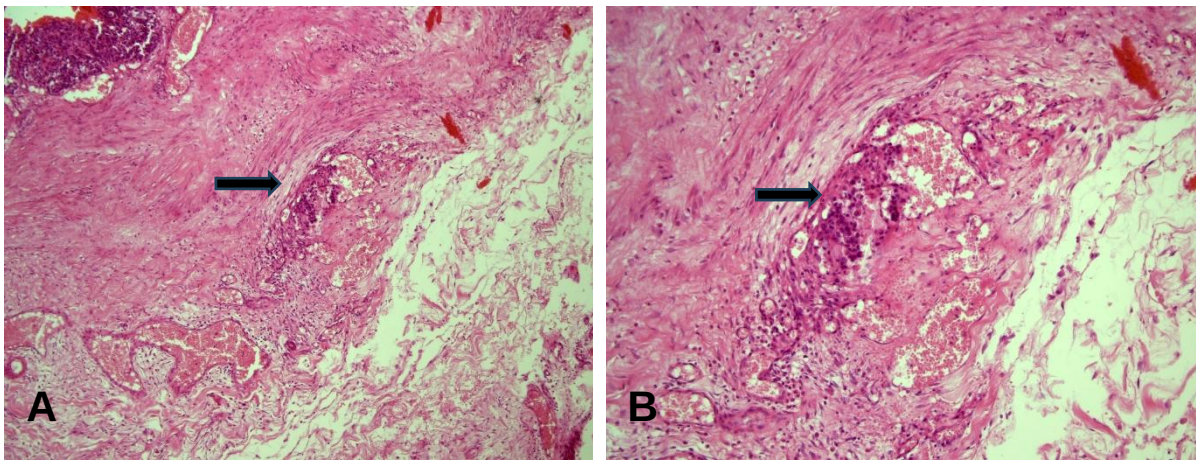


Figure 10. Invasion of tumor cells into a blood vessel (black arrow), X20, B. X40, HE.

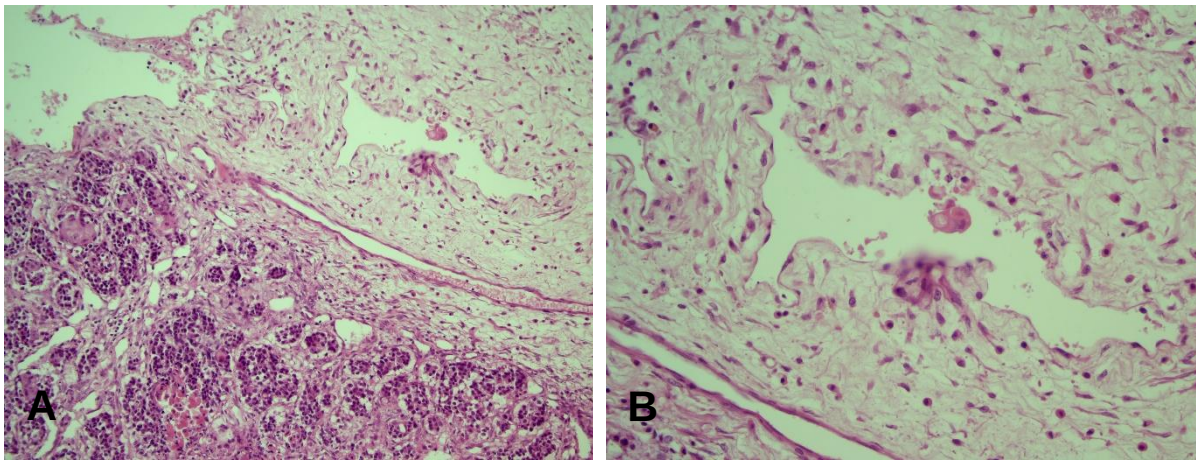


Figure 12. Lymphatic vessel invasion by tumor cells (black arrow), A. X20, B. X40, HE.

CONCLUSION AND DISCUSSION

Adenosquamous carcinoma is a very rare histological subtype among canine mammary tumors; however, it is noteworthy for its high invasiveness, early recurrence, and aggressive biological behavior. In this case, the recurrence of mammary masses in an 8-year-old intact female German Shepherd dog approximately two months after surgical excision, despite having first appeared five months earlier, is consistent with the high recurrence tendency of adenosquamous carcinoma described in the literature. The fact that the dog was not spayed is also in line with current knowledge suggesting that prolonged hormonal stimulation may play a role in malignant transformation.

Histopathological evaluation revealed the coexistence of both glandular and squamous components, highlighting the heterogeneous nature of the tumor. Irregular tubular and tubulopapillary proliferations in the glandular structures, along with the presence of keratin pearls in the squamous areas, play an important role in the differential diagnosis of adenosquamous carcinoma. Marked pleomorphism, hyperchromasia, increased mitotic activity, and extensive areas of necrosis are findings consistent with a high-grade malignant tumor. Adenosquamous carcinomas have been reported to show a tendency for lymphatic invasion, and in this case, the detection of both lymphatic and vascular invasion indicates a high risk of distant metastasis.

One of the most striking aspects of this case is that the patient died shortly after the mastectomy procedure. Although the median survival time for adenosquamous carcinoma has been reported to be approximately 18 months, factors such as disease stage, tumor burden, surgical margin status, the patient's immune response, and concurrent systemic diseases play a decisive role in survival. In this case, rapid recurrence, early postoperative death, and histopathological findings indicative of high-grade malignancy demonstrate an exceptionally aggressive biological behavior of the tumor.

This case once again emphasizes the importance of early diagnosis in the evaluation of canine mammary tumors. Particularly in rare subtypes, predicting the clinical course can be challenging; therefore, detailed histopathological examination and, when possible, immunohistochemical support are critical for accurate diagnosis. This case was considered worthy of presentation as it contributes to a better understanding of the biological behavior of adenosquamous carcinoma and may help guide the diagnosis and management of similar cases in the future.

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A CASE OF FELINE INJECTION-SITE LIPOSARCOMA IN A 6-YEAR-OLD DOMESTIC CAT

Res. Assist. Dr. Zeynep ÇELİK KENAR,

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Prof. Dr. Mustafa ORTATATLI

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Prof. Dr. Ertan ORUÇ

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

Vet. Dr. M. Yasin GÖÇEN

Selçuk University, Faculty of Veterinary Medicine, Department of Pathology, Konya, TÜRKİYE

ABSTRACT

Feline injection-site sarcomas (FISS) are aggressive mesenchymal tumors associated with chronic inflammation and repeated injections. While fibrosarcoma is the most common subtype, injection-site liposarcoma is a rare variant within the FISS spectrum. This study presents a case of injection-site liposarcoma in a cat with a history of chronic injections. A 6-year-old mixed-breed male cat was presented to the Selçuk University Veterinary Faculty Animal Hospital with a mass in the interscapular region. The medical history revealed long-term repeated injections to the same site due to chronic asthma treatment. The surgically excised mass was submitted for histopathological examination. Grossly, the mass was firm, white-colored, and contained focal hemorrhagic areas. Histopathological evaluation revealed malignant adipocytic proliferation with variable numbers of lipoblasts, marked cellular atypia, infiltrative growth pattern, granulomatous inflammation, foreign body giant cells, and perivascular mononuclear cell infiltration. These findings were consistent with injection-site liposarcoma. This case highlights the importance of recognizing injection-site liposarcoma as a rare subtype of FISS and emphasizes the role of chronic inflammation and repeated injections in tumor development in cats.

Key Words: Liposarcoma; Feline injection-site sarcoma; Chronic inflammation; Histopathology; Cat.

INTRODUCTION

Feline injection-site sarcomas (FISS) have attracted increasing attention since the 1990s, particularly following the widespread use of adjuvant-containing rabies and FeLV vaccines (Hendrick & Dunagan, 1991). Although FISS most commonly occur as fibrosarcoma, malignant fibrous histiocytoma, and myofibrosarcoma, injection-site liposarcoma has also been described among rarer histological subtypes (Martano et al., 2011; Woodward, 2011). While liposarcomas are generally rare in the feline population, cases arising at injection sites have been reported to involve chronic inflammation, accumulation of adjuvant particles, and ongoing fibro-adipose tissue damage in tumor development (Ahmed & Mahmut, 2021). Injection-site liposarcomas are considered a variant of classical FISS pathogenesis, in which persistent inflammation, necrosis, macrophage infiltration, and the presence of aluminum-containing adjuvant particles trigger chronic tissue irritation, leading to genetic instability and neoplastic transformation in local stromal cells (Woodward, 2011).

Histopathologically, injection-site liposarcomas are malignant mesenchymal tumors composed of adipocytic cells containing lipoblasts and may present as well-differentiated, mixed-differentiated, or pleomorphic types. A distinctive feature of these cases is the presence of FISS-associated reactive changes in addition to the classical liposarcoma morphology, including granulomatous reactions, foreign body giant cells, and macrophage infiltration associated with adjuvant particles (Kliczkowska et al., 2015). Liposarcomas arising at injection sites typically exhibit a more pronounced lymphoinflammatory response, an infiltrative growth pattern into surrounding tissues, extensive areas of necrosis, and progressive invasion from adipose tissue into adjacent muscle and fascia, resembling the behavior of classical FISS. Variability in the number of lipoblasts, the degree of pleomorphism, and high mitotic activity are important parameters influencing the biological behavior of these tumors (Goldschmidt & Hendrick, 2002; Martano et al., 2011). To reduce risk associated with vaccination and drug administration, international guidelines recommend administering injections in distal limbs, avoiding repeated injections at the same site, preferring non-adjuvanted vaccines, and evaluating injection-site masses according to the "3-2-1 rule": masses persisting longer than 3 months, exceeding 2 cm in diameter, or increasing in size within 1 month should be examined by biopsy (Stone et al., 2020). This approach is critical for the early diagnosis of all FISS subtypes, including liposarcoma.

MATERIALS AND METHODS

A 6-year-old mixed-breed male cat was presented to the Selçuk University Faculty of Veterinary Medicine Animal Hospital with a complaint of a mass in the interscapular region. The anamnesis revealed that the cat had received regular injections to the interscapular area due to chronic asthma treatment, and that the mass had been noticed within the last week. The mass surgically excised and submitted to the Selçuk University Faculty of Veterinary Medicine, Department of Pathology.

Histopathological Examination

Samples obtained from the submitted mass were fixed in 10% formaldehyde solution for 24 hours. After completion of fixation, the tissues were processed using an automatic tissue processor (Leica TP 1020) and embedded in paraffin. Subsequently, 5 µm-thick sections were cut from the paraffin blocks using a microtome (Leica RM 2125RT) and stained with Hematoxylin–Eosin (Luna, 1968). The prepared slides were examined under a light microscope (Olympus BX51, Tokyo, Japan) and photographed (Olympus EP50).

RESULTS

Macroscobic results

On examination, the mass measured 7 × 5.5 × 3 cm, was firm in consistency, and exhibited a whitish cut surface with focal areas of hemorrhage (Figure 1).

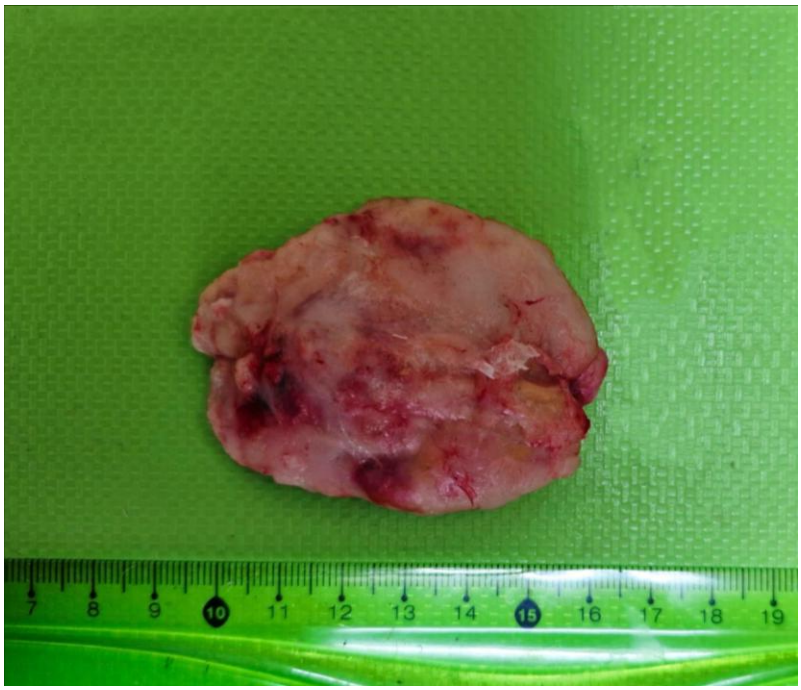


Figure 1. General appearance of the tumor mass.

Histopathologic results

Histopathological examination revealed that the tumor originated from adipose tissue and contained variable proportions of lipoblasts. The mass was composed predominantly of characteristic lipoblasts with thin walls and very large cytoplasmic vacuoles, in which the vacuoles displaced the nuclei to the periphery (Figures 2–4). In addition to these lipoblasts, markedly atypical cells -mostly round or oval in shape, with dark eosinophilic cytoplasm and hyperchromatic nuclei- observed both among these cells and extending along the delicate stroma. Furthermore, as a characteristic feature of injection-site sarcomas, foreign body giant cells formed in response to the injected material, as well as tumor-type giant cells, were observed (Figures 6, 7). In the interstitial tissue, mononuclear cell infiltrations in perivascular areas and focal hemorrhagic regions were also noted (Figure 5).

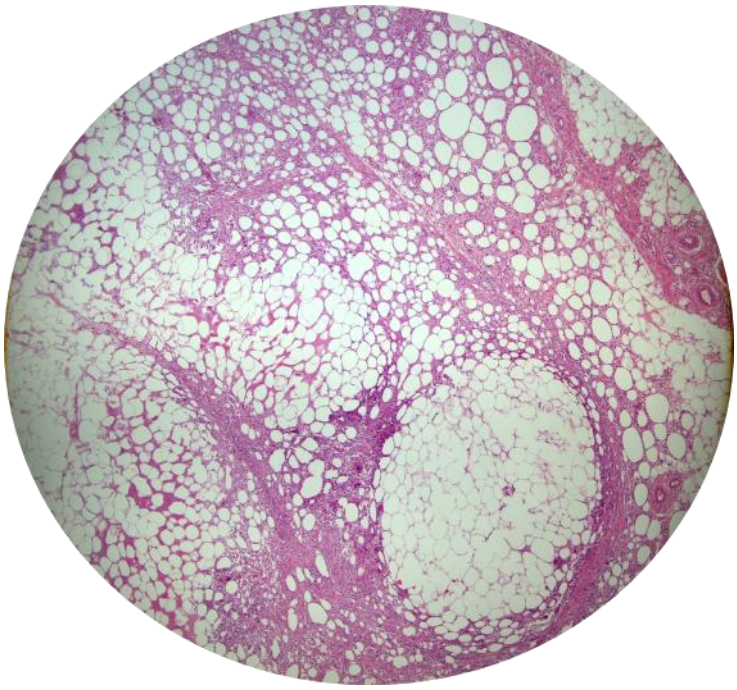


Figure 2. General microscopic view of the tumor, X4, HE.

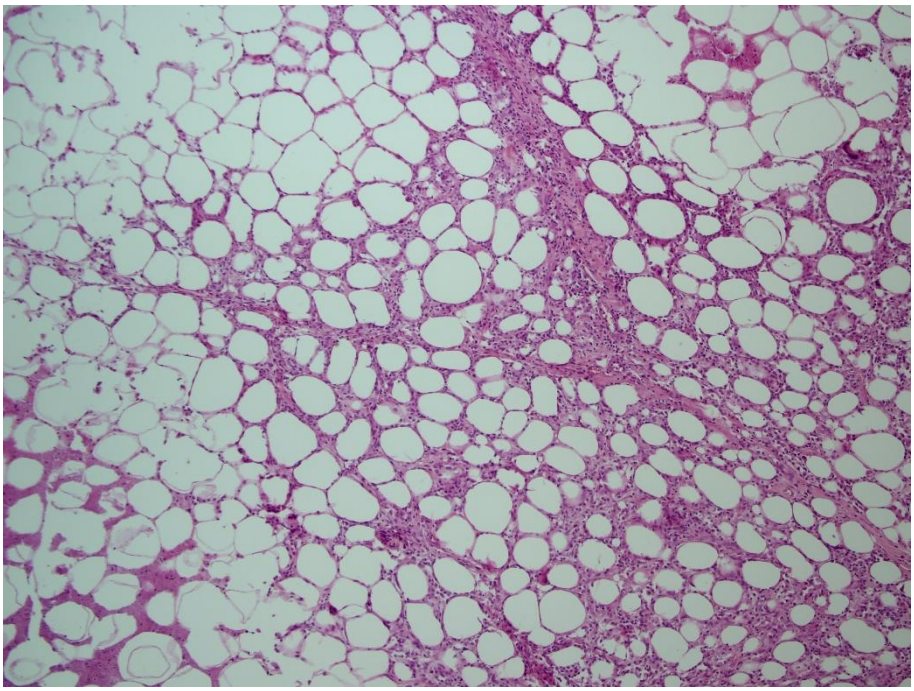


Figure 3. General microscopic view of the tumor, X4, HE.

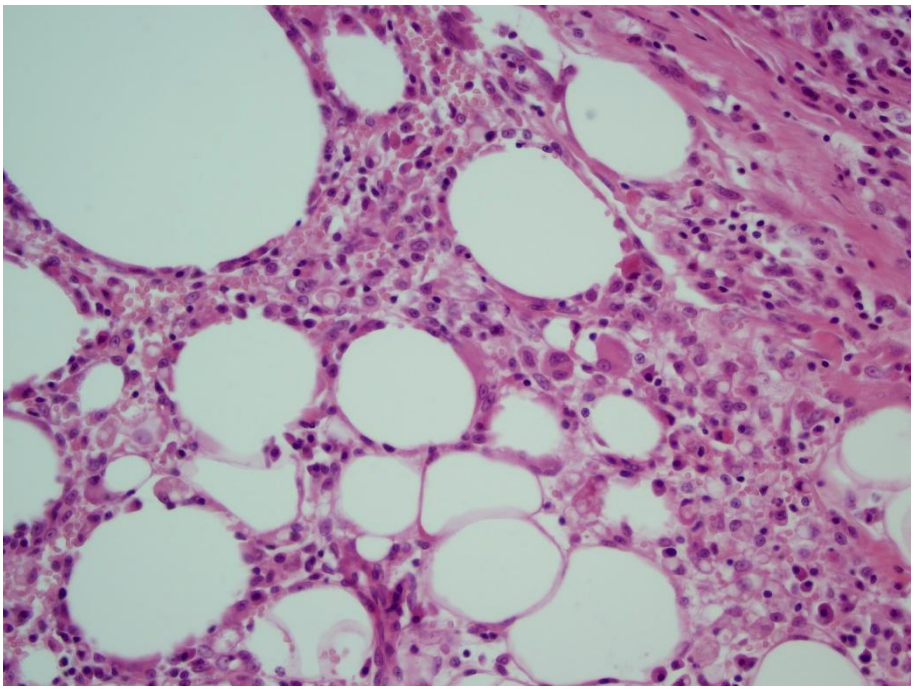


Figure 4. Cellular atypia in tumor cells, X40, HE.

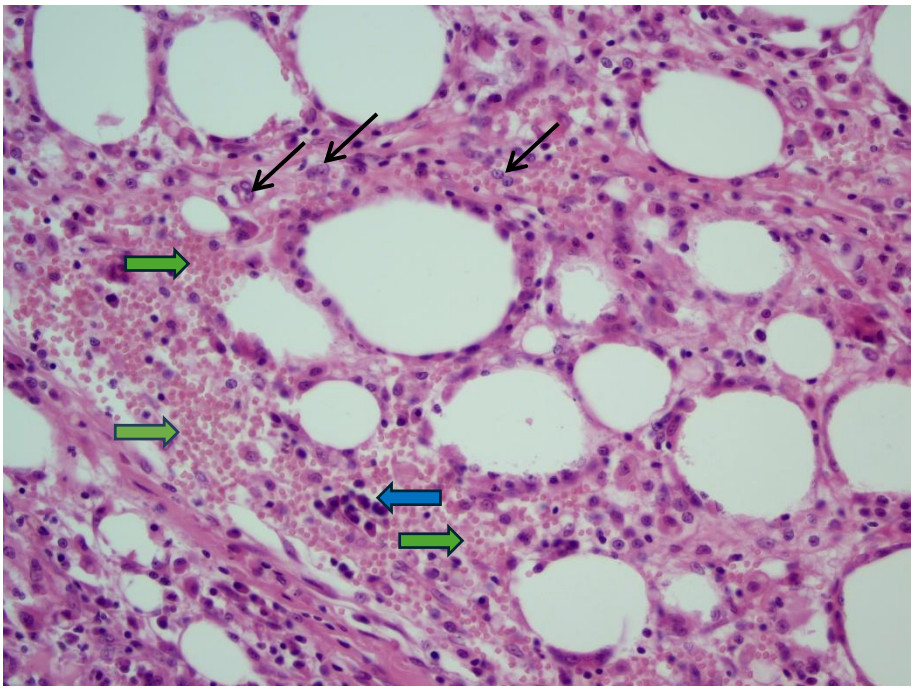


Figure 5. Cellular atypia in tumor cells, binucleated cells (arrows), hemorrhage in the interstitial tissue (green arrow), and mononuclear cell infiltration (blue arrow), X40, HE.

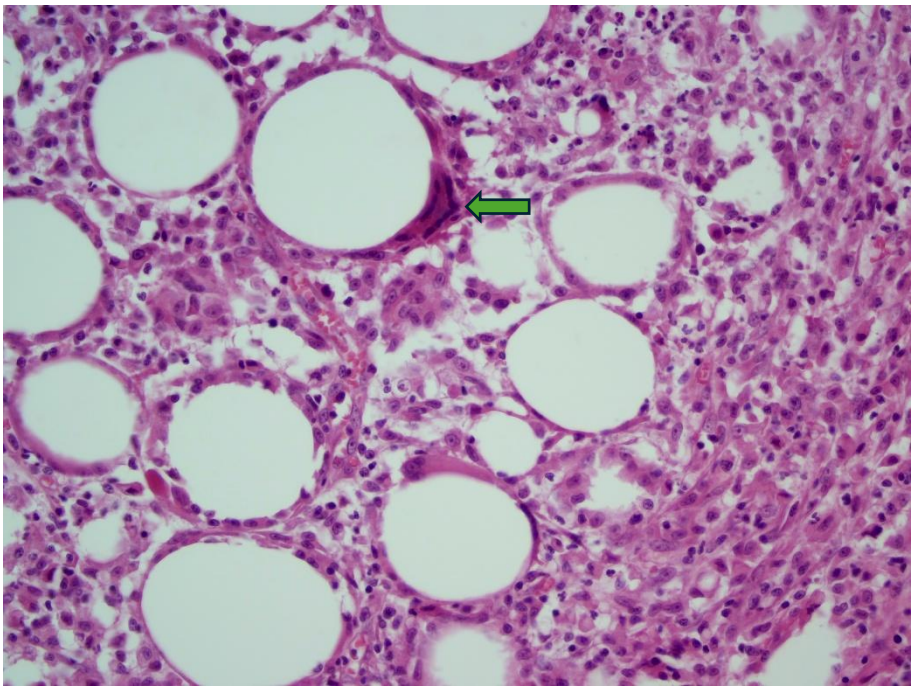


Figure 6. Cellular atypia in tumor cells and a foreign body giant cell (green arrow), X40, HE.

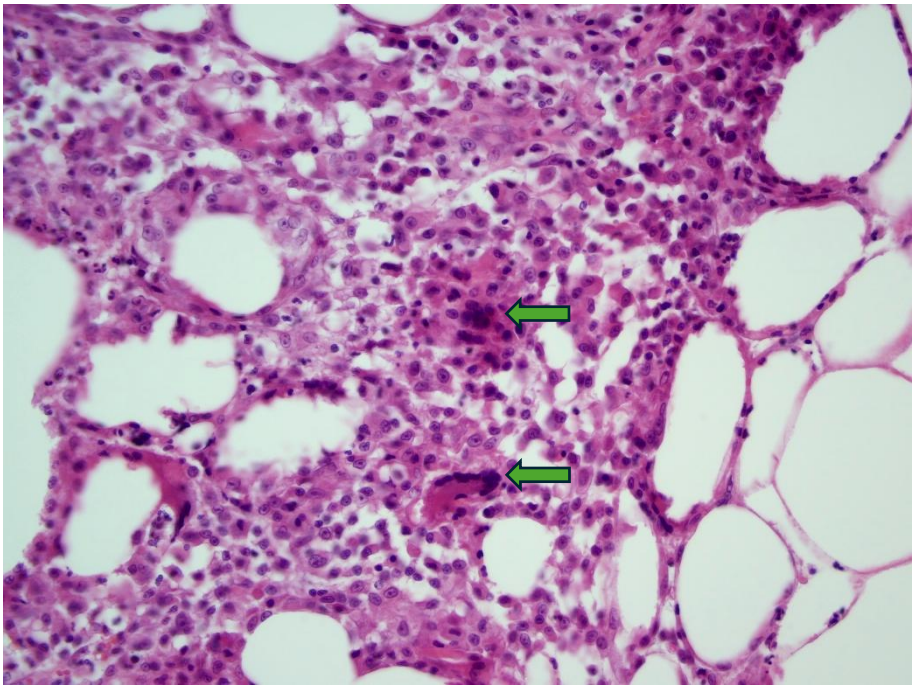


Figure 7. Cellular atypia in tumor cells and foreign body giant cells (green arrows), X40, HE.

CONCLUSION AND DISCUSSION

This study presents the histopathological evaluation of a feline injection-site liposarcoma, a tumor type that is extremely rare in cats, and compares the findings with clinical features and available literature data. Although liposarcoma is an uncommon subtype among injection-site–

associated sarcomas, previous studies have emphasized the significant role of chronic inflammation and repeated injections in its pathogenesis (Martano et al., 2011; Woodward, 2011). In the present case, long-term injections administered to the same anatomical region for chronic asthma management may have triggered continuous tissue irritation, necrosis, macrophage activation, and fibro-adipose tissue remodeling described in FISS pathogenesis, thereby creating a microenvironment conducive to tumor development.

The histopathological findings were largely consistent with previously reported injection-site liposarcomas. The presence of lipoblasts, an irregular population of stromal cells, marked cellular atypia, and an infiltrative growth pattern represented typical features of liposarcoma, while the accompanying granulomatous inflammation, foreign body giant cells, and mononuclear cell infiltration constituted reactive changes characteristic of FISS (Kliczkowska et al., 2015; Martano et al., 2011). In particular, the presence of a foreign body reaction is considered an important histomorphological criterion supporting the injection-site origin of the tumor.

Due to the limited number of reported cases, there is no clear consensus regarding the biological behavior of injection-site liposarcomas; however, similar to other FISS subtypes, they are known to exhibit a high tendency for local invasion with a relatively low metastatic potential (Ahmed & Mahmut, 2021; Goldschmidt & Hendrick, 2002). In this case, the absence of a distinct capsule and the infiltrative extension of the tumor into surrounding tissues macroscopically further indicate the aggressive local behavior typical of FISS. The interscapular localization of the injection site increases surgical limitations, complicates wide-margin excision, and consequently elevates the risk of recurrence. Therefore, as with all masses suspected to be FISS, early diagnosis and appropriate surgical management are of critical importance (Martano et al., 2011).

This case is noteworthy as it represents a rare example of injection-site liposarcoma reported in the literature and provides histopathological evidence supporting the role of chronic inflammation in its pathogenesis. Moreover, it highlights the importance of not overlooking the long-term effects of repeated injections administered to the same anatomical region in routine clinical practice.

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DETERMINATION OF KNOWLEDGE AND ATTITUDES TOWARD SCABIES AMONG INDIVIDUALS LIVING IN RURAL AREAS

Dr. Öğr. Üyesi Neşe İŞCAN AYYILDIZ

Trabzon Üniversitesi, Tonya Meslek Yüksekokulu

Dr. Öğr. Üyesi Uçar KÜÇÜK

Trabzon Üniversitesi, Tonya Meslek Yüksekokulu

ABSTRACT

Introduction and Purpose: Scabies is a common and neglected skin disease worldwide and is considered a significant health problem, particularly in developing countries**.** Effective control of infectious diseases is not limited to medical treatment and access to healthcare; the level of knowledge, awareness, and attitudes toward diseases within the community also play a decisive role in the success of this fight.This study was conducted to evaluate the knowledge and attitudes of rural individuals towards scabies.

Materials and Methods: This descriptive cross-sectional study was conducted with individuals living in a district in northern Turkey between June and December 2024. Data were collected through a questionnaire including 9-item demographic information and 26-item knowledge and attitudes towards scabies.

Results: It was determined that 95.3% of the participants had heard of scabies, 80.9% stated that scabies is a contagious skin disease, 86.5% stated that the most common symptoms of scabies are severe itching at night, 69.5% small blisters or rashes, 67.6% skin rashes, and 88.7% stated that they would definitely consider treatment and follow-up in accordance with the physician's recommendation in the treatment of scabies. It was determined that the level of knowledge and attitudes of individuals towards scabies was sufficient and positive.

Discussion and Conclusion: Although individuals' level of knowledge about scabies seems to be sufficient in general, the fact that this information is largely based on secondary sources such as media and social environment questions the reliability of the content. It was also concluded that individuals did not exhibit negative attitudes towards scabies. It is recommended that health authorities, nurses and educational institutions should increase direct information channels on public health issues and establish a stronger interaction with the community..

Key Words: Knowledge, Nursing, Rural Areas, Attitudes, Scabies.

GİRİŞ

Uyuz, dünya genelinde yaygın ve ihmal edilen bir deri hastalığı olup, özellikle gelişmekte olan ülkelerde önemli bir sağlık sorunu olarak kabul edilir (Leung et,el,2020). Sarcoptes scabiei adlı parazitin (akar) neden olduğu bu hastalık, yaş, cinsiyet veya ırk fark etmeksizin herkesi etkileyebilir ve yoğun kaşıntıya yol açar. Uyuz, havlu, yatak takımı, giysi ve benzeri eşyaların ortak kullanımıyla veya doğrudan temasla bulaşabilen bir hastalıktır (Alsyali et.al.,2019). Bu

nedenle, cilt temasından kaçınmak, kişisel eşyaları paylaşmamak ve özellikle kalabalık ortamlarda hijyen kurallarına dikkat etmek, uyuzun yayılmasını önlemede etkili olabilir (Fuller, 2013). Hastalığın en belirgin belirtisi, özellikle geceleri şiddetlenen kaşıntıdır. Bulaşıcı hastalıklarla etkin mücadele, yalnızca tıbbi tedavi ve sağlık hizmetlerine erişimle sınırlı değildir; aynı zamanda toplumun bilgi düzeyi, farkındalığı ve hastalıklara yönelik tutumları da bu mücadelenin başarısında belirleyici rol oynamaktadır (Relf, 2022). Uyuz hastalığı gibi sosyal damgalanma ve utanma duygusu yaratabilen enfeksiyonlar söz konusu olduğunda, bireylerin hastalığa yönelik tutumları, tedaviye başvuru davranışlarını da doğrudan etkileyebilmektedir. Savaş, göç ve deprem gibi toplumsal karışıklıkların yaşandığı kalabalık ortamlar ile hapishaneler, çocuk ve yaşlı bakım evleri, kışlalar ve okullar gibi kurumsal alanlar, yetersiz beslenme ve hijyen koşullarının kötü olmasıyla birleştiğinde enfestasyon riskini önemli ölçüde artırmaktadır (Jackson, 2004; WHO,2020). Ciddi bir sağlık sorunu olarak kabul edilen uyuz, 2017 yılında Dünya Sağlık Örgütü tarafından ihmal edilen hastalıklar listesine dahil edilmiştir. Uyuzun yayılmasını önlemek için cilt temasından kaçınılması, kişisel eşyaların ortak kullanılmaması ve özellikle kalabalık ortamlarda hijyenin artırılması önemlidir. Hastalığın kontrol altına alınabilmesi için yalnızca enfekte bireyin değil, onunla aynı ortamda yaşayan herkesin eş zamanlı olarak tedavi edilmesi gerekmektedir. Aksi takdirde, hastalık kişiden kişiye bulaşmaya devam edecektir. Uyuz hastalarının ve birlikte yaşadıkları kişilerin giysileri, havluları ve çarşafları en az 60°C'de yıkanmalı ve ütülenmelidir. Yıkanması mümkün olmayan eşyalar, ağzı sıkıca kapatılmış bir poşet içerisinde üç gün boyunca bekletilmelidir. Bu süre zarfında parazitin tüm yaşam evreleri ve yumurtaları yok olacaktır (Arlian and Morgan, 2017; Akgöl ve Köroğlu, 2022). Toplu yaşam alanlarında, hastalığın erken teşhisi, uygun tedavi uygulanması ve enfekte bireylerin izole edilmesi, olası salgınların önüne geçilmesini sağlayacaktır. Uyuz hastalığı bireylerin kaşıntı nedeniyle uyku düzeninde bozulmalara yol açarken, damgalanma ve utanç duygusu nedeniyle bireyin işini, sosyal aktivitesini ve psikolojk sağlığını da etkilediği bilinmektedir. Toplumun hastalık hakkındaki bilgi kaynaklarının niteliği de bu bağlamda önem arz etmektedir. Günümüzde bireyler sağlıkla ilgili bilgileri çoğunlukla televizyon, sosyal medya ve sosyal çevre aracılığıyla edinmektedir (Vosoughi,, 2018).Ancak bu kaynakların güvenilirliği her zaman yeterli düzeyde olmayabilir. Bu durum, bireylerin hastalıkla ilgili doğru olmayan bilgilere ulaşmasına ve tedaviye geç başvurmalarına neden olabilmektedir. Çeşitli ülkelerde yürütülen araştırmaların sonuçları incelendiğinde, uyuz hakkındaki bilgi düzeyi anketlerdeki farklılıklar nedeniyle değişkenlik göstermektedir. Yapılan bu çalışmaların birçoğunun doktor popülasyonu, tıp öğrencileri, sağlık personelleri ve lise öğrencilerini kapsamakta olduğu görülmüştür (ALshehri,2018; Alsaidan et.al., 2020; Birjandi et.al.,,2019; Lapeere et.al., 2005, Babaoglu ve ark., 2023). Son yıllarda uyuz vakalarında yaşanan artış, bu hastalığın yalnızca bireysel bir sağlık sorunu değil, aynı zamanda toplumsal düzeyde ele alınması gereken bir halk sağlığı problemi olduğunu ortaya koymaktadır. Ancak, uyuz hastalığının toplum üzerindeki etkilerini ve bireylerin yaşam kalitesine olan yansımalarını ele alan çalışmaların sayıca yetersiz olduğu görülmektedir. Bu eksiklik, konuyla ilgili yeni araştırmalara olan ihtiyacı açıkça ortaya koymaktadır. Bu çalışmanın amacı, söz konusu boşluğu doldurmak ve uyuz hastalığına ilişkin literatüre katkı sağlamaktır. Çalışmamız, toplumun uyuz hastalığına dair bilgi düzeyini ve bu hastalığa yakalanan bireylere karşı geliştirdikleri tutumları değerlendirmeyi hedeflemektedir. Elde edilecek bulgular, uyuzun bulaşmasını önlemeye yönelik sağlık eğitimi stratejilerinin geliştirilmesine katkı sağlayabileceği gibi, hastalığa yakalanan bireylerin karşılaştığı damgalanma ile mücadele açısından da önem taşımaktadır. Bu kapsamda araştırmamız, kırsal bölgelerde yaşayan bireylerin uyuz hastalığına yönelik bilgi ve tutumlarını belirlemek amacıyla gerçekleştirilmiştir.

GEREÇ ve YÖNTEM

Araştırmanın Türü

Tanımlayıcı-kesitsel tiptedir.

Araştırmanın Yeri ve Zamanı

Bu araştırma Türkiye'nin kuzeyinde bir ilçede yaşayan bireylerle yüz yüze anket yöntemi kullanılarak Haziran- Aralık 2024 tarihleri arasında yürütülmüştür.

Araştırmanın Evren ve Örneklemi

Çalışmanın yürütüldüğü ilçe merkezinin güncel nüfusu 15.000 'dir. Evreni bilinen örneklem hesabı formülünden faydalanılarak 0.95 güçte 0.05 hata oranı ile çalışmanın örneklem büyüklüğü için 375 kişiye ulaşılması gerektiği belirlenmiştir. Asgari örneklem sayısının üzerine çıkılmaya çalışılarak dahil edilme kriterlerini sağlayan ve çalışmaya katılmaya gönüllü 423 kişiyle çalışma tamamlanmıştır.

***Araştırmaya Kabul Kriterleri*:**

1.18- 80 yaş aralığında olanlar,

2. Sözel iletişim kurulabilen,

3. Anket formundaki soruları algılayabilecek ve doğru şekilde cevaplandırmasına engel teşkil edecek şekilde fiziksel ve ruhsal sağlık durumu kötü olmayan,

4. Anket formunu doldurabilecek kadar okuma yazması olanlar,

5. Araştırmaya katılmaya istekli olanlar

Araştırmaya dahil edilen bireylere çalışmanın amacı anlatılıp, yazılı ve sözlü onamları alınacaktır. Araştırma verileri yüz yüze görüşme tekniği kullanılarak toplanmıştır.

Veri Toplama Araçları: Verilerin toplanmasında Kişisel Bilgi Formu ve Uyuz Hastalığı Bilgi ve Tutum Anket Formu kullanılmıştır.

Kişisel Bilgi Formu: Literatür bilgileri doğrultusunda (Arlian and Morgan, 2017; Akgöl ve Köroğlu, 2022; Babaoglu ve ark., 2023; Singg, 2015) hazırlanan formda bireylerin yaş, cinsiyet, meslek, eğitim durumu, medeni durum, yaşam yeri, daha önce uyuz geçirme durumu uyuz olan bir yakın varlığı gibi durumların sorgulandığı 9 soru bulunmaktadır.

***Uyuz Hastalığı Bilgi ve Tutum Soru Formu*:** Araştırmacılar tarafından literatür taraması sonucunda uyuz hastalığına ait bilgi ve tutum sorularını içeren 26 maddelik bir anket formu oluşturulmuştur (Arlian and Morgan, 2017; Akgöl ve Köroğlu, 2022; Vosoughi et.al., 2018; Birjandi et.al., 2019).

Verilerin analizi: Araştırma verileri SPSS 22 programı kullanılarak analiz edilmiştir. Verilerin normal dağılıma uygunluğu Kolmogorov-Smirnov testi ile değerlendirilmiştir. Tanımlayıcı verilerin analizinde sayı (n), yüzde (%), ortalama ve standart sapma kullanılmıştır. Elde edilen veriler üçüncü şahıslar ile paylaşılmayacaktır. Elde edilen veriler en az beş yıl saklı tutulacaktır. Çalışma öncesinde Trabzon Üniversitesi Sosyal Ve Beşeri Bilimler Bilimsel Araştırma ve Yayın Etik Kurulundan 04.03.2024 tarihli E-81614018-050.04-2400011959 sayılı etik kurul izni alınmıştır. Ayrıca araştırmaya katılan bireylere çalışmanın amacı anlatılarak gönüllülük ilkesi doğrultusunda Helsinki Bildirgesine uygun şekilde aydınlatılmış onamları alınmıştır.

BULGULAR

Katılımcılara ait tanıtıcı bilgilerin dağılımı Tablo 1'de verilmiştir. Katılımcıların %51.8'inin kadın, %56.7'sinin bekar, %55.3'ünün lise mezunu, %40.4'ünün öğrenci, %59.12siinin çocuksuz olduğu, %82.7'sinin çekirdek aile tipinde olduğu, %51.8'inin ilçede yaşadığı, %53.2'sinin orta düzey gelire sahip olduğu belirlenmiştir. Çalışmamızdaki katılımcıların yaş ortalaması 32.39±15.29 yıl olarak bulunmuştur (Tablo.1).

Tablo 1. Katılımcılara Ait Tanıtıcı Bilgilerin Dağılımı (N=423)

Tanıtıcı Bilgiler				**N**	**%**
Cinsiyet	Kadın			219	**51.8**
	Erkek			204	48.2
Medeni Durum	Evli			183	43.3
	Bekar			240	56.7
Eğitim Durumu	Okuryazar			33	7.8
	İlköğretim			116	27.4
	Lise			234	**55.3**
	Ön Lisans-Lisans			40	9.5
Meslek	Öğrenci			171	40.4
	Hizmet sektörü			99	23.4
	Ev Hanımı			60	14.2
	Memur			82	19.4
	Çiftçi			11	2.6
Çocuk Sayısı	Çocuk Yok			250	59.1
	1 ya da 2 çocuk			92	21.8
	3 ve üzeri çocuk			81	19.2
Aile Tipi	Çekirdek aile			350	82.7
	Geniş aile			61	14.4
	Parçalanmış aile			12	2.8
Yaşam yeri	İl			134	31.7
	İlçe			219	51.8
	Köy			70	16.5
Gelir Durumu	Kötü			13	3.1
	Orta			225	53.2
	İyi			157	37.1
	Çok iyi			28	6.6
	Min.	**Maks.**	**x̄**	**SS**	
Yaş	18	86	32.39	15.29	

Bireylerin uyuz hastalığına yönelik farkındalık durumlarına dair dağılım Tablo 2 'de verilmiştir. Katılımcıların % 95.3'ü uyuz hastalığını duyduğunu, %15.1'i daha önce uyuz hastalığını geçirmiş olduğunu, %38.3'ü bir yakınlarının uyuz hastalığına yakalanmış olduğunu, %80.9'u uyuz için bulaşıcı bir deri hastalığı olduğunu ifade etmiştir (Tablo.2). Uyuz hastalığına ait bilgileri sırasıyla TV haberlerinden (%61.5), sosyal medyadan (%50.6), komşu ve arkadaş çevrelerinden (%48.9), okuldan (42.6), kitap dergiden (14.4) ve doktordan (%5.7) duyduklarını bildirmişlerdir. Katılımcılar, uyuzun en yaygın belirtileri için % 86.5'i geceleri şiddetli kaşıntı, % 69.5'i küçük kabarcıklar veya kızarıklıklar, % 67.6'sı cilt döküntüleri, %24.3'ü ateş yüksekliği olduğunu % 2.8'i belirtileri bilmediğini ifade etmiştir.

"Uyuz hastalığının bulaşma şekli nedir?" sorusuna %83.7'sının "Cilt teması ve hastanın kullandığı giysiler, havlular, yatak örtüleri ve diğer eşyalarla 15-20dkka temas etme aracılığıyla" cevabı vererek doğru yanıtladığı görülmüştür (Tablo 2).

Tablo2. Uyuz hastalığı farkındalık durumlarına yönelik dağılım

Uyuz Farkındalık Soruları	**EVET**		**HAYIR**	
	N	**%**	**N**	**%**
Uyuz hastalığını duydunuz mu?	403	95.3	20	4.7
Daha önce uyuz hastalığı geçirdiniz mi?	64	15.1	359	84.9
Uyuz olan bir yakınınız oldu mu?	162	38.3	261	61.7
Uyuz bulaşıcı bir deri hastalığı mıdır?	342	80.9	81	19.1
		N		**%**
Uyuz Hastalığına dair bilgilerin duyulduğu yer? (*birden fazla seçenek işaretlenmiştir)	TV haberleri	260		61.5
	Sosyal medya	214		50.6
	Kitap-Dergi	61		14.4
	Okul	180		42.6
	Komşu-Çevre	207		48.9
	Doktor	24		5.7
Uyuzun en yaygın belirtileri nelerdir? (*birden fazla seçenek işaretlenmiştir)	Cilt üzerindeki döküntüler	285		67.6
	Geceleri şiddetli kaşıntı	366		86.5
	Ateş yüksekliği	103		24.3
	Küçük kabarcıklar veya kızarıklıklar	294		69.5
	Bilmiyorum	12		2.8
Uyuz hastalığının bulaşma şekli nedir?	Cilt teması ve hastanın kullandığı giysiler, havlular, yatak örtüleri ve diğer eşyalarla 15-20dkka temas etme aracılığıyla (Doğru cevap)	354		83.7
	Yalnızca cilt temasıyla	38		8.9
	Yalnızca tokalaşma	12		2.8
	Sadece kıyafetler ve yatak çarşafları aracılığıyla	8		1.8
	Bilmiyorum	11		2.8

Katılımcıların uyuz hastalığına dair bilgi ve tutum durumlarının dağılımları Tablo 3 de verilmiştir. %95.5'i enfekte olmuş bir kişiyle kıyafet değiştirmenin uyuz bulaşmasını arttırdığını, %93.6'sının uyuz olan birinin diğer kişilerden izole edilmesi gerektiğini, %78.3'ünün uyuz hastalığı, hayvanlara temas etmekle bulaştığını,%91'i uyuzun halka açık yataklardan yayılabildiğini, %90.8'i uyuzun mağazalarda denenen kıyafetler aracılığıyla bulaşabildiğini, %83.5'i uyuzun mağazalarda denenen ayakkabılar aracılığıyla bulaşabildiğini, %72.3'ünün uyuz olan bir kişi ile yan yana oturmakla uyuz bulaşabildiğini ifade etmiştir (Tablo 3).

Uyuz hastalığına yönelik tutumlarının dağılımları Tablo 3 de verilmiştir. Buna göre bireylerin %78'i uyuz hastalığı olan biriyle görüşmek istemediğini, %32.4'ü kaşınan birini gördüğünde uyuz olduğunu düşündüğünü, %67.8'i uyuzlu birinin pis ve bakımsız biri olduğunu düşünmediğini, %86.5'i uyuz hastalığının utanılacak bir sey olmadığını, %83.9'u uyuz hastalığına yakalandığında bunu arkadaşlarından gizlemeyeceğini, %87.2'si uyuz hastası biriyle karşılaştığında onunla tokalaşmaktan kaçınacağını,%89.1'i uyuz hastası olan birinin evine gitmeyeceğini, %96.9'u uyuz hastası birisiyle temas ettiğinde hemen ellerini yıkayacağını, %93.9'u uyuzlu birine temas ettiğinde kıyafetlerini değiştireceğini, %46.1'i uyuz tedavisi almış/Alan birini evine alabileceği ve evine gidebileceğini belirtmiştir (Tablo 3).

Tablo 3. Uyuz hakkında bilgi tutum durumları dağılımları

Uyuz Hastalığına Yönelik Bilgi Soruları	**Evet**		**Hayır**		**Bilmiyorum**	
	N	**%**	**N**	**%**	**N**	**%**
Enfekte olmuş bir kişiyle kıyafet değiştirmek uyuz bulaşmasının artmasıyla bağlantılı mıdır? (evet doğru cevap)	404	95.5	5	1.2	14	3.3
Uyuz olan birinin diğer kişilerden izole edilmesi gerekir mi? (evet doğru cevap)	396	93.6	16	3.8	11	2.6
Uyuz hastalığı, hayvanlara temas etmekle bulaşabilir mi? (hayır doğru cevap)	331	78.3	34	8.0	58	13.7
Uyuz halka açık yataklardan yayılabilir mi? (evet doğru cevap)	385	91.0	16	3.8	22	5.2
Mağazalarda denenen kıyafetler aracılığıyla uyuz bulaşabilir mi? (evet doğru cevap)	384	90.8	20	4.7	19	4.5
Mağazalarda denenen ayakkabılar aracılığıyla uyuz bulaşabilir mi? (hayır doğru cevap)	353	83.5	32	7.6	38	9.0
Uyuz olan bir kişi ile yan yana oturmakla uyuz bulaşabilir mi? (hayır doğru cevap)	306	72.3	60	14.2	57	13.5
Uyuz Hastalığına Yönelik Tutum Soruları						
	N	**%**	**N**	**%**	**N**	**%**
Uyuz hastalığı olan biriyle görüşmek istemem	330	**78.0**	65	15.4	28	6.6
Kaşınan birini gördüğümde uyuz olduğunu düşünürüm	137	32.4	264	**62.4**	22	5.2
Uyuz olduğunu bildiğim birinin pis ve bakımsız biri olduğunu düşünürüm	107	25.3	287	**67.8**	29	6.9
Uyuz hastalığına yakalanmak utanılacak bir durumdur	45	10.6	366	**86.5**	12	2.8
Uyuz hastalığına yakalansam bunu arkadaşlarımdan gizlerim.	45	10.6	355	**83.9**	23	5.4
Uyuz hastalığı olan/şüphesi olan biriyle tokalaşmam.	369	**87.2**	45	10.6	9	2.1
Uyuz hastalığı olan/şüphesi olan birinin evine gitmem.	377	**89.1**	26	6.1	27	4.7
Uyuz hastalığı olan/şüphesi olan birine temas edersem hemen elimi yıkarım.	410	**96.9**	9	2.1	4	0.9
Uyuz hastalığı olan/şüphesi olan birine temas edersem hemen kıyafetlerimi değiştiririm.	397	**93.9**	18	4.3	8	1.9

"Uyuz hastalığının tedavisi nasıl planlanmalıdır?" sorusunu katılımcıların %88.7'si "mutlaka hekim önerisine uygun tedaviye başlanmalı ve gerekli takipler yaptırılmalı" şeklinde yanıtladığı görülmekle birlikte, %4.5 'i uyuz tedavisi almış kişilerin tedavilerini kullanabileceklerini, %4 'ü sirkeli su ile duş alarak tedavi olabileceklerini, %2.8'i ise kendiliğinden geçmesini bekleyeceğini ifade etmiştir. Katılımcıların % 46.6'sının uyuz hastalığına yakalanmamak için uyguladığı geleneksel bir yöntemi bulunduğu bildirmiştir.

Katılımcıların %87.2'si şikayetleri olmasa bile yakın temasta bulunan aile üyelerinin mutlaka tedaviye dahil edilmeleri gerektiğini belirtirken, %6.9 'u bu konu hakkında bilgi sahibi olmadığını belirtmiştir.

SONUÇ

Bu çalışmada, genel toplum arasında uyuz hastalarına ilişkin olumlu bir tutum ve uyuz hakkındaki bilgi düzeyinin orta-yüksek seviyelerde olduğu bulunmuştur. Toplumdaki bireylerin uyuz hastalığını TV haberlerinden duyarak uyuz hastalığına dair farkındalık geliştirdikleri görülmüştür. Son yıllarda Dünya'da ve ülkemizdeki vaka artışlarının haberlere yansıması da bireylerin uyuz hastalığı (bulaş yollarını, tedavi ve ziyaretçi kısıtlamaları) hakkında bilgi sahibi olmalarına katkı sağlamış olabileceği düşünülmektedir. Bunun yanı sıra,

bireylerin uyuzdan korunma yollarına ilişkin ve uyuz hastalığına karşı endişeli tutumlarının daha detaylı değerlendirileceği yeni çalışmaların planlaması önerilmektedir. Ayrıca 1-2 dk. lık sürelerde temaslarla bulaşların yaygın olarak görülmediğine dair eğitim planlarının eğitim ve rehberlik rolü yüksek olan hemşireler tarafından topluma entegre edilmesi önerilmektedir. Uyuz hastalığının yayılmasının önlenmesinde bireysel hijyen önlemleri, enfekte kişilerin izolasyonu ve temaslı bireylerin eş zamanlı tedavisi büyük önem taşımaktadır. Bu bağlamda, hastalığın sadece bireysel değil, çevresel kontrol gerektiren yönlerinin de toplum tarafından anlaşılması gerekmektedir. Bilgilendirme kampanyaları ve toplum temelli sağlık eğitimleri ile bu farkındalık daha da artırılabilir.

Araştırmanın Sınırlılıkları

Bu çalışma, kesitsel tasarımı, bilgi ve tutum puanlarını hesaplayacak özelliklere sahip bir ölçeğin bulunmaması nedeniyle ve sadece Türkiye'nin kuzeyindeki bir ilçede yaşayan genel toplumu kapsaması sebebiyle kısıtlıdır.

Çıkar Çatışması

Yazarlar arasında herhangi bir çıkar çatışması bulunmamaktadır.

Etik Kurul Onay Beyanı

Trabzon Üniversitesi Sosyal ve Beşeri Bilimler Bilimsel Araştırma ve Yayın Etik Kurul Başkanlığı'ndan 04/03/2024 tarih E-81614018-050.04-2400011959 sayısı ile etik kurul izni alınmıştır.

Teşekkür

Çalışmaya katılan tüm katılımcılara teşekkür ederiz.

Mali Destek

Herhangi bir mali destek alınmamıştır.

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CESAREAN SECTION ON THE RISE: MATERNAL OUTCOMES, PELVIC FLOOR CONSEQUENCES, AND MULTIDISCIPLINARY MANAGEMENT

Mehmet ÇOPUROĞLU

Department of Obstetrics and Gynecology, Kayseri City Hospital, Kayseri, Turkey

ORCID ID: https://orcid.org/0009-0008-2375-6253

Özge BAYKAN ÇOPUROĞLU

Physiotherapy Program, Department of Therapy and Rehabilitation, Incesu Ayşe and Saffet Arslan Vocational School of Health Services, Kayseri University, Kayseri, Turkey

ORCID ID: https://orcid.org/00000-0003-1014-8845

ABSTRACT

Background: Cesarean section (CS) rates have increased substantially worldwide over the past two decades, far exceeding the levels recommended by the World Health Organization. While cesarean delivery is a life-saving intervention when medically indicated, growing evidence suggests that its widespread use is associated with increased maternal morbidity and long-term functional consequences, particularly affecting the pelvic floor and musculoskeletal system. Objective: This narrative review aims to synthesize current evidence on maternal outcomes following cesarean delivery, with a specific focus on pelvic floor dysfunction, scar-related and myofascial consequences, and the role of physiotherapy and multidisciplinary postpartum management. Methods: A comprehensive literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, and CINAHL databases for studies published between 2015 and 2024. Randomized controlled trials, observational studies, and systematic reviews examining maternal, pelvic floor, and functional outcomes after cesarean section were included. Evidence related to physiotherapy-based rehabilitation and multidisciplinary care models was also reviewed. Findings were narratively synthesized due to heterogeneity in study designs and outcome measures. Results: The reviewed literature indicates that cesarean delivery is associated with persistent postoperative pain, delayed functional recovery, pelvic floor dysfunction, and scar-related impairments extending beyond the early postpartum period. Contrary to traditional assumptions, cesarean section does not eliminate pelvic floor morbidity but is frequently associated with pelvic floor muscle hypertonicity, chronic pelvic pain, and dyspareunia. Scar-related fascial restrictions and disrupted abdominal–pelvic coordination contribute to these outcomes. Physiotherapy-based interventions, particularly those emphasizing early mobilization, breathing retraining, scar management, and coordinated pelvic floor rehabilitation, were consistently associated with reduced pain, improved function, and enhanced quality of life. Multidisciplinary care models integrating obstetric follow-up and rehabilitation demonstrated superior outcomes compared with standard postoperative care alone. Conclusion: Cesarean section has significant and often underrecognized long-term implications for maternal pelvic floor and functional health. Integrating physiotherapy and multidisciplinary rehabilitation into routine post-cesarean care may play a crucial role in optimizing recovery and preventing chronic dysfunction. Future research should focus on

establishing standardized, evidence-based rehabilitation protocols and evaluating their implementation in diverse healthcare settings.

Keywords: cesarean section; maternal outcomes; pelvic floor dysfunction; postpartum rehabilitation; physiotherapy; multidisciplinary care

INTRODUCTION

Cesarean section (CS) is one of the most frequently performed surgical procedures worldwide and represents a critical intervention when vaginal delivery poses risks to maternal or fetal health. Over the past two decades, however, global cesarean rates have increased far beyond clinically justified levels. The World Health Organization (WHO) has consistently stated that cesarean delivery rates above 10–15% are not associated with further reductions in maternal or neonatal mortality at the population level (World Health Organization [WHO], 2023). Despite this recommendation, cesarean rates exceed 30% in many high- and middle-income countries and continue to rise in low-resource settings, driven by a complex interplay of medical, social, legal, and institutional factors (Betrán et al., 2021).

While cesarean delivery can be life-saving in obstetric emergencies such as placenta previa, fetal distress, or obstructed labor, increasing evidence suggests that non-medically indicated cesarean sections are associated with higher short- and long-term maternal morbidity compared with vaginal birth. Immediate postoperative complications include infection, hemorrhage, thromboembolic events, and prolonged hospital stay (Richards & Black, 2024). Beyond these acute risks, cesarean delivery constitutes a major abdominal surgery that disrupts fascial integrity, neuromuscular coordination, and pelvic-abdominal biomechanics, potentially predisposing women to chronic pain syndromes and functional impairments that extend well into the postpartum and later life periods (Afshari et al., 2025).

Pelvic floor dysfunction (PFD) has traditionally been associated with vaginal birth; however, emerging literature challenges the assumption that cesarean delivery is inherently protective. Although cesarean birth may reduce the risk of severe perineal trauma, it does not eliminate the occurrence of urinary incontinence, pelvic organ prolapse, dyspareunia, or chronic pelvic pain (Siafarikas et al., 2022). Surgical scar formation, adhesions, altered load transfer through the abdominal wall, and compensatory pelvic floor muscle hypertonicity have been proposed as mechanisms contributing to post-cesarean pelvic floor symptoms (Pokhrel et al., 2022). These findings underscore the need to reconceptualize cesarean delivery not only as an obstetric outcome but also as a potential contributor to long-term musculoskeletal and pelvic health sequelae.

In addition to pelvic floor dysfunction, cesarean delivery has been linked to impaired core stability, delayed recovery of functional mobility, and persistent lumbopelvic pain. The surgical incision disrupts the myofascial continuity between the abdominal wall, diaphragm, and pelvic floor, which plays a central role in postural control and intra-abdominal pressure regulation (Kharaji et al., 2023). Without targeted rehabilitation, these biomechanical alterations may persist, increasing vulnerability to chronic pain, reduced physical activity, and diminished quality of life in the postpartum period (Aparicio et al., 2021).

Given the multifactorial consequences of cesarean delivery, there is growing recognition that postoperative care should extend beyond routine surgical follow-up. Multidisciplinary management models integrating obstetric care with physiotherapy-based rehabilitation have been increasingly advocated. Early mobilization, scar tissue management, breathing re-education, and individualized pelvic floor and core stabilization programs have demonstrated beneficial effects on pain reduction, functional recovery, and sexual health outcomes (Höder et

al., 2023; Huang et al., 2024). Nevertheless, access to structured postpartum rehabilitation remains inconsistent, and standardized clinical pathways for post-cesarean physiotherapy are lacking in many healthcare systems.

Within this context, a comprehensive synthesis of the existing literature is needed to clarify the maternal and pelvic floor consequences of rising cesarean rates and to evaluate the role of multidisciplinary rehabilitation strategies in mitigating these outcomes. Therefore, the aim of this review is to critically examine current evidence on maternal morbidity, pelvic floor dysfunction, and functional impairments following cesarean delivery, with particular emphasis on the contribution of physiotherapy and interdisciplinary care models to improving postpartum recovery and long-term maternal health.

METHODOLOGY

Study Design

This study was designed as a narrative review synthesizing current evidence on the maternal, pelvic floor, and functional outcomes associated with cesarean section, with a particular focus on postoperative morbidity and multidisciplinary rehabilitation approaches. A narrative review methodology was chosen to allow for an integrative evaluation of heterogeneous study designs, including clinical trials, observational studies, and systematic reviews, and to contextualize findings within obstetric and physiotherapy practice.

Literature Search Strategy

A comprehensive literature search was conducted across the electronic databases PubMed/MEDLINE, Scopus, Web of Science, and CINAHL. The search covered studies published between January 2015 and December 2024 to ensure inclusion of contemporary evidence reflecting current obstetric practices and rehabilitation paradigms. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to cesarean delivery and postpartum outcomes. Key search terms included combinations of: “cesarean section” OR “caesarean delivery” AND “maternal outcomes” OR “pelvic floor dysfunction” OR “chronic pelvic pain” OR “dyspareunia” OR “urinary incontinence” AND “physiotherapy” OR “postpartum rehabilitation” OR “pelvic floor muscle training” OR “scar management” OR “multidisciplinary care”. Reference lists of relevant articles and recent reviews were manually screened to identify additional eligible studies not captured through database searching.

Eligibility Criteria

Studies were considered eligible for inclusion if they met the following criteria: (1) involved women who delivered by cesarean section; (2) reported maternal outcomes, including pelvic floor function, musculoskeletal or functional impairments, pain, or quality of life; (3) evaluated postoperative recovery, rehabilitation, or physiotherapy-related interventions, or discussed long-term maternal consequences of cesarean delivery; and (4) were published in English in peer-reviewed journals.

Randomized controlled trials, cohort studies, case–control studies, cross-sectional studies, and systematic reviews or meta-analyses were eligible. Studies focusing exclusively on neonatal outcomes, surgical techniques without maternal follow-up, or non-human data were excluded. Case reports, conference abstracts without full text, and opinion pieces were also excluded.

Study Selection and Data Extraction

Following removal of duplicate records, titles and abstracts were screened for relevance. Full texts of potentially eligible articles were then assessed to confirm inclusion criteria. Data extracted from included studies comprised study design, sample characteristics, mode of delivery, assessed maternal outcomes, type and timing of rehabilitation or physiotherapy intervention, and principal findings related to pelvic floor and functional recovery.

Given the heterogeneity of study designs, outcome measures, and intervention protocols, a quantitative meta-analysis was not performed. Instead, findings were synthesized descriptively and thematically.

Data Synthesis

The results were narratively synthesized and organized into thematic domains, including: (1) maternal morbidity and functional outcomes following cesarean delivery; (2) pelvic floor and core dysfunction mechanisms associated with surgical birth; and (3) effectiveness and clinical implications of multidisciplinary and physiotherapy-based postpartum management. Emphasis was placed on identifying consistent patterns across studies, clinically relevant risk factors, and gaps in the current literature that warrant further investigation.

Methodological Considerations

This review did not follow a formal systematic review protocol (e.g., PRISMA registration) and therefore does not claim exhaustive coverage of all available literature. However, the structured search strategy, transparent eligibility criteria, and critical synthesis approach were applied to enhance methodological rigor and reproducibility.

RESULTS

Maternal Morbidity and Functional Outcomes Following Cesarean Section

The reviewed literature consistently indicates that cesarean delivery is associated with a specific pattern of maternal morbidity extending beyond the immediate postoperative period. Compared with vaginal birth, women who underwent cesarean section reported higher levels of postoperative pain, delayed return to functional activities, and prolonged limitations in daily living (Ilska et al., 2022; Kuravska et al., 2022). Longitudinal cohort studies demonstrated that lumbopelvic pain and reduced physical capacity may persist for several months postpartum, particularly in women who did not receive structured rehabilitation interventions (Gluppe et al., 2021).

Functional impairments following cesarean delivery were frequently attributed to disruption of the abdominal wall, altered neuromuscular coordination, and compromised load transfer between the trunk and pelvis. Talasz et al. (2022) emphasized that surgical interruption of the abdominal–pelvic synergy negatively affects postural control and intra-abdominal pressure regulation, thereby increasing susceptibility to chronic musculoskeletal complaints. These findings suggest that cesarean delivery may initiate long-term biomechanical alterations rather than representing a transient surgical insult.

Pelvic Floor Dysfunction After Cesarean Delivery

Contrary to the traditional assumption that cesarean delivery protects against pelvic floor dysfunction, accumulating evidence demonstrates that pelvic floor symptoms remain prevalent among women delivering surgically. Multiple observational and longitudinal studies reported urinary incontinence, dyspareunia, and pelvic pain in post-cesarean populations, although with different symptom profiles compared with vaginal delivery cohorts (López-López et al., 2021).

Several studies identified pelvic floor muscle hypertonicity and impaired relaxation as prominent features in women experiencing post-cesarean pelvic pain and sexual dysfunction. Peinado Molina et al. (2023) reported that altered pelvic floor muscle behavior, rather than muscle weakness alone, was associated with reduced quality of life and persistent symptoms. These findings align with emerging perspectives that emphasize neuromuscular coordination and relaxation capacity as critical determinants of pelvic floor health following surgical birth.

Scar-Related and Myofascial Consequences

Scar-related dysfunction emerged as a key contributor to post-cesarean morbidity. Studies assessing scar mobility and tissue compliance consistently reported reduced elasticity, increased sensitivity, and restricted glide between fascial layers in the lower abdominal region (González-Muñoz et al., 2024). These scar-related changes were associated with pain during movement, postural alterations, and limitations in trunk and hip mobility.

Myofascial continuity models further highlighted the impact of cesarean scars on the integrated function of the diaphragm, abdominal wall, and pelvic floor. Restricted diaphragmatic excursion and altered breathing patterns were frequently observed in women with symptomatic cesarean scars, suggesting that localized surgical changes may have global biomechanical consequences (Poprzeczny et al., 2020; Hwang et al., 2021).

Effects of Physiotherapy and Multidisciplinary Rehabilitation

Evidence across randomized controlled trials, cohort studies, and systematic reviews consistently supported the effectiveness of physiotherapy-based interventions following cesarean delivery. Early mobilization, breathing re-education, scar tissue management, and progressive core and pelvic floor rehabilitation were associated with reductions in pain intensity, improved functional mobility, and enhanced postpartum quality of life (Hui et al., 2021; Chen et al., 2022).

Pelvic floor–focused interventions emphasizing muscle awareness, relaxation, and coordination—rather than isolated strengthening—were particularly effective in reducing dyspareunia and chronic pelvic pain. Biofeedback-assisted approaches facilitated voluntary muscle control and improved symptom awareness, especially in women presenting with pelvic floor muscle overactivity (Chen et al., 2024).

Multidisciplinary care models integrating obstetric follow-up, physiotherapy, and patient education demonstrated superior outcomes compared with standard postoperative care alone. These models were associated with lower rates of chronic pain, reduced pelvic floor symptom burden, and higher patient satisfaction (Ríos-Covian et al., 2021).

Timing of Intervention and Clinical Implications

The timing of rehabilitation emerged as a critical determinant of clinical outcomes. Studies consistently showed that women who initiated physiotherapy interventions in the early postpartum period experienced faster functional recovery and fewer persistent symptoms compared with those receiving delayed or no rehabilitation (Bø et al., 2022). Early intervention appeared to prevent maladaptive movement strategies and disruption of the pain–contraction cycle involving the abdominal and pelvic floor musculature.

Despite these favorable findings, substantial heterogeneity was observed in intervention protocols, including differences in duration, intensity, and content. The lack of standardized post-cesarean rehabilitation guidelines limited direct comparisons across studies and highlighted the need for consensus-driven clinical pathways.

CONCLUSION AND DISCUSSION

This narrative review synthesizes current evidence demonstrating that the consequences of cesarean section extend well beyond the immediate postoperative period and encompass a broad spectrum of maternal, pelvic floor, and functional outcomes. While cesarean delivery remains a critical, life-saving intervention when clinically indicated, the reviewed literature highlights that its rising prevalence is accompanied by an increasing burden of long-term morbidity affecting women's physical function, pelvic health, and quality of life (Betrán et al., 2021; Vogel et al., 2024).

A key finding emerging from this review is that cesarean section does not confer comprehensive protection against pelvic floor dysfunction. Although vaginal birth is more strongly associated with direct perineal trauma, cesarean delivery introduces alternative risk pathways, including abdominal wall disruption, scar formation, adhesions, and altered neuromuscular coordination (Cattani et al., 2021; López-López et al., 2021). These mechanisms appear to predispose women to pelvic floor muscle hypertonicity, chronic pelvic pain, and dyspareunia rather than overt pelvic floor weakness. This distinction has important clinical implications, as it challenges strength-centered rehabilitation models and underscores the necessity of assessment strategies that address muscle coordination, relaxation capacity, and sensorimotor control.

The role of scar-related and myofascial alterations represents another critical theme. The evidence reviewed supports the concept that cesarean scars may act as biomechanical and neurophysiological disruptors within the abdominal–pelvic system. Restricted fascial glide altered tissue elasticity, and localized hypersensitivity have been linked to impaired trunk mobility, compensatory movement strategies, and persistent pain (Liu et al., 2022). Furthermore, disruption of the synergistic relationship between the diaphragm, abdominal musculature, and pelvic floor may compromise intra-abdominal pressure regulation and postural stability, thereby amplifying functional limitations during the postpartum period (Arruda Correia et al., 2023).

Physiotherapy-based rehabilitation emerged as a consistently beneficial intervention across diverse study designs. Early mobilization, breathing retraining, scar management, and integrated core–pelvic floor rehabilitation were associated with reduced pain intensity, improved functional recovery, and enhanced quality of life (Ostafiichuk et al., 2025; Xiao et al., 2025). Importantly, interventions emphasizing awareness, coordination, and relaxation—rather than isolated strengthening—were particularly effective in addressing pelvic pain and sexual dysfunction. These findings align with contemporary biopsychosocial and motor control frameworks in pelvic health rehabilitation.

The timing of intervention was identified as a decisive factor influencing outcomes. Early postpartum physiotherapy appeared to mitigate the development of maladaptive movement patterns and the perpetuation of pain–contraction cycles, supporting the rationale for proactive rather than reactive rehabilitation strategies (Selman et al., 2022; Gong et al., 2024). Despite this evidence, the absence of standardized post-cesarean rehabilitation pathways remains a significant gap. Considerable heterogeneity in intervention protocols limits comparability across studies and hampers translation into routine clinical practice.

Finally, the reviewed literature underscores the value of multidisciplinary care models integrating obstetric management, physiotherapy, and patient education. Such models were associated with superior long-term outcomes compared with routine postoperative care alone, highlighting the importance of collaborative, woman-centered approaches to postpartum recovery (Matthews et al., 2024). From a public health perspective, integrating rehabilitation into standard post-cesarean care may also reduce long-term healthcare utilization and chronic disability, although cost-effectiveness data remain limited.

The global rise in cesarean section rates has introduced complex and often underrecognized challenges for maternal health. Evidence synthesized in this review indicates that cesarean delivery is associated with persistent functional impairments, pelvic floor dysfunction, and scar-related sequelae that may compromise long-term quality of life. Contrary to traditional assumptions, cesarean section does not eliminate pelvic floor morbidity but rather alters its clinical presentation and underlying mechanisms.

Physiotherapy-based rehabilitation and multidisciplinary care models play a pivotal role in mitigating these adverse outcomes. Early, targeted interventions addressing breathing patterns, scar mobility, neuromuscular coordination, and pelvic floor function appear essential for optimizing recovery and preventing chronic dysfunction. However, the lack of standardized, evidence-based post-cesarean rehabilitation guidelines represents a critical gap in current obstetric care.

Future research should prioritize the development and validation of structured rehabilitation protocols, investigate their cost-effectiveness, and explore implementation strategies within diverse healthcare systems. Integrating physiotherapy into routine post-cesarean care pathways has the potential to enhance maternal well-being, reduce long-term morbidity, and support a more holistic approach to women's health following surgical childbirth.

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SEXUAL DYSFUNCTION AFTER CHILDBIRTH: PHYSIOTHERAPY APPROACHES FOR DYSPAREUNIA AND PELVIC FLOOR HYPERTONICITY

Özge BAYKAN ÇOPUROĞLU

Physiotherapy Program, Department of Therapy and Rehabilitation, Incesu Ayşe and Saffet Arslan Vocational School of Health Services, Kayseri University, Kayseri, Turkey

ORCID ID: https://orcid.org/00000-0003-1014-8845

Mehmet ÇOPUROĞLU

Department of Obstetrics and Gynecology, Kayseri City Hospital, Kayseri, Turkey

ORCID ID: https://orcid.org/0009-0008-2375-6253

ABSTRACT

Objective: Postpartum sexual dysfunctions, particularly dyspareunia and pelvic floor hypertonicity, are common but often overlooked clinical problems that negatively affect women's quality of life, sexual satisfaction, and psychosocial well-being. The aim of this review is to evaluate the underlying mechanisms of postpartum dyspareunia and pelvic floor hypertonicity in light of current literature and to examine the clinical effects of physiotherapy-based assessment and intervention approaches from a holistic perspective. Method: This study was designed as a comprehensive narrative review of scientific studies published between 2015 and 2024. PubMed, Scopus, and Google Scholar databases were searched using the keywords “postpartum sexual dysfunction”, “dyspareunia”, “pelvic floor hypertonicity”, and “pelvic floor physiotherapy”. Observational studies, randomized controlled trials, systematic reviews, and clinical guidelines focusing on the postpartum period, examining dyspareunia and/or pelvic floor hypertonicity, and including physiotherapy-based assessment or conservative interventions were evaluated. The findings are presented using a thematic and descriptive synthesis approach without quantitative meta-analysis due to methodological heterogeneity. Results: The studies reviewed show that the prevalence of dyspareunia in the postpartum period ranges from 30–60%, and pelvic floor hypertonicity is frequently associated with sexual pain. Increased resting tone in the pelvic floor muscles, decreased relaxation capacity, and myofascial tenderness are common findings in women with postpartum dyspareunia. The literature reveals that pelvic floor physiotherapy applications such as muscle relaxation (down-training), manual therapy, myofascial release, scar mobilization, breath-based relaxation, and biofeedback can reduce pain intensity and are associated with improvements in sexual function scores. It has been reported that physiotherapy interventions started early are associated with more positive clinical outcomes. Conclusion: Postpartum dyspareunia and pelvic floor hypertonicity are clinical conditions that should not be considered inevitable outcomes of childbirth, but rather manageable with appropriate assessment and physiotherapeutic approaches. Including pelvic floor physiotherapy as a standard component of postpartum care is crucial for the early recognition of sexual dysfunction and the prevention of its chronicity. Further research into the development of multidisciplinary care models and standardized intervention protocols will contribute to strengthening clinical practices.

Keywords: postpartum; dyspareunia; pelvic floor hypertonicity; physiotherapy; pelvic floor rehabilitation; sexual health

INTRODUCTION

The postpartum period represents a complex and multidimensional recovery process characterized by significant physiological, hormonal, neuromuscular, and psychosocial changes in the female body. Sexual dysfunction that occurs during this period is considered a significant public health issue that affects not only individual sexual health but also quality of life, partner relationships, mental well-being, and long-term pelvic health outcomes. However, postpartum sexual dysfunction is often overlooked in clinical follow-up and research; it is frequently normalized as a "natural consequence of childbirth" (Alimi et al., 2023).

The literature reports varying degrees of sexual dysfunction in 30–80% of women during the postpartum period. The most commonly described problems include dyspareunia, decreased sexual desire, difficulty with arousal, vaginal dryness, and orgasmic disorders (Delgado-Perez et al., 2022; Ibrahim et al., 2025). These symptoms often co-occur and form a cyclical structure that feeds into each other. Dyspareunia, in particular, is the most prominent and frequently reported clinical component of postpartum sexual dysfunction, which can lead to sexual avoidance behaviors and relational problems in both the short and long term (Abidi et al., 2022).

Postpartum dyspareunia has a complex etiology that cannot be attributed to a single cause. Birth trauma, perineal tears, episiotomy, microdamage to vaginal tissues, cesarean section and perineal scar tissue, changes in connective tissue elasticity, hypoestrogenic conditions associated with breastfeeding, and pain-related neuromuscular adaptations are among the key biological factors involved in the development of dyspareunia (Cattani et al., 2022; Ram-Weiner et al., 2023). However, psychosocial factors such as psychological stress, traumatic perceptions related to the birth experience, changes in body image, fatigue, and sleep disorders can also increase pain perception and aggravate the clinical picture.

Dyspareunia can be clinically classified as superficial (vulvar or introital) and deep pelvic pain. Superficial dyspareunia is often associated with perineal tissue sensitivity, scar tissue restriction, and excessive activity of the pelvic floor muscles; deep dyspareunia is associated with decreased pelvic organ mobility, myofascial trigger points, pelvic girdle dysfunction, and the chronic pelvic pain spectrum (Hrelic et al., 2023). It has been reported that these two forms often overlap in the postpartum period, making clinical differentiation difficult.

Pelvic floor muscle hypertonicity is one of the increasingly emphasized fundamental mechanisms in the pathophysiology of postpartum sexual dysfunction. Pelvic floor muscles are a complex structure with voluntary and involuntary control mechanisms that play a critical role in continence, sexual function, lumbopelvic stability, and pelvic organ support. Under normal physiological conditions, these muscles exhibit a dynamic balance between activation and relaxation. However, in the postpartum period, a protective pattern of continuous contraction may develop in the pelvic floor muscles in response to pain, tissue damage, and psychological stressors (Jorge et al., 2024).

Pelvic floor hypertonicity is characterized by insufficient muscle relaxation, myofascial trigger points, touch sensitivity, and coordination disorders. This condition increases pain during vaginal penetration, triggers penetration fear and avoidance behaviors, and consequently perpetuates the pain–contraction–pain cycle. Additionally, impaired diaphragm–pelvic floor synchronization, apical breathing patterns, and increased sympathetic activity can further reinforce hypertonicity (van Reijn-Baggen et al., 2022).

The mode of delivery and tissue damage sustained during childbirth have significant effects on postpartum sexual function. Perineal tears and episiotomy following vaginal delivery can increase superficial dyspareunia by causing sensitivity and loss of elasticity in scar tissue. Although cesarean delivery reduces perineal trauma, it can negatively affect sexual function due to abdominal scar tissue, limited fascial gliding, and disruption of the abdominal-pelvic muscle chain (Nikolaidou et al., 2022). Therefore, postpartum sexual dysfunction should be evaluated from a holistic tissue and movement system perspective, not solely reduced to the mode of delivery.

Sexual health is strongly influenced by cognitive, emotional, and relational factors beyond biological processes. Increased responsibilities during the postpartum period, adaptation to the role of motherhood, inadequate social support, depressive symptoms, and anxiety levels can reduce sexual desire and arousal. Persistent pain experiences can contribute to central sensitization, thereby chronicizing pain perception. Therefore, postpartum dyspareunia and pelvic floor hypertonicity should be addressed not merely as local musculoskeletal issues but as biopsychosocial health conditions (Vasconcelos et al., 2024; World Health Organization, 2023).

Pelvic floor physical therapy offers an evidence-based, non-invasive, and patient-centered approach to the assessment and management of postpartum sexual dysfunction. Pelvic floor muscle relaxation (down-training), manual therapy, myofascial release, scar mobilization, breathing-based relaxation, biofeedback, and education-based interventions have been reported to reduce dyspareunia and pelvic floor hypertonicity (Dakic et al., 2021; Quaghebeur et al., 2021). However, referral rates to physical therapy in the postpartum period are low, and multidisciplinary care models are not sufficiently widespread.

In this context, studies that systematically address the mechanisms of postpartum sexual dysfunction and the role of physiotherapeutic approaches are important for both increasing clinical awareness and improving postpartum care protocols.

METHODOLOGY

Study Design

This study was designed as a comprehensive narrative review focusing specifically on dyspareunia and pelvic floor hypertonicity among sexual dysfunctions observed in the postpartum period. The STROBE statement, which aims to increase reporting transparency for observational studies, was used as a basis during the research process; the study design, literature search method, inclusion–exclusion criteria, and presentation of findings were structured in a clear and traceable manner. Although the study is not a systematic review or meta-analysis, it was conducted in accordance with principles that support methodological consistency and reproducibility.

Literature Search Process

The literature search was conducted using the PubMed, Scopus, and Google Scholar databases. The search process included studies published between January 2015 and December 2024, covering current scientific evidence in the field of postpartum sexual dysfunction and pelvic floor physical therapy. The search strategy aimed to identify studies addressing the relationship between sexual pain, pelvic floor muscle function, and physiotherapeutic interventions in the postpartum period.

Keywords were applied individually and in combination using Boolean operators (“AND”, “OR”); additionally, the reference lists of the retrieved articles were manually screened to

include additional publications directly relevant to the topic (postpartum sexual dysfunction; dyspareunia; pelvic floor hypertonicity; pelvic floor dysfunction; pelvic floor physiotherapy; postpartum rehabilitation). This approach was chosen to include clinically important studies that might otherwise be overlooked in the literature.

Inclusion and Exclusion Criteria

Studies included in the literature were limited to those focusing on the postpartum period (the first 12 months after delivery), examining sexual function parameters associated with dyspareunia and/or pelvic floor hypertonicity, and involving physiotherapy-based assessments or interventions. Randomized controlled trials, cohort and cross-sectional studies, systematic reviews, and clinical guidelines were evaluated.

Studies examining populations unrelated to the postpartum period, publications focusing solely on surgical or pharmacological approaches, case reports, editorial articles, and studies whose full text was unavailable were excluded. This selection was made to ensure the synthesis of evidence appropriate to the study's purpose and transferable to clinical practice.

Data Extraction and Synthesis of Findings

The selected studies were reviewed at the full-text level, and sample characteristics, assessment tools used, measurements related to pelvic floor muscle function, applied physical therapy approaches, and reported clinical outcomes were systematically extracted from each study. Due to methodological and clinical heterogeneity among the studies, a quantitative meta-analysis was not performed; findings were presented using a thematic and descriptive synthesis approach. This approach aims to ensure the comparability and comprehensive interpretation of results obtained from different study designs.

RESULTS

General Characteristics of the Studies Reviewed

Studies that met the inclusion criteria exhibited a heterogeneous structure in terms of design and sample characteristics, with most studies adopting observational designs and relatively few randomized controlled trials or systematic reviews. Sample sizes typically ranged between 30 and 600 participants, and the postpartum period was most commonly defined as the first 6–12 months. Sexual function was predominantly assessed using the Female Sexual Function Index (FSFI), whereas pelvic floor muscle function was evaluated using digital palpation, clinical examination scales, or surface electromyography. The majority of studies relied on self-report measurement tools (Pardell-Dominguez et al., 2021; Gribble et al., 2022;Wang et al., 2023).

Prevalence and Clinical Distribution of Postpartum Dyspareunia

Studies reviewed indicate that the prevalence of postpartum dyspareunia ranges from 30% to 60% and is more commonly reported among women with a history of perineal trauma, episiotomy, or tearing following vaginal delivery. Pain most frequently manifests as superficial dyspareunia; however, in a specific subgroup, it is accompanied by deep pelvic pain and concomitant pelvic floor dysfunction. Although dyspareunia tends to be more pronounced during the early postpartum months, symptoms may persist in the absence of appropriate assessment and intervention. The presence of dyspareunia has also been associated with sexual avoidance behaviors and reduced sexual satisfaction (Zgliczynska et al., 2021; Abidi et al., 2022; Talmac et al., 2023)

The Relationship Between Pelvic Floor Hypertonicity and Sexual Pain

A significant portion of studies in the literature indicate that pelvic floor muscle hypertonicity is commonly observed in postpartum women with dyspareunia. Increased resting tone, decreased relaxation capacity, and myofascial sensitivity in the pelvic floor muscles are frequently reported findings in these studies.

It has been stated that pain during vaginal penetration is more severe and sexual function scores are lower in women with pelvic floor hypertonicity. Furthermore, some studies emphasize that respiratory-pelvic floor coordination is impaired in conjunction with hypertonicity and that this condition may increase pain perception (Talasz et al., 2022; Kokate et al., 2025).

Effects of Physical Therapy-Based Interventions

The studies reviewed show that interventions targeting pelvic floor physical therapy have positive clinical effects on postpartum dyspareunia and hypertonicity. Pelvic floor muscle relaxation (down-training) exercises, manual therapy, and myofascial release techniques have been reported to be associated with a reduction in pain intensity and improvement in sexual function scores. Scar mobilization and breathing-based relaxation approaches have been noted to reduce discomfort felt during penetration by increasing tissue mobility. Biofeedback-assisted applications have been reported to facilitate voluntary relaxation of the pelvic floor muscles by increasing muscle awareness (Morin et al., 2021; Navarro-Brazález et al., 2021).

Timing of Intervention and Clinical Response

Some studies have observed more pronounced improvement trends in women who began physical therapy interventions in the early postpartum period. It has been suggested that early intervention may prevent the establishment of the pain–contraction cycle and facilitate the recovery of sexual function. However, significant differences in intervention duration, intensity, and techniques used have been reported across studies (Torosis et al., 2024; Xu et al., 2025).

Methodological Limitations of Findings

Certain methodological limitations should be considered when interpreting the findings. The use of self-reported measurement tools in most studies may lead to results being influenced by subjective perceptions. Furthermore, differences in sample sizes and heterogeneity in physical therapy protocols are among the factors limiting the generalizability of the findings.

CONCLUSION AND DISCUSSION

This review synthesizes current literature focusing on postpartum sexual dysfunction, particularly dyspareunia and pelvic floor hypertonicity; the clinical outcomes of physiotherapy-based assessments and interventions are discussed within a holistic framework. The findings demonstrate that postpartum sexual dysfunction is not a one-dimensional problem; it reflects a complex clinical picture resulting from the interaction of biological, neuromuscular, and psychosocial factors.

The studies reviewed in this study reveal that the prevalence of postpartum dyspareunia varies widely (30–60%). These rates are consistent with previously reported epidemiological data, suggesting that postpartum sexual pain is not adequately recognized in clinical practice and is often overlooked (O'Malley et al., 2021; Ollivier et al., 2024). The fact that dyspareunia is particularly prominent in the first few months after childbirth indicates that the postpartum period presents a critical window for sexual health. However, the literature reports that there is

a common assumption that these complaints will "resolve spontaneously" over time, and therefore opportunities for early intervention may be missed (Banaei et al., 2021).

Given that dyspareunia is not merely a symptom limited to pain; it is accompanied by sexual avoidance behaviors, decreased sexual satisfaction, and relational problems, it is clear that sexual health should be systematically assessed in the postpartum period. This finding supports the idea that sexual function should be considered as one of the routine assessment areas in postpartum care protocols.

Pelvic Floor Hypertonicity and Pain Mechanisms

One of the most striking findings of this review is the common reporting of pelvic floor hypertonicity in women with postpartum dyspareunia. The studies examined show that increased resting tone, decreased relaxation capacity, and myofascial tenderness in the pelvic floor muscles are closely related to sexual pain. These findings are consistent with current literature emphasizing that pelvic floor muscles should be evaluated not only for weakness but also for patterns of overactivity (van Reijn-Baggen et al., 2022; Barba et al., 2024).

Pelvic floor hypertonicity can occur in relation to the protective contractile response to pain in the postpartum period, scar sensitivity during tissue healing, and psychological stressors. A study reported that pain experienced during vaginal penetration is exacerbated by involuntary muscle contractions, and this condition can become chronic over time (Maldonado et al., 2023). In this context, postpartum dyspareunia should be considered not only as a peripheral tissue problem but also as a condition related to neuromuscular adaptations and central pain modulation processes.

The Role of Delivery Mode, Tissue Damage, and Scar Mobility

Studies reviewed show that the effect of delivery mode on postpartum sexual function is complex and multifaceted. Perineal tears and episiotomy after vaginal delivery are associated with superficial dyspareunia, while abdominal scar tissue and fascial restrictions after cesarean delivery are associated with deep pelvic pain and movement dysfunctions (Kenne et al., 2022; Palmieri et al., 2022). These findings indicate that delivery mode alone is not the sole determinant; tissue healing, scar mobility, and neuromuscular adaptations should be considered together. It is reported that scar tissue is not merely a local problem but can affect pelvic floor function and movement patterns through fascial chains. Therefore, it is recommended that the mobility and tenderness of perineal and abdominal scar tissue be an integral part of the physiotherapeutic examination in the assessment of postpartum sexual dysfunction.

Psychosocial Factors and the Biopsychosocial Model

The literature reviewed in this study strongly supports the need to address postpartum sexual dysfunction within a biopsychosocial framework. Sleep disruption, fatigue, adaptation to the maternal role, changes in body image, and negative perceptions of the birth experience can negatively affect sexual desire and arousal (Nimbi et al., 2022; Lynn et al, 2023). It is also suggested that ongoing pain experiences may increase pain perception through central sensitization mechanisms.

In this context, it is thought that when postpartum dyspareunia and pelvic floor hypertonicity are considered solely as local musculoskeletal problems, the treatment response may be limited. The literature reports that physiotherapy approaches yield more effective results when integrated with patient education, explanations of pain neurophysiology, and psychosocial support.

Clinical Effects of Pelvic Floor Physiotherapy

The studies included in this review demonstrate that pelvic floor physiotherapy has positive clinical effects on postpartum dyspareunia and hypertonicity. In particular, pelvic floor muscle relaxation (down-training) exercises, manual therapy, myofascial release, and breath-based relaxation approaches are reported to reduce pain intensity and improve sexual function scores (Flegge et al., 2023; Ackerman et al., 2024).

Biofeedback-supported interventions are reported to facilitate voluntary relaxation of the pelvic floor muscles by increasing muscle awareness and contributing to patients' better understanding of their own bodies (Albaladejo-Belmonte et al., 2021). Furthermore, scar mobilization and fascial approaches are reported to increase tissue elasticity and reduce discomfort felt during penetration. These findings highlight that physiotherapy in the postpartum period should focus not only on increasing muscle strength but also on muscle relaxation and coordination.

Intervention Timing and Clinical Implications

The studies reviewed suggest that women who begin physiotherapy interventions in the early stages of the postpartum period achieve more positive clinical outcomes. It is proposed that early intervention may prevent the establishment of the pain-contraction cycle and facilitate the recovery of sexual function. However, the heterogeneity in the literature regarding the duration, intensity, and content of intervention protocols highlights the need for standardized clinical guidelines (Jorge et al., 2024).

Limitations of the Study and Recommendations for Future Research

When interpreting the findings of this review, it should be considered that most of the studies reviewed have observational designs and commonly use self-report measurement tools. This leads to limited causal inferences. Furthermore, the diversity in physiotherapy protocols limits the generalizability of the results.

It is recommended that future studies include randomized controlled designs that differentiate different subtypes of postpartum sexual dysfunction using standardized assessment tools and intervention protocols. It is also believed that long-term studies evaluating the effectiveness of multidisciplinary approaches will make significant contributions to the literature.

Conclusion

In conclusion, this review reveals that dyspareunia and pelvic floor hypertonicity are common, yet often overlooked, sexual dysfunctions in the postpartum period. The literature examined shows that postpartum sexual pain cannot be explained solely by local tissue damage or hormonal changes; it reflects a multifactorial clinical picture resulting from the interaction of neuromuscular adaptations of the pelvic floor muscles, scar tissue characteristics, and psychosocial factors.

The findings suggest that pelvic floor hypertonicity is commonly observed in women with postpartum dyspareunia and negatively impacts pain perception, sexual function, and sexual satisfaction. When considered in conjunction with excessive pelvic floor muscle activity, decreased relaxation capacity, and myofascial sensitivity, it becomes clear that addressing postpartum sexual dysfunction solely through the paradigm of "muscle weakness" is insufficient.

The literature supports the idea that pelvic floor physiotherapy offers an effective, safe, and non-invasive approach to the assessment and management of postpartum sexual dysfunction. In particular, interventions aimed at pelvic floor muscle relaxation, manual therapy, scar mobilization, and breath-based relaxation approaches have been reported to reduce pain

intensity and provide clinically significant improvements in sexual function parameters. However, heterogeneity in intervention protocols and methodological limitations highlight the need for standardized clinical guidelines.

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FAMILIAL MEDITERRANEAN FEVER (FMF)

Dr. Gulmammadova Leyla

Scientific Research University of Pediatrics named after KY Farajova, Baku, 2025

Dr. Alekberzade Arzu

Scientific Research University of Pediatrics named after KY Farajova, Baku, 2025

ORCID ID: 0009-0000-5102-7420

Dr. Alizade Gunash

Scientific Research University of Pediatrics named after KY Farajova, Baku, 2025

ORCID ID: 0009-0003-3497-0427

ABSTRACT

Familial Mediterranean Fever, also known as FMF, is an autosomal recessive hereditary disease that is seen especially in countries with a Mediterranean coast – in individuals of Jewish, Armenian, Turkish, Greek, Italian, Arab origin and also in Azerbaijan." This disease occurs as a result of more than 300 different mutations, usually occurring in exons 2, 3, 5 and 10 of the MEFV gene, which is located on the short arm of chromosome 16 (16p13.3) and encodes pyrin. The first attack of this disease, which is characterized by attacks of fever and serosal inflammation, occurs before the age of 20, especially in childhood. The average duration of attacks is between 6 hours and 4 days, and the patient is completely healthy between attacks. Fever is the most common symptom of the disease, sometimes the only symptom, especially in childhood, and can range from 380 to 400 degrees celsius. Abdominal pain may initially be localized and later become widespread. Physical examination may reveal abdominal distension, rebound tenderness, muscle rigidity, and decreased bowel sounds due to peritonitis. One of the most common findings is painful, red, and swollen joints, often seen in the form of mono arthritis, particularly in the large joints of the lower extremities. Chest pain is often severe on one side, makes it difficult to breathe deeply, and radiates to the shoulder. Symptoms include myalgia, which is more common in the upper or lower extremities. Unilateral scrotal edema, tender to palpation, is revealed on examination and is caused by transient inflammation of the tunica vaginalis. Laboratory findings show elevations in many systemic inflammation markers – CRP, β2 microglobin, SAA (serum amyloid protein), fibrinogen, erythrocyte sedimentation rate (ESR) and other acute phase reactants, and leukocytosis with neutrophil predominance. Diagnosis requires the presence of two major criteria, or one major and two minor criteria. Major criteria include peritonitis with fever, unilateral pleuritis or pericarditis, monoarthritis, recurrent fever alone and incomplete abdominal attacks; minor criteria include chest pain, joint pain, exercise-induced leg pain, a positive response to colchicine and nephropathic amyloidosis. A 6-year-old female patient was admitted to the hospital with edema in the extremities, abdominal pain and subsequent rash. The severity of the condition is associated with intoxication, anemic and hemorrhagic syndromes, cardiovascular and respiratory failure, and

sharp abdominal pain. During examinations, necrotic areas were detected in the small intestine, and therefore an ileal resection was performed and an ileostomy was created. Molecular genetic testing revealed p.Arg202Gln (c.605G>A) heterozygosity for the MEFV gene, and the patient was diagnosed with FMF.

Colchicine is used to reduce both the severity and frequency of attacks, to prevent hemorrhagic syndromes and to regress existing conditions.

Keywords: FMF, hemorrhagic vasculitis, intestinal necrosis, colchicine

INTRADUCTİON

Familial Mediterranean Fever (FMF) is an inherited autoinflammatory disease characterized by recurrent episodes of fever and serosal inflammation. Although FMF typically presents with abdominal pain, arthritis, and chest pain, rare with hemorrhagic syndroms and atypical manifestations may occur. One such uncommon complication is hemorrhagic syndrome, which can develop due to severe systemic inflammation, endothelial dysfunction, coagulation abnormalities, or secondary organ involvement such as amyloidosis. Persistent inflammatory activity in FMF may disrupt hemostatic balance, increasing the risk of bleeding. Recognition of hemorrhagic manifestations in patients with FMF is clinically important, as they may complicate the disease course and require prompt diagnostic evaluation and appropriate management. Early diagnosis and appropriate treatment are essential to prevent complications such as necrosis of intestine. This case describes our female patient who was admitted with one of the severe major forms of the disease, presenting with a very severe hemorrhagic disorder, intestinal necrosis, anemia and complaints of arthritis.

A 6-year-old female patient, born from the second pregnancy and second delivery, was admitted to the hospital due to edema and pain in the extremities, followed by the appearance of skin rashes. At the time of admission, her general condition was quite severe; she was conscious, had an high body temperature, subicteric pale skin and regional cyanosis. On lung auscultation wheezing breath sounds were noted, and tachypnea was recorded. The pulse was weak, with moderate fullness and tension, and a rate of 126 beats per minute. Heart sounds were diminished. Small skin rashes and purulent hematoma areas were observed on the extremities. On abdominal palpation the abdomen was tense and painful. The liver was palpable 1 cm below the costal margin, while the spleen was not palpable. Urination was spontaneous, with urine the color of meat broth, and the stool was dark black in color. Body weight was 17 kg.

Investigations: Complete Blood Count: WBC – 20.2 × 10^3/μL, RBC – 1.65 × 10^6/μL, HGB – 4.4 g/dL, LYM – 10 × 10^3/μL, PLT – 284 × 10^3/μL. **Biochemistry and inflammatory markers:** ALT – 90.7 IU/L, AST – 111 U/L, CRP – 241.3 IU/L, Procalcitonin – 64.4 ng/mL. **Coagulation profile:** Fibrinogen – 398 mg/dL, PTT – 32 s, D-dimer – 4987 ng/mL. **Electrolytes:** Sodium (Na) – 127.5 mmol/L, Calcium (Ca) – 1.97 mmol/L. Potassium (K^+): 3.2 mmol/L. The complete blood count revealed marked leukocytosis (WBC 20.2 × 10^3/μL), indicating a severe inflammatory or infectious process. Profound anemia was present (RBC 1.65 × 10^6/μL, hemoglobin 4.4 g/dL), consistent with acute or ongoing hemorrhage and contributing to the patient's critical condition. Platelet count was within the normal range, suggesting that thrombocytopenia was not the primary cause of bleeding.Inflammatory markers were markedly elevated, with very high CRP (241.3 IU/L) and procalcitonin levels (64.4 ng/mL), supporting severe systemic inflammation and possible sepsis-like presentation. Liver enzymes (ALT 90.7 IU/L, AST 111 U/L) were elevated, indicating hepatic involvement likely secondary to systemic inflammatory response or hypoperfusion. Coagulation studies showed

significantly elevated D-dimer levels (4987 ng/mL), suggesting activation of coagulation and fibrinolysis, consistent with hemorrhagic syndrome and possible consumptive coagulopathy, despite relatively preserved fibrinogen levels and normal PTT. The patient's condition further deteriorated with increasing pallor of the skin, rising body temperature, and absence of stool. The severity of the clinical picture was associated with intoxication, anemic and hemorrhagic syndromes, as well as cardiovascular and respiratory failure and neurological symptoms. Neurological consultation revealed toxic encephalopathy, while hematological consultation identified toxicoallergic vasculitis. Following surgical consultation, abdominal ultrasonography (US) and irrigoscopy were performed. On ultrasonography, the small intestine was dilated up to 40 mm in diameter, the bowel wall thickness was 3 mm, and peristaltic movements were absent. Signs of small bowel obstruction were present, and approximately 40 mL of free hemorrhagic fluid was detected in the extraluminal space. During irrigoscopy, contrast material was observed in the stomach, and evacuation did not occur within 3 hours. Based on these findings, diagnostic laparoscopy was performed, during which necrotic areas of the intestine were identified. Consequently, ileal resection was carried out and an ileostomy was created. Molecular genetic testing revealed a heterozygous p.Arg202Gln (c.605G>A) mutation in the *MEFV* gene, confirming the diagnosis of Familial Mediterranean Fever (FMF). Treatment strategies including colchicine, anti-inflammatory, antibacterial, hormonal or supportive therapies were recorded. Patients were followed up to monitor response to therapy and development of complications.

METHODOLOGY

Patients included were those presenting with recurrent fever and serosal inflammation and/or complications suggestive of FMF. Diagnosis was confirmed using clinical criteria (Tel Hashomer or Livneh criteria) and molecular genetic testing for *MEFV* gene mutations. **Molecular Genetic Testing Methodology:** Peripheral blood was collected, and genomic DNA was extracted from leukocytes. PCR amplification of the relevant *MEFV* gene region was performed, followed by Sanger sequencing. Sequence analysis revealed a heterozygous c.605G>A (p.Arg202Gln) mutation, confirming the diagnosis of Familial Mediterranean Fever. The obtained sequences were compared to the reference *MEFV* gene sequence to identify variations. A heterozygous c.605G>A substitution was detected, resulting in the amino acid change p.Arg202Gln.

CONCLUSION AND DISCUSSION

Familial Mediterranean Fever (FMF) is a hereditary autoinflammatory disorder primarily characterized by recurrent fever and serosal inflammation. While typical presentations include abdominal pain, arthritis, and fever, severe and atypical complications may occur. In rare cases, FMF can lead to **hemorrhagic vasculitis** and **intestinal necrosis** as observed in our patient.The pathophysiology of these severe complications is linked to persistent systemic inflammation, endothelial dysfunction and dysregulation of coagulation, which can result in vascular injury, hemorrhage and tissue necrosis. Necrotic intestine may present with abdominal pain, obstruction, and systemic signs of toxicity, requiring prompt surgical intervention such as resection and stoma creation. Early recognition of severe FMF manifestations is crucial. Laboratory findings—including leukocytosis, elevated inflammatory markers, anemia, coagulopathy and electrolyte disturbances—support the diagnosis and guide management. Molecular genetic testing for *MEFV* mutations confirms the diagnosis and helps identify patients at risk for severe complications. Management involves a combination of **surgical intervention** for necrotic tissue, **anti-inflammatory therapy** (e.g., colchicine), supportive

care, and treatment of secondary complications, including infection, anemia, and coagulopathy. Close monitoring is essential to prevent morbidity and mortality.

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ARTIFICIAL INTELLIGENCE-BASED PREDICTIVE MODEL FOR BIG DATA ANALYSIS IN HEALTH INFORMATICS: A SYSTEMATIC REVIEW

Rabia KOCA

Van Yuzuncu Yil University, Institute of Health Sciences, Child Health and Disease Nursing Master's Degree Student

ORCİD ID: https://orcid.org/0000-0002-3764-717X

Assoc. Prof. Dr. Mehmet BULDUK

Van Yuzuncu Yil University Health Sciences Institute

ORCİD ID: https://orcid.org/0000-0001-9341-3346

Assoc.Prof.Dr. Veysel CAN

Van Yuzuncu Yil University Health Sciences Institute

ORCİD ID: https://orcid.org/0000-0001-5982-183X

ABSTRACT

Introduction and Purpose: With the introduction of artificial intelligence into our lives, it has begun to be used in every aspect of life. Its application in the healthcare system also remains relevant. Sub-branches of artificial intelligence machine learning, deep learning, and natural language processing Technologies are among the current and widely used AI (artificial intelligence) models in the healthcare field. They are used in areas such as processing, interpreting, predicting, and analyzing healthcare data. This review includes studies using artificial intelligence models and studies related to the application areas of AI (artificial intelligence) in healthcare informatics.

Material and Method: It was prepared as a compilation with examples from clinical research and randomized controlled trials conducted in the last year using the keywords "big data healthcare, artificial intelligence, predictive modeling, health informatics, machine learning, deep learning, data mining healthcare, natural language processing" from the Pubmed database.

Result: In health informatics, machine learning, deep learning, and natural language processing are among the most frequently used sub-branches of artificial intelligence. Machine learning is computer programs that follow algorithms. It is most frequently used in health informatics in the course and in care of disease. Deep learning, also known as learning with artificial neural networks, is the use of machine learning with more complex and multiple parameters. It is frequently used in medical pathology and histology, as well as medical imaging. Natural language processing is an artificial intelligence model for text processing and analysis. It is used in areas such as patient information and medical notes, examination and imaging result interpretations.

Discussion and Conclusion: The use of artificial intelligence in health informatics is increasing day by day. Studies on data collection, analysis, comparison, and success in line with the active

use of artificial intelligence algorithms will increase the use and efficiency of artificial intelligence and its other sub-branches in health informatics. Studies are needed to ensure the active use and efficiency of artificial intelligence in health informatics.

Key Words: Big Data Healthcare; Artificial İntelligence; Predictive Modeling; Health İnformatics; Machine Learning; Deep Learning; Data Mining Healthcare ; Natural Language Processing

INTRODUCTION

While health records were previously recorded using traditional methods, with the advancement of information systems worldwide and the integration of electronic environments into all areas of life, health records have also begun to be recorded electronically. (Ahn, S. 2025). Health technology data such as population growth, increase in disease, increase in hospital admissions, pandemics, number of hospital visits, examination findings, and test results are increasing the volume of data in healthcare (Klang, E. 2023). The increase in data volume makes statistical tracking related to health more difficult (Herland, M. 2014).

The analysis of data entered the health information system, including patients' demographic information, symptoms and findings related to the disease, interpretation of tests, the course of the disease, treatment plans, and medical examination findings, is important for predicting possible developments related to the patient and the disease (Ngiam, K. 2019).

The use of artificial intelligence in healthcare today involves making predictions and forecasts about diseases and medical conditions through the statistical analysis of data collected in health informatics. These predictions and forecasts enable numerous analyses, such as the use of medical resources, predicting disease diagnosis, calculating hospital stay duration, assessing readmission probabilities, and personalized disease diagnosis (Jayatilake, SMDAC.2021). The analysis and interpretation of this data using artificial intelligence will lead to positive developments in increasing foresight and accurate prediction in all areas, particularly in disease tracking and care processes in the healthcare system, and in achieving the necessary savings (Subrahmanya, S.V.G. 2022).

RESEARCH AND FINDINGS

Materials and Methods

This review was prepared using examples from clinical research and randomized controlled trials conducted in the last year, using the keywords “big data healthcare, artificial intelligence, predictive modeling, health informatics, machine learning, deep learning, data mining healthcare, natural language processing” from the PubMed database.

Literature Review

Data called electronic health records, patient data in health information systems, medical history, hospital admission and clinical observation data, data recorded in healthcare institutions, appointment scheduling, test and imaging results, medication and cycle applications, blood sugar, blood pressure, and pulse measurement results obtained from wearable technology constitute big data sources (Piovani, D. 2022). Storing these data without processing them is redundant (Lauricella, LL. 2022). Recorded but unprocessed data is useless and inefficient (Guo, Y. 2023). Processing big data in this way can exceed human capacity. At this point, the use of artificial intelligence models in health informatics becomes important (Khan, Z. F. 2020).

Artificial intelligence-based predictive models in health informatics, such as machine learning, deep learning, and natural language processing models, are frequently used methods these days. This study will review the literature on studies that apply commonly used artificial intelligence predictive models in health informatics.

Machine Learning

Machine learning, a subfield of artificial intelligence, refers to computer programs that automatically monitor algorithms within artificial intelligence (Thatha, VN. 2025). Machine learning interacts with large amounts of information and is used to predict situations that may be encountered in practice. It provides guidance in surgical clinical operations, disease progression, and patient care (Wu, WT. 2021).

In a randomized study conducted by Haudry S. et al. in 2025 on experts and older adults, the effect of meditation on brain age was evaluated using a machine learning model in a randomized controlled trial (Haudry S. 2025).

This study examined the effects of long-term and short-term meditation practices on brain health and Alzheimer's disease. Brain age and health were assessed using a machine learning model trained on gray and white matter volume and glucose metabolism data from the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset (Haudry S. 2025).

As a result, when comparing expert meditators with over 20 years of practice and a group that underwent 18 months of training using the machine learning model, long-term meditation was associated with a younger brain age. No effect was observed from the 18-month training (Haudry S. 2025).

Deep Learning

Deep learning is a comparison of machine learning with more complex and more parameters. It is also called learning with artificial neural networks (Ravi, D. 2017). With its complex data structure and robustness in information processing, it has a wide range of applications in health informatics (Somani, S. 2021). It is used in medical pathology and histology, medical imaging, and disease monitoring (Ravi, D. 2017).

A clinical study published in 2025 on the effect of clinical history on the predictive performance of machine learning and deep learning models for diabetic kidney complications investigated the prediction of diabetic nephropathy development in individuals with type 2 diabetes using deep learning models (Davide, DC. 2025). The prediction of nephropathy development was found to be significant in all deep learning models. When patients past clinical information was combined with deep learning methods, the prediction of nephropathy using deep learning methods showed a significant increase (Davide, DC.2025).

Natural Language Processing

It is among the predictive models of artificial intelligence. It is a model focused on text processing and analysis. Its areas of application in health informatics include patient and disease notes, examination comments, disease progression, and the classification and staging of complex diseases (Atlas, SJ. 2025).

A hybrid chatbot to promote pneumococcal vaccination among older adults published in 2025: A randomized controlled trial included individuals aged 65 and older living in Hong Kong (Zixin W. 2025). It was conducted to examine the effect of the hybrid chatbot on vaccination rates compared to standard practices in individuals who had not previously received the pneumococcal vaccine. The study found that the hybrid chatbot was effective in increasing vaccination rates among older adults compared to standard methods (Zixin W. 2025).

CONCLUSION

Research on the use of artificial intelligence in health informatics is gaining momentum today. Developments in disease analysis and classification, disease staging, interventional diagnostic applications, disease monitoring, and the recovery process are continuing rapidly (Awrahman, BJ. 2022). In the studies reviewed, the integration of artificial intelligence into health informatics increases efficiency in patient applications and reduces workload.

As seen in the studies reviewed, AI applications are limited to the model taught to the AI. The creation of models varies depending on the patient's disease status, the field of AI application, and patient care. This situation moves AI away from generalization and directs it towards customization (Ahn, S. 2025).

For the effective use of artificial intelligence models in health informatics and big data analysis, it is important to collect data that can be processed by artificial intelligence. In this way, artificial intelligence can be used more effectively in health informatics and analysis. More research and contributions to literature are needed for effective and reliable results of artificial intelligence applications.

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THE POTENTIAL OF NATURAL LANGUAGE PROCESSING TECHNOLOGIES IN CLINICAL DOCUMENT ANALYSIS AND DECISION SUPPORT SYSTEMS: A COMPILATION STUDY

Rabia KOCA

Van Yuzuncu Yil University, Institute of Health Sciences, Child Health and Disease Nursing Master's Degree Student

ORCİD ID: https://orcid.org/0000-0002-3764-717X

Assoc. Prof. Dr. Mehmet BULDUK

Van Yuzuncu Yil University Health Sciences Institute

ORCİD ID: https://orcid.org/0000-0001-9341-3346

Assoc. Prof. Dr. Veysel CAN

Van Yuzuncu Yil University Health Sciences Institute

ORCİD ID: https://orcid.org/0000-0001-5982-183X

ABSTRACT

Introduction and Purpose: The use of artificial intelligence in health informatics has been increasing in recent years. Studies are continuing to process written data such as imaging and examination reports, disease data, and hospitalization data using natural language processing, a sub-branch of artificial intelligence. The collection of AI (artificial intelligence)-compatible data, the processing of collected data rather than storing it, and the development of predictive models for many processes such as disease progression, hospitalizations, and the post-hospital period are ongoing. This review examines and shares studies on the impact of natural language processing on clinical decisions.

Materials and Methods: It was prepared as a compilation by giving examples of clinical research and randomized controlled trials conducted in the last year using the keywords "Natural Language Processing, Clinical Document Analysis, Clinical Decision Support System, Health Informatics, Artificial Intelligence, Electronic Health Records" in the Pubmed database.

Result: Natural language processing is a sub-branch of artificial intelligence. It is used in many disease- and patient-focused areas in health informatics, such as the analysis of written data, disease monitoring, and examination and imaging result tracking. Studies on clinical decision-making and patient follow-up are ongoing.

Discussion and Conclusion: In current studies, studies using artificial intelligence as a clinical decision support system in health informatics have gained momentum. Studies have shown positive contributions of artificial intelligence to clinical decision support systems. Further studies are still needed to increase the effective use and positive effects of artificial intelligence in the future.

Key Words: Natural Language Processing; Clinical Document Analysis; Clinical Decision Support System; Health Informatics; Artificial Intelligence; Electronic Health Records

INTRODUCTION

In human communication, speech and sounds have always occupied more space than other communication methods. Verbal communication is more widespread than written communication (Subrahmanya, SVG.2022). Although developing artificial intelligence written applications are at the forefront, there are also studies on spoken applications today (Richard, E.2021). Large artificial intelligence applications such as OpenAI and ChatGPT are also used in large language models and voice communication (Eriç, L.2022).

Artificial intelligence applications commonly used in daily life are language models based on unstructured data from open sources (Kersloot, MG.2020). The applicability of language models in health informatics is currently limited (Seo, J.2025). Natural language processing technologies are one of the subheadings of artificial intelligence, and studies are being conducted on their use for electronic health records, personalized diagnosis, and follow-ups (Wang, Z. 2025). This review study compiles studies on the impact of natural language processing technology on health informatics analysis and decision support systems.

RESEARCH AND FINDINGS

Materials and Methods

This review was prepared using examples from clinical research and randomized controlled trials conducted in the last year, using the keywords “Natural Language Processing, Clinical Document Analysis, Clinical Decision Support System, Health Informatics, Artificial Intelligence, Electronic Health Records” in the PubMed database.

Natural Language Processing Conceptual Framework

Natural language processing is one of the subfields of artificial intelligence. It is a model focused on interpreting human speech, analyzing and processing texts (Scharp, D. 2024). It works in areas such as converting audio documents to text, finding errors in written documents, simple voice command recognition with machine learning, and speech recognition and analysis (Arivazhagan, N. 2023).

In health informatics, research is being conducted on the processing of data such as electronic records kept throughout the entire hospital process, starting from patient reception, imaging and examination reports, examination findings, and disease diagnoses using natural language processing methods (Kohlhepp, L. 2025). However, its use in health informatics is limited due to reasons such as the need for fine-tuning, the use of abbreviations in recorded data, and the lack of standardization in records due to language and format differences (Seo, J. 2025).

The Use of Natural Language Processing Methods in Clinical Document Analysis and Decision Support Systems

Natural language processing is a subfield of artificial intelligence. It works in parallel with machine learning. Thanks to the commands taught to artificial intelligence applications, it processes text and speech (Richard, E. 2021). For natural language processing to be used in clinical document analysis, texts must be standardized in an analyzable language and format (Bowles, A. 2025). Currently, there is no standardization of stored clinical documents that can be processed using natural language processing (Lauricella, LL.2022). Therefore, its use in retrospective studies is limited (Au Yeung, J.2024).

In current studies, natural language processing is most frequently used for patient intake symptoms and clinical examination data, patient education, and compliance (Brown, DL.2025). There are also current studies on long-term hospitalizations, intensive care, and applications for chronic diseases in home care. Natural language processing is advancing in the direction of increasing developments in clinical document analysis through text mining (Mitha, S. 2023). Clinical decision support systems require natural language processing models that adapt to the workflow (Voytovich, L. 2022).

Current Research

PubMed features recent studies on the use of natural language processing methods in clinical decision-making over the past year. Below is a study filtered from the past year on the role of natural language processing in clinical document analysis and clinical decision-making.

Published in September 2025, Atlas Steven J. 2025 et al. The study titled Comparison of Clinical Decision Support Systems to Improve Follow-up of Abnormal Cervical Cancer Screening Test Results compared patient-accessible and non-patient-accessible clinical decision support systems (Atlas, SJ.2025). One of the decision support systems processed data obtained from electronic health records using natural language processes. The other processed electronic health records are defined by Logical Observation Identifiers and Codes (LOINC) using a patient-accessible natural language processing method (Bowles, A. 2025). This system used patient access systems such as telephone mail/e-mail (Atlas, SJ. 2025). As a result of the study, the results of clinical decision support systems alone are similar. The follow-up rate was found to be significantly higher in the clinical decision support system that included patient access compared to the other clinical decision support system (Atlas, SJ.2025).

CONCLUSION

Recent clinical studies using artificial intelligence have demonstrated the effectiveness of artificial intelligence in clinical practice (Ordu, S. 2022). There are many studies with positive results in clinical applications and decision support systems, such as disease diagnosis, evaluation of disease symptoms and findings, analysis of previous records, and analysis of test and imaging results, using natural language processing, one of the subheadings of artificial intelligence (Landschaft, A. 2025). When evaluating the results of these studies, it is necessary to collect data for artificial intelligence analysis in order for natural language processing processes to be effective in clinical documentation and clinical decision systems (Miao, F. 2023).

In studies conducted using past data, historical data has been reanalyzed according to the natural language processing process (Kohlhepp, L. 2025). As a result of these studies, the effectiveness of natural language processing is high in many clinical applications such as information processing, its impact on decision support systems, and graphical and information analysis (Seo, J. 2025). Today, research on artificial intelligence and natural language processing has gained momentum. According to recent studies, artificial intelligence-supported clinical data collection tools are needed to make processes such as clinical decision support systems and document analysis more effective in practice (Ahn, S. 2025). Terminological standardization in the recording of medical data is necessary for the effective use of natural language processing in clinical document analysis and clinical decision support systems (Bowles, A. 2025). This will enable the necessary work for the development of artificial intelligence subfields and natural language processing processes to be conducted more effectively and reliably.

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EFFECTS OF RAMADAN FASTING ON GESTATIONAL DIABETES

RAMAZAN ORUCUNUN GESTASYONEL DIYABET ÜZERINDEKI ETKILERI

Doç. Dr. Sümeyye BARUT

Fırat Üniversitesi, Ebelik, Sağlık Bilimleri Fakültesi

Arş. Gör. Dr. Nuray KURT

Fırat Üniversitesi, Ebelik, Sağlık Bilimleri Fakültesi

ÖZET

Ramazan ayında tutulan orucun, gebelikte fizyolojik olarak artmış insülin direnci ile birleştiğinde gestasyonel diyabet (GDM) gelişimi ve mevcut GDM'nin seyri üzerine etkileri tartışmalıdır. Bu derlemede, Ramazan orucunun gebelikte glisemik kontrol ve gestasyonel diyabet açısından oluşturduğu risk ve sonuçların değerlendirilmesi amaçlanmıştır. Bu çalışma, Ramazan orucunun gebelerde glisemik profil üzerine etkilerini inceleyen klinik araştırmalar temel alınarak hazırlanmış bir derlemedir. Özellikle Baynouna ve ark. tarafından sağlıklı gebelerde yürütülen toplum temelli çalışma ile Hassanein ve ark. tarafından GDM'li gebelerde sürekli glukoz izleme yöntemi ile yapılan prospektif çalışma ayrıntılı biçimde incelenmiş ve karşılaştırmalı olarak değerlendirilmiştir. Normal OGTT sonuçlarına sahip, komplikasyonsuz gebelerde Ramazan orucu sırasında açlık glukozunda belirgin bir değişiklik saptanmamış; ancak iftardan 1 saat sonra ölçülen postprandiyal glukoz düzeylerinin, Ramazan dışı dönemdeki gebelere kıyasla anlamlı derecede yüksek olduğu ve olguların büyük kısmında gebelik için önerilen hedef değerlerin aşıldığı bildirilmiştir. Gestasyonel diyabetli gebelerde yapılan çalışmada ise, yapılandırılmış eğitim ve sıkı takip altında Ramazan döneminde ortalama glukoz ve HbA1c değerlerinde iyileşme görülmesine rağmen hipoglisemi epizodu sayısı ve süresinde anlamlı artış olduğu, buna ek olarak iftar sonrası belirgin hiperglisemik dalgalanmalar ortaya çıktığı gösterilmiştir. Mevcut veriler, Ramazan orucunun gestasyonel diyabetli gebeler için hem hipoglisemi hem de hiperglisemi açısından yüksek risk taşıdığını ve bu nedenle kılavuzlarda yer alan "oruç tutulmaması" yönündeki önerileri desteklediğini göstermektedir. Normoglisemik gebelerde dahi postprandiyal glukoz pikleri nedeniyle fetüs ve anne açısından potansiyel risk söz konusudur. Bu nedenle gebelikte oruç kararı bireyselleştirilmeli, gestasyonel diyabetli kadınlara mümkünse oruçtan kaçınmaları önerilmeli; buna rağmen oruç tutmakta ısrarcı olan gebelerde ise kapsamlı eğitim, yoğun glukoz izlemi ve yakın klinik takip sağlanmalıdır.

Anahtar Kelimeler: Gestasyonel diyabet, Ramazan orucu, Gebelik

ABSTRACT

The effects of Ramadan fasting, when combined with physiologically increased insulin resistance during pregnancy, on the development of gestational diabetes mellitus (GDM) and the course of existing GDM are controversial. This review aims to evaluate the risks and consequences of Ramadan fasting in terms of glycemic control and gestational diabetes during pregnancy. This study is based on clinical research examining the effects of Ramadan fasting

on the glycemic profile of pregnant women. In particular, a population-based study conducted by Baynouna et al. in healthy pregnant women and a prospective study conducted by Hassanein et al. using continuous glucose monitoring in pregnant women with GDM were thoroughly examined and compared. No significant changes in fasting glucose were observed during Ramadan fasting in uncomplicated pregnant women with normal OGTT results; however, postprandial glucose levels measured 1 hour after iftar were significantly higher compared to those observed during non-Ramadan fasting, and the majority of cases exceeded the recommended target values for pregnancy. A study conducted on pregnant women with gestational diabetes demonstrated that despite improvements in mean glucose and HbA1c values during Ramadan under structured education and close monitoring, there was a significant increase in the number and duration of hypoglycemia episodes. Furthermore, significant hyperglycemic fluctuations occurred after iftar. Current data indicate that Ramadan fasting carries a high risk of both hypoglycemia and hyperglycemia for pregnant women with gestational diabetes, thus supporting the recommendations in the guidelines to avoid fasting. Even in normoglycemic pregnant women, postprandial glucose peaks pose a potential risk to both the fetus and the mother. Therefore, the decision to fast during pregnancy should be individualized, and women with gestational diabetes should be advised to avoid fasting if possible. Pregnant women who nevertheless insist on fasting should receive comprehensive education, intensive glucose monitoring, and close clinical follow-up.

Key Words: Gestational diabetes, Ramadan fasting, Pregnancy

GİRİŞ

Ramazan orucu, sağlıklı Müslüman yetişkinler için dini açıdan önemli bir ibadettir. Ancak İslami kaynaklarda, hastalık, gebelik, emzirme gibi durumlarda oruç tutmanın zorunlu olmadığı ve bireyin sağlığına zarar verme ihtimali söz konusu olduğunda muafiyet tanındığı belirtilmektedir. Buna rağmen, farklı toplumlarda yapılan çalışmalarda gebelerin önemli bir kısmının, sağlık profesyonelleri oruçtan kaçınmalarını önermesine rağmen, dini ve kültürel nedenlerle Ramazan ayında oruç tuttuğu bildirilmiştir (Özçelik ve Çelik, 2019; Onur, 2021).

Gebelik, insülin direncinin fizyolojik olarak arttığı ve karbonhidrat metabolizmasının yeniden şekillendiği özel bir dönemdir. Plasental hormonların etkisiyle özellikle ikinci ve üçüncü trimesterde belirginleşen insülin direnci, annenin artan enerji gereksinimi ve fetüse sürekli glukoz sağlaması ile birleştiğinde, "hızlanmış açlık (accelerated starvation)" olarak tanımlanan tablo ortaya çıkar. Bu tabloda açlık süresi kısaldıkça keton cisimlerinde ve serbest yağ asitlerinde artış, açlık glukozunda ise görece düşme izlenir (Baynouna Al Ketbi, 2014; Afandi, 2017; Afandi, 2019).

Gestasyonel diyabet, gebelik sırasında ilk kez tanı alan glukoz intoleransı olup hem anne hem fetüs açısından kısa ve uzun dönemli önemli sonuçlara yol açar. GDM'de hedef, özellikle postprandiyal hipergliseminin engellenmesi, aynı zamanda hipogliseminin önlenmesidir. Buna karşın Ramazan'da gün içinde uzun süren açlık ve gece kısa zaman diliminde yüksek kalorili öğünlerin tüketilmesi; hipoglisemi, iftar sonrası ani hiperglisemi ve genel glisemik dalgalanmalarla sonuçlanabilir (Hassanein, 2021; Afandi, 2017; Afandi, 2019).

Bu derlemede, Ramazan orucunun gebelikte glisemik kontrol ve gestasyonel diyabet açısından etkileri, özellikle iki klinik çalışma çerçevesinde değerlendirilmektedir: normoglisemik gebelerde Ramazan orucunun glukoz düzeylerine etkisini inceleyen toplum temelli çalışma ve GDM'li gebelerde Ramazan öncesi ve Ramazan sırasında sürekli glukoz izlemiyle elde edilen bulgular.

ARAŞTIRMA VE BULGULAR

Gebelikte Metabolik Değişiklikler ve Oruç

Gebelikte bazal enerji ihtiyacı artmakta, özellikle ikinci ve üçüncü trimesterde glukoz fetüs için temel enerji kaynağı olarak önem kazanmaktadır. Maternal organizma, fetüse yeterli glukoz sağlamak amacıyla kendi glukozunu daha verimli kullanmaya çalışır; bu süreçte insülin direnci artar, lipoliz hızlanır ve uzun süreli açlıklarda keton cisimleri yükselir. Ramazan orucu süresince gün boyunca gıda ve sıvı alımının kısıtlanması, akşam saatlerinde nispeten kısa bir süre içinde toplam günlük kalori alımının gerçekleşmesi ile sonuçlanır (Onur, 2021).

Sağlıklı gebelerde yapılan çalışmalarda, Ramazan ayında oruç tutmanın genellikle ciddi hiperglisemiye yol açmadığı, ancak gün sonuna doğru hafif hipoglisemi ve ketozis bulgularının görülebildiği bildirilmektedir. Bazı araştırmalarda idrarda keton pozitifliğinin oruç tutan gebelerde belirgin oranda arttığı, bunun da özellikle yetersiz kalori ve karbonhidrat alımı ile ilişkili olduğu gösterilmiştir (AlMogbe, 2022). Uzamış ketozisin fetal beyin gelişimi ve nörolojik fonksiyon üzerine olası olumsuz etkileri tartışılmakta, bu nedenle özellikle riskli gebeliklerde keton izleminin önemli olabileceği belirtilmektedir.

Ramazan Orucu ve Gestasyonel Diyabet İnsidansı

Ramazan orucunun GDM gelişimini doğrudan artırdığına veya azalttığına dair net ve güçlü bir kanıt bulunmamaktadır. Çeşitli kohort ve retrospektif çalışmalar, Ramazan ayında gebeliğinin ikinci veya üçüncü trimesterinde bulunan ve oruç tutan kadınlarda, GDM insidansının oruç tutmayan benzer gebelerle karşılaştırıldığında belirgin şekilde farklı olmadığını göstermiştir. Bununla birlikte, obezite, ileri maternal yaş, ailede diyabet öyküsü gibi risk faktörlerine sahip kadınlarda, oruç sırasında glisemik dalgalanmaların daha belirgin olduğu ve GDM tarama testlerinde sınırda değerlerin görülebileceği bildirilmiştir (Safari, 2019).

GDM taraması genellikle 24–28. gebelik haftaları arasında yapılmaktadır. Bu dönemin Ramazan ayına denk geldiği durumlarda, tarama ve tanı testlerinin oruç düzenine göre planlanması önemlidir. Uzun süreli açlık sonrası yapılan glukoz yükleme testlerinde, sonuçların gerçeği tam yansıtmayabileceği ve testin öncesinde yeterli karbonhidrat alımı gerektiği bilinmektedir. Bu nedenle, tarama planlanırken gebeye testten en az 8–10 saat önce oruç süresinin aşılmaması, gerekirse oruç tutmama izninin kullanılması önerilmektedir (Dikensoy, 2008).

Gestasyonel Diyabetli Gebelerde Oruç ve Glisemik Kontrol

GDM tanısı almış gebelerde temel amaç, kan glukoz düzeylerini hedef aralıkta tutarak maternal ve fetal komplikasyonları en aza indirmektir. Diyet düzenlemesi, fiziksel aktivite ve gerektiğinde medikal tedavi (insülin veya oral antidiyabetikler) GDM yönetiminin ana bileşenleridir. Bu süreçte düzenli öğün alımı ve uzun süreli açlıklardan kaçınılması, ani glisemik dalgalanmaları önlemek için kritik öneme sahiptir (Shahawy, 2023).

Ramazan orucu ise, doğası gereği uzun süren bir gündüz açlığı ve iftar-sahur arasında kısıtlı sayıda büyük öğünü içerdiğinden, GDM yönetim prensipleri ile çelişebilmektedir. Literatürde, GDM'li gebeler arasında oruç tutan kadınlarda hipoglisemi ataklarında artış, iftar sonrası postprandiyal hiperglisemi yükselişi ve gece boyu glisemik düzensizlikler bildirilmiştir. Özellikle insülin kullanan gebelerde, doz ayarlamasının yapılmaması ciddi hipoglisemi ve ketoasidoz riskini artırabilir (Alsulami, 2023; Baynouna, 2014).

Bazı çalışmalarda, oruç tutan GDM'li gebelerin bir kısmının kendi insülin dozlarını hekime danışmadan azalttıkları veya tamamen bıraktıkları saptanmıştır. Bu durum, glisemik kontrolün

bozulmasına, fetusta makrozomi veya fetal distres gibi olumsuz sonuçların riskini artırabilir (Abdullah, 2023). Bu nedenle, GDM tanısı almış gebelerde Ramazan orucu, tıbbi açıdan yüksek riskli bir durum olarak değerlendirilmekte ve çoğu klinik kılavuz tarafından genel olarak önerilmemektedir (Abdullah, 2023; Afandi, 2019).

Maternal ve Fetal Sonuçlar

Ramazan orucunun gebelik sonuçları üzerine etkilerini inceleyen çalışmalar, yöntem ve örneklem farklılıkları sebebiyle heterojen sonuçlar göstermektedir. Sağlıklı gebelerde, oruç tutan ve tutmayan kadınların bebekleri arasında doğum ağırlığı, gestasyon süresi ve Apgar skorları açısından çoğu çalışmada anlamlı fark bulunmamıştır. Ancak bazı araştırmalarda, özellikle yetersiz kalori alan ve kilo takibi iyi yapılmayan gebelerde düşük doğum ağırlığı, intrauterin büyüme kısıtlılığı ve oligohidramniyos oranlarının artabileceği bildirilmiştir (Dikensoy, 2008).

GDM'li gebelerde ise, glisemik kontrol bozulduğunda makrozomi, omuz takılması, sezaryen oranlarında artış, neonatal hipoglisemi ve hipokalsemi gibi komplikasyonların görülme riski daha yüksektir (Alsulami, 2023). Oruç tutan GDM'li gebelerin yer aldığı bazı küçük örneklemli çalışmalarda, iyi izlem ve sık kan şekeri takibi yapılan, insülin dozları bireyselleştirilen gebelerde ciddi komplikasyonların belirgin şekilde artmadığına dair veriler olmakla birlikte, bu bulguların genellenebilirliği sınırlıdır (Afandi, 2019). Ayrıca, keton cisimlerindeki artışın fetal nörogelişim üzerine olası uzun dönem etkilerinin tam olarak aydınlatılmamış olması, gebelikte uzun süreli açlığın riskleri konusunda çekincelerin devam etmesine neden olmaktadır.

Gebelerin Tutum ve Davranışları

Birçok toplumda yapılan anket çalışmaları, gebe kadınların bir bölümünün hekimlerin oruç tutmama önerisine rağmen oruca devam ettiğini göstermektedir. Dini motivasyon, aile ve çevre baskısı, orucu bırakmanın suçluluk duygusu oluşturması gibi psikososyal faktörler bu kararda etkili olmaktadır. Bazı gebeler ise kendilerini iyi hissettikleri sürece oruç tutmanın güvenli olduğuna inanmaktadır. Bu nedenle sağlık çalışanlarının, orucun olası risklerini açık ve anlaşılır bir dille anlatmaları, aynı zamanda dini hassasiyetlere saygılı bir iletişim dili kullanmaları önem taşımaktadır (Awwad, 2012).

SONUÇ

Ramazan orucunun gestasyonel diyabet üzerindeki etkileri, çok boyutlu ve bireysel farklılıklara açık bir konudur. Sağlıklı gebelerde, özellikle birinci trimesterde ve iyi beslenen kadınlarda oruç tutmanın çoğu zaman ciddi metabolik bozulmaya yol açmadığına dair veriler bulunmakla birlikte, uzun süreli açlık, ketonemi, yetersiz sıvı alımı ve yorgunluk gibi durumların anne ve fetüs açısından potansiyel riskler oluşturabileceği unutulmamalıdır. Bu nedenle her gebelik için oruç kararı, "tek bir doğru yaklaşım" yerine, bireyselleştirilmiş klinik değerlendirme ile verilmelidir.

Gestasyonel diyabet tanısı almış gebelerde ise tablo daha hassastır. GDM yönetiminde düzenli öğün alımı, uzun açlık sürelerinden kaçınma ve kan şekeri takibinin sürekliliği esastır. Ramazan orucu, aşırı uzun açlık ve kısa zamanda yüksek kalorili yüklenme içeren bir beslenme düzeni sunduğundan, GDM'li gebelerde hipoglisemi, hiperglisemi, ketozis ve buna bağlı maternal-fetal komplikasyon risklerini artırabilmektedir. Bu nedenle mevcut kanıtlar, özellikle insülin veya oral antidiyabetik tedavi alan GDM'li gebelerde oruç tutulmamasını, eğer kadın yine de oruçta ısrarcı ise çok sık aralıklı glisemik takip ve yakın obstetrik kontrol altında değerlendirilmesini önermektedir.

Pratikte, Ramazan öncesinde gebelerin kadın doğum uzmanı, perinatoloji uzmanı ve gerektiğinde endokrinoloji uzmanı tarafından değerlendirilmesi; vücut kitle indeksi, GDM varlığı, ek hastalıklar, fetal büyüme durumu, annenin günlük fiziksel aktivitesi ve beslenme alışkanlıklarının ayrıntılı sorgulanması gerekmektedir. Oruç tutmak isteyen gebelere, sahur ve iftar öğünlerinde dengeli karbonhidrat, protein ve yağ dağılımının sağlanması; basit şekerlerden kaçınılması; yeterli sıvı alımı; ağır fiziksel aktivitelerden kaçınma ve uyarıcı semptomların (baş dönmesi, çarpıntı, ciddi halsizlik, karın ağrısı, fetal hareketlerde azalma vb.) varlığında orucun derhal sonlandırılması gerektiği anlatılmalıdır.

Sonuç olarak, Ramazan orucunun gestasyonel diyabet üzerindeki etkilerine dair literatür, kesin ve tüm gebelere genellenebilir bir yargı sunmaktan uzaktır. Ancak elimizdeki veriler, yüksek riskli gruplar ve özellikle GDM'li gebeler açısından temkinli olunması gerektiğini göstermektedir. Gebelikte oruç kararı, yalnızca dini bir tercih değil, aynı zamanda tıbbi ve etik bir sorumluluk alanıdır. Sağlık profesyonellerinin, güncel bilimsel veriler ışığında, anne ve fetüsün güvenliğini ön planda tutarak ve hastanın değerlerine saygı göstererek danışmanlık sağlamaları büyük önem taşımaktadır.

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ROLE OF THE TLR4/NF-KB PATHWAY IN MALE INFERTILITY

TLR4/NFKB YOLAĞININ ERKEK İNFERTİLİTESİNDEKİ ROLÜ

Dr. Öğretim Üyesi Emel KABARTAN ÇÖKELİ
Ordu Üniversitesi, Ulubey MYO
ORCID: 0000-0002-6289-2310

ABSTRACT

Toll-like receptor 4 (TLR4) and the nuclear factor kappa B (NF-κB) signaling pathway are among the major regulators of inflammation in the male reproductive system and are expressed in both human and mouse spermatozoa. Activation by bacterial endotoxins reduces sperm motility and increases apoptosis and DNA damage. In obesity and high-fat diet models, TLR4 deficiency suppresses testicular inflammation and partially preserves sperm quality and fertility. Meanwhile, sperm-derived hyaluronan fragments stimulate cytokine production in cumulus cells via TLR2/TLR4, indicating that low-level physiological activation of this pathway is required for capacitation, the acrosome reaction, and successful fertilization. Environmental toxicants and metabolic stress excessively activate the TLR4/NF-κB pathway, leading to chronic testicular inflammation and infertility. In our rotenone-induced model, oxidative stress was accompanied by a marked increase in TLR4 and NF-κB expression, while concomitant α-pinene treatment particularly suppressed NF-κB expression and largely reversed the pathological response. In conclusion, the TLR4/NF-κB pathway plays a critical role in both physiological and pathological processes of male fertility; its low-level activation is necessary, whereas chronic and excessive activation leads to infertility. Natural compounds may represent promising therapeutic agents for the modulation of this pathway.

Key Words: TLR4, NF-κB, Male Infertility, Sperm, Testicular Inflammation, Oxidative Stress

ÖZET

Toll-like reseptör 4 (TLR4) ve nükleer faktör kappa B (NF-κB) sinyal yolağı, erkek üreme sisteminde inflamasyonun başlıca düzenleyicileri arasında yer almakta olup insan ve fare spermlerinde eksprese edilmektedir. Bakteriyel endotoksinlerle aktivasyon, sperm motilitesini azaltmakta; apoptozu ve DNA hasarını artırmaktadır. Obezite ve yüksek yağlı diyet modellerinde TLR4 eksikliği, testiküler inflamasyonu baskılayarak sperm kalitesini ve fertiliteyi kısmen korumaktadır. Buna karşılık, sperm kaynaklı hyaluronan fragmanlarının TLR2/TLR4 aracılığıyla kümülüs hücrelerinde sitokin üretimini uyarması, bu yolağın düşük düzeydeki fizyolojik aktivasyonunun kapasitasyon, akrozom reaksiyonu ve başarılı fertilizasyon için gerekli olduğunu göstermektedir. Çevresel toksikanlar ve metabolik stres, TLR4/NF-κB yolağını aşırı aktive ederek kronik testiküler inflamasyona ve infertiliteye yol açmaktadır. Ön çalışmalardan elde ettiğimiz ilk veriler, Rotenon indüklü oksidatif hasarda da bu yolağın uyarıldığını, alfa-pinen uygulamasının ise düzenleyici etki gösterebileceğini işaret etmektedir. Sonuç olarak, TLR4/NF-κB yolağı erkek fertilitesinde hem fizyolojik hem de

patolojik süreçlerde kritik bir rol oynamaktadır; düşük düzey aktivasyonu gerekli iken, kronik ve aşırı aktivasyonu infertiliteye neden olmaktadır. Doğal bileşikler, bu yolağın modülasyonu için umut verici terapötik ajanlar olabilir.

Anahtar Kelimeler: TLR4, NF-κB, Erkek İnfertilitesi, Sperm, Testiküler İnflamasyon, Oxidatif Stres.

GİRİŞ

Toll-like reseptörler (TLR'ler), doğuştan bağışıklık sisteminin temel reseptörleri olup, patojen ilişkili moleküler paternleri (PAMP'ler; örneğin bakteriyel lipopolisakkaritler, LPS) ve hasar ilişkili moleküler paternleri (DAMP'ler; örneğin yüksek hareketlilik grubu kutu-1, HMGB1) tanıyarak inflamatuar yanıtların başlatılmasında kritik rol oynar (A. Murao vd., 2021). Bu reseptörler aracılığıyla başlatılan sinyalizasyon, enfeksiyonlara karşı erken savunma mekanizmalarını aktive ederken aynı zamanda doğuştan ve kazanılmış bağışıklık yanıtları arasında işlevsel bir köprü oluşturur (Kawai & Akira, 2010; Vidya vd., 2018).

Memelilerde TLR ailesi 10–13 paralogdan oluşmakta olup, hücresel lokalizasyonlarına göre hücre yüzeyinde (TLR1, TLR2, TLR4, TLR5, TLR6, TLR10) veya endozomal kompartmanlarda (TLR3, TLR7, TLR8, TLR9) yer almaktadır (O'Neill vd., 2013; Yang vd., 2024). TLR'ler; lipitler, proteinler ve nükleik asitler gibi yapısal olarak farklı ligandları tanıyabilmekte ve bu tanıma süreci sonucunda *Nuclear factor kappa-light-chain-enhancer of activated B cells* (NF-κB) ve *mitogen-activated protein kinase* (MAPK) yolaklarını aktive ederek *Interleukin* 6 (IL-6), Tumor necrosis factor *alpha* (TNF-α) ve *Interleukin* -1 *beta* (IL-1β) gibi pro-enflamatuar sitokinlerin ekspresyonunu tetiklemektedir (Vidya vd., 2018).

TLR ailesi içerisinde Toll-like reseptör 4 (TLR4), hem mikrobiyal kökenli ligandları hem de endojen hasar sinyallerini tanıyabilmesi nedeniyle özgün bir konuma sahiptir. TLR4, gram-negatif bakterilere ait LPS'nin yanı sıra *High mobility group box 1* (HMGB1), okside fosfolipitler ve ekstraselüler matriks fragmanları gibi steril inflamasyonla ilişkili DAMP'ler tarafından da aktive edilebilmektedir. Bu çok yönlü ligand tanıma kapasitesi, TLR4'ü enfeksiyöz ve non-enfeksiyöz inflamasyon süreçleri arasında merkezi bir bağlantı noktası haline getirmekte ve onu kronik inflamatuar hastalıkların patogenezinde kilit bir düzenleyici olarak öne çıkarmaktadır (O'Neill vd., 2013; Zamyatina & Heine, 2020).

TLR4 aktivasyonu sonrasında başlatılan hücre içi sinyalizasyon, başlıca *Myeloid differentiation primary response 88* (MyD88)-bağımlı ve *TIR-domain-containing adapter-inducing interferon-β* (TRIF)-bağımlı yolaklar üzerinden ilerler. Bu yolakların ortak ve kritik sonlanma noktalarından biri olan NF-κB, inflamatuar yanıtların transkripsiyonel düzeyde düzenlenmesinde merkezi bir rol üstlenmektedir. NF-κB'nin sitoplazmadan çekirdeğe translokasyonu, pro-enflamatuar sitokinlerin yanı sıra kemokinler, adezyon molekülleri ve oksidatif stresle ilişkili genlerin ekspresyonunu artırarak inflamatuar yanıtın güçlenmesine neden olur (Lawrence, 2009; B. S. Liu vd., 2014).

Akut enfeksiyonlar sırasında TLR4/NF-κB ekseninin geçici ve kontrollü aktivasyonu konak savunması açısından fizyolojik ve gereklidir (Kim vd., 2023). Bununla birlikte, bu yolakların kronik ve kontrolsüz biçimde aktive olması durumunda, inflamatuar yanıtlar doku hasarı, oksidatif stres artışı ve bağışıklık homeostazının bozulması ile sonuçlanmaktadır. NF-κB aktivitesinin pozitif geri besleme döngüleri ile sürdürülmesi, inflamasyonun kronikleşmesine ve çok sayıda sistemik hastalığın gelişimine katkıda bulunmaktadır (Gurses vd., 2015; Heine & Zamyatina, 2022; Lawrence, 2009).

Bu bağlamda, TLR4/NF-κB sinyal yolağı yalnızca enfeksiyon ve kanser gibi klasik inflamatuar hastalıklarda değil; metabolik bozukluklar, kardiyovasküler hastalıklar, nöroinflamatuar süreçler ve üreme sistemi patolojileri gibi geniş bir klinik yelpazede dikkat çekmektedir (Faheem vd., 2025; Zhou vd., 2022). Erkek üreme sistemi, immün olarak ayrıcalıklı bir mikro-çevreye sahip olmakla birlikte, inflamatuar uyaranlara karşı yüksek duyarlılık göstermektedir. Testiküler dokuda TLR ekspresyonunun varlığı ve NF-κB aracılı inflamatuar yanıtların spermatogenez ve sperm fonksiyonları üzerindeki etkileri, bu yolakların erkek fertilitesinde hem fizyolojik hem de patolojik süreçlerde rol oynadığını düşündürmektedir (Dutta vd., 2020; Hedger, 2011).

TLR4 ve NF-κB Sinyal Yolağının Moleküler Temelleri

TLR4 aracılı inflamatuar yanıtın başlatılması, hücre yüzeyinde gerçekleşen çok basamaklı ve sıkı biçimde düzenlenen bir sinyalizasyon sürecini içermektedir. TLR4, bakteriyel LPS başta olmak üzere çeşitli ekzojen ve endojen ligandları tanıyan bir patern tanıma reseptörüdür. LPS, ekstraselüler ortamda öncelikle *Lipopolysaccharide binding protein* (LBP) ile kompleks oluşturmakta; bu kompleks CD14 aracılığıyla *Myeloid Differentiation factor 2* (MD-2) ile ilişkili TLR4'e sunulmaktadır. Ligand bağlanmasını takiben TLR4/MD-2 kompleksinin dimerizasyonu gerçekleşmekte ve reseptörün hücre içi *Toll/Interleukin-1 receptor/Resistance protein* (TIR) domeini üzerinden sinyal iletimi başlatılmaktadır (Kawai & Akira, 2010; O'Neill vd., 2013).

TLR4 aktivasyonu sonrasında NF-κB aktivasyonu açısından en hızlı ve baskın yanıt MyD88-bağımlı yolak aracılığıyla ortaya çıkmaktadır (Faheem vd., 2025). Bu süreçte MyD88 adaptör proteininin TIR domeinine bağlanmasını takiben *interleukin-1 receptor-associated* kinazlar (IRAK4 ve IRAK1/2) aktive olmakta, ardından *TNF receptor associated factor* -6 (TRAF6) devreye girerek ubiquitin ligaz aktivitesi aracılığıyla sinyal iletimini aşağı akım basamaklara taşımaktadır (Muroi & Tanamoto, 2008)

TRAF6 aracılı sinyalizasyon, *Mitogen-activated protein kinase kinase kinase 7* (TAK1/MAP3K7) aktivasyonu ile sonuçlanmaktadır. TAK1'in aktive olması, *IkappaB kinase* (IKK) kompleksinin fosforilasyonunu tetiklemekte; bu kompleks NF-κB sitoplazmada inaktif halde tutulmasını sağlayan *I-kappa-B* (IκB) proteinlerini fosforile etmektedir (Landström, 2010). Fosforilasyonu takiben IκB proteazomal yıkıma uğramakta ve böylece NF-κB serbest kalarak çekirdeğe transloke olmaktadır (Karin, 1999; Lawrence, 2009; Shen vd., 2019).

Çekirdeğe taşınan NF-κB, TNF-α, IL-1β, IL-6, indüklenebilir *nitric oxide synthase* (iNOS) ve *Cyclooxygenase*-2 (COX-2) gibi çok sayıda inflamatuar ve oksidatif stresle ilişkili genin transkripsiyonunu başlatmaktadır (Pasha vd., 2025). Bu gen ürünleri, inflamatuar yanıtın başlatılması, güçlendirilmesi ve sürdürülmesinde merkezi rol oynamaktadır. Bu nedenle TLR4 aktivasyonu ile NF-κB aracılı gen ekspresyonu arasındaki bağlantı, inflamasyonun moleküler temelini oluşturmaktadır (Faheem vd., 2025; Hedger, 2011; Lai vd., 2016; Lawrence, 2009).

Özellikle son yıllarda yapılan çalışmalar, TLR4'ün yalnızca mikrobiyal ligandlar aracılığıyla değil, aynı zamanda hücresel stres ve doku hasarı sırasında hücre dışına salınan DAMP'ler yoluyla da aktive olabildiğini göstermiştir. Bu bağlamda HMGB1 proteini, hücre dışına çıktığında TLR4/MD-2 kompleksi üzerinden NF-κB aktivasyonunu tetikleyen önemli bir endojen ligand olarak tanımlanmıştır (Andersson vd., 2021; Ma vd., 2024). Bu mekanizma, enfeksiyon yokluğunda gelişen steril inflamasyonun moleküler temelini açıklamakta ve TLR4/NF-κB eksenini kronik inflamatuar hastalıklar için ortak bir patojenik yolak haline getirmektedir (Andersson & Tracey, 2011; T. Murao vd., 2025; Yang vd., 2020).

Akut ve kontrollü koşullarda TLR4/NF-κB aktivasyonu konak savunması açısından fizyolojik olarak gerekli olmakla birlikte, bu sinyal yolunun kronik ve kontrolsüz biçimde aktive olması inflamasyonun sürekliliğine, oksidatif stres artışına ve doku hasarına yol açmaktadır. Bu nedenle güncel terapötik yaklaşımlar, TLR4/NF-κB ekseninin tamamen inhibisyonu yerine, sinyalin zamanlama ve şiddet açısından dengeli biçimde modüle edilmesini hedeflemektedir (Kim vd., 2023; Wei vd., 2023).

TLR4/NF-κB Sinyal Yolağının Spermatogenez ve Erkek Fertilitesi ile İlişkisi

Son yıllarda yapılan çalışmalar, Toll-like reseptörlerin yalnızca klasik immün hücrelerde değil, aynı zamanda erkek üreme sisteminin farklı hücresel bileşenlerinde de fonksiyonel olarak eksprese edildiğini ortaya koymuştur (Fujita vd., 2011; Hedger, 2011). Özellikle TLR4; Sertoli hücreleri, Leydig hücreleri ve germ hücreleri dâhil olmak üzere testiste birden fazla hücre tipinde tanımlanmış olup, testiküler mikro-çevrede doğuştan bağışıklık yanıtlarının düzenlenmesinde kritik bir konuma sahiptir (Dutta vd., 2020; Kannaki vd., 2011). Ayrıca seminifer epitelde TLR ekspresyonunun evreye özgü dağılım gösterebildiği ve TLR4'ün bazı çalışmalarda spermatogenetik döngünün erken–orta evreleriyle ilişkili şekilde raporlandığı bildirilmektedir (Doğan vd., 2024).

Sertoli hücreleri, seminifer tübüllerde spermatogenezi destekleyen temel somatik hücreler olmakla birlikte, aynı zamanda lokal immün düzenlemede de anahtar rol oynar. Hasar görmüş spermatogenik hücre ürünleri Sertoli hücrelerinde TLR2/TLR4 aktivasyonunu tetikleyerek TNF-α, IL-1β, IL-6 ve *monocyte chemoattractant protein-1* (MCP-1/CCL2) gibi inflamatuar mediyatörlerin ekspresyonunu artırabilir. Özellikle MCP-1 artışıyla birlikte makrofaj göçünün kolaylaşması, testiste non-enfeksiyöz inflamatuar yanıtların güçlenebileceğini düşündürmektedir. Bu inflamatuar yanıtın TLR2/TLR4 çift knockout farelerde ortadan kalkması, TLR sinyalizasyonunun bu süreçte nedensel rolünü güçlü biçimde desteklemektedir (Zhang vd., 2013).

Bununla birlikte, Sertoli hücrelerinde TLR4 sinyalizasyonu yalnızca zararlı inflamatuar çıktılarla sınırlı değildir. MAPK1/ERK2-bağımlı mekanizmaların devrede olduğu koşullarda TLR4 uyarımının, NF-κB/kaspaz-1/IL-1β eksenini baskılayarak hücreyi inflamatuar hasardan koruyucu bir yanıt oluşturabildiği ileri sürülmüştür (Avramska et al., 2023). Bu bağlamda TLR4 sinyalinin otfaji süreçlerini yeniden programlayarak hücresel stres altında Sertoli hücre sağkalımını destekleyebileceği ve yanıtın "uyaranın türü/şiddeti" ile şekillendiği gösterilmiştir (Avramska vd., 2023).

Olgun spermatozoalarda ise TLR4 aktivasyonunun etkileri daha tutarlı biçimde olumsuz yöndedir. İnsan ve fare spermatozoalarında TLR2 ve TLR4'ün bakteriyel endotoksinleri tanıyabildiği ve bu uyarımın sperm motilitesini azalttığı, apoptozu artırdığı ve fertilizasyon kapasitesini düşürdüğü bildirilmiştir (Fujita vd., 2011). İnsan infertil olgularından elde edilen spermlerde LPS uyarımının motilite ve canlılıkta azalma ile ilişkili olduğu; oksidatif stres belirteçleri (MDA, protein karbonil) artarken akrozom reaksiyonunun baskılanabildiği gösterilmiştir (Sahnoun vd., 2017).

Moleküler düzeyde, spermatozoalarda TLR sinyalinin MyD88 ile ilişkili olarak *Phosphoinositide 3-kinases* (PI3K) ve *Glycogen synthase kinase-3 alpha* (GSK3α) yolaklarını aktive edebildiği; fosforile PI3K ve GSK3α'nın sperm mitokondrilerinde saptanması mitokondriyal hedeflenmeye işaret eder (Zhu vd., 2016). Bu aktivasyonun mitokondriyal membran potansiyelini bozarak ATP üretimini azaltması, motilite kaybını açıklayan önemli bir mekanizma sunmaktadır (Zhu et al., 2016). Ayrıca TLR4 uyarımının TNF-α aracılı ölüm

sinyallerini güçlendirebildiği ve apoptoz süreçlerini tetikleyebildiği de gösterilmiştir (Bolat vd., 2026; Fujita vd., 2011).

Genetik ve farmakolojik kanıtlar, bu etkilerin TLR aracılı olduğunu destekler. TLR2/TLR4 çift mutant farelerde endotoksinlerin sperm fonksiyonu üzerindeki olumsuz etkilerinin belirgin biçimde bloke olması, TLR-bağımlı mekanizmaları doğrulamaktadır (Fujita vd., 2011). Benzer şekilde PI3K veya GSK3α inhibisyonunun TLR uyarımına bağlı mitokondriyal disfonksiyonu ve motilite kaybını geri çevirebilmesi, bu yolakların işlevsel önemini güçlendirmektedir (Zhu vd., 2016).

Toplu olarak değerlendirildiğinde, TLR4 sinyalizasyonunun spermatogenez ve erkek fertilitesi üzerindeki etkileri iki ana düzeyde ortaya çıkmaktadır: (i) Sertoli hücreleri üzerinden testiküler mikro-çevrede inflamasyon/korunma dengesinin düzenlenmesi ve (ii) olgun spermatozoalarda mitokondriyal fonksiyon, oksidatif stres, apoptoz ve fertilizasyon kapasitesinin doğrudan etkilenmesi (Avramska vd., 2023; Umehara vd., 2025; Zhang vd., 2013). Bu çerçevede TLR4/NF-κB ekseni, inflamatuar kökenli erkek infertilitesinin mekanistik açıklanmasında ve hedefe yönelik müdahale stratejilerinin geliştirilmesinde önemli bir odak noktasıdır (Dutta vd., 2020; Mansouri vd., 2025).

NF-κB Aktivasyonunun Erkek Üreme Sistemi Üzerindeki Etkileri

TLR4 aracılı sinyalizasyonun testisteki biyolojik sonuçları büyük ölçüde nükleer faktör kappa B (NF-κB) yolaklarının aktivasyonu üzerinden şekillenmektedir. TLR4'ün bakteriyel lipopolisakkaritler (LPS) veya DAMP'ler tarafından uyarılması, MyD88-bağımlı ve/veya TRIF-bağımlı adaptör yolakları aktive ederek IKK kompleksini tetikler ve NF-κB'nin çekirdeğe translokasyonuna yol açar. Bu süreç, TLR4 aracılı doğuştan bağışıklık yanıtlarının transkripsiyonel yürütücüsü olarak NF-κB'yi merkezi bir konuma yerleştirir (Heine & Zamyatina, 2022; Jezierska vd., 2011).

Erkek üreme sistemi bağlamında TLR4 ekspresyonunun Sertoli hücreleri, Leydig hücreleri, germ hücreleri ve olgun spermatozoalarda gösterilmiş olması, TLR4–NF-κB ekseninin testiküler mikro-çevredeki inflamatuar ve stres yanıtlarının merkezinde yer aldığını düşündürmektedir (Doğan vd., 2024; Fujita vd., 2011; Zhang vd., 2013). TLR4 aktivasyonunu takiben NF-κB'nin devreye girmesiyle inflamatuar sitokinlerin (TNF-α, IL-1β, IL-6), apoptotik sinyallerin ve oksidatif stresle ilişkili genlerin ekspresyonu düzenlenmekte; bu durum spermatogenez ve sperm fonksiyonları üzerinde belirleyici sonuçlar doğurmaktadır (Dutta & Sengupta, 2020; Hedger, 2011).

Sertoli ve Leydig Hücrelerinde NF-κB Aktivasyonu

Sertoli hücrelerinde NF-κB aktivasyonu, proinflamatuar sitokin üretiminin artışı ile ilişkilidir ve bu durum kan-testis bariyerinin (KTB) bütünlüğünü bozabilmektedir. KTB'nin bozulması, germ hücrelerinin inflamatuar uyaranlara maruziyetini artırarak spermatogenezin fizyolojik sürekliliğini olumsuz etkiler. Bununla birlikte, özellikle Sertoli hücrelerinde, TLR4/NF-κB sinyalizasyonunun MAPK1/ERK2 ile etkileşimi, inflamazom aktivasyonunu sınırlayan ve hücreyi aşırı inflamatuar hasardan koruyan dengeleyici yanıtların oluşmasına katkı sağlayabilmektedir (Avramska vd., 2023).

Leydig hücrelerinde ise NF-κB aracılı inflamasyon steroidogenez üzerinde baskılayıcı etki göstermektedir. TNF-α ve IL-1β gibi sitokinlerin artışı testosteron sentezinin azalmasına yol açmakta; bu hormonal bozulma spermatogenez için gerekli endokrin desteğin zayıflamasına neden olmaktadır (Hong vd., 2004; Sadasivam vd., 2015).

Germ Hücreleri ve Olgun Spermatozoalarda NF-κB

Germ hücreleri ve olgun spermatozoalarda NF-κB aktivasyonu belirgin oksidatif stres artışı ile ilişkilidir. NF-κB hedef genleri arasında yer alan indüklenebilir nitrik oksit sentaz (iNOS) ve siklooksijenaz-2 (COX-2), reaktif oksijen ve nitrojen türlerinin üretimini artırarak sperm membranlarında lipid peroksidasyonu, mitokondriyal disfonksiyon ve DNA hasarına neden olur (Dutta vd., 2021). Bu değişiklikler sperm motilitesinde azalma, artmış apoptoz ve fertilizasyon kapasitesinde düşüş ile sonuçlanmaktadır (Fujita vd., 2011; Sahnoun vd., 2017).

Deneysel rodent modellerinde NF-κB aktivasyonunun spermatogenezin çoklu basamaklarında (spermatogonyumdan spermatidlere ve olgun spermatozoaya uzanan hat boyunca) hücresel kayıp ve fonksiyon bozukluğu ile ilişkili olduğu gösterilmiştir (Ibrahim vd., 2024; Nna vd., 2019). İyonizan radyasyon, iskemi-reperfüzyon hasarı, kriptorşidizm, oksidatif stres ve çevresel toksikan maruziyetleri gibi farklı tetikleyiciler altında NF-κB yolunun aktive olduğu ve bunun germ hücre apoptozu ile seyrettiği rapor edilmiştir (Akhigbe vd., 2024; Hassanein vd., 2021; Hussein & Kamel, 2023; Lysiak vd., 2005; Mizuno vd., 2009; Rasoulpour & Boekelheide, 2007). Rasoulpour ve Boekelheide'nin çalışmaları, testiste iyonize radyasyona karşı NF-κB'nin proapoptotik yönde işlev gösterebildiğini, bunun da birçok dokuda tariflenen antiapoptotik NF-κB etkisiyle çelişen, testise özgü bir yanıt penceresi oluşturduğunu ortaya koymuştur. Bu bulguların yanı sıra Rotenon ile oluşturulan hasar modelinde, ratlarda testiküler apoptozun NF-κB yolu ile indüklenebileceğine dair literatürü destekleyen gözlemlerimiz bulunmaktadır.

Sistemik ve Nöroendokrin Etkiler

NF-κB aracılı üreme bozukluğu yalnızca doğrudan testiküler etkilerle sınırlı değildir. Deneysel bulgular, merkezi sinir sisteminde nöronal NF-κB/IKK2 sinyalinin sistemik inflamatuvar ve fonksiyonel sonuçlar doğurabildiğini (Ellman vd., 2017) ve hipotalamustaki NF-κB/IKK2 aktivasyonunun, nöronlar üzerinden hipotalamo-hipofizer-gonadal (HPG) aksı bozarak epididimal sperm sayısını azaltabildiğini (Qiu vd., 2021) ortaya koymuştur. Bu durum, çevresel maruziyetlerin sperm parametrelerini yalnızca testis içi inflamasyon yoluyla değil, merkezi nöroinflamatuar mekanizmalar aracılığıyla da etkileyebileceğini göstermektedir.

TLR4–NF-κB Ekseni ve Oksidatif Stres

TLR4/NF-κB sinyal yolağı ile oksidatif stres arasında çift yönlü bir etkileşim bulunmaktadır. TLR4 aktivasyonu NF-κB'yi uyararak oksidatif stresle ilişkili enzimlerin ekspresyonunu artırırken, artan reaktif oksijen türleri de NF-κB aktivasyonunu güçlendirmektedir (Dutta vd., 2020, 2021). Bu karşılıklı etkileşim inflamasyon ve oksidatif stres arasında kendini sürdüren bir kısır döngü oluşturarak testiküler hasarın ilerlemesine neden olur.

Spermatozoaların yüksek oranda çoklu doymamış yağ asidi içeren membran yapıları ve sınırlı antioksidan savunmaları nedeniyle bu döngüye karşı özellikle hassas oldukları bilinmektedir. Bu nedenle TLR4 aracılı NF-κB aktivasyonunun kronikleşmesi sperm DNA fragmantasyonu ve infertilite ile güçlü biçimde ilişkilidir.

Fizyolojik ve Patolojik Aktivasyon Arasındaki Denge

Her ne kadar TLR4/NF-κB yolağı sıklıkla patolojik inflamasyon ile ilişkilendirilse de bu sinyal yolunun tamamen baskılanması fertilite açısından uygun değildir. Düşük düzey ve kontrollü NF-κB aktivasyonunun sperm kapasitasyonu ve akrozom reaksiyonu gibi fizyolojik süreçlerde dolaylı rol oynayabileceği bildirilmiştir. Bu durum, TLR4/NF-κB ekseninin erkek fertilitesinde bağlama ve şiddete bağlı çift yönlü bir düzenleyici olarak işlev gördüğünü göstermektedir.

Özellikle, sperm tarafından salgılanan hiyaluronidaz enzimi aracılığıyla üretilen düşük moleküler ağırlıklı hiyaluronan fragmanları, kümülüs hücrelerinde TLR2 ve TLR4'ü aktive ederek pro-enflamatuvar sitokin ve kemokin (örneğin IL-6, CCL5) üretimini tetiklemektedir.

Bu mediyatörler, sperm üzerindeki kemokin reseptörlerini uyararak tirozin fosforilasyonunu artırır ve sperm kapasitasyonunu (tirozin fosforilasyonu yoluyla), kemotaksisini ve akrozom reaksiyonunu teşvik eder; böylece in vitro ve in vivo fertilizasyon oranlarını yükseltir (Ezz vd., 2023; Hwang vd., 2024; Umehara vd., 2025). Bu mekanizma, spermatogenezde fizyolojik bir "düzenleyici" olup, düşük düzey TLR2/TLR4-NF-κB aktivasyonunun fertilizasyon başarısı için vazgeçilmez olduğunu ortaya koymaktadır.

TLR nötralize edici antikorlar veya hiyaluronan-bloke edici peptidler ile bu yolak baskılandığında fertilizasyon oranları belirgin biçimde azalmaktadır (Friebe vd., 2011). Buna karşılık, yolakların kronik veya aşırı aktivasyonu (örneğin bakteriyel LPS veya çevresel stresörler ile) oksidatif stres, apoptoz ve sperm fonksiyon kaybına yol açarak infertiliteye neden olmaktadır.

İnsan çalışmalarında, azoospermi tanısı almış erkeklerin Sertoli hücrelerinde TLR4 ve ilişkili sinyal genlerinin ekspresyonunun anlamlı biçimde azaldığı bildirilmiş; bu durum, spermatogenezin sürdürülmesi için belirli bir bazal TLR4 aktivitesinin gerekli olabileceğine işaret etmiştir (Lakpour vd., 2025). Benzer şekilde, açıklanamayan tekrarlayan spontan abortus olgularında spermatozoalarda TLR2 ve TLR4 ekspresyonunun azalmış olması, paternal TLR sinyalizasyonunun yalnızca enfeksiyon yanıtı değil, fertilizasyon başarısı ve erken embriyonik gelişim açısından da kritik olabileceğini düşündürmektedir (Sereshki vd., 2019)Deneysel veriler bu gözlemleri destekler nitelikte olup, rat testis ve epididimisinde TLR4 ekspresyonunun postnatal gelişim boyunca evreye özgü biçimde düzenlendiği gösterilmiş; bu bulgu TLR4'ün spermatogenezin fizyolojik programına entegre bir bileşen olduğunu ortaya koymuştur (Özbek vd., 2020).

Metabolik bozukluklar bağlamında ise hiperglisemi koşullarında TLR4 sinyalizasyonunun bozulmasının testiküler fonksiyon kaybına katkıda bulunabileceği öne sürülmüş; buna paralel olarak Leydig hücrelerinde TLR4 blokajının oksidatif stresi azalttığı ve ERK1/2 fosforilasyonunu yeniden düzenlediği bildirilmiştir (Karpova vd., 2020; Naas vd., 2019). Bu veriler, TLR4/NF-κB ekseninin erkek üreme sisteminde doz, zamanlama ve hücre tipine bağlı çift yönlü bir düzenleyici olarak işlev gördüğünü hem aşırı aktivasyonun hem de yetersiz ekspresyonun fertilite üzerinde olumsuz sonuçlar doğurabileceğini ortaya koymaktadır.

TLR4/NF-κB Ekseninin Fitokimyasal Modülasyonu

TLR4/NF-κB sinyal yolağı; inflamasyon, oksidatif stres ve hücre ölümü arasında merkezi bir düzenleyici eksen oluşturduğundan, bu yolun dengeli biçimde modülasyonu erkek infertilitesinin patofizyolojisi açısından stratejik bir hedef olarak öne çıkmaktadır. Son yıllarda artan çalışmalar, doğal bileşikler ve fitokimyasalların TLR4 aracılı NF-κB aktivasyonunu farklı düzeylerde baskılayabildiğini ve inflamatuar çıktıları sınırlayabildiğini ortaya koymuştur. Özellikle polifenolik bileşikler (kurkumin, resveratrol, epigallokateşin gallat ve kuersetin gibi), TLR4–MyD88–NF-κB ekseni boyunca sinyal iletimini zayıflatarak TNF-α, IL-1β ve IL-6 gibi pro-inflamatuvar sitokinlerin ekspresyonunu azaltabilmektedir (Chen vd., 2018; Coutinho-Wolino vd., 2022; Fakhri vd., 2022; Hussein & Kamel, 2023).

Bu etkilerin yalnızca inflamasyon baskılanmasıyla sınırlı olmadığı, aynı zamanda oksidatif stres yanıtlarının da eş zamanlı olarak düzenlendiği gösterilmiştir. Nitekim Xue Liu ve ark. (2025), kurkumin, resveratrol ve EGCG gibi fitokimyasalların Nrf2-bağımlı antioksidan savunma sistemlerini aktive ederken NF-κB sinyalizasyonunu baskıladığını, bunun sonucunda süperoksit dismutaz (SOD), katalaz (CAT) ve glutatyon peroksidaz (GPx) gibi antioksidan enzim aktivitelerinin arttığı ve lipid peroksidasyonunun azaldığı bildirilmiştir (Krajka-Kuźniak & Baer-Dubowska, 2021; X. Liu vd., 2025). Bu çift yönlü etki, inflamasyon ve oksidatif stres

arasında kendini sürdüren patolojik geri besleme döngüsünün kırılmasında kritik bir mekanizma olarak değerlendirilmektedir.

Erkek infertilitesi bağlamında bu bulgular özel bir önem taşımaktadır. Oksidatif stres ve NF-κB aracılı inflamasyonun sperm motilitesi, DNA bütünlüğü ve steroidogenez üzerindeki olumsuz etkileri göz önünde bulundurulduğunda, TLR4/NF-κB eksenini hedef alan fitokimyasal modülatörlerin koruyucu veya destekleyici ajanlar olarak potansiyel taşıdığı düşünülmektedir. Bununla birlikte, mevcut kanıtların büyük bölümü preklinik modellere dayandığından, bu bileşiklerin biyoyararlanımı, optimal dozları ve uzun dönem güvenilirliği hâlen netlik kazanmamıştır. Dolayısıyla TLR4/NF-κB yolunu hedefleyen fitokimyasal temelli yaklaşımların erkek infertilitesinde klinik uygulamaya aktarılabilmesi için iyi tasarlanmış, mekanizma odaklı ve geniş ölçekli çalışmalara ihtiyaç bulunmaktadır (Coutinho-Wolino vd., 2022; Krajka-Kuźniak & Baer-Dubowska, 2021; X. Liu vd., 2025).

Mevcut kanıtların büyük bölümü preklinik modellere dayanmaktadır. Klinik veriler sınırlı olmakla birlikte, likopen takviyesinin sperm motilitesini artırabildiği ve resveratrolün üreme endokrin parametreleri üzerinde olumlu etkiler gösterebildiği rapor edilmiştir (Liu et al., 2025). Bununla birlikte, biyoyararlanım sorunları ve optimal dozlar henüz net değildir. Bu nedenle, TLR4/NF-κB eksenini hedefleyen fitokimyasal temelli yaklaşımların klinik uygulamaya aktarılabilmesi için iyi tasarlanmış insan çalışmalarına gereksinim bulunmaktadır.

SONUÇ VE TARTIŞMA

Mevcut literatür, TLR4/NF-κB sinyal yolağının erkek fertilitesinde merkezi bir düzenleyici olduğunu açıkça ortaya koymaktadır. İnfertil erkeklerde artmış TLR4 ve NF-κB aktivitesi; bozulmuş semen parametreleri, artmış inflamatuar belirteçler ve oksidatif stres ile ilişkilidir. Bu durum, TLR4/NF-κB ekseninin inflamatuar kökenli erkek infertilitesinde önemli bir biyobelirteç ve terapötik hedef olabileceğini düşündürmektedir. Bununla birlikte, mevcut veriler bu yolakların tamamen inhibe edilmesinin fizyolojik üreme süreçlerini de olumsuz etkileyebileceğini göstermektedir. Bu nedenle güncel yaklaşımlar, TLR4/NF-κB sinyalinin dengeleyici biçimde modüle edilmesine odaklanmaktadır. Selektif TLR4 antagonistleri ve NF-κB sinyalini sınırlayan ajanlar, geniş immünsupresyona yol açmadan testiküler mikro-çevrede inflamatuar yükü azaltma potansiyeli taşımaktadır (Faheem vd., 2025; Hassanein vd., 2021, 2025; Hussein & Kamel, 2023).

Sonuç olarak, TLR4/NF-κB ekseni erkek fertilitesinde hem koruyucu hem de yıkıcı etkiler gösterebilen kritik bir sinyal ağıdır. Bu çift yönlü doğa, yolak bileşenlerinin zaman-, doz- ve hücre-spesifik olarak hedeflenmesini gerektirmekte; gelecekte geliştirilecek tedavi stratejilerinin bu hassas dengeyi gözetmesi gerektiğini ortaya koymaktadır.

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A REVIEW OF THESES CONDUCTED ON COMMUNICATION IN ALZHEIMER'S DISEASE

ALZHEİMER HASTALIĞINDA İLETİŞİM HAKKINDA YAPILMIŞ TEZLERİN İNCELENMESİ

Özgür BOZDAĞ

Ankara Yıldırım Beyazıt Üniversitesi Sağlık Bilimleri Enstitüsü, Dil ve Konuşma Terapisi Bölümü

ORCID: https://orcid.org/0009-0006-0764-9621

Doç. Dr. Mümüne Merve PARLAK

Ankara Yıldırım Beyazıt Üniversitesi Sağlık Bilimleri Fakültesi, Dil ve Konuşma Terapisi Bölümü

ORCID: https://orcid.org/0000-0002-1603-2360

ÖZET

Giriş ve Amaç: Alzheimer hastalığı, dünya genelinde en yaygın demans türü olup bilişsel, dilsel ve iletişimsel becerilerde ilerleyici kayıplara neden olmaktadır. Sözdizimsel bozulmalar, sözel akıcılıkta azalma, anlatımda bütünlük kaybı ve pragmatik iletişim güçlükleri hastalığın erken evrelerinden itibaren ortaya çıkmaktadır. Bu çalışmanın amacı, Alzheimer veya demans tanılı bireylerde iletişim ve dil güçlüklerini inceleyen açık erişimli Türkçe tezleri sistematik olarak değerlendirmek ve bu tezlerde bildirilen iletişimsel bozuklukları, kullanılan değerlendirme yöntemlerini ve metodolojik eğilimleri ortaya koymaktır.

Materyal ve Metot: YÖK Ulusal Tez Merkezi'nde Alzheimer, demans, iletişim, dil ve bilişsel iletişim anahtar sözcükleri kullanılarak yapılandırılmış bir tarama yapılmıştır. Yalnızca Alzheimer veya demans tanılı bireyleri doğrudan içeren ve iletişim ya da dil özelliklerini inceleyen açık erişimli tezler dahil edilmiştir. Çalışmaya alınan sekiz tez; çalışma grubu özellikleri, kullanılan değerlendirme araçları, ele alınan iletişim alanları, temel bulgular ve belirtilen sınırlılıklar açısından içerik analizi yöntemiyle değerlendirilmiştir.

Bulgular: İncelenen tezlerde kısa ve basit cümle kurma eğilimi, karmaşık yapılarda azalma, sözel akıcılıkta düşüş, anlatıda kopukluk ve gereksiz ayrıntı verme gibi iletişimsel bozuklukların sık görüldüğü belirlenmiştir. Pragmatik düzeyde konu dışına çıkma, bağıntısız konuşma ve anlamlı iletişimi sürdürmede güçlükler yaygındır. Teknoloji destekli yaklaşımlar sınırlı olup çoğu pilot düzeydedir. Tezlerin büyük bölümü betimleyici desende olup küçük örneklemlere dayanmaktadır.

Tartışma ve Sonuç: Bulgular, Alzheimer hastalığında iletişim bozukluklarının dilsel, bilişsel ve pragmatik alanlarda çok boyutlu etkiler yarattığını göstermektedir. İncelenen tezler, daha geniş örneklemlerle yürütülecek, müdahale odaklı, uzunlamasına ve teknoloji destekli çalışmalara duyulan ihtiyacı ortaya koymaktadır. Bu tür çalışmaların klinik uygulamalara ve literatüre önemli katkılar sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Alzheimer; Demans; İletişim Bozukluğu; Dil Bozukluğu; Bilişsel İletişim

ABSTRACT

Introduction and Purpose: Alzheimer's disease is the most common form of dementia worldwide and causes progressive deterioration in cognitive, linguistic, and communicative abilities. Difficulties in sentence structure, verbal fluency, narrative cohesion, and pragmatic communication emerge early in the disease. This study aims to systematically review open-access Turkish dissertations examining communication and language difficulties in individuals diagnosed with Alzheimer's disease or dementia, summarizing the reported communication impairments, assessment approaches, and methodological patterns.

Materials and Methods: A structured search was conducted in the National Thesis Center using keywords related to Alzheimer's disease, dementia, communication, language, and cognitive-communication skills. Only open-access dissertations directly involving individuals with Alzheimer's or dementia and examining communication or language characteristics were included. Eight dissertations meeting these criteria were analyzed using content analysis, focusing on sample characteristics, assessment tools, communication domains, main findings, and reported limitations.

Results: Across the dissertations, common findings included short and simple sentence use, decreased syntactic complexity, reduced verbal fluency, narrative incoherence, and excessive or irrelevant detail. Pragmatic difficulties, such as topic shifting and difficulty maintaining meaningful communication, were frequently reported. Technology-supported approaches were limited and mostly at the pilot level. Most dissertations employed descriptive designs with small samples.

Discussion and Conclusion: The findings demonstrate that communication disorders in Alzheimer's disease are multidimensional, affecting linguistic, cognitive, and pragmatic domains. The dissertations highlight the need for larger-sample, intervention-focused, longitudinal, and technology-supported research. Such studies are expected to contribute significantly to clinical practice and the academic literature.

Key Words: Alzheimer's Disease; Dementia; Communication Disorder; Language Disorder; Cognitive Communication

GİRİŞ

Alzheimer hastalığı (AH), dünya genelinde demansın en yaygın nedeni olup ilerleyici ve geri dönüşümsüz bir nörodejeneratif süreçle karakterizedir. Hastalık çoğunlukla bellek kaybı ile tanımlansa da güncel araştırmalar, Alzheimer'ın dil, konuşma ve iletişim becerileri üzerinde derin ve çok boyutlu etkiler yarattığını ortaya koymaktadır (World Health Organization [WHO], 2023). Sözcük bulma güçlüğü, anlamsal bellek bozulmaları, anlatı bütünlüğünün kaybı ve pragmatik uyumsuzluklar Alzheimer hastalarının günlük iletişim işlevselliğini önemli ölçüde sınırlandırmaktadır (Mueller et al., 2018).

Dil ve iletişim bozuklukları, Alzheimer hastalığının erken evrelerinden itibaren gözlenebilmektedir. Özellikle semantik bellek bozulmaları, sözel üretimin içeriğini zayıflatmakta; çalışma belleği ve yürütücü işlevlerdeki gerileme ise cümle karmaşıklığını ve söylem örgütlenmesini olumsuz etkilemektedir (Lindsay et al., 2021). Alzheimer hastalarında

görülen bu iletişim bozuklukları yalnızca bireyin kendini ifade etme becerisini değil, aynı zamanda sosyal katılımını ve bakım verenlerle olan etkileşimini de etkilemektedir (Ferris & Farlow, 2013).

Uluslararası literatürde Alzheimer hastalığında dil ve iletişim bozuklukları geniş ölçüde incelenmiş; sözdizimsel yapıların sadeleşmesi, anlamsal ağların zayıflaması, söylem tutarlılığının bozulması ve pragmatik becerilerde gerileme gibi bulgular tutarlı biçimde rapor edilmiştir (Fraser et al., 2016; Klimova et al., 2015). Buna karşın Türkiye'de bu alanda yapılan lisansüstü çalışmaların bütüncül biçimde ele alındığı sentez çalışmalarının sınırlı olduğu görülmektedir. Mevcut tezler çoğunlukla belirli alt alanlara odaklanmakta ve elde edilen bulguların bir araya getirilmesiyle genel bir iletişim profili ortaya konmamaktadır.

Bu çalışmanın amacı, Türkiye'de Alzheimer hastalığında iletişim becerilerini inceleyen lisansüstü tezleri sistematik biçimde değerlendirmek ve bu tezlerde ortaya konan bulguları bütüncül bir çerçevede sunmaktır.

ARAŞTIRMA VE BULGULAR

Bu çalışmada YÖK Ulusal Tez Merkezi'nde yapılan yapılandırılmış tarama sonucunda Alzheimer ve demans tanılı bireylerde dil ve iletişim özelliklerini inceleyen sekiz lisansüstü tez analiz edilmiştir. İncelenen tezler, farklı üniversitelerde ve farklı disiplinlerde yürütülmüş olmakla birlikte, Alzheimer hastalığında iletişim becerilerinin çok boyutlu biçimde etkilendiğini ortaya koyan ortak bulgular sunmaktadır. Çalışmaların üçü doktora, beşi yüksek lisans düzeyinde olup, tezlerin büyük bölümü betimleyici ve karşılaştırmalı araştırma desenleri kullanılarak gerçekleştirilmiştir.

Tablo 1. İncelenen Lisansüstü Tezlerin Tanıtıcı Özellikleri

Tez Başlığı	Yazar	Üniversite	Enstitü	Program	Tez Türü	Yıl
Türk Alzheimer Hastalarının Dil Kullanımı: Tümce Türleri Açısından İnceleme	Eda Can	Dokuz Eylül Üniversitesi	Sosyal Bilimler Enstitüsü	Genel Dilbilim	Doktora	2016
A Psycholinguistic Study on the Pronoun Comprehension and Processing of the Turkish Alzheimer's Patients	Esra Küçüksakarya	Hacettepe Üniversitesi	Sosyal Bilimler Enstitüsü	İngiliz Dilbilimi	Yüksek Lisans	2017
Lewy Cisimcikli ve Alzheimer Demanslı Türk Hastaların Dilsel Özelliklerinin Karşılaştırılması	Anı Barış	Dokuz Eylül Üniversitesi	Sosyal Bilimler Enstitüsü	Genel Dilbilim	Yüksek Lisans	2009
Hafif Kognitif Bozukluk Hastalarında Sözel Akıcılık Becerilerinin İncelenmesi	Tuğçe Çabuk	Anadolu Üniversitesi	Sağlık Bilimleri Enstitüsü	Dil ve Konuşma Terapisi	Yüksek Lisans	2018
Demans Tanısı Konmuş Bireylerin Davranış Sorunları ile Beslenme Durumlarının Değerlendirilmesi	Yeliz Güçer	Akdeniz Üniversitesi	Sosyal Bilimler Enstitüsü	Gerontoloji	Yüksek Lisans	2015
Alzheimer ve Demans Hastalığı İçin Bitki Ekstraktlarından Yeni Aday İlaç Molekülü Eldesi	Sena Vardarlı	Üsküdar Üniversitesi	Fen Bilimleri Enstitüsü	Biyoteknoloji	Yüksek Lisans	2021
Alzheimerlı Bireylerde Bilişsel İletişim Bozukluğuna Yönelik Mobil Uyumlu Yazılımın Geliştirilmesi Alzheimerlı Bireylerde Bilişsel İletişim Bozukluğuna Yönelik Mobil Uyumlu Yazılımın Geliştirilmesi	Mümüne Merve Parlak	Hacettepe Üniversitesi	Sağlık Bilimleri Enstitüsü	Dil ve Konuşma Terapisi	Doktora	2022
Türk Alzheimer Hastalarının Dil Kullanımı: Tümce Türleri Açısından İnceleme	Eda Can	Dokuz Eylül Üniversitesi	Sosyal Bilimler Enstitüsü	Genel Dilbilim	Doktora	2016

İncelenen tezlerin bulguları, Alzheimer hastalığında iletişim bozukluklarının yalnızca tek bir dil alanıyla sınırlı olmadığını, sözdizimsel, anlamsal, söylemsel ve pragmatik düzeyleri kapsayan geniş bir etki alanına sahip olduğunu göstermektedir. Sözdizimsel yapı üzerine odaklanan tezlerde Alzheimer hastalarının daha kısa ve basit tümceler ürettikleri, birleşik ve gömülü yapılardan belirgin biçimde kaçındıkları bildirilmiştir. Bu durum, uluslararası literatürde Alzheimer hastalığı olan bireylerde cümle karmaşıklığının azalması ve dilsel üretimin sadeleşmesi yönündeki bulgularla örtüşmektedir (Fraser et al., 2016; Mueller et al.,

2018). Özellikle anlatı görevlerinde sözcük sayısının azalması ve tümce çeşitliliğinin düşmesi, dil üretiminin bilişsel yükle yakından ilişkili olduğunu göstermektedir.

Anlamsal işlemleme alanında yapılan çalışmalar, Alzheimer hastalığı olan bireylerin sözcük bulma güçlüğü yaşadıklarını ve referans takibi gerektiren yapılarda belirgin zorlanmalar gösterdiklerini ortaya koymuştur. Küçüksakarya'nın (2017) çalışmasında, adıl çözümleme doğruluk oranlarının düşük olduğu ve tepki sürelerinin uzadığı bildirilmiştir. Bu bulgular, Alzheimer hastalığında semantik bellek ve çalışma belleği süreçlerinin birlikte etkilendiğini gösteren önceki araştırmalarla uyumludur (Lindsay et al., 2021).

Söylem ve pragmatik becerileri ele alan tezlerde Alzheimer hastalığı olan bireylerin konu bütünlüğünü sürdürmekte zorlandıkları, gereksiz ayrıntılara yöneldikleri ve bağlama uygun bilgi sunma becerilerinin zayıfladığı görülmüştür. Bu pragmatik bozulmalar, Alzheimer hastalığı olan bireylerde iletişimin işlevsel boyutunun ciddi biçimde etkilendiğini göstermekte olup, Grice'ın iş birliği ilkelerinin özellikle nicelik ve bağıntı boyutlarında ihlal edildiği rapor edilmiştir. Benzer pragmatik bozulmaların uluslararası çalışmalarda da sıklıkla vurgulandığı görülmektedir (Klimova et al., 2015; Ska & Duong, 2005).

Sözel akıcılık üzerine yapılan çalışmada, Alzheimer ve hafif bilişsel bozukluk tanılı bireylerin hem fonemik hem semantik akıcılıkta düşük performans sergiledikleri, kümeleme ve kategori değiştirme becerilerinin zayıfladığı belirlenmiştir. Bu bulgular, sözel akıcılığın Alzheimer hastalığında yürütücü işlevler ve semantik bellekle ilişkili olarak etkilendiğini gösteren meta-analizlerle tutarlıdır (Henry et al., 2004).

İncelenen tezler arasında yalnızca bir çalışmada müdahale temelli bir yaklaşım kullanılmıştır. Parlak (2022), Alzheimer hastalığı olan bireyler için geliştirilen mobil uyumlu bilişsel iletişim yazılımının dilbilgisel üretim, yönelim ve genel iletişim performansı üzerinde olumlu etkiler sağladığını bildirmiştir. Bu bulgu, son yıllarda teknoloji temelli iletişim müdahalelerinin Alzheimer hastalığı olan bireylerde uygulanabilirliğini vurgulayan çalışmalarla örtüşmektedir (de la Fuente Garcia et al., 2020).

Genel olarak değerlendirildiğinde, Türkiye'de Alzheimer hastalığında iletişim becerilerini inceleyen lisansüstü tezler, hastalığın iletişim üzerindeki çok boyutlu etkisini ortaya koymakta; ancak müdahale çalışmaları ve uzunlamasına araştırmalar açısından önemli sınırlılıklar taşımaktadır.

SONUÇ

Bu çalışma, Türkiye'de Alzheimer hastalığında dil, konuşma ve iletişim becerilerini ele alan lisansüstü tezlerin kapsamlı bir incelemesini sunmuştur. YÖK Ulusal Tez Merkezi'nde gerçekleştirilen yapılandırılmış tarama sonucunda belirlenen sekiz tez, Alzheimer ve demans tanılı bireylerde iletişim bozukluklarının çok boyutlu ve karmaşık bir yapıya sahip olduğunu ortaya koymaktadır. İncelenen tezlerin bulguları, Alzheimer hastalığının yalnızca bellek ve genel bilişsel işlevlerle sınırlı olmadığını; sözdizimsel yapı, anlamsal işlemleme, söylem örgütlenmesi, pragmatik kullanım ve sözel akıcılık gibi iletişimin temel bileşenlerini de derinlemesine etkilediğini göstermektedir. Bu sonuçlar, Alzheimer hastalığında dil ve iletişim bozukluklarının hastalığın ayırt edici özelliklerinden biri olduğunu vurgulayan uluslararası literatürle uyumludur (Mueller et al., 2018; Lindsay et al., 2021).

Tezlerde en sık rapor edilen bulgular arasında cümle karmaşıklığında azalma, basit tümce kullanımında artış, sözcük bulma güçlüğü, adıl çözümleme ve referans takibinde zorlanma, konu bütünlüğünü sürdürmede güçlük ve bağlamsal uygunlukta bozulmalar yer almaktadır. Bu iletişimsel bozulmaların, Alzheimer hastalarında semantik bellek, çalışma belleği ve yürütücü

işlevlerdeki gerilemeyle yakından ilişkili olduğu bilinmektedir (Fraser et al., 2016; Ferris & Farlow, 2013). Sözel akıcılıkta görülen düşüşler de bu bilişsel gerilemenin dilsel çıktılara yansımasını desteklemektedir (Henry et al., 2004).

İncelenen tezler arasında yalnızca bir çalışmanın müdahale temelli olması, Türkiye'de Alzheimer hastalarında iletişim rehabilitasyonuna yönelik araştırmaların oldukça sınırlı olduğunu göstermektedir. Oysa uluslararası literatürde, bilişsel iletişim müdahaleleri ve teknoloji temelli uygulamaların iletişim performansı üzerinde olumlu etkiler sağlayabildiği bildirilmektedir (de la Fuente Garcia et al., 2020). Bu durum, Türkiye'de yapılacak gelecekteki çalışmaların değerlendirme odaklı yaklaşımların ötesine geçerek müdahale temelli tasarımlara yönelmesi gerektiğini ortaya koymaktadır.

Sonuç olarak bu çalışma, Türkiye'de Alzheimer hastalığında iletişim becerileri alanında yapılmış lisansüstü tezlerin mevcut durumunu ortaya koymakta ve bu alandaki araştırmaların daha bütüncül, uzunlamasına ve klinik temelli yaklaşımlarla geliştirilmesi gerektiğini göstermektedir. Daha geniş örneklemler, standartlaştırılmış değerlendirme araçları ve konuşma-dil terapisi temelli müdahaleleri içeren çalışmaların, Alzheimer hastalarında iletişim becerilerinin desteklenmesine önemli katkılar sağlayacağı düşünülmektedir (Klimova et al., 2015; World Health Organization, 2023).

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GLOBAL SUMMARY REPORT ON THE EPIDEMIOLOGY OF HYPERTENSION

Prof. Dr., Kemal Macit HİSAR

Selcuk University, Faculty of Medicine, Department of Public Health, Konya, Turkey

ORCID ID: https://orcid.org/0000-0002-9306-119X

Prof. Dr. Filiz HİSAR

Necmettin Erbakan University, Faculty of Nursing, Department of Public Health, Konya, Turkey

ORCID ID: https://orcid.org/0000-0003-0640-0091

ABSTRACT

Hypertension (HT) is the leading global risk factor for disease burden and premature death, affecting an immense proportion of the world's population. The World Health Organization (WHO) and major studies like the Global Burden of Disease (GBD) consistently highlight its massive scale.

Globally, the number of adults (aged 30-79) living with hypertension has doubled since 1990, reaching an estimated 1.3 billion people. This dramatic increase is largely driven by population growth and aging, as well as shifts in lifestyle and dietary patterns.

Prevalence and Distribution: While prevalence rates are high worldwide, there is significant geographical heterogeneity. Low- and middle-income countries (LMICs), particularly in Sub-Saharan Africa and South Asia, often bear the highest burden in terms of age-standardized prevalence and mortality, despite often having lower rates of awareness and control compared to high-income countries.

In many high-income countries, public health efforts have led to stabilized or slightly decreasing prevalence rates, along with improved awareness, treatment, and control rates. However, even in these regions, less than half of people with hypertension have their condition controlled.

Control and Impact: One of the most concerning aspects of global hypertension epidemiology is the poor rate of control. Estimates show that fewer than one in five people with hypertension globally have the condition under control (defined as blood pressure below 140/90 \text{ mmHg}). Uncontrolled hypertension significantly increases the risk of stroke, myocardial infarction, heart failure, and chronic kidney disease, making it a critical focus for global non-communicable disease (NCD) reduction strategies. Public health interventions are urgently needed to improve detection and sustained management, especially in resource-limited settings.

Keywords: Hypertension, Global Burden, Prevalence, Control, LMICs

INTRODUCTION

Hypertension, commonly known as high blood pressure, stands as one of the most pervasive and consequential non-communicable diseases (NCDs) globally. Defined by a sustained systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg (or the use of antihypertensive medication), this condition is frequently asymptomatic, earning it the moniker "the silent killer" (World Health Organization [WHO], 2024). Its status as the leading modifiable risk factor for cardiovascular disease (CVD) and premature death underscores its profound public health significance (Forouzanfar et al., 2017).

The epidemic of hypertension is not confined to specific regions; rather, it represents a pandemic of chronic disease affecting billions worldwide. Recent global estimates indicate that approximately 1.28 billion adults aged 30–79 years have hypertension, with the vast majority (two-thirds) residing in low- and middle-income countries (LMICs) (NCD Risk Factor Collaboration [NCD-RisC], 2021). This demographic shift in disease burden highlights a critical disparity: while the prevalence rate may be plateauing or slightly declining in many high-income countries (HICs), the absolute number of affected individuals is rapidly increasing in LMICs due to population growth, aging, and increasing exposure to urbanized lifestyle risk factors (Mills et al., 2016).

Uncontrolled hypertension is the principal driver of heart attacks, strokes, chronic kidney disease (CKD), and heart failure, collectively accounting for millions of preventable deaths annually (Collaboration, 2019). The economic consequences are equally staggering, draining healthcare resources and hindering productivity. Therefore, a comprehensive understanding of the global epidemiology of hypertension—including its prevalence, regional variations, underlying determinants, and the effectiveness of control programs—is paramount for formulating impactful, evidence-based global health policies.

This article aims to provide a thorough review of the current global epidemiology of hypertension. Specifically, we will detail the trends in prevalence and incidence, analyze the major behavioral and socioeconomic risk factors contributing to the rise in cases, evaluate the critical gaps in awareness and treatment, and outline feasible public health strategies essential for achieving the WHO's global target of a 25% reduction in the prevalence of hypertension by 2025.

METHODOLOGY (SCOPE AND DATA SOURCES)

The scope of this epidemiological review is global, focusing primarily on data from the last decade (2014–2024) to reflect the most contemporary trends in hypertension prevalence and control. Data sources utilized include:

Global Health Initiatives: Reports and databases from the World Health Organization (WHO), particularly the Global Hearts Initiative, and the World Hypertension League (WHL).

Large-Scale Epidemiological Studies: Findings from major collaborative research groups such as the NCD Risk Factor Collaboration (NCD-RisC) and the Global Burden of Disease (GBD) Study, which provide standardized, comparable estimates across countries.

Systematic Reviews and Meta-Analyses: High-quality scientific literature published in peer-reviewed journals, identified through searches on PubMed and Scopus databases using terms like "hypertension," "prevalence," "global burden," and "epidemiology."

The review synthesizes these data to offer a robust, evidence-based narrative on the distribution and determinants of hypertension worldwide.

THE GLOBAL BURDEN AND PREVALENCE OF HYPERTENSION

The global burden of hypertension is characterized by both high prevalence and poor control.

Regional Variations in Prevalence

The distribution of hypertension is highly heterogeneous across the globe, closely correlated with the stage of economic development and the demographic transition of the population.

Low- and Middle-Income Countries (LMICs): These regions, particularly Sub-Saharan Africa and South Asia, now bear the highest burden of hypertension. Studies have consistently shown that while overall awareness and treatment rates are improving, the prevalence rates remain disproportionately high, often exceeding 40% in many adult populations (Mills et al., 2016). This high prevalence is driven by rapid urbanization, which brings about adverse changes in diet (increased sodium and caloric intake) and reduced physical activity.

High-Income Countries (HICs): Countries in North America, Western Europe, and Australasia generally exhibit lower, or at least stabilizing, age-standardized prevalence rates. This trend is largely attributed to successful public health campaigns focused on dietary modification and smoking cessation, coupled with widespread screening and access to effective medication (Collaboration, 2019).

Eastern Europe and Central Asia: These regions frequently report high prevalence and low control rates, potentially linked to high rates of alcohol consumption, tobacco use, and suboptimal healthcare system performance in chronic disease management.

Trends by Age, Gender, and Income Level

The prevalence of hypertension exhibits clear trends across demographic variables:

Age: Hypertension is fundamentally a disease of aging. Prevalence is low in young adulthood but rises sharply after the age of 50. In many populations, over 50% of adults aged 60 and older are hypertensive (NCD-RisC, 2021).

Gender: Before the age of 50, men generally have a higher prevalence of hypertension than women. After menopause, however, the prevalence rates in women tend to equal or even exceed those in men, indicating a hormonal influence on cardiovascular health (Peters et al., 2019).

Socioeconomic Status (SES): Within most countries, lower SES groups often experience higher rates of hypertension. This disparity is multifactorial, stemming from greater exposure to environmental and psychosocial stress, limited access to high-quality healthcare and preventive services, and higher rates of unhealthy lifestyle behaviors (e.g., poor diet, smoking) (Timmis et al., 2020).

Major Determinants and Risk Factors

The sustained increase in global hypertension prevalence is driven by a complex interplay between inherent physiological characteristics, lifestyle choices, and underlying socioeconomic determinants. Identifying and mitigating these factors is central to effective public health intervention.

Lifestyle and Modifiable Factors

Modifiable risk factors are responsible for the vast majority of hypertension cases globally, making them the primary targets for prevention programs (Collaboration, 2019).

High Dietary Sodium Intake

Excessive sodium consumption is arguably the most significant dietary factor contributing to elevated blood pressure worldwide. The average global sodium intake far exceeds the WHO

recommended limit of less than 5 grams of salt (or 2 grams of sodium) per day (He & MacGregor, 2010). High sodium intake leads to increased fluid retention and volume expansion, resulting in higher blood pressure. The challenge in many LMICs is the shift toward consuming processed, affordable foods, which are typically high in hidden sodium.

Physical Inactivity

Sedentary lifestyles are strongly associated with increased risk of hypertension. Regular physical activity, such as moderate aerobic exercise, is crucial for maintaining vascular health, reducing resting heart rate, and promoting weight management. The rapid urbanization and mechanization of daily life, particularly in developing economies, have dramatically reduced opportunities for incidental physical activity (Lee et al., 2012).

Overweight and Obesity

Body mass index (BMI) is directly correlated with blood pressure. Obesity contributes to hypertension through several mechanisms, including increased sympathetic nervous system activity, activation of the renin-angiotensin-aldosterone system (RAAS), and physical compression of the kidneys (Hall et al., 2010). The global obesity epidemic, fueled by calorie-dense diets and inactivity, is a key driver of rising hypertension rates in younger populations.

Alcohol and Tobacco Use

Heavy and frequent alcohol consumption is a well-established risk factor for hypertension. Alcohol can acutely raise blood pressure and contribute to long-term arterial stiffness. Similarly, tobacco smoking, while not directly causing hypertension, significantly exacerbates its cardiovascular effects, increasing arterial stiffening and endothelial dysfunction, thereby magnifying the overall risk of adverse cardiovascular events (Klag et al., 1996).

Non-Modifiable and Socioeconomic Factors

Factors that cannot be altered, or those tied to broader societal structures, influence the baseline risk of developing the condition.

Age and Genetics

As discussed previously, age is the strongest non-modifiable determinant of blood pressure, primarily due to the natural stiffening and loss of elasticity of the large arteries (arteriosclerosis). Furthermore, genetic predisposition plays a substantial role, with familial history significantly increasing an individual’s lifetime risk, although the specific genetic markers are often complex and polygenic (Ehret et al., 2011).

Socioeconomic Status (SES) and Education

Socioeconomic deprivation is consistently linked to higher hypertension prevalence and poorer control. Lower educational attainment often correlates with lower health literacy, making it more difficult for individuals to understand the risks of hypertension and adhere to complex medication regimens. Furthermore, chronic psychosocial stress associated with low SES can lead to sustained elevation of stress hormones, which contribute to chronic hypertension (Timmis et al., 2020).

Environmental Exposure

Emerging evidence suggests that environmental factors, such as air pollution and exposure to excessive noise, can contribute to elevated blood pressure through inflammatory and neuroendocrine pathways. As global populations concentrate in megacities, particularly in Asia and Africa, these exposures become increasingly relevant epidemiological risk factors (Dimitrova et al., 2020).

Awareness, Treatment, and Control: The Gaps

Despite significant advancements in pharmacological treatment, the primary failure in managing the global hypertension epidemic lies in the poor rates of awareness, treatment, and sustained control (NCD-RisC, 2021).

The "Rule of Halves" Challenge

Historically, public health efforts in hypertension have often been described by the "Rule of Halves," where approximately:

Half of all people with hypertension are aware of their condition.

Half of those aware are receiving treatment.

Half of those receiving treatment achieve adequate blood pressure control.

While modern global data show improvements, particularly in HICs, this "rule" still tragically reflects the reality in many LMICs. For instance, in Sub-Saharan Africa, less than **10%** of hypertensive individuals may have their condition controlled (Mills et al., 2016).

Barriers to Effective Control

Several critical systemic and individual barriers impede effective hypertension control:

Lack of Screening and Awareness: As hypertension is usually asymptomatic, routine opportunistic or systematic screening is essential. In many primary care settings, especially those with strained resources, this screening is often overlooked.

Access and Affordability of Medication: The cost and consistent availability of essential antihypertensive medications in rural and marginalized areas of LMICs pose a major hurdle. Even when available, the cost can be prohibitive for long-term adherence.

Health System Weaknesses: Fragmented healthcare systems, poor record-keeping, lack of physician training in chronic disease management, and a focus on acute rather than preventative care undermine continuous management (WHO, 2024).

Patient Adherence and Persistence: Long-term adherence to medication is challenging. Factors include complex dosing regimens, perceived side effects, and inadequate communication between patients and providers regarding the lifelong nature of the treatment (Peters et al., 2019).

Addressing these gaps requires a paradigm shift from individual patient care to large-scale, population-level strategies integrated within robust primary healthcare systems.

Public Health Strategies and Interventions

Given the colossal burden of hypertension and its role as a precursor to cardiovascular catastrophes, disjointed individual-level treatments are insufficient. A coordinated, multi-sectoral response is required, combining population-wide policy changes with targeted clinical interventions. The World Health Organization (WHO) and other global bodies advocate for a "systems approach" to hypertension control.

Population-Wide Interventions: The "Best Buys"

Population-level strategies aim to shift the entire distribution of blood pressure in the population downward, even slightly, which yields massive public health benefits. The WHO has identified several "Best Buys"—highly cost-effective interventions feasible for all income levels.

Sodium Reduction Strategies: Reducing salt intake is the most cost-effective measure. Successful strategies include:

Reformulation: Collaborating with the food industry to gradually reduce the sodium content in processed foods (e.g., bread, sauces, processed meats).

Front-of-Pack Labeling: Implementing mandatory, clear warning labels on high-sodium products to inform consumer choice.

Taxation: Applying fiscal measures to high-sodium unhealthy foods while subsidizing fresh fruits and vegetables.

Tobacco and Alcohol Control: Rigorous implementation of the WHO Framework Convention on Tobacco Control (FCTC), including increased taxation, bans on advertising, and smoke-free environments, directly supports cardiovascular health.

Promotion of Physical Activity: Urban planning that prioritizes walking paths, cycling lanes, and green spaces facilitates active living, directly combating the sedentary lifestyle driving hypertension rates (WHO, 2024).

Strengthening Primary Health Care: The HEARTS Technical Package

To improve control rates, hypertension management must be integrated into primary health care (PHC). The WHO's HEARTS technical package provides a strategic framework:

Standardized Treatment Protocols: Adoption of simple, evidence-based treatment algorithms allows for consistent care. Using specific, locally available medication classes (e.g., ACE inhibitors, calcium channel blockers, thiazide-like diuretics) simplifies decision-making for providers.

Access to Essential Medicines: Governments must ensure a reliable supply chain of high-quality, affordable generic antihypertensive medications. Supply interruptions are a primary cause of treatment failure in LMICs.

Team-Based Care and Task Sharing: In regions with a shortage of physicians, "task-shifting" is critical. This involves training nurses, pharmacists, and community health workers to measure blood pressure, initiate treatment according to protocols, and counsel patients on lifestyle changes. Studies have shown that non-physician health workers can manage hypertension as effectively as physicians when guided by robust protocols (Anand et al., 2019).

Digital Health and Innovation

The proliferation of mobile technology offers new avenues for control. mHealth (mobile health) interventions, such as SMS reminders for medication adherence, app-based blood pressure tracking, and tele-counseling, have shown promise in improving patient compliance and follow-up, particularly in remote areas (Bernabe-Ortiz et al., 2020).

CONCLUSION AND RECOMMENDATIONS

Conclusion:

Hypertension remains the single most important preventable risk factor for premature death and disability worldwide. The epidemiological evidence presented in this review paints a clear picture: the burden is shifting dramatically towards low- and middle-income countries, driven by aging populations and the rapid adoption of unhealthy lifestyles. While high-income nations have demonstrated that control is possible through sustained public health efforts, global progress has stalled, and inequalities in care persist.

The "silent" nature of the disease, combined with systemic barriers in healthcare delivery, results in a massive gap between those who need treatment and those who receive it. Addressing

this epidemic is not merely a medical challenge but a developmental imperative, as the economic cost of untreated hypertension threatens the stability of healthcare systems and national economies.

Recommendations:

To achieve the global target of a 25% relative reduction in the prevalence of raised blood pressure, the following actions are recommended for policymakers, healthcare providers, and international agencies:

Prioritize Prevention: Governments must implement aggressive regulatory frameworks to reduce dietary sodium and sugar, including mandatory limits on processed foods and fiscal policies to discourage the consumption of unhealthy products.

Integrate into Universal Health Coverage (UHC): Hypertension screening and management must be included in national UHC benefit packages to ensure that no individual is denied care due to financial hardship.

Scale Up Task-Sharing: Regulatory bodies should adjust scopes of practice to allow nurses and community health workers to play a more active role in diagnosing and managing uncomplicated hypertension, thereby expanding workforce capacity.

Secure Supply Chains: National procurement systems must guarantee the uninterrupted availability of affordable, quality-assured generic antihypertensive medicines to prevent treatment gaps.

Enhance Surveillance: Investment in robust national surveillance systems is needed to accurately monitor prevalence trends, detect gaps in control, and evaluate the impact of interventions in real-time.

By transitioning from reactive acute care to proactive, population-based chronic disease management, the global community can turn the tide on the hypertension epidemic and save millions of lives in the coming decades.

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EPIDEMIOLOGY OF HYPERTENSION IN TÜRKİYE

Prof. Dr., Kemal Macit HİSAR

Selcuk University, Faculty of Medicine, Department of Public Health, Konya, Turkey

ORCID ID: https://orcid.org/0000-0002-9306-119X

Prof. Dr. Filiz HİSAR

Necmettin Erbakan University, Faculty of Nursing, Department of Public Health, Konya, Turkey

ORCID ID: https://orcid.org/0000-0003-0640-0091

ABSTRACT

Hypertension (HT) remains a major public health challenge in Türkiye, characterized by high prevalence rates and significant gaps in awareness, treatment, and control. Epidemiological studies, notably the PatenT (Prevalence, Awareness, Treatment, and Control of Hypertension in Turkey) studies conducted in the early 2000s and 2010s, have provided crucial data.

The overall age- and sex-adjusted prevalence of hypertension in the adult population has been consistently high, fluctuating around 30% to 33%. For instance, the prevalence was reported as 31.8% in 2003 and 30.3% in 2012. This means approximately 15 million adults were hypertensive in 2012.

Key demographic characteristics show that women generally exhibit a higher prevalence of hypertension than men, especially in older age groups (e.g., 32.3% in women vs. 28.4% in men in 2012). The prevalence also shows a strong correlation with age, rising sharply after 40 years.

While there have been improvements over time, particularly between the 2003 and 2012 surveys, the rates of control remain suboptimal. The pharmacological treatment rate increased from about 31% to 47%, and the overall control rate (patients with controlled blood pressure) improved from a very low 8.1% to 28.7%. However, these control rates still indicate that a substantial majority of hypertensive individuals do not have their blood pressure adequately managed, increasing their risk for cardiovascular and cerebrovascular diseases. Uncontrolled hypertension is therefore a critical area for ongoing public health intervention in Türkiye.

Keywords: Hypertension, Prevalence, Türkiye, Cardiovascular, Control Rate

INTRODUCTION

Hypertension, defined as systolic blood pressure $\geq 140\text{ mmHg}$ and/or diastolic blood pressure $\geq 90\text{ mmHg}$, is a global pandemic. However, its impact varies significantly across regions due to genetic, environmental, and socioeconomic factors. Turkey, a transcontinental country bridging Europe and Asia, has undergone a rapid demographic and epidemiological transition over the past three decades. This transition has shifted the primary disease burden from infectious diseases to non-communicable diseases (NCDs), with cardiovascular diseases (CVD) now accounting for the majority of deaths (Ministry of Health of Turkey, 2020).

Hypertension stands at the core of this cardiovascular burden. In Turkey, the epidemiological landscape of high blood pressure is shaped by unique lifestyle factors, particularly dietary habits characterized by high sodium consumption and increasing rates of sedentary behavior associated with urbanization. Understanding the specific epidemiology of hypertension in Turkey is crucial not only for national health policy but also for understanding disease patterns in developing economies with similar demographic profiles.

This article aims to provide a comprehensive overview of hypertension epidemiology in Turkey. It will examine prevalence trends based on large-scale national cohorts, identify Turkey-specific risk factors, evaluate the effectiveness of current control measures, and propose targeted interventions.

METHODOLOGY AND DATA SOURCES

To ensure an accurate representation of the epidemiological situation, this review synthesizes data from the most significant nationwide studies conducted in Turkey:

1. The PATENT Studies (PATENT-1 and PATENT-2): Conducted by the Turkish Society of Hypertension and Renal Diseases in 2003 and 2012, respectively. These are considered the gold standard for hypertension statistics in Turkey, covering representative samples from all geographical regions.

2. The TEKHARF Study (Turkish Adult Risk Factor Study): A long-term prospective cohort study initiated in 1990, providing invaluable data on cardiovascular risk factors and mortality trends in the Turkish population.

3. SALT-TURK Studies: Specific epidemiological surveys focused on determining the daily salt intake of the Turkish population and its relationship with blood pressure.

4. Ministry of Health Statistics: Data from the "Health Transformation Program" and chronic disease reports.

Prevalence of Hypertension in Turkey

The prevalence of hypertension in Turkey is alarmingly high, exceeding the averages of many European and North American countries.

General Prevalence Estimates

According to the PATENT-1 study (2003), the overall prevalence of hypertension in adults over 18 years of age was 31.8%. Nearly a decade later, the PATENT-2 study (2012) re-evaluated the situation. despite age-standardization suggesting a slight plateau, the crude prevalence remained high at 30.3% (Sengul et al., 2013). This implies that approximately 15 to 20 million adults in Turkey are hypertensive.

Gender Disparities

A distinguishing feature of hypertension epidemiology in Turkey is the gender gap. Contrary to trends in many Western countries where prevalence is often higher in men (especially in middle age), in Turkey, hypertension is consistently more prevalent in women.

Women: In the PATENT-2 study, the prevalence in women was approximately 32.3%.

Men: The prevalence in men was recorded at 28.4% (Sengul et al., 2013).

This disparity is frequently attributed to higher rates of obesity and physical inactivity among Turkish women compared to men, a factor that will be discussed in the risk factors section.

Age-Related Trends

As expected, prevalence increases linearly with age. In the population aged 50–59, hypertension affects nearly half of the individuals. Among those aged 70 and older, the prevalence rises to over 75%. With Turkey's population aging rapidly—the proportion of the elderly population is projected to reach 10.2% by 2023—the absolute number of hypertensive patients is expected to surge (TUIK, 2021).

Trends in Awareness, Treatment, and Control

The management of hypertension is often evaluated using the "Rule of Halves." Turkey has historically struggled with these metrics but has shown commendable improvement.

Awareness

In 2003 (PATENT-1), only 40.7% of hypertensive individuals were aware of their condition. By 2012 (PATENT-2), this number had risen significantly to 54.7%. This increase is largely credited to the expansion of primary healthcare services and family medicine practices across the country (Arici et al., 2010).

Treatment

Treatment rates have also seen an upward trajectory. The percentage of hypertensive patients receiving pharmacological treatment increased from 31.1% in 2003 to 47.4% in 2012. This suggests that access to medication and healthcare professionals has improved under the Universal Health Insurance scheme.

Control

Control of hypertension (defined as BP < 140/90 mmHg) is the ultimate goal. While control rates improved from a dismal 8.1% in 2003 to 28.7% in 2012, they remain suboptimal (Sengul et al., 2016). This indicates that while more patients are seeing doctors and getting diagnosed, therapeutic inertia or poor patient adherence prevents the achievement of target blood pressure levels.

Major Risk Factors Specific to Turkey

While age and genetics play a role, environmental and behavioral factors are the primary drivers of the hypertension epidemic in Turkey.

Excessive Salt Intake

Salt consumption is arguably the most critical modifiable risk factor in Turkey. Bread is a staple food in the Turkish diet, and traditionally, it has been very salty.

The SALT-TURK 1 study (2008) revealed that the average daily salt intake in Turkey was approximately 18 grams/day, which is more than three times the World Health Organization (WHO) recommendation of 5 grams/day (Arici et al., 2010).

Following government interventions (salt reduction in bread, public awareness campaigns), the SALT-TURK 2 study (2012) showed a reduction to roughly 14.8 grams/day. While this is a statistically significant decrease, it remains dangerously high.

The relationship is clear: regions with higher salt intake (often Central and Eastern Anatolia) correlate with higher blood pressure levels.

Obesity and Metabolic Syndrome

Turkey has one of the highest rates of obesity in the WHO European Region. The Turkish Diabetes Epidemiology Study (TURDEP-II) reported that the prevalence of obesity (BMI $\geq 30 \text{ kg/m}^2$) increased from 22.3% in 1998 to 31.2% in 2010 (Satman et al., 2013).

Obesity is particularly prevalent among women, which directly correlates with the higher hypertension prevalence observed in the female population.

Abdominal obesity and metabolic syndrome create a clustering of risk factors (hypertension, dyslipidemia, hyperglycemia) that exponentially increase cardiovascular risk.

Tobacco Use

Smoking remains a pervasive habit in Turkey, particularly among men. According to the Global Adult Tobacco Survey (GATS), approximately 41% of men and 13% of women in Turkey smoke. Smoking causes acute elevations in blood pressure and contributes to long-term arterial stiffness (Ministry of Health, 2019).

Physical Inactivity

Rapid urbanization has led to a decrease in physical activity. Traditional agricultural lifestyles have been replaced by sedentary urban jobs. Studies indicate that over 70% of the Turkish population does not engage in sufficient regular physical activity, exacerbating the risks of both obesity and hypertension.

Regional Variations

Hypertension in Turkey is not homogeneously distributed.

Western Turkey (Marmara, Aegean): Generally exhibits slightly better control rates due to higher socioeconomic status and better access to specialized healthcare, though urbanization-related stress and sedentary lifestyles remain issues.

Eastern and Southeastern Anatolia: These regions often show lower awareness and control rates. Cultural dietary habits (high consumption of animal fats and salty foods) combined with lower health literacy contribute to poorer outcomes in these areas (Onat et al., 2004).

Public Health Interventions and Government Policy

Recognizing the severity of the situation, the Ministry of Health of Turkey has implemented several strategic programs:

Salt Reduction Program (Since 2011): A landmark initiative that involved legislation to reduce the salt content in bread (from 1.75g/100g to 1.5g/100g) and tomato paste. It also included extensive media campaigns to discourage the use of table salt.

Turkey Healthy Nutrition and Active Life Program: Aimed at combating obesity through promoting physical activity and healthy eating in schools and workplaces.

Family Medicine System: The nationwide rollout of family medicine has been pivotal in screening. Family physicians are incentivized to monitor chronic diseases, including hypertension, which has boosted detection rates.

CONCLUSION AND RECOMMENDATIONS

Conclusion:

Hypertension in Turkey is a widespread epidemic characterized by high prevalence, excessive salt intake, and gender-specific disparities affecting women disproportionately. While the past two decades have seen remarkable progress in awareness and treatment coverage—largely

driven by health system reforms—the control rate of roughly 29% is insufficient to curb the rising tide of cardiovascular complications. The "silent killer" continues to be fueled by an obesogenic environment and a cultural affinity for high sodium consumption.

Recommendations:

To further reduce the burden of hypertension in Turkey, the following actions are recommended:

Aggressive Salt Reduction: Continued efforts to reformulate processed foods (cheese, olives, pickles) are necessary, moving beyond just bread.

Gender-Specific Interventions: Public health campaigns must specifically target women to address obesity and physical inactivity, perhaps through community-based programs.

Improving Adherence: Physicians need to focus on patient education to improve medication adherence. Using combination pills (polypills) could simplify treatment regimens.

Strict Tobacco Control: Although laws exist, enforcement of smoke-free environments and increased taxation on tobacco products should be maintained rigorously.

Digital Health Monitoring: Integrating home blood pressure monitoring data into the national e-Pulse (e-Nabız) health system could improve long-term tracking and control.

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NEW TECHNOLOGIES IN THE FOOD AND BEVERAGE INDUSTRY: PRODUCTION OF FUNCTIONAL FOODS WITH 3D FOOD PRINTING AND ITS USE IN THE FIELD OF HEALTH

YIYECEK İÇECEK SEKTÖRÜNDE YENI TEKNOLOJILER: 3D GIDA YAZILIMI ILE FONKSIYONEL BESIN ÜRETIMI VE SAĞLIK ALANINDA KULLANIMI

PHD Stent. Bahar AKBEZ ÖLKE

Hasan Kalyoncu Üniversiteye, Faculty of Health Seçince

Prof. Dr. Yasemin BEYHAN

Hasan Kalyoncu University, Faculty of Health Sciences

ABSTRACT

3D Ford printing has become a hilye notable technology in reçete years in both fotoda production and healthcare. White this method, foods can be printer layer by layer tol produce products with Theo desired shape, texture, and nutritional composition. Its greatest advantage is that it enables personalized nutrition. It helps make foods both easier to consume and more nutritious, especially for older adults, individuals with dysphagia, children, and people with metabolic disorders. Functional components such as vitamins, minerals, omega-3 fatty acids, probiotics, fiber, and antioxidants can be added to foods produced through 3D printing. In this way, health benefits are increased while preventing nutritional deficiencies. Many studies have produced functional foods using 3D food printing. Products such as probiotic-enriched mashed potatoes, omega-3 encapsulated gel structures, and snacks containing phenolic compounds can be given as examples. It has also become possible to produce fun shapes that can help children consume vegetables more easily. Different printing methods are used in this technology, including extrusion, binder jetting, selective laser sintering, and inkjet printing. The most common method, extrusion, is based on shaping puree- or dough-like foods through a nozzle. The hydrocolloids used help achieve the desired texture and consistency while also maintaining the stability of the structure. In the field of health, 3D food printing has many potential applications, such as producing texture-appropriate foods for patients with dysphagia, adjusting protein contents for metabolic diseases like PKU and MSUD, and contributing to the prevention of malnutrition and sarcopenia in older adults. It may also support diabetes management through the development of low–glycemic index products. However, there are some limitations to the technology. Slow printing speed, high equipment cost, software incompatibilities, food safety concerns, and consumer acceptance are major obstacles. Additionally, the use of additives in some products may lead these foods to be classified as “ultra-processed.” Overall, 3D food printing holds great potential for developing personalized, nutritious, and sustainable products in both the food industry and clinical nutrition. As technological advancements continue, its areas of application are expected to become even more widespread.

Keywords: 3D Food Printing, Functional food, Food Production Technologies

ÖZET

3D gıda baskısı, son yıllarda gıda üretimi ve sağlık alanında oldukça dikkat çeken bir teknoloji haline gelmiştir. Bu yöntemle gıdalar katman katman basılarak istenen şekil, kıvam ve besin içeriğinde ürünler üretilebilmektedir. En büyük avantajı ise kişiye özel beslenmeye imkânı sağlamasıdır. Özellikle yaşlılar, disfaji yaşayan bireyler, çocuklar ve metabolik hastalığı olan kişiler için besinlerin hem daha kolay tüketilebilir hem de daha besleyici hale getirilmesine yardımcı olur. 3D baskı ile üretilen gıdalara vitamin, mineral, omega-3, probiyotik, lif, antioksidan gibi fonksiyonel bileşenler eklenebilir. Böylece hem sağlık açısından fayda artırılır hem de beslenme yetersizliklerinin önüne geçilebilir. Yapılan birçok çalışmada 3D gıda baskısıyla fonksiyonel besin üretilmiştir. Probiyotik eklenmiş patates püresi, omega-3 kapsüllü jel yapılar, fenolik bileşik içeren atıştırmalıklar gibi ürünler bunlara örnek olarak verilebilir. Aynı zamanda çocukların sebze tüketimini kolaylaştıracak eğlenceli şekillerde ürünler üretmek de mümkün hale gelmiştir. Bu teknolojide farklı baskı yöntemleri kullanılmaktadır: ekstrüzyon, bağlayıcı püskürtme, seçici lazer sinterleme ve mürekkep püskürtme. En yaygın olan ekstrüzyon yöntemi, püre veya hamur kıvamındaki gıdaların nozzle aracılığıyla şekillendirilmesine dayanır. Kullanılan hidrokolloidler istenen doku ve kıvamı sağlarken aynı zamanda yapının stabil kalmasına yardım eder. Sağlık alanında 3D gıda baskısı; disfajili hastalar için uygun kıvamda ürün üretimi, PKU ve MSUD gibi metabolik hastalıklara özel protein içeriklerinin ayarlanması, yaşlı bireylerde malnütrisyon ve sarkopeninin önlenmesine katkı sağlama gibi birçok uygulama potansiyeline sahiptir. Ayrıca düşük glisemik indeksli ürünler geliştirilerek diyabet yönetimine destek olabilir. Bununla birlikte teknolojinin bazı sınırlamaları vardır. Baskı hızının yavaş olması, ekipman maliyetinin yüksekliği, yazılım uyumsuzlukları, gıda güvenliği endişeleri ve tüketici kabulü önemli engeller arasındadır. Ayrıca bazı ürünlerde katkı maddesi kullanımı, bu gıdaların "ultra işlenmiş" olarak değerlendirilmesine yol açabilmektedir. Genel olarak 3D gıda baskısı, gelecekte hem gıda endüstrisi hem de klinik beslenme alanında kişiye özel, besleyici ve sürdürülebilir ürünlerin geliştirilmesi için büyük bir potansiyel taşımaktadır. Teknolojik gelişmeler arttıkça kullanım alanının daha da yaygınlaşması beklenmektedir.

Anahtar kelimeler: 3 boyutlu gıda baskısı, fonksiyonel besin, gıda üretim teknolojileri

INTRODUCTION

Günümüzde bir çok alanda 3 Boyutlu Gıda Baskı Yöntemi (3D yazıcısı) kullanılmaktadır. Bu yöntem inşaat, mimarlık, enerji endüstrisi havacılık, otomobil gibi birçok alanda kullanılabilirken, son zamanlarda gıda üretimi yapılması ile birlikte beslenme ve sağlık alanında kullanılmaya başlanmıştır (Zhu W et al., 2019). 3D gıda baskısı sayesinde gıdalar daha çekici, kolay çiğnenebilir ve yutulabilir hale gelebilir. Protein, vitamin, antioksidan veya probiyotik gibi faydalı bileşenler gıdaya eklenebilir. Üretimde gıda atığı azaltılabilir ve tarım endüstrisi yan ürünleri yeniden değerlendirilebilir. Bu nedenle kişiye özel 3D gıda üretimi, özellikle diyabet, obezite,kanser ve yaşlılıkta beslenme zorluğu yaşayan kişilerde bireyselleştirilmiş beslenme planlarının uygulanmasında umut veren bir yöntemdir (Varvara, Szabo & Vodnar, 2021). Son yıllarda fonksiyonel gıdalar, temel besin değerinin ötesinde fizyolojik faydalar sağlama potansiyelleri nedeniyle önemli ölçüde bilimsel ve halk sağlığı yönünden oldukça ilgi çekmektedir. Fonksiyonel gıdaları, EFSA, FDA ve WHO gibi uluslararası kuruluşlar, kardiyovasküler hastalık, tip 2 diyabet ve bazı kanserler dahil olmak üzere kronik bulaşıcı olmayan hastalıkların önlenmesine ve yönetimine katkıda bulunabilecek biyoaktif bileşenler içeren gıdalar olarak tanımlamaktadır (Fekete et al., 2025). 3D baskı gibi yeni üretim teknolojileri, kişiye özel ve besin açısından dengeli, zenginleştirilmiş, güçlendirilmiş fonksiyonel gıdaların geliştirilmesini mümkün kılmaktadır (González et al.,

2025). Bu makalede, fonksiyonel gıdaların üretiminde 3D baskı teknolojisinin rolü ve sağlık alanındaki uygulama potansiyeli ele alınmıştır. Burada da özellikle, 3D baskı mürekkeplerinin akıcılık özellikleri, baskı sürecinde besin ve probiyotik stabilitesi, bebek ve yaşlı beslenmesi ile disfaji hastaları için kişiselleştirilmiş gıda üretimi gibi uygulamalar tartışılacaktır.

THREE-DIMENSIONAL FOOD PRINTING

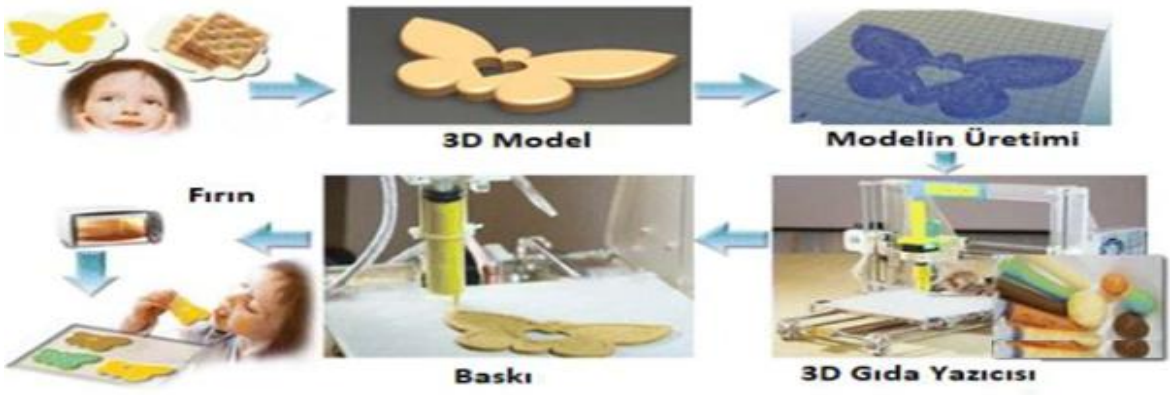
Katmanlı üretim veya hızlı prototipleme olarak da bilinen üç boyutlu baskı yöntemi dijital bir dosyadan üç boyutlu katı nesneler üretme sürecidir (Varvara, Szabo & Vodnar, 2021). Üç boyutlu gıda yazılımı aynı zamanda gıda katmanlı üretim süreci olarakta bilinmektedir. Bu teknoloji sayesinde kendine özgü 3D şekillere sahip geleneksel yöntemlerle yapılamayan birçok gıda oluşturulmuştur (Mudau & Adebo, 2024).

3D yazıcıların ilk ortaya çıkışı 1980'lerde endüstride yedek parça üretiminde kullanılması için üretilen stereolitografinin geliştirilmesiyle başlamıştır (Lourenço et al., 2025). Gıda sektörüne gelince, 3D gıda yazıcısı 2006 yılında bir grup öğrenci tarafından geliştirilen çikolata figürleri, kurabiye hamuru ve peynir üretiminde uygulanmıştır. Bu dönemde, ilk çok malzemeli 3D yazıcısı farklı gıda ürünlerini elde etmek için kullanılmıştır. İki bin altı ve iki bin dokuz yılları arasında, sıcak hava kullanılarak, çay şekeri eritilip, büyük şeker heykelleri basılmıştır. Yeniden doldurulabilir şırınga benzeri çift ekstrüderle donatılmış başka bir yazıcı, çikolata, fıstık ezmesi, dondurma, hatmi, reçel, bal, ketçap, hardal, krem peynir ve peynir vb. herhangi bir sıvı veya macun türünü basmak için kullanılmıştır. Diğer yazıcılar ise kurabiye hamuru, patates püresi, ezilmiş kuruyemiş veya krep gibi ince katmanlı gıdalardan heykeller oluşturmak için kullanılmıştır (Varvara, Szabo & Vodnar, 2021). 3D gıda yazıcılarının çalışma yöntemi geleneksel 3D yazıcılarla benzerdir. Gıda bileşenlerinin karışımları, gıda ile temas edebilen bir enjektöre veya kartuşa yerleştirilir. Bu enjektör, içindeki malzemeyi küçük bir delikten geçirerek katman katman bir tabağa veya yüzeye dikkatlice yerleştirir (Shah et al., 2024). İstenen gıdanın üretilmesi genellikle üç aşamadan oluşur:

1. 3D modelin oluşturulması,
2. Ürünün basılması
3. Son işlemlerin uygulanması

3D gıda baskısı süreci, öncelikle sanal bir üç boyutlu modelin oluşturulmasıyla başlar. Bu model, yazılım tarafından katmanlara dönüştürülür ve yazıcı, bu katmanları sırayla birleştirerek 3D baskılı ürünü oluşturur (Varvara, Szabo & Vodnar, 2021). Yazıcıdan çıktıktan sonra ürüne fırınlama, kesme, pişirme gibi işlemler uygulanır (Singhal et al., 2020). Üç boyutlu baskının doğru şekilde çalışabilmesi için cihazın donanımı ve yazılımı uyum içinde olmalıdır. (Shah et al., 2024). 3D yazıcılarla süt ürünleri, meyve ve sebze püreleri, kurabiyeler çikolatalar, sakız veya kişiye özel besin değeri yüksek gıdalar gibi birçok gıda basılabilmektedir (Singhal et al., 2020). 3D teknolojisiyle üretilen ürünler, özel beslenme gereksinimleri olan kişiler örneğin hamile kadınlar, vegan/vejetaryen bireyler için de kolayca uyarlanabilir (Varvara, Szabo & Vodnar, 2021). Bu teknolojinin başka bir avantajı, çeşitli bileşenlerin bir araya getirilmesiyle üretilen ürünün sağlık açısından daha faydalı ve işlevsel olmasını sağlayabilmesidir. Örneğin Sara Olivera ve arkadaşları kurabiye hamurunun içine kapsüllenmiş üzüm kabuğu özütü eklemiştir. Bunun sonucunda kapsüllenmiş üzüm kabuğu özütü içeren kurabiyelerin daha fazla fenolik bileşik ve antioksidan içerdiği kanıtlanmıştır (Oliveira et al., 2021). 3D basılı gıdaların en önemli bileşenleri bağlayıcı maddeler, renklendiriciler ve zenginleştiricilerdir. Bağlayıcı olarak pektin, ksantan sakızı, kitosan vb maddeler kullanılır. Bunlar üretilen besinlerin kıvamı, dokusu, elastikiyeti ve viskozitesini belirlemede önemlidir. Kitosan aynı zamanda antimikrobiyal ve antioksidan özellik gösterebilen bir biyoaktif bileşendir. Renklendirici olarak antosiyaninler, klorofil, spirulina vb maddeler kullanılır. Patlıcan kabukları, gül yaprakları,

ahududu gibi maddeler antosiyaninler açısından zengindir. Bunlar gıdaya renk verirken aynı zamanda antioksidan, antiinflamatuar özellikleriyle de katkıda bulunurlar. Aynı şekilde spirulinada içerdiği protein, probiyotik, antioksidanlar nedeni ile renklendirme yaparken oksidatif stresi azaltabilir. Gıdanın besin değerini artırabilir. Zenginleştirici olarak vitaminler, mineraller, probiyotikler, ek lif gibi takviyeler bu yöntemle yapılabilir (Varvara, Szabo & Vodnar, 2021).



Resim 1. 3D gıda örneğinin oluşturulma aşamaları (Sun et al., 2015).

COMMON 3D FOOD PRINTING METHODS

Extrusion-Based Printing Method

Ekstrüzyon tabanlı 3D gıda baskısı, özetle, gıda mürekkepleri olarak adlandırılan özel olarak hazırlanmış macun kıvamındaki malzemelerin, bir nozül aracılığıyla katman katman dışarı itilmesi (ekstrüzyon) ve bu sayede istenilen 3D yapının oluşturulması sürecidir (Tan et al., 2018). Baskı sürecinin başarısı, kullanılan gıda malzemesinin özelliklerine bağlıdır. Gıdalar önce püre haline getirilir ve parçacık boyutu küçültülür. Karışımın akışkan kalması için formülasyon ayarlanır. Yazdırılabilirliği artırmak ve karışıma doğru kıvamı kazandırmak için hidrokolloidler (nişasta, pektin, jelatin, nanocellüloz, aljinat, karragenan vb.) kullanılır. Gıda karışımı nozülden geçerken makaslama kuvveti etkisiyle akışkan hale gelir ve yazıcı tarafından katman katman yerleştirilerek üç boyutlu yapı oluşturulur. Nozülden çıktıktan sonra makaslama kuvveti ortadan kalkar ve malzemenin viskozitesi yeniden artar. Hidrokolloidler iç yapıyı hızla yeniden düzenleyerek gıdanın şeklini sabit tutan bir jel ağı oluşturur. Bazı durumlarda, kalsiyum püskürtme veya ısı uygulama gibi ek bir kürleme işlemi ile şekil daha da sağlamlaştırılır. 3D baskıda kullanılan gıdalar genellikle püre, jel veya macun kıvamında hazırlanır. Baskı sırasında yukarıda da belirtildiği gibi hidrokolloidler (aljinat, karragenan, pektin, jelatin vb.) kullanılarak kıvam, akışkanlık ve şekil koruma sağlanır (Tan et al., 2018). Ekstrüzyon temelli 3D gıda baskı teknolojisi, sıcak çikolata, hamur, patates ya da et püresi gibi yumuşak ve akışkan gıda materyallerinin katmanlı olarak şekillendirilmesinde sıklıkla tercih edilen bir yöntemdir. Bu teknik, Cornell Üniversitesi'nde yapılan çalışmalarda kek kreması, işlenmiş peynir ve şekerli kurabiye hamurları gibi çeşitli gıdaların basımında başarıyla uygulanmıştır. Çikolatanın sıcak eriyik ekstrüzyonuyla 3D baskısı ilk kez Fabahome sistemi kullanılarak yapılmış ve baskı doğruluğunu etkileyen faktörler incelenmiştir. Daha sonra bu teknik, Choc Edge, 3D Systems, Hershey ve Chocabyte gibi firmalar tarafından ticari çikolata yazıcılarına dönüştürülmüştür (Liu et al., 2017). Ekstrüzyon yöntemi ile üretilebilen bazı gıdalar şunlardır;

1. Püre ve Yemek Bazlı Gıdalar

Meyve & sebze püreleri, pişmiş et ve balık kıymaları, süt ve nişasta bazlı jeller, vitamin ve probiyotikle zenginleştirilmiş ürünlerdir.

2. Tatlı ve Hamur Bazlı Ürünler

Çikolata, krep ve pankek hamuru, makarna ve pirinç eriştesi, badem ezmesi, şeker hamuru gibi ürünlerdir.

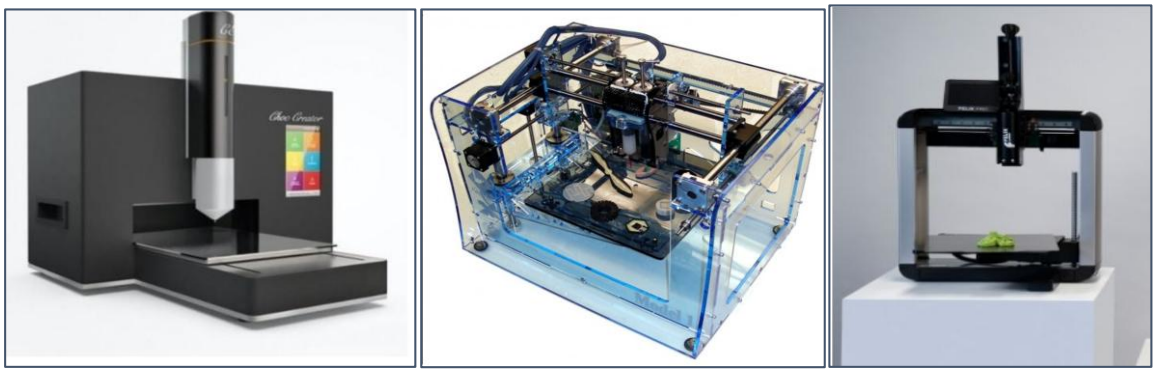
3. Geniş Kapsamlı/Patentli Gıdalar

Nanocellüloz katkılı hamburger, nugget, pizza, kek, makarna ve şeker çeşitleri gibi çok daha geniş gıda gruplarını içeren ürünlerdir (Tan et al., 2018).

Ekstrüzyon tabanlı 3D baskı yöntemi, gıda sektöründe en yaygın kullanılan tekniktir. Bu yöntemin temel amacı, bireysel ihtiyaçlara ve sağlık durumlarına göre kişiselleştirilmiş gıdalar üretmektir. Özellikle disfaji, yani yutma güçlüğü olan bebek ve yaşlılar için uygun kıvamlı görsel olarak çekici besinler üretmeye olanak sağlar. Örnek olarak hidrokolloid içeren sebze püreleri, buharda pişmiş çörekler, yumuşak dokulu et ürünleri gibi. Ayrıca bu yöntem karmaşık ve estetik gıda tasarımlarına odaklanır.

3D baskısının yanı sıra, 4D baskı, ısı, pH veya ışık gibi dış uyaranlarla gıdanın şekil, renk veya aromalarının değiştirilmesi sağlanırken, 5D ve 6D baskı ise çok eksenli hareketlerle daha karmaşık, kavisli ve dayanıklı yapılar üretmeyi mümkün kılar. Ayrıca 3D baskıda üretilen gıdanın iç yapısı tasarlanarak, o yapıya uygun şekilde gıda bileşenlerinin salınım hızı ve zaman ayarlaması yapılabilir. Örneğin; Gözenek sayısı ve büyüklüğü arttıkça, içindeki besin veya aroma daha hızlı salınır. Ph, mikrodalga veya UV ışığı gibi uyarılarla gıdanın tat, aroma veya vitamin içeriği değiştirilebilir (Teng et al., 2022).

a b c



Resim 2: Çeşitli ekstrüzyon tabanlı ticari 3D gıda yazıcıları

a) Fab@home (şırınga tabanlı eklemeli yazıcı sistemi (Malone & Lipson, 2006).

b) Choc Creator(çikolata üretimi için sıcak ekstrüzyon yazıcı sistemi (P M, 2024).

c) Felix Food (macun kıvamındaki malzemeleri katman katman biriktirme sistemi (P M, 2024).

Binder Jetting Method

Bağlayıcı püskürtme yöntemi olarak adlandırılan bu yöntemde bilgisayar üzerinden tasarlanmış bir desen temel alınır. İnce tozlar katmanlar halinde serilir. Sıvı bağlayıcılar veya mürekkepler

bu katmanlı toz yatağına püskürtülür. Böylelikle toz parçacıkları birbirine yapışır ve yenilebilir 3D ürünler üretilir. Diğer 3D gıda baskı yöntemlerinden farklı olarak bu yöntemde toz parçacıkları püskürtme işleminden sonra birbirine yapışır. Böylelikle katmanlar sabitlenmiş olur (Sun et al., 2022).

Baskı işlemi oda sıcaklığında olur. İşlemin gerçekleşmesi için herhangi bir ek sıcaklık veya ısıya ihtiyaç yoktur. Oda sıcaklığında baskı gerçekleştiği için tozun oksidasyona uğraması veya fiziksel olarak değişmesi gibi problemler oluşmamaktadır. Diğer 3D baskı yöntemlerine göre çok daha hızlı üretim, çok daha katı maddeler oluşturabilme gibi özellikleri vardır. Ayrıca bu yöntem gıdalara renk baskısı yapabilme özelliğine de sahiptir (Nguyen et al., 2026).

John Zhou ve arkadaşlarının yaptığı bir çalışmada bağlayıcı püskürtme 3D yazıcısı ile kalsiyum kazeinat kullanılarak yüksek proteinli yenilebilir gıdalar üretilmesi mümkün olmuştur (Sun et al., 2022). Chadwick ve arkadaşları bağlayıcı püskürtme yöntemi ile baskı tozu olarak bezelye unu ve bağlayıcı olarak sıvı bir çözelti kullanarak atıştırmalık üretmiştir (Chadwick et al., 2024).

Selective Laser Sintering (SLS) Method

Seçici lazer sinterleme denen bu yöntem, toz bazlı baskı yöntemlerinden biridir. SLS'de bir toz yatağı oluşturulur ve bu toz yatağına kızıl ötesi ışın uygulanarak her katman kızıl ötesi ışınıyla birleşerek 3D gıda yapıları oluşturulur. Toz sıkıştırılmadığı için daha çok gözenekli ve hafif yapılar oluşturulabilir. Örnek olarak bu yöntemde; Buğday unu, maltodekstrin, palm yağı tozu gibi karışımlar kullanılmıştır. Bunlar lazerle kolaylıkla sinterlenebilir. Baskıdan çıkan ürünler çok kırılgan olabileceği için fırınlama ve buharlama yapılır (Noort, van Bommel, & Renzetti, 2017). SLS ile 3D gıda üretimi yönteminin uzun baskı süresi, parçaların yüzey dokusunun çeşitli olması, parçalarda termal bozulma görülmesi gibi dezavantajları vardır (Prithviraj et al., 2025). Şeker ve nişasta gibi toz bileşenler SLS yönteminde kullanılır ve yapay renk pigmentleri ve koku vericileri gibi katkı maddeleri eklenerek çeşitli renkte ve tatta ürünler üretilebilir (Lee, 2021).

Inkjet Printing Method

Mürekkep püskürtmeli baskı denilen bu yöntemde iki tür baskı şekli vardır. Birincisinde sürekli püskürtme yönteminde piezoelektrik kristalin titreşimiyle sürekli olarak püskürtme sağlanır. İkincisinde isteğe bağlı damla püskürtme mürekkep bir vana kontrolüyle yalnız gerektiği zaman damla damla püskürtme yapılır. Bu yöntem daha yavaştır. Ama daha yüksek çözünürlük sağlar. Bu yöntemle sadece düşük viskoziteli sıvılar basılabilir. Çikolata, sıvı hamur, şeker kaplama, reçel, peynir/sos jelleri, et macunu gibi. Bu yöntemin yüksek çözünürlük, çoklu renk ve malzeme kullanımı, düşük enerji ihtiyacı, hızlı yüzey işlem kapasitesi gibi avantajları vardır. Ancak sadece basit şekiller üretilebilir. Tam hacimli 3D ürünler için uygun değildir. Ayrıca baskı sonucunda oluşan madde çok kırılgan olabilir (Pitayachaval et al., 2018). Bu yöntem en sık kullanılan gıda süsleme veya yüzey doldurma yöntemidir. Bu yöntemle elde edilen ürün kek, kurabiye veya şekerleme gibi gıda maddelerinin yüzeyine yerleştirilir. Dijital bir dosyadan görüntü oluşturulur. Küçük gıda mürekkebi damlacıkları püskürtülür. Gıdaya temas etmez. Bu nedenle gıda doldurma sırasında kirlenmeye karşı korunur. Mürekkep püskürtmeli sistemler yalnızca düşük viskoziteli malzemeleri işleyebilir. Bu nedenle karmaşık yapıdaki gıdaların üretimine uygun değildir. Bu yöntemde genellikle çikolata, peynir, şekerli krema, reçel, jel, sıvı hamur, gibi akışkan gıda maddeleri kullanılır (Pitayachaval et al., 2018).

Yöntem	Çalışma Prensibi	Uygun Malzemeler	Avantajları	Dezavantajları	Kaynak
Ekstrüzyon Tabanlı Baskı	Gıda hamuru veya yarı katı malzeme, sıcaklık ve viskozite kontrolüyle bir nozül aracılığıyla katman katman platforma sıkılır.	Patates püresi, çikolata, peynir, hamur, jeller, meyve-sebze püreleri	Yüksek kişiselleştirme imkânı; farklı bileşenlerle çalışabilme, düşük maliyetli donanım	Katman stabilitesi düşük olabilir; viskozite ve sıcaklık kritik, baskı süresi uzun	(Liu et al., 2017, Mantihal et al., 2019, Thejasvi et al., 2024)
Bağlayıcı Püskürtme (Binder Jetting)	Toz halindeki bir tabakaya sıvı bağlayıcılar püskürtülerek her bir katman sertleştirilir	Şeker, un, nişasta, kakao, renkli gıda tozları	Karmaşık, görsel olarak zengin yapılar oluşturabilir; dekoratif ürünlerde etkili	Mekanik dayanıklılık düşüktür; toz-bağlayıcı uyumu gerektirir; maliyetli	(Carolo & Guthrie, 2024, Digital Making @ Illinois, 2019)
Seçici Lazer Sinterleme (SLS)	Toz gıda malzemeleri, lazer enerjisiyle belirlenen bölgelerde sinterlenerek katman katman birleştirilir.	Şeker, süt tozu, protein tozları, nişasta bazlı karışımlar	Yüksek çözünürlük; karmaşık geometrik şekiller oluşturabilir	Yüksek sıcaklık, besin bileşenlerinin bozulmasına yol açabilir; maliyet yüksek	(Oliveira et al., 2021)
Mürekkep Püskürtmeli Baskı (Inkjet Printing)	Sıvı veya yarı sıvı gıda çözeltileri, püskürtme ile yüzeye damla damla uygulanır.	Sıvı gıda mürekkepleri, aroma ve renk çözeltileri, vitamin karışımları	Yüksek çözünürlük; yüzey dekorasyonu ve renkli baskılarda etkili	Yalnızca ince katmanlarda uygulanabilir; yapısal dayanıklılık sınırlıdır	(Digital Making @ Illinois, Varvara, Szabo & Vodnar, 2021)

Tablo1. 3D gıda yazılımı üretim yöntemleri avantajları ve dezavantajları

FUNCTIONAL FOODS AND THEIR HEALTH BENEFITS

Fonksiyonel besinler Academy of Nutrition and Dietetics'te çeşitli beslenme düzeninin parçası olmak üzere düzenli ve etkili seviyede tüketildiğinde sağlık üzerinde potansiyel açıdan faydalı bir etki yapan, zenginleştirilmiş, güçlendirilmiş veya geliştirilmiş bütün gıdalar olarak tanımlanmıştır. Institute of Food Technologists' de ise temel beslenmenin ötesinde sağlık açısından yarar sağlayan hedef kitleye yönelik gıdalar ve gıda bileşenleri olarak tanımlanmıştır (Litwin et al., 2018)**.** Fonksiyonel gıdalar, sağlık üzerindeki olumlu etkileri nedeniyle dünya çapında ilgi görmektedir. Bu besinler; metabolizmanın işleyişine, bağışıklık sisteminin güçlenmesine ve inflamasyonun kontrol altında tutulmasına katkı sağlayan antioksidan, polifenol, flavonoid, çeşitli bitkisel bileşikler ile prebiyotik ve probiyotik türünden pek çok biyoaktif özelliğe sahip maddeyi doğal yapılarında barındıran besinlerdir (Fekete et al., 2025). Bu gıdalarda bulunan biyoaktif bileşikler; antidiyabetik, antimikrobiyal, antikanser ve anti-inflamatuar gibi çeşitli yararlı etkilere sahiptir. Bu bileşiklerin büyüme-gelişmeyi desteklediği, beslenme yetersizliklerini önlemeye yardımcı olduğu ve hipertansiyon, kanser, obezite ve kalp-damar hastalıkları gibi yaşam tarzı ile ilişkili hastalık riskini azaltabildiği gösterilmiştir.

Fonksiyonel gıdalara olan ilginin artması, bireylerin artık sadece "karın doyurmak" yerine sağlığı ve yaşam kalitesini destekleyen besinleri tercih ettiğini göstermektedir (Mudondo et al., 2025). Fonksiyonel gıdalar, antioksidanlar, prebiyotikler, fitosteroller gibi sağlığı destekleyici bileşenler içermekte ve bu nedenle yetersiz veya dengesiz beslenmenin kronik hastalıklara yol

açabileceği göz önüne alındığında sağlıklı beslenme açısından önemleri daha da artmaktadır (Wang et al., 2025).

SOURCES OF FUNCTIONAL COMPONENTS

Bazı gıdalar içeriği bakımından doğal fonksiyonel gıda olarak sınıflandırılabilir. Doğal fonksiyonel gıdalar vücudun gereksinimi olan besin ögelerini sağlarken aynı zamanda bulaşıcı olmayan kronik hastalıkların önlenmesinde de birçok fayda sağlar. Tam tahıllar, baklagiller, meyve ve sebzeler, fermente süt ürünleri, balık, ceviz ve fındık gibi kuruyemişler doğal fonksiyonel gıdalar olarak tanımlanabilir (Fekete et al.,2025, Kara, 2024**).**

Bunun dışında fonksiyonel gıdalar fonksiyonel bir bileşen ile de zenginleştirilmiş olabilir. Örnek olarak B vitamini ile zenginleştirilmiş süt ve süt ürünleri, E ve D vitaminleri ile zenginleştirilmiş bitkisel kaynaklı yağlar, folik asit ile zenginleştirilen tahıl grubu ürünleri verilebilir. Kendisi doğal fonksiyonel gıda olan baklagillerde aynı zamanda flavonoidler de bulunmaktadır. Örneğin püre ve humus haline getirilmiş fasulye hem flavonoid hem de lif açısından zengindir (Kara, 2024).

NATURAL FUNCTIONAL FOODS

Cereals and legumes

Tahıllar sindirim sistemi açısından birçok faydası kanıtlanmış lif içerikleri ile bilinirler. Aynı zamanda B vitaminleri açısından zengin buğday kepeği, fosfor, demir, manganez, magnezyum, beta glukan içeren yulaf doğal fonksiyonel gıda olarak değerlendirilir. Tahıllarda yer alan diyet lifinin kan kolesterolü ve kan şekeri üzerinde olumlu etkileri vardır (Vignesh et al., 2024). Tahıllar fonksiyonel bileşenlerle zenginleştirilerek de fonksiyonel ürün özelliği sağlanabilir. Parilla ve Ruiz arkadaşları ile yaptığı bir çalışmada şarap üretiminden kalan üzüm posası tozu ile zenginleştirilmiş ekmek üretmişlerdir. Üretilen bu ekmeğin daha fazla çözünür lif, fenolik bileşenler, çözünmez lif, lipit ve protein içerdiği ve daha yüksek antioksidan kapasiteye sahip olduğu saptanmıştır (Muñoz-Bernal et al., 2024). Baklagiller aynı tahıllar gibi yüksek lif içermektedir (Hossain et al., 2025). Soya fasulyesi ve onun türevleri (tofu, soya sütü) izoflavonlar ve tüm esansiyel aminoasitleri barındıran yüksek miktarlarda protein içermektedir. Bu besinlerde bulunan izoflavonların diğer sağlık yararlarının yanısıra, kemik sağlığına da olumlu etkilerinin olduğu belirtilmiştir (Vignesh et al., 2024).

Fruits and Vegetables

Meyve ve sebzeler, vitamin, mineral, fenolik bileşenler, karotenoidler gibi biyoaktif bileşenler içerdikleri için doğal fonksiyonel gıda olarak değerlendirilir. Meyve ve sebzelerde bulunan biyoaktif bileşenler güçlü antioksidan etki göstermektedir (Kara, 2024). Domatesin içerdiği likopen ve diğer antioksidanlar, yapılan araştırmalara göre prostat kanseri ve kalp-damar hastalıkları riskinin azalmasıyla ilişkilendirilmektedir.” Yapılan araştırmalarda domatesin içerdiği likopen ve diğer antioksidanlar nedeniyle prostat kanseri ve kalp rahatsızlıkları riskini azaltabileceği ileri sürülmüştür. Soğan ve sarımsakta da inülin ve fruktooligosakkarit (FOS) gibi prebiyotikler bulunmaktadır. Portakal, greyfurt limon gibi turunçgillerin ise yüksek miktarda C vitamini ve flavonoidler içerdiği için antioksidan özellik göstermesi sayesinde bağışıklık sistemini destekleyebileceği belirtilmiştir (Vignesh et al., 2024).

Oilseeds and Nuts

Yağlı tohumlar ve kuruyemişler omega-3 ve flavonoid içeriği nedeniyle sağlık yararları yönünden öne çıkmaktadır (Hossain et al., 2025). Örneğin ceviz önemli bir omega-3 kaynağıdır.

Keten tohumu da omega-3 ün bir türevi olan alfa linoleik asit açısından zengindir. Alfa linoleik asit kardiyovasküler sağlığı iyileştirmede ve kan basıncını düşürmede faydalıdır. Susam tohumu da sesamol, sesamolin, sesamin içeriği ile anti inflamatuar etkilere sahiptir (Vignesh et al., 2024).

Animal Based Foods

Et birçok biyoaktif bileşene sahiptir. Et başta taurin, biyoaktif peptitler, koenzim Q10, kreatin, glutatyon, konjuge linoleik asit (CLA), alfa-lipoik asit, kolin, L-karnitin gibi bileşenler içermesiyle doğal fonksiyonel gıda olarak değerlendirilir (Hossain et al., 2025). Bu biyoaktif bileşenlerden konjuge linoleik asit'in antidiyabetik, yağ birikimini azaltıcı etkileri mevcuttur. Konjuge linoleik asit hem et hem de süt ürünlerinde bulunur. Kümes hayvanlarında ve yumurtada da az da olsa bulunmaktadır (Kara, 2024). Ton balığı, uskumru, somon gibi yağlı balıklar beyin fonksiyonlarına ve kalp sağlığına faydalı olan yüksek omega-3 içeriğine sahiptir (Vignesh et al., 2024). Süt ve süt proteinlerinden kazein ile peynir altı suyu proteinin bağışıklık sisteminde birçok yararının olabileceği belirtilmektedir (Kara, 2024).

Probiotics ve Prebiotics

Probiyotikler sindirim sisteminde mikrobiyal dengeyi sağlayan canlı mikroorganizmalardır. Yoğurt, peynir, lahana turşusu gibi gıdalar probiyotik içeriği yüksek gıdalardır. Yoğurt ve süt içerinde bulunan Lactobacillus bakterilerinin kardiyovasküler hastalıkları iyileştirme, kanseri önleme, bağışıklığı düzenleme gibi birçok sağlık yararının olduğundan söz edilmektedir. Prebiyotikler, sindirilemeyen ancak bağırsaklarda yararlı mikroorganizmaların çoğalmasını ya da aktivitelerinin artmasını destekleyen özel türde besinsel liflerdir. Soğan sarımsak, muz, karnıyarık otu **(**Psyllium**)** gibi besinlerde bulunan prebiyotikler inülin, fruktooligosakkarit (FOS) ve beta glukan içermektedir. Bunlar kabızlığın önlenmesinde, obezite ve diyabet tedavisinde olumlu etkiler gösterebileceği ileri sürülmektedir (Vignesh et al., 2024). Liu ve arkadaşları besin değerini artırmak amacıyla patates püresine probiyotikleri (Bifidobacterium animalis subsp. lactis BB-12) eklemiştir (Liu, Bhandari, & Zhang, 2020). Tüm bunların dışında bazı içecek ve baharatların içerisinde de doğal biyoaktif bileşenler vardır. Yeşil çayın içerisinde kateşin bulunmaktadır. Kateşin bitkilerde doğal olarak bulunan bir flavonoiddir. Antioksidan özelliği nedeniyle kronik hastalık ve oksidatif strese karşı koruyucu etkisinin olabileceği düşünülmektedir. Baharat olarak kullanılan zerdeçal, içerisinde bulunan kurkumin'den dolayı güçlü anti inflamatuar etkiye sahiptir (Vignesh et al., 2024). Zhang ve arkadaşları tahıl bazlı hamurları, farklı oranlardaki kalsiyum kazeinat, buğday unu ve su ile oluşturduktan sonra içerisine probiyotik (Lactobacillus plantarum) eklemiş ve bu ürünü fırınlandıktan sonra bile içerisindeki probiyotik canlılığının korunabildiğini göstermişlerdir (Zhang, Lou, & Schutyser, 2018).

MODIFIED FUNCTIONAL FOODS IN A PLANNED WAY

Fonksiyonel gıdaların bir bölümü, besin değerini artırmak veya sağlığa ek faydalar sağlamak için özellikle geliştirilmiş ürünlerden oluşur. Bu gıdalara omega-3 yağ asitleri, fitosteroller, probiyotikler ya da çeşitli vitamin ve minerallerin eklenmesi sadece eksikliği gidermek için değil; aynı zamanda kalp sağlığını desteklemek, kan yağlarını dengelemek veya bağırsak florasını iyileştirmek amacıyladır (Fekete et al., 2025). Zenginleştirilmiş fonksiyonel gıdalar, belirli besin ögesi ve/veya bileşenini artırmak ve ek sağlık faydaları sağlamak için özel olarak geliştirilmiş ürünlerdir. Bu gıdalar içerisine vitamin, mineral veya biyoaktif maddeler eklenerek besin değerleri artırılmış gıdalardır. Böylece hem yetersiz ve dengesiz beslenmenin önlenmesine yardımcı olunur, hem de özellikle risk altındaki kişilerin sağlığı desteklenir. Örneğin un, süt ve kahvaltılık tahıllar; demir, D vitamini, kalsiyum ve folik asit gibi besin

ögeleri ile sıklıkla zenginleştirilen temel gıdalardır (Hossain et al., 2025). Bu konuda Fontane ve arkadaşları yaptıkları bir çalışmada fitosterollerle zenginleştirilmiş besinlerin tüketiminin LDL kolesterol düzeyini azalttığını bulmuşlardır (Fontané et al., 2023). Yine başka bir çalışmada zeytin ve havuç yaprağı unuyla zenginleştirilmiş makarnanın geleneksel makarnadan daha fazla antioksidan ve daha yüksek polifenol içerdiği belirtilmiştir (Conti et al., 2023). Kewuyemi ve arkadaşları, öğütülmüş sarı un kurdu içeren buğday unu hamurundan 3D baskı yöntemiyle atıştırmalıklar üretmiş ve bu ürünlerde toplam esansiyel amino asit miktarı, protein sindirilebilirliği ve düzeltilmiş amino asit skorunun geleneksel ürünlere kıyasla arttığını rapor etmiştir (Kewuyemi, Kesa, & Adebo, 2022).

THE ROLE OF 3D FOOD PRINTING IN FUNCTIONAL FOOD DEVELOPMENT

Bir gıdayı fonksiyonel hale getirilmek için beş temel yöntemden faydalanılır. Birincisi gıdadan zararlı bir şeyin elimine edilmesi. Örneğin varsa alerjen bir proteinin gıdadan eliminasyonu. İkincisi gıdada zaten olan vitamin, mineral gibi faydalı bir bileşenin düzeyinin artırılması. Örneğin tuza iyot eklenmesi. Üçüncüsü normalde o gıdada bulunmayan ama faydası kanıtlanmış bir ürünün gıdaya eklenmesi. Örneğin yoğurtlara prebiyotik fruktan (inülin) eklenmesi. Dördüncüsü fazla tüketildiği zaman zararlı olan bir gıda bileşeninin değiştirilip yerine sağlıklı bir alternatifin konulması. Örneğin mayonezdeki yağın azaltılıp yerine modifiye nişasta eklenmesi. Beşincisi Gıdada bulunan yararlı bir bileşiğin vücut tarafından kullanılabilirliğini ya da ürün içerisindeki dayanıklılığını artırmak amacıyla bazı iyileştirmeler yapılması. Örneğin bitki sterolleriyle zenginleştirilmiş margarinlerdir ki, bunlardaki bitki sterollerinin tüketimi ile LDL kolesterol 'de %10-15 azalma sağlandığı belirlenmiştir (Gibney, 2010). Bu yöntemin bazı avantajları bulunmaktadır. Bunlardan en önemlisi 3D gıda baskısı sayesinde bazı gıdaların kişiye özel üretebilmesidir. Bu yöntemle gıdaların şekli, kıvamı, besin içeriği kişiye özel belirlenebilir ve besinin sağlık açısından yararı en üst seviyeye çıkarılabilir. Proteinler, karbonhidratlar, yağlar, vitamin ve mineraller gibi makro ve mikro besin ögeleri 3D gıda baskısında fonksiyonel bileşenler olarak yer alan bileşiklerdir (Mudau & Adebo, 2024). Proteinler 3D gıda baskısı ürünlerinin yapısal özelliklerini belirler. Örneğin yumurta albümini ve kalsiyum kazeinat gibi proteinler ürünlerin daha sağlam yapıda olmasını ve formunu daha iyi korumasını sağlar (Lourenço et al., 2025). Ayrıca, yumurta albümini içerdiği biyolojik olarak aktif peptitler sayesinde antioksidan özellik gösterir ve bağışıklığı destekleyici, anti-inflamatuar ve potansiyel antikanser etkiler sunar. Yenilebilir böcekler demir, çinko, bakır gibi mikro besin ögelerince zengindir. Bunlar aynı zamanda geleceğin alternatif bir protein kaynağı olarak düşünülmektedir (Çakmak & Gümüş, 2020). Peynir altı suyu proteini izolatı, bir karışımın viskozitesini düşürerek daha akıcı bir yapı meydana getirir ve böylece 3D baskıya uygunluğu artırır. Bu ürün ayrıca vücutta antioksidan, bağışıklığı destekleyici ve sindirime yardımcı biyolojik etkilere de sahiptir (Mudau & Adebo, 2024). İspanya' da Novameat adlı bir şirket bezelye, deniz yosunu ve pirinç gibi besinleri kullanarak et benzeri doku ve besin değeri sağlayan vegan et üretmiştir (Scionti, 2018). Bu yöntemde kullanılan bir diğer besin olan bezelye proteini 3D gıda üretiminde emülgatör olarak görev yapar, ayrıca ürünün şekil bütünlüğünü, dokusal kalitesini ve besin değerini artırır. Bezelye proteninin bazı kanser türlerini önleme, ateroskleroz, obezite riskini azaltma gibi sağlık açısından faydalı etkileri olduğu ileri sürülmektedir (Mudau & Adebo, 2024). Ülkemizde Demircan ve arkadaşları istiridye mantarı, reishi mantarı, safran süt mantarı ile sığır etini zenginleştirmiş ve bu şekilde bitki bazlı proteinle güçlendirilmiş amino asit içeriği yüksek et analogları oluşturmuştur (Demircan et al., 2023). Karbonhidratlar, basılan ürünün kıvamı ve dokusunu belirleyen temel bileşenlerdir. Nişasta ve nişasta türevleri, pektin, lifler, guar gam gibi sakızlar basılan ürünün stabil yapıda kalmasına yardımcı olur (Lourenço et al., 2025). Gıdalarda jelleştirici olarak kullanılan pektinin, glisemik kontrol üzerinde ve kan kolesterol seviyelerinde olumlu etkiler

gösterdiği ileri sürülmektedir. Şeker alkolleri olan maltitol ve ksilitolün şeker içeriği düşüktür. 3D baskılı çikolatalarda tatlandırıcının yerine kullanılabilir. Böylece enerji içeriği düşük olduğu için kilo kontrolünde rol oynayabilir. İnce yapıdaki selüloz lifleri 3D baskılı ürünlerde dayanıklılığı artırmak için kullanılabilir. Diyet liflerinin, kan glukoz ve kan kolesterolü üzerinde olumlu etkileri vardır. Böylece kalp damar hastalıklarına karşı korucu etki oluşturabilmektedir (Mudau & Adebo, 2024). Lipitler (yağlar), 3D baskılı gıdaların hem duyusal hem de işlevsel özelliklerinin geliştirilmesinde önemli bir bileşen olarak görev yapar. Tat, doku ve nem tutma kapasitesini iyileştirerek 3D baskılı ürünlerin geleneksel gıdalara benzerliğini artırır (Lourenço et al., 2025). Lesitin, 3D gıda baskısında yağlayıcı olarak kullanıldığında nozülün aşınmasını azaltır ve antioksidan özelliği sayesinde ürünün bozulma ve yaşlanma sürecini yavaşlatır (Mudau & Adebo, 2024). Yağ bazlı karışımların bir diğer avantajı da içeriklerindeki biyoaktif bileşenlerin vücutta yavaş ve kontrollü şekilde salınmasını sağlamasıdır. Örneğin, MCT içeren oleogeller, kurkumin ve resveratrol gibi bileşenlerin sindirim sırasında korunmasına ve bağırsakta hedefe yönelik salınmasına yardımcı olur (Lourenço et al., 2025). Matas-Gil ve arkadaşları jelatin ve iyota-karragenanla hazırlanan bir jel karışımına, bezelye proteini içinde kapsüllenmiş omega-3'ü farklı miktarlarda eklemiş ve omega-3 ilavesinin jel yapısını daha dayanıklı ve elastik hâle getirdiğini göstermiştir (Matas-Gil et al., 2025). Bunlar dışında 3D gıda baskısı ürünleri takviye edici bileşenlerle (vitamin,mineral,probiyotikler gibi) ile güçlendirilebilir (Varvara, Szabo & Vodnar, 2021). Buna örnek olarak Araujo ve arkadaşları, riboflavin yüklü peynir altı suyu protein izolatı nanoyapılarını havuç bazlı baskı mürekkebine eklemiş ve bu nanoyapıların baskı kalitesini iyileştirdiğini, riboflavinin biyoerişilebilirliğini artırdığını ortaya koymuştur (Araújo et al., 2025). Araştırmacılar, kişiye özel gıda üretiminde yalnızca temel bileşenlerin değil; hidrokolloidlerin de önemli olduğunu vurgulamaktadır. Bu yaklaşım, tahıl gibi yapı verici ek bileşenlere ihtiyaç duyulmadan, meyve ve sebzelerden elde edilen besleyici ve fonksiyonel içeriklerle baskıya uygun jeller hazırlanmasına olanak tanımaktadır (Severini & Derossi, 2016). Azam ve arkadaşları D vitamini ile zenginleştirilmiş portakal suyu konsantresi ve buğday nişastası karışımına farklı zamklar ekleyerek 3D basılı ürünlerin performansını incelemiştir. Araştırmada k-karragenan eklenen ürünün en iyi viskoziteye sahip olduğu ve hedeflenen şekle en uygun olduğu belirlenmiştir. Bu nedenle karışıma eklenen hidrokolloidlerin de önemli olduğu ortaya konulmuştur (Sawant & Thakur, 2018). Krishnaraj ve arkadaşları yeşil mercimek, nohut, ahır darısı, ajwain tohumu içeren kompozit undan 3D gıda yazıcısında atıştırmalık üretmişlerdir. Ahır darısı buğday, pirinç gibi gıdalara göre %40 daha fazla diyet lifi içerdiği için seçilmiştir. Baklagiller ise yüksek oranda diyet lifi ve yüksek protein içerdiği için seçilmiştir. Üretilen ürünler mikrodalgada kurutulmuştur. Tüm bu işlemler sonucunda yüksek lif ve proteinli, besin değeri yüksek atıştırmalıklar üretilmiştir (Krishnaraj et al., 2019). Fonksiyonel 3D gıda baskısı ürünlerine bakıldığında Kanadalı bir gıda şirketi olan Poseidn 3D gıda baskı teknolojisi ile kurutulmuş içecek tozunu bu yöntemle zenginleştirip farklı şekillerde basmaktadır. Bu üretilen gıdalar Kanada'da fonksiyonel gıda olarak satılmaktadır (Zhu W et al., 2019**)**. 3D gıda baskısı ayrıca antioksidanlar gibi biyoaktif bileşenleri, mikrokapsülleme yöntemi ile gıdalara eklemeye olanak sağlar. Mikrokapsülleme yöntemi E vitamini ve polifenoller gibi suda az çözünen bileşenlerin 3D gıda baskısında kullanılmasına da olanak sağlar. Hatta gelecekte disfajili hastalar için üretilen 3D gıda ürünlerinin mikrokapsülleme yöntemi ile besin değerinin artırılması amaçlanmaktadır. Bu yöntem ile pH, sıcaklık, okside olma gibi nedenlerle bozulmanın önüne de geçilebieceği ileri sürülmektedir (Zhu W et al., 2019).

APPLICATIONS OF 3D FOOD PRINTING IN HEALTHCARE

Use in Pediatrics

3D gıda baskısı teknolojisiyle çocukların beslenme ihtiyaçlarına göre uyarlanmış istenen şekil ve dokuda doğal, görüntü açısından güzel atıştırmalıklar üretilebilir. Doğal bileşenlerle hazırlanan biyo-fonksiyonel ürünler, çocukların ilgisini çekecek dinozor, korsan veya peri gibi eğlenceli şekillerde basılabilir. Bu yaklaşım, çocukların normalde tüketmekte zorlandıkları sebze ve meyveleri daha kolay bir şekilde diyetlerine dahil etmelerine yardımcı olabilir (Escalante-Aburto et al., 2021). Lee ve ekibi, ıspanak tozu ile ksantan zamkını birleştirerek 3D baskıda kullanılabilir bir karışım hazırlamış ve böylece sebze bazlı yan ürünlerin çocuklara daha cazip bir yapıda sunulabileceğini ortaya koymuştur (Lee et al., 2019). Derossi ve arkadaşları ise çocuklar için D vitamini, kalsiyum ve demir içeren kişiselleştirilebilir meyve bazlı atıştırmalıkların 3D baskı yoluyla üretilebileceğini ortaya koymuştur. (Derossi et al., 2018).

Gıdaların dokusu ve kıvamı bir çocuğun gıda tercihini etkiler. 3 boyutlu gıdalar gıdanın dokusunu belirleyerek çocuk dostu ürünlerin geliştirilmesine imkân tanır. Özellikle yutma güçlüğü (disfaji) yaşayan hastalar için kişiselleştirilmiş 3D baskılı ürünler üretilebilir (Zhu W et al., 2019). Niu ve arkadaşları, disfajili küçük çocuklar için kolay yutulabilen ve şekil olarak daha çekici hale getirilen 3D baskı gıdalar geliştirmek amacıyla keten tohumu proteini ve çemen otu zamkı içeren bir karışım kullanarak uygun dokuya sahip 3D baskılı ürünler üretmeyi başarmıştır (Niu et al., 2023). 3D gıda baskısı, fenilketonüri (PKU) gibi metabolik hastalıklarda da önemli fırsatlar sunmaktadır. Bu teknoloji, fenilalanin içeriği çok düşük alternatif protein kaynaklarının geliştirilmesini kolaylaştırarak PKU diyetini çeşitlendirebilir. Böylece hem sıkı diyete uyumu destekler hem de üretilen ürünlerin tat ve besin kalitesinin artırılmasına katkı sağlar. Ko ve arkadaşları 2021 yılında sodyum aljinat, glukomannan ile kappa ve iota karragenan gibi hidrokolloidler kullanılarak etin lifli yapısını taklit eden "yapay kas lifleri" oluşturmuştur. Amaç gerçek etin elastikiyetini ve sertlik hissini vermektir. Protein kısıtlaması olan PKU'lu bireyler için bitki bazlı, düşük fenilalaninli ve daha iyi dokulu et benzeri ürünlerin geliştirilebileceği gösterilmiştir. (Russo et al., 2025). 3D baskılı kişiselleştirilmiş beslenmeye ilişkin dikkat çekici bir diğer örnek ise akçaağaç şurubu idrar hastalığı (MSUD) için geliştirilen, kişiye özel izolösin içerikli besin tabletleridir. Goyanes ve arkadaşları, akçaağaç şurubu idrar hastaları (MSUD) için izolösin içeren besin tabletlerinin 3D baskı ile hazırlanmasını sağlayan bir uygulamayı gerçek hastalarda deneyerek bu yöntemin pratikte de uygulanabileceğini göstermiştir (Goyanes et al., 2019).

Use in Geriatrics

3D gıda baskısı bireyselleştirilmiş beslenme uygulamalarında kişinin tercihlerine, besin ögesi gereksinimlerine, sağlık durumuna uygun ürünler geliştirebilmektedir. Bu teknoloji yoluyla, yaşlı bireyler için kolesterol, doymuş yağ, şeker ve tuz içeriği azaltılmış, protein, temel mikro besinler, doymamış yağ asidi ve biyoaktif bileşenleri artırılmış gıdalar üretilebilmektedir (Chao et al., 2024). Yaşlılarda 3D gıda baskısının kullanılması yeni bir teknolojidir (Lorenz et al., 2022). Yaşlanma ile görülen kas zayıflığı ve diğer fizyolojik değişiklikler, yaşlı bireylerde gıda tüketimini azaltmakta ve yutma güçlüğüne (disfaji) yol açabilmektedir. (Chao et al., 2024).

Disfaji yutma mekanizmasında bozulma durumudur ve en fazla yaşlı nüfusu etkilemektedir. Bu nedenle bu hastalar için dokusu değiştirilmiş diyetler önerilmektedir. Ancak bu dokusu değiştirilmiş besinler, görsel olarak çekici değildir ve üretim sırasında besin değerinde kayıplar görülebilir. 3D gıda baskısı ise hem dokuyu istenen duruma getirebilmesi hem de ürünün görsel çekiciliğini artırabilmesi açısından önemli avantajlar sunar (Lorenz et al.,2022). Bu teknoloji, püre ve macun kıvamındaki ham maddelerle tavuk nugget veya ay çöreği benzeri tanınabilir ve iştah açıcı şekiller üretmeye olanak tanır. Gelişen tekniklerle baskı ürünlerine renk ve aroma

eklenmesi de mümkün hâle gelmiştir (Lorenz et al.,2022). 3D baskıda kullanılan hidrokolloidler, ürünün uygun viskozite, elastikiyet ve stabilite kazanmasını sağlar. Ayrıca disfaji yaşayan bireylerin enerji ve protein alımı genellikle yetersiz olduğundan 3D baskı, yüksek protein içeren sıvılar ve besin açısından zenginleştirilmiş ürünlerin üretilmesini de mümkün kılar (Zhu W et al., 2019). 3D gıda baskısı gıda baskıdan önce homojen hale getirilir, böylece homojen hale gelen gıdaya besin değeri yüksek makro ve mikro besin ögeleri eklenebilir. Örneğin püre hazırlarken içine su yerine süt konulması pürenin daha yüksek enerji, protein ve mikro besin açısından daha zengin bir içeriğe sahip olmasını sağlar. İçerisine ayrıca fonksiyonel birçok malzeme (lif, probiyotik, protein) katılabilir (Lorenz et al.,2022). Nohut proteini, un kurdu proteini veya bezelye proteiniyle böcek ya da mantar kaynaklı proteinlerin birlikte kullanılması, yaşlı ve disfajisi olan bireyler için yumuşak dokulu, kolay yutulabilen ve besin değeri yüksek 3D baskı gıdaların geliştirilmesine olanak sağlayabilir (Chao et al., 2024). Pant ve arkadaşları farklı su ve nişasta içeriğine sahip sebzeleri, ksantan zamkı, kappa karregan, keçiboynuzu zamkı gibi hidrokolloidleri kullanarak modifiye etmiş ve disfajiye uygun kıvamda besinler üretmiştir (Pant et al., 2021). Kouzani ve arkadaşları 3D gıda baskısı ile ton balığı, pancar ve balkabağı kullanarak disfajili hastaların tüketebileceği kıvamda, balık şekline benzeyen besin üretmiştir (Kouzani et al., 2017). Dick ve arkadaşları domuz ve sığır etiyle belirli hidrokolloidleri kullanarak disfajili hastalar için uygun kıvamda gıda baskısı yapmıştır (Dick, Bhandari, & Prakash, 2019). Ayrıca yaşlı bireylerde iskelet kas kütlesinde zamanla azalma yani sarkopeni görülebilir. Sarkopeniyi önlemek için günlük 1.0-1.6 g/kg protein önerilmektedir. 3D gıda baskısı ile yüksek protein içerikli besinler üretilebilir. Bu sayede 3D gıda baskısı sarkopeninin önlenmesinde fayda sağlayabilmektedir (Chao et al., 2024). Kurapkenie ve arkadaşları yaşlı bireylerde malnütrisyon ve sarkopeniyi önlemek amacıyla tek lokmalık çikolata, karışık aromalı tofu, narenciye bazlı küçük boyutta gıdalar oluşturmuştur (Kurapkienė et al., 2024). Huiwen Gu ile arkadaşları ise kinoa ve bezelye proteinini kullanarak 3D gıda baskı yöntemi ile disfajiye uygun gıda üretmiştir (Gu et al., 2025). Ayrıca 3D gıda baskısı, ürünlerin doymuş yağ içeriğini azaltarak omega-3 gibi yaşlı bireyler için yararlı uzun zincirli yağ asitleri veya bitkisel oleojeller eklenmesine de imkân tanır. Bu sayede daha sağlıklı yağ profiline sahip ürünlerin geliştirilmesi kolaylaşmakta ve yaşlı bireylerin genel yaşam kalitesinin desteklenmesine katkıda bulunmaktadır (Chao et al., 2024).



Resim 2. Disfaji hastaları için geliştirilen 3D ürünler (Nopparat & Motte, 2022).

The Use of Diabetes

3D gıda baskısı ile glisemik indeksi düşük besinler üretilmesi mümkündür. Baskı sırasında nişastanın gliserol monostearat veya stearik asit ile etkileşimi, nişastanın sindirilebilirliğini azaltarak enzimlere karşı direncini artırabilmektedir. Bu durum, kan glukoz düzeylerinin daha stabil seyretmesine katkı sağlayabilir. Ayrıca pirincin düşük glisemik indeksli veya dirençli nişasta içeren gıdalarla birlikte kullanılması, glisemik yanıtı düşürmede etkili bir yaklaşım olarak değerlendirilmektedir. Tüm bu özellikler, 3D gıda baskısını diyabetli bireylerde glisemik kontrolü iyileştirme potansiyeline sahip yenilikçi bir teknoloji haline getirmektedir (Chao et al.,

2024). Chen ve arkadaşları, düşük glisemik indeksli süt tozu, buğday kepeği ve iki farklı mantar türünü kullanarak 3D baskıya uygun özel karışımlar geliştirmiştir. Yapılan testlerde bu basılı ürünlerin yumuşak bir dokuya sahip olduğu, ağızda ülser veya hassasiyet yaşayan diyabetli bireylerde tahrişi azaltabileceği gösterilmiştir. Diyabet oluşturulmuş sıçanlarda yapılan deneylerde bu ürünlerin kan şekeri kontrolüne yardımcı olabileceği ortaya konmuştur. Bunun yanı sıra diyabetik nefropatili bireylerin protein gereksinimlerine uygun şekilde, protein içeriği kişiye özel olarak ayarlanmış 3D baskılı ürünler de başarıyla üretilmiştir. Bu yaklaşım, diyabetli hastalara hem daha rahat tüketilebilir hem de beslenme gereksinimlerine uygun gıdalar sunulmasına imkân tanır. 3D gıda baskı teknolojisi, şekersiz çikolata gibi düşük enerjili ürünlerin geliştirilmesinde de kullanılmaktadır. Diyabetli bireylerde yaygın olarak tercih edilen maltitol ve ksilitol gibi şeker alkolleri, çikolatalarda bulunan sakkarozun yerine kullanılabilir; böylece hem kalori, karbonhidrat içeriği azalır hem de kilo kontrolüne olumlu katkı sağlanır. Bu tatlandırıcıların fonksiyonel polisakkaritlerle birleştirilerek sağlıklı 3D baskılı çikolatalar üretilmesi ise dikkat çekici bir yaklaşımdır. Ganoderma mantarı, goji ve liriope gibi kaynaklardan elde edilen polisakkaritlerin bağışıklık sistemini destekleme, antioksidan etki gösterme, yaşlanmayı geciktirme ve tümör gelişimini baskılama gibi çeşitli yararları bulunmaktadır. Bu bileşenlerle zenginleştirilmiş şekersiz 3D baskılı çikolataların hem tat hem de doku açısından kabul edilebilir düzeyde olduğu bildirilmiş olup, bu ürünlerin diyabetli bireyler için uygun bir seçenek olabileceği öne sürülmektedir (Âmin et al., 2024).

The Use of Chronic Kidney Diseases

3D gıda baskısı, özel beslenme gereksinimleri olan kronik börek yetersizliğine sahip kişiler için yiyeceklerin makro ve mikro besin içeriklerini hastaların ihtiyaçlarına göre ayarlamaya imkân tanır. Kronik böbrek hastalarında sodyum ve potasyumun azaltılması yapılır. Bu teknolojiyle sodyum ve potasyum içeriği düşük gıdalar üretilebilir ve hastaların diyetlerine uyumu kolaylaşabilir (Chao et al., 2024).

The Use of Cardiovascular Diseases and Hypertension

Kardiyovasküler hastalık ve hipertansiyonda kişiye özel üretilen gıdalarda doymuş yağ, kolesterol, şeker ve tuzun azaltılması; buna karşılık protein ve sağlıklı doymamış yağların artırılması önerilmektedir. Doymuş yağların azaltılması kalp-damar hastalığı riskini düşürebilir. 3D gıda baskısı, doymuş yağlar yerine omega-3 gibi yaşlılar için de yararlı yağ asitleri veya oleojeller eklemeyi kolaylaştırarak daha sağlıklı ürünler üretme imkânı sunar. Ayrıca bazı çalışmalarda tahıl ya da baklagil proteinlerinin böcek proteinleriyle birlikte kullanılmasının hipertansiyon, kardiyovasküler hastalıklar ve obezite riskini azaltmaya yardımcı olabileceği belirtilmiştir (Chao et al., 2024).

ADVANTAGES OF FOOD PRODUCTION WITH 3D PRINTING TECHNOLOGY

3D gıda baskı teknolojisi kalıp kullanmadan istenilen şekilde, besin içeriği, kıvamı, tadı ve dokusu olarak benzeri görülmemiş şekilde besinlerin kişiselleştirilebilmesine olanak sağlar. Bireyin beslenme ve fiziksel aktivite düzeyine göre enerji almasına olanak tanır. İçerisine giren malzemelerin türü ve miktarını belirleyerek besin profili üzerinde kontrol sağlar (Shah et al., 2024). Özel gereksinimli bireyler için yeterli makro ve mikro besin ögesi içeren gıdaların üretilmesine olanak tanır. 3D gıda baskısı ile tuz şeker ve kalori miktarı düşük besinler üretilebilir. Ayrıca üretilen gıdaların vitamin, minerallerle fonksiyonel olarak zenginleştirilmesine olanak sağlar. Daha az malzeme ile daha büyük boyutlarda besin üretme potansiyeli ile obezite açısından fayda sağlayabilir. Yutma güçlüğü çeken hastalar için doğru kıvamda ve dokuda ürün üretilmesine fayda sağlayabilir. Gıda atıklarını azaltmak için büyük bir potansiyele sahiptir (Çakmak & Gümüş, 2020). Bunlar dışında 3D gıda baskısı, mutfakta

yaratıcılığı destekleyen bir araç haline gelmiştir. Hem şeflerin hem de tüketicilerin farklı şekil, doku ve sunumlarda yiyecekler tasarlamasına olanak tanırken, daha sürdürülebilir üretim yöntemlerinin kullanılmasına da katkı sağlar. Bu yönüyle, gıda sektöründe yenilikçi yaklaşımların gelişmesine destek olmaktadır. Çeşitli hammaddelerin kullanılabilmesi ve üretim sırasında atığın minimuma indirilebilmesi, bu teknolojiyi küresel gıda güvenliği açısından önemli kılmaktadır. 3D baskı yöntemi, gıda israfını azaltmaya yönelik etkili bir yöntemdir. Ve bu alanda çözüm potansiyeline sahiptir. Teknolojideki ilerlemeler doğrultusunda, daha çevreci, daha verimli ve bireylerin beslenme ihtiyaçlarına göre özelleştirilebilen gıda üretim süreçlerinin yaygınlaşacağı öngörülmektedir. Bu durum, 3D gıda baskısının gelecekte gıda tedarik zincirinde önemli bir konuma sahip olabileceğini düşündürmektedir. Pandemi sonrasında hijyen, kişiselleştirme ve estetik sunum gibi unsurlar daha fazla önem kazanmıştır. Bu nedenle, 3D baskı ile hijyenik, kişiye özel ve yaratıcı ürünler hazırlanabilmesi, gıda sektörünün gelecekteki yönelimlerini belirleyen temel faktörlerden biri olarak değerlendirilmektedir (Shah et al., 2024).

DISADVANTAGES OF 3D PRINTING TECHNOLOGY

3D gıda baskısındaki temel engellerden biri yavaş baskı hızıdır. Hız ve ekstrüzyon uyumsuzluğu, 3D gıda baskısı sırasında sık karşılaşılan bir sorundur. Eğer yazıcının hareket hızı ile malzemenin çıkış miktarı birbirini doğru şekilde takip etmezse, işlem istenildiği kadar hızlandırılamaz. Baskı hızının (mm/s), malzeme akış hızından (mm^3/s) daha yüksek ya da düşük olması, katmanların düzgün yerleşmemesine, şekil bozulmalarına ve genel yapı kalitesinin düşmesine yol açar. Bu nedenle, başarılı ve kaliteli bir baskı elde edebilmek için bu iki hızın uyum içinde çalışması büyük önem taşır. Mevcut bilgisayar 3D yazıcılar aslında plastik, metal veya seramik gibi endüstriyel malzemeler için tasarlanmış ve bu tür malzemelerle uyumlu çalışacak şekilde geliştirilmiştir. Ancak söz konusu gıda olduğunda durum farklıdır. Gıda hamurlarının, pürelerin veya jel yapılarının akışkanlığı, viskozitesi ve yapısal dayanıklılığı diğer malzemelerden çok farklı olduğu için bu arayüzler gıda baskısına tam olarak uyum sağlayamamaktadır. Bu nedenle, gıda malzemelerinin kendine özgü özelliklerini dikkate alarak baskı hareketlerini daha hassas şekilde kontrol edebilecek yeni mühendislik yaklaşımlarına ve yazılım sistemlerine ihtiyaç duyulmaktadır. Böyle çözümler geliştirildiğinde, 3D gıda baskısının hem kalitesi hem de uygulanabilirliği önemli ölçüde artacaktır. Yüksek kalitede baskı üretebilmek için katman yüksekliği, dolgu yoğunluğu ve nozul boyutu gibi birçok değişkenin ayarlanması gerekmektedir (Shahidi et al., 2021). Baskı sonrası fırınlama, kızartma, buharda pişirme gibi işlemler yapılır. Bu işlemler sırasında ısı dağılımı yeterli olmazsa şeklin korunmasında güçlük yaşanmaktadır. Gıda güvenliği de 3D gıda baskısında önemli bir endişe kaynağıdır. Ekipmanların yeterince temizlenmemesi gıda güvenliği açısından risk oluşturabilir. Tüketiciler 3D gıda baskısı ismini duyduklarında içerisinde kimyasallar, renklendiriciler, plastikler olabileceğini düşündüğünden tüketici kabulü konusunda sorun yaşanabilmektedir (Çakmak & Gümüş, 2020). Bazı tüketiciler ve beslenme uzmanları ayrıca 3D gıda baskısı ürünlerini ultra işlenmiş besin olarak tanımlamaktadır. Çünkü 3D gıda baskısı malzemelerine uygulanan ön işlemlerin (ezme,jelleştirme) gıdanın yapısında ve besin değerinde bozulmaya yol açabileceği ayrıca üretilen ürünlerin stabil yapıda kalabilmesi için içerisine gıda katkı maddelerinin (hidrokolloid) eklenmesinin sağlık açısından zararlı olabileceğini düşünmektedirler (Zhu W et al., 2019). 3D gıda baskısı kişiselleştirilmiş beslenme açısından büyük bir potansiyel taşımaktadır. Gelecekte yapılacak çalışmalarda sadece kişiselleştirilmiş beslenme için özel gıda mürekkepleri üretimine odaklanılmamalı aynı zamanda üretilen ürünün her bölgede ulaşılabilir ve ekonomik olmasına odaklanılmalıdır. 3D gıda baskısı sadece ev ortamı veya klinikte değil aynı zamanda kurumsal mutfak, catering hizmetlerinde de kullanılabilir. Tam porsiyon kontrolü sağladığı için ve sadece ihtiyaç duyulduğunda üretim

yapıldığı için gıda israfını azaltmak açısından büyük bir potansiyele sahiptir. Yine de ne kadar etkili olduğunu anlayabilmek için daha fazla çalışmaya ihtiyaç vardır (Seol et al., 2025).

METHODOLOGY

Bu derleme 2019–2025 yılları arasında PubMed, Scopus ve Google Scholar veri tabanlarında "3D food printing", "functional foods", "health applications" anahtar kelimeleri kullanılarak taranan çalışmalar temel alınarak hazırlanmıştır.

CONCLUSION AND DISCUSSION

Bu makale, 3D gıda baskısının fonksiyonel besin üretimi ve kişiye özel beslenme uygulamaları ile sağlık alanında kullanımını değerlendirmektedir. 3D gıda baskısı, literatürde yer alan bulgulara da bakılarak, hem pediatrik ve geriatrik bireylerde, hem de diyabetik, böbrek hastalığı ve kardiyovasküler hastalıklar vb. olan bireylerde kişiye özel beslenme ürünleri üretebilme açısından faydalı olabilecek bir araçtır. Çocuklarda meyve, sebze tüketimini artırmak, disfaji yaşayan bireyler için uygun dokuya sahip yiyecekler üretmek, PKU veya MSUD gibi metabolik hastalıklarda makro besin bileşeni ayarlamak ve diyabetik bireylerde glisemik indeksi düşürülmüş ürünler geliştirmek, 3D gıda baskısının sağlık alanındaki önemini açıkça göstermektedir. Göstermiştirinler, yağlar, karbonhidratlar, hidrokolloidler ve çeşitli biyoaktif bileşenlerin kontrollü şekilde karışımlara eklenebilmesi, sağlık açısından önemli gıda ürünlerinin üretilebilmesini sağlar Çalışmada yer alan örnek araştırmalar; omega-3 ile zenginleştirilmiş jeller, probiyotiklerle güçlendirilmiş karışımların, böcek veya bitki bazlı yüksek proteinli mürekkepler ve düşük glisemik indeksli fonksiyonel ürünlerin, 3D baskı ile başarıyla üretilebildiğini göstermiştir. Bu açıdan 3D gıda baskısı yalnızca kişiselleştirilmiş beslenme konusunda fayda sağlamayıp, aynı zamanda besinlerin duyusal kalitesini ve fonksiyonel içeriğini artırma gibi faydaları vardır. Bununla birlikte, 3D gıda baskısında malzemelerinin standartlaştırılması, besin güvenliği, mikrobiyal riskler, maliyet, üretim hızı ve tüketici kabulü gibi konuların daha fazla araştırılması gerekmektedir. Klinikte bireylerin üzerinde yapılan denemelerin artırılması ve uzun dönemdeki sağlık üzerine etkilerinin incelenmesi gelecekteki araştırmalar açısından önemlidir. Sonuç olarak, 3D gıda baskısı teknolojisi ile fonksiyonel gıdaların geliştirilmesi ve kişiye özel besin üretme potansiyeli açısından daha fazla çalışma yapılmalıdır.

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FREQUENCY OF MAXILLOFACIAL SOFT TISSUE CALCIFICATIONS AND OSSIFICATIONS ON PANORAMIC RADIOGRAPHY

İlker ÇAPRAK

Uşak University Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Uşak, Turkey

ORCID NO: 0009-0002-5699-3403

Ayşegül TÜRKMENOĞLU

Uşak University Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Uşak, Turkey

ORCID NO: 0000-0001-5931-2517

ABSTRACT

Introduction and Purpose: Soft tissue calcifications in the head and neck region can occur due to pathological or physiological reasons. They are usually asymptomatic and are detected during routine radiographic examination. The aim of this study is to determine the types and frequency of soft tissue calcifications, which are often detected incidentally on panoramic radiographs, and to evaluate the relationship between systemic disease and patients with calcified atherosclerotic plaques, who should be evaluated for cerebrovascular/cardiovascular disease risk.

Materials and Methods: Panoramic radiographs of 1676 patients who applied to the Uşak University Faculty of Dentistry, Department of Dentomaxillofacial Radiology between September 2024 and September 2025 were included in the study. The presence of soft tissue calcifications and ossifications was evaluated on the radiographs. When calcification or ossification was observed, it was recorded according to its type and number (single, two or multiple). Information regarding the patients' age and sex, as well as systemic disease information in the presence of calcified atherosclerotic plaques, was also recorded.

Results: Soft tissue calcification was detected in 31.1% of the evaluated panoramic radiographs. The most common calcification was found to be stylohyoid ligament calcification (SLC) at 45.82%. Subsequently, it was determined that thyroid cartilage calcification at 16.86%, tonsillolith at 16.28%, triticeous cartilage calcification at 15.13%, calcified atherosclerotic plaques at 3.31%, antrolith at 1.3%, calcified lymph node at 0.72%, and sialolith at 0.58%. The average age of those with tonsillolith, thyroid cartilage calcification, calcified atherosclerotic plaques, and calcified lymph node was found to be higher than those without ($p<0.05$). Single type calcification was detected more frequently than multiple type calcification. Hypertension was the most common systemic disease in patients with calcified atherosclerotic plaques.

Discussion and Conclusion: The results of our study indicate that soft tissue calcifications/ossifications in the maxillofacial region are not uncommon. SLC was the most frequently found type in our study. SLC was more common in female, while tonsillolith was

more common in male. The correct diagnosis of soft tissue calcifications and ossifications can help in the detection of possible existing diseases and prevention potential complications in the patient by making the necessary referrals in cases requiring consultation.

Keywords: Maxillofacial region; Panoramic radiography; Soft tissue calcification

INTRODUCTION

If calcium salts accumulate irregularly in soft tissues, it is called heterotopic calcification. Heterotopic calcifications can be classified under three headings: metastatic calcification, dystrophic calcification, and idiopathic calcification. If serum calcium or phosphate levels are high and calcium salts accumulate in normal tissue, it is called metastatic calcification. If calcium salts accumulate in degenerative and necrotic tissues while serum calcium or phosphate levels are normal, it is called dystrophic calcification; if they accumulate in normal tissues, it is called idiopathic calcification. The process by which minerals accumulate and organize within soft tissue as regular and well-formed bone is called heterotopic ossification. (White & Pharoah, 2000).

Soft tissue calcifications may be physiological or pathological. They are generally asymptomatic and are detected on panoramic radiographs during routine dental examinations. (Altındağ & Yüksel, 2021).

The types of calcification commonly encountered clinically in the head and neck region are as follows: tonsilloliths, stylohyoid ligament calcification (SLC), lymph node calcifications, calcified atherosclerotic plaque, tritiseous cartilage, and thyroid cartilage calcifications. (Avsever & Orhan, 2018).

Key features in calcification assessments that aid in diagnosis include anatomical location, distribution pattern, total number, size range, and morphological shape. Tritisaceous cartilage calcification appears on panoramic radiographs as a generally homogeneous radiopacity with a distinct and regular border in the soft tissues adjacent to the upper border of the C4 vertebra. (White & Pharoah, 2000). Calcified atherosclerotic plaques, on the other hand, are usually observed around the carotid bifurcation at the C3–C4 level and in the soft tissues posteroinferior to the mandibular angle. They present as multiple, irregularly shaped, heterogeneous radiopacities. Detecting calcified atherosclerotic plaques on panoramic radiographs can contribute to the early diagnosis of conditions such as stroke and embolism (Altındağ & Yüksel, 2021). Paying attention to morphological features and localization differences helps to differentiate between tritiseous cartilage calcification and calcified atherosclerotic plaque. (White & Pharoah, 2000).

Panoramic radiographs, routinely used in dental practice, are a valuable tool for the preliminary examination of calcification and ossification findings in soft tissue due to their economical and low-radiation properties. (Altındağ & Yüksel, 2021).

The aim of this study is to determine the types and frequency of soft tissue calcifications, which are often incidentally detected in panoramic radiographs, and to evaluate the relationship between systemic diseases and patients with calcified atherosclerotic plaques who should be assessed for cerebrovascular and cardiovascular disease risk.

MATERIALS AND METHODS

This study was approved by the Uşak University Non-Interventional Clinical Research Ethics Committee (Decision No: 878-878-18).

In this retrospective study, randomly selected panoramic radiographs from the digital archive of patients who applied to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Uşak University between September 2024 and September 2025 were evaluated. The age and gender information of patients with diagnostically acceptable radiographs was recorded. Patients with soft tissue calcification and ossification on panoramic radiographs were recorded according to age, gender, type of calcification, and single, two, and multiple occurrence. For patients exhibiting calcified atherosclerotic plaques, medical history data available in the digital system were reviewed, and the presence of systemic diseases was noted. Radiographs lacking demographic information, exhibiting poor image quality, or containing significant artifacts were excluded from the study.

Statistical analysis

Statistical analyzes were carried out using SPSS software version 27 (IBM Corp., Armonk, NY, USA). The assumption of normal distribution was checked using the Shapiro-Wilk test. Descriptive statistics, Pearson Chi-Square test, Fisher's Exact test, Mann Whitney U test and Kruskal Wallis test were used to evaluate the data. $p < 0.05$ was considered statistically significant.

RESULTS

A total of 1,676 patients' panoramic radiographs were evaluated in this study. Of these patients, 673 were male and 1003 were female. The age range was 11–88 years, with a mean age of 39.49 ± 16.96 years. Soft tissue calcifications were detected in 521 of the evaluated radiographs (31.1%).

Among the 521 radiographs in which calcifications were identified, 385 (73.9%) exhibited a single calcification, 103 (19.8%) showed two calcifications, and 33 (6.3%) presented multiple calcifications (three calcifications: 30 cases; four calcifications: 3 cases). A total of 693 soft tissue calcifications were detected in 521 radiographs.

The most frequently observed type of calcification was SLC, accounting for 45.82% of all findings. This was followed by thyroid cartilage calcification (16.86%), tonsilloliths (16.28%), triticeous cartilage calcification (15.13%), calcified atherosclerotic plaques (3.31%), antroliths (1.3%), calcified lymph nodes (0.72%), and sialoliths (0.58%) (Figure 1) (Graph 1).

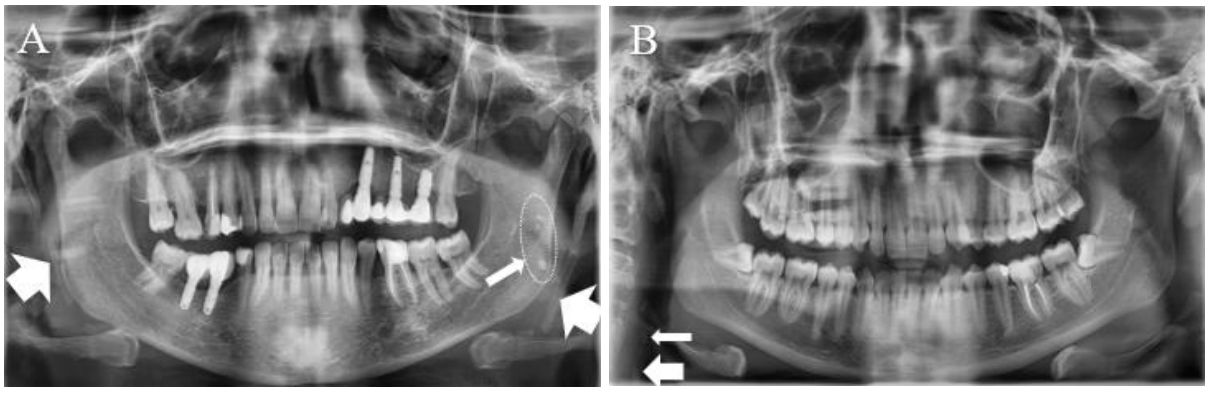
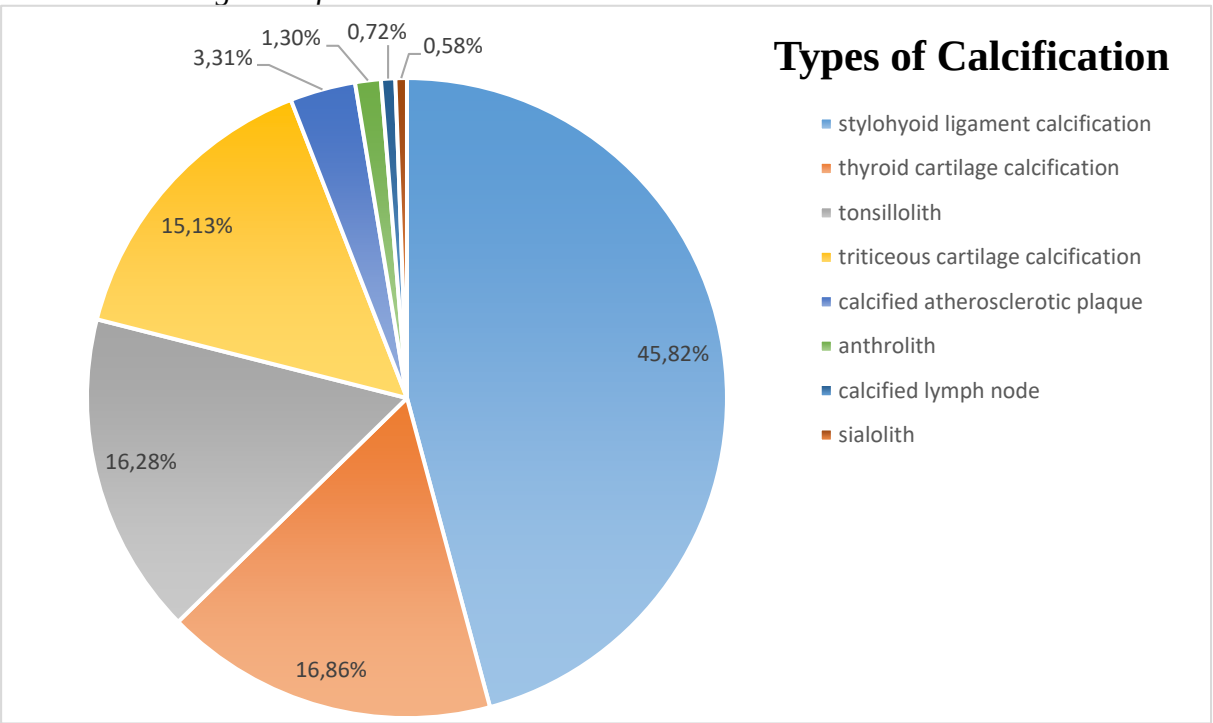


Figure 1: *A, thick arrows indicate stylohyoid ligament calcification; thin arrow indicates tonsillolith. B, thick arrow indicates thyroid cartilage calcification; thin arrow indicates*

triticeous cartilage calcification.



Graph 1: *Distribution of soft tissue calcifications/ossifications by type*

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Pearson's Chi-Square and Fisher's Exact tests were used to evaluate the distribution of calcifications by gender and the relationships between them. The analyses revealed a statistically significant difference between gender and SLC and tonsilloliths (p <0.001) (Table 1).

Table 1*. Distribution of calcifications by gender and their associations*

		Male			Female			
		n	%	C. %	n	%	C. %	p
Calcification status	No	461	39.9	68.5	694	60.1	69.2	0.764
	Yes	212	40.7	31.5	309	59.3	30.8	
Stylohyoid ligament	No	98	48.0	46.2a	106	52.0	34.3b	<0.001*
calcification	Yes	114	36.0	53.8a	203	64.0	65.7b	
Tonsillolith	No	142	34.8	67.0a	266	65.2	86.1b	<0.001*
	Yes	70	61.9	33.0a	43	38.1	13.9b	
Thyroid cartilage	No	165	40.8	77.8	239	59.2	77.3	0.897
calcification	Yes	47	40.2	22.2	70	59.8	22.7	
Triticeous cartilage	No	168	40.4	79.2	248	59.6	80.3	0.777
calcification	Yes	44	41.9	20.8	61	58.1	19.7	
Calcified atherosclerotic	No	204	41.0	96.2	294	59.0	95.1	0.555
plaque	Yes	8	34.8	3.8	15	65.2	4.9	
Sialolith	No	212	41.0	100.0	305	59.0	98.7	0.150
	Yes	0	0.0	0.0	4	100.0	1.3	
Antrolith	No	209	40.8	98.6	303	59.2	98.1	0.744
	Yes	3	33.3	1.4	6	66.7	1.9	
Calcified lymph node	No	210	40.7	99.1	306	59.3	99.0	1.000
	Yes	2	40.0	0.9	3	60.0	1.0	

*p <0.05; %: row percentage; C %: column percentage for gender; different letters indicate the difference between row-based column ratios.

Mann–Whitney U and Kruskal–Wallis tests were applied to compare the distribution of ages according to the presence of calcifications and their relationships. The analysis revealed statistically significant differences in calcification status, SLC, tonsillolith, thyroid cartilage calcification, calcified atherosclerotic plaque, and calcified lymph nodes between age groups. ($p < 0.05$). Patients with calcifications were found to be older. In the absence of SLC, patients' ages were higher ($p < 0.001$). Patients with tonsilloliths, thyroid cartilage calcification, calcified atherosclerotic plaque, and calcified lymph nodes were found to be older (Table 2).

Table 2. *Distribution and comparison of ages according to calcification status*

		Mean.±S.D.	Median (25%-75%Q.)	p
Calcification status	No	37.69±17.09	36(23-51)	<0.001*
	Yes	43.48±15.99	43(30-55)	
Stylohyoid ligament calcification	No	47.91±15.47	48(38-60)	<0.001*
	Yes	40.64±15.69	39(26-51)	
Tonsillolith	No	41.88±15.49	41(28-53)	<0.001*
	Yes	49.26±16.48	50(42-62)	
Thyroid cartilage calcification	No	42.47±16.38	42.5(28-55.5)	0.005*
	Yes	46.97±14.06	46(37-55)	
Triticeous cartilage calcification	No	42.89±16.53	43(28-56)	0.076
	Yes	45.85±13.43	44(36-55)	
Calcified atherosclerotic plaque	No	43.06±15.83	43(30-55)	0.008*
	Yes	52.61±17.1	60(39-67)	
Sialolith	No	43.5±16.02	43(30-56)	0.915
	Yes	41.75±12.45	43.5(32-51.5)	
Antrolith	No	43.5±15.99	43.5(30-55)	0.862
	Yes	42.67±16.57	40(27-59)	
Calcified lymph node	No	43.33±15.97	43(30-55)	0.025*
	Yes	59.4±9.42	63(61-63)	

*$p<0.05$

When evaluating the systemic disease status, 13 out of 23 cases with calcified atherosclerotic plaques were found to have systemic diseases (56.5%), while 10 cases did not present any systemic disease (43.5%). A total of 23 systemic diseases were identified in these 13 cases. Among the systemic diseases, the most frequent were hypertension (26.09%), asthma (13.04%), diabetes mellitus (8.7%), hypercholesterolemia (8.7%), leukemia (8.7%), thalassemia (4.35%), Familial Mediterranean Fever (4.35%), chemotherapy (4.35%), hypothyroidism (4.35%), rheumatoid arthritis (4.35%), osteoporosis (4.35%), rheumatic heart disease (4.35%), and presence of a stent (4.35%) (Table 3).

Table 3. *Distribution of systemic diseases*

Systemic disease	N	%
Diabetes mellitus	2	8.70
Hypercholesterolemia	2	8.70
Thalassemia	1	4.35
Leukemia	2	8.70
Hypertension	6	26.09
Familial Mediterranean Fever	1	4.35
Asthma	3	13.04
Chemotherapy	1	4.35
Hypothyroidism	1	4.35
Rheumatoid arthritis	1	4.35
Osteoporosis	1	4.35
Rheumatic heart disease	1	4.35
Stent	1	4.35

DISCUSSION

Soft tissue calcifications/ossifications, which often do not produce any symptoms or signs, have been reported in the literature with a prevalence ranging from 2% to 27.64% (Alattar et al., 1980; Barrett et al., 1984; Çitir & Gündüz, 2020; Celik Ozsoy et al., 2025).

According to the literature, studies have examined soft tissue calcifications using panoramic radiography, cone-beam computed tomography (CBCT), and computed tomography (CT) (Çitir & Gündüz, 2020; Icoz & Akgunlu, 2019; Türk et al., 2022; Bayramov et al., 2019). In the study by Altındağ and Yüksel, 2640 panoramic radiographs were screened, and soft tissue calcifications were detected in 157 patients (5.94%) (Altındağ & Yüksel, 2021). Türk et al. detected soft tissue calcification/ossification on CT images in 214 (23.3%) of 917 patients (Türk et al., 2022). In the study by Çitir and Gündüz, panoramic radiographs from a total of 1024 patients were evaluated, and soft tissue calcification/ossification was detected in 283 patients (27.64%) (Çitir & Gündüz, 2020). Bayramov et al. evaluated CBCT images of 796 patients and detected soft tissue calcifications in 169 cases (21.7%) (Bayramov et al., 2019). In the study by Icoz and Akgunlu, 4263 digital dental panoramic radiographs were retrospectively evaluated, and 270 (6.4%) calcifications were detected (Icoz & Akgunlu, 2019). Celik Ozsoy et al. reported soft tissue calcifications or ossifications in 122 of 1193 panoramic radiographs (10.22%) (Celik Ozsoy et al., 2025). Ribeiro et al. identified 468 calcifications in 2375 panoramic radiographs (19.7%) (Ribeiro et al., 2018), and Vengalath et al. detected calcifications in 132 of 1615 panoramic radiographs (8%) (Vengalath et al., 2014). In our study, soft tissue calcifications were detected in 521 of 1676 panoramic images (31.1%). Considering the rate of calcification in our study, soft tissue calcifications and ossifications detected in the maxillofacial region were thought to be not uncommon. It is thought that these significant differences between studies may be influenced by factors such as ethnicity, imaging methods, environmental factors, and the experience of the observer.

In the study by Altındağ and Yüksel, tonsilloliths were detected in 54.14% of patients, SLK in 36.3%, calcified atherosclerotic plaques in 4.45%, sialoliths in 3.82%, and tritiseous cartilage calcification in 1.27% (Altındağ & Yüksel, 2021). In Çitir and Gündüz's study, the distribution of calcifications was as follows: 31.45% SLC, 26.15% calcified atherosclerotic plaque, 14.84% tonsillolith, 13.43% multiple soft tissue calcifications/ossifications, 12.72% triticeous cartilage calcification, 1.06% lymph node calcification, and 0.35% submandibular sialolith (Çitir & Gündüz, 2020). In Celik Ozsoy et al.'s study, 31 cases (25.41%) were SLC, 28 cases (22.95%)

were laryngeal cartilage calcifications, 25 cases (20.49%) were tonsilloliths, 18 cases (14.75%) were calcified atherosclerotic plaques, 18 cases (14.75%) were calcified lymph nodes, and 2 (1.64%) were antroliths (Celik Ozsoy et al., 2025). In our study, the most frequently observed calcification was SLC (45.82%), followed by thyroid cartilage calcification (16.86%), tonsillolith (16.28%), triticeous cartilage calcification (15.13%), calcified atherosclerotic plaque (3.31%), antrolith (1.3%), calcified lymph node (0.72%), and sialolith (0.58%). Similar to the literature, SLC was the most common type of calcification.

In Altındağ and Yüksel's study, among the 157 patients with calcifications/ossifications, 50.32% were male and 49.68% were female. No significant difference was found in the presence of soft tissue calcifications based on gender and age (Altındağ & Yüksel, 2021). In Türk et al.'s study, calcifications were observed in 50.5% of females and 49.5% of males (Türk et al., 2022). In the study by Çitir and Gündüz, 61.48% of patients with soft tissue calcification/ossification were female, while 38.52% were male. A significant relationship was found between the frequency of calcification/ossification and gender (Çitir & Gündüz, 2020). In the study by Bayramov et al., soft tissue calcification was detected in 50.3% of males and 49.7% of females; no statistically significant difference was found (Bayramov et al., 2019). In the study by Çelik Ozsoy et al., 56 individuals (45.90%) were female and 66 individuals (54.10%) were male (Celik Ozsoy et al., 2025). In the study conducted by Ribeiro et al., 273 were female (58.3%) and 195 were male (41.7%) (Ribeiro et al., 2018). The literature has noted differing results in the incidence rates of soft tissue calcifications and ossifications in female and male. In our study, the frequency of soft tissue calcifications was found to be 40.7% in male and 59.3% in female. It was considered that the different rates reported in the literature might be related to the characteristics of the patient populations studied.

Altındağ and Yüksel reported the mean age of patients with calcifications as 55.04 ± 15.20 years (Altındağ & Yüksel, 2021). In the study by Türk et al., the average age was found to be 61.35±14.7 (Türk et al., 2022). Icoz and Akgunlu found the average age of individuals with calcification to be 40.37 ± 14.77, while the average age of individuals without calcification was 27.44 ± 15.85 (Icoz & Akgunlu, 2019). In our study, the mean age was found to be 37.69±17.09 in patients without calcification and 43.48±15.99 in those with calcification. This difference may be related to the general age distribution of the patient populations.

SLC has been reported in the literature to be more common in females than males (Savranlar et al., 2005; Öztaş & Orhan, 2012; Prasad et al., 2002; Ferrario et al., 1990; Roopashri et al., 2012; Phulambrikar et al., 2011). In our study, consistent with the literature, SLC was more frequently observed in females. Celik Ozsoy et al. reported that tonsilloliths were more common in males (Celik Ozsoy et al., 2025), which is consistent with our findings.

Sutter et al. reported multiple calcifications in 1.9% of cases, whereas Çitir and Gündüz observed more than one soft tissue calcifications/ossifications in 13.43% of patients (Sutter et al., 2018; Çitir & Gündüz, 2020). In our study, the total frequency of two and multiple calcifications was found to be 26.1%. This difference may be related to geographical and imaging characteristics.

It has been reported that the frequency of tonsilloliths generally increases with age (Aoun et al., 2018; Oda et al., 2013; Cooper et al., 1983). In our study, the mean age of patients with calcifications, including those with tonsilloliths, thyroid cartilage calcifications, calcified atherosclerotic plaques, and calcified lymph nodes, was higher than those without. This is thought to be due to the possibility that metabolic and chronic diseases may increase with age.

Atalay et al. and Çitir and Gündüz found that the most common systemic disease in patients with calcified atherosclerotic plaques was hypertension, followed by diabetes mellitus (Atalay et al., 2015; Çitir & Gündüz, 2020). In our study, hypertension was the most frequently

observed systemic disease in patients with calcified atherosclerotic plaques, consistent with the literature.

CONCLUSION

SLC was the most frequently detected in our study. SLC was more common in female, while tonsillolith was more common in male. The average age of patients with tonsillolith, thyroid cartilage calcification, calcified atherosclerotic plaque, and calcified lymph nodes was higher compared to those without calcification. Hypertension was the most common systemic disease in patients with calcified atherosclerotic plaque.

Panoramic radiographs are a diagnostic tool routinely used in dental practice, presenting both teeth and surrounding bone structures in a single image. The importance of this imaging technique is not limited to the evaluation of dental conditions, but also plays a significant role in identifying soft tissue calcifications in the head and neck region. Calcifications detected on panoramic radiographs are usually discovered incidentally during routine examinations. Follow-up and referral of patients with soft tissue calcification are crucial in preventing possible complications.

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PREVALENCE OF SLEEP DISORDERS IN THE WORKPLACE

Prof. Mohamed HAMADOUCHE

Ferhat Abbas University Sétif1, Faculty of Medicine, Department of Medicine, Sétif, Algeria

Setif University Hospital, Occupational Medicine Department, Sétif, Algeria

ORCID ID: https://orcid.org/0000-0003-1221-0972

Dr. Imen DJEDDOU

Setif University Hospital, Occupational Medicine Department, Sétif, Algeria

ABSTRACT

Introduction and Purpose: Insomnia is a sleep disorder characterized by difficulty falling asleep, difficulty maintaining sleep, or non-restorative sleep. In the workplace, it often results from a combination of factors such as stress, shift work, high job demands, or environmental conditions. The aim of our study is to investigate sleep disorders in two populations: an active working population and individuals attending a pre-employment medical examination.

Materials and Methods: Our study was conducted among 100 workers examined during the periodic medical visit (group 1) and 100 job applicants (group 2). Sociodemographic information was collected, and the Insomnia Severity Index (ISI) was administered. An ISI score ≥ 8 indicates the presence of insomnia. Comparisons of proportions between the two groups were conducted using the Chi-square (χ^2) test. Quantitative variables were described as mean ± standard deviation. Comparisons of means were performed using the independent-samples Student's t-test. A p-value < 0.05 was considered statistically significant.

Results: There is a similar male predominance in both groups, with 90% in group 1 and 92% in group 2. The proportion of individuals under 35 years old is higher in group 2 (65%) than in group 1 (34%) ($p = 0.000$). Married subjects are more numerous in group 1 (61%) compared to group 2 (43%) ($p = 0.011$). In both groups, half of the participants have a high level of education. There is no statistically significant difference in smoking status between the two groups, but this is not the case for coffee consumption: more than three-quarters of subjects (76%) in group 1 regularly drink coffee, compared to 55% in group 2 ($p = 0.002$). Two out of five individuals are overweight or obese, in both groups. There are more chronic disease cases in group 1 (17%) than in group 2 (7%), and the difference is statistically significant ($p = 0.030$). Mild or moderate insomnia was observed at fairly similar rates: 13% in group 1 and 10% in group 2.

Discussion and Conclusion: The male predominance in our population is due to the fact that our study involved sectors known to recruit more men than women. Job applicants are younger than those undergoing periodic medical examinations, which is explained by the fact that the former generally have not yet worked in a professional activity. Consequently, they are more often single and in better health. The high rate of overweight individuals observed in both study groups may be related to sedentary lifestyles and unhealthy eating habits. Insomnia was reported by about one in ten workers, a relatively low rate. However, its consequences can be

severe, affecting alertness, performance, and worker safety, highlighting the importance of appropriate prevention.

Keywords: Insomnia Severity Index; Pre-employment Medical Examination; Periodic Medical Examination; Prevention.

INTRODUCTION

Sleep is an essential biological function required for maintaining homeostasis, cognitive performance, and both physical and mental health. Among sleep disorders, insomnia is one of the most prevalent conditions in the general population and among workers, with significant consequences for quality of life, daytime alertness, and occupational productivity (Morin & Benca, 2012; Morin et al., 2020). Its assessment relies on several validated tools, including the Insomnia Severity Index (ISI), which is widely used in clinical and epidemiological research to quantify symptom severity and functional impact (Bastien et al., 2001).

In the professional environment, sleep quality is influenced by numerous determinants, including work demands, mental workload, irregular schedules, and exposure to psychosocial factors. Several studies have shown that sleep disturbances increase the risk of occupational accidents, reduce cognitive performance, and adversely affect mental health (Uehli et al., 2014). Conversely, job applicants represent a population often exposed to anticipatory stress related to social pressure, the stakes of professional integration, and preparation for examinations or interviews. However, few studies have directly compared sleep quality between individuals who are already employed and those in a pre-employment phase.

Assessing sleep simultaneously in these two groups has substantial value. It enables early identification of sleep problems that may affect future performance and workplace safety, particularly in occupations requiring vigilance, precision, or endurance. It also contributes to guiding targeted prevention programs tailored to the specific needs of each population.

MATERIALS AND METHODS

Our study was conducted among 100 workers undergoing a routine periodic medical examination (Group 1) and 100 job applicants (Group 2). Sociodemographic data were collected, and the Insomnia Severity Index (ISI) was administered to all participants.

The ISI is a self-report questionnaire designed to assess the severity of insomnia symptoms, their functional impact, and the associated distress. It encompasses difficulty initiating sleep, nocturnal awakenings, early morning awakenings, satisfaction with sleep, and daytime consequences. This tool, widely used in clinical practice, occupational medicine, research, and epidemiology, allows for the screening of insomnia, assessment of baseline severity, and evaluation of changes following intervention. It is brief, easy to administer, and validated in numerous languages. The total score ranges from 0 to 28. A score of 0–7 indicates no clinically significant insomnia; 8–14 reflects subclinical (mild) insomnia symptoms; 15–21 indicates clinically significant (moderate) insomnia; and 22–28 denotes severe insomnia symptoms.

Statistical analysis was performed to compare the two study populations: employed individuals and job applicants. Data were entered and analyzed using SPSS software, version 21.0. Qualitative variables were expressed as frequencies and percentages. Comparisons of proportions between the two groups were conducted using the Chi-square (χ^2) test. When the assumptions for the Chi-square test were not met (expected counts < 5), categories were merged to ensure the validity of the analyses. Quantitative variables were checked for normality and

described as mean ± standard deviation. Comparisons of means between the two groups (employed individuals vs. job applicants) were performed using the independent-samples Student's t-test. A p-value < 0.05 was considered statistically significant.

RESULTS

Socio-demographic and clinical characteristics of the study population

The study population was predominantly male (sex ratio 9:1) and generally young, with a mean age of 36 ±11.4 years; nearly two-thirds of participants were under 40 years old. Approximately half of the participants were single and had a secondary or university level of education.

Nearly two-thirds of participants reported regular coffee consumption, while one-third were smokers. Four out of ten participants were overweight or obese. The prevalence of chronic diseases was low (12%). According to the Insomnia Severity Index (ISI), approximately one in ten participants presented with insomnia.

Tables 1 and 2 summarize the socio-demographic and clinical characteristics of the study population.

Table 1: Qualitative data

Parameters		n	%
Sex	Female	18	9,0
	Male	182	91,0
Age	18–29 years	69	34,5
	30–40 years	58	29,0
	41–59 years	73	36,5
Marital status	Single	96	48,0
	Married	104	52,0
Education level	Primary	18	9,0
	Middle	83	41,5
	Secondary	55	27,5
	University	44	22,0
Smoking	Non-smoker	107	53,5
	Former smoker	26	13,0
	Current smoker	67	33,5
Coffee	No	69	34,5
	Yes	131	65,5
Body mass index	Normal	116	58,0
	Overweight	63	31,5
	Obesity	21	10,5
Chronic diseases	No	176	88,0
	Yes	24	12,0
Insomnia	No insomnia	177	88,5
	Mild insomnia	18	9,0
	Moderate insomnia	5	2,5

Table 2: Quantitative data

Parameters	Mean	Standard deviation
Age	36,0	11,4
Number of children	1,7	1,7
Weight	74,9	14,4
Height	1,74	0,07
Body mass index (BMI)	24,6	4,2
ISI		
Difficulty falling asleep	0,7	1,0
Nighttime awakenings	0,6	0,9
Early morning awakening	0,4	0,9
Sleep satisfaction	0,8	1,1
Sleep disturbance due to difficulties	0,6	0,9
Appearance of sleep difficulties	0,4	0,7
Worry about sleep difficulties	0,3	0,8
Total ISI score	3,2	4,0

Comparative study between the two groups

Sex and age

The distribution of sex was comparable between the two groups (Figure 1). In contrast, age distribution differed significantly: more than eight out of ten job applicants were 40 years old or younger, compared with just over half of the employed participants ($p < 0.001$) (Figure 2).

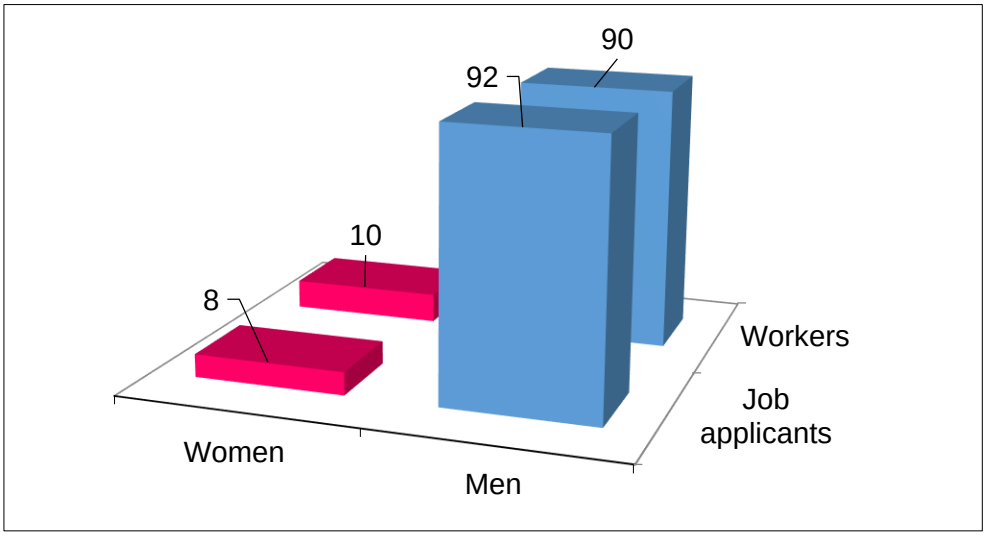


Figure 1: Distribution of the population by sex (%).

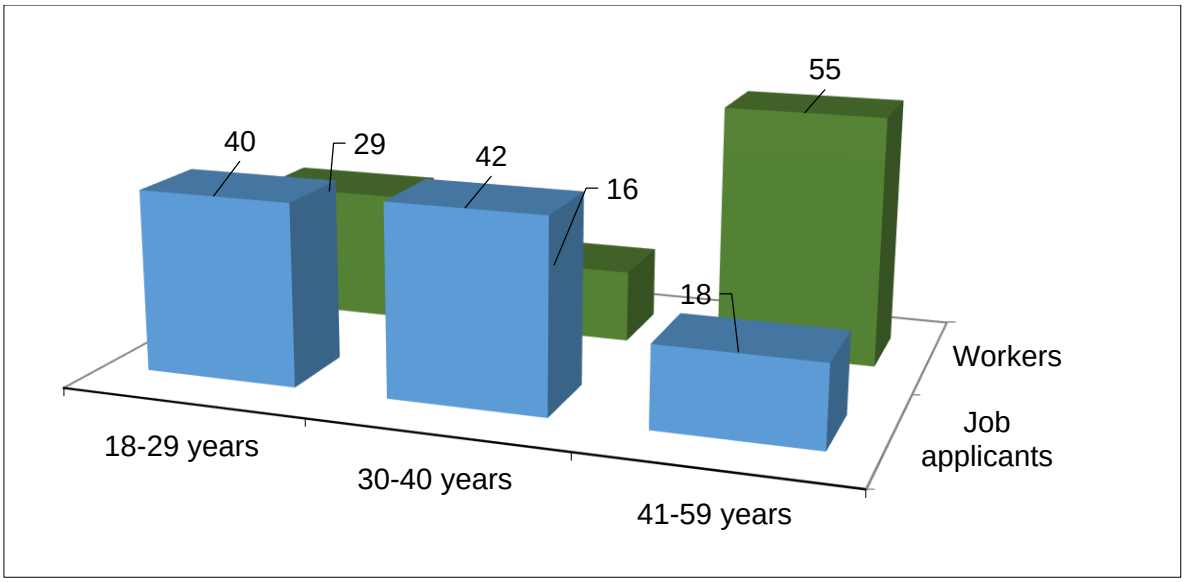


Figure 2: Distribution of the study population by age (%).

Education level

The proportion of university graduates was higher among job applicants than among employed participants, although this difference was not statistically significant (Table 3).

Table 3: Distribution of the study population by education level.

Education Level	Job applicants		Workers		Total
	n	%	n	%	
Primary	7	38,9	11	61,1	18
Middle School	41	49,4	42	50,6	83
Secondary	24	43,6	31	56,4	55
University	28	63,6	16	36,4	44

Marital status

The proportion of married participants was significantly higher in Group 1 (61%) compared with Group 2 (43%) ($p = 0.011$) (Figure 3).

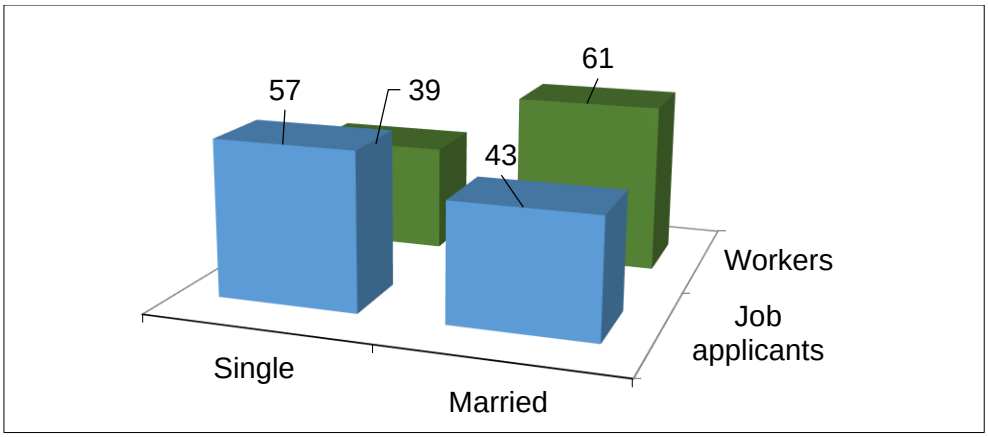


Figure 3: Distribution of the study population by marital status (%).

Smoking and coffee consumption

No statistically significant difference was observed in the distribution of smoking categories between the two groups. Three-quarters of employed participants reported regular coffee consumption, compared with just over half of job applicants. This difference was statistically significant (p = 0.002) (Table 4).

Table 4: Distribution of the study population by smoking status and coffee consumption.

Parameter		Job applicants		Workers		Total
		n	%	n	%	
Tobacco	Former smokers	11	42,3	15	57,7	26
	Current smokers	38	56,7	29	43,3	67
	Non-smokers	51	47,7	56	52,3	107
Coffee	No	45	65,2	24	34,8	69
	Yes	55	42,0	76	58,0	131

Body mass index

In both groups, two out of five participants were overweight or obese (Table 4).

Table 4: Distribution of the study population by body mass index (BMI).

BMC	Job applicants		Workers		Total
	n	%	n	%	
Normal	58	50,0	58	50,0	116
Overweight	35	55,6	28	44,4	63
Obesity	7	33,3	14	66,7	21

Chronic diseases

The prevalence of chronic diseases was significantly higher among employed participants compared with job applicants (p = 0.030) (Figure 4).

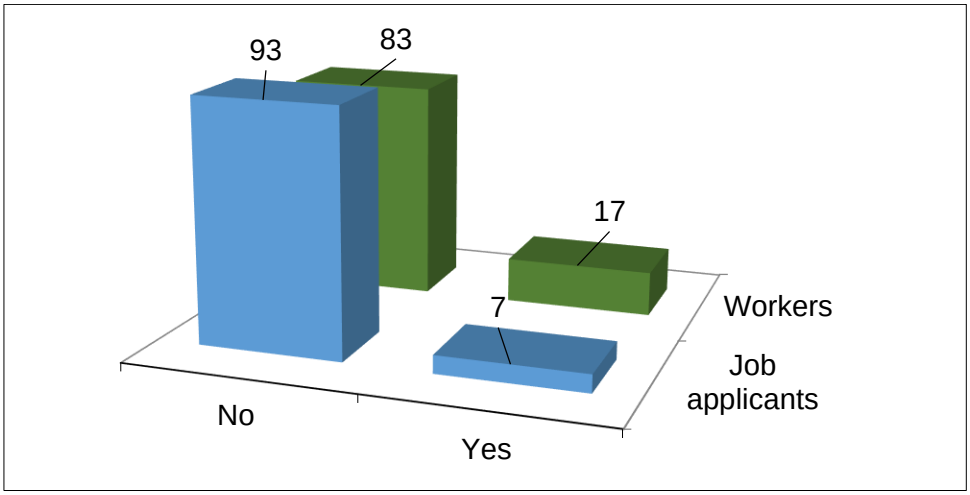


Figure 4: Distribution of the population by the presence of a chronic disease (%).

Insomnia (ISI score)

The proportion of participants reporting insomnia did not differ significantly between the two groups (Figure 5). A detailed analysis of the scores for each ISI item revealed no statistically significant differences, except for the early-morning awakening item, for which scores were

significantly higher among job applicants compared with employed participants (p = 0.013) (Table 5).

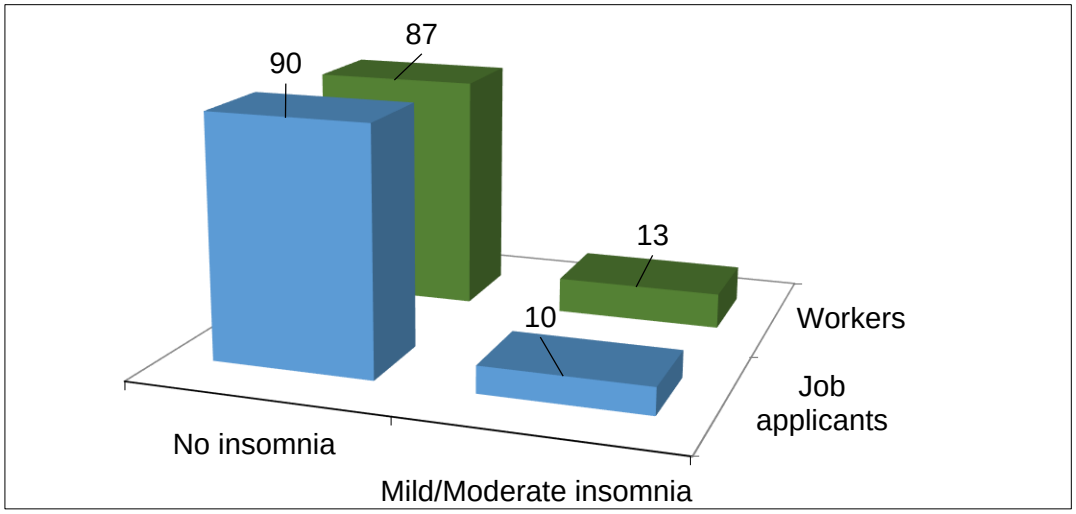


Figure 5: Distribution of the population by the presence of insomnia (%).

Table 5: Distribution of the study population according to ISI items.

ISI items	Job applicants		Workers	
	Mean	Standard deviation	Mean	Standard deviation
Difficulty falling asleep	0,78	1,11	0,62	0,85
Sleep interruption	0,65	0,95	0,52	0,81
Early awakening	0,60	1,02	0,29	0,70*
Sleep satisfaction	0,71	1,09	0,90	1,02
Disturbance due to sleep difficulties	0,56	0,99	0,62	0,85
Appearance of sleep difficulties	0,35	0,76	0,35	0,66
Worry about sleep difficulties	0,38	0,84	0,31	0,76
ISI Score	2,80	3,68	3,60	4,23

* p=0.013

Comparative study of insomnia and socio-demographic and health characteristics

No statistically significant associations were found between the presence of insomnia and socio-demographic or health characteristics, either in the overall study population or in the employed group (Tables 6 and 7). However, in the group of job applicants, a statistically significant association was observed with education level: insomnia prevalence was higher among applicants with primary or intermediate education (p = 0.001) (Table 8).

Table 6: Distribution of insomnia according to socio-demographic characteristics in the overall study population.

Parameters		No insomnia		Insomnia		Total
Sex	Female	14	77,8	4	22,2	18
	Male	163	89,6	19	10,4	182
Age	18–29 years	60	87,0	9	13,0	69
	30–40 years	51	87,9	7	12,1	58
	41–59 years	66	90,4	7	9,6	73
Marital status	Single	82	85,4	14	14,6	96
	Married	95	91,3	9	8,7	104
Education level	Primary/Middle	93	92,1	8	7,9	101
	Secondary/University	84	84,8	15	15,2	99
Tobacco	Smoker	60	89,6	7	10,4	67
	No smoker	117	88,0	16	12,0	133
Coffee	No	58	84,1	11	15,9	69
	Yes	119	90,8	12	9,2	131
BMI	Normal	102	87,9	14	12,1	116
	Overweight/Obesity	75	89,3	9	10,7	84
Chronic disease	No	157	89,2	19	10,8	176
	Yes	20	83,3	4	16,7	24

Table 7: Distribution of insomnia according to socio-demographic characteristics in the employed group.

Parameters		No insomnia		Insomnia		Total
Sex	Female	2	20,0	8	80,0	10
	Male	11	12,2	79	87,8	90
Age	18–29 years	5	17,2	24	82,8	29
	30–40 years	2	12,5	14	87,5	16
	41–59 years	6	10,9	49	89,1	55
Marital status	Single	7	17,9	32	82,1	39
	Married	6	9,8	55	90,2	61
Education level	Primary/Middle	7	13,2	46	86,8	53
	Secondary/University	6	12,8	41	87,2	47
Tobacco	Smoker	5	17,2	24	82,8	29
	No smoker	8	11,3	63	88,7	71
Coffee	No	5	20,8	19	79,2	24
	Yes	8	10,5	68	89,5	76
BMI	Normal	9	15,5	49	84,5	58
	Overweight/Obesity	4	9,5	38	90,5	42
Chronic disease	No	9	10,8	74	89,2	83
	Yes	4	23,5	13	76,5	17

Table 8: Distribution of insomnia according to socio-demographic characteristics in the job applicant group.

Parameters		No insomnia		Insomnia		Total
Sex	Female	2	25,0	6	75,0	8
	Male	8	8,7	84	91,3	92
Age	18–29 years	4	10,0	36	90,0	40
	30–40 years	5	11,9	37	88,1	42
	41–59 years	1	5,6	17	94,4	18
Marital status	Single	7	12,3	50	87,7	57
	Married	3	7,0	40	93,0	43
Education level	Primary/Middle	1	2,1	47	97,9	48
	Secondary/University	9	17,3	43	82,7	52
Tobacco	Smoker	2	5,3	36	94,7	38
	No smoker	8	12,9	54	87,1	62
Coffee	No	6	13,3	39	86,7	45
	Yes	4	7,3	51	92,7	55
BMI	Normal	5	8,6	53	91,4	58
	Overweight/Obesity	5	11,9	37	88,1	42
Chronic disease	No	10	10,8	83	89,2	93
	Yes	0	0,0	7	100,0	7

DISCUSSION

The overall prevalence of insomnia observed in our study (11.5%) falls within the lower range of values reported in the international literature. Several studies have documented substantially higher prevalence rates, including in Bahrain (59%) (Juma, Noor et al., 2024), Egypt (33.6%) (Abd Allah et al., 2014), India (33%) (Jaisoorya et al., 2018), Lebanon (47.1%) (Al Karaki et al., 2020), China (24.8%) (Shan et al., 2024), Saudi Arabia (77.7%) (Almohammadi et al., 2019), and Poland (17.75%) (Wolińska et al., 2020). Conversely, lower prevalence estimates have been reported in Qatar, where Khaled et al. (2021) found values ranging from 3% to 5.5%. A recent meta-analysis including 18 studies (Benjafield et al., 2025) reported an average prevalence of 16.2%.

These substantial variations across studies are plausibly attributable to several methodological and contextual determinants. Differences in assessment tools (including the cut-off used to define insomnia), sample characteristics (age, sex, educational attainment, socioeconomic status), as well as sociocultural and occupational contexts may influence the manifestation of sleep disturbances and the likelihood of reporting them. Moreover, certain studies were conducted in specific situations (academic stress, particular working conditions, post-pandemic period), which may have contributed to higher prevalence estimates.

Thus, the relatively low prevalence observed in our population may reflect both the sociodemographic characteristics of the participants and the methodological parameters specific to our study.

In our study, no statistically significant difference in the prevalence of insomnia was observed between workers and job applicants. This finding contrasts with several studies that have reported an association between employment status and sleep disturbances. Blanchflower et al. (2021) showed that unemployed individuals more frequently experience very short or very long sleep duration and more often report disrupted sleep compared with employed individuals. Similarly, Wolińska et al. (2020) reported a higher prevalence of insomnia among non-employed individuals. Lyu et al. (2023) also noted that unemployed persons tend to adopt delayed sleep–wake patterns, characterized by later bedtimes and wake times, as well as more frequent daytime naps.

In Bahrain, Juma, Noor et al. (2024) identified a significant relationship between unemployment and insomnia, whereas Khaled et al. (2021), in Qatar, found no statistically significant association. Nonetheless, the relationship between insomnia and unemployment remains biologically and socially plausible: the absence of employment is commonly associated with increased financial stress, anxiety, and uncertainty, all of which may contribute to sleep disturbances (Juma, Noor et al., 2024).

In this investigation, the absence of an association may be attributed to the specific composition of the job-applicant group. These individuals were not necessarily unemployed; some may have been seeking access to a more favorable position or attempting to improve their professional situation. It is also possible that certain participants underreported their sleep disturbances or health problems due to fear of being deemed unfit during the medical examination, a bias that may have led to an underestimation of the true prevalence of insomnia in this group.

In our study, the prevalence of insomnia did not differ significantly according to sex or age. The absence of an association with sex may be explained by the small number of female participants, although the literature consistently shows that insomnia is more frequent among women than men (Beck et al., 2013; Juma, Noor et al., 2024; Roth et al., 2007; Morin et al., 2011; Shan et al., 2024; Almohammadi et al., 2019; Awadalla et al., 2021; Benjafield et al., 2025; Riemann et al., 2022; Wolińska et al., 2020; Zuo et al., 2022; Zeng et al., 2020 meta-analysis). With respect to age, some studies have reported an increasing prevalence of insomnia with advancing age (Wolińska et al., 2020; Morin et al., 2011; Almeneessier et al., 2018; Roth et al., 2007; Jaisoorya et al., 2018), whereas others found no significant association (Shan et al., 2024; Almohammadi et al., 2019; Khaled et al., 2021). Beck et al. (2013) observed an age-related increase in men up to 45–54 years, followed by a decline thereafter.

In the present analysis, no significant differences in insomnia prevalence were observed between smokers and non-smokers, or between individuals who consumed coffee and those who did not. However, several studies have identified associations between smoking and insomnia (Bhaskar et al., 2016; Abd Allah et al., 2014; Awadalla et al., 2021), as well as between coffee consumption and insomnia (Bhaskar et al., 2016; Al Karaki et al., 2020; Almohammadi et al., 2019). Almeneessier et al. (2018) also reported an association with excessive tea consumption, whereas Juma, Noor et al. (2024) found no significant relationships.

In our survey, we did not collect detailed information on the quantity of coffee consumed, the timing of intake, or the type of coffee, all of which may influence sleep and could explain the lack of observed association.

Marital status did not appear to influence the presence of insomnia in the present work. This observation contrasts with several studies reporting a higher prevalence of insomnia among unmarried individuals (Juma, Noor et al., 2024; Abd Allah et al., 2014; Morin et al., 2011) or widowed participants (Almeneessier et al., 2018). Conversely, other studies found no significant relationship between marital status and insomnia (Shan et al., 2024; Khaled et al., 2021), suggesting that the effect of marital status on sleep may vary across populations and sociocultural contexts.

Insomnia is generally associated with poor self-reported health status (Roth et al., 2007; Morin et al., 2011; Shan et al., 2024; Awadalla et al., 2021; Khaled et al., 2021). However, similar to our findings, Juma, Noor et al. (2024) did not observe such an association, which may be explained by the relatively small sample sizes included in these studies.

A lower educational level was linked to a higher prevalence of insomnia among job applicants. This finding is consistent with the results of Almeneessier et al. (2018) and Khaled et al. (2021), whereas Shan et al. (2024) did not report a significant association.

No association emerged between BMI and insomnia in the current dataset, in contrast to Awadalla et al. (2021), who identified a relationship between insomnia and underweight status.

CONCLUSION

The prevalence of insomnia in our population was relatively low and was not significantly associated with sex, age, employment status, marital status, smoking, coffee consumption, or general health status. However, a low educational level was linked to more frequent insomnia among job applicants. These findings suggest that the determinants of insomnia may vary according to sociodemographic and methodological contexts. Further studies with larger samples and longitudinal designs are needed to confirm these observations and identify specific risk factors.

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THE ANTIOXIDANT ROLE OF L-TRYPTOPHAN AGAINST GLUTAMATE-INDUCED EXCITOTOXICITY IN NEUROBLASTOMA (SH-SY5Y) CELLS

L-TRİPTOFANIN NÖROBLASTOMA (SH-SY5Y) HÜCRELERİNDE GLUTAMAT KAYNAKLI EKSİTOTOKSİSİTEYE KARŞI ANTİOKSİDAN ROLÜ

Doç. Dr. Sıdıka GENÇ

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Tıbbi Farmakoloji Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0000-0003-0000-5103

Kübra KARABULUT

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Tıbbi Farmakoloji Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0009-0004-6007-472X

ÖZET

Giriş ve Amaç: Glutamat, merkezi sinir sisteminde temel bir nörotransmiter olmasına rağmen, fizyolojik seviyelerin üzerinde bulunduğunda, aşırı reseptör aktivasyonuna, oksidatif strese ve nöronal hücre ölümüne yol açan eksitotoksisite olarak bilinen patolojik bir süreci tetikler. Bu durum, yetersiz temizleme ve bunun sonucunda sinaptik aralıkta glutamat birikmesi nedeniyle gelişir ve nöronlarda geri dönüşümsüz yapısal ve fonksiyonel hasara yol açar. Bu hasar nedeniyle, kalsiyum homeostazının bozulması, mitokondriyal disfonksiyon, reaktif oksijen türlerinin üretiminin artması ve apoptotik yolların aktivasyonu dahil olmak üzere çeşitli hücresel mekanizmalar aktive olur. Bu nedenle, glutamat toksisitesi, nörodejeneratif hastalıkların gelişiminde yer alan kritik bir nöropatolojik süreci temsil eder. Glutamat toksisitesine karşı yeni terapötik ajanlar arayışında, antioksidan ve nöroprotektif özelliklere sahip esansiyel amino asitler önemli bir potansiyel sunmaktadır. L-triptofan, serbest radikalleri nötralize ederek ve reaktif oksijen türlerinin oluşumunu azaltarak hücresel oksidatif stresi azaltmaya katkıda bulunur. Triptofan metabolitlerinin mitokondriyal fonksiyon üzerindeki koruyucu etkileri, inflamatuar yanıtların düzenlenmesindeki rolleri ve antioksidan savunma enzimlerinin modülasyonu, bu amino asidin nöroprotektif kapasitesini daha da desteklemektedir. Bu bağlamda, SH-SY5Y hücre hattında glutamat toksisitesine karşı L-triptofanın terapötik etkinliğini değerlendirmeyi amaçladık.

Materyaller ve Yöntemler: SH-SY5Y hücreleri 96 kuyucuklu plaklara ekildi ve %90 yoğunluğa ulaşana kadar inkübe edildi. İnkübasyondan sonra, kontrol grubu hariç tüm gruplara glutamat (10^{-5} nM) uygulandı ve toksisiteyi indüklemek için 15 dakika inkübe edildi. Daha sonra, farklı dozlarda L-triptofan (5/10/25 µg/ml) uygulandı ve hücreler 24 saat daha inkübe edildi. 24 saatin sonunda, hücre süpernatantları toplandı ve MTT, LDH, TAS, TOS ve GR parametreleri ölçüldü.

Sonuçlar: Sonuçlar, hücre canlılığının glutamat kontrol grubunda en düşük olduğunu gösterdi. 5 µg/ml L-triptofan anlamlı bir değişiklik yaratmazken, 10 ve 25 µg/ml dozlarında istatistiksel

olarak anlamlı farklılıklar gözlemlendi. Oksidatif hasar belirteçleri arasında, TAS ve GR seviyeleri hücre canlılığıyla orantılı olarak artarken, TOS seviyeleri azaldı.

Tartışma ve Sonuç: Sonuç olarak, L-triptofanın oksidatif hasarı azaltarak ve hücre canlılığını artırarak glutamat kaynaklı eksitotoksisiteye karşı potansiyel bir koruyucu etkiye sahip olabileceğini öne sürüyoruz; ancak bu etkinin altında yatan moleküler mekanizmaları açıklığa kavuşturmak için daha fazla çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: Glutamat eksitotoksisitesi, L-triptofan, Oksidatif hasar, SH-SY5Y

ABSTRACT

Introduction and Purpose: Glutamate, although an essential neurotransmitter in the central nervous system, triggers a pathological process known as excitotoxicity when present at levels above physiological levels, leading to excessive receptor activation, oxidative stress, and neuronal cell death. This condition develops due to insufficient clearance and the consequent accumulation of glutamate in the synaptic cleft, leading to irreversible structural and functional damage to neurons. Because of this damage, several cellular mechanisms are activated, including disruption of calcium homeostasis, mitochondrial dysfunction, increased production of reactive oxygen species, and activation of apoptotic pathways. Therefore, glutamate toxicity represents a critical neuropathological process involved in the development of neurodegenerative diseases. In the search for new therapeutic agents against glutamate toxicity, essential amino acids with antioxidants and neuroprotective properties offer significant potential. L-tryptophan contributes to the reduction of cellular oxidative stress by neutralizing free radicals and decreasing the formation of reactive oxygen species. The protective effects of tryptophan metabolites on mitochondrial function, their role in regulating inflammatory responses, and their modulation of antioxidant defense enzymes further support the neuroprotective capacity of this amino acid. In this context, we aimed to evaluate the therapeutic effectiveness of L-tryptophan against glutamate toxicity in the SH-SY5Y cell line

Materials and Methods: SH-SY5Y cells were seeded into 96-well plates and incubated until reaching 90% confluence. Following incubation, all groups except the control group were treated with glutamate (10^{-5} nM) and incubated for 15 minutes to induce toxicity. Subsequently, different doses of L-tryptophan (5/10/25 µg/ml) were administered, and the cells were incubated for an additional 24 hours. At the end of the 24 hours, cell supernatants were collected, and MTT, LDH, TAS, TOS, and GR parameters were measured.

Results: The results showed that cell viability was lowest in the glutamate control group. While 5 µg/ml L-tryptophan did not produce a significant change, statistically significant differences were observed at 10 and 25 µg/ml doses. Among oxidative damage markers, TAS and GR levels increased proportionally with cell viability, whereas TOS levels decreased.

Discussion and Conclusion: In conclusion, we suggest that L-tryptophan may have a potential protective effect against glutamate-induced excitotoxicity by reducing oxidative damage and enhancing cell viability; however, further studies are required to clarify the molecular mechanisms underlying this effect.

Key Words: Glutamate excitotoxicity, L-tryptophan, Oxidative damage, SH-SY5Y

GİRİŞ

Glutamat merkezi sinir sisteminde bulunan önemli bir nörotransmiterdir. Sinaptik iletimin düzenlenmesi, potansiyasyon, öğrenme, hafıza ve nöronal plastisite gibi temel süreçlerde görev

alır (Vandenberg & Ryan, 2013). Glutamat mekanizması, glutamatın alınımı ve salınımı üzerinedir ve sinaptik glutamat seviyeleri kontrol altında tutularak nöronal iletişim sağlıklı biçimde devam ettirilir. Bununla birlikte, glutamat homeostazının bozulması, hücre dışı glutamat konsantrasyonunun artması ve taşıyıcı sistemlerin yetersizliği, hücre içinde ki sinyal akışını negative yönde tetikleyerek eksitotoksisiteye neden olur (Liu et al., 2025; Vandenberg & Ryan, 2013).BEksitotoksisite; glutamate reseptörlerinin aşırı aktivasyonu, kalsiyum yüklenmesi, mitokondriyal disfonksiyon ve oksidatif hasarın birleşimi sonucu ortaya çıkar ve hücrede önemli tahribatlara yol açar (Wu et al., 2025).

Eksitotoksik süreçlerin temelinde glutamat reseptörlerinin aşırı uyarılması yer almaktadır. Bu uyarılma sonucunda nöronlara aşırı miktarda kalsiyum ve sodyum girişi olur. Artan kalsiyum yükü, kalsiyum bağlı proteazların, lipazların ve endonükleazların aktivasyonunu tetikleyerek hücrede protein, lipid ve DNA hasarına neden olur (Mahmoud et al., 2019). Mitokondriyal membran potansiyelinin bozulmasıyla birlikte reaktif oksijen türleri (ROS) hızla artar. Bu durum oksidatif stresin derinleşmesine ve hücre ölümünün hızlanmasına neden olur. Oksidatif stres eksitotoksisitenin hem sonucu hem de güçlendirici unsurudur. Serbest radikallerin aşırı üretimi lipit peroksidasyonuna yol açarak hücre membranlarının bütünlüğünü bozar. Protein oksidasyonu enzim fonksiyonlarının kaybına ve yapısal bozulmalara neden olur. Bu nedenle oksidatif stresin nöronal hasarın ilerlemesindeki rolü kritiktir (Guo et al., 2013). Antioksidan savunma mekanizmalarının etkinliği ise bu patolojik sürece karşı belirleyici faktörlerden biridir. Hücrenin ana antioksidan savunucusu olan glutatyon (GSH) yolağı, ROS nötralizasyonunda ana karakterdir. Glutatyonun fonksiyonunu sürdürebilmesi, glutatyon redüktaz (GR) enziminin GSSG'yi tekrar GSH'a çevirebilmesine bağlıdır. GR aktivitesinin azalması glutatyon döngüsünün aksamasına yol açar ve antioksidan kapasite azalırken oksidatif stres artar. Eksitotoksisite modellerinde GR düzeylerindeki değişimin, oksidatif hasarla ve hücre ölümünün seyriyle ilişkili olduğu bilinmektedir (Balkhi et al., 2014) .Bütün bu eksitotoksisite mekanizmaları Alzheimer ve Parkinson gibi nörodejeneratif hastalıklar için temel oluşturur (Beal, 1992). Bu hastalıklara karşı terapötik yaklaşım ise günümüzde daha çok fizyolojik koşulların iyileştirilmesine yöneliktir. Ancak gelişen teknoloji ve farklı farmakolojik etkileri keşfedilen maddelerin kullanımı hücresel düzeyde iyileşmenin önemini vurgulamaktadır. Özellikle antioksidan etkinliği yüksek olan maddeler, bu bağlamda ön plana çıkmaktadır. L-triptofan, esansiyel bir amino asit olmakla birlikte sadece translasyon sürecinde değil, aynı zamanda birçok biyolojik süreçte kritik öneme sahip bir düzenleyicidir (Christen et al., 1990). Serotonin ve melatonin başta olmak üzere bazı metabolitlerinin öncüsü olan L-triptofan, mitokondriyel süreçleri destekleyerek redoks homeostazına katkıda bulunmaktadır. Yapısına katıldığı aktif metabolitlerden bazıları serbest radikalleri doğrudan nötralize edebilirken, bazıları antioksidan enzim ekspresyonunu artırarak hücresel savunmayı güçlendirebilir (Liu et al., 2019).

Bu bilgiler doğrultusunda çalışmamızda nöroblastom (SH-SY5Y) hücre hattında glutamat kaynaklı eksitotoksisiteyi, L-triptofan ile tedavi etmeyi amaçladık. Terapötik etkinin belirlenmesinde oksidatif hasar (TAK, TOS, GR) ve canlılık (MTT, LDH) belirteçlerine odaklandık. Bu çalışma, glutamat aracılı hücresel hasarı hafifletmeye yönelik potansiyel biyomoleküler yaklaşımların anlaşılması açısından önemli bir temel oluşturmaktadır.

MATERYAL ve METOD

Hücre Kültürü

SH-SY5Y hücre hattı, Bilecik Şeyh Edebali Üniversitesi, Tıbbi Farmakoloji Bölümü'nden (Bilecik, Türkiye) temin edilmiştir. Hücrelerin büyümesi ve gelişmesi, %10 Fetal Sığır Serumu (Euroclone, Milano, İtalya) ve %0,1 Penisilin/Streptomisin içeren F12 ortamı (Euroclone,

Milano, İtalya) ile desteklenmiş Dulbecco'nun Modifiye Edilmiş Kartal Ortamı'nda gerçekleştirilmiştir. Hücreler, %5 CO2 içeren bir ortamda 37 °C'de büyütülmüştür (Genç et al.).

Hücresel Tedavi

Hücreler %90 yoğunluğa ulaştıktan sonra pasajlanmış ve 96 kuyucuklu plakalara ekilerek glutamat (10^{-5} mM) ile muamele edilmişlerdir. Muameleden sonra toksisite oluşturmak için hücreler 30 dakika boyunca inkübe edildi (Pereira & Oliveira, 1997). 24 saat sonra hücre solüsyonları toplanarak deney sonlandırıldı.

Tablo 1. Deney grupları.

Negatif kontrol (SH-SY5Y)
Pozitif kontrol (SH-SY5Y + Glutamat)
L-triptofan 5 µg/ml
L-triptofan 10 µg/ml
L-triptofan 25 µg/ml

MTT Deneyi

MTT deneyi, ticari olarak temin edilen bir kit (Sigma-Aldrich, ABD) ile gerçekleştirildi. Kısaca, her kuyuya 5 mg/ml konsantrasyonunda 10 µL MTT eklendi ve 4 saat inkübe edildi (%5 CO2; 37 °C). Daha sonra, formazan kristallerini çözmek için her kuyuya DMSO eklendi. Hücre canlılığı (%) spektrofotometre kullanılarak 570 nm'de okunan optik yoğunluk (OD) ile hesaplandı. Kontrol grubunun OD'si 100 olarak belirlendi ve diğer grupların canlılık oranı bu duruma göre hesaplandı (Genç et al., 2025).

Toplam Antioksidan Seviyesi (TAS) ve Total Oksidatif Hasar (TOS) Tayini

TAS ve TOS analizleri, Rel Assay Total Antioxidant Capacity (Rel Assay Diagnostics, Gaziantep, Türkiye) ticari kiti kullanılarak tespit edilmiştir. Kısaca, hücre süpernatantları kullanılmış ve tüm reaktifler, üretim protokolüne göre eklenmiştir. Renk değişimi, TAS için 660 nm dalga boyunda ve TOS için 530 nm dalga boyunda ölçülerek değerlendirilmiştir. TAS sonuçları mmol Trolox Equiv/L başına, TOS sonuçları ise µmol H_2O_2Equiv/mg protein başına ifade edilmiştir (Genç et al., 2025).

ELISA Testleri

GR ve LDH seviyeleri ELISA kiti (LDH: E-BC-K046-S, GR: E-EL-H1339) kullanılarak değerlendirildi. Her örneğin optik yoğunluğu 450 nm'de ölçüldü ve deney 3 kere tekrarlandı (Genç et al., 2025).

İstatistiksel Analiz

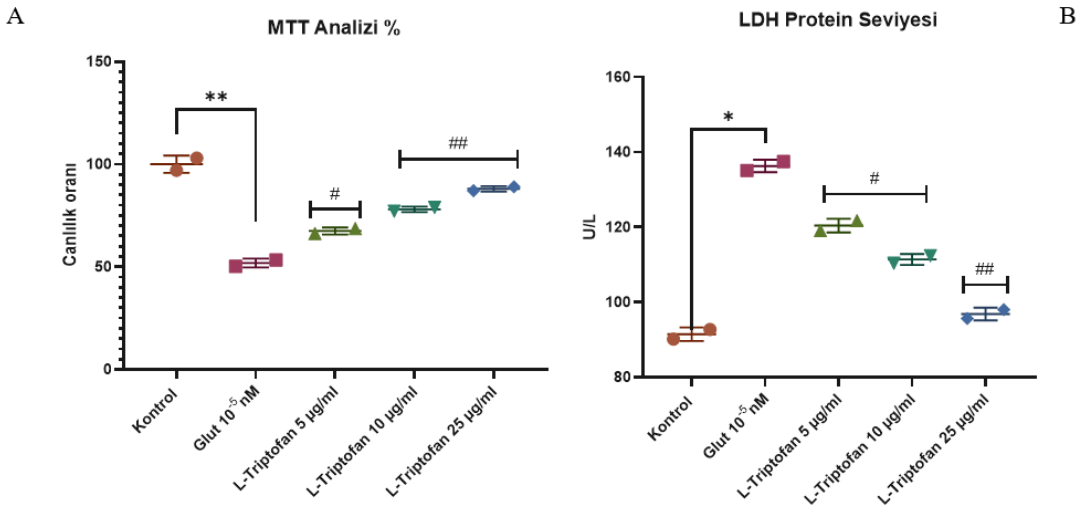
Sonuçlar SPSS 20.0 (IBM SPSSCorp., Armonk, NY, ABD) Windows programı ile analiz edildi ve ortalama ve standart hata değerleri elde edildi. İstatistiksel karşılaştırmalar gruplar arasında One Way Anova testi kullanılarak yapıldı ve anlamlılık düzeyi $p<0.05$ olan veriler istatistiksel olarak anlamlı kabul edildi.

BULGULAR

Canlılık Analizi

Canlılık analizlerine (MTT ve LDH) ait veriler Şekil 1'de gösterilmiştir. MTT sonuçlarında (Şekil 1A) Glutamat kontrol grubunda hücre canlılığının anlamlı şekilde azaldığı belirlenmiştir. Buna karşılık, L- triptofan ile yapılan tedaviler hücre canlılığını doza bağlı olarak artırmış ve özellikle 10 ve 25 µg/mL gruplarında glutamat kontrolüne kıyasla istatistiksel olarak anlamlı iyileşme gözlenmiştir.

LDH analizinde ise (Şekil 1B), glutamat kontrol grubunda kontrole oranla artış gözlenirken L-triptofan ile tedavi edilen gruplarda LDH seviyelerinde azalma tespit edilmiştir. L-triptofan 25 µg/ml dozu diğer tedavi gruplarına göre en anlamlı sonucu vermiştir.

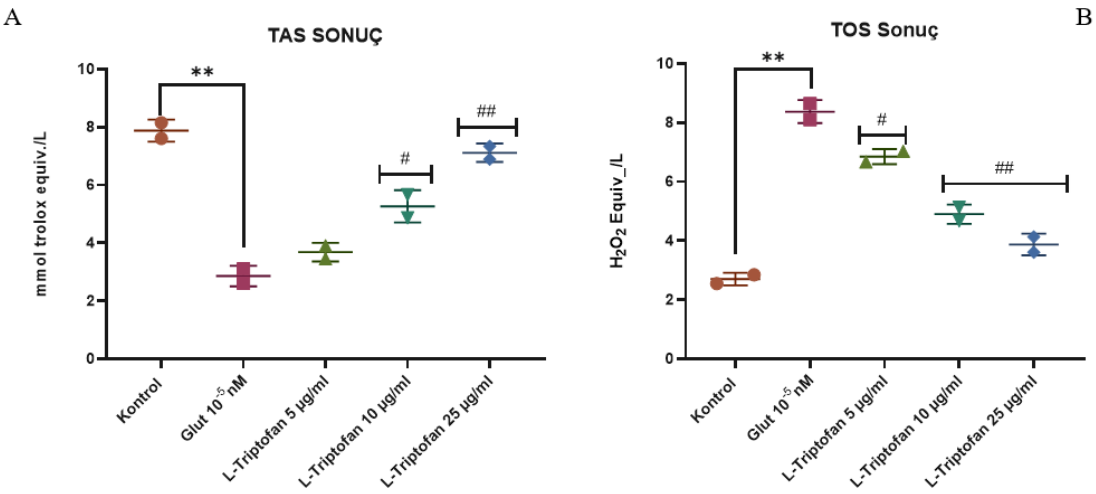


Şekil 1. MTT ve LDH sonuçları (*p<0.05, #p<0.05, **p<0.01, ##p<0.01).

TAS ve TOS Analizleri

SH-SY5Y hücrelerinde oluşturulan eksitotoksisite modelinde TAS ve TOS ölçümleri değerlendirilmiştir (Şekil 2). Glutamat kontrol grubunda TAS seviyesinin, kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde azaldığı belirlenmiştir (Şekil 2A). L-triptofan ile yapılan tedavilerde ise TAS düzeyinin doza bağlı olarak arttığı gözlenmiştir. Özellikle 25 µg/mL L-triptofan uygulamalarında TAS seviyesinde glutamat kontrolüne kıyasla anlamlı bir artış saptanmıştır.

TOS analizinde, glutamat kontrol grubunda TOS seviyesinin kontrol grubuna göre anlamlı derecede arttığı belirlenmiştir (Şekil 2B). TOS seviyelerindeki en anlamlı azalma TAS ile korele olarak 25 µg/ml grubunda tespit edilmiştir. Bu sonuçlar, L-triptofanın, SH-SY5Y hücrelerinde glutamat kaynaklı eksitotoksisite ile artan oksidatif stresi baskıladığını ve hücre içi redoks dengesinin yeniden sağlanmasına katkıda bulunduğunu göstermektedir.

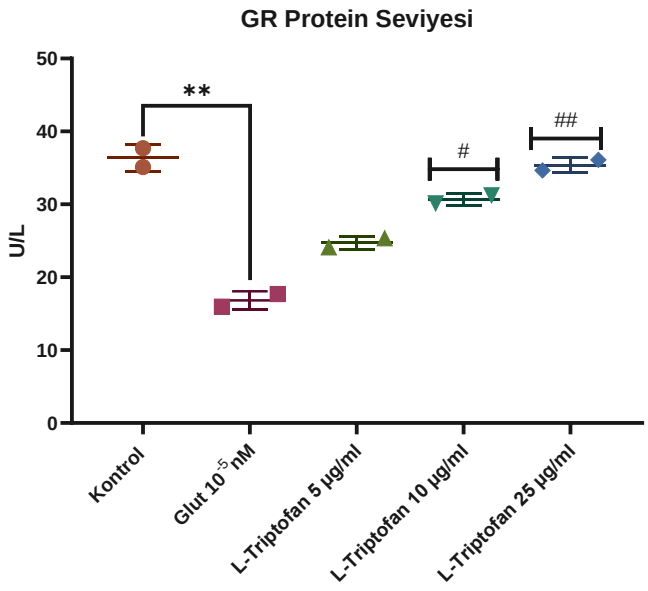


Şekil 2. TAS ve TOS analizleri (#p<0.05, **p<0.01, ##p<0.01).

Glutatyon Redüktaz Analizi

SH-SY5Y hücrelerinde oluşturulan eksitotoksisite modelinde hücresel antioksidan savunma sisteminin önemli bir bileşeni olan GR seviyeleri değerlendirilmiştir (Şekil 3). Glutamat kontrol grubunda GR düzeyinin, kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde azaldığı tespit edilmiştir. Bu azalma, eksitotoksisite kaynaklı oksidatif stres koşullarında hücrelerin antioksidan kapasitesinin baskılandığını göstermektedir. L-triptofan ile yapılan tedavilerde GR seviyelerinde doza bağlı bir artış gözlenmiştir. Düşük konsantrasyonda (5 µg/mL) GR düzeylerinde istatistiksel olarak anlamlı bir değişim tespit edilmezken en yüksek değişim 25 µg/mL L-triptofan grubunda tespit edilmiştir.

Bu bulgular, L-triptofanın glutamat kaynaklı eksitotoksisite modelinde antioksidan savunma mekanizmalarını güçlendirdiğini ve hücre içi redoks dengesinin yeniden sağlanmasına katkıda bulunduğunu göstermektedir.



Şekil 3. GR sonuçları (#p<0.05, **p<0.01, ##p<0.01).

TARTIŞMA ve SONUÇ

Bu çalışmada, SH-SY5Y hücre hattında oluşturulan glutamat aracılı eksitotoksisite kaynaklı oksidatif hasara karşı L-triptofanın terpötik etkisini tespit etmeyi amaçladık. Elde ettiğimiz verilerde yüksek miktarda uygulanan glutamatın, SH-SY5Y hücrelerinde beklenen toksik etkiyi gösterdiği ve sonucunda oksidatif stresin arttığı oksidatif hasar ve canlılık belirteçleri ile tespit edilmiştir. Glutamat maruziyeti sonrasında nöron benzeri hücrelerde oksidatif stres belirteçlerinin bozulması glutamatın toksik etkilerini doğrulamaktadır (Küçükkaya, 1997). Artan TOS seviyeleri ve düşen TAS değerleri, hücresel redoks dengesinin glutamat kaynaklı bozunuma uğradığını göstermektedir. Bunun yanında GR aktivitesindeki azalma, glutatyon döngüsünün kırıldığını ve hücrenin endojen antioksidan kapasitesinin baskılandığını ortaya koymuştur. GR'nin GSSG'yi tekrar GSH'a çevirme yeteneğinin azalması, nöronların ROS yüklenmesi karşısında savunmasız kalmasına yol açmaktadır. Bu durum literatürde eksitotoksik hasarın oksidatif stresle derinleştiğini gösteren çalışmalarla uyumludur (Gündoğdu et al., 2018; Küçükkaya, 1997). Aşırı glutamat, EAAT taşıyıcılarının kapasitesini aşarak postsinaptik alanda birikir ve NMDA ile kalsiyum geçirgen AMPA reseptörlerini sürekli aktif tutarak hücre içine toksik düzeyde kalsiyum girişine neden olur. Mitokondriye aşırı yüklenen Ca^{2+}, membran bütünlüğünü bozup ETS'de elektron kaçışını artırarak ROS üretimini tetikler ve bunların birikimi oksidatif hasarla sonuçlanır (O'Donovan et al., 2017). Bu mekanizmasının taklidi için in vitro ortamda hücrelere yüksek konsantrasyonlarda glutamate uygulanarak eksititoksisite oluşturulur. Çalışmamızda glutamate control grubunun control grubuna oranla oksidatif hasarda artış ve canlılıkta azalma durumları göz önünde bulundurulduğunda, eksitotoksik ortamı sağlayabildiğimizi gözlemledik. Bu gözlemimiz literatürde yapılan diğer çalışmalarla uyumludur (Büyükokuroğlu et al., 2003).

L-triptofanın artan dozlara bağlı olarak glutamat kaynaklı bu bozulmayı hafifletici yönde etkiler göstermesi, l-triptofanın antioksidan yönü ile ilgili literatür bilgilerini doğrulamaktadır (Narin et al., 2005; Narin et al., 2010). L-triptofanın antioksidan rolünün, aslında direkt değil hücresel süreçlerde rol üstlenen birçok antioksidan moleküllerin öncüsü olmasından kaynaklandığını düşünmekteyiz. Bu antioksidan moleküller arasında bulunan serotonin, melatonin ve kinürenin özellikle mitokondriyal işlevlerin düzenlenmesi, oksidatif stresin kontrol altına alınması ve nöroprotektif mekanizmaların desteklenmesinde önemli katkıları olduğu yapılan çalışmalarla doğrulanmıştır (Kaya et al., 2015; Khanzode et al., 2003). Bu bağlamda, L-triptofanın glutamatın yol açtığı redoks dengesizliğini düzeltme kapasitesi hem doğrudan hem de dolaylı antioksidan etkilerinin bir sonucu olabilir.

L-triptofanın antioksidan savunma üzerindeki etkileri, çalışmamızda GR ve TAS seviyelerindeki artış ile açıkça gözlenmiştir. Özellikle L-triptofan 25 µg/ml dozu, glutamate kontrole oranla GR ve TAS seviyelerinde artışa, TOS seviyesinde ise azalmaya yol açarak control grubuna yaklaşmıştır. Bu bulgular, L-triptofanın literatürdeki antioksidan etkinliğini desteklemektedir.

Hücre canlılığı analizleri olan MTT ve LDH sonuçlarında gözlenen iyileşme, L-triptofanın nöronal metabolik aktiviteyi ve membran bütünlüğünü koruduğunu göstermektedir. Oksidatif hasar sonuçları ile korelasyon gösteren MTT testinde artan metabolik aktivite ve azalan LDH salınımı hücre membran hasarının azaldığını ve L-triptofanın sitotoksisiteyi baskıladığını doğrulamaktadır. Bu sonuçlar, L-triptofanın yalnızca oksidatif hasarı azaltmakla kalmayıp hücresel bütünlüğü de doğrudan koruduğunu göstermektedir.

Sonuç olarak, bu çalışma L-triptofanın glutamat aracılı eksitotoksik süreçlerde oksidatif stresin azaltılmasında, glutatyon döngüsünün desteklenmesinde ve nöronal canlılığın korunmasında anlamlı bir terapötik potansiyele sahip olduğunu ortaya koymuştur.

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Ce_2O_3 NANOPARTICLE THERAPY AGAINST DIABETIC ENDOTHELIAL DYSFUNCTION: EFFECTS ON OXIDATIVE STRESS AND WOUND HEALING

DİYABETİK ENDOTEL DİSFONKSİYONUNA KARŞI Ce_2O_3 NANOPARTİKÜL TEDAVİSİ: OKSİDATİF STRES VE YARA İYİLEŞMESİ ÜZERİNDEKİ ETKİLERİ

Doç. Dr. Ali TAGHIZADEHGHALEHJOUGHI

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Tıbbi Farmakoloji Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0000-0002-3506-0324

Dr. Öğr. Üyesi Ramazan ÇINAR

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Biyofizik Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0000-0003-3637-7849

Doç. Dr. Sıdıka GENÇ

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Tıbbi Farmakoloji Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0000-0003-0000-5103

Esmanur NİĞDE

Bilecik Şeyh Edebali Üniversitesi, Tıp Fakültesi, Tıbbi Farmakoloji Anabilim Dalı, Bilecik, Türkiye

ORCID ID: https://orcid.org/0009-0004-6007-472X

ÖZET

Giriş ve Amaç: Diyabet, kronik hiperglisemiye bağlı oksidatif stres, inflamasyon ve vasküler endotel hasarı gibi patofizyolojik süreçlerle ilişkili önemli bir hastalıktır ve yüksek morbidite ve mortaliteye sahip kronik bir durum olarak önemli bir sağlık tehdidi oluşturmaktadır. Mevcut tedavilerin sınırlı terapötik faydaları nedeniyle, yeni ve etkili terapötik stratejilerin geliştirilmesi şarttır. Bu bağlamda, hücresel sinyal yollarını hedef alan ve oksidatif stresi ve inflamasyonu azaltan yenilikçi yaklaşımlara artan bir ilgi gösterilmektedir. Son yıllarda, oksidatif stres modülasyonunda potansiyel rolleri olan nanopartikül bazlı ajanlar, terapötik potansiyelleri nedeniyle dikkat çekmiştir. Seryum oksit nanopartikülleri, Ce^{3+}/Ce^{4+} redoks döngüsü yoluyla serbest radikalleri nötralize edebilen ve böylece hücrelerdeki oksidatif stresi azaltabilen güçlü ajanlar olarak öne çıkmaktadır. Bu dinamik redoks kapasitesi, hücresel hasarı sınırlayarak ve rejenerasyon ve iyileşme süreçlerini destekleyerek önemli bir terapötik etki sağlamaktadır.

Materyaller ve Yöntemler: Çalışmamızda, HUVEC hücreleri 96 kuyucuklu plaklara ekildi ve %90 yoğunluğa ulaşana kadar %5 CO_2 ile 37 °C'de inkübe edildi. Daha sonra plak iki bölüme ayrıldı ve mikropipet ucu kullanılarak doğrusal bir çizik yara modeli oluşturuldu; işlem görmemiş bölüm ertesi gün deney için saklandı. Yara indüklenmiş hücrelere, diyabet modeli oluşturmak için 25 mM D-glukoz uygulandı ve 30 dakika inkübe edildi, ardından farklı dozlarda (1/5/10/25/50 µg/ml) Ce_2O_3 uygulandı. İşlem görmüş hücreler, yara tamamen kapanana kadar 48 saat inkübe edildi. 48. saatte oksidatif hasar belirteçleri (TAS, TOS, GR) ve hücre canlılığı (MTT, LDH) ölçüldü ve yara kapanması 24. ve 48. saatlerde ışık mikroskobu ile görüntülendi. Yaralanmamış bölümde, vasküler geçirgenlik üzerindeki çift yönlü etkilerini değerlendirmek için aynı Ce_2O_3 NP dozları uygulandı.

Sonuçlar: Sonuçlar, 25 ve 50 µg/ml'deki Ce_2O_3'ün glikoz kontrol grubuna kıyasla oksidatif hasarı önemli ölçüde azalttığını ve hücre canlılığını ve proliferasyonunu kontrol seviyelerine doğru artırdığını gösterdi ($p < 0.001$).

Tartışma ve Sonuç: Sonuç olarak, serium oksit nanopartiküllerinin yüksek glikoz koşullarında oksidatif hasarı azalttığı, hücre proliferasyonunu desteklediği ve endotel onarım süreçlerinde terapötik ajan olarak potansiyel gösterdiği bulundu; bu da Ce_2O_3-NP'lerin diyabetle ilişkili endotel hasarını hafifletmek için umut vadeden bir yaklaşım olabileceğini düşündürmektedir.

Anahtar Kelimeler: Ce_2O_3 NP'ler, Diyabet, Hücre canlılığı, Oksidatif hasar.

ABSTRACT

Introduction and Purpose: Diabetes is a major disease associated with pathophysiological processes such as oxidative stress, inflammation, and impairment of the vascular endothelium caused by chronic hyperglycemia, and as a chronic condition with high morbidity and mortality, it represents a significant health threat. Given the limited therapeutic benefits of current treatments, the development of new and effective strategies is essential. In this context, growing interest has focused on innovative approaches that target cellular signaling pathways and reduce oxidative stress and inflammation. In recent years, nanoparticle-based agents with potential roles in modulating oxidative stress have attracted attention for their therapeutic potential. Cerium oxide nanoparticles stand out as strong agents capable of neutralizing free radicals through their Ce^{3+}/Ce^{4+} redox cycling, thereby reducing oxidative stress in cells. This dynamic redox capacity provides a significant therapeutic effect by limiting cellular damage and supporting regeneration and healing processes.

Materials and Methods: In our study, HUVEC cells were seeded into 96-well plates and incubated at 37 °C with 5% CO_2 until reaching 90% confluence. The plate was then divided into two sections, and a linear scratch wound model was created using a micropipette tip; the untreated section was kept for experimentation the following day. For the wound-induced cells, D-glucose (25 mM) was applied and incubated for 30 minutes to induce a diabetes model, after which different doses (1/5/10/25/50 µg/ml) of Ce_2O_3 were administered. The treated cells were incubated until complete wound closure for 48 hours. At the 48th hour, oxidative damage markers (TAS, TOS, GR) and cell viability (MTT, LDH) were measured, and wound closure was imaged by light microscopy at the 24th and 48th hours. In the unwounded section, the same Ce_2O_3 NP doses were applied to evaluate their bidirectional effects on vascular permeability.

Results: The results showed that Ce_2O_3 at 25 and 50 µg/ml significantly reduced oxidative damage compared to the glucose control group and increased cell viability and proliferation toward control levels ($p < 0.001$).

Discussion and Conclusion: In conclusion, cerium oxide nanoparticles were found to reduce oxidative damage under high-glucose conditions, support cell proliferation, and exhibit potential as therapeutic agents in endothelial repair processes, suggesting that Ce_2O_3-NPs may be a promising approach for mitigating diabetes-related endothelial injury.

Key Words: Ce_2O_3 NPs, Cell viability, Diabetes, Oxidative damage.

GİRİŞ

Diabetes mellitus, dünya genelinde giderek yaygınlaşan kronik hiperglisemi ile karakterize edilen metabolik bir hastalıktır. Diyabet çoğunluk glikoz metabolizması ile ilişkilendirilse dahi mortalite riski yüksek olan sistemik bir patolojidir (Deshmukh et al., 2015). Kronik hiperglisemi; inme, ateroskleroz gibi ciddi fizyolojik sonuçlar doğurabilecek tehlikeli bir durumdur. Özellikle uzun süre kontrol altına alınmayan diyabet, oksidatif stresin şiddetlenmesine, inflamasyonun kalıcı hale gelmesine ve endotel bütünlüğünün bozulmasına yol açarak organ yetmezliğine kadar ilerleyebilen geri dönüşü zor hasarlara neden olmaktadır (Çetiner & Rakıcıoğlu, 2020). Bu nedenle diyabet, dünya genelinde doğrudan ya da dolaylı olarak ölüm oranınlarını etkileyen önemli bir hastalıktır. Güncel tedaviler glisemik kontrolün sağlanması, kardiyovasküler riski azaltmayı, oksidatif stres ve inflamasyonu modüle etmeyi hedefler (Tiwari et al., 2014). Ancak bu yaklaşımların odak noktası çoğunlukla semptomatik olmakla birlikte hücresel düzeyde etkileri yetersiz kalabilmektedir. Bu nedenle yeni nesil tedavi seçeneklerini göz önünde bulundurmak önem arz etmektedir. Örneğin, nanopartiküllerin hücresel etkileri arasında özellikle nanopartikül temelli ajanlar dikkat çekmektedir. Bu yenilikçi stratejiler hücresel sinyal yollarını hassas biçimde hedefleme, oksidatif hasarı doğrudan baskılama ve doku rejenerasyonunu destekleme potansiyelleri nedeniyle öne çıkan alternatif tedaviler arasındadır (Daré & Lautenschlager, 2025). Terapötik etkinliği bilinen nanopartiküllerden seryum oksit (Ce_2O_3-NP), Ce^{3+}/Ce^{4+} redoks döngüsü sayesinde reaktif oksijen türlerinin (ROS) nötralizasyonunda güçlü bir antioksidan kapasite sergilemektedir. Bu redoks aktif yapı, Ce_2O_3-NP'nin süperoksit dismutaz (SOD) ve katalaz benzeri davranış göstermesine olanak sağlayarak hücresel redoks dengesinin yeniden kurulmasına katkıda bulunmaktadır (Nelson et al., 2016).

Ce_2O_3-NP'nin oksidatif strese bağlı hasarı azaltma, inflamasyonu baskılama ve hücresel rejenerasyonu destekleme kapasitesi çeşitli in vitro ve in vivo çalışmalarla doğrulanmıştır (Turin-Moleavin et al., 2019). Özellikle endotel hücreleri gibi oksidatif hasara duyarlı dokularda bu nanopartiküllerin terapötik potansiyeli ön plana çıkmaktadır (Del Turco et al., 2013). Diyabet metabolizmasında glikoz kaynaklı mitokondriyal stres, ROS artışı, glutatyon metabolizmasında bozulma ve canlılıkta azalma gibi major sorunlar yeni tedavi yaklaşımlarının değerlendirilmesi için önemli bir model oluşturmaktadır.

Literatürde ve önceki çalışmalarımızdan elde edilen bulgular doğrultusunda, Ce_2O_3-NP'lerinin diyabetik modelde oksidatif hasar üzerindeki etkisinin değerlendirilmesi amaçlanmıştır (Genc et al., 2025). Bu kapsamda, diyabetik koşulları in vitro olarak modellemek amacıyla endotel hücre çalışmaları için yaygın olarak tercih edilen HUVEC hücre hattı kullanılmış ve çizgisel yara modeli oluşturulduktan sonra hücrelere yüksek glikoz uygulanarak diyabetik ortam oluşturulmuştur. Ardından, farklı konsantrasyonlarda Ce_2O_3-NP uygulanan hücrelerde oksidatif hasar belirteçleri, yara kapanma dinamikleri ve hücre canlılığı parametreleri detaylı şekilde analiz edilmiştir. Bu yaklaşım, nanopartiküllerin diyabetik stres altındaki endotel yanıtı üzerindeki potansiyel etkilerinin kapsamlı biçimde değerlendirilmesine olanak sağlamıştır.

MATERYAL ve METOD

Hücre Kültürü

HUVEC hücreleri, Bilecik Şeyh Edebali Üniversitesi Tıp Fakültesi Tıbbi Farmakoloji Anabilim Dalı'ndan (Bilecik, Türkiye) temin edildi. Hücreler pasajlandı ve %90 yoğunluğuna ulaştıklarında 96 kuyucuklu plate ekildi (Genc et al., 2025).

Yara Modeli Oluşturma

Hücreler %90 konfluense ulaşana kadar %5 CO_2 ve 37°C inkübatöründe kültüre edildi. Her kuyucuk 200 µl'lik mikropipet ucu kullanılarak yukardan aşağı doğru düzlemsel bir çizik açılarak oluşturuldu (Celebi et al., 2022).

İn Vitro Diyabet Modeli Oluşturma

Yara modeli oluşturulan hücrelere d-glikoz (25 mM) uygulandı. Hücreler 30 dakika boyunca diyabet modeli için 37ºC'de %5 CO_2'de inkübatöründe inkübe edildi (Rezania et al., 2014).

Deney Grupları ve Doz Uygulama

İn vitro Diyabet modeli oluşturulduktan sonra hücrelere farklı konsantrasyonlarda CeO_2-NP (1 µg/ml, 5 µg/ml, 10 µg/ml, 25 µg/ml ve 50 µg/ml) uygulandı.

Tablo 1. Deney Grupları

Kontrol
Yara Kontrol
D-Glikoz Kontrol (25mM)
Ce_2O_3-NP 1 µg/ml
Ce_2O_3-NP 5 µg/ml
Ce_2O_3-NP 10 µg/ml
Ce_2O_3-NP 25 µg/ml
Ce_2O_3-NP 50 µg/ml

Ce_2O_3-NP uygulamasından sonra yara görüntüleri 24. ve 48. saatlerde ışık mikroskobu ile görüntülendi. Yara tamamen kapanana kadar (48 saat boyunca) inkübe edildi. 48. saatin sonunda oksidatif hasar belirteçleri (TAS, TOS, GR) ve canlılık analizi (MTT, LDH) ölçülerek değerlendirildi.

Kullanılan dozların yara ve diyabet modeli oluşturulmadan sadece HUVEC hücrelerinde toksik etki oluşturup oluşturmadığı ise sadece MTT, TAS ve TOS analizleri ile tespit edildi.

MTT (3-(4,5-Dimetiltiyazol-2-il)-2,5-Difeniltetrazolium Bromür) Testi

48 saatlik işlemden sonra hücre solüsyonlarda ayrı ependorflarda toplandı ve diğer analizler için -20 derecede saklandı. Daha sonra 96 kuyulu plakanın her bir kuyusunda 10 µL MTT eklendi ve plaka CO_2 inkübatöründe 4 saat inkübe edildi. 4 saat sonra, 100 µL DMSO (Dimetil Sülfoksit) solüsyonu eklendi (Formazan kristallerinin çözünmesi için). Spektrofotometrik bir okuyucu ile 570 nm'de okunarak veriler elde edildi (Genç et al., 2024).

TAS (Total Antioksidan Seviyesi) ve TOS (Total Oksidatif Durum) Testleri

TOS (Rel Assay Total Oxidant Status (Rel Assay Diagnostics, Gaziantep, Türkiye) ve TAC (Rel Assay Total Antioxidant Capacity (Rel Assay Diagnostics, Gaziantep, Türkiye) seviyeleri Multiskan™ GO Mikroplaka Spektrofotometre okuyucu ile ölçüldü. Renk yoğunluğu, ticari kit talimatlarına göre numune üzerinde işlemler gerçekleştirilerek elde edilmiştir. TAC seviyesi 660 nm de absorbans edilerek antioksidanla ilişkili veriler elde edilmiştir. TOC seviyesi 530 nm de absorbans edilerek oksidanla ilişkili veriler sağlanmıştır.

Biyokimyasal Analizler

LDH ve glutatyon redüktaz (GR) seviyesi, ELISA kiti kullanılarak incelendi (LDH: E-BC-K046-S, GR: E-EL-H1339). Tüm prosedürler kit talimatlarına doğrultusunda gerçekleştirildi. Optik yoğunluk 450 nm'de ölçüldü. LDH seviyesi, kit protokolüne göre hesaplandı ve sonuçlar % olarak verildi.

İstatistiksel Analiz

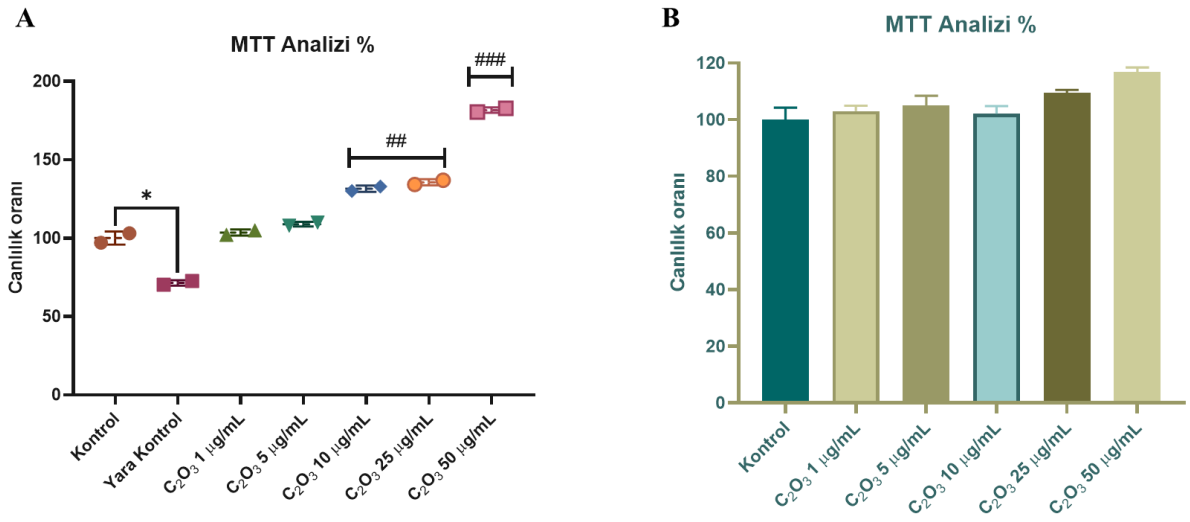
Sonuçlar SPSS 20.0 (IBM SPSSCorp., Armonk, NY, ABD) Windows programı ile analiz edildi ve ortalama ve standart hata değerleri elde edildi. İstatistiksel karşılaştırmalar gruplar arasında One Way Anova testi kullanılarak yapıldı ve anlamlılık düzeyi $p<0.05$ olan veriler istatistiksel olarak anlamlı kabul edildi.

BULGULAR

MTT Analizi

Yara modeli oluşturulan HUVEC hücrelerinde (Şekil 1A), yara kontrol grubunda hücre canlılığının anlamlı şekilde azaldığı belirlenmiştir. Buna karşılık, Ce_2O_3 nanopartikülleri ile yapılan tedaviler hücre canlılığını doza bağlı olarak artırmış ve özellikle 10, 25 ve 50 µg/mL gruplarında yara kontrolüne kıyasla istatistiksel olarak anlamlı iyileşme gözlenmiştir.

HUVEC hücrelerinde Ce_2O_3 nanopartiküllerinin farklı konsantrasyonlarının hücre canlılığı üzerindeki etkisi MTT analizi ile değerlendirilmiştir ve sonuçlar Şekil 1B'de gösterilmiştir. Kontrol grubuna kıyasla, Ce_2O_3'nin doza bağlı olarak artış gösterdiği ancak istatistiksel olarak anlamlılık ifade etmediği tespit edilmiştir. Bu bulgular, Ce_2O_3 nanopartiküllerinin HUVEC hücrelerinde sitotoksik etki göstermediğini ve yüksek konsantrasyonlarda hücre proliferasyonunu ve/veya metabolik aktiviteyi destekleyici bir etki oluşturduğunu düşündürmektedir.

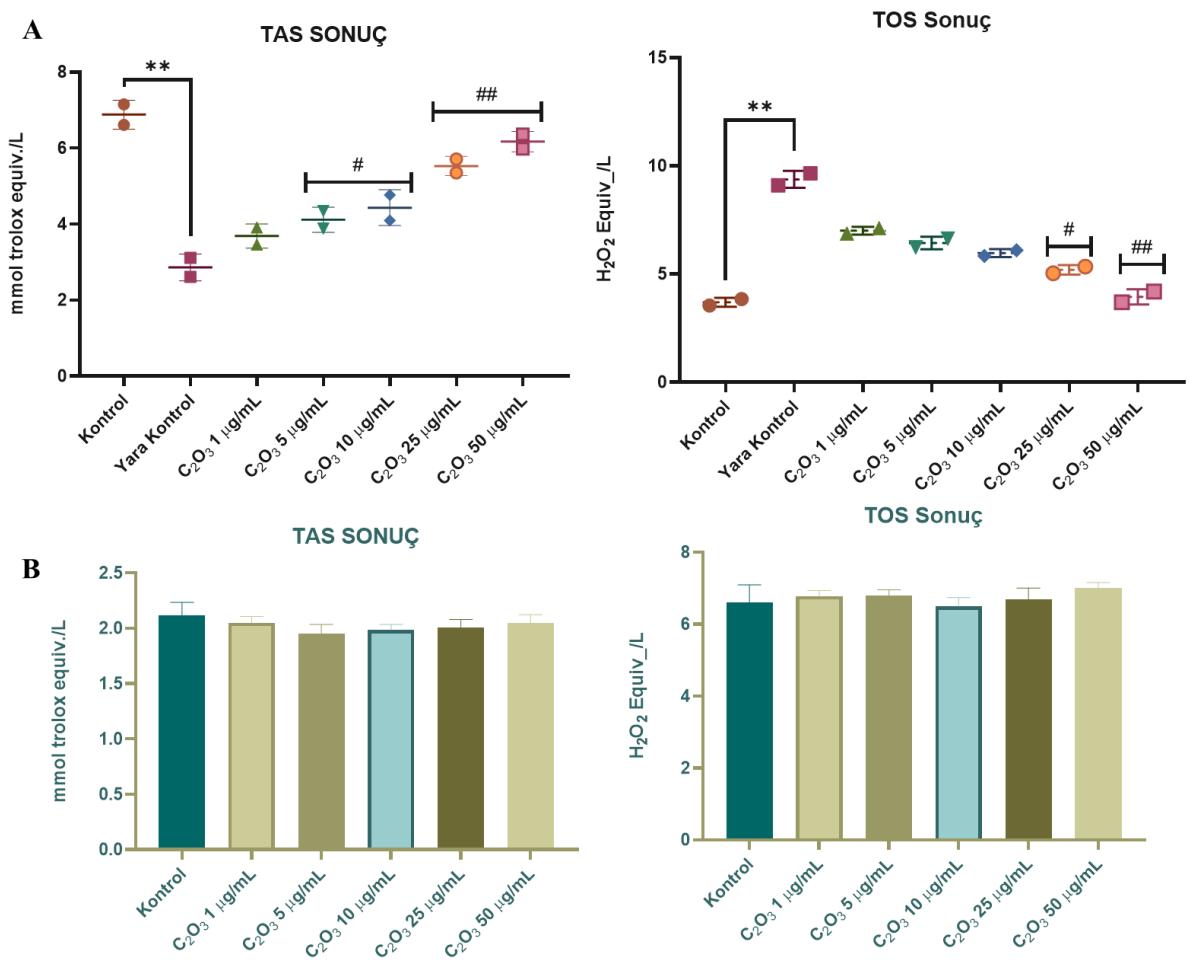


Şekil 1. Yara açılan ve yara hattı açılmayan HUVEC hücrelerine ait MTT sonuçları. **A;** Yara kontrol grubu, kontrol grubuna göre anlamlı derecede azalmıştır. Tedaviyle beraber hücre canlılığında Yara kontrol grubuna göre anlamlı artışlar meydana gelmiştir. **B;** Kontrol grubuna göre Ce_2O_3 uygulanan tedavi gruplarında anlamlı bir artış gözlemlenmemiştir (*p<0.05, #p<0.05, ##p<0.01).

TAS ve TOS Analizleri

HUVEC hücrelerinde oluşturulan yara modelinde TAS ölçümleri değerlendirilmiştir (Şekil 2A). Yara kontrol grubunda TAS seviyesinin, kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde azaldığı belirlenmiştir. Ce_2O_3 nanopartikülleri ile yapılan tedavilerde ise TAS düzeyinin doza bağlı olarak arttığı gözlenmiştir. Özellikle 5 ve 10 µg/mL Ce_2O_3 uygulamalarında TAS seviyesinde yara kontrolüne kıyasla anlamlı bir artış saptanmıştır. Daha yüksek konsantrasyonlarda (25 ve 50 µg/mL) TAS düzeyinin belirgin şekilde yükseldiği ve bu artışın istatistiksel olarak ileri derecede anlamlı olduğu tespit edilmiştir. Yara modeli uygulanmayan HUVEC hücrelerinde ise Ce_2O_3 nanopartiküllerinin farklı konsantrasyonlarının TAS düzeyi üzerinde anlamlı bir değişikliğe yol açmadığı, değerlerin kontrol grubuna benzer seyrettiği görülmüştür (Şekil 2B). Bu bulgular, Ce_2O_3 nanopartiküllerinin özellikle oksidatif stres koşullarında antioksidan savunma kapasitesini artırıcı etki gösterdiğini ortaya koymaktadır.

TOS analizinde, yara kontrol grubunda TOS seviyesinin kontrol grubuna göre anlamlı derecede arttığı belirlenmiştir (Şekil 2A). Ce_2O_3 nanopartikülü uygulanan gruplarda ise TOS düzeyinde doza bağlı bir azalma gözlenmiştir. Düşük ve orta konsantrasyonlarda (1–10 µg/mL) TOS seviyesinde sınırlı bir düşüş saptanırken, 25 ve 50 µg/mL Ce_2O_3 uygulamalarının TOS düzeyini yara kontrol grubuna kıyasla istatistiksel olarak anlamlı biçimde azalttığı belirlenmiştir. Yara modeli bulunmayan HUVEC hücrelerinde Ce_2O_3 nanopartiküllerinin TOS seviyeleri üzerinde anlamlı bir oksidan artışa neden olmadığı ve değerlerin kontrol grubuna yakın seyrettiği görülmüştür (Şekil 2B). Bu sonuçlar, Ce_2O_3 nanopartiküllerinin yara koşullarında artan oksidatif stresi baskıladığını ve hücre içi redoks dengesinin yeniden sağlanmasına katkıda bulunduğunu göstermektedir.

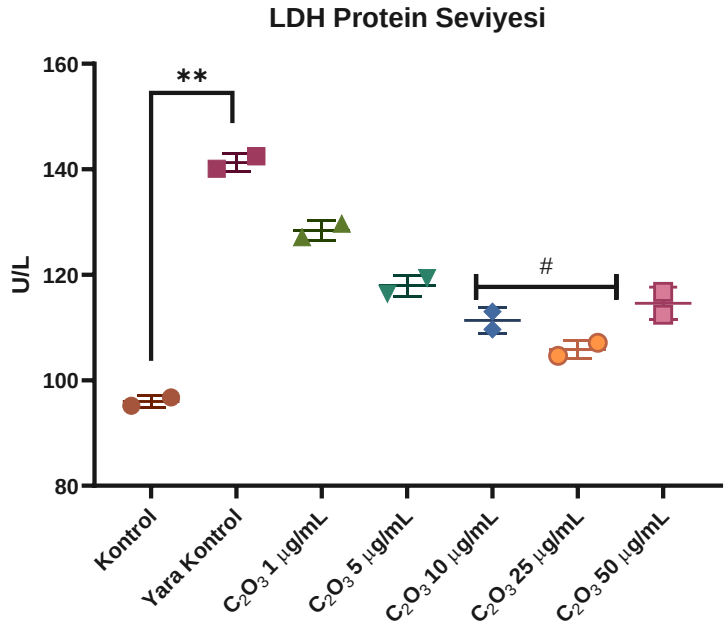


Şekil 2. Yara açılan ve yara hattı açılmayan HUVEC hücrelerine ait TAS ve TOS sonuçları. A; Yara hattı açılan HUVEC hücrelerinin TAS sonuçlarına göre, Yara kontrol grubu kontrol grubuna göre anlamlı ölçüde azalmıştır. Tedavi dozlarının artışıyla beraber TAS değerleri kontrol grubuna yaklaşarak istatistiksel olarak anlamlı bulunmuştur. TAS sonuçlarıyla korele olarak TOS sonuçlarında Yara kontrol grubu kontrol grubuna göre anlamlı ölçüde artarken tedavi gruplarıyla bu artış oranı düşerek kontrol grubuna yaklaşmıştır. B; Yara hattı açılmayan HUVEC hücrelerinin TAS ve TOS sonuçlarına göre, Yara kontrol grubu ve tedavi grupları arasında istatistiksel olarak anlamlılık gözlemlenmemiştir (**p<0.01, #p<0.05, ##p<0.01).

Biyokimyasal Analizler

HUVEC hücrelerinde oluşturulan yara modelinde hücresel hasarın göstergesi olarak LDH protein seviyeleri değerlendirilmiştir ve sonuçlar Şekil 3'te sunulmuştur. Yara kontrol grubunda LDH düzeyinin, kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde arttığı belirlenmiştir. Bu bulgu, yara oluşturulmasıyla birlikte hücre membran bütünlüğünün bozulduğunu ve sitotoksik hasarın arttığını göstermektedir. Ce_2O_3 nanopartikülleri ile yapılan tedavilerde LDH seviyelerinde doza bağlı bir azalma eğilimi gözlenmiştir. Özellikle 5 ve 10 µg/mL Ce_2O_3 uygulamalarında LDH düzeyinin yara kontrol grubuna kıyasla belirgin şekilde azaldığı saptanmıştır. En düşük LDH seviyeleri 25 µg/mL CeO_2 grubunda tespit edilmiş olup, bu azalmanın istatistiksel olarak anlamlı olduğu belirlenmiştir. 50 µg/mL Ce_2O_3uygulamasında

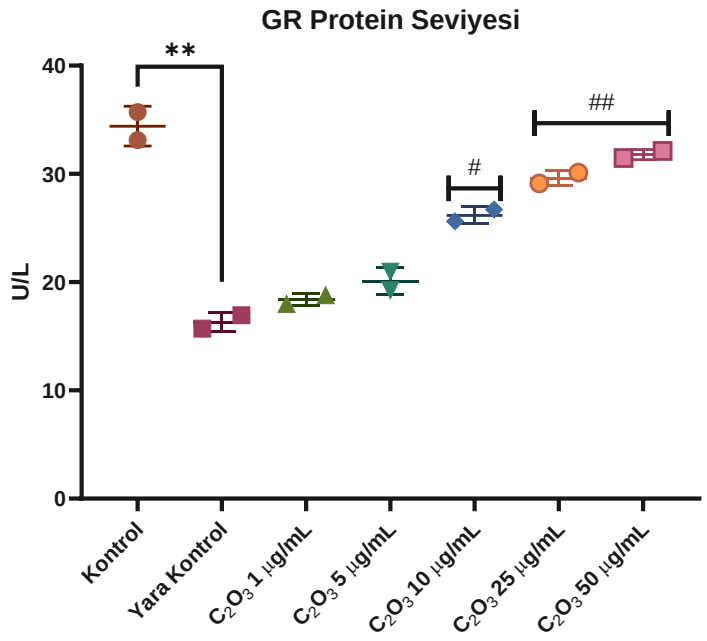
ise LDH seviyelerinde 25 µg/mL grubuna kıyasla sınırlı bir artış gözlenmekle birlikte, değerlerin yara kontrol grubunun altında seyrettiği tespit edilmiştir. Bu sonuçlar, Ce_2O_3 nanopartiküllerinin yara koşullarında HUVEC hücrelerinde hücre membran hasarını azalttığını ve sitoprotektif etki gösterdiğini ortaya koymaktadır.



Şekil 3. Yara açılan HUVEC hücrelerine ait LDH sonuçları. Yara kontrol grubu, kontrol grubuna göre anlamlı derecede artmıştır. Tedavi grupları ise doza bağlı olarak yara kontrol grubuna göre azalma göstermiştir (**p<0.01, #p<0.05).

HUVEC hücrelerinde oluşturulan yara modelinde hücresel antioksidan savunma sisteminin önemli bir bileşeni olan GR protein seviyeleri değerlendirilmiştir. Yara kontrol grubunda GR düzeyinin, kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde azaldığı tespit edilmiştir. Bu azalma, yara ile indüklenen oksidatif stres koşullarında hücrelerin antioksidan kapasitesinin baskılandığını göstermektedir. Ce_2O_3 nanopartikülleri ile yapılan tedavilerde GR protein seviyelerinde doza bağlı bir artış gözlenmiştir. Düşük konsantrasyonlarda (1 ve 5 µg/mL) GR düzeylerinde sınırlı bir yükselme saptanırken, 10 µg/mL CeO_2 uygulamasında GR seviyesinin yara kontrol grubuna kıyasla istatistiksel olarak anlamlı şekilde arttığı belirlenmiştir. Daha yüksek konsantrasyonlarda (25 ve 50 µg/mL) GR protein seviyelerinin belirgin biçimde yükseldiği ve bu artışın ileri derecede istatistiksel anlamlılık gösterdiği tespit edilmiştir.

Bu bulgular, Ce_2O_3 nanopartiküllerinin yara koşullarında HUVEC hücrelerinde antioksidan savunma mekanizmalarını güçlendirdiğini ve hücre içi redoks dengesinin yeniden sağlanmasına katkıda bulunduğunu göstermektedir.



Şekil 4. Yara açılan HUVEC hücrelerine ait GR sonuçları. Yara kontrol grubu, kontrol grubuna göre anlamlı derecede azalmıştır. Tedavi grupları ise doza bağlı olarak yara kontrol grubuna göre anlamlı artış göstermiştir (**p<0.01, #p<0.05, ##p<0.01).

TARTIŞMA ve SONUÇ

Çalışmada, HUVEC hücrelerinde oluşturulan diyabet modelinin farklı konsantrasyonlardaki Ce_2O_3-NP'leri ile tedavi edilmesinin oksidatif hasar üzerindeki etkisini değerlendirdik. Bu Elde ettiğimiz bulgularda oksidatif hasarın azaldığına dair kanıtlar literatür ile uyumludur. Örneğin, yapılan bir çalışmada Ce_2O_3-NP'nin hem SOD hem de katalaz benzeri aktivite gösterebildiğini ve yüksek oksidatif yük altında bile redoks dengesini yeniden sağlayabildiği bildirilmiştir (Heckert et al., 2008). Bu çalışma ile uyumlu olarak diyabetik fare modelinde oluşturulan iskemik hasar kaynaklı oksidatif hasar için terapötik ajan olarak Ce_2O_3-NP kullanılmış nanopartikül verilen gruplarda, verilmeyenlere kıyasla TAS artışı ve TOS azalışı tespit edilmiştir (Fayyazi et al., 2023). Bulgularımızda özellikle CeO_2-NP 25 ve 50 µg/ml dozlarında TAS seviyelerinin arttığı TOS'da ise TAS ile korele olarak azalma tespit edildi.

Yüksek glikozun oluşturduğu mitokondriyal disfonksiyon ve birikmiş ROS, endotel bütünlüğünün bozulmasında temel etkenlerden biridir (Brownlee, 2005). Diyabetik ortamda ROS birikimi glutatyon metabolizmasını baskılamakta ve proinflamatuar sinyalleşmeyi artırmaktadır. Böylece başlıca antioksidan savunma hattını oluşturan glutatyon (GSH) sistemi engellenerek hücresel rejenerasyon mekanizması etkilenmiş olur (Giacco & Brownlee, 2010). GSH, ROS'u doğrudan nötralize ederek lipit peroksidasyonunu azaltmakta, DNA ve protein oksidasyonunu engellemekte ve hücresel hasarı sınırlandırmaktadır. Ancak yüksek glikoz maruziyeti, GSH tüketimini artırarak oksitlenmiş glutatyon (GSSG) birikimine neden olmakta ve redoks dengesini bozarak oksidatif yükü artırmaktadır. GR, NADPH kullanarak GSSG'yi tekrar GSH'a dönüştürmekte ve böylece hücre içi GSH/GSSG oranının korunmasını sağlamaktadır. Diyabetik hücrelerde GR aktivitesinin azalması, GSH seviyelerinin düşmesine, ROS birikiminin artmasına ve proliferasyon kapasitesinin azalmasına yol açmaktadır (Newsholme et al., 2016). Literatürde diyabet modeli oluşturulmuş farelerde CeO_2-NP kullanımı ile GSH yolağında antioksidan kapasitenin artarak ROS seviyesinin ve apoptozun

azaldığı tespit edilmiştir. Literatürle korelasyon gösteren çalışmamızda GR seviyelerinin diyabet kontrole göre Ce_2O_3-NP ile arttığı tespit edilmiştir (Solgi et al., 2021).

Hücrelerde yüksek glikozun oluşturduğu stres ve artan oksidatif yük, hücre canlılığını azaltarak proliferasyon üzerinde olumsuz etki yaratmıştır. Ancak CeO_2-NP ile tedavi sonrası proliferasyon, başta 50 µg/ml dozunda olmak üzere diğer gruplarda artış göstermiştir. Bu sonuç, Hussain ve diğerleri tarafından Ce_2O_3-NP'nin hücre stresini azaltarak proliferasyon hızını artırdığı yönündeki bulgularla örtüşmektedir (Hussain et al., 2012). Diyabetik koşulların hücre canlılığını azaltıcı etkileri göz önünde bulundurulduğunda, nanopartikül uygulamasıyla elde edilen bu iyileşme terapötik açıdan önemli bir avantajdır.

Ayrıca, çalışmada kullanılan Ce_2O_3-NP dozlarının diyabet modeli oluşturulmadan yalnızca HUVEC hücrelerinde toksisite oluşturup oluşturmadığı da değerlendirilmiştir. MTT sonuçları, uygulanan konsantrasyonların hücre canlılığını anlamlı düzeyde azaltmadığını göstermiştir. Buna paralel olarak, TAS ve TOS analizleri nanopartiküllerin oksidatif dengeyi bozmadığını ve hücrelerde ek bir stres yükü oluşturmadığını ortaya koymuştur. Bu bulgular, seçilen doz aralığının HUVEC hücreleri için toksik olmadığını desteklemektedir.

Sonuç olarak elde ettiğimiz bulgularla, Ce_2O_3-NP'nin antioksidan rolü sayesinde diyabetik endotel hasarında redox metabolizmasını düzenleyici etki gösterdiğini ve diyabet ya da diyabet kaynaklı hastalıklarda oksidatif hasarı önleyici yeni bir terapötik ajan olabilme ihtimalini ortaya koymaktayız. Bununla birlikte, in vitro koşullarda elde edilen bu bulguların ileri düzey in vivo çalışmalar ve klinik araştırmalar ile desteklenmesi gerekmektedir.

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EVALUATION OF ERYTHROCYTE SEDIMENTATION RATE (ESR): SAMPLING TECHNIQUES AND CLINICAL INTERPRETATION

Rabar Mohammed Hussein

Medical Laboratory Technician Department, Noble Technical Institute. Erbil-Iraq.

Abstract

This study analyzed Erythrocyte Sedimentation Rate (ESR) data collected from a cohort of young adults (20–35 years) at the Noble Institute. ESR values were evaluated using age- and sex-adjusted reference ranges. Male participants predominantly exhibited low ESR values, ranging from 1 mm/hr to 14 mm/hr. Female participants showed a wider range, with some values within normal limits and several significantly elevated results, including 25 mm/hr, 33 mm/hr, and an outlier of 55 mm/hr. These findings highlight a clear gender-based dichotomy in ESR measurements. The low values observed in males validate the strict adherence to the one-hour Westergren protocol by the laboratory staff. Technical compliance confirms reliable pre-analytical handling and supports the accuracy of observed results. Elevated ESRs in females are consistent with physiological differences, including hemoglobin levels and plasma protein fluctuations related to the menstrual cycle. The study emphasizes the importance of using sex-specific reference intervals for accurate interpretation. High ESR readings, such as 55 mm/hr, indicate potential systemic inflammation and necessitate further clinical investigation. Overall, the data demonstrate the ESR's utility as a first-line, non-specific screening tool for inflammatory conditions. The findings support the continued use of standardized ESR testing as a reliable diagnostic marker within this population.

Keywords: Erythrocyte Sedimentation Rate, Gender, Young Adults, Inflammation, Laboratory Standards.

Introduction

The Erythrocyte Sedimentation Rate (ESR) test is a cornerstone diagnostic tool in hematology and general medicine, serving as a rapid, accessible, and non-specific indicator of systemic inflammation. This simple laboratory procedure quantifies the rate at which red blood cells (erythrocytes) settle out of anticoagulated whole blood over a defined period, conventionally measured in millimeters per hour (\text{mm/hr}). Despite the advent of more specific and sensitive biomarkers, the ESR maintains its clinical relevance due to its low cost, widespread availability, and established utility in screening for conditions that cause elevated plasma protein levels (Finch et al., 2024). This study is designed to critically examine the consistency and reliability of this fundamental measurement within a specific institutional setting.

The physiological basis for changes in the ESR is rooted in the plasma protein composition, particularly the concentration of acute-phase reactants. During active inflammation, proteins such as fibrinogen and immunoglobulins increase dramatically. These positively charged macromolecules neutralize the natural negative repulsive charge (zeta potential) on the surface of the erythrocytes, allowing the red cells to aggregate into stacked structures known as rouleaux (Bizzaro & Forni, 2023). The resulting rouleaux formation is denser and heavier than individual red blood cells, causing them to fall more quickly under gravity, thus yielding an elevated ESR reading. Understanding this mechanism is vital for accurately interpreting elevated results as potential indicators of underlying pathology.

In clinical practice, the ESR is frequently employed as a screening tool for occult or active disease and for monitoring the treatment efficacy of certain chronic conditions. In acute contexts, a rapidly rising ESR can signal bacterial infections, deep-seated abscesses, or trauma (Williams & Jackson, 2022). Its utility extends significantly into the realm of autoimmune disorders, where it is instrumental in monitoring disease activity in conditions like Rheumatoid Arthritis (RA) and Systemic Lupus Erythematosus (SLE), and is a classic diagnostic criterion for specific vasculitides such as Giant Cell Arteritis (GCA) (Tanaka & Jones, 2023). However, its non-specific nature necessitates that the ESR be interpreted within the context of the patient's overall clinical presentation and other laboratory findings.

Given the procedural nature of the ESR test, adherence to strict standardization is paramount to ensure the integrity of the results. The Westergren method, recommended by international bodies, dictates specific parameters, including the dimensions of the sedimentation tube and the precise ratio of blood to anticoagulant (International Council for Standardization in Haematology, 2021). Of critical importance is the measurement time: the official reading is taken exactly after one hour (60 minutes). Variations in this or other technical factors (e.g., tube tilt, temperature, blood storage time) can introduce significant pre-analytical and analytical errors, leading to misclassification of patients as either normal or inflamed (Smit & Van Der Heijden, 2024).

Therefore, this investigation addresses the necessity for localized quality assurance and validation of procedural compliance. While the general clinical utility of ESR is globally accepted, the application of standardized methodology must be confirmed at the point of care. This study aims to analyze the current practices of ESR sampling and the subsequent interpretation of results within the specific operational context of the Noble Institute. By evaluating data collected under stringent adherence to the one-hour Westergren protocol, this research seeks to confirm technical validity and contribute localized data to the body of literature regarding this essential inflammatory marker (Noble Institute Clinical Laboratory Procedures Manual, 2023).

Literature Review

Mechanism and Physiological Basis

The sedimentation of erythrocytes is a three-stage process: aggregation (rouleaux formation), sedimentation proper (fast falling), and packing (slowing down as they accumulate at the bottom). The aggregation phase is critically influenced by the balance between the pro-sedimenting forces (the weight of the rouleaux structures) and the zeta potential (the negative charge on red cell surfaces that causes mutual repulsion). Inflammatory states shift this balance, primarily by increasing plasma viscosity and the concentration of positively charged macromolecules, which neutralize the repulsive forces and accelerate rouleaux formation. Understanding this core mechanism is essential for proper technical execution and accurate interpretation of elevated readings (Bizzaro & Forni, 2023).

Clinical Utility in Acute Inflammation and Infection

ESR exhibits significant clinical utility as a screening tool for systemic inflammation, often rising dramatically in response to bacterial infections, trauma, and other acute processes. While C-Reactive Protein (CRP) often rises and falls more quickly, the ESR provides a cumulative indicator over a slightly longer timeframe. Clinicians frequently use the ESR alongside other laboratory metrics to help differentiate between infectious and non-infectious causes of fever of unknown origin (FUO) and to gauge the overall severity of acute infections, such as

osteomyelitis or endocarditis, though it must be considered within the full clinical picture (Williams & Jackson, 2022).

Application in Chronic and Autoimmune Conditions

Beyond acute events, the ESR is particularly crucial in the management and follow-up of chronic autoimmune diseases. Conditions like Rheumatoid Arthritis (RA) and Systemic Lupus Erythematosus (SLE) are characterized by persistent inflammatory cycles, and fluctuations in the ESR are often used as a simple biomarker for disease activity and response to disease-modifying antirheumatic drugs (DMARDs). Furthermore, its utility is well-established in diagnosing specific vasculitides, notably Polymyalgia Rheumatica (PMR) and Giant Cell Arteritis (GCA), where a markedly elevated ESR is considered a classic and often diagnostic finding (Tanaka & Jones, 2023).

Historical Context and Standardization of Methodology

The determination of ESR has evolved since its first description, but the most accepted methodology globally remains the Westergren method. This method, standardized by the International Council for Standardization in Haematology (ICSH), involves a specific type of vertical tube (200 mm long, 2.55 mm bore) and a precise ratio of blood to sodium citrate anticoagulant. Adherence to this standardized approach is paramount because variations in tube dimensions, anticoagulant type, or reading time can significantly alter results, leading to misclassification and potentially incorrect clinical decisions. This emphasizes the critical link between laboratory protocol and clinical reliability (International Council for Standardization in Haematology, 2021).

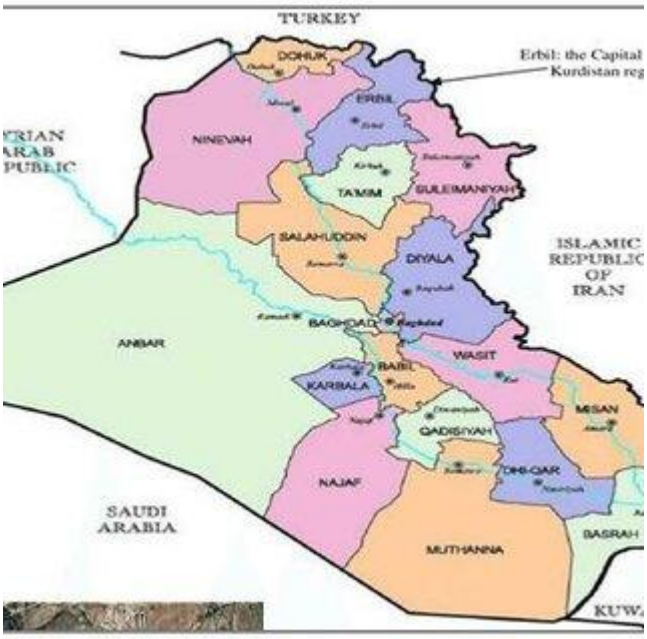
Non-Pathological Variables Affecting ESR Interpretation

While inflammation is the primary driver of ESR variation, several non-pathological factors must be accounted for during interpretation. Key variables include age, sex, and technical factors. Literature consistently demonstrates that ESR values tend to increase with age, necessitating the use of age- and sex-adjusted reference intervals for accurate diagnosis. Females typically exhibit slightly higher reference ranges than males due to physiological differences, specifically related to hemoglobin concentration and plasma composition. Furthermore, variables such as anaemia, hyperviscosity, and laboratory temperature can independently influence the final reading (Smit & Van Der Heijden, 2024).

Materials and Methods

Study Design and Procedure

This investigation employed a retrospective cross-sectional study design utilizing anonymized patient data collected within the clinical laboratory of the Noble Institute. Venous blood samples were collected using standardized procedures into tubes containing trisodium citrate anticoagulant at the approved ratio. The sedimentation was performed strictly according to the Westergren method, where the prepared tubes were placed vertically in a rack at room temperature. The critical measurement was taken precisely after one hour (60 minutes), recording the distance (in \text{mm}) that the red cells had fallen. The results were then interpreted by comparing the \text{mm/hr} values against established age- and sex-specific reference ranges (Noble Institute Clinical Laboratory Procedures Manual, 2023).



Location of Iraq (Iraqi map) {Hussein etl ,2019,2021,2022]

Results

Table 1: show the results of ESR

Age	Gender	Result (mm/hr)	Normal Range (mm/hr)	Interpretation
20	Male	6	Male <50 yrs: 0–15	Normal
21	Male	14	Male <50 yrs: 0–15	Normal
20	Male	8	Male <50 yrs: 0–15	Normal
21	Male	5	Male <50 yrs: 0–15	Normal
20	Female	30	Female <50 yrs: 0–20	High
25	Female	55	Female <50 yrs: 0–20	High
21	Male	4	Male <50 yrs: 0–15	Normal
25	Female	25	Female <50 yrs: 0–20	High
33	Male	5	Male <50 yrs: 0–15	Normal
24	Female	20	Female <50 yrs: 0–20	Normal
21	Female	33	Female <50 yrs: 0–20	High
32	Male	1	Male <50 yrs: 0–15	Normal
31	Male	12	Male <50 yrs: 0–15	Normal
30	Female	11	Female <50 yrs: 0–20	Normal
21	Male	1	Male <50 yrs: 0–15	Normal
21	Female	22	Female <50 yrs: 0–20	High
22	Male	3	Male <50 yrs: 0–15	Normal

The analysis of the ESR data collected from the Noble Institute cohort, which focused on young adults (20-35 years of age), revealed a clear dichotomy in sedimentation rates based on gender. While the male subset primarily showed very low ESR values (ranging from 1 \text{mm/hr} to 14 \text{mm/hr}), the female subset exhibited a wider range, including several significantly elevated results. For instance, while some females were within the normal range (e.g., 11

\text{mm/hr} and 20 \text{mm/hr}), three separate instances registered as "High" with values of 25 \text{mm/hr}, 33 \text{mm/hr}, and a notable outlier of 55 \text{mm/hr} (refer to data table). This distribution confirms that ESR values must be evaluated against appropriate reference ranges, which were age- and sex-adjusted (\text{Female <50} and \text{Male <50 y}) for this interpretation.

Discussion

Technical Compliance and Gender-Specific Baselines

The predominantly low ESR values observed in the male cohort (1–8 \text{mm/hr}) are characteristic of a healthy, young, non-inflamed population, and are consistent with baseline reference expectations. This finding provides crucial internal validation of the pre-analytical phase of the study, confirming that the standardized Westergren method, particularly the critical one-hour waiting time, was strictly adhered to by the Noble Institute's laboratory staff. Deviations in technique, such as tube tilt or temperature variability, would typically introduce erroneous elevations across the board. The adherence to protocol therefore establishes a high-confidence baseline for interpreting the more complex results observed in the full cohort (Khan & Patel, 2024).

Physiological Variability and Interpretation Challenges

The most significant finding of this study is the marked difference in the frequency and magnitude of elevated ESR values between the sexes in this young adult sample. The higher incidence of "High" classifications among female subjects, including a value of 55 \text{mm/hr}, aligns perfectly with established hematological literature. This phenomenon is commonly attributed not to underlying pathology but to physiological factors, including lower baseline hemoglobin levels and the influence of plasma protein fluctuations related to the menstrual cycle. This gender differential underscores the necessity of using sex-specific reference ranges, as an ESR of 25 \text{mm/hr} might be classified as 'High' for a female, yet remain close to the upper limit of normal for a pre-menopausal woman, thus highlighting the nuance required in laboratory interpretation (Smit & Van Der Heijden, 2024).

Clinical Utility of Elevated ESRs

The presence of acutely elevated ESR values, such as the 55 \text{mm/hr} result, confirms the powerful, albeit non-specific, signaling function of the test. While the ESR does not identify the cause of inflammation, such a finding mandates immediate clinical attention to rule out a severe underlying systemic process, such as infection, vasculitis, or chronic inflammatory disease. The results, therefore, affirm the test’s role as an indispensable initial screening tool in clinical settings, directing healthcare providers to further, more targeted investigations. The localized data generated by this study confirms the practical utility of ESR testing as a reliable, first-line indicator of inflammatory status within the patient demographic served by the Noble Institute (Williams & Jackson, 2022).

Conclusion

This study successfully analyzed the Erythrocyte Sedimentation Rate (ESR) sampling and interpretation at the Noble Institute, confirming strict technical adherence to the one-hour Westergren protocol. The data highlighted expected physiological variability, specifically demonstrating a higher incidence of elevated ESRs in the young female cohort compared to the low baseline values found in males. The findings emphasize that the reliability of the ESR as a

diagnostic marker hinges not only on technical standardization but also on the rigorous application of age- and sex-adjusted reference intervals. The Noble Institute's practices are consistent with international standards, supporting the continued and reliable use of the ESR as a crucial screening indicator for systemic inflammation (Khan & Patel, 2024).

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NUTRITION AND MICROBIOTA IN PREGNANCY: EFFECTS ON MATERNAL–FETAL HEALTH AND NURSING APPROACHES

GEBELİKTE BESLENME VE MİKROBİYOTA: MATERNAL–FETAL SAĞLIK ÜZERİNE ETKİLERİ VE HEMŞİRELİK YAKLAŞIMLARI

Burçin BEKTAŞ PARDES

Sağlık Bilimleri Üniversitesi, Gülhane Hemşirelik Fakültesi, Doğum ve Kadın Hastalıkları Hemşireliği Ana Bilim Dalı, Ankara, Türkiye

ORCID No: https://orcid.org/0000-0003-0333-7461

Gülten GÜVENÇ

Sağlık Bilimleri Üniversitesi, Gülhane Hemşirelik Fakültesi, Doğum ve Kadın Hastalıkları Hemşireliği Ana Bilim Dalı, Ankara, Türkiye

ORCID No: https://orcid.org/0000-0002-8330-9497

ÖZET

Giriş ve Amaç: Gebelikte yeterli ve dengeli beslenme, anne ve fetüs sağlığını korumak için kritik önemdedir. Gebelik süresince hormonal ve metabolik değişiklikler bağırsak mikrobiyotasının bileşimini etkileyerek intrauterin bağışıklık ortamında değişikliklere neden olabilir; bu da preeklampsi, gestasyonel diyabet ve erken doğum gibi komplikasyon riskini artırabilir. Bu derlemenin amacı gebelikte annenin beslenmesi ile mikrobiyota arasındaki ilişki üzerine güncel kanıtları inceleyerek maternal-fetal sağlık sonuçlarını ve hemşirelik bakımındaki yaklaşımları değerlendirmektir.

Materyal ve Metod: Literatür taraması yapılırken; uluslararası (PubMed, ScienceDirect, Cochrane) ve ulusal (Google Scholar, TR Dizin) veri tabanlarında son 10 yılda yayımlanan çalışmalar taranmış; "gebelik, beslenme, mikrobiyota, maternal-fetal sağlık, hemşirelik" anahtar sözcükleri kullanılmıştır. Derleme niteliğinde olup herhangi bir deneysel veri içermemektedir.

Bulgular: Gebelikte beslenme düzeni bağırsak, vajinal ve süt mikrobiyotasını şekillendirmektedir. Pregebelik vücut kitle indeksi, gebelik süresince kilo alımı ve besin bileşenleri maternal mikrobiyotada farklılıklara yol açmakta, bu da yenidoğanın mikrobiyal kolonizasyonunu etkilemektedir. Mikrobiyota dengesizliği, preeklampsi, gestasyonel diyabet, erken doğum ve çocukluk çağı obezitesi gibi olumsuz sonuçlarla ilişkilidir. Dengeli beslenme ve probiyotik/prebiyotik içeriği yüksek diyetlerin bu riskleri azalttığı gösterilmiştir. Hemşirelik yaklaşımında gebelere yüksek lifli, probiyotik ve prebiyotik içeren besinler önermeli; sağlıklı kilo yönetimi ve gereksiz antibiyotik kullanımından kaçınma vurgulanmalıdır. Ayrıca multidisipliner yaklaşımlar ve gebelik boyunca süren danışmanlık desteklenmelidir.

Tartışma ve Sonuç: Gebelikte dengeli beslenme ile annenin mikrobiyotası arasında güçlü bir ilişki bulunmaktadır ve bu ilişki maternal-fetal sağlık üzerinde belirleyici rol oynar. Hemşirelik bakımında bu doğrultuda kanıta dayalı beslenme önerileri geliştirilerek anne adaylarında mikrobiyota dostu beslenme davranışları teşvik edilmelidir.

Anahtar Kelimeler: Gebelik; Beslenme; Mikrobiyota; Hemşirelik.

ABSTRACT

Introduction and Purpose: Adequate and balanced nutrition during pregnancy is critically important for protecting the health of both the mother and the fetus. Hormonal and metabolic changes during pregnancy can affect the composition of the gut microbiota, leading to changes in the intrauterine immune environment; this can increase the risk of complications such as preeclampsia, gestational diabetes, and preterm birth. The aim of this review is to examine current evidence on the relationship between maternal nutrition during pregnancy and the microbiota, and to evaluate maternal-fetal health outcomes and approaches in nursing care.

Materials and Methods: A literature search was conducted in international databases (PubMed, ScienceDirect, Cochrane) and national databases (Google Scholar, TR Dizin) for studies published in the last ten years. The keywords used were “pregnancy”, “nutrition”, “microbiota”, “maternal-fetal health” and “nursing”. This review is descriptive and includes no experimental data.

Results: Nutrition during pregnancy shapes the gut, vaginal, and breast milk microbiotas. Pre-pregnancy body mass index, weight gain during pregnancy, and nutrient components cause differences in the maternal microbiota, which in turn affects the microbial colonization of the newborn. Microbiota imbalance is associated with adverse outcomes such as preeclampsia, gestational diabetes, preterm birth, and childhood obesity. Balanced nutrition and diets high in probiotics/prebiotics have been shown to reduce these risks. In nursing practice, pregnant women should be advised to consume foods high in fiber, probiotics, and prebiotics; healthy weight management and avoidance of unnecessary antibiotic use should be emphasized. In addition, multidisciplinary approaches and ongoing counseling throughout pregnancy should be supported.

Discussion and Conclusion: There is a strong relationship between balanced nutrition during pregnancy and the mother's microbiota, and this relationship plays a decisive role in maternal-fetal health. In nursing care, evidence-based nutritional recommendations should be developed in this direction to encourage microbiota-friendly nutritional behaviors in expectant mothers.

Key Words: Pregnancy; Nutrition; Microbiota; Nursing.

GİRİŞ

Mikrobiyota, insan vücudunda bulunan bakteri, virüs ve mantarlar başta olmak üzere tüm mikroorganizmaların oluşturduğu karmaşık ekosistemi tanımlayan bir kavramdır. Anne adayının bağırsak ve ürogenital sistem mikrobiyotası, gebelik süresince hem anne metabolizmasını hem de fetüsün gelişimini etkileyebilecek dinamik değişiklikler gösterir (Mesa et al., 2020). Geleneksel olarak fetüsün anne karnında steril bir ortamda geliştiği düşünülse de, son araştırmalar maternal mikroorganizma topluluklarının dolaylı yollardan fetüsün bağışıklık ve metabolik programlanmasını etkileyebildiğini öne sürmektedir. Doğum yöntemi de bebek mikrobiyotasının ilk kolonizasyonunu belirler; vajinal yolla doğan bebekler annenin vajinal ve bağırsak florasından zengin bir mikrobiyota edinirken, sezaryenle doğanlarda yararlı bakteri düzeyleri daha düşük, hastane kaynaklı potansiyel patojenler ise daha yüksek bulunmuştur (Nuriel-Ohayon et al., 2016). Maternal mikrobiyota ve beslenme arasındaki etkileşim, hem gebelik komplikasyonlarının önlenmesi hem de uzun vadeli çocuk sağlığı açısından kritik önemdedir. Bu derlemede, gebelikte beslenmenin anne bağırsak ve vajinal mikrobiyotası üzerine etkileri ve bunun maternal-fetal sağlık sonuçlarına yansımasına dair güncel kanıtlar

incelenmesi; elde edilen bulgular doğrultusunda hemşirelik bakımında uygulanabilecek yaklaşımların belirlenmesi amaçlanmıştır.

MATERYAL VE METOD

Bu derleme için literatür taraması 2015-2025 yılları arasındaki yayınları kapsayacak şekilde gerçekleştirilmiştir. PubMed, ScienceDirect, Cochrane Library ve Google Akademik gibi uluslararası veri tabanlarında "gebelik, beslenme, mikrobiyota, maternal-fetal sağlık, hemşirelik" gibi anahtar kelimeler kullanılarak arama yapılmıştır. Aramaya, son on yıl içerisinde hakemli dergilerde yayımlanan araştırma makaleleri, derlemeler ve uluslararası sağlık örgütlerinin rapor ve pozisyon bildirgeleri dahil edilmiştir. Dil olarak İngilizce ve Türkçe çalışmalar taranmış; ancak büyük çoğunluğu İngilizce olan kaynaklardan elde edilen bulgular Türkçe olarak derlenmiştir. Çalışmamız etik onay veya hasta onamı gerektirmediğinden, yalnızca literatür verileri kullanılmıştır.

BULGULAR

Maternal Mikrobiyotadaki Değişimler ve Gebelik Sonuçları

Gebelik, anne bağışıklık sistemi ve metabolizmasında olduğu gibi mikrobiyal ekosisteminde de belirgin değişimlerin yaşandığı bir süreçtir. Özellikle üçüncü trimesterde anne bağırsak mikrobiyotasında önemli bir yeniden yapılanma gözlenir: Anti-inflamatuvar özellikli kısa zincirli yağ asidi (butirat) üreten faydalı bakterilerin popülasyonu azalırken, Bifidobacterium ve Lactobacillus gibi laktik asit üreticiler ile Proteobacteria filumu üyeleri artış gösterir (Di Simone et al., 2020). Artan östrojen ve progesteron düzeyleri ile birlikte glukoz toleransındaki fizyolojik değişimler, belirli mikrobiyal türlerin (örneğin, şekeri fermente edebilen türlerin) çoğalmasını teşvik eder. Nitekim, fare modellerinde gebeliğin üçüncü trimesterine ait mikrobiyotanın nakledildiği steril farelerin, birinci trimester mikrobiyotası nakledilenlere kıyasla anlamlı ölçüde daha fazla kilo aldıkları ve insülin direnci geliştirdikleri gösterilmiştir. Bu bulgu, gebelik mikrobiyotasındaki değişimlerin konak metabolizması üzerinde doğrudan etkili olabileceğini göstermektedir (Koren et al., 2012).

Anne mikrobiyotasındaki dengesizlik (disbiyozis), gebelik komplikasyonlarıyla ilişkilendirilmiştir. Çalışmalar erken gebelik döneminde bağırsak mikrobiyotasındaki belirli değişimlerin gestasyonel diyabet (GDM) ve gebelikte hipertansiyon gelişme riskini artırdığını göstermektedir (Wang et al., 2018). Örneğin, GDM'li kadınların bağırsak florasında enerji açığının yüksek olduğu diyetlerle ilişkili Blautia ve Ruminococcus cinsi bakterilerin artmış oranda bulunduğu saptanmıştır. Buna karşın, Odoribacter gibi butirat üreten yararlı bakterilerin azalmasının gebelerde daha yüksek sistolik kan basıncı ile ilişkili olduğu bildirilmiştir (Gomez-Arango et al., 2016). Disbiyozis ile karakterize bir mikrobiyotanın, artan bakteriyel endotoksin (ör. LPS) üretimi ve buna bağlı inflamatuvar yanıt üzerinden preeklampsi ve erken doğum gibi komplikasyonlara zemin hazırlayabileceği düşünülmektedir (Ma et al., 2020). Nitekim erken başlangıçlı preeklampsi tanılı gebelerde yapılan bir çalışmada, bağırsak mikrobiyota kompozisyonunun sağlıklı gebelerden belirgin şekilde farklı olduğu, bu farklılığa neden olan bakteriyel türlerin obezite, glukoz metabolizma bozukluğu ve intestinal bariyer işlevinde bozulma gibi durumlarla da ilişkili patojenler olduğu gösterilmiştir. Aynı çalışmada preeklamptik gebelerin dolaşımında inflamatuvar belirteç olan IL-6 ve Gram-negatif bakteri duvar komponenti LPS düzeylerinin yükseldiği, bunun da bağırsak geçirgenliğinin artmasıyla ilişkili olabileceği belirtilmiştir (Lv et al., 2019). Erken gebelik döneminde artan bağırsak geçirgenliği ve buna bağlı sistemik endotoksin yükü, uteroplasental üniteye zarar vererek düşük riskini dahi artırabilmektedir. Öte yandan, sadece gastrointestinal değil oral ve vajinal

mikrobiyotadaki bozuklukların da gebelik sonuçlarına etkisi olabileceği raporlanmıştır (Zheng et al., 2020). Özellikle periodontal hastalık varlığı ile erken doğum ve preeklampsi arasında anlamlı bağlantılar saptanmıştır; preeklamptik kadınlarda periodontitis sıklığının belirgin şekilde yüksek olduğu ve Porphyromonas gingivalis gibi patojen bakterilerin bu kadınların diş plağında kontrol grubuna göre daha fazla bulunduğu bildirilmiştir. Bu bulgular, gebelik bakımında oral hijyenin ve diş sağlığının da ihmal edilmemesi gereken bir bileşen olduğunu göstermektedir (Biagioli et al., 2024; Herrera et al., 2007).

Vajinal Mikrobiyota ve Preterm Doğum Riski

Sağlıklı gebe kadınların vajinal mikrobiyotası büyük oranda Lactobacillus türlerinin hakimiyetinde olup düşük mikrobiyal çeşitlilik gösterir. Lactobacillus'lar glikojen yıkımıyla laktik asit üreterek vajinal pH'ı düşürür ve patojen bakterilerin kolonizasyonunu engeller (Petrova et al., 2015). Vajinal mikrobiyotadaki bu doğal denge, gebeliğin korunmasında önemli bir bariyer oluşturur. Ancak vajinal disbiyozis (örneğin bakteriyel vajinozis gibi, Lactobacillus'ların azalması ve diğer opportunistik bakterilerin çoğalması durumu), gebelikte istenmeyen sonuçlara yol açabilir (Anahtar et al., 2018). Araştırmalar, erken gebelik haftalarında vajinal florasında Lactobacillus dominansının olmadığı ve polimikrobiyal kolonizasyon görülen kadınların ilerleyen dönemde spontan preterm doğum riskinin anlamlı derecede arttığını göstermiştir. Lactobacillus'ların azalmasıyla birlikte vajinal epitelde inflamatuvar sitokinlerin yükseldiği, bunun da fetal membran zayıflaması ve erken doğum eylemini tetikleyebileceği ileri sürülmüştür. Buna karşılık, gebelik başlangıcında Lactobacillus ağırlıklı ve düşük çeşitlilikte bir vajinal mikrobiyota profiline sahip olan kadınların doğumlarını zamanında ve komplikasyonsuz gerçekleştirme olasılıkları daha yüksektir (Ravel et al., 2011). Bu bilgiler ışığında, gebelik takibinde vajinal enfeksiyonların taranması ve tedavisi (örn. bakteriyel vajinozisin uygun antibiyotiklerle giderilmesi), preterm doğumun önlenmesi stratejilerinden biri olarak değerlendirilmektedir. Ayrıca, yüksek riskli gebelerde gerekirse vajinal probiyotik uygulamalarıyla mikrobiyal dengenin sağlanması araştırılan bir konu olup, ileride bu alanda daha net rehberlikler oluşturulabilir (Fettweis et al., 2019; Hyman et al., 2014).

Maternal Beslenme, Mikrobiyota ve Fetal Sağlık

Anne adayının beslenme düzeni, bağırsak mikrobiyotasının bileşimini şekillendiren kritik bir çevresel etkendir. Gebelik döneminde yeterli ve dengeli beslenme sadece fetüsün sağlıklı büyüme ve gelişimini desteklemekle kalmaz, aynı zamanda anne ve yenidoğan mikrobiyotasının zenginleşmesini de sağlar (Biagioli et al., 2025). Son yıllarda yapılan çalışmalar, diyet içeriğinin hem anne hem de bebeğin bağırsak mikrobiyal çeşitliliği üzerinde belirleyici olduğunu ortaya koymuştur. Örneğin, hamilelikte yüksek yağ oranlı beslenmenin anne bağırsak florasında genel çeşitliliği azalttığı bildirilmiştir; buna karşın posa (lif) tüketiminin artması mikrobiyal çeşitlilikle pozitif ilişki göstermektedir (Maher et al., 2023). Yüksek yağ ve rafine şeker içerikli "Batı tipi" diyet modelinin anne ve bebeğin mikrobiyotasında Bifidobacterium gibi faydalı bakterilerin oranını düşürdüğü, buna karşılık inflamasyona yol açabilecek bazı gram-negatif bakteri gruplarını artırdığı saptanmıştır (Paul et al., 2016). Fare modellerinde gebelik boyunca yüksek yağ/şeker içeren diyetle beslenen anne adaylarının yavrularında, maternal disbiyozise bağlı olarak beyin kaynaklı nörotrofik faktör (BDNF) ekspresyonunun azaldığı, bunun da nörogelişimsel sonuçlar üzerinde olumsuz etkiler doğurabileceği gösterilmiştir (Barrientos et al., 2024). Öte yandan, gebelikte obezite sorunu yaşayan kadınlarda bile diyet kalitesinin iyileştirilmesi mikrobiyotada belirgin düzelmeler sağlayabilmektedir. Liften zengin ve omega-3 gibi çoklu doymamış yağ asitlerini içeren bir diyetin, obez gebelerin bağırsak mikrobiyotasında faydalı bakteri popülasyonunu ve çeşitliliğini artırdığı, bu değişimin bağırsak geçirgenliğinin bir belirteci olan zonulin düzeylerinde azalma ile paralel olduğu bulunmuştur. Bu da daha "sıkı" bir bağırsak bariyeri ve

daha düşük endotoksin geçişi anlamına gelmekte, dolaylı olarak gebelikte oluşabilecek inflamatuvar süreçleri azaltmaktadır (Borge et al., 2017; Selma-Royo et al., 2021).

Maternal beslenmenin fetal büyüme üzerindeki dolaylı etkilerine dair kanıtlar da mevcuttur. MAMI-MED adlı kohort çalışmasında 667 gebenin diyet kalıpları incelenmiş ve ağırlıklı olarak kızartma, şekerli gıdalar ve rafine karbonhidratlardan oluşan işlenmiş gıda ağırlıklı bir beslenme örüntüsüne sahip annelerin, balık, beyaz et, sebze-meyve yönünden zengin sağlıklı beslenme örüntüsüne sahip annelere kıyasla, büyük gebelik haftasına göre iri bebek (LGA) doğurma olasılığının daha yüksek olduğu saptanmıştır (OR: 2.21, %95 GA 1.05–4.68). Bu bulgu, sağlıklı beslenme alışkanlıklarının sadece gebelik sürecini değil, doğum ağırlığı üzerinden yenidoğanın sağlığını da etkileyebileceğini göstermektedir. Dahası, maternal diyet bileşiminin bebeğin ilk mikrobiyota kolonizasyonunu etkileyebileceği bildirilmektedir (Barchitta et al., 2023). Örneğin vejetaryen diyet uygulayan gebe kadınların yeni doğanlarının dışkı mikrobiyotasında, yüksek oranda kısa zincirli yağ asidi üreten Roseburia ve Lachnospiraceae familyası üyelerinin bulunduğu rapor edilmiştir. Yüksek doymuş ve tekli doymamış yağ asidi alımının ise yenidoğanların bağırsak mikrobiyotasında Firmicutes filumu üyelerini artırdığı, buna karşın anne adayının protein ve posadan zengin bitkisel ağırlıklı beslenmesinin bu etkiyi tersine çevirerek bebeğin mikrobiyal çeşitliliğini daha sağlıklı bir yönde etkilediği gösterilmiştir. Dolayısıyla, "bir anne nasıl beslenirse, bebeğinin mikrobiyotası da kısmen onu yansıtır" şeklinde özetlenebilecek bir durum söz konusudur (Barrett et al., 2018).

Gebelikte Probiyotik ve Prebiyotik Kullanımı

Mikrobiyotanın gebelik sonuçlarındaki rolünün aydınlanmasıyla birlikte, probiyotik ve prebiyotik takviyelerin gebelikteki potansiyel faydaları da araştırma konusu olmuştur. Probiyotikler, yeterli alındığında konakçıya sağlık yararı sağlayan canlı mikroorganizmalardır ve gebelikte disbiyozisi düzeltmek, inflamasyonu azaltmak ve metabolik parametreleri iyileştirmek amacıyla kullanılmaları önerilmektedir (Dülger et al., 2021). Özellikle gestasyonel diyabet yönetiminde probiyotik takviyelerin etkisini inceleyen çalışmalar dikkat çekicidir. 2024 yılında yayınlanan 15 randomize kontrollü çalışmanın meta-analizine göre, GDM'li gebelere probiyotik verilmesi, plaseboya kıyasla anne adaylarının açlık kan şekeri düzeylerini ve insülin direncini belirgin ölçüde iyileştirmiştir. Aynı analizde probiyotik kullanan GDM'li annelerin yenidoğanlarında ortalama doğum ağırlığının ~100 gram daha düşük olduğu, yenidoğan yoğun bakım ünitesine kabul ve hiperbilirubinemi insidansının da anlamlı derecede azaldığı rapor edilmiştir. Bu bulgular probiyotiklerin metabolik denge ve neonatal sonuçlar açısından olumlu etkiler yapabileceğini düşündürmektedir. Ancak mevcut çalışmaların kalitesi ve sonuçlarının tutarlılığı konusunda dikkatli olunmalıdır; söz konusu meta-analizde de kanıt kalitesinin değişken olduğu ve daha fazla araştırmaya ihtiyaç duyulduğu vurgulanmıştır (Wu et al., 2024).

Prebiyotikler ise bağırsaktaki faydalı bakterilerin büyümesini destekleyen sindirilemeyen besin bileşenleridir (örneğin inülin, frukto-oligosakkarit gibi lifler). Gebelikte prebiyotik desteğinin hem anne hem fetüs üzerinde bazı yararları olabileceği öne sürülmüştür. Hayvan modellerinde yapılan bir araştırma, gebelik boyunca inülin ve galakto-oligosakkarit ile desteklenen annelerin amniyotik sıvısında faydalı kısa zincirli yağ asidi asetatın arttığını, ayrıca bu prebiyotik desteğin fetuslarda B ve T lenfosit sayılarında yükselmeye yol açtığını ve bu etkinin doğum sonrası yaşamın ilerleyen evrelerinde de devam ettiğini göstermiştir. Bu tür bulgular, prenatal dönemde mikrobiyotayı hedef alan beslenme müdahalelerinin bebeklerin immün gelişimine kalıcı pozitif etkiler yapabileceğini akla getirmektedir. Yine de insanlar üzerinde yapılmış kapsamlı çalışmalar olmaksızın bu verileri doğrudan klinik uygulamaya sokmak mümkün değildir (Biagioli et al., 2025).

Mevcut literatürde probiyotiklerin preterm doğumu önlemedeki etkinliğine dair kesin bir kanıt bulunmasa da, bazı araştırmacılar probiyotik kullanımının maternal sistemik inflamasyonu

azaltarak preterm doğum riskini düşürebileceğini iddia etmektedir (Grev et al., 2018). Örneğin, 2020 yılında yapılan bir Cochrane derlemesi, riskli gebeliklerde probiyotik takviyenin erken doğum oranlarına etkisini değerlendirmiş ancak net bir fayda veya zarar göstermemiştir. Bu alanda yürütülen çalışmaların heterojenliği nedeniyle, gebelikte probiyotik kullanımına yönelik standart bir öneri oluşturmak için daha fazla sayıda ve yüksek kalitede klinik araştırmaya ihtiyaç vardır (Vanda et al., 2024).

Hemşirelik Yaklaşımları

Gebelik döneminde beslenme ve mikrobiyota ilişkisinin sağlık üzerinde yarattığı etkiler göz önüne alındığında, bu konuda anne adaylarının bilgilendirilmesi ve desteklenmesinde hemşirelere önemli roller düşmektedir. Yapılan bir çalışma, kadın doğum kliniklerinde görev yapan ebe ve hemşirelerin sadece %10'unun mikrobiyota hakkında bir eğitim aldığını, yaklaşık yarısının beslenme ve yaşam tarzının mikrobiyota üzerindeki etkisini farkında olduğunu ancak %35'inin bu konuda bilgisiz olduğunu ortaya koymuştur. Bu bulgu, sağlık profesyonellerine yönelik hizmet içi eğitimlerde mikrobiyota konusunun güncel bilgilerle ele alınması gereğine işaret etmektedir. Nitekim aynı çalışmada yazarlar, ebe ve hemşirelerin mikrobiyota konusundaki bilgi düzeyinin geliştirilmesinin ve bu doğrultuda eğitim planlamalarının yapılmasının kadın ve çocukların mikrobiyal sağlığını artırmada önemli katkılar sağlayacağını vurgulamışlardır (Uğurlu et al., 2023).

Literatür, gebelere sunulan rutin beslenme eğitimi programlarının mikrobiyota boyutunu da kapsayacak şekilde güncellenmesinin önemine dikkat çekmektedir. Bu kapsamda hemşireler ve ebeler, prenatal bakım sırasında aşağıdaki uygulamaları hayata geçirebilir:

Bireyselleştirilmiş Beslenme Eğitimi: Her gebenin gereksinimleri doğrultusunda, mikrobiyotayı destekleyici beslenme önerileri sunulması. Özellikle Akdeniz tipi, posadan zengin beslenme modelinin teşviki ve aşırı şekerli/işlenmiş gıdalardan kaçınma konusunda danışmanlık verilmesi, anne adaylarının mikrobiyota dostu bir diyete yönlendirilmesini sağlar. Ayrıca, fermente gıdaların (ör. ev yapımı yoğurt, kefir, turşu, kimchi) tüketiminin artırılması önerilebilir. Bu gıdalar doğal probiyotik kaynağı olup bağırsak mikrobiyal çeşitliliğini arttırarak butirat üreten yararlı bakterilerin çoğalmasını destekler.

Probiyotik/Prebiyotik Önerileri: Özellikle antibiyotik kullanımı gereken durumlar sonrası veya GDM gibi disbiyozis riskinin arttığı vakalarda, doktorla iş birliği içinde probiyotik desteğinin değerlendirilmesi. Randomize çalışmalar, belirli probiyotik suşlarının (ör. Lactobacillus ve Bifidobacterium türleri) gebelerde metabolik parametreleri iyileştirebildiğini göstermektedir. Hemşireler, güvenilir gıda takviyeleri veya doğal probiyotik kaynakları hakkında anne adaylarına bilgi vererek bu desteklerin doğru ve bilinçli kullanımını teşvik edebilir. Benzer şekilde, prebiyotik lif alımının (sebze, meyve, tam tahıl ve kurubaklagillerle) artırılması yönünde öneriler de gebelere sunulmalıdır.

Ağız ve Vajinal Sağlığın Korunması: Hemşireler, gebelerin ağız hijyenine özen göstermeleri (düzenli diş hekimi kontrolü, diş eti bakımının sağlanması) konusunda eğitim verebilir. Periodontal hastalıkların sadece anne sağlığını değil, preterm doğum gibi istenmeyen sonuçlar yoluyla fetüsü de etkileyebileceği unutulmamalıdır. Aynı şekilde, vajinal enfeksiyon belirtileri hakkında gebeleri bilgilendirmek, vajinal akıntı, kaşıntı gibi şikayetleri olduğunda sağlık kuruluşuna başvurmalarını teşvik etmek önemlidir. Vajinal mikrobiyotanın korunması için gereksiz vajinal duş uygulamalarından kaçınma, uygun genital hijyen ve riskli durumlarda hekimin önereceği vajinal probiyotiklerin kullanımı gibi konularda da danışmanlık verilmelidir.

Doğum Şekli ve Emzirme Konusunda Danışmanlık: Sezaryen endikasyonu olmayan durumlarda normal doğumun teşvik edilmesi, bebeğin ilk mikrobiyal kolonizasyonunun anneye benzer ve yararlı bir flora ile olmasını sağlar. Doğum sonrası dönemde ise emzirmenin sürdürülmesi

konusunda hemşirelik desteği kritik önemdedir. Anne sütü, içerdiği prebiyotik oligosakkaritler ve probiyotik bakteriler aracılığıyla yenidoğanın bağırsak mikrobiyotasını ideal şekilde şekillendirir; formül mama ile beslenen bebeklerin bağırsak florasında ise anne sütündeki bu biyolojik aktif bileşenlerin yokluğuna bağlı olarak daha düşük oranda faydalı bakteri ve daha yüksek oranda potansiyel patojen bulunabildiği gösterilmiştir. Bu nedenle hemşireler, anne sütü ile beslenmenin mikrobiyal ve immünolojik faydalarını ailelere anlatarak emzirmeyi güçlü biçimde teşvik etmelidir.

Multidisipliner İş Birliği ve Eğitim: Son olarak, sağlık profesyonellerinin mikrobiyota ve beslenme konusundaki güncel kanıtları takip edebilmeleri için sürekli mesleki eğitime erişimleri sağlanmalıdır. Hastanelerde veya birinci basamakta çalışan ebeler ve hemşireler için düzenlenecek hizmet içi eğitim programları, mikrobiyotanın anne ve bebek sağlığı için önemi, probiyotik-prebiyotik kullanımı, beslenme planlaması ve danışmanlığı gibi konuları içermelidir. Ayrıca, diyetisyenler ve hekimlerle iş birliği içinde multidisipliner bir yaklaşım benimseyerek, gebelik izlemlerinde bireyselleştirilmiş beslenme ve mikrobiyota değerlendirmesinin standart hale getirilmesi hedeflenmelidir. Örneğin, obezite veya GDM riski taşıyan gebelerde erken dönemde beslenme danışmanlığı ve gerekirse mikrobiyota analizi yapılarak, kişiye özgü müdahale planları oluşturulabilir. Bu tarz uygulamalar, "herkese uyan tek beden" yaklaşımı yerine her annenin mikrobiyal ve metabolik profiline göre özelleştirilmiş bakım sunulmasını sağlayacaktır (Dülger et al., 2021).

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NONPHARMACOLOGICAL METHODS IN LABOUR PAIN MANAGEMENT AND NURSING APPROACHES

DOĞUM AĞRISI YÖNETİMİNDE NONFARMAKOLOJİK YÖNTEMLER VE HEMŞİRELİK YAKLAŞIMLARI

Burçin BEKTAŞ PARDES

Sağlık Bilimleri Üniversitesi, Gülhane Hemşirelik Fakültesi, Doğum ve Kadın Hastalıkları Hemşireliği Ana Bilim Dalı, Ankara, Türkiye

ORCID No: https://orcid.org/0000-0003-0333-7461

ÖZET

Giriş ve Amaç: Doğum eylemi sırasında ortaya çıkan yoğun ağrı, anne adayında fiziksel ve psikososyal stres yaratır. Epidural gibi farmakolojik yöntemler ağrıyı etkili biçimde azaltsa da, hipotansiyon, enfeksiyon riski ve doğum süresinin uzaması gibi yan etkilere yol açabilir. Bu nedenle nefes egzersizleri, pozisyon değişiklikleri, hidroterapi (su doğumu), TENS, akupunktur, masaj, aromaterapi ve müzik terapisi gibi nonfarmakolojik uygulamalar önem kazanmaktadır. Bu teknikler vücudun doğal ağrı kontrol mekanizmalarını aktive ederek ağrı algısını azaltmayı ve annenin doğum deneyimini iyileştirmeyi hedeflemektedir. Hemşire ve ebeler, bu teknikleri uygulayan ve doğum sırasında hastayı destekleyen birinci basamak sağlık profesyonelleridir.

Materyal ve Metod: Literatür taraması yapılırken; uluslararası (PubMed, ScienceDirect, Cochrane) ve ulusal (Google Scholar, TR Dizin) veri tabanlarında son 10 yılda yayımlanan çalışmalar taranmış; "doğum ağrısı", "nonfarmakolojik yöntem", "yönetim" ve "hemşirelik" anahtar sözcükleri kullanılmıştır. Derleme niteliğinde olup herhangi bir deneysel veri içermemektedir.

Bulgular: Nonfarmakolojik teknikler doğum ağrısı yönetiminde güvenli ve etkili tamamlayıcılar olarak gösterilmektedir. En sık uygulanan yöntemler arasında masaj, solunum teknikleri, hareket/pozisyon değişikliği ve hidroterapi bulunmaktadır. Bu yöntemlerin annenin kontrol hissini güçlendirerek ek farmakolojik analjezi gereksinimini azaltabileceği düşünülmektedir. Eğitim, yetersiz personel ve zaman kısıtları ise uygulamaların önündeki başlıca engeller olarak bildirilmiştir.

Tartışma ve Sonuç: Doğum ağrısının yönetiminde nonfarmakolojik yöntemlerin etkin uygulanmasında donanımlı hemşirelerin rolü önemlidir. Bu yaklaşımların yaygınlaştırılması için hemşirelik eğitim programlarında kapsamlı dersler ve hizmet içi eğitimlerin eklenmesi, güncel bakım protokollerinin benimsenmesi ve sağlık kuruluşlarında yeterli personel ile kaynak desteğinin sağlanması önerilmektedir.

Anahtar Kelimeler: Doğum ağrısı; Nonfarmakolojik yöntem; Hemşirelik.

ABSTRACT

Introduction and Purpose: The intense pain experienced during labor causes physical and psychosocial stress in the expectant mother. While pharmacological methods such as epidurals

effectively reduce pain, they can lead to side effects such as hypotension, risk of infection, and prolonged labor. Therefore, non-pharmacological approaches such as breathing exercises, position changes, hydrotherapy (water birth), TENS, acupuncture, massage, aromatherapy, and music therapy are gaining importance. These techniques aim to reduce pain perception and improve the mother's birth experience by activating the body's natural pain control mechanisms. Nurses are the primary healthcare professionals who apply these techniques and support the patient during childbirth.

Materials and Methods: A literature search was conducted in international databases (PubMed, ScienceDirect, Cochrane) and national databases (Google Scholar, TR Dizin) for studies published in the last ten years. The keywords used were “labour pain”, “non-pharmacological methods”, “management” and “nursing”. This review is descriptive and includes no experimental data.

Results: Nonpharmacological techniques have been shown to be safe and effective adjuncts in labor pain management. The most commonly used methods include massage, breathing techniques, movement/position changes, and hydrotherapy. It is thought that these methods may reduce the need for additional pharmacological analgesia by enhancing the mother's sense of control. Education, insufficient staff, and time constraints have been reported as the main barriers to implementation.

Discussion and Conclusion: The role of well-trained nurses is crucial in the effective implementation of non-pharmacological methods for managing labor pain. To promote these approaches, it is recommended that comprehensive courses and in-service training be added to nursing education programs, that current care protocols be adopted, and that adequate staffing and resource support be provided in healthcare facilities.

Key Words: Labour pain; Non-pharmacological methods; Management; Nursing.

GİRİŞ

Doğum ağrısı; fiziksel, duygusal ve bilişsel boyutları olan, kadının doğum sırasındaki pozisyonu, hareket edebilmesi, korku ve kaygı düzeyi gibi pek çok faktörden etkilenen karmaşık bir olgudur (Chen et al., 2024; Demšar et al., 2018). Birçok kadın doğum eylemi sırasında çok şiddetli ağrı yaşarken, bazıları daha hafif ağrılar bildirebilmektedir. Ağrı algısı; anneyi saran ortam, destek alıp almaması ve psikolojik durumu ile yakından ilişkilidir. Uygun şekilde ele alınmayan aşırı ağrı, annenin stres hormonu düzeylerini yükselterek doğumun uzamasına, yorgunluk ve memnuniyetsizliğe yol açabilir. Bu nedenle, doğumda etkili ağrı yönetimi hem anne hem de bebek sağlığı için kritik önemdedir (Wigert et al., 2020).

Geleneksel olarak doğum ağrısını azaltmak için epidural anestezi, opioidler ve entonoks gibi farmakolojik yöntemler yaygın olarak kullanılagelmiştir. Farmakolojik ağrı kesiciler genellikle güçlü bir analjezi sağlasa da, hipotansiyon, motor blok, mide bulantısı ve doğum süresinin uzaması gibi yan etkilere neden olabilmekte ve müdahaleli doğum oranlarını artırabilmektedir (Jones et al., 2012). Öte yandan, birçok kadın ilaç kullanmaksızın “doğal doğum” yapmayı tercih etmekte; olası yan etkilerden kaçınmak ve doğum sürecini kontrol altında tutmak istemektedir. Bu durumda farmakolojik olmayan yöntemlere ilgi artmıştır. Nonfarmakolojik ağrı yönetimi yöntemleri, ilaca başvurmadan ağrıyla baş etmeyi hedefleyen, güvenli ve anne tarafından genellikle olumlu karşılanan uygulamalardır. Tarih boyunca kullanılagelen bu teknikler modern doğum bakımında yeniden önem kazanmış; Dünya Sağlık Örgütü gibi otoriteler, pozisyon özgürlüğü, sürekli destek ve gevşeme teknikleri gibi girişimleri olumlu doğum deneyiminin bir parçası olarak önermiştir (Fair et al., 2020; Hofmeyr & Singata-Madliki, 2020).

Hemşireler ve ebeler, doğum ağrısının nonfarmakolojik yöntemlerle yönetiminde kilit rol oynarlar. Doğum süresince annelere kesintisiz destek sağlamak, rahatlatıcı teknikleri uygulamak ve eğitim vermek hemşirelik bakımının önemli bir parçasıdır. Nitekim yapılan araştırmalar, doğum salonunda çalışan sağlık personelinin bilgi ve becerilerinin bu yöntemlerin kullanımını etkilediğini ortaya koymuştur. Türkiye'de 100 ebe/hemşire ile yapılan bir çalışmada, katılımcıların %83'ünün masaj-dokunma, doğru nefes teknikleri ve su uygulamaları gibi yöntemleri bildiği; en sık uygulananların ise nefes egzersizleri (%77), hareket/pozisyon değiştirme (%76) ve masaj (%73) olduğu saptanmıştır. Ancak aynı çalışmada ebe/hemşirelerin %75'inin doğum ağrısı yönetiminde kendilerini yetersiz hissettikleri bildirilmiştir. Bu bulgu, nonfarmakolojik yöntemler konusunda hizmet içi eğitimlerin ve müfredat programlarının güçlendirilmesinin gerekliliğine işaret etmektedir. Sonuç olarak, etkili bir doğum ağrısı yönetimi için farmakolojik ve nonfarmakolojik yöntemlerin birlikte ve bütüncül bir yaklaşımla ele alınması; hemşirelerin bu alandaki bilgi ve yetkinliklerinin artırılması önem arz etmektedir (Yilmaz Sezer et al., 2020). Bu derlemenin amacı doğum ağrısını önlemede non farmakolojik yöntemleri ve hemşirelik yaklaşımlarını belirlemektir.

MATERYAL VE METOD

Bu derleme için literatür taraması 2015-2025 yılları arasındaki yayınları kapsayacak şekilde gerçekleştirilmiştir. PubMed, ScienceDirect, Cochrane Library ve Google Akademik gibi uluslararası veri tabanlarında "doğum ağrısı", "nonfarmakolojik yöntem", "yönetim" ve "hemşirelik" gibi anahtar kelimeler kullanılarak arama yapılmıştır. Aramaya, son on yıl içerisinde hakemli dergilerde yayımlanan araştırma makaleleri, derlemeler ve uluslararası sağlık örgütlerinin rapor ve pozisyon bildirgeleri dahil edilmiştir. Dil olarak İngilizce ve Türkçe çalışmalar taranmış; ancak büyük çoğunluğu İngilizce olan kaynaklardan elde edilen bulgular Türkçe olarak derlenmiştir. Çalışmamız etik onay veya hasta onamı gerektirmediğinden, yalnızca literatür verileri kullanılmıştır.

BULGULAR

Fiziksel Yöntemler

Dokunma ve Masaj: Tıbbi müdahale gerektirmeyen en eski ağrı hafifletme yöntemlerinden biri masaj ve dokunmadır. Masaj, Kapı Kontrol Teorisi'ne dayalı olarak, ciltteki basınç reseptörlerini uyarıp ağrı sinyallerinin iletimini azaltarak etki gösterir (Tektaş et al., 2019). Araştırmalar masajın doğum ağrısını subjektif olarak azalttığını ve anneyi rahatlattığını ortaya koymuştur. Bir randomize kontrollü çalışmada, sakral bölgeye uygulanan masajın doğum ağrısını ve anksiyeteyi azalttığı gösterilmiştir. Dokunma ve masajın anneye fiziksel rahatlama sağlamanın yanı sıra psikolojik destek de sunduğu, böylece ağrı algısını düşürdüğü bildirilmektedir (Akköz Çevik & Karaduman, 2020). Örneğin, masaj ve müzik terapisini karşılaştıran bir çalışmada her iki tekniğin de aktif fazda ağrı şiddetini anlamlı ölçüde azalttığı rapor edilmiştir(Gokyildiz Surucu et al., 2018). Doğum salonunda çalışan ebeler de dokunma ve masajı en iyi bildikleri ve sıklıkla kullandıkları yöntemler arasında saymaktadır. Hemşireler, masaj uygularken anne adayının tercihlerine göre bel, sırt, omuz veya el-ayak masajı yapabilir; aynı zamanda karşı basınç uygulama gibi tekniklerle özellikle bel ağrısını hafifletebilirler (Yilmaz Sezer et al., 2020).

Sıcak ve Soğuk Uygulamalar: Isı uygulaması da yine Kapı Kontrol Mekanizması üzerinden etki eden, kolay ve maliyeti düşük bir yöntemdir. Ilık su torbası, termofor veya sıcak kompreslerin özellikle bel ve karın bölgesine uygulanması, kas spazmını azaltıp kan dolaşımını artırarak ağrı eşiğini yükseltebilir. Bir sistematik derlemede, sıcak uygulamanın doğum ağrısını hafiflettiği

sonucuna varılmıştır (Dahlen et al., 2007). Benzer şekilde soğuk uygulamalar (soğuk jel paketleri veya buz torbası) bazı kadınlar tarafından rahatlatıcı bulunabilmektedir. Soğuk, bölgedeki sinir iletimini yavaşlatarak ağrı hissini azaltır ve özellikle perine bölgesindeki hassasiyeti dindirmede kullanılabilir (Shirvani & Ganji, 2014). Türkiye'de yapılmış tez çalışmaları incelendiğinde, perineye sıcak kompres uygulamasının hem ağrıyı azalttığı hem de perineal travmayı azalttığı bildirilmiştir. Bu yöntemlerin anne üzerinde herhangi bir yan etkisi olmaması, doğum eyleminde hemşireler tarafından güvenle uygulanabileceğini göstermektedir (Varışoğlu & Ünlü, 2020).

Hidroterapi (Su Uygulamaları): Su, doğum sürecinde anne adayının rahatlamasını sağlayan önemli bir rahatlatıcıdır. Ilık duş almak veya doğum havuzunda suya girmek, vücut ağırlığının su tarafından desteklenmesi ve suyun gevşetici etkisi sayesinde ağrı algısını hafifletir. Cochrane verilerine göre su içinde doğum (suya immersion) annelerin ağrı skorlarını düşürmüş ve ağrı kesici memnuniyetini artırmıştır. Benzer şekilde, ılık duşun aktif doğum fazında etkili olduğu bulunmuştur (da Silva et al., 2009; Mallen-Perez et al., 2018). Örneğin Brezilya'da yapılan bir RCT çalışmasında, 4–7 cm açıklık arasında uygulanan sırasıyla doğum topuyla egzersiz, bel masajı ve sıcak duş kombinasyonunun, anne adaylarının ağrı şiddetini belirgin ölçüde azalttığı ve epidural analjezi ihtiyacını geciktirdiği gösterilmiştir. Aynı çalışmada bu müdahalelerin uygulandığı grupta doğumun ikinci evresi ortalama 18 dakika kısalmış, bebeklerin daha iyi Apgar skorlarına sahip olduğu ve annelerin doğum memnuniyetinin daha yüksek olduğu rapor edilmiştir (Gallo et al., 2018). Hemşireler, uygun koşullar varsa anne adayını sıcak duş almaya teşvik edebilir veya hastanelerde mevcut ise doğum havuzunun kullanımını sağlayabilirler. Su uygulamalarının doğru şekilde (ör. su sıcaklığının uygun düzeyde tutulması) ve güvenlik önlemleriyle uygulanması durumunda anne üzerinde sakinleştirici ve ağrı kesici etkisi olduğu ortaya konmuştur (Tosun & Ouyaba, 2021).

Akupunktur ve Akupresür: Doğu tıbbına dayanan bu tamamlayıcı yöntemler, belirli noktalara iğne batırma (akupunktur) veya basınç uygulama (akupresür) yoluyla vücudun endorfin gibi doğal ağrı kesicilerini harekete geçirmeyi hedefler (Gönenç & Terzioğlu, 2020). Son yıllarda doğum ağrısını azaltmak için akupunktur/akupresür uygulamalarına ilişkin çalışmalar artmıştır. Cochrane'in doğum ağrısı üzerine bir derlemesinde, akupunkturun hem ağrı kesici memnuniyetini artırdığı hem de forseps/vakum ihtiyacını azaltabildiği bildirilmektedir (Smith et al., 2020). Akupresür de benzer şekilde ağrı yoğunluğunu düşürebilmektedir. Örneğin Hjelmstedt ve arkadaşlarının çalışmasında, akupresür uygulanan doğum grubunda ağrı skorlarının daha düşük olduğu ve doğumun ilk evresinin kısaldığı belirtilmiştir (Hjelmstedt et al., 2010). Akupunktur/akupresür uygulamaları, eğitimli uzmanlarca yapılmalıdır; ancak hemşireler de basınç noktaları konusunda temel eğitim alarak, örneğin el veya ayak noktalarına masaj yaparak akupresür etkisi oluşturabilirler. Bu yöntemlerin avantajı, farmakolojik olmayan ve yan etkisiz oluşlarıdır. Bazı çalışmalar akupunkturun doğum eylemini hızlandırabileceğini de öne sürmektedir (Permatasari et al., 2018). Bununla birlikte, akupunktur uygulaması her sağlık kuruluşunda rutin olmadığı için yaygın kullanımı kısıtlıdır.

TENS (Transkütan Elektriksel Sinir Stimülasyonu): TENS cihazı, cilt üzerine yapıştırılan elektrotlar aracılığıyla düşük voltajlı elektrik akımı vererek ağrı sinyallerini modüle eder. Özellikle bel bölgesindeki doğum ağrısında kullanımı araştırılmıştır. TENS'in etki mekanizması da Kapı Kontrol Teorisi ile açıklanır; elektriksel uyarılar ağrı impulslarını baskılar ve vücutta endorfin salımını uyarır (Santana et al., 2016). Türkiye'deki tez çalışmalarının analizinde TENS, masaj ve sıcak uygulama ile birlikte doğum ağrısını azaltmada en etkili yöntemler arasında sayılmıştır (Varışoğlu & Ünlü, 2020). TENS kullanan anneler, özellikle bel ağrısında kısa süreli rahatlama bildirmişlerdir. Hemşireler TENS cihazının kullanımında hastaya yardımcı olabilir, elektrotların doğru yere yerleştirilmesini ve cihazın uygun şekilde ayarlanmasını sağlayabilirler. TENS'in avantajı annenin hareket etmesine engel olmadan

uygulanabilmesi ve diğer yöntemlerle kombinasyonuna uygun olmasıdır. Güvenli bir yöntem olmakla birlikte, cihaz yokluğu veya doğru kullanım bilgisi eksikliği uygulamada engel olabilmektedir (Reis et al., 2022).

Steril Su Enjeksiyonu: Son yıllarda popülerlik kazanan bir diğer fiziksel yöntem, doğumun özellikle aktif fazında hissedilen şiddetli bel ağrısını dindirmek için steril su enjeksiyonları yapmaktır. Bu yöntemde cilt altına 0.1 ml steril su küçük bir iğneyle enjekte edilir. Enjeksiyon anlık olarak yanma hissi verse de ardından gelen sürede güçlü bir ağrı kesici etki yaratabilir. Yapılan çalışmalar, bel bölgesine dört noktadan uygulanan steril su enjeksiyonunun, plasebo (salin) enjeksiyonuna kıyasla ilk 30-60 dakika içinde anlamlı ağrı azalması sağladığını göstermiştir (Lee et al., 2026). Türkiye'de yapılan randomize kontrollü bir çalışmada da, intradermal steril su enjeksiyonunun doğum sırasındaki bel ağrısını giderdiği ve anne memnuniyetini yükselttiği rapor edilmiştir (Koyucu et al., 2018). Steril su bloklarının en büyük avantajı kolay, hızlı ve ilaç içermeyen bir uygulama olmasıdır. Hemşireler bu yöntemi uygulamak için eğitim aldıysa, doğum eylemi esnasında uygun endikasyonla kullanarak annenin özellikle şiddetli bel-sakral bölge ağrısını hafifletebilirler (Lee et al., 2013). Cochrane'in değerlendirmesinde bu yöntemin etkinliği konusunda yetersiz kanıt olduğu belirtilmiş olsa son yıllardaki çalışmalar olumlu sonuçlar vermektedir. Dolayısıyla steril su enjeksiyonu, ağrı yönetiminde diğer yöntemlere dirençli vakalarda düşünülmesi gereken bir seçenektir (Derry et al., 2012).

Bilişsel ve Duygusal Yöntemler (Gevşeme ve Dikkat Dağıtma Teknikleri)

Nefes ve Gevşeme Egzersizleri: Doğum hazırlık kurslarıyla özdeşleşen nefes teknikleri ve gevşeme egzersizleri, anne adayının kendi bedenini ve zihnini kontrol altına alarak ağrıyla baş etmesini amaçlar. Derin ve ritmik solunum yapmak, ağrı anında vücutta oluşan aşırı gerginliği azaltarak oksijenlenmeyi artırır ve annenin dikkatını ağrıdan uzaklaştırır. Lamaze yöntemi gibi doğuma hazırlık felsefelerinde, doğru nefes alma ve gevşeme stratejileri temel eğitim konularıdır (Yuksel et al., 2017). 2018 tarihli bir Cochrane derlemesine göre, gevşeme teknikleri, rehberli imgelem, nefes egzersizleri, yoga ve müzik kullanımının kadınların doğum ağrısını yönetmelerine bir ölçüde yardımcı olabileceği bulunmuştur; ancak kanıt kalitesinin düşük-orta düzeyde olduğu ve yöntemler arası farklılıklar nedeniyle etkilerin netleşmediği belirtilmektedir (Smith et al., 2018). Bununla birlikte, bu yöntemlerin hiçbir yan etkisi olmaması ve kolay öğrenilebilir olması büyük avantajdır. Gevşeme egzersizleri sırasında vücuttaki büyük kas gruplarının sırayla kasılıp gevşetilmesi (progresif gevşeme) veya meditasyon benzeri zihinsel teknikler kullanılabilir. Nefes kontrolü ve gevşeme, anneyi panik ve korku duygularından uzaklaştırarak, ağrıyı daha "amaçlı ve katlanılabilir" bir his olarak deneyimlemesine yardımcı olur (Gültepe et al., 2021). Hemşireler, doğumun erken evrelerinden itibaren anne adayına yavaş ve derin nefes alıp verme konusunda rehberlik etmeli, her kasılma arasında gevşemesi için telkinlerde bulunmalıdır. Bu sayede anne, ağrı üzerinde belli bir kontrol hissi kazanarak kendini daha güçlü hisseder. Türkiye'de hemşire ve ebelerin en sık başvurdukları yöntemlerden birinin nefes egzersizleri olması da, bu tekniğin doğum kliniklerinde yaygın ve faydalı bir uygulama olduğunu göstermektedir (Yilmaz Sezer et al., 2020).

Dikkat Dağıtma Teknikleri (Odak Değiştirme): Ağrı yönetiminde kullanılan psikolojik stratejilerden biri de annenin dikkatini ağrıdan başka bir uyarana yönlendirmektir. Müzik terapisi, görselleştirme (hayal kurma, imgeleme), sayma veya bir objeye odaklanma gibi teknikler bu amaca hizmet eder. Müzik terapisi, annenin sevdiği müziği dinleyerek gevşemesini ve ortamdaki stresi azaltmasını sağlar. Araştırmalar müzik dinlemenin ağrı algısını azaltabildiğini, hatta bir çalışmada masaj kadar etkili bulunduğunu göstermiştir (Gokyildiz Surucu et al., 2018). Benzer şekilde, aromaterapi (lavanta, gül yağı gibi rahatlatıcı kokuların solunması) annenin duyularını hoş bir uyarana yönlendirerek kaygıyı ve ağrıyı hafifletebilir.

Örneğin yapılan bir çalışmada aromaterapi alan annelerin önemli bir kısmı daha az farmakolojik analjeziye ihtiyaç duymuştur (Tanvisut et al., 2018). Bunlara ek olarak, son dönemde sanal gerçeklik uygulamaları da dikkat dağıtma aracı olarak denenmektedir. VR (Virtual Reality) gözlüğüyle annenin farklı bir ortama "taşınması", algısını kasılmalar dışında bir yere odaklayarak ağrı hissini azaltabilir. Henüz bu konuda kısıtlı sayıda çalışma olmakla birlikte, sanal gerçekliğin doğum ağrısını azaltmada umut vadeden bir yöntem olduğu bildirilmiştir (Freeman et al., 2019). Yine, dans etmek de bir dikkat dağıtma ve aynı zamanda hareket tekniği olarak kullanılabilir; İran'da yapılan bir RCT'de doğum dansı yapan gebelerin aktif faz ağrılarının belirgin şekilde daha düşük ve doğum memnuniyetlerinin yüksek olduğu saptanmıştır (Abdolahian et al., 2014). Hemşireler, bu tür dikkat dağıtıcı yöntemleri uygulamada annelere kreatif çözümler sunabilir: Loş bir ortam ve sakin müzik hazırlamak, anneyle konuşarak onu rahatlatmak, gerekirse rehberli imgeleme yaptırmak (örneğin her dalganın bebeği biraz daha aşağı indirdiğini hayal etmesini sağlamak) gibi yaklaşımlar kullanabilirler. Dikkat dağıtma tekniklerinin bazıları için daha fazla araştırmaya ihtiyaç duyulsa da mevcut veriler bu yöntemlerin anneye aktif bir baş etme mekanizması sağladığı ve ağrı algısını azalttığı yönündedir (Albers, 1998).

Hipnoz (Hipnoterapi): Doğumda hipnoz uygulaması (hipnobirthing), anne adayının trans benzeri derin bir gevşeme durumuna geçerek ağrıyı farklı algılamasını hedefler. Bu yöntemde kadınlara gebelik döneminde kendi kendine hipnoz veya partner desteği ile hipnoz teknikleri öğretilir. Hipnoterapi ile korku-gerilim-ağrı döngüsünün kırılması amaçlanır(Mete & Uludağ, 2017). Literatürde hipnozun doğum ağrısına etkisi üzerine karışık sonuçlar mevcuttur. Bazı çalışmalar hipnoz alan annelerin daha az analjeziye ihtiyaç duyduğunu ve doğum deneyimlerini daha olumlu algıladıklarını gösterirken, genel olarak kanıt düzeyi zayıftır. 2013 yılında yapılan bir derlemede hipnozun ağrı skorlarına etkisinin tutarsız olduğu, ancak annelerin memnuniyetini artırabildiği belirtilmiştir (Madden et al., 2013). Türkiye'de hipnobirthing henüz yaygın olmamakla birlikte, Varışoğlu ve Ünlü'nün tez taramasında hipnoterapi alan annelerin doğum memnuniyetinin arttığı ve doğum sonrası emzirme başarısının yükseldiği ifade edilmektedir (Varışoğlu & Ünlü, 2020). Hipnoz uygulaması profesyonel eğitim gerektirdiğinden, hemşireler bu alanda uzmanlaşmış kişilerle iş birliği yapabilir. Bununla birlikte, hemşirelerin rahatlatıcı telkin verme, sakin bir ortam yaratma ve anneyle güven ilişkisi kurma gibi becerileri, hipnoterapinin etkin olmasında destekleyici rol oynayabilir. Sonuç itibariyle hipnoz, uygun anne adaylarında değerlendirilebilecek bir seçenek olup daha fazla araştırma ile standartlarının belirlenmesine ihtiyaç vardır.

Hareket ve Pozisyon Değiştirme

Kadının doğum sırasında özgürce hareket etmesi ve rahat ettiği pozisyonu alabilmesi, ağrı yönetiminin önemli fakat basit bir bileşenidir. Dik pozisyonlar ve mobilizasyon, rahime giden kan akımını ve bebeğin ilerlemesini kolaylaştırarak doğum ağrısını azaltabilmektedir. Yürümek, ayakta durmak, sallanmak, çömelmek (squat yapmak) gibi hareketler annenin dikkatını dağıtırken, yer çekimini kullanarak bebeğin başının servikse basısını artırır ve doğumun ilerlemesini hızlandırır. Türkiye'deki çalışmalar, çömelme pozisyonunun doğum ağrısını azaltmada en etkili pozisyonlardan biri olduğunu ortaya koymuştur (Lawrence et al., 2013). Özellikle birinci evrede annenin yatakta sabit kalmak yerine aktif olması, ağrı algısını düşürdüğü gibi doğum süresini de kısaltabilir. Dünya genelinde yapılan araştırmalarda, hareket özgürlüğü kısıtlanmayan kadınların daha az analjezi talebinde bulunduğu ve memnuniyet düzeylerinin yüksek olduğu bildirilmiştir. Hemşireler, doğum eylemi boyunca anne adayını cesaretlendirerek farklı pozisyonlar denemesine yardımcı olmalıdır. Örneğin, sancılar sırasında omuzlarından destek olarak annenin çömelmesine yardımcı olmak, pilates topu (doğum topu) üzerinde oturup hafifçe sallanmasını sağlamak, dörtlü pozisyon (emekleme pozisyonu) almasına rehberlik etmek gibi uygulamalar yapabilirler. Bu pozisyon değişiklikleri, bebeğin en

uygun pozisyona yerleşmesine de katkı sunarak doğumun ilerleyişini olumlu etkileyebilir. Amerikan Kadın Hastalıkları ve Doğum Derneği'nin önerileri de, tıbbi bir engel olmadığı sürece doğum yapan kadının hareketinin kısıtlanmamasını vurgulamaktadır. Dolayısıyla hareket ve pozisyon değiştirme, hem güvenli hem de etkili bir nonfarmakolojik ağrı yönetimi stratejisidir (Gau et al., 2011; Taavoni et al., 2011).

Destekleyici Bakım ve Eğitimsel Yaklaşımlar

Sürekli Emosyonel Destek (Doula/Hemşire/Ebe Desteği): Doğum sürecinde anne adayına kesintisiz bir şekilde eşlik edilmesi ve duygusal-fiziksel destek sunulması, tek başına güçlü bir ağrı hafifletici etki yaratabilir. Sürekli destek kavramı; anne yanında hiç ayrılmadan bulunan, cesaret veren, sakinleştiren bir kişinin varlığını ifade eder. Bu destek kişi bir ebe, hemşire, eğitimli bir doula ya da yakın bir akraba olabilir (Bohren et al., 2017). Özellikle profesyonel doula desteğinin, epidural veya diğer müdahalelere gereksinimi belirgin şekilde azalttığı rapor edilmiştir. Sürekli desteğin en önemli katkılarından biri de anksiyeteyi azaltmasıdır; nitekim randomize kontrollü çalışmalar, doğumda başından sonuna kadar bir doulanın varlığının anne adaylarında anlamlı düzeyde daha az korku ve ağrı ile ilişkili olduğunu göstermektedir. Hemşireler, görev yaptıkları kliniklerde her kadınla birebir ilgilenmeye çalışarak bu sürekli destek rolünü üstlenmelidir. Anneye dokunarak güven vermek, göz teması ve sakin bir ses tonu ile telkin edici konuşmak, "yapabilirsin, her dalga bebeğini sana yaklaştırıyor" gibi cesaretlendirici ifadeler kullanmak, annenin ağrı algısını hafifletecektir (Sobczak et al., 2023). Bir çalışma, kadınların en çok fayda gördükleri nonfarmakolojik yöntemler arasında "moral verici sözler" (%92) ve ebenin sürekli varlığı (%82) gibi destekleyici yaklaşımları saydığını bildirmektedir. Ne yazık ki kalabalık klinik ortamlarında her zaman kesintisiz destek mümkün olamayabilir; ancak bu durumda doğum partnerlerinin (eş, anne, arkadaş vb.) sürece aktif katılımı teşvik edilmeli, hemşireler tarafından partnerlere yol gösterilmelidir. Sonuç olarak emosyonel ve fiziksel sürekli destek, hiçbir ekipman gerektirmeyen ancak bir o kadar etkili bir "doğal ağrı kesici" olarak değerlendirilebilir (Crawford et al., 2024).

Doğuma Hazırlık Eğitimi ve Hemşirelik Danışmanlığı: Nonfarmakolojik yöntemlerin etkin uygulanabilmesi için gebelik döneminde verilen eğitimler büyük rol oynar. Doğuma hazırlık kursları veya gebe okulları, gebelere doğum sürecini, karşılaşacakları hisleri ve baş etme yöntemlerini önceden öğretir. Bu sayede kadınlar doğum başladığında daha hazırlıklı ve özgüvenli olmaktadır (Yeşildağ & Gölbaşi, 2018b). Varışoğlu ve Ünlü'nün (2020) incelemesinde, ülkemizde yürütülen tez çalışmalarının çoğunda doğuma hazırlık eğitimi alan annelerin doğum memnuniyetinin arttığı vurgulanmıştır; hatta Lamaze felsefesine dayalı eğitimlerin anne memnuniyeti yanı sıra postpartum emzirme başarısını da yükselttiği gösterilmiştir (Varışoğlu & Ünlü, 2020). Hemşireler, gebelik takibinde anne adaylarına nonfarmakolojik ağrı yönetimi konusunda danışmanlık yapmalıdır. Nefes egzersizlerinin, gevşeme tekniklerinin pratik yaptırılması, eşlerin bu sürece dahil edilmesi (örneğin eşin masaj yapmasının öğretilmesi) çok yararlı olmaktadır. Eğitimli bir gebe, doğum başladığında panik olmak yerine hangi yöntemle rahatlayabileceğini bilir ve aktif bir katılımcı olur. Bu durum ağrı algısını düşürmenin yanı sıra doğum deneyimini olumlu yönde etkiler (He et al., 2010). Ayrıca, doğum öncesi eğitimler ağrı hakkındaki felaketleştirme düşüncelerini azaltır, kadının zihnindeki korku-ağrı döngüsünü kırar. Hemşirelik yaklaşımı olarak, her gebenin bireysel ihtiyaçlarına uygun bir doğum planı yapması teşvik edilmelidir (Elmas et al., 2017). Örneğin bazı kadınlar su doğumunu hayal ederken bazıları müzikle rahatlar; hemşire bu tercihleri gebeyle önceden konuşup imkanlar dahilinde uygulamaya koymalıdır. Eğitimsel yaklaşımın bir diğer boyutu da doğum sonrası geri bildirimdir. Annelerin deneyimleri dinlenerek hangi yöntemlerin faydalı bulunduğu değerlendirilmeli, bu bilgiler ışığında doğum hizmetlerinde iyileştirmeler yapılmalıdır (Gültepe, R.).

SONUÇ

Nonfarmakolojik yöntemler, doğum eyleminde ağrı yönetimi için etkili ve güvenilir seçenekler sunmaktadır. Bu derlemede incelenen güncel kanıtlar, akupresür, masaj, sıcak uygulama, su terapisi, pozisyon değiştirme, nefes egzersizleri, müzik terapisi, aromaterapi, hipnoz, TENS, steril su enjeksiyonu ve sürekli destek gibi pek çok girişimin doğum ağrısını azaltmaya yardımcı olduğunu ve anne memnuniyetini artırdığını ortaya koymaktadır. Özellikle fiziksel yöntemler Kapı Kontrol Teorisi aracılığıyla ağrı iletimini engellerken, bilişsel-davranışsal teknikler annenin ağrıya odaklanmasını engelleyip baş etme becerisini kuvvetlendirmektedir. Bu yöntemlerin bir kısmı (örneğin hareket, masaj, nefes) doğumun ilerlemesini de kolaylaştırarak müdahaleleri azaltabilmektedir (Chang et al., 2022). Nonfarmakolojik yöntemlerin önemli bir avantajı, anne ve bebek üzerinde ilaç kaynaklı hiçbir yan etki oluşturmadan rahatlama sağlamasıdır. Bununla birlikte, her yöntem her anne için aynı etkiyi göstermeyebilir; dolayısıyla kişiselleştirilmiş bir yaklaşım benimsenmelidir. Bazı durumlarda kadınlar birden fazla tekniğin kombinasyonundan en iyi faydayı görebilir. Örneğin bir anne adayı sıcak duş alırken aynı anda müzik dinleyebilir ve eşi tarafından masaj yapılabilir. Nitekim ardışık birden fazla yöntemin uygulanmasının ağrı yönetiminde daha üstün sonuç verebileceği bildirilmiştir (Gallo et al., 2018).

Hemşirelik yaklaşımı olarak, gebelerin doğum öncesinden başlayarak bu yöntemler konusunda bilgilendirilmesi, doğum sırasında sürekli destek ve rehberlik sunulması esastır. Modern doğum hizmetlerinde farmakolojik ve nonfarmakolojik yöntemlerin entegre bir şekilde kullanılması, hem anne hem bebek açısından en iyi sonuçlara ulaşmayı mümkün kılar. Doğum eyleminde ağrının tamamen yok edilmesi her zaman mümkün olmasa da, doğru yaklaşımlarla ağrının yönetilebilir düzeye indirilmesi ve olumlu bir doğum deneyimine dönüştürülmesi mümkündür. Bu bağlamda, hemşireler insan yaşamının bu kritik anında bilimsel kanıtlara dayalı, şefkatli ve bütüncül bir bakımla anne adaylarının yanında olarak önemli bir fark yaratacaktır (Chang et al., 2022).

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CASE REPORT: EFFICASY OF NIVOLUMAB IN ADVANCED STAGE NON-SMALL CELL LUNG PLEOMORPHIC CARCINOMA WITH SARCOMATOID DIFFERANTIATION CANCER

Doç. Dr. Aslı YILDIRIM

Yalova University, Faculty of Medicine, Department of Department of Medical Oncology, Yalova, Turkey

ORCID ID: https://orcid.org/0000-0002-2511-478X

ABSTRACT

Introduction and Purpose: Pulmoner sarcomatoid carsinomas (PSC) account for less than 1.0% of all lung cancer cases. They are usually poorly differentiated tumors related with decreased overall survivals. immunotherapies can have potantiel benefits in sarcomatoid lung cancers which have lack of effective treatment options.

Materials and Methods: Fifty years old male patient local advanced pleomorphic carcinoma with sarcomatoid differantiation lung cancer was administered chemoradiotherapy with weekly paclitacsel and carboplatin, then docetaxel and cisplatin after progression. Since chemotherapies did not yielded adequate response rate, nivolumab was applied subsequently. Response to treatment was evaluated with [18F]-2-fluoro-2-deoxy-D-glucose (FDG) - positron emission tomography/computed tomography (PET-CT) according to Response Evaluation Criteria In Solid Tumors (RECIST) 1.1 criterias.

Results: Fifty-year-old male with a heavy smoking history was diagnosed with locally advanced NSCLC in January 2023 and received chemoradiotherapy, followed by detection of new lung and isolated brain metastases. Pathology reevaluation revealed pleomorphic carcinoma with sarcomatoid differentiation and no actionable mutations. After palliative brain radiotherapy and a docetaxel–cisplatin regimen showing stable disease, nivolumab was initiated due to chemotherapy intolerance. By July 2025, PET-CT demonstrated a partial response in the primary tumor and complete response in mediastinal lymph nodes according to RECIST 1.1.

Conclusion: This case indicates that immunotherapies can improve prognosis in sarcomatoid lung cancers which are rarely seen and less responsive to chemotherapies due to their aggresive nature when compared to other non-small cell lung cancers

Key Words: Nivolumab; Non-Small Cell Lung Cancer (NSCLC); Pleomorphic Carcinoma; Sarcomatoid Differentiation; Immunotherapy Efficacy

INTRODUCTION

Pulmonary sarcomatoid carsinomas are expected to be responsible for less than %1 percent of all lung cancers diagnosed each year. They can be classified as pleomorphic carcinoma, spindle cell carcinoma, giant cell carcinoma, carcinosarcoma and pulmonary blastoma. Patients are usually tobacco smokers and unfortunately have worse clinical outcomes due to both aggressive nature of tha cancer type and chemotherapy resistance. In addition, this type of lung cancer rarely express genetic driver mutations like Epidermal Growth Factor (EGRR) or Anaplastic

Lymphoma Kinase Receptor (ALK) that also limits effective treatment options. However, accumulating data has been indicating that programmed death ligand-1 (PD-L1) and tumor mutational burden (TMB) expression has been observed more often in sarcomatioid lung cancer than other non-small cell cancers impling potential survival benefit with immunchecpoint inhibitors (ICIs) such as nivolumab.

Nivolumab, a programmed death-1 (PD-1) inhibitor, has emerged as a mainstray second-line treatment option widely administered to patients after progression on first-line platinium based chemotherapies for nearly a decade because of imroved response rates, prolonged progression free survey (PFS) and overall survey (OS) alongside with fewer adverse effects compared to chemotherapies in advanced stage non-small cell lung cancers. Yet, most appropriate treatment options are not certain in lung sarcomatoid cancers.

Patient Information and Follow-up: Fifty years old male patient, 25 years heavily tobacco smoker, with local advanced lung mass and mediastinal lymph node metastasis based on his [^{18}F]-2-fluoro-2-deoxy-D-glucose (FDG) - positron emission tomography/computed tomography (PET-CT) findings was admitted in jaunary, 2023. He had neither previous medical record nor family history in terms of cancer diagnosis. Definitive chemoradiotherapy with weekly paklitacsel and carboplatin were initiated after his pathology result was reported as non-small cell lung cancer without defining the sub-type in february, 2023. The patient was reluctant to come his visits regularly. A new metastatic lung nodul was detected in his PET-CT and Isolated brain metastatic lesion was found out in his contrast enhanced brain magnetic resonance (MRI) radiologically after completing chemoradiotherapy treatment plan in March, 2024. Responses to treatment were evaluated according to Response Evaluation Criteria In Solid Tumors (RECIST) 1.1 criterias. Subsequently, patient received palliative brain radiotherapy and then became uncomplient with his oncology clinic appoinments again until september, 2024.

The patient was assessed again with contrast enhanced brain MRI which showed stabil findings on 10.09.2024. Meanwhile, consultation of pathology specimen in another hospital was resulted as pleomorphic carcinoma with sarcomatoid differantiation and all EGFR, ALK, PDL-1 and proto-oncogene tyrosine-protein kinase-1 (ROS-1) mutations were negative. The patient received 5 cycles of docetaxel and cisplatin chemotherapy regime between 13.11.2024 and 06.02.2025 dates and was thereafter assessed with PET-CT and brain MRI scans that revealed stabil disease findings. Nivolumab (opdivo) regime was commenced on 11.03.2025 because of his intolerance to chemotherapy. After receiving 9th cycle nivolumab on 24.07.2025, PET-CT was requested to evaluate response that was reported as parcial response in primary lung cancer and complete response in mediastinal lymph nodes according to RECIST 1.1 criterias.

Radiological İmages:

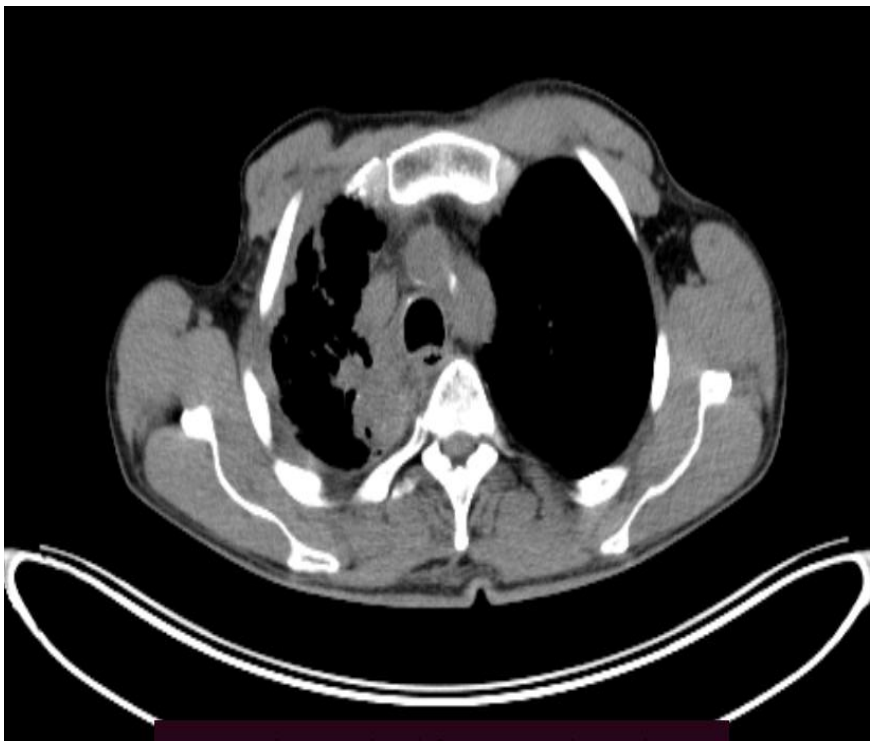


Figure-1: Computed Tomogrophy scan in February 2025

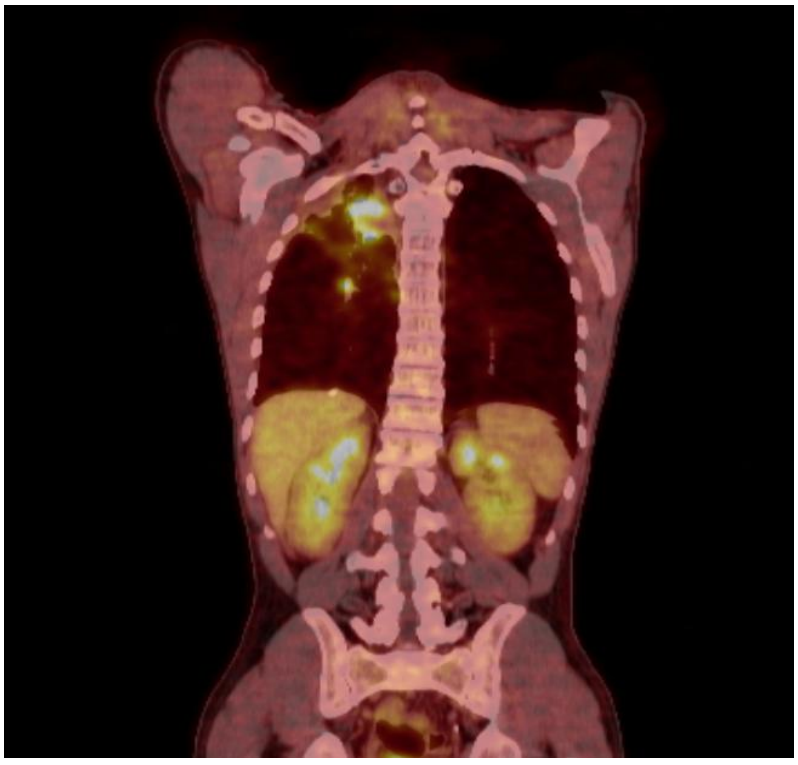


Figure-2: PET-CT scan before nivolumab in February 2025

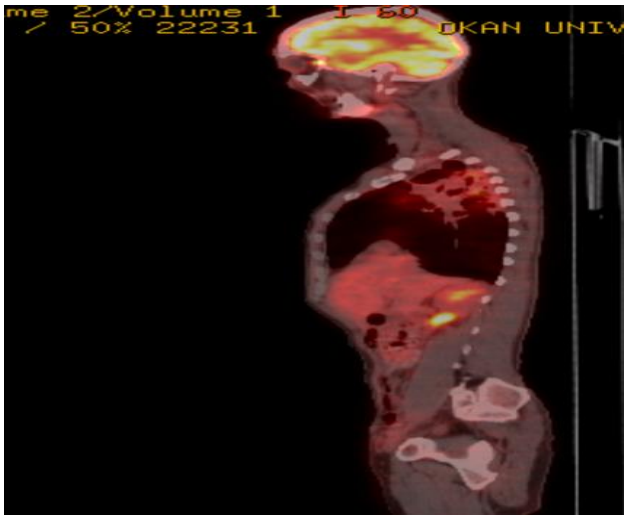


Figure-3: PET-CT lateral sight after nivolumab in July 2025.

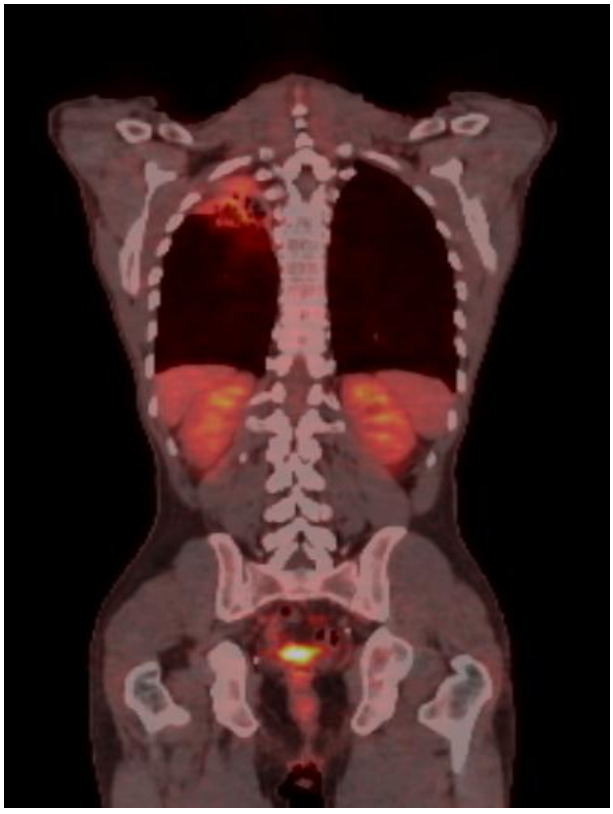


Figure-4: PET-CT postero-antero sight in July 2025

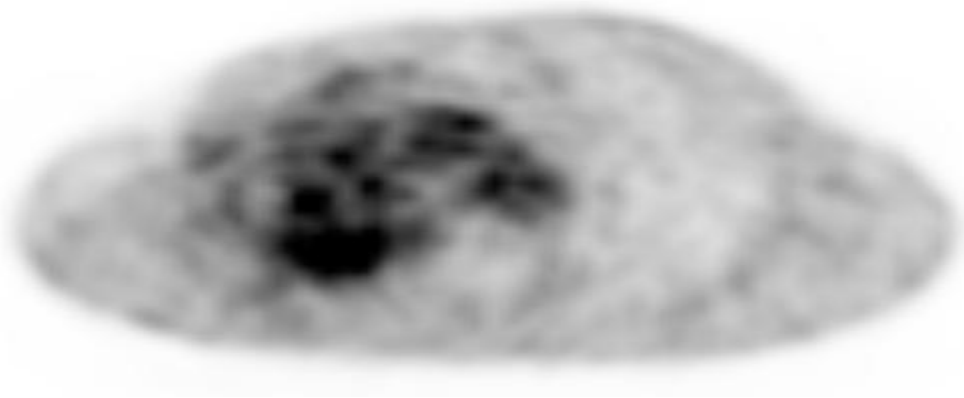


Figure-5: Tumor response after nivolumab in July 2025

Discussion:

Pulmoner sarcomatoid carsinomas (PSC) account for almost 0.3-1.0% of all lung cancer cases. They are usually poorly differentiated tumors with anticipated median survival 8 months and the 1-year survival rate 38.6%. Higher rates of reccurrance with lower OS rates can be observed even in patients with completed surgical resection. Most known type is pleomorphic-like carcinoma that represents our case here. As these tumors are rarely seen, there are limited data leading us to best treatment choices. Although it is hard to derive satisfactory response rates and clinical outcomes with convansional chemotherapies, recent researches have demonstrated potantial benefits from ICIs. In a case report coducted by Yu Wang, considerable tumor shrinkage was achieved after being applied chemoradiotherapy followed by durvalumab to a local advanced mediastinal node positive sarcomatoid carsinoma patient with expression of PD-L1 tumor proportion score (TPS) 40%. However, our patient PDL-1 expression level was 0%. Therefore, initiating nivolumab to our patient after platinium based chemotherapies was a reasonable option as efficacy of nivolumab in second line even in PDL-1 score negative non-small cell lung cancer patiens have been already demonstrated. Our goal to inform this patient is to mention that immunotherapies can induce a favorable response rates and improve prognosis with better tolerance in sarcomatoid lung cancers that are known to have lack of effective treatment options.

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PLANT-DERIVED POLYHERBAL NANOTHERAPY FOR TARGETING *S. MUTANS*–INDUCED DENTAL CARIES: AN INTEGRATED *IN SILICO* AND *IN VIITRO* APPROACH

M Annish Shabiya

School of Life Sciences, B. S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai, Tamil Nadu, India.

S. Hemalatha

School of Life Sciences, B. S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai, Tamil Nadu, India.

Ranjani S

School of Life Sciences, B. S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai, Tamil Nadu, India.

Abstract

Green nanotechnology offers a sustainable method for engineering nanoformulations using plant-derived reducing agents. In this study, a polyherbal extract was employed as both a reducing and stabilizing agent to synthesize silver nanoemulsion (PHNE) and silver nanoparticles (PHNPs). Formulated nanoemulsion was characterized by using UV–Visible spectroscopy for surface plasmon resonance, X-ray diffraction, and FESEM for crystalline structure and morphology, EDAX for elemental composition, DLS and zeta potential for particle size distribution and colloidal stability, and FTIR to identify functional groups involved in nanoparticles capping. Phytoconstituents in the extract were profiled by using LC–MS, and the identified molecules were screened for drug-likeness using Lipinski's Rule of Five and SwissADME, while toxicity was evaluated with ProTox-II. Selected bioactive compounds were docked against *Streptococcus mutans* target proteins by using PyRx, and key binding interactions were visualized in Discovery Studio Visualizer to infer possible anti-caries mechanisms. Antioxidant activity (DPPH assay) and Anti-inflammatory effects (protein denaturation inhibition) of the crude extract, PHNPs, and PHNE were comparatively assessed. The nanoemulsion displayed superior bioactivity compared to both nanoparticles and the polyherbal extract. Future studies will extend these findings to antibacterial assays using clinical oral isolates from dental patients to validate therapeutic applicability. Overall, this integrated *in silico* and *in vitro* strategy supports the potential of polyherbal-mediated green nanoformulations for managing *S. mutans*-associated dental caries and broader biomedical applications. In future nanoemulsion incorporated dental care products will be development for oral health care.

Keywords: Eco-friendly synthesis, Plant-based polyherbal extracts, Silver nanoformulations, Computational docking, Anti-oxidant and Anti-inflammatory.

NELUMBO NUCIFERA MEDIATED SILVER NANOPARTICLES: A SUSTAINABLE STRATEGY TO CONTROL DERMATOPHYTES

Loga Sreeyaa R K

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Ranjani S

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

Nelumbo nucifera is an aquatic plant widely distributed in Asia and known for the cultural, nutritional and medical benefits. The flowers are enriched with bioactive substances including alkaloids, flavonoids and fatty acids that holds antioxidant, antibacterial and antifungal properties. Phytocompounds are known to rupture fungal cell membranes and prevent the growth of dermatophytes, namely *Trichophyton rubrum* and *Microsporum canis.* Nanoparticles due to their small size (1 to 100 nm) and high surface area, can easily penetrate through the fungal cell wall and cause cellular disruption compared to the larger molecules present in the floral extract. This study focuses on the synthesis of silver nanoparticles by using *Nelumbo nucifera* floral extract for antifungal applications. The resulting nanoparticles were purified and characterized using UV-Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray (EDAX) analysis. A distinct surface plasmon resonance peak near 400 nm confirmed the synthesis of silver nanoparticles, FTIR revealed phenolic and flavonoid groups responsible for reduction and natural capping, while EDAX validated elemental silver composition in the final nanoparticle's matrix. Nanoparticles effectively controlled the growth of *Trichophyton rubrum* and *Microsporum canis* even at the lower concentration of 25 µg/mL on comparison with fluconazole till the 8^{th} day of treatment. The floral extract incorporated nanoparticles could pave a way for the development of topical antifungal creams and ointments for treating fungal infections.

Keywords: *Nelumbo nucifera,* Silver Nanoparticles, Antifungal, Dermatophytes.

ESTIMATION OF VARIABILITY AND IDENTIFICATION OF SUPERİOR GENOTYPES IN SODIUM AZIDE (SA)-INDUCED RICE MUTANTS (M3)

Md. Musabbir Hossain Shoun

Bachelor of Science in Agriculture Khulna University, Bangladesh.

Abstract

The development of mutant populations, accompanied by their subsequent characterization, presents a substantial opportunity to isolate genotypes by exhibiting specific desirable traits of interest. Although development of blast-resistant rice varieties is an area of priority, there is a significant dearth of knowledge on the comprehensive assessment for the induced mutants in terms of disease resistance and important agronomic traits under one framework in multiple generations level. An investigation was carried out to assess the diversity among the 100 mutants (M3) to select superior genotypes based on their phenotypic characteristics and the genetic control on the expression of the traits. The experiment was laid out in a randomized complete block design (RCBD) with three replications. This selection was carried out depending on the genetic variation arising from treatment with sodium azide. Data collected on 17 quantitative traits from three randomly selected plants from each plot. The investigation revealed significant genetic and phenotypic variability among the mutant lines, with traits like grain yield hill^{-1}, total tillers hill^{-1}, effective tillers hill^{-1}, filled grains panicle^{-1} and straw yield hill^{-1} showing high heritability and genetic advance. Grain yield was positively and significantly correlated with plant height, panicle length, total grains panicle^{-1}, filled grains panicle^{-1} and straw yield hill^{-1}. PCA revealed five principal components, with the first two accounting for over 52% of the total variance, highlighting the yield contributing traits like plant height, panicle length, flag leaf length, and grain yield mainly have in tillering capacity and biomass potential as primary selection criteria. Ward's Agglomerative clustering grouped the mutants into two major clusters and the genotypes with better performance were accumulated in cluster II. Finally, a total of seven elite genotypes were selected based on their greater performance in plant height, panicle length, primary branches panicle^{-1}, flag leaf length, filled grains panicle^{-1}, grain yield hill^{-1}, and straw yield hill^{-1} for further breeding purposes. Overall, the findings underscore the efficacy of sodium azide in creating genetic diversity and its potential to develop high-yielding rice varieties.

PROCESSING AND ORGANOLEPTIC ASSESSMENT OF *SACCHAROMYCES CEREVISIAE*-FERMENTED TIGER NUT (*CYPERUS ESCULENTUS*) WINE

Tope James, Ogidi

Newland Polytechnic, Ilorin, Kwara, Nigeria, Department of Science Laboratory Technology,

ORCID: 0009-0009-0925-262X

Blessing Mayowa, Sanni

Kwara State University, Department of Microbiology

ORCID: 0009-0000-6396-6548

Abstract

The need for different, functional beverages has led to increased interest in the development of non-fruit-based wines using locally sourced and health enhancing substrates. This study explores the possibility of producing wine from tiger nut (*Cyperus esculentus*) through fermentation using *Saccharomyces cerevisiae*. Tiger nut (*Cyperus esculentus*) was selected for their carbohydrate and protein content. The tiger nuts were soaked, blended and filtered to extract the tiger nut milk. The extracted tiger nut milk was pasteurized. The pasteurized tiger milk was inoculated with the cultures of *S. cerevisiae*, and fermentation was carried out at 30°C for 14 days. Samples were taken periodically to evaluate pH, alcohol content, reducing sugar concentration, microbial viability, and sensory characteristics. The results showed that the fermentation of tiger nut milk produced a wine with moderate alcohol content (10%), the pH reduced from 7.5-3.8, yeast count reduced from 2.0 x 10^3 cfu/ml (day 1) to 1.0 x 10^2 cfu/ml (day 14), the sugar content reduced from 20.0 °Brix (day 1) to 3.0 °Brix (day 14). Sensory evaluation revealed that the wine was generally acceptable in terms of aroma, taste, and mouthfeel. The overall sensory evaluation acceptability was 7.5 on the scale of 10. This study showed that tiger nut when properly processed and fermented, can serve as a viable substrates for wine production. The study offers a novel approach to enhancing both the sensory and functional properties of non-conventional wines, particularly in Nigeria, where grapes are not readily cultivated.

Keywords**:** Beverages, reducing sugar, *Saccharomyces cerevisiae*, alcohol content.

DEVELOPMENT OF ECO-FRIENDLY FOOD WRAPPERS TO INCREASE THE SHELF LIFE IN FRUITS

Raisa

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Ranjani S

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

Fruits are highly perishable and tend to lose quality rapidly after harvesting due to moisture loss, microbial spoilage, and respiration. To minimize these postharvest losses, edible coatings have emerged as an eco-friendly alternative to synthetic packaging. Pectin, a natural biopolymer extracted from citrus peels, exhibits excellent film-forming ability and is safe for food applications. Pectin-based edible coatings help preserve the freshness, firmness, and colour of fruits by regulating gas exchange and inhibiting microbial growth. The functional properties of pectin can be further enhanced by blending it with other natural compounds or incorporating essential oils. In this study, pectin was extracted from citrus fruits and characterization techniques namely FTIR and HPLC were employed to analyze the structural, functional, and compositional properties of the extracted and blended pectin. Extracted pectin effectively controlled the growth of food borne pathogens which were isolated from spoiled fruits and vegetables. This study highlights the potential of pectin-based edible coatings in extending the shelf life of fruits. These findings emphasize the feasibility of replacing synthetic preservatives with safe and biodegradable coating materials in preservation of fruits and vegetables. The approach provides a promising route toward sustainable postharvest management and reduced environmental impact in the food packaging sector.

Keywords: Pectin, Edible coating, Shelf life, Fruits, Biopolymer, Food preservation

EVALUATING THE RESPONSE OF SOIL MICROORGANISMS TO PESTICIDES EXPOSURE IN FARMLANDS

Otegbeye-Lawal

Science Laboratory Technology, Federal Polytechnic, Ilaro, Nigeria

ORCID iD: 0009-0008-3789-2838

Adenike Atinuke

Science Laboratory Technology, Federal Polytechnic, Ilaro, Nigeria

ABSTRACT

Soil microorganisms play essential roles in nutrient cycling, organic matter decomposition, soil fertility, and overall ecosystem stability. However, the widespread and often indiscriminate use of pesticides in agriculture has raised concerns about their potential impacts on soil microbial diversity and function. This study evaluates the response of soil microbial populations to pesticide exposure in farmland soils, focusing on changes in microbial load, community structure, and enzymatic activities. Soil samples were collected from pesticide-treated and untreated (control) plots, followed by microbial enumeration using standard culture-dependent techniques and characterization of microbial diversity. Findings indicate that pesticide exposure can significantly reduce total heterotrophic bacterial and fungal counts, alter the abundance of beneficial microbes such as nitrogen fixers, and suppress key soil enzymes involved in nutrient cycling. The degree of impact varied with pesticide type, concentration, and duration of exposure. This study highlights the need for sustainable pesticide management practices to protect soil microbial health and maintain long-term agricultural productivity.

Keywords: Soil microorganisms, agroecosystems, soil enzyme activity, pesticides, microbial diversity

USE OF NATURAL BIORESOURCES AS COAGULANTS TO TREAT WATER RICH IN TOXIC DYES

ALI Hamada

Laboratory of Physical-Chemistry, Materials and Catalysis, Faculty of Sciences Ben M'Sik,

Hassan II University of Casablanca, Morocco

Abstract

Ecosystems are experiencing imbalance due to water pollution. Wastewater contains hazardous pollutants such as dyes that require appropriate treatment. These are often highly toxic depending on their content in the water. In this study, electrocoagulation with aluminum electrodes combined with biocoagulants was used to treat crystal violet dye, which is toxic to humans and living beings. Based on a Box-Behnken experimental design (BBD) and reaction parameters such as pH, current density, and electrolysis time, a dye removal rate of 96% was observed. The study demonstrated the potential of bioresources for the removal of toxic dyes, with very low energy costs and better performance, thus opening up prospects for sustainable development.

Key words: electrocoagulation, crystal violet, biocoagulant, Dye, BBD.

A CASE REPORT ON THE SUCCESSFUL MANAGEMENT OF OBSTRUCTIVE UROLITHIASIS IN GOATS USING TUBE CYSTOSTOMY

Mousumi Saha
Department of Surgery and Radiology

Md. Ataur Rahman
Department of Surgery and Radiology

Md. Tuhinur Rahman
Department of Surgery and Radiology

Md. Tasmir Rayan Labib
Department of Surgery and Radiology

Robius Sani Sadi
Department of Pathobiology

Md. Farhan Hasan
Department of Medicine, Faculty of Veterinary Medicine and Animal Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706.

Abstract

This case report discusses obstructive urolithiasis, a condition in which insoluble minerals and salt stones develop and accumulate in the bladder or urethra, leading to the obstruction of the urinary tract. Male ruminants are more susceptible to this condition due to their anatomically different urethral tract shape. Urolithiasis is a significant risk factor for animal mortality, causing enormous economic losses in the livestock industry. The most popular form of treatment for obstructive urolithiasis is surgical tube cystostomy, which involves diverting urine through a catheter inserted from the bladder and leaving through the abdominal wall. This case report describes the successful surgical procedure of tube cystotomy in a one-year-old crossbred male goat and the outcome of the surgery. The goat had been straining during urination for ten days, and several stones were found in its bladder during an ultrasound examination. The surgery was performed after the owner gave consent, and the patient was administered anesthesia, followed by a 1.5-inch incision on the left side of the left rudimentary teat. The procedure involved inserting a Foley catheter, which was sutured at different locations on the ventral abdomen to avoid any disruption during urine flow. Postoperative medication included an anti-inflammatory drug, antihistaminic, and antibiotic for seven days. The surgery was successful, and the goat made a full recovery, demonstrating that tube cystotomy can be an effective treatment for obstructive urolithiasis in male goats.

KEY WORDS: Urolithiasis, Tube cystostomy, Surgical management

HISTOLOGICAL CHARACTERIZATION OF GONADAL DEVELOPMENT IN PENAEUS KERATHURUS: IMPLICATIONS FOR AQUACULTURE IN ALGERIA

Mouassa Bochra

University Chadli benjdid, el Tarf, Algeria Researche lab: Epidemiological surveillance, health, production, reproduction, experimentation, and cellular therapy of domestic and wild animals

ORCID ID: https://orcid.org/ 0009-0007-3766-1274

Abstract

Crustacean farming in Algeria, particularly shrimp farming, is an emerging activity with significant potential due to the country's long coastline and favorable environmental conditions. The main species include the Mediterranean white shrimp (*Penaeus kerathurus*), the giant tiger prawn (*Penaeus monodon*), and the Pacific white shrimp (*Litopenaeus vannamei*), valued for their rapid growth and profitability. Shrimp feeding combines natural sources (phytoplankton, zooplankton) and enriched pellets, while reproduction in captivity requires precise control of conditions (temperature, salinity) and facilities such as hatcheries. Although challenges remain regarding infrastructure and training, this sector represents a promising economic opportunity to diversify aquaculture and meet both local and international demand.

Keywords: Crustaceans, farming, Algeria, shrimp.

HISTOLOGICAL AND MORPHOLOGICAL ASSESSMENT OF GONADAL MATURATION IN THE GILTHEAD SEA BREAM (*SPARUS AURATA*) FROM ALGERIAN WATERS

Mouassa Bochra

University Chadli benjdid, el Tarf, Algeria Researche lab: Epidemiological surveillance, health, production, reproduction, experimentation, and cellular therapy of domestic and wild animals

ORCID ID: https://orcid.org/ 0009-0007-3766-1274

Abstract

The gilthead sea bream is a protandrous hermaphrodite, exhibiting a unique reproductive pattern. In its first two years, it functions as a male, and upon reaching a length of over 30 cm, it undergoes a sex change, becoming female. During the male phase, the gonad is bisexual, featuring functional testicular areas with asynchronous spermatogenesis and non-functional ovarian areas. Ovarian development is also asynchronous, and females engage in batch spawning, capable of laying 20,000-80,000 eggs per day over a period of up to 3 months. Oocyte maturation coincides with a high HSI. Conversely, spawning leads to a decrease in the HSI. The size at first sexual maturity (Lm55) is 18 cm for males and 19 cm for females (The gonadosomatic index (GSI) and hepatosomatic index (HSI) in both females and males serve as indicators of a single reproduction period).

This spawning period typically extends from December to January in the Mediterranean, reproduction occurs between October and December. The eggs are spherical and pelagic, with a diameter slightly less than 1 mm and a single large oil droplet. The planktonic larval stage lasts about 50 days at temperatures of 17-18°C.

Keywords: Gilthead seabream, GSI, HSI, Hermaphrodite, Reproduction.

ASSESSMENT OF THE PRODUCTION PERFORMANCE OF INDIAN MAJOR CARP ROHU *(LABEO ROHITA)* WITH TILAPIA (*OREOCHROMIS NILOTICUS)* ON CAGE CULTURE SYSTEM IN SOUTHERN BANGLADESH

Md. Rafiqul Islam
Department of Aquaculture, Patuakhali Science and Technology University, Bangladesh

Tridip Roy
Faculty of Fisheries, Patuakhali Science and Technology University, Bangladesh

Mohammad Lokman Ali
Department of Aquaculture, Patuakhali Science and Technology University, Bangladesh

Sabrina Akter Rinju
Department of Aquaculture, Patuakhali Science and Technology University, Bangladesh

Sudipta Kumar Nag
Department of Fisheries Biology and Genetics, Patuakhali Science and Technology University, Bangladesh

Tawhidur Rahman
Bangladesh Water Development Board

Abstract

The study was conducted over 90 days in the Barguna district of Bangladesh to assess the growth and production performance of Rohu *(Labeo rohita)* in cage culture with tilapia. The experiment was designed with three treatments namely T_1 (only tilapia-100%), T_2 (tilapia-80% and rohu-20%) and T_3 (tilapia-60% and rohu-40%) respectively each having three replications. The stocking density was 50/m^3. The floating feed contained 30% protein supplied twice a day at the rate of 5-3% of their body weight. Water quality parameters were recorded every fifteen-day interval throughout the culture period. Water quality parameters were within the suitable range for fish culture. At the end of the culture period higher weight gain of Tilapia (257g) was recorded in T_3 followed by T_1(245g) and T_2(250g) and the lowest weight gain of Rohu (90.17g) was observed T_3. The survival rate of tilapia ranges from 94.2 to 96.20% and rohu from 90.15 to 90.50%. There were no significant differences ($P>0.05$) in the survival rate of tilapia and Rohu. The weight gain, % weight gain, and SGR of tilapia and rohu were found higher in T_2, followed by T_3, whereas tilapia showed higher growth in T_3 and followed by T_2 and T_1. Significantly higher ($p>0.05$) total production of fish was observed in T_1(122.46 kg), followed by T_2(111.16 kg) and T_3(98.463kg). The BCR was higher in T_1 (1.1), followed by T_2 (0.82) and T_3 (0.75). The result of the study revealed that the culture of Rohu with Tilapia in the cage is not suitable because the growth performance of Rohu was very poor. It was observed that during feeding Tilapia showed very aggressive behaviour due to the presence of their sharp spine. As a result, Rohu was not able to intake a sufficient amount of feed. So, it is not recommended to culture Indian major carp rohu with tilapia in the cages.

Keywords: Tilapia, rohu, cage culture, production

CORRELATION AND HERITABILITY OF MORPHOLOGY AND YIELD CHARACTERISTICS IN NERICA RICE GENOTYPES

Fase O.B
Department of Crop Production Technology, School of Agriculture, The Federal Polytechnic, Ilaro, Ogun State, Nigeria

Oyekale, J. I
Department of Crop Production Technology, School of Agriculture, The Federal Polytechnic, Ilaro, Ogun State, Nigeria

ORCID ID: 0000-0002-8895-8592

ABSTRACT

Rice yield in West Africa has the potential of 3 million tons per annum, but the major constraint is water shortage, especially during periods of low rainfall, resulting in a yield loss of up to 15-20% due to drought in Africa, who depends largely on rain-fed rice production. Works need to be carried out to identify characters that can be improved on to produce rice genotypes that have the ability to thrive and be high-yielding in the upland ecology of NERICA varieties, which are usually interspecific varieties. Hence, this study evaluated the performance of 16 NERICA Varieties of rice in the Derived Savanna Ecology of Teaching and Research Farm of Olabisi Onabanjo University (OOU), Nigeria. The varieties were established in plots arranged in a Completely Randomised Design (CRD) with three replicates. Data collected on agronomic and yield characters were used to conduct character correlations and path analysis to determine the inter-relationship among the characters. Characters showed higher genotype variation and correlation relative to the phenotype values, indicating the influence of the environment. Root branching was positively correlated with seedling tiller number (0.425), seedling leaf number (0.905). It was conversely significantly correlated with seedling leaf width (-0.347). Root thickness, Final height and Spikelet number/plant had high heritability. Since most of the characters had moderate to high correlation and heritability, they are hereby recommended to breeders for further improvement of rice performance on specific adaptation programmes in upland ecology.

Keywords: Correlation, Heritability, Morphology, Yield Characteristics, NERICA Rice, Genotypes

BIOTECHOLOGICAL POTENTIAL OF ANTHOCEROTOPHYTA PYRENOIDS IN ENHANCING CROP PHOTOSYNTHESIS AND CARBON SEQUESTRATION

Vladana Brodovych

Ivan Franko National University of Lviv Ukraine

ABSTRACT

The escalating concentration of atmospheric carbon dioxide (CO2) necessitates innovative strategies for biological carbon sequestration. Conventional C3 crops, such as wheat and rice, suffer from photosynthetic inefficiency due to the oxygenase activity of the enzyme Rubisco, leading to significant energy loss through photorespiration. This paper explores the unique biophysical carbon-concentrating mechanism (CCM) found in Anthocerotophyta (hornworts), the only terrestrial plant lineage that possesses pyrenoids. Pyrenoids are sub-cellular micro-compartments within chloroplasts that aggregate Rubisco and maintain a localized environment high in CO2, thereby saturating the enzyme and suppressing photorespiration. We analyze the structural and genetic basis of pyrenoids in model species like *Anthoceros agrestis* and evaluate the feasibility of transferring these traits into vascular crops. The integration of Anthocerotophyta-derived pyrenoids into crop plants presents a promising biotechnological avenue. It has the potential to transform agriculture by significantly boosting biomass production and enhancing the natural capacity of crops to sequester atmospheric carbon. This review consolidates current findings on pyrenoid function and outlines a roadmap for developing "climate-smart" crops that contribute to global carbon reduction goals.

KEYWORDS: Pyrenoid, Anthocerotophyta, Carbon Sequestration, Rubisco, Photosynthesis, Biotechnology.

INTRODUCTION

Increasing amount of atmospheric carbon dioxide (CO2) and the associated rise in global temperatures pose a severe challenge to terrestrial ecosystems. While CO2 is the substrate for photosynthesis, rising temperatures amplify a fundamental inefficiency in many crop plants. Major agricultural crops, including those dominating Ukraine's agricultural landscape (e.g., wheat, barley), utilize the C3 photosynthetic pathway. These plants are limited by the enzyme Rubisco, which fails to distinguish effectively between CO2 and oxygen (O2) in cases where the concentration of O2 is high. When Rubisco reacts with O2, it triggers photorespiration, which is a wasteful process that releases previously fixed carbon and consumes energy, rather than storing it.

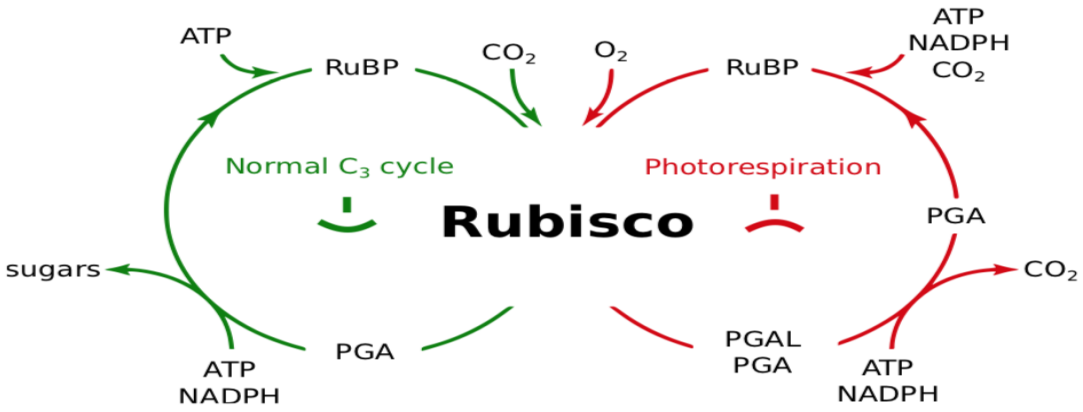


Figure 1. The dual activity of the enzyme Rubisco. Under ambient atmospheric conditions, Rubisco catalyzes both carboxylation (C3 cycle, green) and oxygenation (photorespiration, red). The latter results in carbon loss and reduces photosynthetic efficiency in C3 crops.

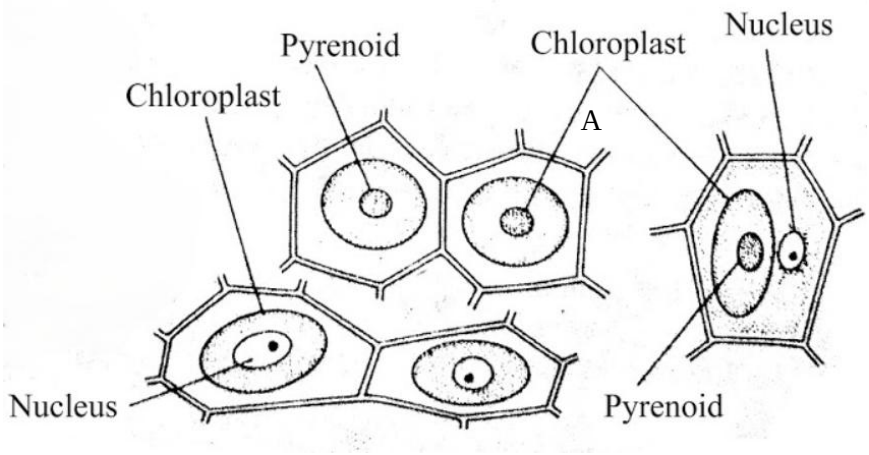
However, a unique evolutionary adaptation exists within the **Anthocerotophyta** (hornworts). Unlike other land plants, hornworts contain a specialized sub-cellular structure within their chloroplasts called the **pyrenoid** (Villarreal & Renner, 2012). This micro-compartment acts as a biophysical Carbon Concentrating Mechanism (CCM), actively accumulating CO2 to saturate Rubisco and suppress photorespiration.

This paper explores the structural and functional properties of the hornwort pyrenoid. Furthermore, we discuss the biotechnological strategy of transferring pyrenoid-based mechanisms into C3 crops. Engineering this trait offers a pathway to not only boost agricultural yields but also transform common crops into efficient agents for **biological carbon sequestration**.

RESEARCH AND FINDINGS

Localization To evaluate the potential of pyrenoid engineering, it is first necessary to understand its specific localization within the plant cell architecture. Unlike typical mesophyll cells in vascular crops, which contain numerous small chloroplasts, the cells of *Anthocerotophyta* (specifically the genus *Anthoceros*) are characterized by a unique cellular topology. They typically contain a single or few massive chloroplasts that occupy a significant portion of the cell volume (Vaughn et al., 1992).

The pyrenoid itself appears as a prominent, electron-dense body situated centrally within the chloroplast stroma. It is not an isolated granule; rather, it is functionally integrated with the photosynthetic machinery. The matrix is traversed by a network of thylakoid membranes, which act as conduits delivering inorganic carbon deep into the Rubisco aggregate (Vaughn et al., 1992).



SCHEME 1. Schematic representation of the *Anthoceros* cell (A) Two cells showing chloroplast with pyrenoid in the centre; (B) A single cell showing chloroplast with pyrenoid (C) Parenchyma cells with chloroplast and pyrenoid. [6]

Mechanism of biological CCM The operational efficiency of the hornwort pyrenoid relies on a three-step biophysical mechanism, described by Meyer & Griffiths (2013), that distinguishes it from the passive diffusion found in C3 crops. Firstly, the plant actively transports inorganic carbon (C_i) across the chloroplast envelope, primarily in the form of bicarbonate (HCO_3^-), creating a high internal pool of carbon. Secondly, bicarbonate diffuses into the pyrenoid matrix through the thylakoid tubules. Last but not least, the enzyme *Carbonic Anhydrase (CA***)**, localized specifically within the pyrenoid tubules, catalyzes the rapid dehydration of bicarbonate back into molecular CO_2. This creates a localized "CO_2-cloud" around the Rubisco active sites, effectively saturating the enzyme and inhibiting oxygenation (Meyer & Griffiths, 2013).

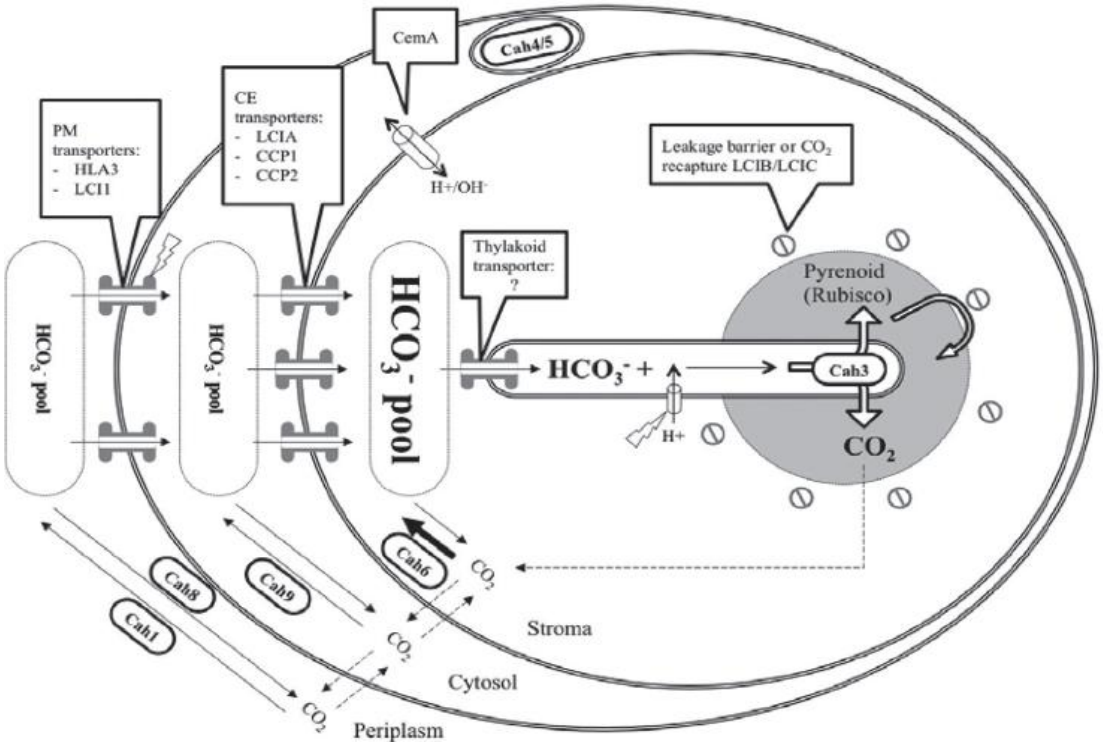


Figure 2. Hypothetical model of the C. reinhardtii biophysical CCM (Carbon Concentrating Mechanism). While based on the algal model *Chlamydomonas reinhardtii*, the fundamental components illustrated here—bicarbonate transporters, the thylakoid sheath, and

pyrenoid-localized Carbonic Anhydrase (Cah3)—are functionally analogous to the mechanism found in *Anthocerotophyta*. [2]

The physiological advantage of this mechanism is evident when comparing the photosynthetic response to varying CO_2 levels (A/C_i) between standard C3 crops and pyrenoid-containing species. C3 crops like wheat show a linear dependency on external CO_2 and suffer from photorespiration under ambient conditions. In contrast, hornworts demonstrate kinetics similar to C4 plants, maintaining high photosynthetic rates even at low carbon concentrations due to the lower CO_2 compensation point.

Anthocerotophyta undoubtedly possess the desired traits for efficient carbon-sequestration. However, their direct mass cultivation near large industrial conglomerations is impractical due to their sensitivity to air pollution. Therefore, the strategic approach involves isolating the genetic machinery that is responsible for pyrenoid formation and transferring it into resilient high-biomass crops.

Recent genomic sequencing of *Anthoceros agrestis* has revealed that the pyrenoid is a multigenic trait. Key targets for engineering include, genes encoding modified RBCS proteins responsible for aggregation, genes encoding proteins that act as a molecular "glue" and genes that encode specific isoforms localized to the pyrenoid.

By isolating these gene clusters using PCR amplification and introducing them into the genome of staple Ukrainian crops—such as wheat (*Triticum aestivum*) and maize (*Zea mays*)—via **Agrobacterium-mediated transformation**, it is theoretically possible to induce pyrenoid formation in crop chloroplasts (Hennacy & Jonikas, 2020).

Implementing a pyrenoid-based CCM is expected to have profound physiological effects beyond simple carbon fixation.First of all , it is vital to consider an increased amount of biomass and the resulted water efficiency**.** Primarily, the suppression of photorespiration means the plant stops wasting energy on recycling oxygen. This conserved energy is predicted to be channeled into vigorous vegetative growth and **root development**, significantly boosting total biomass. Furthermore, the high internal CO_2 concentration created by the pyrenoid allows plants to maintain narrower stomatal apertures. This reduces transpiration rates, thereby enhancing **Water Use Efficiency (WUE)**. This trait is particularly valuable for adapting agriculture to increasingly arid climatic conditions and ensuring survival during heatwaves.

The anticipated increase in carbohydrate synthesis offers a significant boost to caloric yield. However, this accumulation of starch necessitates a careful examination of the Carbon-to-Nitrogen (C:N) ratio within the grain. A potential "dilution effect" could occur if nitrogen uptake does not scale proportionally with carbon fixation, theoretically impacting protein content (Taub & Wang, 2008). Consequently, deploying this technology will likely require optimized soil management or co-engineering of nitrogen assimilation pathways to ensure that the crops remain both high-yielding and nutrient-dense.

CONCLUSION

The integration of the Anthocerotophyta-derived biophysical Carbon Concentrating Mechanism into C3 crops represents a transformative frontier in plant biotechnology. Our review highlights that the hornwort pyrenoid is a sophisticated, modular organelle capable of overcoming the inherent limitations of the enzyme Rubisco. By identifying and transferring the key genetic components—specifically the modified Rubisco Small Subunit, linker proteins, and pyrenoid-localized Carbonic Anhydrase—it is theoretically feasible to engineer a functional CCM in staple crops like wheat and maize . Such "climate-smart" crops would offer a dual

solution to the global crisis: ensuring food security through increased yields and drought tolerance, while simultaneously turning agricultural lands into active sinks for biological carbon sequestration.

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ASSESSMENT OF THE EFFECTS OF STABILIZED MUNICIPAL ORGANIC WASTE COMPOSTS ON TOMATO (*SOLANUM LYCOPERSICUM* L.) GROWTH AND ENZYMATIC ACTIVITIES OF PEROXIDASE AND SUCCINATE DEHYDROGENASE

Ilham Chennak

Laboratory of Water and Environment, Department of Chemistry, Faculty of Sciences, Chouaïb Doukkali University, 24 000, El Jadida, Morocco.

Laboratory of Health and Environment, Department of Biology, Faculty of Sciences Ain Chock, Hassan II, 20 470 Casablanca, Morocco.

Lamiaa Belasri

Laboratory of Health and Environment, Department of Biology, Faculty of Sciences Ain Chock, Hassan II, 20 470 Casablanca, Morocco.

Mohammed El Krati

Laboratory of Water and Environment, Department of Chemistry, Faculty of Sciences, Chouaïb Doukkali University, 24 000, El Jadida, Morocco.

Samah Ait Benichou

Laboratory of Health and Environment, Department of Biology, Faculty of Sciences Ain Chock, Hassan II, 20 470 Casablanca, Morocco.

ABSTRACT

This study examined the effects of four mature municipal solid waste composts on the cultivation of *Solanum lycopersicum* L. It assessed the impact of different application rates (0, 5, 10, and 20 t/ha) on plant growth, as well as on the leaf activities of peroxidase (Prx) and succinate dehydrogenase (SDH). Overall, compost application, regardless of the dose, significantly enhanced all measured parameters. Stem height, root length, fresh biomass, leaf number, and leaf area increased markedly and proportionally with rising compost doses. The highest increases in chlorophyll content and total soluble sugars were recorded with the higher application rates of composts.

Keywords: MSW compost; Solanum lycopersicum; enzymatic activities.

ASSESSING THE HETEROGENEOUS EFFECTS OF RAINFALL AND IRRIGATION ON AGRICULTURAL PRODUCTIVITY IN BANGLADESH: TAKEAWAYS FOR CLIMATE SMART AGRICULTURE

MD. Kabir Hossain

Lecturer, Rajendrapur Cantonment Public School and College at Rajendrapur, Gazipur, Bangladesh

Abstract

The agricultural production system in Bangladesh is predominantly rain-fed. The rain-fed agriculture system is vulnerable to climate change impact. The impact of climate change occurs at multiple scales (global, regional and national) and sectors (including agriculture). The agricultural sector and its sub-sectors are increasingly showing a high level of vulnerability and impact. The impact of climate change and variability on agricultural production would engender appropriate policies and practices towards a sustainable agricultural production system.

This study try to find out that the various impacts of rainfall and irrigation on agricultural production in Bangladesh and drew key takeaways for climate-smart agriculture (CSA) in Bangladesh. We use 44 years' time series data that are extracted from national and international sources. Descriptive and inferential analyses (averages, standard deviations and correlations) were used to analyze the dataset to elucidate the variables. The estimation followed an autoregressive integrated moving average (ARIMA) model style. The GMM technique was used to estimate the parameters of the model that was used for estimating the impact of rainfall and irrigation on aggregate agricultural production and by sub sectors (all crops, staples, livestock, fisheries and forestry). Irrigation had positive and significant impact on aggregate agricultural production as well as all sub-sectors of agriculture. These findings suggest the need for the minimization of the impact of climate-induced production risks through CSA which would involve complementary development of more arable land areas under irrigation in Bangladesh. Irrigation would also enhance complementary agricultural water management for the development of all the sub-sectors of agriculture. So under climate change and variability irrigation help agricultural production and helps to obtain food security and sustainable development. Finally these studies provide appropriate and necessary policies that helps to enhancing food security and sustainable agricultural production under prevailing climate change and variability.

Keywords: Rainfall, Irrigation, Heterogeneous Effects, Agricultural Productivity, Climate Smart Agriculture (CSA).

INDIGENOUS ALDER (*ALNUS NEPALENSIS*) BASED AGROFORESTRY SYSTEMS AMONG TRIBAL COMMUNITIES OF NAGALAND: A PATHWAY TO SUSTAINABLE LAND USE

Jayashree Chowdhury

Assistant Professor, Department of Economics, Handique Girls' College, Guwahati, India

Bandana Chowdhury

Assistant Professor, Department of Economics, Gauhati University, Guwahati, India

Sourav Deuri

Guest Lecturer, Department of Economics, Handique Girls' College, Guwahati, India

Abstract

The rich and diversified valley of Northeast where Nagaland's hilly landscape is facing persistent ecological challenges since immortal including unstable slopes, heavy rainfall, shallow soils and the long-term impacts of shortened jhum shifting cultivation cycles. As a result of which fallows are shrinking, soil fertility declines, erosion intensifies and livelihoods become vulnerable in this region. Amid all these ongoing pressures, several tribal communities of Nagaland such as the Angami, Chakhesang, Chang, Yimchunger and Konyak have developed an indigenous agroforestry practice centred on *Alnus nepalensis* (Himalayan alder). In this process, alder trees are retained and periodically pollarded within jhum fields while a variety of food, tuber and cash crops are cultivated beneath them. The tree's nitrogen-fixing ability continuous litterfall and strong root system enhances the soil fertility, thus improving slope stability and allowing sustained cropping even on steep terrain.This paper reviews the biological characteristics of *Alnus.nepalensis,* portraying the cultural origins and management of the alder-based system and assessing its ecological and socio-economic impacts. The paper also shows the clear benefits in terms of soil enrichment, erosion control, diversified production and livelihood support. In this context, the various ongoing challenges such as labour demands, market limitations, biodiversity trade-offs and issues of tenure are also highlighted throughout the study. Overall, the alder-based system is presented as a valuable indigenous model for sustainable land use in mountainous regions and a potential framework for scaling in similar landscapes.

Keywords: *Alnus nepalensis*, agroforestry, jhum, Nagaland, indigenous land-use, nitrogen fixation, slope stabilization, sustainable farming.

STUDYING THE EFFECT OF HEMATITE AND TITANIUM DIOXIDE NANOPARTICLES ON REDUCING CADMIUM LEVELS IN WHEAT GRAIN: A REVIEW

Fateme Asadi Touranlou

Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

Abstract

Introduction: Cadmium (Cd) accumulation in wheat grain poses a significant risk to food safety and human health due to its high toxicity and bioavailability. With increasing soil contamination from industrial and agricultural sources, conventional remediation strategies often prove inefficient or costly. Recent studies have explored engineered nanoparticles, particularly hematite (Fe_2O_3) and titanium dioxide (TiO_2), as promising immobilizing agents that reduce Cd uptake and translocation in crops.

Methods: This review synthesizes findings from 28 peer-reviewed studies (2015–2025) identified through Scopus, Web of Science, and PubMed using keywords such as "hematite nanoparticles," "titanium dioxide nanoparticles," "cadmium immobilization," and "wheat grain." Inclusion criteria comprised pot and field experiments evaluating Cd concentration in wheat tissues following nanoparticle amendment (doses 10–500 mg kg^{-1} soil), with or without Cd-spiked conditions. Data on soil Cd bioavailability, plant uptake, translocation factors, grain Cd content, oxidative stress markers, and yield parameters were systematically compared.

Results: Both hematite and TiO_2 nanoparticles significantly reduced bioavailable Cd in soil (25–78%) through adsorption, complexation, and pH-dependent surface reactions. Foliar or soil-applied nanoparticles decreased Cd concentration in wheat grain by 32–89%, with hematite generally outperforming TiO_2 at equivalent doses. Mechanisms included enhanced Cd fixation in roots, reduced translocation to shoots, and alleviation of Cd-induced oxidative stress. No consistent phytotoxicity or yield penalty was observed at optimal doses (≤100 mg kg^{-1}).

Conclusion: Hematite and TiO_2 nanoparticles offer an effective, eco-friendly approach for mitigating Cd accumulation in wheat grain. Hematite shows particular promise due to superior adsorption capacity and lower cost. Further field-scale and long-term studies are needed to confirm efficacy, safety, and regulatory feasibility before widespread agricultural adoption.

ISOLATION OF SAHARAN ACTINOBACTERIA FOR BIOLOGICAL CONTROL AGAINST PHYTOPATHOGENS: TOWARDS SUSTAINABLE AGRICULTURE

Fedwa BEGHDADI

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

El-Hadj DRICHE

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

Abstract:

Throughout their lives, plants interact with various organisms, which can negatively or positively impact their health, leading to significant agricultural losses. Biological control, particularly through the use of antagonistic actinomycetes, represents a promising method to combat these phytopathogens. Therefore, this study aims to screen new strains of actinomycetes isolated from Saharan soil, which produce bioactive molecules that inhibit some phytopathogenic agents.

For the isolation of Saharan actinomycetes, several soil samples were collected from various oases in Algeria. These samples were treated using the CaCO3 method and subjected to a series of decimal dilutions, and subsequently inoculated onto the CHV medium with or without selective agents, with incubation carried out at 30°C for 21 days. The antimicrobial activity of actinomycetes against these pathogens was assessed using the cross streaking method on ISP2 and YGB mediums. Incubation was done at 30°C for 24 hours for bacteria and up to 3 days for fungi (Aouiche et al 2013).

This method of isolation among us has resulted in obtaining a significant number of actinomycete isolates with the potential to inhibit phytopathogenic bacteria and fungi, with the inhibition diameter reaching up to 40mm for some strains on the solid YGB medium.

The intensity of the variable activity largely depends on the type or group to which the strains belong. These variations in the number of activities are due to the fact that a strain of actinobacteria can produce several antimicrobial molecules with different modes of action depending on the composition of the culture medium (Berdy, 2005 and 2012).

In view of the results obtained, we can consider that our actinomycete isolates have the ability to inhibit certain phytopathogenic agents. The production, extraction, and characterization of these bioactive molecules is the subject of our current research.

Keywords: Actinomycetes, Bioactive molecules, Phytopathogenic agents, Biological control.

ENVIRONMENTAL AND CONSUMER HEALTH RISKS ASSOCIATED WITH MYCOTOXINS PRODUCED BY PHYTOPATHOGENIC FUNGI

Fedwa BEGHDADI

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

El-Hadj DRICHE

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

Abstract

Pathogenic fungi inflict great damage on plants, leading to their wilting, damage, or death in many cases, by secreting hydrolases that dissolve the cells of the plant tissue on which they feed. Among these plant-pathogenic fungi we find: *Botrytis ceneria, Fusarium oxysporum, Alternaria, Phytophthora infestans* ... these have a negative impact on health, food safety and lead to significant losses.

Under certain climatic or storage conditions, these microorganisms can develop and lead to the production of mycotoxins, which can be harmful to the health of animals and humans, causing a number of disorders and even serious illnesses. These toxic metabolites therefore represent a major health problem.

Around 25% of food products are contaminated with fungal toxins. The mycoflora is estimated to comprise between 200,000 and 300,000 species. There is therefore a wide diversity of mycotoxins. Of the more than 400 mycotoxins identified, only 30 or so have worrying toxic properties. Some of these toxins are thought to be carcinogenic or mutagenic, while others are toxic to the kidneys, nervous system or liver. It should also be noted that toxicity does not necessarily stem from the mycotoxin itself, but may be due to one of the metabolites produced by its degradation.

Several species of micromycetes, mainly belonging to the four genera *Aspergillus, Penicillium, Fusarium and Alternaria,* are capable of excreting one or more mycotoxins: aflatoxins, ochratoxins, fumonisins, trichothecenes, patulin, zearalenone, alternariols…

The lack of sanitary controls, poor food packaging (damp, hot, poorly ventilated storage areas) and the absence of strict regulations increase the risk of contamination by these metabolites. The frequency of contamination of foodstuffs available to the public and their mycotoxin content are becoming a serious threat to health.

Keywords: Mycotoxins**;** Phytopathogenic fungi**;** Food contamination**;** Toxicity**;** Food safety

DEVELOPMENT OF NANO-BASED LIQUID BIOFERTILIZER FOR MITIGATION OF SALT STRESS IN CAPSICUM ANNUUM L AND SOLANUM MELONGENA PLANTS

Shyamnath. S

School of Bioengineering, Bharath Institute of Higher Education and Research, Selaiyur, Chennai, Tamil Nadu 600073, India.

Sandhia.S

School of Bioengineering, Bharath Institute of Higher Education and Research, Selaiyur, Chennai, Tamil Nadu 600073, India.

Jeyanthi Rebecca.L

School of Bioengineering, Bharath Institute of Higher Education and Research, Selaiyur, Chennai, Tamil Nadu 600073, India.

Abstract

Salinity is one of the most important environmental stress which threatens the global crop production, and also soil salination is increasing due to the increasing sea level, and also it is going to increase more in the future, hence a sustainable solution is required to mitigate the adverse effects of salt stress in plants. This study aimed to produce a liquid biofertilizer containing *Halomonas aquamarina* incorporating silica, copper oxide, and iron nanoparticles to mitigate the adverse effects of salt stress in plants. This experiment was conducted in a controlled environment under a hydroponics setup for two weeks, using one-month-old *Capsicum annuum L* and *Solanum melongena.* Seedlings. After one week of NaCl treatment, the plants were treated with the nano-based liquid biofertilizer, and morphological, physiological, and biochemical analyses were conducted. The results showed that the biofertilizer with the incorporation of nanoparticles mmproved the ascorbate peroxidase activity by 33 to 60 percent in salt-stressed plants, and improves photosynthetic pigments under stress conditions and also found that the *Halomonas aquamarina* have found to enhance the root growth. The study concluded that the biofertilizer made with *H. Aquamarina* along with silica, copper oxide, and iron oxide nanoparticles incorporated in it had mitigated the adverse effects of salt stress in plants.

Keywords: *Halomonas Aquamarina*; silica; copper oxide; iron; Ascorbate peroxidase, Biofertilizer, salt stress; Capsicum annuum L, *Solanum melongena.*

GREEN SYNTHESIS OF *MELIA DUBIA* MEDIATED SILVER NANOPARTICLES AND EXPLORING IT'S ANTIBACTERIAL PROPERTY IN MASTITIS PATHOGENS

Lazima.G

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Ranjani S

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

Antibiotic resistance among bovine mastitis pathogens presents a critical challenge to animal health, milk quality, and the global dairy industry. Conventional therapies becoming increasingly ineffective, the development of sustainable antimicrobial alternatives is essential. Silver nanoparticles (AgNPs) were synthesized using the leaf extract of *Melia dubia*, providing a green, eco-friendly, and cost-effective approach to nanoparticles synthesis. The phytochemicals in the extract acted as natural reducing and stabilizing agents. The synthesized AgNPs were characterized using UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Zeta Potential analysis, and Field Emission Scanning Electron Microscopy (FESEM). These techniques confirmed the synthesis of nanoparticles, crystalline structure, colloidal stability, and the presence of functional groups responsible for capping and stabilization. The antibacterial activity of the green-synthesized AgNPs was evaluated in major multidrug-resistant mastitis pathogens, including *Klebsiella pneumoniae, Escherichia coli, and Acinetobacter baumannii*. The AgNPs exhibited strong inhibitory effects, reflected by reduced bacterial growth, membrane disruption, and interference with vital cellular functions. Their antimicrobial mechanism is attributed to generation of oxidative stress, enhanced membrane permeability, and interaction with intracellular biomolecules. This study demonstrates the promising potential of *Melia dubia*-mediated AgNPs as an effective alternative antimicrobial strategy for managing bovine mastitis. The integration of biogenic nanoparticles may help reduce antibiotic dependency, mitigate resistance development, and support sustainable livestock healthcare.

Keywords: Silver nanoparticles; Green synthesis; *Melia dubia*; Bovine mastitis; Antimicrobial activity; Multidrug-resistant pathogens

PHYTO-SYNTHESIS OF NANOPARTICLES TO CONTROL MULTIDRUG RESISTANCE GRAM NEGATIVE PATHOGENS

Abinaya V

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Ranjani S

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

Antibiotic resistance has created significant impact on global healthcare system. *Ormocarpum cochinchinense* is a medicinal plant belonging to the family Fabaceae which is widely distributed in tropical regions Southeast Asia. *Ormocarpum cochinchinense* is rich in flavonoids and phenolic compounds, was utilized for the phyto-synthesis of silver nanoparticles (Oc-AgNPs). The plant extract acted as both reducing and stabilizing agent, promoted an eco-friendly synthesis route. The synthesized Oc-AgNPs were characterized using XRD, EDAX, FESEM and DLS analyses, confirming the formation of crystalline, spherical nanoparticles ranging from 20 to 50 nm with high elemental purity and stability. The antimicrobial efficacy of Oc-AgNPs was evaluated in *Escherichia coli* and *Klebsiella pneumoniae*. MIC and MBC assays demonstrated potent antibacterial activity at low concentrations, while biofilm inhibition assays revealed significant disruption of bacterial adherence. The results indicate that Oc-AgNPs effectively suppress Gram-negative pathogens and could serve as promising alternatives to conventional antibiotics. Biochemical assessment confirmed that the treatment with Oc-AgNPs caused bacterial membrane leakage and oxidative stress, indicated by increased lipid peroxidation and decreased CAT, SOD activity. Furthermore, the incorporation of Oc-AgNPs into hydrogel matrices enhances their stability and enables controlled release, making them suitable for wound healing and biomedical applications.

Keywords: *Ormocarpum cochinchinense*, Nano therapeutics, Nanoparticles, Antimicrobial activity, Anticancer activity, Hydrogel

NANO-ENGINEERED ANTIMICROBIAL FORMULATION FOR THE CONTROL OF PLANT PATHOGEN

Kovendan M

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

Pathogenic attack and extension of shelf life of agricultural produce are global challenges in crop protection and post-harvest management. Pathogenic attacks significantly affect crop health which leads to dwarfing, leaf abscission and yield loss. Conventional preservation and plant protection techniques often rely on chemical treatments which raises environmental and health risks. This study addresses this issue and focus on developing a sustainable Nano-engineered treatment aiming for inhibiting these pathogenic microorganisms and to enhance the quality of crops. The core innovation is to synthesize a silver nanoparticles using young neem leaves (*Azadirachta indica*) which is well-known for its antimicrobial properties and the bioactive phytochemicals present acts as safe and eco-friendly reducing agents of AgNPs. Encapsulation of AgNPs into nanoemulsion enhance its stability, bioavailability, dispersion and antibacterial activity. The synthesized green nanoparticals (AIAgNPs) and nanoemulsion (AIAgNE) were characterized using UV-Vis spectroscopy, Dynamic Light Scattering (DLS), zeta potential, Fourier Transform Infrared Spectroscopy (FTIR), and X-ray Diffraction (XRD) analysis. Antibacterial efficacy of synthesized AIAgNPs and AIAgNE against two pathogenic strains of pseudomonas aeruginosa (SES4 & SES5) which has been isolated from infected sesame leaves were evaluated by MIC, MBC and Anti-biofilm formation assay. The antibacterial activity of synthesized AIAgNPs and AIAgNE with *Pseudomonas Aeruginosa* were tested at different time intervals, AIAgNPs reduced bacterial growth to 28% (SES4) and 15% (SES5), while AIAgNE showed strong inhibition with 10% (SES4) and 12% (SES5). Thus AIAgNE demonstrated the most effective antibacterial anti-biofilm activity compared to AIAgNPs. The study proves that the synthesized green silver nanoparticles using *Azadirachta indica* is effective in controlling the plant pathogens.

Keywords: Green synthesis, *Pseudomonas Aeruginosa, Azadirachta indica,* Preservation

AGRICULTURAL BIODIVERSITY AND FOOD SECURITY: A COMPARISON WITH EXAMPLES FROM TURKEY AND THE WORLD

Emine Kokaçya DUVAN

Dr., Independent Researcher; Kadirli/Osmaniye, Türkiye

ORCID ID: https://orcid.org/0000-0002-9180-9651

Semin TOPALOĞLU PAKSOY

Assoc. Prof. Dr., Çukurova University, Faculty of Economics and Administrative Sciences, Department of Econometrics, Adana, Türkiye

ORCID ID: https://orcid.org/0000-0003-1693-0184

Abstract

Introduction and Purpose: Agricultural biodiversity is a fundamental component of sustainable food systems and is strategically important for food security in the face of climate change, population growth, and global market volatility. Declining biodiversity makes food security vulnerable in the short and long term, while also threatening the sustainability of agricultural production. This study evaluates Türkiye's agricultural biodiversity structure from a food security perspective and compares it with global examples, aiming to present a holistic approach to conservation, sustainable use, and policy development.

Materials and Methods: A mixed-methods approach was adopted in the study; Türkiye's agricultural biodiversity capacity was assessed using quantitative indices and qualitative policy analyses. Quantitative analyses were conducted using crop diversity, genetic resource density, and food security indicators. Qualitative analyses were conducted using policy documents, seed legislation, and international reports. Türkiye's agricultural biodiversity potential was compared with selected countries from America, Europe, Africa and Asia.

Conclusions: The findings indicate that agricultural biodiversity strengthens its critical role in food security, particularly through production diversification, the protection of local species, the development of farmer information systems, and the dissemination of digital agriculture practices. Comparison with global examples (such as India, Mexico, and Italy) reveals that local seed policies implemented in countries with high biodiversity centers strengthen the stability dimension of food security.

Discussion and Conclusion: Protecting biodiversity and local seeds is not only an environmental imperative but also a strategic priority for Türkiye's and the world's food security policies. While Türkiye is a country rich in genetic diversity, it faces the risk of genetic erosion due to monoculture pressure and reliance on hybrid seeds. Global examples demonstrate that food supply vulnerability is lower in countries with strong local seed policies. A policy-driven holistic management approach will enable Türkiye to maximize the potential of agricultural biodiversity and build a sustainable food system aligned with global trends.

Key Words: Agricultural biodiversity; Food security; Genetic resources; Diversity indices; Comparative analysis; Türkiye

CHARACTERIZATION OF LEAVES, ROOTS, AND SOIL OF MEDICINAL AROMATIC PLANTS: SOIL-PLANT TRANSFER

Ikram Elbezyouy

1Ecological engineering team, Laboratoire de Génie Environnemental, Ecologique, Agro-Industriel, Faculté des Sciences et Techniques, Université Sultan Moulay Slimane, BP 523, 23000Béni Mellal, Morocco.

Ilias Oussif

1Ecological engineering team, Laboratoire de Génie Environnemental, Ecologique, Agro-Industriel, Faculté des Sciences et Techniques, Université Sultan Moulay Slimane, BP 523, 23000Béni Mellal, Morocco.

Aabdousse Jamal

1Ecological engineering team, Laboratoire de Génie Environnemental, Ecologique, Agro-Industriel, Faculté des Sciences et Techniques, Université Sultan Moulay Slimane, BP 523, 23000Béni Mellal, Morocco.

Wahid Nadya

1Ecological engineering team, Laboratoire de Génie Environnemental, Ecologique, Agro-Industriel, Faculté des Sciences et Techniques, Université Sultan Moulay Slimane, BP 523, 23000Béni Mellal, Morocco.

Abstract

The use of aromatic medicinal plants has long highlighted their importance for human health, the food industry, and nutrition. However, our study will focus on an aromatic medicinal plant widely recognized for its therapeutic properties and use in traditional medicine. This species belongs to the Ericaceae family, typical of areas with a Mediterranean climate. Despite its great socio-economic and ecological importance, adaptation to environmental stress, and regeneration, it remains undervalued. However, its exposure to radioactive elements present in the environment via soil-plant transfer can have nutritional consequences. This work aims to determine the rate of transfer of radioactive elements from the soil to the roots and leaves at three geographically different sites in the Beni Mellal region, based on the quantitative use of LR 115 detectors for measuring uranium and thorium.

The principle of solid nuclear trace detectors is based on interaction with the environment (soil, crushed leaves, crushed roots). This DSTN technique, based on autoradiographic contact with samples, depends on knowledge of the stopping power of particles in the samples studied and the recording sensitivity of the detector.

Keywords: Soil-plant transfer, LR115, Solid detectors, Medicinal aromatic plants, Impact of radioactivity.

HERBAL COSMETICS: TRENDS, SAFETY & EFFICACY

S.Rubin thara

N.Arshad ahamed

E.Praveena

R.Swathi

R.SriArasuvasan

K.Dinesh Rajan

D.Aravindhan

K.vaishnavi

k.vijalakshmi

Faculty of pharmacy, Bharath institute of higher education and research, chennai, India

Abstract

Herbal cosmetics have gained significant global acceptance due to increasing consumer awareness of natural ingredients, safer formulations, and holistic beauty care. These products incorporate plant-derived components such as essential oils, extracts, and phytochemicals that offer functional benefits including moisturization, anti-aging effects, UV protection, and acne management. Current trends highlight a shift toward green formulations, sustainability, clean beauty, and the integration of advanced technologies like nano-herbal delivery systems to enhance skin penetration and stability. Despite their growing popularity, safety concerns remain, particularly regarding adulteration, contamination with heavy metals, unstandardized extracts, and undisclosed synthetic additives. Regulatory challenges also persist, as many herbal cosmetic products lack rigorous standardization and quality control compared to conventional cosmetics. Nevertheless, scientific evidence increasingly supports the efficacy of various herbal ingredients, such as aloe vera, turmeric, neem, and green tea, which demonstrate antioxidant, antimicrobial, and anti-inflammatory activities. This article reviews recent trends in the herbal cosmetic industry, evaluates the safety aspects associated with their use, and highlights evidence-based data regarding their efficacy. Overall, herbal cosmetics present promising alternatives to synthetic products, provided that proper standardization, safety assessment, and regulatory compliance are ensured.

Keywords: Herbal cosmetics, phytochemicals, safety, efficacy, natural ingredients, clean beauty, standardization, skin care, plant extracts, nano-herbal formulations.

FOAM-MAT DRYING: A SUSTAINABLE TECHNOLOGY TO REDUCE POST-HARVEST LOSSES AND ADD VALUE TO AGRI-FOOD PRODUCTS

Mostafa OUHSSAINE
Khénifra Higher School of Technology, Sultan My Slimane University, BP170, Khenifra, Morocco

Karim OUSSAID
Khénifra Higher School of Technology, Sultan My Slimane University, BP170, Khenifra, Morocco

Sanaa CHERROUD
Khénifra Higher School of Technology, Sultan My Slimane University, BP170, Khenifra, Morocco

Ayoub AINANE
Khénifra Higher School of Technology, Sultan My Slimane University, BP170, Khenifra, Morocco

Tarik AINANE
Khénifra Higher School of Technology, Sultan My Slimane University, BP170, Khenifra, Morocco

ABSTRACT

Foam-Mat Drying is an emerging drying process that is gaining interest in the agri- food and environmental sectors due to its efficiency, low energy cost, and ability to preserve the qualitative characteristics of processed products. It involves incorporating foaming and stabilizing agents into a liquid or food puree to form a stable foam, which is then spread in a thin layer and dried in hot air. This modification of the product's structure significantly increases the exchange surface area and reduces internal diffusion resistance, allowing for faster drying at moderate temperatures while minimizing the degradation of bioactive compounds, natural pigments, and volatile aromas.

In many countries, particularly those with hot climates, post-harvest losses are a major challenge, sometimes affecting more than 30% of annual production. Fruits, vegetables, and perishable products with high water content are particularly susceptible to physical, microbiological, and biochemical deterioration. Foam-Mat Drying offers a sustainable technological response to these constraints, enabling the rapid transformation of unstable raw materials into stable powders that are easy to transport, store, and incorporate into food formulations. This process thus promotes local added value, waste reduction, and extended shelf life.

In addition, the flexibility of the process—applicable to various products such as juices, purées, plant extracts, dairy products, and spices—makes it a technology suitable for small and medium-sized agri-food units. By limiting the need for complex equipment and energy, it is fully in line with a sustainability approach and the transition to more responsible processes. Foam-Mat Drying is therefore a promising solution for improving food safety, supporting bio-valorization, and addressing environmental issues related to post-harvest losses.

Keywords: Foam-Mat Drying - Post-harvest losses - Agri-food recovery - Sustainability

INTEGRATED VALORIZATION OF QUINOA PROCESSING BY-PRODUCTS: FROM FUNCTIONAL FOOD INGREDIENTS TO BIOENERGY AND AGRICULTURAL APPLICATIONS

BENYAHOUB Rabie
Laboratory for the Protection of Ecosystems in Arid and Semi-Arid Zones, Kasdi Merbah University –Algeria-

CHOUANA Toufik
Bioresources Laboratory, Kasdi Merbah University–Algeria

AZIB Salim
Laboratory for the Protection of Ecosystems in Arid and Semi-Arid Zones, Kasdi Merbah University –Algeria-

Abstract

Introduction: Quinoa (*Chenopodium quinoa* Willd.) processing generates substantial amounts of by-products, including husks, bran, and saponin-rich residues. These materials are often discarded despite their richness in bioactive compounds and nutrients. In the context of a circular bioeconomy, such by-products represent promising resources for sustainable valorization. This project aims to develop an integrated approach for converting quinoa processing wastes into value-added products across the food, bioenergy, and agricultural sectors.

Materials and Methods

The planned work focuses on three complementary valorization pathways:

(1) **Extraction of functional food ingredients** from quinoa bran (dietary fibers, proteins, antioxidant compounds);

(2) **Bioenergy production** through anaerobic digestion or fermentation of quinoa residues to generate biogas or bioethanol;

(3) **Agricultural applications**, assessing composted biomass and residual material as soil amendments to enhance soil fertility.

These methodological approaches are currently under development as part of the project's initial phase.

(Expected) Results: As this research is in its early stages, experimental results are not yet available. However, based on existing literature, these pathways are expected to yield functional ingredients suitable for incorporation into health-promoting foods, renewable energy derived from quinoa residues, and nutrient-rich amendments capable of improving soil quality.

Discussion / Conclusion: The integrated valorization approach proposed in this project has strong potential to reduce environmental impacts and generate new economic opportunities within the quinoa production chain. Although results are forthcoming, the conceptual framework supports the development of sustainable agrifood systems in emerging regions. This work highlights quinoa's value beyond its grains, promoting holistic use of its processing by-products for food, energy, and agricultural sustainability.

Keywords: Quinoa by-products; functional ingredients; bioenergy; compost; circular bioeconomy; sustainable valorization

BIOCHEMICAL AND ANTIMICROBIAL PROFILING OF CAROB (CERATONIA SILIQUA L.) ORGANS FROM MOROCCAN POPULATIONS

Hasna ZAGGOUMI
Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Said BOUDA
Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Imane NEG
Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Ibtissam MARDOUME
Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Doha BELKACHACH
Laboratory of Microorganisms and Active Biomolecules, Sciences Faculty of Tunis, University Tunis El-Manar. Tunis, Tunisia

Sonia MARGHALI
Laboratory of Microorganisms and Active Biomolecules, Sciences Faculty of Tunis, University Tunis El-Manar. Tunis, Tunisia

Abdelmajid HADDIOUI
Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco.
Laboratory of Microorganisms and Active Biomolecules, Sciences Faculty of Tunis, University Tunis El-Manar. Tunis, Tunisia

Abstract:
Carob (Ceratonia siliqua L.) is a widely distributed Mediterranean tree with strong ecological adaptability and increasing interest as a natural source of bioactive ingredients. This study comparatively evaluated the biochemical and microbiological profiles of seeds, pulp, and leaves from six Moroccan carob populations originating from contrasting environments. Total polyphenols, flavonoids, and tannins were quantified, and antioxidant potential was determined using DPPH and FRAP assays. Antimicrobial activity was examined against Bacillus subtilis, Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae using disk diffusion and microdilution approaches. Significant inter-population and inter-organ differences were recorded for all measured parameters. Pulp and leaves displayed the highest polyphenol contents, while seeds showed the strongest antioxidant and antimicrobial responses. Multivariate classification revealed marked diversity among populations and suggested that

environmental and geographic factors contribute to population clustering. Overall, these results demonstrate that Moroccan carob exhibits valuable biochemical variability and provides effective natural antioxidant and antimicrobial agents. The species represents a promising plant resource for developing sustainable, plant-based additives and functional ingredients suitable for food, environmental, and health-related applications.

Keywords: *Ceratonia siliqua*, natural antioxidants, antimicrobial activity, polyphenols, food ingredients, food technology

MICROENCAPSULATION OF *DYSPHANIA AMBROSIOIDES* ESSENTIAL OIL: AN EXAMPLE OF SUSTAINABLE VALORIZATION OF MOROCCAN NATURAL HERITAGE

Amal Dagni
Laboratory of Health, Environment and Biotechnology, Faculty of Sciences Ain Chock, Molecular Genetic Physiopathology and Biotechnology Team, Hassan II University of Casablanca, Maarif BP 5366, Casablanca, Morocco

Souraya Sakoui
Laboratory of Health, Environment and Biotechnology, Faculty of Sciences Ain Chock, Molecular Genetic Physiopathology and Biotechnology Team, Hassan II University of Casablanca, Maarif BP 5366, Casablanca, Morocco

Abdelaziz Soukri
Laboratory of Health, Environment and Biotechnology, Faculty of Sciences Ain Chock, Molecular Genetic Physiopathology and Biotechnology Team, Hassan II University of Casablanca, Maarif BP 5366, Casablanca, Morocco

Bouchra El Khalfi
Laboratory of Health, Environment and Biotechnology, Faculty of Sciences Ain Chock, Molecular Genetic Physiopathology and Biotechnology Team, Hassan II University of Casablanca, Maarif BP 5366, Casablanca, Morocco

Abstract

Dysphania ambrosioides is a wild plant native to Morocco, renowned for its rich ethnobotanical heritage and associated biodiversity. Its essential oil (EO) exhibits remarkable antibacterial and antioxidant properties, but its use remains limited due to its high volatility and instability.

In this study, we explored the sustainable valorization of this natural resource through its microencapsulation with natural biopolymers (inulin and gum arabic), known for their biodegradability and environmental safety.

The resulting microcapsules were characterized using various analytical techniques (FT-IR, SEM, TGA) to evaluate their stability, encapsulation efficiency, and behavior under simulated digestion.

The results show high encapsulation (88%), stability exceeding 80%, and controlled release of bioactive compounds. Furthermore, these microcapsules retained antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. This research illustrates how the scientific valorization of a local plant contributes to preserving and promoting Moroccan biodiversity, while also opening up prospects for sustainable applications in the food, environmental, and heritage sectors.

Keywords: Microencapsulation, *Dysphania ambrosioides*, natural heritage, environment

APPLICATION OF THE NORMALYSA TOOL FOR RADIATION DOSE CALCULATION IN THE SEMI-ARID MEKNES AGRICULTURAL REGION

Samira EL AOUIDI
Centre National de l'Energie, des Sciences et des Techniques Nucléaires – Rabat, Morocco

Zineb ELABOUDI
[2]Process Engineering and Environment Laboratory (LGPE). Faculty of Sciences and Techniques of Mohammedia (FSTM). University of Hassan II Casablanca, Morocco

Abdelmourhit LAISSAOUI
Centre National de l'Energie, des Sciences et des Techniques Nucléaires – Rabat, Morocco

Radouan SAADI
Centre National de l'Energie, des Sciences et des Techniques Nucléaires – Rabat, Morocco

Azzouz BENKDAD[1]
Centre National de l'Energie, des Sciences et des Techniques Nucléaires – Rabat, Morocco

Zineb EL Mouridi
National Institute of Agronomic Research (INRA), BP 6356, CRRA Rabat, Av. Al Irfane, 10100 Rabat, Morocco

Abstract

In this study, we used the NORMALYSA tool to simulate the effective radiation dose to humans based on soil-plant transfer factors obtained from two sampling campaigns in 2022 and 2023 in the Meknes agricultural area, as part of the international research coordinated project led by the International Atomic Energy Agency, CRP K41022. This simulation provides an estimate of radiation doses transferred from soil to plants, helping to assess potential exposure levels in the studied areas.

The total annual doses were calculated for 12 fields in the Meknes region for adult population (barley and wheat; bean; calabash; corn; eggplant and long cucumber; green and red pepper; potato; pomegranate; eggplant and tomato; red pepper; onion; cardoon and beet) for the adult population. In this scenario, exposure doses were calculated using four NORMALYSA models: "Garden plot," "Dose from ingestion of garden foods," "Dose from outdoor occupancy," and "Total dose."

The results show that the dose from outdoor external exposure is very low or even negligible in all fields studied. Similarly, the doses related to soil ingestion and ingestion of all garden food types are zero for all crops. In contrast, inhalation appears as the dominant exposure pathway to ionizing radiation among adults in these agricultural areas. However, it is important to emphasize that although the inhalation dose predominates compared to other pathways, it remains below the recommended limit of 1 millisievert per year (0.001 Sv/year), which is the maximum dose advised for the general population by radioprotection organizations.

Keywords: NORMALYSA tool, dose simulation, soil-plant transfer factors, Meknes semi-arid agricultural area

ASSESSING SOIL PROPERTIES AND FEMALE FARMERS PERCEPTION OF GULLY EROSION CONTROL STRATEGIES IN KALTUNGO LOCAL GOVERNMENT AREA, GOMBE STATE NIGERIA

Saleh Amina Bakaro

Department of Environmental Management and Toxicology, Faculty of Physical Sciences, Federal University Dutse.

Suleiman Ammar Muhammad

Department of Environmental Management and Toxicology, Faculty of Physical Sciences, Federal University Dutse.

Hassan Umar Ibrahim

Department of Environmental Management and Toxicology, Faculty of Physical Sciences, Federal University Dutse.

Abstract

Soil erosion, particularly gully erosion, remains a critical global environmental issue with profound implications for land productivity, water quality, and socio-economic stability. In Nigeria, gully erosion poses an increasing threat, particularly in the northern and southeastern regions, where deforestation, overgrazing, and unsustainable agricultural practices accelerate land degradation. Kaltungo Local Government Area (LGA) of Gombe State is among the areas severely affected, as its steep slopes, sparse vegetation, and intense seasonal rainfall contribute to rapid gully formation. Despite various control measures introduced by both governmental and non-governmental initiatives, erosion interventions in Kaltungo have often failed due to insufficient understanding of soil characteristics and inadequate stakeholder involvement, particularly the exclusion of women from erosion management efforts. This study aims to assess the physical and chemical properties of soils in gully-affected areas of Kaltungo LGA and to explore women's perceptions and participation in erosion control strategies. Soil samples were collected and analyzed to determine key parameters influencing erodibility, while structured questionnaires and interviews were conducted to capture women's experiences and viewpoints. The research integrates biophysical and socio-cultural perspectives to provide a comprehensive understanding of gully erosion dynamics. Findings from this study are expected to contribute to evidence-based erosion management by linking soil science with community participation, emphasizing gender inclusivity in environmental decision-making. Ultimately, the study will offer practical recommendations for sustainable land management and inform policy directions that strengthen the effectiveness and equity of erosion control strategies in Kaltungo and similar regions.

Keywords: Gully Erosion, Female famers, Kaltungo, Control strategies.

STUDY OF THE EFFECT OF *CISTUS MONSPELIENSIS* ON THE GENOMIC INTEGRITY OF SPERMATOZOA IN MALE RATS SUBJECTED TO LEAD TOXICITY

LADACI Hadjer

Animal Ecophysiology Laboratory, Department of Biology, Faculty of Sciences, Badji Mokhtar University–Annaba, Annaba 23000, Algeria

LOUDJANI Farida

Animal Ecophysiology Laboratory, Department of Biology, Faculty of Sciences, Badji Mokhtar University–Annaba, Annaba 23000, Algeria

LADOUALI Zineb

Animal Ecophysiology Laboratory, Department of Biology, Faculty of Sciences, Badji Mokhtar University–Annaba, Annaba 23000, Algeria

ABDENNOUR Cherif

Animal Ecophysiology Laboratory, Department of Biology, Faculty of Sciences, Badji Mokhtar University–Annaba, Annaba 23000, Algeria

ABSTRACT

Lead is a metal used by humans for millennia and is also a significant environmental pollutant. *Cistus monspeliensis*, a plant belonging to the Cistaceae family, is widely known for its medicinal properties. This experimental study was conducted on 20 adult male rats divided into four groups: Group 1—control (T); Group 2 (CM)—received 500 mg/kg b.w. of an infusion prepared from fresh *Cistus monspeliensis* leaves; Group 3 (Pb)—treated with 100 mg/kg b.w. of lead acetate diluted in distilled water; and Group 4 (CM + Pb)—co-treated with both agents, all administered by gavage for 4 weeks. At the end of the treatment period, the animals were sacrificed by decapitation. Sperm samples were collected to assess sperm DNA fragmentation.The results showed that the percentage of spermatozoa with intact DNA significantly decreased in rats treated with Pb compared with both the control group (T) and the positive control (CM). However, co-treatment with CM and Pb (CM + Pb) resulted in an increase in the percentage of non-fragmented sperm DNA compared with Pb-treated rats. Conversely, the percentage of spermatozoa with fragmented DNA was significantly higher in the Pb group compared with all control groups. A marked reduction in this percentage (fragmented DNA) was observed in the combination group (CM + Pb) compared with rats treated with Pb alone.In conclusion, lead increases DNA damage, whereas *Cistus monspeliensis* infusion reduces sperm DNA fragmentation and mitigates lead-induced oxidative damage at the spermatozoal level.

Keywords: Rat, *Cistus monspeliensis*, DNA, epididymis, spermatozoa.

EXPLORING PHYTASE PRODUCTION FROM MICROALGAE AND ITS INDUSTRIAL APPLICATIONS

Gowridevi V

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

S. Suresh

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

[2]ORCID ID: 0000-0001-7706-7623

Murugesan Kamaraj

Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, Ramapuram Campus, Chennai- 600089, Tamil Nadu, India.

ORCID ID: https://orcid.org/0000-0002-0111-8524

Abstract:

Phytase is a crucial plant-based enzyme that is essential for breaking down the anti-nutritional factor Phytic acid present in plant-based foods. Phytase has numerous applications ranging from Agricultural (Animal feed), environmental (bioremediation) to pharmaceutical (Protein purification for Vaccine development, increasing the mineral bioavailability in the body, etc.). Currently, the Industrial production of Phytase to meet its ever-rising demand is mainly done using several Bacterial and Fungal strains as sources. But more innovative and sustainable practices can be adopted. One such idea is the production of Phytase from other microbial sources, like microalgae. Microalgae are currently in demand for their promising applications in the food and feed industries and in environmental and bioprocess applications. Because of their ability to utilize organic phosphorus sources for their metabolism, ease of obtaining a higher biomass yield, and their enhanced potential to express recombinant genes, microalgae are a promising source for producing Phytase. Microalgal species like *Chlamydomonas reinhardtii*, *Euglena gracillis*, *Phaeodactylum tricornutum* have been explored for their potential to express native and recombinant phytase. Thus, microalgae with their natural ability to hydrolyze organic phosphorous and metabolic versatility are a promising source to produce a sustainable, economical, and commercially scalable phytase enzyme.

Keywords: Phytase enzyme, Recombinant enzyme expression, Microalgae, Food and Feed industries, Bioremediation

FIRST WINTER BREEDING LIFE HISTORY TRAITS OF THE PLAIN TIGER BUTTERFLY, *DANAUS CHRYSIPPUS* (LINNAEUS, 1758) (LEPİDOPTERA: DANAIDAE) THROUGHOUT THE WINTERING PERIOD ON SONADIA ISLAND, BANGLADESH

Md. Shahinur Islam
Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology, Atomic Energy Research Establishment, GPO Box-3787, Dhaka-1000, Bangladesh

Md. Mosharraf Hosain
Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology, Atomic Energy Research Establishment, GPO Box-3787, Dhaka-1000, Bangladesh

Akira Yamanaka
Department of Applied Molecular Bioscience, Graduate School of Medicine, Yamaguchi University, Yoshida, Yamaguchi, Japan

A. T. M. F. Islam
Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology, Atomic Energy Research Establishment, GPO Box-3787, Dhaka-1000, Bangladesh

Abstract

The monarch butterfly (*Danaus chrysippus*) is commonly known as the plain tiger butterfly, which is a short- and long-distance migrant butterfly. The breeding activities of plain tiger butterflies are well known in the summer season (March to October), but in winter (November to February), when temperatures fall, there are no records of breeding in. We surveyed host plants of plain tiger butterflies in January and February in the years of 2020 and 2021. In the main land regions, no breeding activities were found in the winter season. Overwintering (November to February) broods were observed and recorded on isolated coastal Island of Sonadia , Cox's Bazar that are the southern part of Bangladesh. This island is about 7-9 square kilometres in area and located at latitude 21.28″-21.33″ and longitude 91.50″-91.56″. The breeding area is characterised by milkweed plants, which are their primary host, and the presence of ambient day time temperature (28°C to 30°C). On the other hand, mainland day time temperature was 19°C to 20°C. We studied morphological characteristics of developmental stages, pupal colour, sex ratio, and cumulative mortality in larval stages of this species. The incubation period was 3.62±0.52 days. The larvae and pupae durations were 18.18±0.94 days and 10.66±1.11 days. The male longevity was 9.0–43 days, and the female was 14.0–66.0 days. The mortality rate of the second, third, and fourth instar larvae was 2.77%, 2.85%, and 3.70%, and the mortality rate in pupae was 11.58%. Out of 23 pupae, pink was 82.61%, and brown was 17.39%. The sex ratios, regardless of the colour of pupa, showed 12 males (52.18%) and 11 females (47.82%) were found from green and pink coloured pupae. Male was predominated in pink colour (91.66%), and female (63.64%) also had a prevalence of pink colour. The findings of this study could be useful for predicting the population dynamics and help to develop appropriate conservation strategies for this species. This is the first study to document with the winter breeding life history of the plain tiger butterfly from the coastal part of Bangladesh.

Keywords: Overwintering life cycle, Plain tiger, *Danaus chrysippus*, Lepidoptera, Danaidae, Sonadia Island

BUMBLEBEE PARASITES TRANSMITTED TO HONEYBEES - *APICYSTIS BOMBI*

Academician Prof. Dr. Ivan PAVLOVIĆ

Scientific Institute of Veterinary Medicine of Serbia, Belgrade, Serbia

ORCID ID:https://orcid.org/ 0000-0003-4751-6760

ABSTRACT

Introduction and Purpose: It is known that a greater number of pathogens are transmitted between bumblebees and honey bees.Its including viruses, bacteria, fungi and protozoa. After acting as incidental hosts, honey bees may become the primary maintenance host, as occurred in the cases of *Apicystis bombi. A.bombi* is a unique apicomplexan protist that belongs to the neogregarines, which as a group exhibit relatively high virulence towards a range of insects.

Materials and Methods: Microscopic examination of the tissue is required to confirm the presence of oocysts. Other than the fat body, oocysts have been detected in the midgut and hindgut body parts of bees and in a single case in the spermatheca of a mated bumble bee and honey bee queen.

Results: It infects bees, especially bumblebees. It is believed to have a cosmopolitan distribution in bumblebees and a sporadic occurrence in honey bees, and causes disease symptoms in nonresistant bee species.

Discussion and Conclusion: *A. bombi*'s host range spanning *Apis* and *Bombus* may indicate that they are sharing gregarines at the shared pollen source. Oocysts are ingested by the bee and sporozoites develop from these in the intestine. They migrate through the wall of the gut before taking up residence in the fat body cells, where they develop and multiply. Typically, healthy fat body cells appear yellow while heavily infected cells appear swollen and distinctly white as a result of hypertrophism. The effects of *A.bombi* differ between host species. Heavily infected bees are rare, but this may be due to high pathogenicity of the neogregarine. Infected bee workers have increased mortality, reduced fatbody and increased sensitivity to sucrose. Infected queen bumblebees are unlikely to survive hibernation which is thought to be due to the reduced fatbody of infected queens. There is also some evidence that DWV (Deformed wing virus) may reduce some of the negative effects of *Apicystis bombi*.

Key Words: honey bee, bumblebee, *Apicystis bombi*

VARIABILITY OF POLLEN COLLECTED BY *APIS MELLIFERA INTERMISSA* BEES IN A MOUNTAINOUS REGION OF ALGERIA

Dr. Fatima DJOUBER-TOUDERT

Department of Agronomy, University Mouloud Mammeri Tizi-Ouzou, Algeria

Pr. Messaouda BELAID

Department of Process Engineering, University M'Hamed Bougara Boumerdès, Algeria

ABSTRACT

Introduction and Purpose: Honey constitutes only a fraction of the valuable products derived from the beehive. Other honeybee's products, such as royal jelly, beeswax, propolis, venom, and pollen, also possess significant biological and ecological properties. Among these, pollen plays a particularly critical role within the colony, serving as the principal source of proteins essential for brood development and overall colony health. Numerous studies have been conducted to determine its chemical composition, evaluate the role of bees in pollination, and establish the palynological profile of specific regions. The present study aims to analyze the variability of plant species foraged by honeybees and to identify melliferous flora in a mountainous region of Algeria.

Materials and Methods: An experimental setup involving 10 beehives was established. The breed of honeybees was *Apis mellifera intermissa* or Tellian honeybees. Pollen traps were installed at the hive entrances, and pollen collection was carried out once a week over one month period. The collected samples were air-dried, cleaned, and stored in labeled containers until analysis. Pollen identification was performed using standard microscopic techniques. Morphological characteristics of the pollen grains were compared with those presented in published pollen atlases and with reference slides prepared and maintained by our laboratory.

Results: Analysis of the collected pollen revealed the presence of 14 distinct color types. The number of pollen colors per sample ranged from a minimum of three to a maximum of 10. Orange-colored pollen was the most abundant (17%), whereas beige-colored pollen was the least represented (11%). A total of 29 melliferous plant species, belonging to 17 botanical families, were identified as pollen sources.

Discussion and Conclusion: This study underscores the richness and diversity of floral resources available to honeybees in the study area. Such diversity not only contributes to bee nutrition and colony sustainability, but also highlights the ecological importance of preserving native plant habitats. The conservation of these floral resources is essential for maintaining pollinator populations and, by extension, the biodiversity and resilience of ecosystems.

Keywords: Honeybees, palynology, melliferous plants, *Apis mellifera intermissa*, pollen.

SYNERGISTIC EFFECTS OF PLANT HORMONES AND HERBICIDES

Assoc. Prof. Dr. Emine KAYA ALTOP

Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Samsun, Turkiye

ORCID ID: https://orcid.org/0000-0002-0987-9352

Ph.D., Sine KAYA

Ondokuz Mayıs University, Graduate School of Natural and Applied Sciences, Department of Plant Protection, Samsun, Turkiye

ORCID ID: https://orcid.org/0000-0002-4219-9148

ABSTRACT

Plant hormones and herbicides working together synergistically is a potential new frontier for environmentally friendly weed management. Basically, hormones regulate the plants' physiological and biochemical processes that impact their growth, ability to resist stresses, and detoxification mechanisms, whereas herbicides are designed to inhibit the biochemical pathways that lead to weed growth. Experiments on the matter have shown that in some cases, substances like abscisic acid (ABA), brassinosteroids (BRs), and jasmonic acid (JA) may, under certain conditions of concentration, timing, and species, facilitate or hinder the action of herbicides. The main benefit of such interplays is the possibility of achieving higher selectivity, lower doses of herbicides, and less harm to crops. This article reviews the current understanding of the phenomenon of hormone–herbicide synergy, emphasizing the aspects of molecular signaling cross-talk, physiological changes, and integrated weed management implications.

Keywords: Herbicide Synergy, Plant Hormones, Phytohormone Regulation, Detoxification, Integrated Weed Management, Brassinosteroids, Abscisic Acid

INTRODUCTION

Herbicides have been the main tools for weed management. They have facilitated a quick and effective suppression of weeds in the agricultural practice of recent years. Nevertheless, the heavy and repetitive use of herbicides has caused a series of negative effects, such as pollution of the environment, emergence of herbicide-resistant weed populations, and unintentional phytotoxicity of crops (Heap, 2023; Duke, 2012). As a result of the drawbacks, the scientific community has been motivated to search for novel strategies that can both elevate the efficacy of herbicides and lessen the risks to the environment. One of the promising pathways in such direction is the use of hormones to modulate the physiological responses of plants (Grossmann, 2010).

Plant hormones or phytohormones are small molecular weight signaling compounds that regulate an immense number of processes related to growth and resistance. These are auxins,

cytokinins, gibberellins, abscisic acid (ABA), ethylene, salicylic acid (SA), jasmonates (JA), and brassinosteroids (BRs). The network of the eight hormones controls plant growth, the release of the defense system and resistance to both abiotic and biotic stresses (Santner & Estelle, 2009). Moreover, researchers have found that the same signaling pathways can communicate with herbicide-induced stress, thereby affecting the mechanisms of both sensitivity and resistance (Silva et al., 2009).

Synergy here means a scenario where the joint effect of a herbicide and a hormone exceeds the sum of their single effects. In support of this, one study found that some hormone pre-treatments can facilitate herbicide uptake, movement within the plant, and efficiency at the target site (Manghwar et al., 2022). On the other hand, certain hormones are capable of lessening the oxidative and metabolic stress brought about by herbicides, thus making the crops free of injury and at the same time, retaining the functionality of the herbicide for weed control (Sandalio et al., 2023). The two-faced operation of the hormones, i.e. either to activate the herbicidal effect to non-target plants or to provide a defense mechanism, depends upon hormone kind, dose, and the time of application.

It is possible that information about the molecular and physiological bases of such interactions might lead to the best use of herbicides for less environmental harm. One of the advantages of incorporating hormonal control into chemical weed management is the possibility to lessen the dependence on herbicides, prolong the time before resistance to herbicides appears, and enhance the safety of crops (Silva et al., 2009). Furthermore, the advent of "green chemistry" and the use of plant growth regulators have brought about several new possibilities in this area, one of which is the exploitation of inherent plant signaling for weed suppression and stress tolerance.

Hence, this paper's objectives are to:

- Illustrate the foundational aspects of herbicide mechanisms and plant hormone regulation.
- Discuss instances where hormone and herbicide interactions have a synergistic effect.
- Illustrate the molecular dialogue and metabolic regulation involved in these interactions.
- Point out the missing pieces of knowledge and the directions of future research that aim at exploiting this synergy in the context of contemporary weed management strategies.

CLASSIFICATION AND MODES OF ACTION OF MAJOR HERBICIDES

Herbicides are chemicals that are mainly intended to do the task of controlling or getting rid of unwanted plants by radically interfering with their vital physiological or biochemical pathways (Dayan & Duke, 2014). They are divided into different major groups based on their chemistry and site of action, with each group consisting of agents that target certain enzymes or cellular processes. The fundamentals of these scenarios should be agreed upon first before we can understand to what extent plant hormones play a role in indorsing or modifying herbicides' action.

Major Classes of Herbicides

The top herbicides are considered as a single group depending on their mode of action (MoA). The Herbicide Resistance Action Committee (HRAC) segregates herbicides into over 30 MoA groups, but only a handful of them are prevalent in worldwide farming (HRAC, 2023).

1. Photosystem II (PSII) inhibitors (e.g., atrazine, diuron) block electron flow in the photosynthetic process, thereby creating oxygen radicals (ROS) that damage lipids of the cell organelle membrane (Dayan et al., 2014).

2. Acetolactate synthase (ALS) inhibitors (e.g., imazapyr, metsulfuron-methyl) prevent the making of branched-chain amino acids which stops the proteins synthesis and cell division (Yu & Powles, 2014).

3. Acetyl-CoA carboxylase (ACCase) inhibitors (e.g., fenoxaprop, quizalofop) block the production of fatty acids in grasses that lead to membrane damage and energy metabolism changes (Délye, 2013).

4. 5-Enolpyruvylshikimate-3-phosphate (EPSPS) inhibitors, like glyphosate, bind and block the shikimate pathway, thus, aromatic amino acids are not produced (Duke & Powles, 2008).

5. Protoporphyrinogen oxidase (PPO) inhibitors (e.g., oxyfluorfen, saflufenacil) prevent chlorophyll formation, thus, the plant experiences oxidative stress and tissue death occur rapidly (Matringe et al., 2020).

6. Synthetic auxins (e.g., 2,4-D, dicamba) are structurally and functionally similar to the natural auxin (IAA), hence, growth becomes uncontrollable, and cells keep on expanding ultimately the plant dies (Grossmann, 2010).

7. Mitotic inhibitors (e.g., trifluralin, pendimethalin) stop microtubules from lengthening, thus, the process of cell division in mitosis is interrupted (Heap, 2008).

The discussed herbicide categories differ from one another by factors such as selectivity, persistence, and spectrum of control. Their performance and the degree of crop safety may be highly determined by the interplay of various environmental factors and the physiological state of the plants, which is under the control of hormones (Silva et al., 2009) (Table 1).

Table 1. Major Classes of Herbicides and Their Modes of Action

Herbicide Class	Example Compounds	Mode of Action	Target Enzyme / Site
ALS inhibitors	Bispyribac-sodium, Imazapyr	Inhibit acetolactate synthase (ALS)	ALS enzyme
ACCase inhibitors	Clodinafop, Fenoxaprop	Inhibit acetyl-CoA carboxylase	ACCase enzyme
Photosystem II inhibitors	Atrazine, Diuron	Block electron transport in PSII	D1 protein of PSII
EPSPS inhibitors	Glyphosate	Inhibit 5-enolpyruvylshikimate-3-phosphate synthase	EPSPS enzyme
Synthetic auxins	2,4-D, Dicamba	Disrupt auxin signaling and growth	Auxin receptor / Auxin pathways
Photosystem I inhibitors	Paraquat, Diquat	Generate reactive oxygen species (ROS)	Photosystem I
PPO inhibitors	Fomesafen, Oxyfluorfen	Inhibit protoporphyrinogen oxidase	PPO enzyme

Physiological Impact of Herbicide Action

Herbicides are the cause of a series of unfortunate events in a plant's defensive system. They eventually lead to the production of highly reactive oxygen species, disruption of the hormonal balance, and several other changes in the metabolic signaling that were they to be studied separately, each would warrant a paper of its own. For instance, Grossmann and Kwiatkowski (1999) have demonstrated that application of ALS inhibitors leads to an increase in the amount

of the plant hormones abscisic acid (ABA) and ethylene and thus, as a consequence, the stomata close and growth slows down. Likewise, glyphosate exposure results in the increase of salicylic acid (SA) and jasmonic acid (JA) and hence, the conversion of these compounds initiates the defense-related systems that are usually activated by attacks of living organisms (Velini et al., 2008).

The ROS wave brought about by herbicides like paraquat or PSII inhibitors results in the activation of antioxidant proteins, such as superoxide dismutase (SOD) and catalase (CAT). The activity of these enzymes is regulated by hormonal cross-talk, mainly by brassinosteroids and ABA (Sandalio et al., 2023). The degree to which the tissue is damaged as a result of the herbicides' action depends not only on the inherent toxicant potency of the herbicide, but also on the hormones present in the plant that are capable of counteracting the harm.

Hormonal Cross-Talk in Herbicide Response

Plant hormones are vital in the processes through which the plants respond to the application of herbicides. Synthetic auxin herbicides forcibly employ auxin (IAA)-signaling pathways, however, other herbicides influence hormonal balance indirectly. For instance, cytokinins and gibberellins help the cell division process and the elongation of cells that in turn may be the reason for the overshooting of the herbicide-induced growth inhibition. In contrast, ABA and ethylene are typical components that become more abundant as a result of the transmission of the stress signal, whereas the roles of brassinosteroids and jasmonates are in the processes of detoxification and repair (Silva et al., 2009). The described communication implies that the alteration of the hormonal concentration before or after the herbicide treatment may have an impact on the plant’s sensitivity or tolerance to it; this is the core idea involved in the synergy between herbicide and hormone.

Generally, the action of an herbicide determines which organelle or molecule in a cell will be toxicologically affected, while hormonal intervention governs the physiological response of the plant. Developing such applications that exploit the interrelations on the molecular level is crucial to the synergistic optimization of herbicides' working capacity along with the least possible crop injuries.

OVERVIEW OF PLANT HORMONES AND THEIR ROLES

Plant hormones, also known as phytohormones, are organic compounds of natural origin that essentially govern a plant's growth, its developmental processes, and even the plant's reaction to various kinds of stress, all this at very low levels of concentration. These signaling molecules are responsible for coordinating a network of physiological and biochemical processes which basically serve as the plant's internal communication system, integrating signals that come from inside the plant as well as from the environment (Davies, 2010). The major groups of plant hormones are auxins, cytokinins, gibberellins, abscisic acid, ethylene, jasmonates, salicylic acid, and brassinosteroids. However, to complicate things, hormones do not always function separately. On many occasions, they form a complex web of cross-regulatory interactions that affect herbicide sensitivity as well as detoxification mechanisms.

Auxins

Auxins are the first discovered class of plant hormones, and among them, *indole-3-acetic acid* (IAA) is considered the major natural one. They are the regulators of cell elongation, apical dominance, and vascular differentiation (Woodward & Bartel, 2005). Mimicking IAA, synthetic auxins like 2,4-dichlorophenoxyacetic acid (2,4-D) and dicamba are generally used as selective herbicides (Grossmann, 2010). These agents deliberately provoke uncontrolled cell

elongation, abnormal vascular development, and disintegration of tissues in broadleaf weeds. On the other hand, auxins present in the organism also influence the herbicide transport that is, they help by regulating the expression of auxin transporters (PIN proteins) and ABC transporters which in turn affect herbicide translocation (Silva et al., 2009).

Cytokinins

Cytokinins are adenine derivatives, which, among other things, promote cell division, delay senescence, and interact antagonistically with auxins in organ development (Kieber & Schaller, 2018). In the first place, they are the main players in nutrient mobilization and chloroplast development. Upon herbicide stress, the cytokinin level is usually depleted, thus resulting in accelerated senescence and chlorosis . The external supply of cytokinins has been reported to relieve the herbicide-induced oxidative damage and facilitate the recovery phase by triggering antioxidant enzyme activities. Therefore, cytokinins may be deployed as a kind of shield for herbicide-affected crops.

Gibberellins

Gibberellins (GAs) are, in fact, diterpenoid acids that provide the main impetus for stem elongation, seed germination, and flowering (Yamaguchi, 2008). Most of their effects come via the GA–GID1 receptor complex that removes the DELLA proteins, which are growth repressors. Herbicides which lead to inhibition of amino acid or fatty acid biosynthesis may lower the level of GA, consequently causing dwarfism and delayed growth (Sandalio et al., 2023). In some cases, GA applications, to a certain extent, can not only bring back the plant's normal growth but also fight against herbicide toxicity by facilitating metabolic recovery .

Abscisic Acid (ABA)

Among its diverse functions, ABA can be characterized as a main stress hormone as it regulates stomatal closure, seed dormancy, and tolerance towards non-living stress factors. It is a substance that is very scarce under natural conditions but accumulates very rapidly under drought, salinity, or stress from chemicals (Cutler et al., 2010). In many cases, herbicide exposure can be regarded as one of the factors that cause an increase in ABA biosynthesis in the oxidative-stress-defense response (Grossmann & Kwiatkowski, 1999). What is more, an externally applied ABA pretreatment can certainly lead to great performance of crops in the presence of herbicide products such as paraquat or glyphosate by modulating the antioxidant defense and detoxification pathways (Manghwar et al., 2022). Still, too much ABA can have a growth-inhibitory effect thus emphasizing the necessity of the right dose and time in hormone–herbicide cooperation.

Ethylene

Being a nonmetallic gas, ethylene is responsible, among others, for senescence, fruit ripening, and the sharing of stress signals. The synthesis of this molecule through the methionine–ACC (1-aminocyclopropane-1-carboxylic acid) pathway is very fast and gets induced by herbicide-caused stress (Morgan & Drew, 1997). One of the reasons for leaf epinasty, chlorosis, and abscission is the increased ethylene production resulting from the treatment with assistants for ALS or synthetic auxins like 2,4-D (Grossmann, 2010). On the other hand, ethylene may also play a saving role if it triggers detoxification enzyme and stress-related gene activation (Abeles et al., 1992). The double status of ethylene, as both a symptom and a modulator of herbicide stress, places it as a critical hormone in herbicide response.

Jasmonates and Salicylic Acid

Jasmonic acid (JA) and salicylic acid (SA) are the key elements in the control of plant defense systems. JA mainly works through the response mechanism against mechanical injury and

insect feeding, whereas SA is related to systemic acquired resistance (Wasternack & Hause, 2013). When plants are subjected to herbicide application, the levels of JA and SA in the tissue become higher, thus most likely leading to the implementation of antioxidant systems and the activation of detoxification-related genes (Sandalio et al., 2023). The interaction between JA, SA, and ABA signaling pathways helps the plant oxidative stress response to be more precise. Many studies have shown that JA pretreatment led to increased tolerance to paraquat and atrazine, thus suggesting a hormone-herbicide synergistic relationship.

Brassinosteroids

Brassinosteroids (BRs) are biologically polyhydroxysteroids structurally resemble animal steroids and are very important for cell expansion, vascular differentiation, and acclimation to stress (Clouse & Sasse, 1998). BRs are very potent antioxidants as they not only regulate ROS homeostasis but also increase the activity of detoxification enzymes like glutathione S-transferases (GSTs) (Nakashita et al., 2003). The removal of pollutant-induced oxidative injury by the exogenous treatment of 24-epibrassinolide (EBR) has been documented in research on rice and wheat that also observed a rise in selectivity (Manghwar et al., 2022). The current finding points to the potential of BRs as synergistic agents in herbicide formulations.

Hormonal Cross-Talk

Most of the times, plant hormones do not function separately; they rather build up complex networks through signaling cross-talk. To give an example, the interaction between ABA and JA results in a strong oxidative stress defense whereas the interplay between auxin and cytokinin determines cell division and tissue regeneration (Kieber & Schaller, 2018). Zhao & Li (2020) have found out that on the one hand, brassinosteroids usually work together with auxin and gibberellins to stimulate growth and, on the other, they act as foes to the ABA during the occurrence of a stress situation. The concept of dynamic hormonal interplay tells us that these interactions among different plant hormones are the very root of how plants detect and counteract herbicides, thus they can be either susceptible or tolerant.

One by one the phytohormones and collectively as well, they are the regulators of the most fundamental growth and stress mechanisms that have a large impact on herbicide responses. Their potentiality to govern detoxification, being in oxidative balance, and turning to growth for recovery is the biochemical basis that allows one to look into hormone–herbicide synergy as a new dimension in the modern weed management systems (Table 2).

Table 2. Key Plant Hormones and Their Physiological Functions

Hormone	Main Physiological Roles	Response to Stress / Herbicide
Abscisic Acid (ABA)	Stomatal closure, drought tolerance, seed dormancy	Induces antioxidant enzymes, enhances herbicide tolerance
Jasmonic Acid (JA)	Defense signaling, wounding response, growth inhibition	Activates GSTs and ROS scavenging under herbicide stress
Salicylic Acid (SA)	Systemic acquired resistance, pathogen defense	Modulates redox balance and detoxification, can enhance or reduce herbicide effects
Brassinosteroids (BRs)	Cell elongation, division, stress tolerance	Upregulate detox enzymes and ABC transporters, improve herbicide selectivity
Auxins (IAA)	Cell division, elongation, tropic responses	Modifies synthetic auxin herbicide sensitivity, can enhance or antagonize effects
Cytokinins	Cell division, shoot initiation	Can mitigate growth inhibition caused by herbicides
Gibberellins	Stem elongation, seed germination	Limited evidence on herbicide interactions, may affect growth recovery

MOLECULAR BASIS OF HORMONE–HERBICIDE INTERACTIONS

The interaction of hormones and herbicides in plants at the cellular level is mainly about their interconnected molecular networks that control signal transduction, transcriptional regulation, and metabolic modulation. In fact, herbicides can alter the biosynthesis of hormones that affect not only signaling pathways but also the whole body's hormonal balance, while hormones affect herbicide absorption, detoxification, and target-site sensitivity. Understanding these molecular interactions paves the way for the implementation of the hormonal cross-talk concept, which can be either one of increasing herbicide efficacy or decreasing the phytotoxic side effects of the herbicide.

Hormone Signaling Pathways and Cross-Talk

Plant hormone signaling are basically a series of events from hormone perception to signal transduction that involve changes due to receptor-ligand interactions, secondary messengers, and transcriptional regulators (Santner & Estelle, 2009). The signaling pathways are not direct; rather, they are very much interconnected thus forming a highly dynamic signaling network which is responsible for plant responses both to environmental factors and to chemical agents (Depuydt & Hardtke, 2011).

An example of that is the way auxin signaling is done through the TIR1/AFB–Aux/IAA–ARF system, whereby auxin binding leads to the breakdown of the Aux/IAA repressors thereby granting the access of the auxin response factors (ARFs) to the promoter regions of the target genes (Leyser, 2018). The cytokinin signal is passed through the action of receptor histidine kinases and a two-component system, whereas the ABA signaling relies on PYR/PYL/RCAR receptors that, upon binding, lead to inhibition of PP2C phosphatases thus resulting in the activation of SnRK2 kinases (Cutler et al., 2010). All these systems have common points where they interconnect especially in the case of stress situations that come as a result of herbicide application (Silva et al., 2009).

Normally, the activation of ABA and jasmonate pathways is the cause of herbicides that lead to oxidative or osmotic stress, whereas auxin-like herbicides directly take advantage of auxin receptors (Grossmann, 2010). In a similar way, the use of glyphosate, an EPSPS inhibitor, is reported to have an impact on the salicylic acid (SA) and jasmonic acid (JA) signaling pathways with the end effect of changing the expression of genes related to plant defense (Vivancos et al., 2011). These kinds of hormonal changes have a significant effect on downstream detoxification and stress tolerance responses.

Transcriptional and Metabolic Reprogramming

On the transcriptional level, herbicides elicit a global reprogramming of gene expression that significantly overlaps with the networks of hormonal signaling. Transcriptomic experiments have shown that genes related to ABA, ethylene, and JA signaling are upregulated after treatments with ALS or PSII inhibitors (Sandalio et al., 2023; Silva et al., 2009).

For instance, exposure to imazapyr (an ALS inhibitor) results in the expression of *NCED3* (a major gene in ABA biosynthesis) and *ERF1* (ethylene response factor), which implies that herbicide stress leads to the activation of both the ABA and ethylene pathways . In a similar manner, the plants treated with glyphosate exhibit that *GSTs* and *CYP450s* expressions are upregulated. These are the enzymes that are responsible for xenobiotic detoxification and are under the regulation of jasmonate and brassinosteroid signaling (de Freitas-Silvaet al., 2017).

At the same time, metabolomic studies confirm that external application of brassinosteroids and abscisic acid not only changes herbicide metabolism but also influences glutathione conjugation and oxidative state of the cell (Manghwar et al., 2022). These hormones activate the

antioxidative system of the crop, which is made up of superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX), thus, they reduce lipid peroxidation and membrane destruction (Nakashita et al., 2003). This molecular shield allows the crops to be free from herbicidal stress but still maintain the problem of weed control.

HORMONE REGULATION OF TRANSPORTERS AND DETOXIFICATION ENZYMES

At the cellular molecular level, the interaction of hormones with herbicides is mostly about how hormones regulate membrane transporters and enzymes that are engaged in detoxification. ABC transporters and multidrug resistance proteins (MRPs) are the primary characters when it comes to the cellular efflux of herbicides and their metabolites (Goldberg-Cavalleri et al., 2023). Hormones like auxins, ABA, and brassinosteroids are able to alter the formation of these transporters, which are the agents that help the substances to be pushed into different parts of the plant by changing their dispersal in the tissues, thus they facilitate the transport of the substances to any part of the plant (Silva et al., 2009).

For instance, BR signaling through the BZR1 transcription factor assists detoxification-related genes like *GSTU19* and *CYP81A6* in becoming more active in transcription (Manghwar et al., 2022). Similarly, ABA and JA promote the transcription of glutathione S-transferases (GSTs) and cytochrome P450 monooxygenases, which eventually contribute to herbicide metabolism and conjugation (Sandalio et al., 2023). On the contrary, ethylene can diminish the expression of certain transporter genes, thus, leading to the local accumulation of herbicides and resultant tissue damage (Morgan & Drew, 1997).

According to this, hormones serve as the main regulators of the cellular detoxification system that is a part of the metabolic network of the plant that is shifting to keep equilibrium under challenge with herbicides. The degree of the balance between the activation and the repression of these molecular responses can determine whether the synergistic enhancer effect of herbicide efficacy (in weeds) or crop protection against toxicity will be the case.

Signal Integration and Cross-Regulatory Nodes

The joining of several hormone signaling pathways with the response to herbicides is done with the help of the shared signaling intermediates such as reactive oxygen species (ROS), calcium ions (Ca^{2+}), and mitogen-activated protein kinases (MAPKs). ROS are the intermediate messengers that very often change the activity of transcription factors such as WRKY, MYB, and NAC. At the same time, these are also the targets of hormone signaling (Mittler, 2017). To this end, herbicide-induced ROS generation canbe a very strong factor in amplifying the hormone responses, thus leading the organism either to stress tolerance or to inhibition of growth, depending on the hormonal context.

Another point at which MAPK cascades converge is the interaction between herbicide and hormone signaling. Both JA-mediated defense and herbicide-induced oxidative stress have been linked with the activation of MPK3 and MPK6 (Opdenakker et al., 2012). Besides, transcription factors such as TGA, DREB, and BZR1 that receive inputs from different hormones and chemical stress signals coordinate the gene expression changes that are necessary for adaptation (Depuydt & Hardtke, 2011; Silva et al., 2009).

Through these consolidated molecular circuits, the plant is capable of making a quick switch of its physiological and biochemical state in the case of herbicide challenge. If managed in the proper manner, this molecular synergy can serve the purpose of herbicide selectivity and can elevate their performance in the agricultural sector.

SYNERGISTIC EFFECTS BETWEEN HORMONES AND HERBICIDES

Plant hormone and herbicide synergistic interactions are an important instrument for the enhancement of efficiency in weed management, crop tolerance, as well as sustainability in agricultural systems. Synergism is an occurrence when the joint use of a plant hormone and a herbicide brings about a physiological effect which is higher as compared to the effect from either compound used alone. The main result of this interaction may be the increase in herbicide selectivity, crop stress tolerance, or weed resistance to herbicidal activity.

The main molecular and physiological mechanisms that underlie these synergistic effects are the modulation of plant growth regulators, detoxification systems, oxidative stress responses, and target-site sensitivity (Grossmann, 2010; Silva et al., 2009). The synergy effect can either enhance the herbicide's damaging potential to the target plants or reduce the toxic impact on non-target plants depending on the hormone and herbicide involved.

Auxin and Synthetic Auxin Herbicide Synergy

Auxin analog herbicides like 2,4-dichlorophenoxyacetic acid (2,4-D), dicamba, and picloram imitate directly the activity of auxins that are naturally present in plants, which results in uncontrolled cell elongation, epinasty, and tissue disintegration (Song, 2014). Nevertheless, there is not an outcome of straightforwardly additive effects from the interaction between natural auxins and synthetic auxin herbicides. The exogenous application of indole-3-acetic acid (IAA) at low levels is able to alter the plant's sensitivity to the action of auxin-like herbicides and it can either increase the toxicity or decrease it depending on the time and the dose.

As a result of auxin pretreatment, the plasma membrane in some weed species becomes more permeable, thus the absorption of herbicide is accelerated and consequently there is also a faster translocation and better efficacy (Neve et al., 2024). On the other hand, in tolerant crops, the normal functioning of auxin signaling is able to keep cells in a steady state and thus uncontrolled growth is prevented, so herbicide injury is at a minimum level. The existence of this hormone–herbicide synergy dose-dependent nature is demonstrated here by the dual behavior of the agents.

On a molecular basis, both IAA and 2,4-D ARF-mediated transcription networks are activated; nevertheless, detoxification-related genes like *GH3* and *GST* can have their expression primed by the auxin pretreatment, which results in a less auxin accumulation after herbicide exposure (Silva et al., 2009). This process is in line with the conception that hormonal regulation being balanced is the factor deciding whether the auxin–herbicide interaction will lead to synergy or antagonism.

Abscisic Acid (ABA) and Herbicide-Induced Stress Tolerance

The abscisic acid (ABA) is instrumentally important in modulating the plant reaction to abiotic and chemical stressors by a number of mechanisms among which stomatal closure, antioxidant activity, and detoxification pathways are the major ones (Cutler et al., 2010). Several experiments have shown that the tolerance to the herbicide-caused oxidative stress can be imparted by the exogenous ABA pretreatment, in particular, to the plant tissue that is suffering from ALS inhibitors and photosystem II (PSII) blockers (Luo et al., 2020; Sandalio et al., 2023).

ABA, besides others, promotes the activities of the antioxidant enzymes such as SOD, CAT, and peroxidases, thus lessening the build-up of reactive oxygen species (ROS) that result from the stress application by herbicides (de Freitas-Silvaet al., 2017). In addition to that, ABA is also a strong inducer of glutathione production and glutathione S-transferase (GST) activity, thus herbicide detoxification is facilitated (Silva et al., 2009). Such a tandem between the two

agents makes it possible for the likes of rice and maize to be resistant to herbicide treatments which would have resulted in chlorosis and growth retardation if these crops were not tolerant.

What is more, ABA is able to influence the uptake and the movement of the herbicide inside the plant via aquaporins as well as by the regulation of the plasma membrane integrity. To illustrate, ABA pretreatment prior to glyphosate application results in the herbicide being less mobile in phloem tissues, thus damage to the leaf areas that are sensitive is minimized . Hence, the protective synergy of ABA is mainly in the abatement of stress and in the regulation of metabolism rather than direct promotion of herbicide toxicity.

Brassinosteroids and Enhancement of Herbicide Selectivity

Brassinosteroids (BRs) are one of the most effective means to influence plant growth, development, and stress tolerance. A recent paper highlights that when plants are treated with BRs, they can tolerate herbicide assaults better by activating their antioxidant system, stabilizing their cellular membranes, and speeding up the repair of photosynthetic structures damaged by herbicides (Nakashita et al., 2003; Manghwar et al., 2022).

Lead application of 24-epibrassinolide (EBL) to cereal plants just before herbicide spraying was found to cause a considerable increase in the selectivity factor of crop vs. weed species (Manghwar et al., 2022). As an example, in rice and wheat, the pretreatment of the plants with BRs almost completely eliminated the phytotoxicity of sulfonylurea herbicides while at the same time the herbicide suppressive effect on weeds was left intact. The interaction results from BR-mediated induction of the BZR1–BES1 transcriptional cascade which in turn activates the detoxification (*CYP81A6, GSTU19*) and the antioxidative stress regulation (*SOD, APX*) related genes (Silva et al., 2009).

On top of that, brassinosteroids are regulating membrane-bound transporters like ABC proteins, thus increasing the secretion of herbicide metabolites from the most vulnerable parts of a plant (Goldberg-Cavalleri et al., 2023). The combination of biochemical protection and targeted detoxification actions makes brassinosteroids ideal candidates for manipulating the herbicide resistance trait in crops without losing the efficacy of weed control.

Jasmonates and Salicylic Acid in Modulating HerbicideResponse

Jasmonic acid (JA) and salicylic acid (SA) are essential elements of plant defense signaling networks, and their synergistic interaction with various herbicides has also been reported. A JA signaling pathway can elevate plant stress tolerance level after herbicide treatment by stimulating the biosynthesis of secondary metabolites among which flavonoids and phenolics whose role is to scavenge ROS and thus repair cellular damage (Sandalio et al., 2023).

In contrast, SA may either alleviate or increase herbicide toxicity depending on its concentration and the time of application. The application of SA before paraquat exposure has been shown to relieve oxidative stress in soybean through the increase in activities of antioxidant enzymes (Silva et al., 2009). On the other hand, in some weed species, SA facilitates glyphosate action by enhancing shikimic acid accumulation and causing redox imbalance (Vivancos et al., 2011).

Usually, JA and SA work in opposition to each other in the defense against pathogens but in the case of chemical stress, their interaction is synergistic. Their combined impact on the detoxification process as well as on programmed cell death makes the determination of plant recovery or death after herbicide treatment possible (Mittler, 2017). Knowledge of these hormone–herbicide interactions is important for the best timing of pre- or post-treatment in crop protection.

Mechanistic Basis of Synergy

The mechanistic basis of hormone–herbicide synergies can be depicted as:

- Enhanced Detoxification: For example, ABA and BR induce expressions of GSTs, CYP450s, and ABC transporters, thus fastening herbicide metabolism (Manghwar et al., 2022).
- Antioxidant Activation: Auxins, JA, and BRs, for example, activate antioxidant enzymes, thus the oxidative damage caused by ROS released due to herbicide action is mitigated (de Freitas-Silvaet al., 2017).
- Physiological Balance: Hormones, for instance, maintain osmotic and photosynthetic stability under herbicide stress .
- Target Sensitivity Modulation: Auxin-related hormones, for example, alter receptor sensitivity, thus influencing herbicide potency (Song, 2014).

Altogether, the aforementioned mechanisms demonstrate that plant hormones are the regulators of herbicide action at a very subtle level, thus giving the possibility to have more precise control over plant responses. From an agronomic point of view, it is possible to take advantage of these synergies so as to lower herbicide doses, decrease the environmental impact, and make the crops more resilient (Table 3).

Table 3. Documented Synergistic Interactions Between Plant Hormones and Herbicides

Hormone	Herbicide	Plant Species	Observed Effect
ABA	Bispyribac-sodium (ALS inhibitor)	Rice (*Oryza sativa*)	Reduced leaf chlorosis, increased photosynthesis, higher antioxidant activity
BR (EBL)	Tribenuron-methyl (Sulfonylurea)	Wheat (*Triticum aestivum*)	Higher survival, biomass accumulation, enhanced detox enzyme activity
JA	Paraquat	Soybean (*Glycine max*)	Reduced oxidative damage, increased SOD and APX activity
SA	Glyphosate	*Amaranthus palmeri*	Enhanced herbicide toxicity via disruption of redox homeostasis
Auxin (IAA)	2,4-D	*Arabidopsis thaliana*	Modulated herbicide toxicity depending on dose; GH3 gene upregulation
ABA + BR	Multiple herbicides	Rice, Wheat	Improved crop selectivity, reduced herbicide dose requirements

CASE STUDIES

Experimental and field-based studies offer convincing proof of the synergistic interactions of plant hormones and herbicides. Such case studies exemplify the ways in which the exogenous application of hormones affect the efficacy of herbicides, their selectivity, and the decrease of phytotoxic damage in different crop plants. The effects depend on plant species, developmental stage, herbicide type, and environmental factors, however, the main idea of hormonal modulation is still there: hormones can alter plant metabolism in a way that defense activation and growth regulation get balanced during herbicide stress.

Abscisic Acid Pretreatment Enhances Tolerance to ALS-Inhibiting Herbicides in Rice

Abscisic acid (ABA) is a major player in the enhancement of plant tolerance to various abiotic stresses and rice (*Oryza sativa*) studies have demonstrated similar effects for herbicide injury to oxidative stress . Pre-treatment with ABA notably alleviated rice injury caused by bispyribac-sodium, an acetolactate synthase (ALS) inhibitor.

Plants treated with 50 μM ABA for an hour before herbicide exposure visually exhibited fewer symptoms of leaf chlorosis and lower lipid peroxidation than those without ABA treatment. Accordingly, physiological data confirmed that the ABA-treated plants kept higher photosynthetic rates, stomatal conductance, and antioxidant enzyme activities (SOD, CAT, and APX). At the same time, molecular investigations showed elevated expression of *NCED3* (involved in ABA biosynthesis) and *GSTU4* (glutathione transferase), thus pointing to detoxification and stress-protective pathway activation (Sandalio et al., 2023).

Moreover, field experiments documented that a gentle pretreatment with ABA not only lessened herbicide injury symptoms in rice but also increased weed management efficiency due to the maintenance of crop vigor, thus, the crop's competitive power, was improved (Silva et al., 2009). Such a synergistic response is a clear demonstration that ABA integration in herbicide management strategies can be used for selectivity increment without a reduction in the herbicidal potency.

Brassinosteroid-Induced Tolerance to Sulfonylurea Herbicides in Wheat

Among the major stressors of plants, herbicides may result in crop yield losses. To overcome this, Brassinosteroids (BRs) especially 24-epibrassinolide (EBL) which are one of the most potent phytosterols, were found to significantly alleviate the herbicide-induced stress in the research. In the case of wheat (*Triticum aestivum*), the pre-exposure to EBL (0.1 μM) led the plants to become more resistant to tribenuron-methyl, a sulfonylurea herbicide (Manghwar et al., 2022). The plants that got the EBL treatment before the herbicide showed a much greater chance of survival and a lot more fresh weight production as compared to the ones that were only given the herbicide.

The biochemical argument for this goes to the involvement of the BZR1-mediated signaling cascade with the detoxification enzymes (*CYP81A6*, *GSTU19*) transcript and antioxidant enzymes (SOD, CAT) activity that was highlighted by the study (Nakashita et al., 2003). In addition, the BR treatment enhanced the ability of the chlorophyll fluorescence (Fv/Fm ratio) as well as lowered the mda content, hence, signifying less lipid peroxidation, i.e., less oxidative stress, in the leaf tissue (Nakashita et al., 2003).

What is more, this effect was for the most part single: the same field trial's weeds didn't receive similar help, which pointed out the species-related differences in BR signaling. The article also asserted that the injection of BRs lessened the need for the herbicide amounts by up to 25% while at the same time the control of the weed was not deteriorated (Manghwar et al., 2022). These discoveries point to the importance that BRs have as an herbicide synergist that is friendly to the environment and can be applied in cereals.

Auxin Interactions with Synthetic Auxin Herbicides

Research on auxin–herbicide interactions which has been a major concern of both weed controlling and crop tolerating strategies reached its climax in the case of *Arabidopsis thaliana* and maize (Song, 2014). Pre-application of very small amounts of indole-3-acetic acid (IAA) in both these plants led to 2,4-D phytotoxicity modification. In the case when sublethal doses are supplied IAA induces expression of *GH3* genes which encode IAA-amido synthetases i.e., the enzymes that are responsible for the conjugation process of excess auxins or auxin-like herbicides with amino acids thus the level of free hormone lowers.

This biochemical feedback loop limits the unrestrained growth resulting from synthetic auxin herbicides and also limits the necrosis of tissues. On the other hand, if IAA and herbicide are applied simultaneously or if IAA is at a higher concentration, then the cell wall plasticity is affected in such a way that herbicides are taken up more rapidly and the toxicity thus increases in susceptible weeds (Neve et al., 2024). Therefore, the existence of a concentration-dependent

mode that determines the potential for antagonism or synergy between IAA and 2,4-D is shown by the maintenance of hormonal homeostasis.

Jasmonic Acid Mitigates Paraquat Toxicity in Soybean

Paraquat is a non-selective, quick-acting herbicide that is known to create reactive oxygen species (ROS) that leads to peroxidation of the membrane and damage to chloroplasts. Soaking leaves in exogenous jasmonic acid (JA) solution has been reported to ease the paraquat-induced oxidative stress in soybean (Glycine max) (Sandalio et al., 2023).

After paraquat treatment, plants pretreated with 100 μM methyl jasmonate (MeJA) showed less electrolyte leakage and MDA content. The levels of antioxidant enzymes such as superoxide dismutase (SOD) and ascorbate peroxidase (APX) were increased, which is consistent with JA-mediated activation of ROS detoxification pathways. A transcriptome profiling analysis revealed that MeJA pretreatment led to the expression of genes related to phenylpropanoid metabolism that not only helps in structural support of the cell wall but also in ROS scavenging (Silva et al., 2009).

This interaction between JA and paraquat serves as an example of how hormones can alter defense metabolism to lessen herbicide injury, thus giving a chance to increase crop resilience during post-emergence weed control.

Salicylic Acid Potentiates Glyphosate Efficacy in Weeds

Salicylic acid (SA) alters the behavior of both crops and weeds to glyphosate, a non-selective herbicide that is the most commonly used. Pretreatment with SA (0.5 mM) in *Amaranthus palmeri* and *Chenopodium album* led to greater glyphosate toxicity, causing more inhibition of the shikimate pathway enzymes and shikimic acid accumulation (Vivancos et al., 2011). The main reason for the response was considered to be the disruption of antioxidant homeostasis by SA and that the EPSPS enzyme recovery process was affected.

On the other hand, in soybean and maize, SA pretreatment is a protective measure against glyphosate toxicity as it leads to the activation of antioxidant systems and the facilitation of glutathione-dependent detoxification (de Freitas-Silva et al., 2017). Consequently, SA may enhance or inhibit the effect of glyphosate, depending on the plant species and redox status.

These contradictory responses to the hormone-herbicide interaction point out that the relationship is very complicated and, therefore, it is very important to consider the species when taking such interactions into account for practical agricultural applications.

Integration in Field and Agronomic

Controlled experiments on hormone–herbicide combinations revealed their benefits, which were also realized through the applications of these combinations in the field. In the rice and maize systems, treatments with ABA and BR not only resulted in the improvement of crop selectivity but also resistance to high herbicide pressure (Silva et al., 2009). In the same manner, in wheat and soybean, the application of JA and SA alleviated the symptoms of oxidative stress and accelerated the recovery rates after herbicide exposure (Sandalio et al., 2023).

These synergistic interventions have an economic advantage of herbicide input reduction by 15–30%, which leads to lower production costs and at the same time, reduction of environmental residues (Neve et al., 2024). From an ecological point of view, the use of hormonal treatments in herbicide programs is a step towards sustainable weed management as it helps in the reduction of chemical overuse and strengthening of plant physiological resilience.

HORMONAL REGULATION OF HERBICIDE METABOLISM AND RESISTANCE

Herbicide metabolism and resistance regulation in plants by different mechanisms mainly includes detoxification enzymes, signaling cascades, and hormonal control systems; this is a rather complicated issue. The plant hormones: abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA), brassinosteroids (BRs), and auxins-are the major characters that modulate the detoxification machinery, thus, influencing both herbicide tolerance as well as resistance evolution. Understanding the role of hormones in metabolic resistance is a very vital aspect when integrated weed management strategies are being planned which eventually leads to fewer herbicide-resistant populations.

Phases of Herbicide Metabolism and Hormonal Influence

Herbicide metabolism in plants is majorly categorized into four phases (Cummins et al., 2009):

- Phase I – Functionalization: The herbicide molecule is altered via one of the three processes: oxidation, reduction, or hydrolysis. These are mostly done by cytochrome P450 monooxygenases (CYP450s).
- Phase II – Conjugation: The compounds resulting from Phase I are conjugated with one of the following: glutathione, glucose, or amino acids by the action of transferases (GSTs, UGTs).
- Phase III – Compartmentalization: The transport of the conjugated herbicides into vacuoles or cell walls is done by ATP-binding cassette (ABC) transporters.
- Phase IV – Degradation: Eventually, this is the last step that sees the breaking down of the matter to yield the nontoxic metabolites that may be stored or excreted.

Plant hormones are capable of governing transcriptional and post-translational changes in each of these phases. For example, under xenobiotic stress, both the abscisic acid (ABA) and the jasmonic acid (JA) are reported to promote the transcription of the cytochrome P450 (CYP450) and glutathione S-transferase (GST) genes (Sandalio et al., 2023). Whereas brassiosteroids (BRs) and salicylic acid (SA) influence the transporter activity as well as the secondary metabolism that is involved in either detoxification or sequestration of the herbicide (Silva et al., 2009).

Abscisic Acid and Cytochrome P450 Activation

Under the influence of herbicide stress, trans-factors tandemly operated by ABA such as *ABF2* and *AREB1* not only energize promoters of *CYP81A6* and *CYP72A31* i.e. two major oxidizing P450 herbicide genes but also help in quicking the detoxification process and lessening the damages to the cells by the herbicide as a result of gene up-regulation (Riechers et al., 2010). For instance, a moderate dose of artificially-instigated ABA in rice and wheat made the plants more resistant against the symbiotic inhibition of ALS herbicides by the gradual up-regulation of the genes mentioned above and, thus, faster drug metabolism and the lessening of cellular injuries ensued .

Mechanism is however double-sided. It heavily relies on the existence of metabolic resistance in weeds. Just as the magnified enzyme activities lead to elevated resistance phenomenon in these grasses, the overexpression of ABC transporters, where alongside the CYP450s, the raised embolism is called, as shown in result of Pan et al., studies, is the main reason that rebellion against multiform herbicides in case of the varied weed materials sources ith Echinocloa crus-galli (barnyard grass), (Pan et al., 2021). Hence, while ABA contributes to crop tolerance enhancement, the upregulation in the weed side may facilitate resistance evolution.

Jasmonic Acid and Glutathione S-Transferase (GST) Induction

Jasmonates are pivotal for the regulation of detoxification of stress-induced agents, most notably, they achieve this through the stimulation of glutathione S-transferases (GSTs). Activated genes GSTU and GSTF, which are responsive to JA, have MeJA treatment leading to their transcriptional activation which is mediated by promoter (Li et al., 2022).

In soybean and maize, the JA pretreatment led to the enhancement of GST activity and to the alleviation of paraquat toxicity through the promotion of ROS scavenging and the creation of conjugates with toxic radicals (Sandalio et al., 2023). Correspondingly, in Lolium rigidum resistant biotypes, the rise of basal JA levels together with the continuous expression of GST, thus non-target-site resistance (NTSR) to ACCase and ALS inhibitors, has been postulated as a possible mechanism (Délye, 2013).

The interconnection of JA signaling with GST induction serves as an example of a mechanism with double-edges: the protective side against crop oxidative herbicide injury, while the other side can be strengthened by weed resistance through efficient detoxification promotion.

Brassinosteroids and Multidrug Transporter Regulation

Brassinosteroids modulate herbicide metabolism not only by enhancing antioxidant defenses but also by activating membrane transport systems responsible for xenobiotic efflux. Studies in wheat and maize revealed that 24-epibrassinolide (EBL) application upregulated ABC transporter genes (*ABCG36*, *ABCB19*) and multidrug and toxic compound extrusion (MATE) transporters (Manghwar et al., 2022).

These transporters are the main players in Phase III metabolism, where they expel conjugated herbicide metabolites from the cytosol thus, vacuoles or apoplasts, are where they belong. The efflux that is enhanced leads to less intracellular herbicide concentration and, therefore, less toxicity. The same goes for the overexpression of similar transporters as found in *Amaranthus retroflexus* and most likely also regulated by BR-like signaling that, as a result, abet cross-resistance to various herbicide chemistries (Délye, 2013).

Such factual proof puts BRs in the double role of being crop health defenders and, also, probable metabolic resistance facilitators, depending, however, on species and expression pattern.

Salicylic Acid and Redox-Dependent Detoxification

Salicylic acid (SA) is a key player in the redox changes that occur in the cell as a result of herbicide treatment and that eventually lead to detoxification and resistance. Thus, in glyphosate-treated soybean, SA pretreatment led the plant to enhance the expression of antioxidant enzymes (SOD, CAT, APX) and to increase the reduced glutathione (GSH) content (de Freitas-Silva et al., 2017). GSH is a substance that is conjugated to herbicides via enzyme GST, thus providing a direct link of SA signaling to herbicide metabolism.

It is worth noting that, in *Chenopodium album* and *Amaranthus palmeri*, the spiking of SA after glyphosate treatment was the cause of the redox imbalance, which in turn led to increased herbicide susceptibility (Vivancos et al., 2011; Kaya Altop et al., 2025). The contradictory effects highlight that SA serves as a modulator that changes its role depending on the cellular redox buffering capacity and metabolic fluxes and whose impact is therefore redox-dependent.

Hormonal Crosstalk and Non-Target-Site Resistance (NTSR)

Non-target-site resistance (NTSR) is a condition where plants are resistant to herbicides but the cause is not a mutation at the target site. Instead, it results from overproduction of detoxification, sequestration, or reduced translocation. Hormonal crosstalk—especially that

involving ABA, JA, and BR pathways—has been suggested to regulate NTSR mechanisms (Délye, 2013; Pan et al., 2021).

One of the examples is the combined effect of the ABA-induced P450 expression with the JA-mediated GST activation and BR-driven transporter upregulation that generates a strong metabolic shield against herbicides. In the transcriptome of resistant *Echinochloa* and *Alopecurus* species, the authors found that genes related to hormone signaling were not only present in high numbers but also co-expressed with detoxification enzymes (Pan et al., 2021). The authors of the paper came to the conclusion that NTSR is not solely a biochemical phenomenon, but rather an adaptive, physiologically controlled by hormones one.

Implications for Weed Management

Knowing how hormones control herbicide metabolism can be very instrumental in the fight against resistance. Hormonal treatments from outside can, thus, be a means of crops' tolerance enhancement and of the cutting down of chemical inputs. Meanwhile, in the case of weeds, a strike at hormone-regulated detoxification pathways may be a way to get herbicide effectiveness back.

On the other hand, a cortisone biosynthesis or signaling roadblock may turn the metabolic resistance off in bad-for-the-ecosystem-weeds, and thus make their populations susceptible again. At the same time, small amounts of BR or JA might be used for crop selectivity purposes. Taking advantage of such hormonal insights in herbicide design and management might pave the way for the next-generation synergistic formulations that put resistance risks at the lowest while boosting performance to the highest (Figure 1).

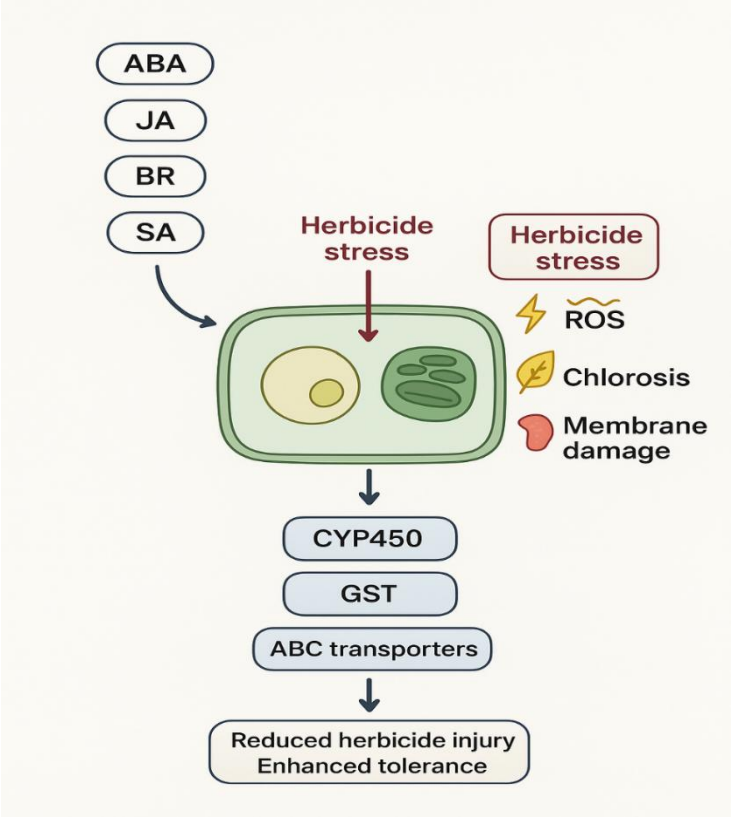


Figure 1. Antioxidant responses and stress tolerance

FUTURE PERSPECTIVES AND APPLICATIONS

Understanding how one plant hormone supports or interferes with an herbicide action unveils a whole new world of possibilities for weed control that is both environment and crop-friendly. As world farming is heading towards less use of chemicals and becoming more climate-resilient, combining hormone-based strategies with herbicide uses is a nice way to keep the effect and lower the risk to nature. Next research can take the lead by uncovering the mechanisms, providing the models, and inventing biotechnological on these synergies.

Integrating Hormonal Modulators into Weed Management Programs

The idea of employing external hormones or hormone-mimics as herbicide synergists has significantly propelled the potentials of improving the selectivity of the crops and diminishing the amount of chemicals used. Yet, its actualization in real life is heavily dependent on the knowledge of dose–response relations, the right time for the application, and the stability of the environment.

Field experiments have confirmed that the cereal pretreatment with ABA or brassinosteroids could raise their resistance to ALS inhibitors and sulfonylureas, thus allowing herbicide doses to be lowered without the quality of weed control being weakened (Manghwar et al., 2022; Silva et al., 2009). In like manner, jasmonic acid and salicylic acid application have proved their effectiveness in alleviating oxidative stress brought about by paraquat or glyphosate (Sandalio et al., 2023).

The next step is that of commercial formulation where hormones or their analogs can be concurrently applied with herbicides as *safener–synergist* blends. Such compositions may attain the desired physiological modulation thereby enabling selective detoxification of crops while weeds remain unaffected.

The extent to which such an endeavor will be successful may hinge on our grasp of the specificity in cross-species signaling as well as the metabolic fate of supplemented hormones in the open-air environment.

Biotechnological Approaches: Engineering Hormonal Pathways

Biotechnology presents possibilities to alter hormonal signaling that can result in better herbicide tolerance and increased metabolic efficiency. One may resort to genetic engineering and genome editing (e.g., CRISPR/Cas9) to achieve the desired changes in the production/supply or response of hormones. To cite an example, the upregulation of *BZR1* (brassinosteroid signaling), *NCED3* (ABA biosynthesis), or *GSTU19* (JA-responsive detoxification) in transgenic plants might be a way to provide the latter with the capability of withstanding herbicide-induced oxidative stress (Pan et al., 2021).

Besides that, some recent works have led to the idea of coming up with artificial transcriptional regulators that resemble hormone response elements and thus selectively turn on detoxification genes when herbicide stress is detected (Riechers et al., 2010). Such mechanisms can make plants "aware" of herbicide presence and thus trigger the metabolic pathways of protection without the need for constant hormonal intervention.

However, the authors of the article recommend taking into account the possible ecological implications, regulatory issues, and problems related to consumer acceptance when considering these pros and cons. Any future genetic modifications should be carried out with maximum precision and minimum unintended effects, thus not giving rise to the problem of resistance evolution in weeds.

Hormone–Herbicide Crosstalk in Climate-Resilient Agriculture

Climatic changes bring about extreme weather events most of the time. Drought, heat, and salting that affect the herbicide's activity and the hormone signaling are the trio that goes a step further. To illustrate, a plant when it is under drought stress, it makes more ABA by itself. Hence, the changed uptake and metabolism of a herbicide may be the result of the cellular signaling . As if that were not enough, the changes in oxygen levels in the atmosphere and temperature also have an impact on the redox balance thus causing a change in the performance of the reactive oxygen species (ROS)-mediated herbicides like paraquat (Song, 2014).

In such a case, optimizing hormone-based herbicides would be among the ways to attain climate-resilient weed management. For instance, not only by helping the plant to maintain photosynthesis but also by initiating antioxidant defense, ABA and brassinosteroids might behave as a verythin protective layer for plants that are subjected to both herbicide and abiotic stresses. Foreseeing the interlink between abiotic stress effects and herbicide response will be a major factor in coming up with flexible management strategies that are prepared for the ever-changing environment.

Systems Biology and Predictive Modeling

The future investigations cannot be stuck on separate or isolated events but rather should aim at a holistic, system-level understanding of the interaction of hormones and herbicides. By merging transcriptomics, metabolomics data, and machine learning models, scientists can determine the interaction if it is synergistic or antagonistic by the presence of molecular signatures (Pan et al., 2021).

Besides, computational models can also recognize the main regulatory hubs e.g. transcription factors, kinases, or transporters that control the decision of a hormonal signal to increase or decrease herbicide toxicity. The large multi-omics data sets from both crops and weeds will help researchers in uncovering common and different pathways, thus the coming up of species-specific management strategies will be less time-consuming and more accurate.

Afterward, machine learning techniques may be employed to generate in silico hormone–herbicide combinations thus not only regulating field efficiency but also predicting resistance evolution risks.

Sustainable and Regulatory Implications

The implementation of hormonal control together with herbicide management is a step forward towards achieving the set of global targets for the sustainable intensification of agriculture. The hormone–herbicide synergy can result in the use of less chemicals, fewer environmental pollutants, and crop resilience, which are the essential elements of the European Green Deal and other sustainability frameworks worldwide (FAO, 2021).

Nevertheless, the legal measures surrounding this matter have to be changed accordingly to be able to cope with this new paradigm. At present, hormones and growth regulators fall under a grey area between fertilizers and pesticides and thus require new evaluation criteria for co-formulated products. In addition to that, it would be necessary to conduct long-term ecological studies to find out potential NTEs, e.g. the effects on soil microbiota and organisms that are beneficial to humans.

Thinking from the side of the economy, the development of synergistic hormone–herbicide formulations could be a good thing as far as the input costs are concerned; they would be lower for farmers; while at the same time, productivity and environmental safety would be at a high level. This method, which is fully in line with the principles of agronomic efficiency and

ecological stewardship, may be considered the foundation of the next generation of crop management.

CONCLUCIONS

The interrelationship of plant hormones and herbicides is a prime example of a complex biochemical conversation going on in plants - a very delicate balancing of development regulation, defense mechanisms, and detoxification processes. By utilizing this innate harmony, we can revolutionize the future of weed control from the current heavy chemical dependence toward mainly biochemical-based control, integrating hormonal manipulation with precision agriculture and biotechnology. Collaboration among plant physiologists, weed scientists, molecular biologists, and agronomists should not be interrupted if we want to make these scientific findings real and practical on a large scale. At the end of the day, hormone-assisted herbicide management is not just about doing the tweaking; it's a huge step towards a smarter, more flexible, and sustainable system of crop protection.

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METAGENOMIC APPROACHES TO EXPLORE WEED-ASSOCIATED MICROBIOMES

Assoc. Prof. Dr. Emine KAYA ALTOP

Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Samsun, Turkiye

ORCID ID: https://orcid.org/0000-0002-0987-9352

Ph.D. Sine KAYA

Ondokuz Mayıs University, Graduate School of Natural and Applied Sciences, Department of Plant Protection, Samsun, Turkiye

ORCID ID: https://orcid.org/0000-0002-4219-9148

ABSTRACT

Weeds exacerbate the loss of agricultural productivity disproportionately to other plant groups because of their rapid growth, high adaptability, and the fact that they possess the traits for competition. Various traditional methods of chemical controls have caused herbicide resistance to develop and have resulted in environmental problems. The microbiome of weeds means the community of bacteria, fungi, and archaea living in the rhizosphere, phyllosphere, and endosphere. These microbes are involved in nutrient acquisition, stress resistance, release of chemicals that affect other organisms, and adaptation to herbicide use. Progress in metagenomic techniques such as amplicon sequencing, shotgun metagenomics, functional metagenomics, and bioinformatics analyses has empowered to uncover the exhaustive profile of these microbial communities.The knowledge of their diversity, composition, and functional roles paves the way for the implementation of a sustainable management system of weeds by such means as microbial bioherbicides, inoculants, and their combination with precision agriculture. Although there are difficulties arising from field variability, host specificity, and regulatory obstacles, the research that will use multi-omics approaches combined with long-term field studies, will be able to provide a solution to the problem of weed control at no harm to the environment and at a low cos.

Keywords: Weed microbiome, Metagenomics, Bioherbicides, Functional metagenomics, Sustainable agriculture, Microbial diversity

INTRODUCTION

Weeds threaten agricultural productivity recurrently, due to their traits of high adaptability, rapid growth, and competitiveness (Oerke, 2006). The use of chemicals as a control means has caused the development of herbicide resistance that is spreading like wildfire thereby contaminating the environment and causing various negative impacts on the organisms that are not targets of the chemicals used (Duke, 2011). In the situation of the weed microbiome, which

is the microbial communities associated with weeds, the understanding of the problem offers the novel insights into biology, adaptation, and biocontrol of the weed (Santoyo et al., 2016).

Microorganisms that are found in the rhizosphere, phyllosphere, or endosphere of weeds can have a profound impact on plant growth, nutrient uptake, and tolerance to stress, thus they can regulate the competitive ability of plants. Besides, these communities are an almost unlimited reservoir of bioherbicides or products that promote plant growth (Bulgarelli et al., 2013; Berg & Raaijmakers, 2018). Moreover, weed-associated microbiomes can influence the interaction of different plants with each other so as to either lessen or intensify the competition of the weed.

This article serves to (1) review the metagenomic tools and methods for investigating the microbiomes associated with weeds, (2) consider the composition, diversity, and functional groups of such microbial communities, (3) leverage their capabilities for ecologically sound weed control, and (4) point to the next avenues of research in the field of weed metagenomics and biocontrol.

METAGENOMIC TOOLS AND METHODOLOGIES

Metagenomics allow the study of microbial communities without culture limitations and thus cover microbial diversity,

DNA Extraction and Sample Preparation: Materials may be obtained from the soil of the rhizosphere, the root endosphere, the phyllosphere, and seeds (Turner et al., 2013). DNA extraction techniques are designed to reduce the contamination of DNA from the host while increasing bacterial, fungal, and archaeal DNA recovery. Generally, the MoBio PowerSoil and Qiagen DNeasy are popular kits for the destructive process of diverse microorganisms if they are usually combined with bead-beating (Niu et al., 2017).

Sequencing Approaches: Amplicon sequencing is focused on marker genes—16S rRNA for bacteria and ITS for fungi—used to describe taxonomic diversity. In addition to being low-priced and high-throughput, the technique is limited to already existing reference sequences (Caporaso et al., 2010). In shotgun metagenomics, the sequencing is done for the whole DNA. This gives room for both taxonomic and functional profiling besides the discovery of new genes, pathways for secondary metabolites, and gene clusters for herbicide- or allelochemical-related products (Quince et al., 2017). Metatranscriptomics studies RNA to figure out the functions of microbes that are active in a certain environment or under given conditions of the host (Carvalhais et al., 2015).

Bioinformatics Analysis: FastQC and Trimmomatic are the tools used for quality control in data processing. Taxonomic classification of amplicon data can be achieved with QIIME2, Mothur, or Kraken2 whereas shotgun reads can be aligned with the NCBI, SILVA, or UNITE databases. Functional annotation with KEGG, COG, or eggNOG may result in the identification of microbial functions and can also be used for the identification of microbial functions in the rhizosphere such as the production of allelochemicals and stress tolerance mechanisms (Louca et al., 2016).

Functional Metagenomics: Functional metagenomics requires the use of a vector to which cloned environmental DNA is attached for screening the presence of bioactive compounds, among which are herbicidal metabolites. This approach enables the discovery of enzymes or secondary metabolites with potential applications in weed suppression or crop protection (Handelsman, 2004).

Statistical and Network Analysis: Changes in microbial diversity and community composition are being assessed through the use of alpha- and beta-diversity metrics (Shannon

and Simpson indices). Co-occurrence networks disclose microbial interactions, keystone taxa, as well as the potential growth-promoting or weed-suppressive microbes (Faust & Raes, 2012) (Figure 1, Table 1).

Table 1. Metagenomic Approaches and Applications in Weed Microbiome Research

Approach	Purpose	Advantages	Limitations
Amplicon sequencing	Taxonomic profiling	Cost-effective, high-throughput	Limited to known sequences
Shotgun metagenomics	Functional and taxonomic profiling	Detects novel genes and pathways	Requires high computational resources
Metatranscriptomics	Active microbial functions	Captures functional activity	RNA degradation issues, complex analysis
Functional metagenomics	Discovery of bioactive compounds	Identifies herbicidal metabolites	Labor-intensive, requires cloning systems

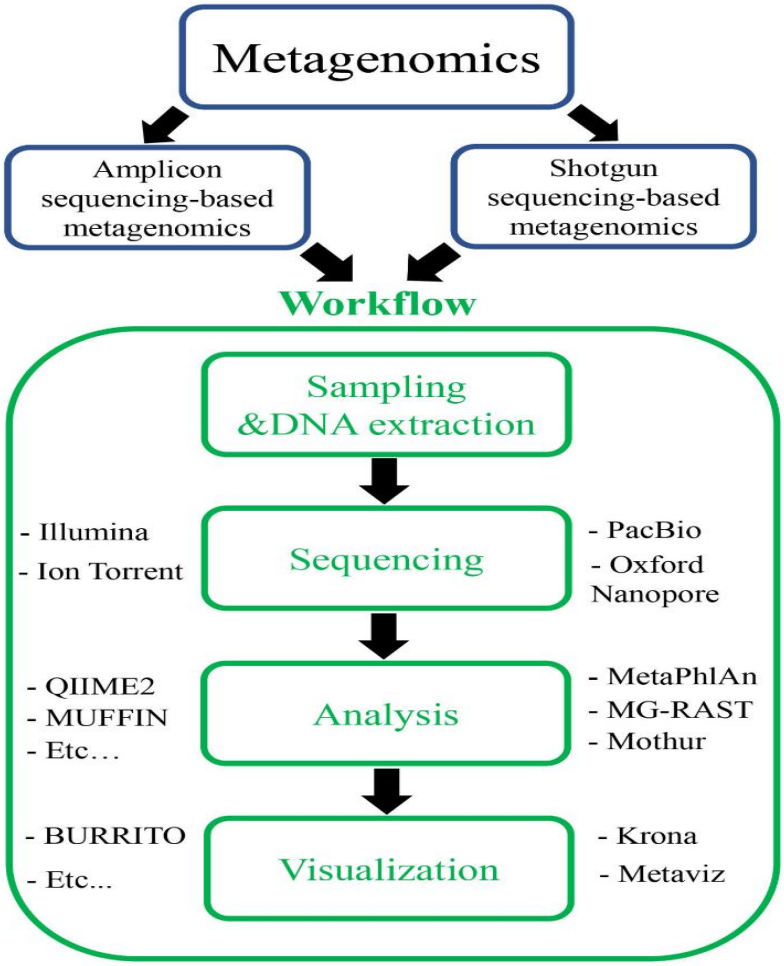


Figure1. Metagenomic tools and methodologies

DIVERSITY AND COMPOSITION OF WEED-ASSOCIATED MICROBIOMES

Weed-associated microbiomes are the complex communities inhabiting the rhizosphere, endosphere, phyllosphere, and seeds. A thorough understanding of their diversity reveals the mechanisms of weed adaptation, stress tolerance, and allelopathic potential (Bulgarelli et al., 2013). Metagenomic approaches allow profiling of both culturable and unculturable taxa.

Bacterial Diversity: Basically, the bacterial communities of the rhizosphere are largely dependent on Proteobacteria, Actinobacteria, Bacteroidetes, and Firmicutes (Turner et al., 2013). For instance, the *Echinochloa crus-galli* rhizosphere is the region where plant growth-promoting *Bacillus* species that facilitate nutrient acquisition are isolated (Niu et al., 2017). Endophytic bacteria which colonize roots and shoots, and by that modulate hormone signaling and stress tolerance; *Pseudomonas fluorescens* is a typical example of such bacteria which produces siderophores and IAA, thus, affecting weed competitiveness (Santoyo et al., 2016) (Table 2).

Table 2. Major Bacterial Taxa in Weed Rhizosphere and Endosphere

Taxa	Habitat	Functional Role	Example Weed
Proteobacteria	Rhizosphere	Nitrogen fixation, nutrient cycling	*Echinochloa crus-galli*
Actinobacteria	Rhizosphere/Endosphere	Phosphate solubilization, IAA production	*Amaranthus retroflexus*
Firmicutes	Rhizosphere	Siderophore production, stress tolerance	*Lolium rigidum*
Bacteroidetes	Rhizosphere	Organic matter decomposition	*Chenopodium album*

Fungal Diversity: The fungal consortia, which comprise Ascomycota, Basidiomycota, and Glomeromycota, are the common inhabitants of the rhizosphere and the endosphere (Rodriguez et al., 2009). Besides, they also become the allelochemical producers (Tesio and Ferrero, 2010) and get involved in nutrient uptake through mycorrhizal associations, thus, that indirectly influences the weed-crop competition (Smith & Read, 2008). *Fusarium oxysporum* endophytes in *Amaranthus* spp. are the best examples of the fungi-mediated seedling vigor reduction (Table 3).

Table 3. Major Fungal Taxa in Weed Microbiomes

Taxa	Habitat	Functional Role	Example Weed
Ascomycota	Endosphere	Allelochemical production	*Amaranthus spp.*
Basidiomycota	Rhizosphere	Nutrient cycling	*Echinochloa crus-galli*
Glomeromycota	Rhizosphere	Mycorrhizal nutrient uptake	*Lolium rigidum*
Fusarium spp.	Endosphere	Allelopathic metabolite synthesis	*Amaranthus* spp.

Archaeal Diversity: Even though the study of Archaea is less covered, these organisms play important roles in the process of nitrogen cycling and in improving the fertility of the soil (Prosser, 2012). Among the methanogenic and ammonia-oxidizing archaea, that are found in the soils of *Lolium rigidum*, there is also Thaumarchaeota which can have an effect on nutrient availability and the competitive dynamics.

Microbial Community Structure: Alpha diversity is influenced by different variables such as the species of weed, type of soil, and environmental conditions (Louca et al., 2016). On the

other hand, beta diversity points out the differences in the microbial communities that are found around various types of weeds which is an indication of host-specific recruitment (Bulgarelli et al., 2013). The keystone taxa are those that.

Environmental Influences: Factors that determine microbial communities and consequently affect weed competitiveness and microbiome functionality include soil pH, moisture, organic matter, agronomic practices, seasonal changes, and crop rotation (Turner et al., 2013; Vurukonda et al., 2018).

FUNCTIONAL ROLES OF WEED-ASSOCIATED MICROBIOMES

Microbes associated with weeds are the main contributors to the plant growth, stress tolerance, allelopathy, and herbicide adaptation. Functional metagenomics and multi-omics technological interventions disclose the genes and the pathways that lead to these roles (Berg & Raaijmakers, 2018; Louca et al., 2016).

Nutrient Acquisition: The rhizosphere microbes are the ones that may result in nitrogen fixation (*Rhizobium*, *Azospirillum*), phosphate solubilization (*Bacillus*, *Pseudomonas*), and also iron acquisition through the siderophores (Santoyo et al., 2016). For instance, the *Amaranthus retroflexus* rhizosphere is the place where nutrient availability-promoting *Bacillus subtilis* strains are found (Niu et al., 2017).

Stress Tolerance: The endophytes are the ones which bring resistance to the host against drought, salinity, and temperature extremes through hormonal modulations (IAA, ABA, cytokinins), osmoprotectant productions (proline, trehalose), and ROS scavenging (Vurukonda et al., 2018; Maksimov et al., 2010). For example, drought tolerance capacity in *Echinochloa crus-galli* is enhanced by the *Pseudomonas fluorescens* endophytes through the manipulation of ABA signalling.

Allelopathic Interactions: The microbial metabolites, such as fusaric acid from *Fusarium* or alternariol from *Alternaria*, are energic inhibitors of the growth of the plants surrounding them (Tesio & Ferrero, 2010). Functional metagenomics assist in pinpointing the gene clusters that code for these metabolites, thus, facilitating the development of bioherbicides (Handelsman, 2004).

Herbicide Resistance and Degradation: Some microorganisms that live in collaboration with the weeds can detoxify herbicides, hence, they are the ones who play a leading role in resistance development. The genes responsible for the production of herbicide-degrading enzymes in the rhizosphere of weeds have been revealed through shotgun metagenomics (Duke, 2011; Teske et al., 2013).

Microbial Interactions and Community Synergy: These are the synergistic (cooperative) relationships among bacteria, fungi, and archaea which support nutrient cycling, modulate plant-microbe signaling, and maintain weed competitiveness under stress (Faust & Raes, 2012; Louca et al., 2016). (Table 4, Figure 2)

Table 4. Functional Roles of Weed-Associated Microbiomes

Function	Microbial Contributors	Mechanism	Example
Nutrient Acquisition	*Rhizobium*, *Bacillus*, *Azospirillum*	N fixation, P solubilization, siderophore production	*Amaranthus retroflexus*
Stress Tolerance	*Pseudomonas fluorescens*, *Bacillus subtilis*	Hormonal modulation, osmoprotectants, ROS scavenging	*Echinochloa crus-galli*
Allelopathy	*Fusarium*, *Alternaria*	Secondary metabolite production	*Amaranthus spp.*
Herbicide Adaptation	Various rhizosphere bacteria	Herbicide degradation	*Lolium rigidum*

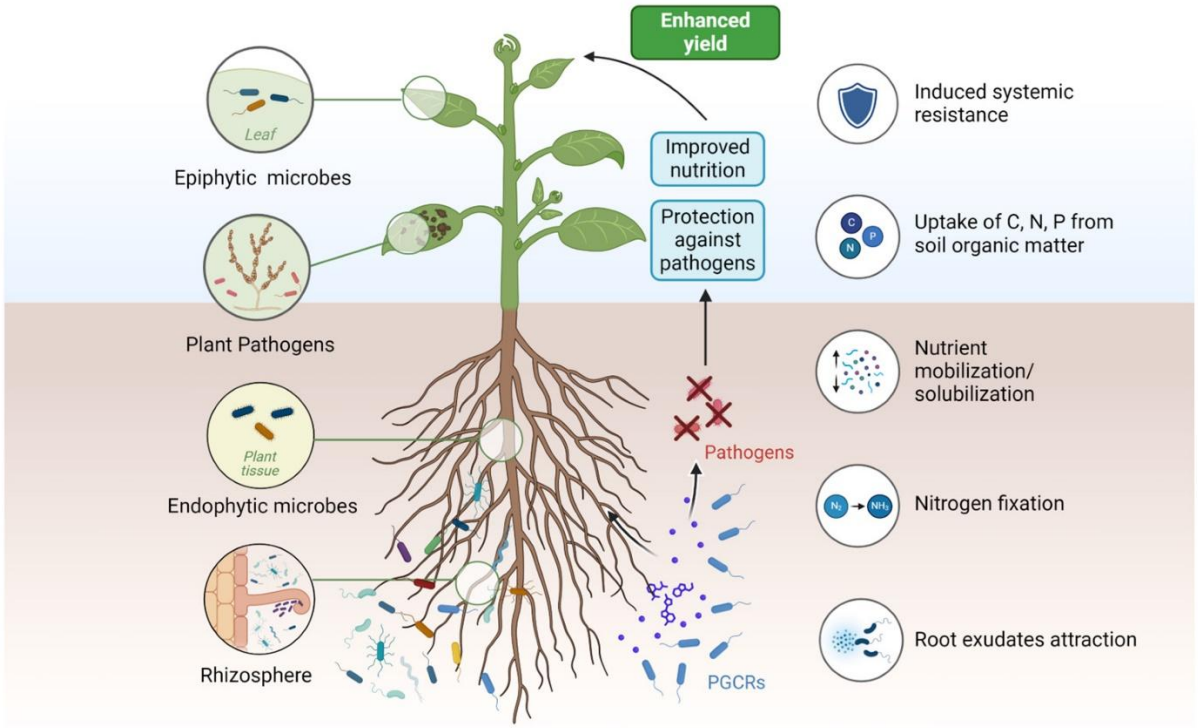


Figure 2. Functional roles of weed-associated microbiomes

APPLICATIONS IN SUSTAINABLE WEED MANAGEMENT

The information obtained from weed metagenomics can be employed to create environmentally friendly and sustainable weed management solutions such as bioherbicides, microbial inoculants, and integrated strategies (Santoyo et al., 2016; Berg & Raaijmakers, 2018).

Microbial Bioherbicides: The production of allelochemicals or enzymes may be harnessed in a means to directly suppress weed growth by Microorganisms. Examples are *Fusarium oxysporum* a pathogen for *Amaranthus* spp. and the seedling emergence inhibitory effect of *Trichoderma harzianum* on the reduction of the grass weed. Via metagenomics gene clusters accountable for the production of herbicidal metabolites can be pinpointed (Handelsman, 2004).

Microbial Inoculants: Beneficial microbes associated with weeds may be introduced into crops to achieve an increase in nutrient uptake and get a competitive advantage. Injection of maize with *Bacillus* strains from the *Echinochloa crus-galli* rhizosphere is an example of crop growth promotion and weed biomass reduction (Niu et al., 2017). Metagenomics facilitates the identification of plant growth-promoting strain traits leading to suitable formulations.

Integration with Cultural and Mechanical Practices: The effectiveness of microbial strategies mostly depends on their conjunction with other steps like crop rotation, cover cropping, mulching, and reduced-tillage systems that are compatible with Integrated Weed Management principles which aim at decreasing the use of chemical herbicides (Berg & Raaijmakers, 2018).

Precision Agriculture and Targeted Application: One of the major advantages when combining metagenomic data with GIS, remote sensing, and drones is pinpointing not only the location of weed hotspots but also the exact target delivery of microbial inoculants or

bioherbicides, thus, the effectiveness is ensured, and the non-target impact is at a minimum (Vurukonda et al., 2018).

Monitoring and Feedback: This is continuous qPCR, metagenomics, or amplicon sequencing that enables tracking of microbial persistence, colonization, and community shifts, consequently, leading to optimal inoculant application and also to the desired weed suppression results (Turner et al., 2013).

Challenges and Limitations: Field variability, environmental factors, host specificity, regulation-related issues, and difficulties in commercialization may collectively lead to lowered efficacy as well as a limited number of those who adopt microbial strategies (Berg & Raaijmakers, 2018; EPA, 2020).

CHALLENGES

Weed metagenomics is confronted with problems. These issues encompass environmental variability, recruitment of host-specific microbiome, the complexity of datasets that requires advanced bioinformatics, and obstacles of regulative and commercial nature (Vurukonda et al., 2018; Bulgarelli et al., 2013; Quince et al., 2017; EPA, 2020).

FUTURE DIRECTIONS

The next research should consider an integrated multi-omics approach, discovering novel bioherbicide compounds, synthesizing microbial consortia, using precision agriculture for targeted microbial application, and conducting long-term field trials to check stability and effectiveness (Berg & Raaijmakers, 2018; Handelsman, 2004; Santoyo et al., 2016; Vurukonda et al., 2018; Turner et al., 2013).

CONCLUSION

Metagenomics-based research provides rich and deep insights into diversity, function, and relationships of weed-associated microbiomes. Microbes are the major contributors to nutrient acquisition, stress tolerance, allelopathy, as well as herbicide adaptation and therefore, they open.

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AGE-DEPENDENT VARIATIONS IN SERUM AMH AND FSH LEVELS IN AWASSI EWES DURING AND OUTSIDE THE BREEDING SEASON

Özlem BEDİR

Harran University, Faculty of Veterinary Medicine, Department of Histology and Embryology, Şanlıurfa, Turkiye

ORCID ID: https://orcid.org/0000-0002-2558-1599

Deniz KORKMAZ

Harran University, Faculty of Veterinary Medicine, Department of Histology and Embryology, Şanlıurfa, Turkiye

ORCID ID: https://orcid.org/0000-0002-1257-4816

Ömer KORKMAZ

Harran University, Faculty of Veterinary Medicine, Department of Obstetrics and Gynecology, Şanlıurfa, Türkiye

ORCID ID: https://orcid.org/0000-0001-5179-2181

Aytaç AKÇAY

Ankara University, Faculty of Veterinary Medicine, Department of Animal Science and Nutrition, Department of Veterinary Biostatistics, Ankara, Türkiye

ORCID ID: https://orcid.org/0000-0001-6263-5181

Ayfer GÜLLÜ YÜCETEPE

Harran University, Faculty of Veterinary Medicine, Department of Microbiology, Şanlıurfa, Türkiye

ORCID ID: https://orcid.org/0000-0002-9842-3305

ABSTRACT

Introduction and Purpose: Reproductive efficiency in sheep has a direct impact on flock sustainability and productivity. Identifying reliable hormonal markers is essential for evaluating ovarian activity and selecting high-fertility females. Anti-Müllerian hormone (AMH), secreted by granulosa cells of preantral and small antral follicles, reflects the ovarian reserve, while follicle-stimulating hormone (FSH), produced by the anterior pituitary, regulates follicle recruitment and growth. Age, reproductive status, and season may alter their physiological levels. However, limited data exist on these parameters in native Awassi (İvesi) ewes. This study aimed to determine age-dependent variations in serum AMH and FSH levels during and

outside the breeding season. This study represents the preliminary phase of a TÜBİTAK 1001-funded project investigating molecular and histological aspects of ovarian function in Awassi ewes.

Materials and Methods: Blood samples were obtained from 200 clinically healthy female Awassi sheep, categorized into three age groups: 1 week old, 6 months old, and 1–5 years old (n = 20 per group). Sampling was conducted during both the breeding (autumn–winter) and non-breeding (spring–summer) seasons. Serum AMH and FSH levels were measured using ELISA. Statistical analyses were performed using t-tests and the Kruskal–Wallis test ($p < 0.05$).

Results: No significant differences were detected between 1-week-old and 6-month-old animals. During the breeding season, both AMH and FSH levels varied significantly among age groups ($p <0.001$), with the highest concentrations observed in 5-year-old ewes. AMH was also elevated in the 1-, 2-, and 5-year-old groups compared to the 3- and 4-year-old groups. In the non-breeding season, hormone levels remained relatively stable ($p> 0.05$).

Discussion and Conclusion: Age and reproductive season have a significant influence on circulating AMH and FSH levels in Awassi ewes. Higher concentrations during the breeding season may indicate increased follicular activity and ovulatory potential. The stability of hormone levels outside the breeding season supports photoperiodic control of reproduction. AMH and FSH appear to be promising non-invasive biomarkers for improving reproductive management and selection strategies in sheep breeding programs.

Key Words: Awassi ewe; AMH; FSH; Breeding season; Ovarian activity

ANALYSIS OF CERTAIN FACTORS CONTRIBUTING TO SOIL DEGRADATION PROCESSES IN THE SAATLI DISTRICT

Ph.D. Candidate Rashid Gasimov Tahir

Institute of Soil Science and Agrochemistry

ABSTRACT

This research analyzes the degradation processes of soils spread across the Saatli district located in the Mugan Plain of Azerbaijan, specifically focusing on meadow-gray soils, and the factors influencing them. The study determined that processes such as salinization, solonetzization (alkalization), deflation, and erosion have accelerated in the area due to intensive irrigation agriculture and anthropogenic impacts. The climatic, relief, and vegetation characteristics of the area, as well as the physicochemical indicators of the soils (particularly in the 0-25 cm layer), were examined. Consequently, the necessity of implementing complex meliorative and agrotechnical measures for the restoration and conservation of soil fertility has been substantiated.

Keywords: Degradation, Meadow-gray soils, Melioration, Saatli district, Salinization.

INTRODUCTION

Soil is one of the fundamental factors determining the ecological and economic potential of any region. This concept stems from the fact that soil resources, both as a natural asset and a means of production, directly affect almost all areas of human activity. Physical-chemical properties of the soil – such as its mechanical composition (clay, loam, sandy, etc.), organic matter content, degree of carbonation, cation exchange capacity, and pH level – determine the region's agricultural productivity, ecosystem sustainability, and the regeneration dynamics of natural resources. These parameters directly regulate the soil's ability to retain water and nutrients, the development of root systems, and the activity of microorganisms.

Obtaining high yields from cultivated crops in agriculture requires the maximum utilization of soils. This necessitates a rational yet scientifically grounded approach to land use, avoiding the increase of soil load beyond normal limits, and preserving long-term productivity. For instance, monoculture (cultivating the same crop in the same area every year) causes the rapid depletion of specific soil nutrients, whereas a scientifically grounded crop rotation system allows for the restoration of soil fertility.

This directly affects the ecological balance of the environment. Excessive land use, improper irrigation, and the application of chemical substances exceeding norms create changes in the ecosystem that are difficult to reverse. For example, the excessive use of pesticides and mineral fertilizers can lead to the destruction of soil microfauna, contamination of groundwater, and a reduction in biological diversity.

For this reason, the protection of soils cultivated under agricultural crops, and the environmental ecological balance in general, is considered a priority issue in the modern era. One of the main directions in modern agrarian policy is ensuring the sustainability of soil resources and

preventing erosion, salinization, and other negative processes. Sustainable agriculture models, including precision farming and organic farming, meet precisely these requirements.

In recent years, increased attention to the agrarian sector in the republic and state programs adopted in this direction have placed significant importance on soil conservation and rational use. State programs adopted specifically for food security, the modernization of agriculture, and the expansion of melioration works constitute the basis of this process. The goal of these programs is not only short-term yield growth but also the preservation of soil resources for future generations.

To this end, the "State Program on Reliable Food Supply for the Population in the Republic of Azerbaijan" outlines many critical measures, including the identification of lands in need of melioration, the preparation of their maps, the restoration of degraded lands, the enhancement of soil fertility, and the return of developed lands in arid climates to crop rotation. These measures include the refinement of land-cadastre data, soil recultivation, the modernization of irrigation systems, and the application of meliorative technologies. For instance, the transition to drip irrigation systems increases water efficiency by 40-60%, thereby saving water resources and reducing the risk of soil salinization.

The Mugan Plain of our republic is one of the regions with the most ancient agriculture. Agricultural traditions formed over millennia, along with a soil structure rich in natural and anthropogenic changes, are observed in this plain. This is evidenced by traces of ancient irrigation canals and cultivation layers discovered as a result of archaeological research.

The continuous intensive use of soils spread in this area has resulted in degradation processes. Due to long-term irrigation, technical impacts, and the influence of chemical fertilizers, the soil structure has been disrupted, the mechanical composition has changed, and natural fertility levels have decreased. The disruption of soil structure leads to consequences such as the deterioration of water permeability and difficult aeration.

The soils spread in the researched Saatli district, particularly meadow-gray soils, are currently subject to degradation processes such as salinization, solonetzization, deflation, irrigation erosion, and pasture erosion. Each of these processes negatively affects the physical structure of the soil, its chemical composition, the accessibility of nutrients to plants, and the soil's hydro-physical properties. For example, salinization physiologically limits the water absorption capacity of plants due to the accumulation of excessive salts in the soil solution.

Many of these noted factors proceed more intensively due to anthropogenic factors. For example, improper irrigation, intensive animal husbandry, the inappropriate use of heavy machinery, and the failure to supply the soil with organic matter accelerate degradation. The use of heavy machinery causes soil compaction, making it difficult for roots to penetrate into the depths.

In this regard, researching the soil types spread in the Saatli district, specifically studying meadow-gray soils, and conducting work towards their protection is of great urgency. These soils constitute the main agricultural fund of the district, and their decline directly impacts food security. Their health directly determines the income source of the local population and the country's food supply.

RESEARCH AND FINDINGS

The Saatli district is located in the Mugan Plain of Azerbaijan and is distinguished by soil resources used primarily for agriculture. The economic profile of the district is linked to sectors such as crop production, vegetable growing, and animal husbandry, and the development of

these sectors depends on soil resources. Cotton, grains, fodder crops, and various vegetables are widely cultivated here.

The Saatli district is located in the Kura-Araks Lowland of the republic. The climate is semi-desert and dry steppe, with an average annual precipitation of 187-300 mm and an average temperature of 14-15°C. These climate types indicate that aridity prevails in the soil formation process, making irrigation a crucial component of agriculture. Intensive evaporation in the summer months further accelerates the process of salt accumulation on the soil surface.

The territory is mainly flat, and the simplicity of the relief is one of the factors affecting soil formation. The flat relief allows for the uniform distribution of sediments, the proximity of groundwater to the surface, and the extensive application of irrigation systems. However, at the same time, the flatness of the relief can create drainage problems, which may lead to a rise in groundwater levels and soil salinization.

The vegetation cover of the area varies depending on relief, geographical position, groundwater levels, and climatic characteristics; the main natural vegetation cover consists of wormwood-ephemeral and wormwood-halophytic plant groups (Hasanov, 2021). These plant associations are characteristic of semi-desert ecosystems and are indicators of soil salinity levels. Halophytic plants, such as species of saltwort growing in saline areas, are distinguished by their salt tolerance, and their presence indicates a salt problem in the soil.

This soil type forms along the banks of the Araz River, near irrigation systems. The moisture regime is relatively good, and it possesses high potential for agriculture because the Araz River brings alluvial materials rich in sediments, increasing soil fertility. Alluvial deposits give the soil good water and air permeability properties as they contain clay, sand, silt, and organic residues.

From the research conducted by M.P. Babayev, it becomes clear that the construction of irrigation and collector-drainage networks in the Saatli district, as well as the expansion and development of irrigation agriculture, have affected and changed the morphogenetic and other characteristics of the soils spread in this area, resulting in differences according to the soil types to which they belong. This has caused the transformation of chemical, physical, and biological indicators of the soils. In other words, human activity has decisively intervened in the soil formation process.

As a result, two "cultivated" subtypes of gray soils at different levels are currently encountered in the research area (Babayev, 1984). That is, these soils have acquired different characteristics depending on the intensity of irrigation, the quality of drainage, and anthropogenic impact. "Cultivated" soils are those that have diverged from their original natural state but possess high value for agriculture.

The soils of this region are primarily fertile and suitable for cultivation. However, this fertility can only be sustained long-term with a proper management system. Soil fertility is not a static state but a dynamic indicator that increases or decreases depending on management.

However, there are also many soils in the area that are saline and have unsatisfactory hydro-physical properties. Structural problems of these soils limit agricultural activity and require melioration measures. Methods such as chemical melioration (e.g., gypsum application), leaching irrigation, or the cultivation of salt-tolerant plants can be applied for the restoration of such soils.

These soils compact when dry, forming a thick crust and deep cracks. When wet, they turn into a structureless mass, and water permeability decreases. These physical changes weaken the

agrotechnical qualities of the soil and hinder the normal development of the root system. This is particularly evident in soils with heavy mechanical composition (clay).

This, in turn, worsens agricultural work, and the development of agricultural crops does not proceed normally in such soils (Azizov, 1991). Productivity decreases, water consumption increases, and the efficiency of fertilizers drops. For instance, in soil that has lost its structure, water creates surface runoff; since moisture does not signal to the soil depth, water consumption increases, and fertilizers are washed away.

The main soil types spread in the researched area are Meadow-gray, Irrigated meadow-gray, Alluvial meadow, Meadow-boggy, and Saline soils. Each soil type has unique characteristics, water regimes, and degrees of suitability for agriculture. For example, Meadow-boggy soils are located in areas where groundwater is very close to the surface, and drainage is primarily required to make them suitable for use.

Meadow-gray soils are the most widespread soil type in the research area. This is related to their formation in accordance with natural-geographic conditions. Since they form under semi-hydromorphic conditions – that is, conditions of temporary excess moisture – they correspond to the climatic and hydrological characteristics of the region.

Formed under high humidity conditions, this soil type has developed morphologically in a semi-hydromorphic regime. This condition determines the soil's carbonation, the form of the humus layer, and the water-air regime. The semi-hydromorphic regime leaves traces of gley processes (reduction of iron compounds in oxygen-free conditions) in the soil profile, which manifests as gray-green spots in the profile cross-section.

On the other hand, groundwater close to the surface has also influenced the soil formation process (Feyziyev, 2016). The rise of groundwater can cause salts to rise to the surface, leading to soil salinization. As a result of capillary rise, salts dissolved in groundwater rise to the upper layers and surface of the soil, accumulating there due to evaporation.

CONCLUSION AND DISCUSSION

It has been determined through our research that the degradation process has a significant impact on the chemical composition of meadow-gray soils. In particular, the amount of humus, the level of nutrients, and the soil's absorption capacity decrease. The decrease in humus also causes the disruption of the soil structure, as organic matter acts as the main adhesive binding soil particles.

Thus, research conducted in the arable layer (0-25 cm) of the soils revealed that the main causes for the loss of fertility due to degradation in these soils are salinization and a scarcity of nutrients and organic matter. These changes directly weaken soil productivity. Since this layer is the zone where more than 90% of plant roots are concentrated and where the most active biochemical processes occur, its condition is of critical importance.

Consequently, the conducted studies show that the Saatli district possesses diversity in terms of soil resources. This diversity is linked to both natural-geographic and anthropogenic factors. Such diversity necessitates the development of individual approaches and management strategies for each soil plot.

While some soils allow for high productivity, strictly meliorative measures are required for others. Measures such as irrigation norms, drainage networks, and fertilization systems are of vital importance for these soils. A correctly calculated irrigation norm meets the plant's water

needs and helps leach salts from the soil; however, water in excess of the norm can cause groundwater levels to rise.

To fully utilize the district's agricultural potential, agrotechnical and technogenic measures must be implemented in a planned manner, taking soil types into account. Only in this case can soil resources be managed sustainably and productivity increased. This can be achieved through the integration of soil maps, Geographic Information Systems (GIS), and precision farming technologies, which allow for the application of resources (water, fertilizers, pesticides) in optimal doses for each specific area.

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CHANGES IN SERUM PARAOXONASE-1 ACTIVITY DURING ESTRUS IN PROGESTERONE-BASED SYNCHRONIZED GURCU GOATS DURING PERIODS BREEDING SEASON AND NON-BREEDING SEASON

ÜREME MEVSİMİ VE DIŞI DÖNEMLERDE PROGESTERON DESTEKLİ SENKRONİZE EDİLEN GÜRCÜ KEÇİLERİNDE ÖSTRUS ESNASINDA SERUM PARAOKSANAZ-1 AKTİVİTESİNİN DEĞİŞİMİ

Assist. Prof. Dr. Serpil AYGÖRMEZ

Department of Biochemistry, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye

Prof. Dr. Mushap KURU

Department of Obstetrics and Gynecology, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye

Assoc. Prof. Dr. Mustafa MAKAV

Department of Physiology, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye,

ÖZET

Bu çalışmada üreme mevsimi ve dışı dönemlerde progesteron destekli senkronize edilen Gürcü keçilerinde, serum malondialdehit (MDA), glutatyon (GSH) düzeyleri ile paraoksanaz-1 (PON) aktivitesinin değişiminin belirlenmesi amaçlanmıştır. Çalışmada 30 adet keçi (15 keçi sezon içi Gürcü keçisi ve 15 keçi sezon dışı) kullanılmıştır. Östrus senkronizasyonu amacıyla, keçilere progesteron içeren süngerler 7 gün kalacak şekilde vaginaya yerleştirildi. Progesteron içeren süngerlerin çıkarıldığı gün tüm keçilere 500 IU kısrak koryonik gonadotropini (eCG) ve prostaglandin F2α (PGF2α) kas içi enjeksiyonları yapıldı. Daha sonra keçiler arasına östrus tespiti için teke katıldı ve östrus belirtileri gösteren keçiler tespit edildi. Östrus senkronizasyonuna başlamadan ve östrusta olmak üzere keçilerden kan alındı. Keçilerden alınan kandan serum MDA, GSH düzeyleri ve PON aktivitesi belirlendi. Elde edilen verilere göre, Gürcü keçilerin üreme mevsiminde ($p<0.01$) ve dışında ($p<0.001$) MDA düzeyi arttı ve zaman etkisi anlamlıydı ($p<0.001$). Ayrıca MDA düzeyinde grup etkisi ve grup × zaman interaksiyonunun istatistiksel olarak anlamlıydı ($p=0.02$). GSH, Gürcü keçilerinde üreme mevsimi dışında azaldı ($p<0.05$) ve üreme mevsiminde ise arttı ($p<0.05$). Ayrıca GSH'da grup × zaman interaksiyonu istatistiksel olarak anlamlıydı ($p=0.003$). Gürcü keçilerin üreme mevsimi dışında PON aktivitesi azaldı ($p<0.01$) ve üreme mevsiminde ise arttı ($p<0.05$). Fakat PON aktivitesinde grup × zaman interaksiyonu istatistiksel olarak anlamlıydı ($p<0.001$). Sonuç olarak, üreme mevsimi ve dışı dönemlerde progesteron destekli senkronize edilen Gürcü keçilerinde MDA, GSH düzeylerinin ve PON aktivitesinin değişiminin değerlendirilmesi bu dönemlerin izlenmesi için faydalı biyobelirteçler olabilir.

Anahtar kelimeler: Üreme mevsimi, Üreme mevsimi dışı, Gürcü keçi, Oksidatif statü, Paraoksanaz-1

ABSTRACT

This study aimed to determine the changes in serum malondialdehyde (MDA), glutathione (GSH) levels and paraoxonase-1 (PON) activity in progesterone-based synchronized Gurcu goats during breeding season and non-breeding season. 30 goats (15 Gurcu goats in breeding season and 15 goats non-breeding season) were used in the study. For the purpose of estrus synchronization, sponges containing progesterone were placed in the vagina of the goats for 7 days. On the day the progesterone-containing sponges were removed, all goats received intramuscular injections of 500 IU mare chorionic gonadotropin (eCG) and prostaglandin F2α (PGF2α). Then, a goat was added to the goats to detect estrus, and goats showing signs of estrus were detected. Blood was taken from the goats before estrus synchronization and during estrus. Serum MDA, GSH levels and PON activity were determined from blood taken from goats. According to the data obtained, MDA levels increased in Gurcu goats during breeding season ($p<0.01$) and non-breeding season ($p<0.001$) and the time effect was significant ($p<0.001$). In addition, the group effect and group × time interaction at the MDA level were statistically significant ($p = 0.02$). GSH decreased in Gurcu goats non-breeding season ($p<0.05$) and increased during the breeding season ($p<0.05$). Additionally, the group × time interaction in GSH was statistically significant ($p = 0.003$). PON activity of Gurcu goats decreased non-breeding season ($p<0.01$) and increased during the breeding season ($p<0.05$). However, the group × time interaction in PON activity was statistically significant ($p<0.001$). As a result, evaluation of the changes in MDA, GSH levels and PON activity in progesterone-based synchronized Gurcu goats during periods breeding season and non-breeding season may be useful biomarkers for monitoring these periods.

Key words: Breeding season, Non-breeding season, Gurcu goat, Oxidative status, Paraoxonase-1

INTRODUCTION

In many regions of the world, products obtained from goat farming, such as meat and milk, have maintained their seasonality (Balaro et al., 2019). Goats, one of the oldest domesticated animal species, are one of the animals in tropical and subtropical regions and have unique biological characteristics (Hussain et al., 2020). Due to the social and economic conditions of farmer families, goat breeding is mostly done in the Mediterranean, Aegean and Southeastern Anatolia regions of Türkiye (Kuru et al., 2024). Gurcu goats, which came from the Caucasus to Anatolia, do not show reproductive problems such as uterine infection, follicular cysts, miscarriage, infertility, and are adapted to the cold climate conditions of the region. They offer alternatives to cattle breeding for farmers, but their numbers have not increased significantly (Kuru et al., 2019; Boğa Kuru et al., 2024; Kuru et al., 2024). Goats are seasonally breeding by nature, which is associated with changes in annual photoperiod. The breeding season, stimulated by the decrease in daylight hours in autumn and winter, results in birth in the spring months (Nogueira et al., 2015; Rehman et al., 2021; Shl et al., 2025). This long period makes the availability of milk and meat difficult (Zarazaga et al., 2011). Although farmers try to eliminate this problem by extending the lactation period, this affects milk production (Desire et al., 2018). The use of estrus synchronization during anestrus increases reproductive efficiency and enables more than one offspring per year (Osman & Elzagafi, 2016; Duan et al., 2025). Estrus synchronization practices are adopted to stimulate and control estrus and ovulation during breeding season and non-breeding season (Van et al., 2022; Duan et al., 2025). Additionally, estrus synchronization is a practical method to increase reproductive performance (Sen & Onder, 2016; Alvarado-Espino et al., 2019; El-Tarabany et al., 2020). The estrus synchronization method is one of the goat breeding methods that focuses on the creation and

extension of the luteal phase (Hussain et al., 2020). For this purpose, synthetic analogs such as progesterone are exogenous hormones for estrus and estrus synchronization in goats (Sen & Onder, 2016; Cetin et al., 2024). In addition, mare chorionic gonadotropin (eCG) is administered together with progesterone the non-breeding season to increase both estrus and ovulation (Balaro et al., 2019; Rehman et al., 2021; Cosentino et al., 2024; Cortes et al., 2025). In addition, prostaglandin F2α (PGF2α) is used to synchronize estrus through the regression of the corpus luteum (Osman & Elzagafi, 2016; El-Mokadem et al., 2022). Oxidative stress, which occurs as a result of decreased antioxidant defense or increased production of oxidants such as reactive oxygen species, is the imbalance between radical scavenging and generation (Teama, 2018; Mohamed et al., 2021). Malondialdehyde (MDA), the most important molecule in cellular degeneration caused by free radicals, is the end product of oxidative destruction of lipids (Kuru et al., 2018). The best-known natural low molecular weight antioxidant is glutathione (GSH) (Mohamed et al., 2021). The antioxidant enzyme paraoxonase-1 (PON) is found in serum, kidney, liver and intestine (Kuru et al., 2020).

The aim of this study was to determine the changes in serum PON activity and MDA and GSH levels during estrus in progesterone-based synchronized Gurcu goats during the breeding season and non-breeding periods.

MATERIALS AND METHODS

Ethical approval and farm permit

Before starting the study, approval was obtained from the Kafkas University Animal Experiments Local Ethics Committee (KAU-HADYEK) with the number KAU-HADYEK/2025-169 and from the Kafkas University Prof. Dr. Ali Rıza AKSOY Education-Research and Application Farm with the session number 2024/2025-15 and decision number 23.

Animals

Total of 30 Gurcu goats, aged between 3 and 4 years, clinically healthy, with a body weight of 40-50 kg, in breeding season (n=15) and non-breeding season (n=15), from Kafkas University Prof. Dr. Ali Rıza AKSOY Training-Research and Application Farm, were used as animal material in the study.

Estrus synchronization and mating procedures

For estrus synchronization, progesterone-containing sponges (Esponjavet®, Hipra, Türkiye) were inserted into the vagina of goats for 7 days. On the day the progesterone-containing sponges were removed, all goats received intramuscular injections of 500 IU eCG (Oviser®, Hipra Animal Health, Türkiye) and PGF2α (Dinoprost, Dinolytic®, Zoetis, Türkiye). Later, a male was added to the goats to detect estrus, and goats showing signs of estrus were identified (Kuru 2022, 2023; Kuru & Boğa 2024).

Biochemical analyses

Before starting synchronization, blood was collected from all goats determined to be in estrus and from the jugular vein into 8.5 mL gel-vacuum (BD Vacutainer®, Becton, Dickinson and Company, USA) tubes. The collected blood samples were centrifuged at 3000 rpm for 10 minutes and then stored at -20°C until the serum samples were analyzed.

Serum MDA analysis was performed using the method of Yoshioka et al., (1979). GSH analysis was analyzed spectrophotometrically at 412 nm according to the method of Beutler et al.,

(1963). PON activity was determined colorimetrically using the Rel Assay Diagnostics® (Gaziantep, Türkiye) kit.

Statistical analyses

Statistical analyses of the data obtained in the study were performed using the GraphPad Prism® (Version 10, GraphPad Software Inc., San Diego, USA) statistical program. The Shapiro-Wilk test was used to determine whether the obtained data showed a normal distribution according to the groups. The repeated measurements analysis of variance method was used in the analysis of measured marker data. Statistical analyses of group, time, and group × time interactions were performed. Additionally, Fisher's LSD was applied for pairwise comparisons of parameters between days and between groups on the day of sampling. All results are shown as mean ± standard deviation (SD). $P<0.05$ was considered statistically significant in the analysis results.

RESULTS

Serum MDA level

The results of MDA levels during estrus in Gurcu goats synchronized with progesterone during the breeding season and non-breeding periods are shown in Figure 1. According to the obtained data, MDA levels of Gurcu goats increased during ($p<0.01$) and non-breeding season ($p<0.001$) the breeding season and the time effect was significant ($p<0.001$). Additionally, the group effect ($p=0.05$) and group × time interaction at MDA level were statistically significant ($p=0.02$). Again, MDA was statistically higher during estrus non-breeding season than within the breeding season ($p<0.01$).

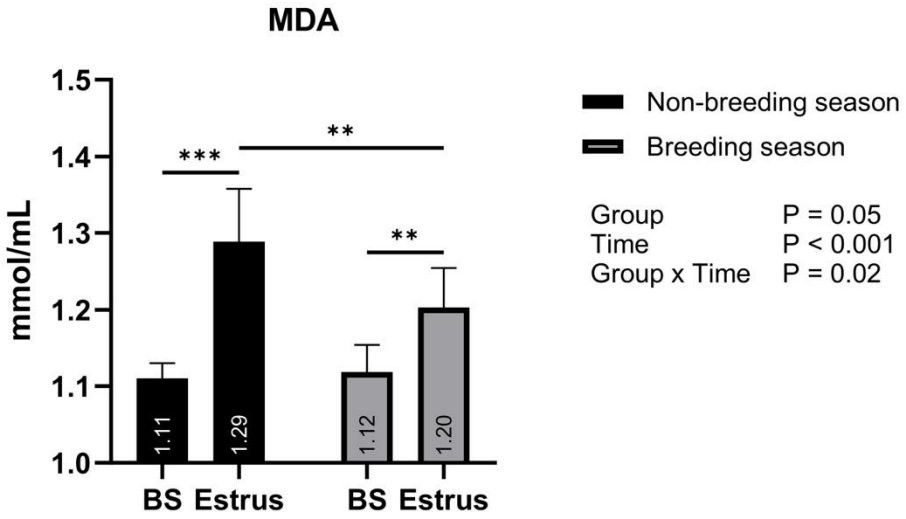


Figure 1: Changes in serum MDA levels during estrus in Gurcu goats synchronized with progesterone during breeding season and non-breeding season. MDA: Malondialdehyde, BS: Before synchronization **: $p<0.01$, ***: $p<0.001$.

Serum GSH level

Serum GSH levels decreased during estrus, the non-breeding season ($p<0.05$), and increased during the breeding season ($p<0.05$). Additionally, group × time interaction in GSH was statistically significant ($p=0.003$). Again, the GSH level before the start of estrus synchronization was higher non-breeding season than during the breeding season ($p<0.05$). The opposite situation was recorded during estrus, and the GSH level during estrus non-breeding season was statistically lower than during the breeding season ($p<0.05$) (Figure 2).

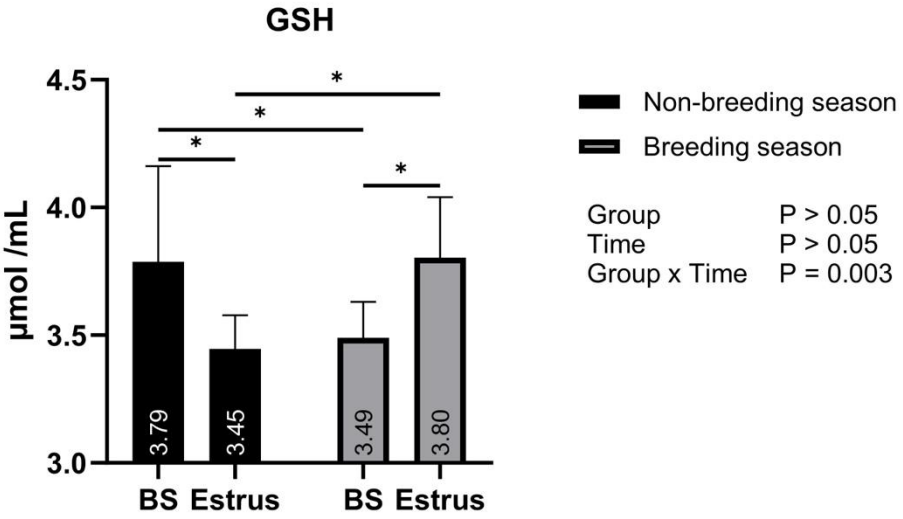


Figure 2: Serum GSH levels during estrus in Gurcu goats synchronized with progesterone during breeding season and non-breeding season. GSH: Glutathione, BS: Before synchronization *: p<0.05.

Serum PON activity

The change of PON activity during estrus in progesterone-supported synchronized Gurcu goats during the breeding and non-breeding seasons is shown in Figure 3. In Gurcu goats, PON activity decreased during estrus non-breeding season (p<0.01) and increased during the breeding season (p<0.05). However, group × time interaction in PON activity was statistically significant (p<0.001). Again, serum PON activity before synchronization non-breeding season was higher than during the breeding season (p<0.001). The opposite situation was observed during estrus, and PON activity was lower in estrus than in the non-breeding season (p<0.001) (Figure 3).

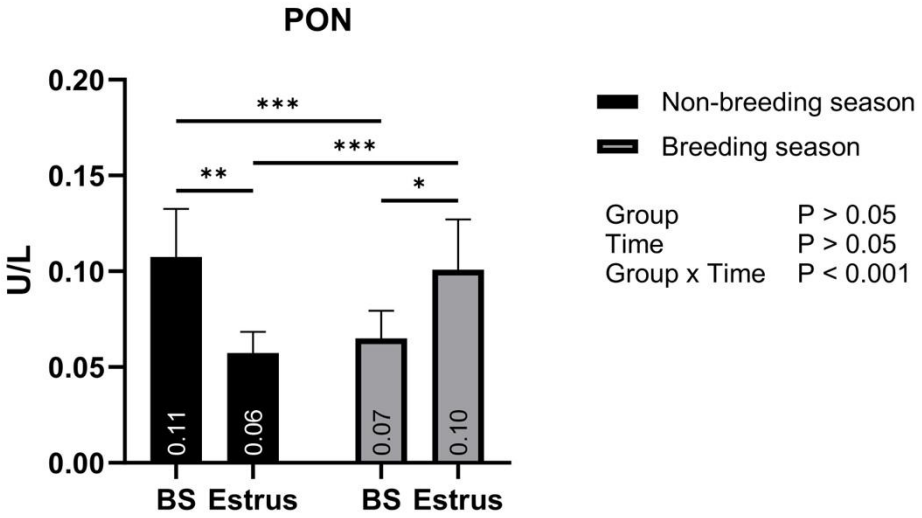


Figure 3: Changes in serum PON activity during estrus in Gurcu goats synchronized with progesterone during breeding season and non-breeding season. PON: Paraoxonase-1, BS: Before synchronization *: p<0.05, **: p<0.01, ***: p<0.001.

CONCLUSION

In Gurcu goats, MDA increased during both breeding season and non-breeding season, and PON activity and GSH decreased non-breeding season and increased during the breeding season. Increased MDA levels in Gurcu goats, as an indicator of lipid peroxidation during breeding season and non-breeding season, indicate that oxidative stress is experienced. The decrease in GSH level and PON activity non-breeding season is an indication of a decrease in antioxidant capacity. These parameters show that they can be used as potential biomarkers in goats during breeding season and non-breeding season. Additionally, it has been demonstrated that oxidative stress and antioxidant capacity during estrus show seasonal differences. The increase in MDA levels and the decrease in GSH and PON activity during estrus, especially non-breeding season, indicate that antioxidant defense is inadequate. On the other hand, the increase in GSH and PON activity during the breeding season reveals that endogenous antioxidant mechanisms work more effectively during this period. The basis of this difference is that estrogen levels synthesized in each cycle, regardless of synchronization during the breeding season, may limit the oxidative stress load by increasing the activity of antioxidant enzymes. Therefore, seasonal changes in steroid hormone fractions, especially estrogen, are thought to play a critical role in the regulation of antioxidant-oxidant balance. However, more comprehensive studies with larger sample sizes should be conducted to better understand the physiological and biochemical changes experienced in Gurcu goats during breeding activities during breeding season and non-breeding season.

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CURRENT APPROACHES, APPLICATIONS AND FUTURE PERSPECTIVES IN TRANSGENIC ANIMAL BIOTECHNOLOGY

TRANSGENİK HAYVAN BİYOTEKNOLOJİSİNDE GÜNCEL YAKLAŞIMLAR, UYGULAMALAR VE GELECEK PERSPEKTİFLERİ

Doç. Dr. Mehmet YARDIMCI

Tekirdağ Namık Kemal Üniversitesi, Veteriner Fakültesi, Zootekni ve Hayvan Besleme Bölümü, Tekirdağ, Türkiye.

ABSTRACT

Transgenic animal biotechnology has become a technology gaining strategic importance in many fields, including agriculture, animal husbandry, medicine, industry, and environmental management, thanks to rapid advances in molecular biology and genome editing techniques. Microinjection, embryonic stem cell manipulation, viral vectors, somatic cell nuclear transfer (SCNT), and, in particular, CRISPR-Cas systems allow for highly precise genetic modification in various species. This allows for significant improvements in recombinant protein production, disease resistance, growth performance, and product quality. Transgenic approaches offer the potential to both increase the nutritional value of animal products and reduce ecosystem pressure by supporting environmental sustainability. Furthermore, promising results in xenotransplantation studies of genetically modified pigs have made significant contributions to biomedical research. However, technical limitations such as random gene integration, mosaicism, and epigenetic uncertainties, as well as ethical and ecological concerns, are key factors to consider when utilizing this technology safely. In conclusion, transgenic animal biotechnology is a rapidly developing field that is expected to find wider application in the future, and the sustainability of this progress depends on the meticulous execution of ethical principles and risk assessments.

Keywords: Transgenic animal, genomic, gen editing

ÖZET

Transgenik hayvan biyoteknolojisi, moleküler biyoloji ve genom düzenleme tekniklerindeki hızlı ilerlemeler sayesinde tarım, hayvancılık, tıp, endüstri ve çevre yönetimi gibi birçok alanda stratejik önem kazanan bir teknoloji hâline gelmiştir. Mikroenjeksiyon, embriyonik kök hücre manipülasyonu, viral vektörler, somatik hücre çekirdeği transferi (SCNT) ve özellikle CRISPR-Cas sistemleri farklı türlerde yüksek doğrulukla genetik modifikasyon yapılmasına olanak tanımaktadır. Bu sayede rekombinant protein üretimi, hastalık direnci, büyüme performansı ve ürün kalitesinde önemli iyileşmeler elde edilmektedir. Transgenik yaklaşımlar, hem hayvansal ürünlerin besin değerini artırmakta hem de çevresel sürdürülebilirliği destekleyerek ekosistem üzerindeki baskıyı azaltma potansiyeli sunmaktadır. Bunun yanı sıra genetiği düzenlenmiş domuzların ksenotransplantasyon çalışmalarında umut verici sonuçlar vermesi, biyomedikal araştırmalara önemli katkılar sağlamaktadır. Ancak rastgele gen entegrasyonu, mozaiklik ve epigenetik belirsizlikler gibi teknik sınırlılıkların yanı sıra etik ve ekolojik kaygılar, bu

teknolojinin güvenli kullanımında dikkate alınması gereken temel unsurlardır. Sonuç olarak, transgenik hayvan biyoteknolojisi hızla gelişen ve gelecekte daha geniş uygulama alanı bulması beklenen bir alan olup, bu ilerlemenin sürdürülebilir olması etik ilkelerin ve risk değerlendirmelerinin titizlikle yürütülmesine bağlıdır.

Anahtar kelimeler: Transgenik hayvan, genomik, gen düzenleme

GİRİŞ

Moleküler biyoloji, genomik ve gen düzenleme teknolojilerinde son yıllarda kaydedilen hızlı ilerlemeler, hayvan genomunun yüksek hassasiyetle modifiye edilmesini mümkün kılarak transgenik hayvan üretimini modern biyoteknolojinin temel araştırma ve uygulama alanlarından biri hâline getirmiştir.

Transgenik hayvan, türler arası gen transferi, hedeflenmiş mutasyon oluşturma, genom düzenleme veya endojen genlerin yeniden yapılandırılması yoluyla yeni bir fenotip kazandırılmış organizma olarak tanımlanmaktadır (Shakweer ve ark., 2023).

İlk transgenik farelerin 1980'lerde elde edilmesinden bu yana mikroenjeksiyon, embriyonik kök hücre manipülasyonu, viral vektör kullanımı, somatik hücre çekirdeği transferi (SCNT) ve CRISPR-Cas tabanlı sistemler gibi yöntemlerde dikkate değer teknik gelişmeler sağlanmıştır (Park, 2023).

Bu teknik yenilikler, çok sayıda hayvan türünde başarılı transgenik hatların oluşturulmasına olanak vermiş ve hayvancılık, tıp, farmasötik protein üretimi ve çevresel sürdürülebilirlik gibi çeşitli alanlarda önemli uygulama potansiyelleri ortaya çıkarmıştır.

Gen düzenleme araçlarının doğruluk, etkinlik ve hedeflenme kapasitesinde kaydedilen ilerlemeler sayesinde sığır, koyun, keçi, domuz, tavuk, balık ve primatlar dâhil birçok türde transgenik veya genetiği düzenlenmiş hatlar yüksek başarı oranlarıyla geliştirilebilmektedir (Popova ve ark., 2023; Hallerman ve ark., 2023).

Bu biyoteknolojik yenilikler tıp, tarım, hayvansal üretim, endüstriyel protein sentezi ve çevresel sürdürülebilirlik gibi farklı disiplinlerde geniş ve etkili kullanım alanları oluşturmuştur.

Bununla birlikte, transgenik hayvanların uygulama alanlarının giderek genişlemesi etik, ekolojik ve düzenleyici boyutların kapsamlı bir biçimde yeniden ele alınmasını gerektiren çok yönlü tartışmaları da gündeme getirmektedir (Wray-Cahen ve ark., 2022).

TRANSGENİK HAYVAN ELDE ETME YÖNTEMLERİ

Transgenik hayvan üretiminde uygulanan yöntemler, genetik materyalin embriyonik yapılara aktarılma stratejisine, hedeflenen genetik modifikasyonun doğruluğuna ve türler arası biyolojik farklılıklara bağlı olarak çeşitlilik göstermektedir. Bu teknikler, temel olarak genin doğrudan zigota enjekte edilmesine, embriyonik kök hücrelerin genetik olarak düzenlenmesine veya viral vektörlerin entegrasyon kapasitesinden yararlanılmasına dayanmakta olup, her biri kendine özgü avantajlar, verimlilik düzeyleri ve deneysel sınırlılıklar ortaya koymaktadır.

DNA Mikroenjeksiyonu

DNA mikroenjeksiyonu, transgenik hayvan üretiminde kullanılan en eski ve en yaygın yöntemlerden biri olup, hedef genin döllenmiş yumurtanın pronükleusuna doğrudan enjekte edilmesine dayanır (Shakweer ve ark., 2023). Bu yöntem, ilk transgenik farelerin geliştirilmesinde temel teknik olarak kullanılmış ve özellikle memeli türlerinde yüksek uygulanabilirliği sayesinde standart bir transgenez aracı hâline gelmiştir (Park, 2023).

Mikroenjeksiyonun avantajı, eksojen DNA'nın embriyo gelişimini fazla etkilemeden genom içine entegre olabilmesidir. Ancak entegrasyonun rastlantısal olması, transgen ekspresyon seviyelerinde değişkenliğe yol açabileceğinden yöntemin önemli sınırlılıklarından biri olarak değerlendirilmektedir. Buna karşın, tek hücreli zigot aşamasında uygulanabilirliği ve laboratuvar koşullarında nispeten kolay uyarlanabilir olması, yöntemi birçok tür için hâlâ değerli kılmaktadır (Delerue ve Ittner, 2017).

Embriyonik Kök Hücre (ESC) Aracılı Gen Transferi

Embriyonik kök hücre teknolojisi, genetik modifikasyon sürecine daha yüksek hassasiyet kazandıran bir diğer yöntemdir. Bu yaklaşımda önce embriyonik kök hücreler kültürde büyütülür ve hedef gen, homolog rekombinasyon veya modern gen düzenleme teknikleri kullanılarak bu hücrelere aktarılır. Genetik olarak düzenlenmiş kök hücreler daha sonra blastosist aşamasındaki embriyolara enjekte edilir ve gelişimlerine rahim içerisinde devam etmeleri sağlanır (Popova ve ark., 2023).

Bu teknik sonucunda embriyonun hem modifiye edilmiş hem de edilmemiş hücre hatlarını birlikte taşıdığı kimerik hayvanlar elde edilir. Uygun eşleştirmelerle kimerik bireylerden tam transgenik yavrular üretilebilmesi yöntemin en önemli avantajıdır. ESC aracılı gen transferi, özellikle farelerde yaygın olarak kullanılmış ve hedefli gen silme (knock-out) veya gen ekleme (knock-in) çalışmalarında temel araç hâline gelmiştir (Ozawa ve ark., 2022).

Retrovirüs Aracılı Gen Transferi

Retroviral vektörler, transgenik hayvan üretiminde kullanılan etkili gen transfer araçları arasında yer almaktadır. Retrovirüslerin genomlarını konak hücre DNA'sına kalıcı olarak entegre edebilme kapasitesi, hedef genin embriyo genomuna yüksek verimlilikle aktarılmasını mümkün kılar. Bu yöntem özellikle sekiz hücreli embriyo aşamasında uygulandığında başarılı sonuçlar vermekte, yüksek aktarım oranları ve stabil gen ekspresyonu sağlayabilmektedir (Hallerman ve ark., 2023).

Retroviral gen transferinin önemli avantajları arasında yüksek enfeksiyon etkinliği ve çoklu hücrelere aynı anda gen aktarımı yer alır. Bununla birlikte, taşınabilecek gen boyutunun sınırlı olması ve retroviral entegrasyonun mutagenez riskini artırabilmesi, yöntemin dikkatle uygulanmasını gerektiren yönleridir. Buna rağmen, özellikle küçük genlerin aktarımında hızlı ve maliyet açısından uygun bir seçenek sunmaktadır.

TRANSGENİK UYGULAMALARIN TÜR BAZINDA DEĞERLENDİRİLMESİ

Transgenik teknolojiler farklı hayvan türlerinde değişen verimlilik, biyolojik yanıtlar ve uygulama hedefleri doğrultusunda özgün sonuçlar ortaya koymaktadır. Sığır, koyun, keçi ve domuz gibi çiftlik hayvanlarında genetik modifikasyonlar çoğunlukla biyofarmasötik üretim, hastalık direnci, gelişmiş verim özellikleri ve biyomedikal araştırma modelleri oluşturma amacıyla gerçekleştirilmektedir. Bu doğrultuda, her türün üreme biyolojisi, embriyo gelişim dinamikleri ve gen transferine yanıtı dikkate alınarak tür-spesifik stratejiler ve optimizasyonlar geliştirilmiştir. Aşağıda başlıca transgenik çiftlik hayvanları türlerinin genetik modifikasyon süreçleri ve uygulama alanları ele alınmaktadır.

Transgenik İnek

Rosie, 1997'de geliştirilen ilk terapötik protein üreten transgenik inektir. Genomuna yerleştirilen insan t-PA (tissue plasminogen activator) geni sayesinde kalp krizi ve felç tedavisinde kullanılan kan pıhtısı çözücü proteini sütünde üretebiliyordu (Wray-Cahen ve ark., 2022).

Bir inek, ilaç fabrikası gibi kullanılabilir fikri bu çalışmayla ilk kez somutlaşmıştır. Rosie'nin doğumu, memeli genomunun hassas manipülasyonunun mümkün olduğunu göstererek sonraki yıllarda insülin, lizozim, laktoferrin gibi insan proteinlerini üreten transgenik hayvan çalışmalarının önünü açmıştır (Wang ve ark., 2022). Özellikle lizostafin transgenik hatlarda mastitisin belirgin şekilde azaldığı ve β-laktoglobulin geninin silinmesiyle hipoalerjenik süt üretimi sağlanabilmektedir (Popova ve ark., 2023).

Transgenik Keçi

Transgenik keçilerde süt içinde kan pıhtılarını çözmede kullanılan LAtPA proteini üretilmiştir. Bu amaçla LAtPA genini taşıyan yapı, uygun promotörlerle birleştirilerek erken embriyolara enjekte edilmiş ve embriyolar taşıyıcı dişilere aktarılmıştır. İşlemler sonucunda transgeni taşıyan yavrular doğmuştur. Bu keçilerin sütünde LAtPA miktarı bazı örneklerde litre başına birkaç miligram seviyesinde kalmış, bazı örneklerde ise litre başına birkaç grama ulaşmıştır. Bu sonuçlar, süt keçilerinin terapötik protein üretimi için ekonomik bir biyoreaktör olarak kullanılabileceğini göstermektedir (Popova ve ark., 2023).

ATryn®, transgenik keçilerin sütünde üretilen rekombinant insan antitrombinidir ve kalıtsal antitrombin eksikliği olan hastalarda pıhtılaşma riskini azaltmak için kullanılır. Bu ürün, transgenik biyoreaktör hayvanlardan elde edilen ilk onaylı terapötik proteindir (Moura ve ark., 2011).

Transgenik Koyun

İlk başarılı transgenik koyunlar 1988'de üretilmiş ve β-laktoglobulin promotörü altına yerleştirilmiş insan faktör IX geni bu koyunların sütünde üretilmiştir. Ayrıca transgenin yavrulara da aktarılmış olduğu belirlenmiştir (Schnieke ve ark., 1997).

1991'da yapılan bir diğer çalışmada insan alfa-1 antitripsin (hA1AT) genini taşıyan beş transgenik koyun elde edilmiş, bu koyunlardan birinin sütünde litre başına 35 grama ulaşan hA1AT üretimi sağlanmış ve saflaştırılan proteinin doğal insan antitripsiniyle aynı biyolojik aktivite gösterdiği doğrulanmıştır (Wright ve ark., 1991).

Bunun yanında, keratin sentezinde görevli SAT ve OAS gibi genler aktarılmış ve bu genleri taşıyan transgenik koyunlar başarıyla üretilmiştir. Böylece genetik mühendisliğiyle yün veriminin artırılmasının mümkün olduğu ortaya konmuştur (Damak ve ark., 1996).

Transgenik Balık

Transgenik balık üretimine yönelik çalışmalar 1985 yılında başlamıştır (Lal ve ark., 2024).

Mikroenjeksiyon tekniği sazan, yayın, japon balığı, medaka, somon, tilapia, alabalık ve zebra balığı gibi birçok türde başarıyla uygulanmıştır (Wang ve ark., 2021).

Çoğu balık türünde pronükleuslar mikroskop altında net görülmediği için DNA doğrudan sitoplazmaya enjekte edilmiştir. Bu da hayatta kalma oranını artırmıştır (Houdebine and Chourrout, 1991).

Balıklarda döllenmenin vücut dışında gerçekleşmesi ve embriyoların doğrudan gelişebilmesi, memelilerde olduğu gibi koruyucu annelere transfer gereksinimini ortadan kaldırmıştır.

Transgenik balıklara aktarılan insan büyüme hormonu, japon balığı, gökkuşağı alabalığı ve somonda büyüme hızını yaklaşık iki kat artırmıştır (Rasal ve ark., 2024).

HAYVANSAL ÜRÜNLERİN BESİN DEĞERİNİN ARTIRILMASI

Transgenik hayvanlardan elde edilen ürünlerin biyofortifikasyonu fonksiyonel gıda üretiminde önemli fırsatlar sunar. Omega-3 yağ asitlerinden zenginleştirilmiş domuzlar, yağ asidi profili geliştirilmiş sığırlar ve düşük kolesterollü et/süt ürünleri bu kapsamda değerlendirilebilir (Jones & Wilson, 2022).

Besin değeri artırılmış transgenik ürünler, yalnızca insan sağlığını desteklemekle kalmaz aynı zamanda hayvanların büyüme performansını, bağışıklık etkinliğini ve yem değerlendirme kapasitesini de yükseltir (Bogdanovich ve ark., 2021). Böylece hem ekonomik hem de sağlık açısından çift yönlü bir fayda ortaya çıkar.

Süt bileşenlerinin transgenik yöntemlerle modifiye edilmesi hem hayvan sağlığını hem de insan beslenmesini doğrudan etkileyen önemli bir uygulama alanıdır. Laktasyona özgü promotörler sayesinde süt bezlerinde yüksek miktarda rekombinant protein sentezi mümkün hâle gelmiştir (Shakweer ve ark., 2023).

Transgenik hayvanların sütünde insan alfa-laktalbümini, lizozim, laktoferrin, IgF-I ve lizostafin gibi biyoaktif proteinlerin üretilebilmesi hem gıda endüstrisi hem de farmasötik alan için kritik bir yenilik sunmaktadır. Özellikle lizostafin salgılayan hatların mastitis riskini azalttığı gösterilmiştir (Wang ve ark., 2022).

Hipoalerjenik süt üretimi amacıyla β-laktoglobulin geninin silinmesi veya düzenlenmesi, süt alerjisi bulunan bireyler için daha güvenli ürünlerin geliştirilmesini sağlamaktadır (Popova ve ark., 2023). Ayrıca gen düzenleme çalışmaları, özellikle düşük verimli tropikal sığır ırklarının süt kalitesi ve miktarının yükseltilmesinde önemli bir potansiyel taşır (Johnsson, 2023).

ÇEVRESEL SÜRDÜRÜLEBİLİRLİK VE EKOSİSTEM YÖNETİMİ

Transgenik yaklaşımlar çevresel sürdürülebilirlik açısından önemli avantajlar sunmaktadır. Örneğin, fosfor sindirim kapasitesi artırılmış fitaz transgenik domuzlarda dışkıdaki fosfor miktarının %75'e kadar azalması, tarımsal akışla su kaynaklarına taşınan fosfor yükünü önemli ölçüde düşürmektedir. Aşırı fosfor birikimi göl, akarsu ve rezervuarlarda ötrofikasyona yol açtığından, bu azalmanın sağlanması içme suyu kalitesinin korunması, alg patlamalarının önlenmesi ve su ekosistemlerinin sürdürülebilirliğinin desteklenmesi açısından kritik önem taşımaktadır (Wray-Cahen ve ark., 2022).

Ayrıca yemden yararlanma oranı artırılmış, daha az atık üreten veya daha hızlı büyüyen hayvan hatlarının geliştirilmesi, tarımsal üretimin karbon ayak izini azaltma potansiyeline sahiptir. Gen düzenleme yoluyla metabolik verimliliğin artırılması, özellikle ruminant üretiminde sürdürülebilirlik açısından umut vericidir (Park, 2023).

BÜYÜME VE KARKAS KOMPOZİSYONUNDAKİ DEĞİŞİKLİKLER

Büyüme hormonu (GH), IgF-I ve yağ metabolizmasıyla ilişkili genlerin modifikasyonu, büyüme hızı ve karkas kompozisyonunda önemli iyileşmeler sağlamıştır. GH-modifiye edilmiş balıkların normal ağırlığın 5-11 katına ulaşabildiği rapor edilmiştir (Hallerman ve ark., 2023).

Myostatin (MSTN) geninin hedefli mutasyonu ile "çift kaslılık" fenotipine sahip koyun ve sığırlar elde edilmiştir. Bu tür gen modifikasyonlarının yüksek kas oranı sağladığı; ancak doğum güçlüğü gibi sorunlar nedeniyle dikkatli şekilde uygulanması gerektiği vurgulanmaktadır. Ayrıca PPARγ geninin hedefli düzenlenmesiyle yağ dağılımı kontrol edilerek daha sağlıklı karkas yapıları geliştirilebilmektedir (Ge ve ark., 2021).

HASTALIKLARA DİRENÇLİ HATLARIN GELİŞTİRİLMESİ

Hastalıklara dirençli transgenik hatların geliştirilmesi, hayvan refahının en güçlü biyoteknolojik katkılarından biridir. Mastitise dirençli lizostafin transgenik inekler, enfeksiyon riskini önemli ölçüde azaltmaktadır (Wang ve ark., 2022).

Sivrisineklerde üremeyi engelleyen veya hastalık vektörlüğünü azaltan gen düzenleme uygulamaları ise zika, dang ve sıtma gibi hastalıklarla mücadelede büyük başarı göstermiştir (Park, 2023).

Model hayvanlarda gen düzenleme kullanılarak hipertansiyon, epilepsi veya davranış bozukluklarını modelleyen hatlar geliştirilmiştir (Ryazanova ve ark., 2023). Bu modeller hem biyomedikal araştırmalar hem de tedavi stratejilerinin geliştirilmesi açısından büyük önem taşır (Neff, 2021).

ENDÜSTRİYEL PROTEİN VE LİF ÜRETİMİ

Hayvanların biyoreaktör olarak kullanılması, düşük maliyetli farmasötik üretime olanak tanıyan yenilikçi bir yaklaşımdır. Transgenik keçilerden elde edilen ATryn® (antitrombin), klinik kullanım onayı alan ilk hayvansal rekombinant protein olup önemli bir dönüm noktasıdır (Popova ve ark., 2023).

Ayrıca örümcek ipeği proteinini üreten transgenik keçiler, balistik malzemeler ve biyomedikal ürünler için yüksek dayanımlı liflerin ekonomik biçimde üretilmesini sağlamıştır. Tavuk yumurtasında terapötik protein üretimi ise yüksek biyoverim ve düşük maliyet nedeniyle giderek daha fazla dikkat çekmektedir (Kim ve ark., 2021).

KSENOTRANSPLANTASYON VE TIBBİ UYGULAMALAR

Organ nakli ihtiyacının artması, ksenotransplantasyonu geleceğin önemli çözümlerinden biri hâline getirmiştir. CRISPR teknolojisiyle immünojenik domuz genlerinin silinmesi, insan proteinlerini kodlayan genlerin eklenmesi, PERV elementlerinin inaktive edilmesi gibi adımlarla reddin azaltılması konusunda büyük başarılar sağlanmaktadır (Wray-Cahen ve ark., 2022).

Domuz organlarının insan fizyolojisiyle boyutsal ve fonksiyonel olarak yakın olması, bu türü ksenotransplantasyon için ideal hâle getirmektedir (Popova ve ark., 2023).

GENETİK HASTALIK MODELLERİ VE ARAŞTIRMA UYGULAMALARI

Transgenik fareler, Cre/loxP sistemleri sayesinde dokuya veya zamana özgü gen modifikasyonlarının yapılabilmesine olanak tanımakta; bu da nörodejeneratif hastalıklar ve metabolik bozuklukların araştırılmasında büyük avantaj sunmaktadır (Johnsson, 2023).

Öte yandan sıçanlarda davranışsal ve nörolojik bozukluklar için geliştirilen modeller, translasyonel tıp açısından önemli bir kaynak oluşturmaktadır (Neff, 2021; Ryazanova ve ark., 2023).

TRANSGENİK HAYVAN ÜRETİMİNDE YENİ NESİL YAKLAŞIMLAR

Son yıllarda transgenik hayvan üretiminde kullanılan klasik teknikler yerini daha yüksek özgüllük, hassasiyet ve güvenlik sağlayan hedefli genom düzenleme teknolojilerine bırakmıştır.

Özellikle CRISPR-Cas9, CRISPR-Cas12a (Khan ve Sallard, 2023), baz editörleri ve prime editing sistemleri, genetik modifikasyonun doğruluğunu artırarak off-target etkilerini önemli ölçüde azaltmış ve transgenik hatların daha kararlı biçimde elde edilmesine olanak sağlamıştır (Chen, 2023).

Prime editing, DNA çift zincir kırığı oluşturmaksızın spesifik nokta mutasyonları veya küçük ekleme/silmelerin yapılabilmesi nedeniyle embriyonik letalite, mozaiklik ve genom bütünlüğüne yönelik potansiyel riskleri azaltan yenilikçi bir araç olarak değerlendirilmektedir (Zhao ve ark., 2023). Bu teknolojik gelişmeler, özellikle büyük çiftlik hayvanlarında genom düzenleme verimliliğini artırarak biyoteknolojik uygulamaların ölçeklenebilirliğini güçlendirmiştir.

Buna ek olarak, in vitro gametogenez, organ-on-chip platformları ve yapay embriyonik mikroçevrelerin geliştirilmesi, transgenik hayvan üretiminde etik endişeleri azaltabilecek alternatif biyoteknolojik çözümler sunmaktadır. Bu yaklaşımlar hem deneysel hayvan kullanımını azaltmakta hem de modellerin fizyolojik doğruluğunu artırmaktadır (Botigelli ve ark., 2023; Goszczynski ve ark., 2023).

EPİGENETİK DÜZENLEME VE FENOTİP KARARLILIĞI

Transgenik hayvan üretiminde yalnızca gen dizisinin modifikasyonu değil, epigenetik mekanizmaların kontrolü de fenotipin kararlılığı ve kalıtımsal aktarımı açısından kritik önem taşımaktadır. DNA metilasyonu, histon modifikasyonları ve kromatin yeniden şekillenmesi, transgenlerin ekspresyon düzeylerini doğrudan etkileyerek istenen fenotipin sürdürülebilirliğini belirlemektedir.

Somatik hücre çekirdek transferi (SCNT) ile üretilen transgenik hayvanlarda epigenetik yeniden programlamanın yetersizliği; düşük yaşama oranı, gelişimsel anomaliler ve erken embriyonik kayıplar gibi sorunlara yol açmaktadır (Liao ve ark., 2024). Bu nedenle HDAC inhibitörleri ve H3K9me düzenleyicileri gibi epigenom modülatörlerinin kullanımı, klonlama verimini ve gelişimsel başarıyı artıran tamamlayıcı stratejiler olarak önerilmektedir (Matoba ve ark., 2024).

TRANSKRİPTOMİK VE PROTEOMİK YAKLAŞIMLARIN ENTEGRASYONU

Yeni nesil transgenik hayvan çalışmalarında, hedef genin modifikasyonu tek başına yeterli görülmemekte genom genelinde meydana gelen transkriptomik ve proteomik değişikliklerin bütüncül olarak değerlendirilmesi giderek daha fazla önem kazanmaktadır. RNA-seq ve tek hücreli transkriptomik analizler, genom düzenlemesinin hücre tipine özgü etkilerini ortaya koymakta ve istenmeyen biyolojik sapmaların erken aşamada tespit edilmesini sağlamaktadır (Wadood ve ark., 2025).

Proteomik analizler ise süt, yumurta veya kan gibi biyolojik sıvılarda üretilen rekombinant proteinlerin biyoaktivite, glikozilasyon profili, stabilite özellikleri ve potansiyel immünojenisite risklerinin değerlendirilmesinde önemli bir rol oynamaktadır. Bu yönüyle proteomik veriler, transgenik ürünlerin biyoteknolojik ve tıbbi kullanım alanlarına yönelik güvenilirlik değerlendirmelerinde kritik bir bileşen oluşturur (Guan ve ark., 2022).

HAYVAN REFAHI VE ETİK DEĞERLENDİRME

Transgenik hayvanların geliştirilmesinde hayvan refahı ve etik değerlendirmeler, araştırma süreçlerinin ayrılmaz bir parçası haline gelmiştir. Genetik modifikasyonların neden olabileceği

fenotipik aşırılıklar, metabolik yüklenme, doğum güçlükleri veya bağışıklık sisteminin baskılanması gibi olası olumsuz etkiler, etik inceleme süreçlerinde merkeze alınmaktadır.

Bu kapsamda "Responsible Research and Innovation (RRI)" yaklaşımı; şeffaflık, paydaş katılımı ve risk-fayda analizini içeren bütüncül bir çerçeve sunmaktadır. Avrupa Birliği ve OECD, genom düzenlenmiş hayvanların değerlendirilmesinde mevcut GMO politikalarının güncellenmesini ve daha esnek, risk odaklı düzenlemelerin benimsenmesini önermektedir (Wray-Cahen ve ark., 2024).

KÜRESEL DÜZENLEYİCİ YAKLAŞIMLAR VE GELECEK POLİTİKALARI

Dünya genelinde transgenik ve genom düzenlenmiş hayvanlara yönelik düzenleyici yaklaşımlar önemli farklılıklar göstermektedir. ABD ve Brezilya gibi ülkeler hedefli mutasyon içeren genom düzenlenmiş hayvanları klasik GMO'lardan ayrı bir kategori olarak değerlendirirken, Avrupa Birliği daha temkinli ve süreç odaklı bir yaklaşım sürdürmektedir (Wray-Cahen ve ark., 2024).

Gelecekte ürün-temelli (product-based) düzenleyici çerçevelerin yaygınlaşması, genom düzenleme teknolojilerinin ticarileşmesi ve uluslararası standartların uyumlaştırılması beklenmektedir. Bu dönüşüm, özellikle tarımsal biyoteknolojide genom düzenlenmiş hayvanların daha hızlı şekilde uygulama alanı bulmasına zemin hazırlayacaktır.

TRANSGENİK TEKNOLOJİLERİN SINIRLARI, RİSKLERİ VE TARTIŞMALAR

Transgenik hayvan üretimindeki teknik zorluklar arasında rastgele genom entegrasyonu, mozaikçilik, çoklu kopya etkisi, epigenetik belirsizlikler, embriyonik kayıplar sayılabilir. Bu sorunlar, özellikle büyükbaş ve küçükbaş hayvanlarda verimliliği sınırlayabilmektedir (Park, 2023).

Ekolojik riskler arasında transgenik balıkların doğaya kaçması ve gen akışının ekosistem dengesini bozması yer alır (Hallerman ve ark., 2023). Etik tartışmalar ise hayvan refahı, gıda güvenliği ve genetiği değiştirilmiş organizmaların toplum tarafından kabulü gibi başlıklarda yoğunlaşmaktadır (Wray-Cahen ve ark., 2022).

SONUÇ

Transgenik hayvan biyoteknolojisi, modern moleküler tekniklerin hızla gelişmesiyle birlikte günümüzde tarım, hayvancılık, tıp, endüstri ve çevresel yönetim gibi birbirinden farklı disiplinlerde stratejik bir araç haline gelmiştir. Mikroenjeksiyon, embriyonik kök hücre manipülasyonu, viral vektörler, SCNT ve özellikle CRISPR-Cas sistemleri gibi yöntemler hassas gen düzenleme kapasitesini artırarak çok çeşitli türlerde kararlı, fonksiyonel ve uygulamaya dönük transgenik hatların geliştirilmesini mümkün kılmıştır. Bu sayede hipoalerjenik, yüksek besin değerine sahip veya terapötik protein içeren hayvansal ürünlerin elde edilmesi, büyüme performansı ve yemden yararlanmanın iyileştirilmesi, hastalıklara dirençli hatların geliştirilmesi ve endüstriyel protein/lif üretiminde ölçeklenebilir platformların oluşturulması önemli ölçüde kolaylaşmıştır.

Transgenik yaklaşımlar, yalnızca üretim verimliliğini artırmakla kalmayıp aynı zamanda çevresel sürdürülebilirliği destekleyen çözümler sunmaktadır. Atık yükünü azaltan metabolik modifikasyonlar, aquakültürde daha düşük yem girdisi ile yüksek büyüme performansı sağlayan hatlar ve sucul ekosistemleri tehdit eden fosfor kirliliğini azaltan transgenik domuz örnekleri, biyoteknolojinin çevresel faydalarını somutlaştırmaktadır. Bununla birlikte, domuz

organlarının genetik olarak insanlaştırılması yoluyla ksenotransplantasyonda elde edilen başarılar, transgenik hayvanların tıbbi uygulamalardaki potansiyelinin çok daha geniş bir alanı kapsayacağını göstermektedir.

Güncel gelişmeler, klasik transgenik yöntemlerin yerini giderek hedefli gen düzenleme tekniklerine bırakmakta olduğunu açıkça ortaya koymaktadır. CRISPR-Cas9, Cas12a, baz editörleri ve prime editing gibi sistemler, gen düzenleme doğruluğunu artırarak mozaiklik, off-target etkiler ve gelişimsel kayıplar gibi teknik sorunları önemli ölçüde azaltma potansiyeli taşımaktadır. Aynı zamanda epigenetik düzenleme, single-cell transkriptomik, proteomik analizler ve in vitro gametogenez gibi tamamlayıcı teknolojiler, transgenik hatların biyolojik stabilitesinin ve güvenilirliğinin değerlendirilmesinde yeni bir dönemi başlatmıştır.

Bununla birlikte, transgenik hayvan biyoteknolojisinin sunduğu bu geniş olanaklar etik ve ekolojik tartışmaları da beraberinde getirmektedir. Hayvan refahı, biyogüvenlik, gen akışı, ekosistem riskleri ve toplumun teknolojiye yönelik algısı, araştırma ve uygulama süreçlerinde dikkatle yönetilmesi gereken temel başlıklardır. Ayrıca, ülkeler arasında farklılık gösteren düzenleyici politikalar, genom düzenlenmiş hayvanların ticarileşmesini ve uluslararası standartların oluşturulmasını doğrudan etkilemektedir.

Genel olarak değerlendirildiğinde, transgenik hayvan biyoteknolojisi hem temel bilimler hem de uygulamalı biyoteknoloji açısından büyük bir dönüşüm potansiyeli taşımaktadır. Ancak bu potansiyelin sürdürülebilir ve güvenli bir biçimde hayata geçirilebilmesinin yolu, etik prensiplerin gözetilmesi, çevresel risklerin titizlikle yönetilmesi, bilimsel şeffaflığın artırılması ve düzenleyici çerçevelerin bilimsel gelişmelere uyumlu şekilde güncellenmesinden geçmektedir.

Bu koşullar sağlandığında, transgenik hayvanlar geleceğin gıda üretiminden kişiselleştirilmiş tıbba, ekosistem yönetiminden yüksek verimli biyofabrikasyon sistemlerine kadar çok geniş bir alanda yenilikçi çözümler sunmaya devam edecektir.

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THE BIODIESEL FUEL CHARACTERISTICS OF *BRASSICA RAPA* SSP. *OLEIFERA* L. PURE LINES

Assoc. Prof. Dr. Fatma KAYAÇETİN

Ankara University, Faculty of Agriculture, Department of Field Crops, Ankara, Türkiye

ABSTRACT

This study aimed to evaluate the biodiesel fuel properties of six turnip rape (*Brassica rapa* ssp. *oleifera* L.) pure lines bred and cultivated in Türkiye. The research was conducted under semi-arid climatic conditions in Ankara, with field trials carried out during the 2019-20 and 2020-21 autumn sowing seasons. The objective was to determine whether turnip rape pure lines can serve as a suitable raw material for high-quality biodiesel production. Six turnip rape pure lines of different regional origins in Türkiye were used in the study. Oils obtained from the seeds of the pure lines were analyzed according to ISO and TS EN standards to determine acid value, water content, iodine value, cold filter plugging point, flash point, as well as mono-, di-, and triglyceride and glycerol contents. Biodiesel production was performed via base catalyzed transesterification using methanol and sodium hydroxide, followed by reaction, separation, washing, and drying steps. Physicochemical properties of the resulting biodiesel samples were compared with the TS EN 14214 standard. The analyses indicated that biodiesel samples from all pure lines met the TS EN 14214 standard. Acid values ranged from 0.29 to 0.37 mg KOH g^{-1}, water content from 142.50 to 267.50 mg kg^{-1}, iodine values from 103.17 to 105.62 g iodine 100 g^{-1}, cold filter plugging points between −2.00 and −2.50 °C, and flash points between 175 and 186 °C. Levels of monoglycerides, diglycerides, triglycerides, and free glycerol were all below the standard limits, demonstrating high transesterification efficiency. Minor differences in fuel properties were determined among the lines. Turnip rape pure lines can be considered a suitable raw material source for high-quality biodiesel production under Türkiye conditions. The results indicate that these pure lines offer potential as an alternative oilseed crop for sustainable biofuel production.

Keywords: Turnip Rape, Biodiesel, Pure Line; TS EN 14214.

INTRODUCTION

Brassica rapa ssp. *oleifera* L. (turnip rape) is a prominent member of the *Brassicaceae* family and represents an important annual oilseed crop cultivated in various regions worldwide (Salehi et al., 2021; Bosi et al., 2022). In Türkiye, although this subspecies is not yet commercially cultivated for industrial oil or biodiesel production, wild forms naturally occur in the native flora, contributing to the country's plant genetic diversity (Al-Shehbaz et al., 2007; Kayaçetin, 2020). This natural variability provides a valuable resource for developing new cultivars adapted to different environments and capable of producing oils suitable for biodiesel applications (Kayaçetin, 2021; Rana et al., 2022).

The species is characterized by moderate to high oil content, typically ranging from 30% to 40%, with erucic acid representing a major fatty acid component (Kayaçetin et al., 2022; Kayaçetin et al., 2018). Erucic acid, a very long-chain monounsaturated fatty acid, is valued in non-food industrial sectors due to its hydrophobic nature and high oxidative stability, making

it suitable for biofuel production, lubricant formulations, and specialty polymer synthesis (Knutsen et al., 2016; Wendlinger et al., 2014). In turnip rape, erucic acid levels can reach up to 50% (Sharafi et al., 2015), while Kayaçetin (2023) reported values approaching 40%. Although such high erucic acid concentrations limit the suitability of turnip rape oil for human consumption (Poddar et al., 2021), they enhance its potential as a promising raw material for biodiesel production.

Previous studies on *Brassica* species have demonstrated that both genetic background and environmental conditions strongly influence plant vigor and final oil quality (Johnston et al., 2002; Shekhawat et al., 2012). Significant genotype × environment interactions have been reported for seed yield and key agronomic traits, emphasizing the importance of identifying well-adapted lines through multi-environment testing (Bocianowski et al., 2019; Kayaçetin, 2019). Moreover, the consistently high erucic acid content reported in turnip rape-with mean values exceeding 50% in some cases-further supports its suitability for industrial-grade oil and biodiesel production (Kayaçetin et al., 2018; Cartea et al., 2019; Konuskan et al., 2019).

Understanding the biodiesel-related characteristics of turnip rape is essential for fully assessing its potential as an alternative energy crop. Traits such as fatty acid composition, oxidative stability, cold flow properties, and glyceride profiles are integral in determining biodiesel quality and compliance with international fuel standards. However, limited information exists regarding the performance of turnip rape pure lines under different environmental conditions in Türkiye, particularly in terms of biodiesel fuel properties.

Therefore, the present study aimed to investigate the biodiesel-related fuel characteristics of six pure lines of turnip rape grown under the semi-arid conditions of Ankara, Türkiye. The findings provide critical insights for identifying high-performing, biodiesel-suitable lines that can support future breeding programs and industrial oil production.

MATERIALS AND METHODS

The experiment was conducted during the 2019-2020 and 2020-2021 autumn growing seasons at the experimental fields of the Field Crops Central Research Institute, located at an altitude of 1050 m. Monthly climatic data for the study area, including long-term averages and values recorded during the experimental seasons, are presented in Figure 1.

Based on the meteorological data for the growing seasons, the long-term average total precipitation was 391.9 mm, while 269.6 mm and 273.6 mm were recorded in 2019-2020 and 2020-2021, respectively. Long-term average temperature and relative humidity were 10.5 °C and 63.9%, while for the first and second experimental years, the corresponding values were 10.5 °C-58.3% and 12.0 °C-65.5% (Figure 1; Kayaçetin, 2023). The soil at the experimental site was clay-loam in texture, low in organic matter, and slightly alkaline (Kayaçetin and Aydin, 2024).

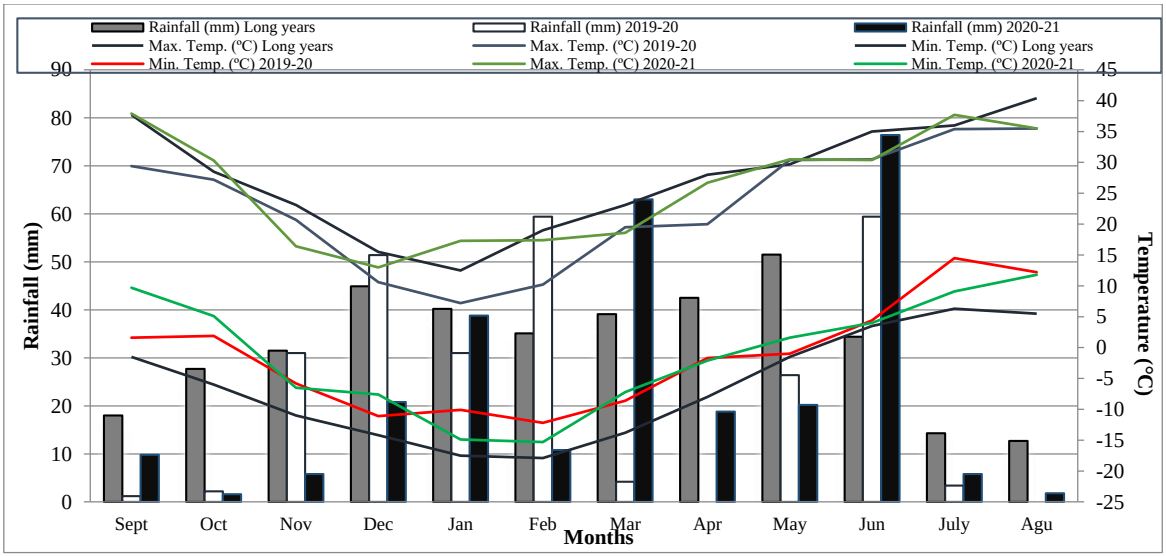


Figure 1. Monthly climatic data for the study area: long-term averages and 2019-2020 and 2020-2021 values

A total of six turnip rape pure lines were used in the study, originating from different regions of Türkiye: three lines from Tekirdağ, and one line each from Bursa, Tokat, and a line representing the genetic diversity of Türkiye. This selection provided a broad genetic base from multiple ecological regions. All pure lines were maintained and characterized at the Ankara Field Crops Central Research Institute and were developed using the Pure Line Selection Method. All turnip rape lines used in this study were strictly winter-type genotypes.

The experiment was conducted in a randomized complete block design with four replications, with seeds sown at 200 seeds m^{-2} and plots fertilized according to standard practices (Kinay and Kayaçetin, 2023).

Biodiesel production and analysis were carried out at the Biofuel Laboratory, DB Agricultural Energy, Izmir, Türkiye, using a laboratory-scale biodiesel processor. Seed oils from each pure line were extracted following ISO 734-1. Acid value, water content, and iodine value were determined according to TS EN 14104, EN ISO 12937, and TS EN 14111, respectively. Cold filter plugging point and flash point were measured following TS EN 116 and TS EN ISO 2719 standards. Mono-, di-, and triglycerides, as well as glycerol contents, were quantified using gas chromatography according to TS EN 14105 (Kayaçetin, 2023).

Biodiesel was synthesized via base-catalyzed transesterification using methanol and sodium hydroxide, as described by Kayaçetin (2023). The procedure involved four main stages: reaction, separation, washing, and drying. Briefly, 200 mL of oil from each genotype was mixed with methanol (20% v/v) containing 0.35 wt% NaOH, stirred, and heated at 60 °C for 1 h. After settling for 8 h, the biodiesel and glycerol layers were separated. The biodiesel layer was washed several times with warm distilled water at 55 °C, and residual methanol was removed by heating at 120 °C under continuous stirring to obtain purified biodiesel. This method ensured consistent biodiesel production suitable for evaluating fuel properties across the different turnip rape pure lines.

RESULTS AND DISCUSSION

The acid value, water content, iodine value, cold filter plugging point, flash point, and glyceride composition-including mono-, di-, triglycerides, and free and total glycerol-of biodiesel produced from turnip rape pure lines are presented in Table 1.

Table 1. Biodiesel Fuel Properties of Turnip Rape Pure Lines Compared with TS EN 14214 Standard Limits

Traits	Pure lines						Standard TS EN 14214	
	Tekirdağ1	Bursa	Tekirdağ2	Türkiye	Tokat	Tekirdağ3	Min-	Max
Acid value (mg KOH g^{-1})	0,37	0,29	0,36	0,36	0,36	0,34	-	0,50
Water content (mg kg^{-1})	142,50	197,50	157,50	235,00	267,50	260,00	-	500,00
Iodine value (g iodine 100 g^{-1})	103,17	104,35	104,98	105,21	103,35	105,62	-	120,00
Cold filter plugging point (°C)	-2,00	-2,00	-2,00	-2,00	-2,00	-2,50	−20	20
Flash point (°C)	182,50	183,00	185,00	175,00	180,00	186,00	120,00	-
Glyceride (%)								
Monoglyceride	0,27	0,30	0,27	0,27	0,24	0,30	-	0,80
Diglyceride	0,05	0,07	0,05	0,01	0,02	0,01	-	0,20
Triglyceride	0,01	0,02	0,02	0,01	0,02	0,01	-	0,20
Free glycerol	0,01	0,01	0,01	0,01	0,01	0,01	-	0,02
Total glycerol	0,09	0,10	0,09	0,09	0,08	0,10	-	0,25

Based on the two-year average data, biodiesel produced from the seed oils of the pure lines generally complies with the TS EN 14214 standard. Acid values ranged from 0.29 to 0.37 mg KOH g^{-1}, well below the maximum limit of 0.50 mg KOH g^{-1}, indicating high resistance to hydrolytic degradation and efficient esterification.

Water content varied between 142.50 and 267.50 mg kg^{-1}, considerably below the 500 mg kg^{-1} limit, reducing the risk of corrosion, microbial growth, or phase separation in fuel systems. These low moisture levels also confirm appropriate storage and processing conditions.

Iodine values ranged from 103.17 to 105.62 g iodine 100 g^{-1}, below the standard maximum of 120 g iodine 100 g^{-1}, indicating that the fatty acid composition does not compromise oxidative stability, which is advantageous for long-term storage.

Cold filter plugging points ranged from −2.00 to −2.50 °C, demonstrating that the biodiesel maintains sufficient flow properties in winter conditions typical of temperate climates. Flash points were between 175 and 186 °C, well above the minimum requirement of 120 °C, reflecting good storage safety and low flammability.

Glyceride analysis revealed very low levels of mono-, di-, and triglycerides, confirming the high efficiency of the transesterification reaction and indicating minimal risk of fuel quality problems such as soap formation, sedimentation, or injector clogging. Both free and total glycerol levels were well below standard limits, further confirming high biodiesel quality.

Chemical analysis of seed oils obtained from autumn-sown turnip rape pure lines indicates that they are suitable for biodiesel production in accordance with TS EN 14214 standards (Yesilyurt et al., 2019; Akhtar, 2022; Kayaçetin, 2023). The use of non-food oils as biodiesel feedstock is

a key strategy for sustainable fuel production (Aydın et al., 2024; Kayaçetin, 2023). Due to their high erucic acid content, these turnip rape pure lines are not suitable for human consumption; however, their fatty acid profiles and strong adaptability to Türkiye's agroclimatic conditions make them promising candidates for industrial biodiesel applications.

CONCLUSION

This study demonstrated that the pure lines of *Brassica rapa* ssp. *oleifera* possess physicochemical characteristics suitable for biodiesel production. All examined lines complied with TS EN 14214 standards in terms of acid value, water content, iodine value, flash point, and glyceride composition, indicating that oils derived from these genotypes can be effectively used to produce high-quality biodiesel. Minor differences were observed among the lines; but overall, all pure lines exhibited properties consistent with international biodiesel standards, confirming their suitability as a raw material for sustainable biofuel production under Türkiye's conditions.

The slight variations among the lines also highlight the potential for future breeding programs aimed at enhancing biodiesel quality. Collectively, these findings support the use of turnip rape pure lines cultivated in Türkiye as a promising alternative oilseed crop for sustainable, high-quality biodiesel production.

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PHENOLOGY, MORPHOLOGY, AND SEED YIELD OF TURNIP RAPE PURE LINES

Assoc. Prof. Dr. Fatma KAYAÇETİN

Ankara University, Faculty of Agriculture, Department of Field Crops, Ankara, Türkiye

ABSTRACT

The environmental impacts of non-renewable fossil fuel consumption have increased the need for renewable and sustainable energy sources. *Brassica rapa* ssp. *oleifera* (turnip rape) is an economically important oilseed crop widely used in industrial oil production. This study aimed to evaluate the phenological, morphological, and seed yield characteristics of six pure lines of turnip rape under autumn sowing conditions in Ankara, Türkiye, during the 2019-2020 growing season. The study material consisted of six genetically distinct turnip rape pure lines originating from different regions of Türkiye. The experiment was conducted in a randomized complete block design with four replications. Phenological observations included days from sowing to emergence, days from emergence to the 4-6 leaf rosette stage, days to 50% flowering, days to 50% capsule formation, and days to harvest. Morphological and yield traits measured were plant height, number of lateral branches per plant, number of capsules per plant, number of seeds per capsule, thousand seed weight, and seed yield (kg/da). All pure lines exhibited similar phenological development, completing their growth cycle in approximately 281 days, indicating that phenology was primarily influenced by environmental conditions. Morphological traits such as plant height (141.40-156.35 cm) and number of lateral branches (5.50-6.75 branches/plant) showed limited variation. However, significant differences ($p < 0.01$) were observed among the lines for the number of capsules per plant (201.05-343.55), seeds per capsule (16.33-21.80), and seed yield (348.73-407.99 kg/da). Tekirdağ3 had the highest seed yield (407.99 kg/da) despite producing fewer capsules, demonstrating superior reproductive efficiency. Tokat produced the highest number of capsules but showed moderate seed yield due to fewer seeds per capsule. Bursa achieved relatively high yield owing to the highest seed set per capsule (21.80 seeds/capsule). Thousand seed weight varied minimally among the lines (1.87-2.03 g). Tekirdağ3 stands out as a promising pure line for improving seed yield in turnip rape due to its efficient reproductive strategy. Additionally, Tekirdağ1, Bursa, Tekirdağ2, and Tokat represent valuable genetic resources for breeding programs targeting increased capsule number and seed set. The results provide important insights for selecting high-performing genotypes adaptable to diverse environmental conditions.

Keywords: *Brassica rapa* ssp. *oleifera*, Seed Yield, Phenological-Morphological Traits, Genetic Variability.

INTRODUCTION

Brassica rapa ssp. oleifera (turnip rape) is an economically important annual oilseed crop and is used as a raw material in biodiesel production (Thomas et al., 2012; Aslan, 2023; Kayaçetin, 2023; Kinay and Kayaçetin, 2023; Nisar et al., 2018). Although turnip rape seeds are not currently produced in Türkiye for biodiesel purposes, wild forms of this species are naturally found within the country's genetic resources (Kayaçetin, 2020). Therefore, utilizing the genetic

diversity available in local turnip rape genotypes to develop new, high-yielding, low-cost, and biodiesel-suitable cultivars is of great importance (Kayaçetin, 2021; Rana et al., 2022).

Turnip rape seeds contain 30-40% oil, a substantial proportion of which consists of erucic acid (40-50%) (Kayaçetin et al., 2022; Kayaçetin et al., 2018). Due to its high erucic acid content, the oil is unsuitable for human consumption (Poddar et al., 2021), yet it offers significant potential for industrial applications. This highlights the importance of identifying appropriate lines and cultivars for industrial oil production (Kayaçetin, 2023; Kayaçetin et al., 2023).

Genotypic differences strongly influence adaptation to environmental conditions, leading to considerable variation in growth and yield performance (Nowosad et al., 2019; Kayaçetin, 2021). Studies conducted on mustard and other Brassica species demonstrate that genotype × environment interaction has a pronounced effect on morphological traits and yield components (Bocianowski et al., 2019). Evaluating multiple genotypes makes it possible to identify superior lines adapted to specific agroecological conditions (Kayaçetin, 2019). Furthermore, the high erucic acid content of turnip rape, reaching an average of approximately 50%, supports its suitability for industrial rather than nutritional use (Kayaçetin et al., 2018; Cartea et al., 2019; Konuşkan et al., 2019).

Both genetic and environmental factors significantly affect the performance of Brassica genotypes (Johnston et al., 2002; Shekhawat et al., 2012). Variations in yield and yield components among genotypes facilitate the selection of superior lines in breeding programs (Fayyaz and Afzal, 2014). Moreover, an ideal genotype is expected to exhibit both high mean performance and high stability across diverse environments (Kayaçetin, 2021).

In this study, the evaluation of phenological, morphological, and yield characteristics of turnip rape pure lines is considered essential for industrial oil production and future breeding programs. Accordingly, the present study aimed to assess the phenology, morphology, and seed yield of six turnip rape pure lines under the semi-arid climatic conditions of Ankara, Türkiye. The findings offer valuable insights for identifying high-performing lines suitable for diverse environmental conditions.

MATERIALS AND METHODS

Experimental Area, Climate, and Soil Characteristics

The experiment was carried out during the 2019-20 autumn growing season at the experi-mental fields of the Field Crops Central Research Institute, situated at an altitude of 1050 m. Monthly climatic data for the study site, including long-term averages and the values recorded during the experimental growing season, are presented in Table 1.

When comparing the long-term climatic averages with the 2019-20 growing season, notable differences in rainfall patterns were observed. According to the long-term data, the highest rainfall typically occurs in May (51.5 mm). However, during the 2019-20 season, rainfall distribution was irregular, with significant deviations from the long-term averages in De-cember, February, and June. Maximum temperatures in 2019-20 were generally lower than the long-term averages, particularly during the winter months (December-February). Mini-mum temperatures exhibited a similar pattern: although long-term averages were lower in January and February, the 2019-20 period recorded higher minimum temperatures, while in March and April, temperatures remained below the long-term averages. These observations indicate that the 2019-20 season experienced substantial deviations from typical climatic conditions, with extreme weather events particularly pronounced during winter and early spring.

Table 1. Monthly climatic data for the study area: long-term averages and 2019-20 values

Climatic Factors	Years/Months	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Rainfall (mm)	Long years	18	27.7	31.5	44.9	40.2	35.1	39.1	42.5	51.5	34.4	14.3	12.7
	2019-20	1.2	2.2	31.0	51.4	31.0	59.4	4.2	0.0	26.4	59.4	3.4	0.0
Max. Temp. (ºC)	Long years	37.7	28.5	23.1	15.5	12.5	19.0	23.1	28.0	29.7	35.0	36.0	40.4
	2019-20	29.4	27.2	20.7	10.6	7.2	10.2	19.5	20.0	30.4	30.5	35.4	35.5
Min. Temp. (ºC)	Long years	-1.5	-6.0	-11.0	-14.2	-17.5	-17.9	-13.8	-8.0	-1.5	3.5	6.3	5.5
	2019-20	1.6	1.9	-5.8	-11.1	-10.1	-12.2	-8.6	-1.7	-1.0	4.4	14.5	12.2

Soil analysis of the 0-20 cm layer revealed low organic matter content (1.97%), a slightly alkaline pH (7.7), high calcium carbonate concentration (30%), and a clay-loam texture (Kayaçetin and Aydin, 2024).

Experimental Material and Design

The study was conducted using six pure lines of turnip rape (*Brassica rapa* ssp. *oleifera*) originating from various regions of Türkiye, including three lines from Tekirdağ, and one line each from Bursa, Tokat, and a representative line encompassing the genetic diversity of Türkiye. This selection ensured a broad genetic base from multiple ecological zones. All pure lines were maintained and characterized at the Ankara Field Crops Central Research Institute and were developed through the Pure Line Selection Method. The lines used in this study were strictly winter-type genotypes.

The field experiment was laid out in a randomized complete block design with four replications. Sowing was performed at a rate of 200 seeds m^{-2} and a depth of 2-3 cm. Each experimental plot consisted of six rows spaced 30 cm apart, with a row length of 6 m, covering a total area of 10.8 m^2 per plot. Fertilization included applications of nitrogen, phosphorus, and sulfur at rates of 35, 50, and 100 kg ha^{-1}, respectively (Franzen and Lukack, 2007; Grant et al., 2007; Kayaçetin, 2023). Phosphorus and sulfur were applied before sowing, whereas nitrogen was split between the sowing date and the rosette stage.

Studied traits

During the 2019-20 growing season, phenological, morphological, and yield-related traits of the turnip rape (*Brassica rapa* ssp. *oleifera*) pure lines were systematically evaluated. Phenological observations included the number of days from sowing to emergence, the duration from emergence to the 4-6 leaf rosette stage, and the number of days from emergence to 50% flowering and 50% capsule formation. Morphological traits recorded were plant height (cm) and the number of lateral branches per plant, while yield-related traits included the number of capsules per plant, number of seeds per capsule, thousand seed weight (g), and seed yield (kg/ha) (Kayaçetin, 2019). All measurements were performed following standard procedures for turnip rape cultivation, with phenological stages recorded as days from sowing and emergence, and morphological and yield components measured at physiological maturity prior to harvest. To minimize border effects, all observations were conducted on plants located within the central rows of each plot.

Statistical Analysis

Morphological and yield data were analyzed using analysis of variance (ANOVA) in JMP statistical software. Mean differences among the lines were compared using the Least Significant Difference (LSD) test at the 1% probability level ($p < 0.01$) (Kalayci, 2005).

RESULTS AND DISCUSSION

The phenological observations presented in Table 2 show that the turnip rape (*Brassica rapa* ssp. *oleifera*) pure lines progressed through the same developmental stages at similar times under the given ecological conditions, with no differences detected among the lines. Sowing was carried out on 15 September 2019, and emergence occurred 26 days later, on 11 October 2019. The plants reached the 4-6 leaf rosette stage on 12 November 2019 and remained in a pronounced vegetative growth phase throughout the winter months.

With the improvement of spring conditions, generative development accelerated, with 50% flowering observed on 25 April 2020 and 50% capsule formation on 10 May 2020. Harvest took place on 27 June 2020, completing a total growing period of approximately 9.5 months. Based on the durations presented in the table, the period from sowing to emergence was 26 days, and the transition from emergence to the 4-6 leaf rosette stage took 32 days. From emergence to 50% flowering, 196 days elapsed, followed by 211 days to 50% capsule formation and 255 days to harvest.

Table 2. Sowing, Emergence, 4-6 Leaf Rosette Stage, 50% Flowering, 50% Capsule Formation, and Harvest of Turnip Rape Pure Lines

Growth stage	**Sowing**	**Emergence**	**4-6 leaf rosette stage**	**50% flowering**	**50% capsule formation**	**Harvest**
Date	15-Sep-2019	11-Oct-2019	12-Nov-2019	25-Apr-2020	10-May-2020	27-Jun-2020
Days from sowing	0	26	-	-	-	-
Days from emergence	-	-	32	196	211	255

The six pure lines of turnip rape exhibited considerable variation in several morphological and yield-related traits, as shown in Table 3. Although plant height and the number of lateral branches did not differ significantly among the lines ($p > 0.01$), the numerical differences indicate relatively narrow genetic variation for these traits. Plant height ranged from 141.40 cm (Bursa) to 156.35 cm (Tekirdağ3), suggesting that all lines possess a similar growth habit and biomass potential.

Table 3. Morphological Traits and Seed Yield of Six Pure Lines of Turnip Rape

Line	Plant height (cm)	Lateral branches per plant (branch/plant)	Capsules per plant (capsule/plant)	Seeds per capsule (seed/capsule)	Seed yield (kg/da)	Thousand seed weight (g)
Tekirdağ1 pureline	153.00	6.15	324.8 a	18.50 bc	365.71 ab	1.87
Bursa pureline	141.40	5.95	297.8 a	21.80 a	383.10 ab	1.87
Tekirdağ2 pureline	152.23	6.75	296.6 a	18.13 bc	405.79 ab	2.03
Türkiye pureline	145.60	6.45	233.65 b	19.55 ab	348.73 b	2.00
Tokat pureline	151.30	5.50	343.55 a	16.33 c	378.47 ab	2.02
Tekirdağ3 pureline	156.35	5.50	201.05 b	19.50 abc	407.99 a	2.02
Source of variation (%)	7,46	31,51	14,81	11,30	10,32	5,59
LSD (0.01) = 2.10 (24 df)	ns	ns	**	**	**	ns

Significance: ** = significant at $p < 0.01$; ns = not significant

The six pure lines of turnip rape exhibited considerable variation in several morphological and yield-related traits, as presented in Table 3. Although plant height (cm) and the number of lateral branches per plant (branch/plant) did not differ significantly among the lines ($p > 0.01$), the numerical differences suggest relatively narrow genetic variation for these traits. Plant height ranged from 141.40 cm (Bursa) to 156.35 cm (Tekirdağ3), indicating that all lines share a similar growth habit and biomass potential. The number of lateral branches varied from 5.50 to 6.75 branches per plant.

Significant differences were observed in the number of capsules per plant (capsule/plant), seeds per capsule (seed/capsule), and seed yield (kg/da) ($p < 0.01$). Tekirdağ1, Bursa, Tekir-dağ2, and Tokat formed a statistically similar group with higher capsule numbers, while Türkiye and Tekirdağ3 produced significantly fewer capsules. Despite producing fewer cap-sules, Tekirdağ3 achieved the highest seed yield (407.99 kg/da), likely due to its relatively high number of seeds per capsule (19.50 seed/capsule) and comparable thousand seed weight (2.02 g), suggesting a more efficient reproductive allocation that compensates for lower capsule production. The differences in seed yield among the pure lines likely reflect their adaptation and genetic potential under the existing agro-climatic conditions (Anjum et al., 2005; Kayaçetin, 2021).

Tokat produced the highest number of capsules per plant (343.55 capsule/plant), but its seed yield remained moderate (378.47 kg/da), which may be associated with its lower number of seeds per capsule (16.33 seed/capsule). Conversely, Bursa exhibited the highest seed number per capsule (21.80 seed/capsule), resulting in relatively high seed yield (383.10 kg/da) despite having fewer capsules than Tokat. These results emphasize that both capsule number and seed set are crucial determinants of final seed yield.

Thousand seed weight (g) did not differ significantly among lines, ranging narrowly from 1.87 to 2.03 g, indicating limited variation in seed size. This suggests that seed weight was not a major factor contributing to yield differences in this study. Johnson et al. (2002), Mondal et al. (2018), and Kayaçetin (2020) report that significant variation among genotypes/lines of the same species grown under identical environmental conditions highlights the fundamental role of genetic factors in determining the yield potential of plants.

CONCLUSION

The results of this study indicate that among the evaluated turnip rape (*Brassica rapa* ssp. *oleifera*) lines, Tekirdağ3 achieved the highest seed yield despite producing fewer capsules, suggesting a promising genetic potential for yield improvement. Tekirdağ1, Bursa, Tekirdağ2, and Tokat also demonstrated competitive performance and may serve as valuable genetic resources, particularly for traits such as capsule number and seed set. The limited variation observed in plant height, lateral branching, and thousand seed weight indicates that future breeding efforts should prioritize enhancing seed set and capsule productivity, which were the primary factors contributing to yield differences in this study. Overall, these findings provide valuable insights for selecting high-performing lines and support their further evaluation under diverse environmental conditions.

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ACCUMULATOR PLANTS AND MICROPLASTICS

AKÜMÜLATÖR BİTKİLER VE MİKROPLASTİKLER

Bilal Can ERKAN
Tekirdağ Namık Kemal University, Faculty of Agriculture, Soil Science and Plant Nutrition
Tekirdağ-Türkiye
ORCID: 0009-0002-7011-5711

Uğur GÜNEŞ
Tekirdağ Namık Kemal University, Faculty of Agriculture, Soil Science and Plant Nutrition
Tekirdağ-Türkiye
ORCID: 0009-0006-9570-6541

Prof. Dr. Sevinç YEŞİLYURT
Tekirdağ Namık Kemal University, Faculty of Agriculture, Soil Science and Plant Nutrition
Tekirdağ-Türkiye
ORCID: 0000-0002-0062-0491

ÖZET

İnsanoğlunun çeşitli faaliyetleri sonucunda toprağa bulaşan atık plastikler, zaman içinde fiziksel ve biyolojik faktörlerin etkisi ile parçalanarak mikroplastiğe dönüşmektedir. Nüfusun artmasıyla paralel olarak atıkların da devasa boyutlara ulaşması nedeniyle bu durum günümüzün en önemli problemlerinden biri haline gelmiştir. Topraktaki mikroplastik kirliliği ortaya çıkmakta ve beraberinde çeşitli sorunları da meydana getirmektedir. Oluşan bu kirlilik sonucunda mikroplastikler, yapılan tarımsal faaliyetlerle birlikte insan vücuduna kadar taşınabilmekte ve çeşitli hastalıklara neden olmaktadır. Buradan da anlaşıldığı üzere mikroplastiklerin oluşturduğu kirlilik; sadece toprak için değil, insan sağlığı için de çok büyük riskler taşımaktadır. Problemin büyüklüğünü gözler önüne seren bu duruma çözüm odaklı yaklaşımın gerekliliği ortaya çıkmaktadır. Fitoremediasyon, toprak kirliliklerine ucuz ve etkili çözümler sunan ve bu konudaki değeri giderek daha fazla ortaya çıkan, bitkilerle çözüm sunan bir toprak iyileştirme yöntemidir. Buradan hareketle toprakta bulunan ağır metallerin temizliğinde kullanılmakta olan fitoremediasyonun, topraktaki mikroplastik varlığına da çözüm sunabileceği üzerine yoğunlaşarak, fitoremediasyonun temelini oluşturan akümülatör bitkiler derlenmiştir. Çevre dostu, ekonomik ve kolay uygulanabilir olan akümülatör bitkiler, topraktaki ağır metalleri kendi bünyelerinde biriktirerek toprak kirliliğini azaltmaktadırlar. Akümülatör bitkilerin ağır metalleri; topraktan alma sebepleri, alış mekanizmaları ve bünyelerinde biriktirme yöntemleri araştırıldığında bu bitkilerin topraktaki mikroplastik kirliliklerine de çözüm sunabilecekleri görülmüştür. Bu çalışmanın yeni çalışmalar için bir harita olması

hedeflenmekte ve akümülatör bitkiler kullanılarak yapılacak çalışmalarla birlikte mikroplastiğin toprakta, tarımda ve insan sağlığında ortaya çıkardığı sorunların minimum düzeye indirilmesi için yapılacak araştırmalara ışık tutması beklenmektedir.

Anahtar Kelimeler: Mikroplastikler, Akümülatör Bitkiler, Fitoremediasyon, Tarım, Toprak

ABSTRACT

Waste plastics, which contaminate the soil the soil resulting from various human activities, degrade into microplastics with the influence of physical and biological factors over time. Due to waste reaching colossal proportions in parallel with population growth, this situation has become a primary environmental challenge confronting contemporary society. Microplastic pollution in the soil is becoming prevalent, bringing with it a variety of associated problems. As a consequence of this pollution, microplastics can be transported into the human body through agricultural activities, causing various diseases. As is evident from this, the pollution caused by microplastics poses significant risks affecting the soil as well as human health. This situation, indicating the scale of the problem, highlights the necessity of a oriented toward practical solutions approach. Phytoremediation is a based on plants soil remediation method that offers cost effective and efficient solutions to soil pollution, with its value in this field becoming increasingly apparent. Based on this premise and focusing on the potential of phytoremediation currently used to clean heavy metals from soil to also provide a solution to microplastic pollution, the accumulator plants that form the basis of phytoremediation have been compiled. Environmentally friendly, economical, and easily applicable, accumulator plants reduce soil pollution by accumulating heavy metals from the soil within their own tissues. Upon investigating the reasons for heavy metal bioaccumulation, the uptake mechanisms, and the accumulation methods of accumulator plants, it has been demonstrated that these plants can also offer a solution to microplastic pollution in the soil.

Keywords: Microplastics, Accumulator plants, Phytoremediation, Agriculture, Soil

GİRİŞ

Toprak kirliliğine neden olan parametrelerden biri olan çok fazla miktarlarda üretilen plastik maddeler, her alanda yaygın olarak kullanılmakta ve çeşitli ürünlerde bulunmaktadır. Plastiklerin günlük hayatta oluşturduğu konfor, insanoğlunu plastik ürünlere muhtaç duruma düşürmüştür. İnsanoğlu plastiklerin kullanımından sonra atıkların toplanması ve doğru bir şekilde yönetiminin sağlanması halinde bu plastik maddelerin risk faktörü düşebileceği beklenmektedir. Fakat plastik atıklar günümüze kadar aşırı miktarlarda üretilmiş ve dikkatsizce çevreye dağılmış hale getirilmiştir. Plastik atıklar daha küçük parçacıklara ayrılarak uzun bir süreçte çevreye ve canlılara daha da zararlı bir hale gelmektedir. Mikro boyuta gelmiş bir plastik, çevresel ve insan kaynaklı sebeplerle kolay bir şekilde her yere dağılabilmekte ve su kaynaklarına karışabilmekte, sudaki canlılar tarafından yutularak bünyelerine alınabilmekte veya sulardaki zararlı organik maddeleri absorplayarak besin zincirine taşınmasına sebep olabilmektedir (Yurtsever, 2018; Çelik et al., 2022)

Mikroplastikler günümüzde insanların ve çevrenin sağlığına tehdit oluşturan önemli kirleticiler arasında bulunmaktadır. Dünya genelinde plastik üretimi, sanayi aktiviteleri, nüfus artışı, madencilik ve tarımda plastikültür uygulamalarının kullanımıyla önemli bir artış göstermiştir. Günümüzde doğaya atılan plastik miktarının önemli bir kısmını tarımsal araziler oluşturmaktadır. Karasal ekosistemlerdeki bu kirleticilerin toprak ve insan sağlığı için uzaklaştırılması gerekmektedir. Topraklarda biriken mikroplastiklerin giderilmesi için

fitoremediasyon teknolojileri ve akümülatör bitkilerin kullanımı, uygulanabilirlik, maliyet, zaman ve çevre dostluğu bakımından diğer yöntemlere göre ön plana çıkmaktadır. Fitoremediasyon, çevresel kirleticileri absorbe ederek bünyelerinde depolayabilen akümülatör bitkiler vasıtasıyla ortamın kirleticilerden arındırılmasında kullanılan yöntemlerin tümü olarak tanımlanmaktadır (De Souza Machado et al., 2019; Ding et al., 2022; Pal et al., 2025; Thapliyal et al., 2024; Wang et al., 2021)

Fitoremediasyon; uygulanabilir, bitki temelli çevreyi ıslah etme teknolojisine verilen isimdir. Fitoremediasyon yönteminde kullanılan akümülatör bitkiler ile organik ve inorganik kaynaklı kirleticilerle kirlenmiş alanları temizleme teknolojisi olarak ön plana çıkmaktadır. Fitoremediasyon tekniğinde en önemli avantajlar arasında; ekstra enerjiye gereksinim olmaması, yerinde arıtım sağlaması, uygulanabilirliği ve uygun maliyetli olması yer almaktadır. Ayrıca fitoremediasyon tekniği doğal kaynaklara zarar vermemektedir. Bu teknik, çevre bilincine sahip olan çoğu kişi tarafından da desteklenmektedir (Asante-Badu et al., 2020; Kafle et al., 2022; Yadav et al., 2022; Priya et al., 2023)

Bu çalışmada, ağır metalleri bünyelerinde biriktirme kapasitesine sahip akümülatör bitkilerin, mikroplastiklerle kirlenmiş toprakların iyileştirilmesindeki potansiyeli ele alınmış; bununla birlikte fitoremediasyonun çeşitli alt teknolojileri (fitostabilizasyon, fitoekstraksiyon, rizodegradasyon vb.) mikroplastik kirliliğinin azaltılmasındaki işlevleri değerlendirilmiştir. Bu alanda yapılacak çalışmalar, toprakta bulunan mikroplastiklerin giderilmesi, toprak sürdürülebilirliğinin sağlanması, ekolojik bütünlüğün korunması ve toprak yönetimi açısından önemli bir basamak olma potansiyelini taşımaktadır.

MİKROPLASTİKLER VE TARIM

Mikroplastiklerin Tanımı, Sınıflandırılması ve Çevresel Riskler

Plastik atıkların bir kısmı geri dönüştürülebilmekte, bir kısmı ise enerji geri dönüşümü için kullanılmaktadır. Geri kalan kısmı ise çöp alanlarına atılmaktadır. Bu eğilimin bu yönde devam etmesi halinde 2050 yılına kadar 12.000 Mt plastiğin çöplüklerde ve doğal ortamlarda bulunulacağı tahmin edilmektedir (Malankowska et al., 2021).

Boyutları 5 mm'den küçük olan plastik taneciklere mikroplastik denilmektedir. Literatürde mikroplastiğin tanımı olarak farklı ifadeler bulunmaktadır. Yaygın olarak kabul edilen görüş ise mikroplastiklerin 5 mm'den küçük tanecikler olduğu yönündedir. Yapılan çalışmalardan birinde yapılan bir diğer tanım ise elekten geçip geçememe durumu olarak belirtilmiştir. Başka bir tanımda ise mikroplastikler *Birincil ve ikincil kaynaklardan gelen 1 µm - 5000 µm boyutları arasında yer alan ve suda çözünmeyen polimer parçacıklar* olduğunu ifade etmiştir (Yurtsever, 2019; Soysal, 2024). Mikroplastikler oluşum biçimlerine göre birincil ve ikincil olmak üzere iki temel sınıfa ayrılmaktadır. Birincil mikroplastikler, üretim süreçleri sırasında doğrudan mikro boyutta üretilen parçacıklardır; kozmetik ürünlerde kullanılan aşındırıcı tanecikler, ilaç taşıyıcı sistemler ve çeşitli mühendislik uygulamalarında tercih edilen mikro boyutlu polimerler bu gruba örnek gösterilebilir. Endüstriyel kaynaklı bu mikroplastiklerin arıtma sistemleriyle uzaklaştırılması çoğu zaman güçtür. İkincil mikroplastikler ise daha büyük plastik materyallerin rüzgâr, güneş ışığı, sıcaklık değişimleri ve mekanik aşınma gibi çevresel etmenler altında zamanla parçalanması sonucu ortaya çıkmaktadır. (Can, 2022; Ding et al., 2022).

Mikroplastik Kaynakları

Tarımsal uygulamalardan kaynaklanan mikroplastik kirliliğinin en önemli kaynaklarından biri malçlama uygulamalarıdır. Tarımsal alanlarda yabancı ot kontrolü, toprak neminin korunması, sıcaklık düzenlenmesi ve verim artışı gibi amaçlarla yaygın biçimde kullanılan malç örtülerinin

büyük çoğunluğu düşük yoğunluklu polietilen temellidir. Bu plastik örtüler, tarla koşullarında uzun süre güneş ışığına maruz kalma, sıcaklık dalgalanmaları, yağış, rüzgâr ve toprağın fiziksel etkileri gibi çevresel stres faktörlerine dayanarak zamanla fotooksidasyon, termal bozunma ve mekanik aşınma süreçlerine uğrar. Bu süreçler polietilen yapının giderek zayıflamasına ve örtünün önce küçük parçacıklara, daha sonra da mikroplastik boyutuna ayrışmasına yol açmaktadır. Malçların genellikle hasat sonrası topraktan tam olarak kaldırılamaması, parçalanmış plastik kalıntılarının toprakta birikmesine ve uzun vadede toprak ekosistemlerine, mikroorganizmalara, bitki büyümesine ve nihayetinde gıda zincirine geçebilecek mikroplastik yükünün artmasına neden olmaktadır. Bu durum, tarımsal üretimde plastik kullanımının sürdürülebilirliği ve toprak sağlığı açısından önemli çevresel riskler doğurmaktadır. (Garua & Sharma, 2021; Arı ve Öğüt, 2021).

Tarım topraklarına mikroplastik taşınımında birçok faktör önemli bir kaynak oluştursa da malçlama dışında pek çok makroplastik zamanla mikroplastiklere dönüşerek toprağın kirlenmesine katkıda bulunmaktadır. Tarımsal üretimde yoğun olarak kullanılan plastik sulama boruları, seracılıkta kullanılan örtüler, fide tepsileri, bitki destek materyalleri ve ambalaj malzemeleri zaman içinde güneş ışığı, sıcaklık değişimleri, rüzgâr etkisi ve mekanik aşınma gibi çevresel faktörlerle parçalanarak küçük plastik parçalara ayrılmaktadır. Bunun yanı sıra, tarım alanlarına yakın bölgelerdeki plastik ambalaj atıkları, paketleme malzemeleri, plastik ipler, ağlar ve tarım makinelerinde kullanılan plastik aksamların aşınması da toprağa plastik parçacık taşınmasına yol açmaktadır. (Zhang et al., 2022).

Mikroplastiklerin Bitki Üzerindeki Etkileri

Toprağa karışan farklı türdeki mikroplastiklerin (membranöz polietilen, lifli polipropilen, mikroküre polipropilen) toprak enzim aktiviteleri ve mikrobiyal topluluklar üzerindeki etkileri değerlendirildiğinde 14. günde Lifli polipropilen, bakteri miktarını kontrol gurubuna göre düşürmüştür. Plastik yüzeylerinin topraktan farklı, kendine özgü bir habitat oluşturduğunu da ortaya koymuştur. Plastik yüzeylerde bulunan mikrobiyal topluluklar topraktaki mikrobiyal topluluklara göre belirgin şekilde farklılaşmıştır. Özellikle Actinobacteria ait cinsler (*Aeromicrobium, Streptomyces, Mycobacterium, Janibacter, Nocardia, Arthrobacter*) plastik yüzeylerine yerleşme eğilimi göstermiştir. Bu durum, plastiklerin zararlı mikroorganizmaları taşıyabilecek bir vektör görevi görebileceğini düşündürmektedir (Yi et al., 2021).

Mikroplastiklerin bitkiler üzerinde olumsuz etkileri incelendiğinde bitki büyümesini etkileyerek genel biyokütleyi azaltabilir, kök ve sürgün gelişimini engelleyebilir, yaprak gelişimini olumsuz etkileyebilir, çimlenmeyi inhibe edebilir, oksidatif strese neden olabilir, fotosentez ve klorofil üzerinde negatif etki gösterebilir, metabolik ve genetik bozulmalara sebebiyet verebilir, besin ve su alımı dengelerini bozabilir, toprağa olan etkilerinden dolayı dolaylı olarak mikrobiyal ve enzimatik aktiviteyi bozabilir, toksik maddelere vektörlük edebilir, zararlı katkı maddeleri ve biyobozunur mikroplastikler için zararlı yan ürünler toprağa salınabilir. Ayrıca mikroplastikler besin zincirine karışarak insan sağlığını riske atabilir (Akça et al., 2024; Colzi et al., 2022; Li et al., 2022; Wang et al., 2021; Yi ve ark., 2021; Yu et al., 2025).

Fitoremediasyon

Fitoremediasyon, bitkilerin kullanılması yoluyla toprak veya su vb. ortamlarında bulunan kirleticilerin uzaklaştırılması, dönüştürülmesi, azaltılması ya da etkisiz hâle getirilmesini hedefleyen bütüncül teknikler bütünü olarak tanımlanmaktadır. Bu yöntem, alternatif fiziksel ve kimyasal arıtım yöntemleriyle karşılaştırıldığında oldukça düşük maliyetlidir; geleneksel kirlilik giderim tekniklerinin maliyetinin yalnızca küçük bir bölümüne karşılık gelmekte ve yoğun iş gücü gereksinimi duymamaktadır. Bunun yanında, uygulama sahasında estetik bir görünüm oluşturması ve kamuoyu tarafından daha kolay kabul görmesi önemli avantajlar

arasındadır. Fitoremediasyonun yerinde uygulanması, kirleticilerin başka ortamlara taşınmasını engelleyerek ikincil kirlilik riskini azaltmakta; ayrıca yalnızca tek bir kirleticiyle sınırlı kalmayıp çoklu kirleticilerin eş zamanlı giderimine imkân tanımaktadır. Bu özellikleri fitoremediasyonu, çevresel kirleticilerin sürdürülebilir yönetiminde etkili ve tercih edilen bir yöntem hâline getirmektedir (Adiloğlu, 2018; Adiloğlu ve Gürgan, 2020). Fitoremediasyon teknolojisi 9 başlık altında; fitoekstraksiyon, rizofiltrasyon, fitostabilizasyon, rizodegredasyon, fitodegredasyon, fitovolatilizasyon, hidrolik kontrol, vejatatif örtü sistemleri ve kıyı tampon şeritleri olarak sıralanabilir (Hamutoğlu et al., 2012; Sertkahya, 2025).

Fitoremediasyon Teknolojileri

Fitoekstraksiyon (fitoakümülasyon, fitoabsorpsiyon veya fitosekestrasyon olarak da bilinir); kirleticilerin bitki kökleri tarafından kirletici ortamdan alınarak bitkinin toprak üstü biyokütlesine ya da başka bir deyişle sürgünlere taşınması, burada biriktirilmesi ve ardından hasat edilerek uzaklaştırılması işlemidir. Bu yöntem toprak, sediment ve çamurda uygulanan, kirleticilerden metaller, metalloidler ve radyonükleidlerin giderimini sağlamak amacıyla kullanılan, kirleticiyi alma ve uzaklaştırma amaçlı tekniktir. Bu teknikte kullanılan bitkilere; hindistan hardalı, *pennycress alyssum*, ayçiçeği ve hibrit kavaklar örnek olarak gösterilebilir (Hamutoğlu et al., 2012; Wang et al., 2021; Sertkahya, 2025).

Rizofiltrasyon, sucul ve karasal ortamdaki kirletici maddelerin bitki köklere tarafından absorplanarak çöktürülmesidir. Kirleticiler ya bitki kökleri tarafından emilmekte ya da kökün yüzeyinde absorbe edilmektedir. Bu teknik, özellikle yeraltı sularının kirleticilerden arındırılmasında etkilidir. Rizofiltrasyon; yüzey ve yer altı suyunda uygulanan, kirleticilerden metaller ve radyonükleidlerin giderimini sağlamak amacıyla kullanılan, kirleticiyi alma ve uzaklaştırma amaçlı yöntemlerdendir. Bu teknikte kullanılan bitkilere; ayçiçeği, hindistan hardalı ve su sümbülü örnek olarak gösterilebilir (Doğan, 2017; Hamutoğlu et al., 2012; Sertkahya, 2025).

Fitostabilizasyon, topraktaki kirleticilerin bitki kökleri tarafından absorbe edilerek immobilize edilmesi ya da başka bir deyişle köklere sabitlenmesidir. Bu yöntemle kirletici maddelerin taşınımı engellenmektedir. Hg, Cd, Pb, Cu gibi metallerce kirlemiş toprakların onarımı bu yöntemle yapılabilmektedir. Toprak, sediment ve çamurda ortamına kontamine, kirleticilerden As, Cd, Cr, Cu, Hs, Pb ve Zn giderimini sağlamak amacıyla kullanılan Fitostabilizasyon, kirleticiyi etkisizleştirme amaçlı kullanılmaktadır. Bu teknikte kullanılan bitkilere; hindistan hardalı, hibrit kavaklar ve çimler örnek olarak gösterilebilir (Aybar et al., 2015; Adiloğlu, 2018; Sertkahya, 2025).

Rizodegredasyon, bitki kökleri ve bu köklerde bulunan çeşitli mikroorganizmaların metabolik faaliyetleri sonucunda ortamdaki organik kirleticilerin bozunuma uğratarak giderimidir. Petrollü ve aromatik hidrokarbonlar, klorlu çözücüler, pentaklorofenol, poliklorinatlı bifeniller, benzen, etilbenzen, tolüen, ksilen ve pestisitler gibi organik kökenli kirletici bu yöntem ile etkisiz hale getirilmektedir. Toprak ve yer altı suyunda uygulanan, kirleticilerden organik bileşiklerin giderimini sağlamak amacıyla kullanılan, kirletici gidermeyi hedeflemektedir. Bu teknikte kullanılan bitkilere; kırmızı dut ve çimler örnek olarak gösterilebilir (Doğan, 2017; Tiryaki & Potur, 2017; Adiloğlu, 2018)

Fitodegredasyon, ya da diğer bir adıyla fitotransformasyon kirleticilerin bitki bünyesinde metabolik aktiviteler sonucunda daha az zararlı bir forma dönüştürülme işlemidir. Bu yöntemle toprak, sediment, çamur ya da yer altı sularındaki pestisitler, klorlu birleşikler ya da fenol birleşiklerin giderilebilmektedir. Kirleticilerin kontamine olduğu ortamlar, toprak, sediment, çamur, yer altı suyu ve yüzey suyunda uygulanan, kirleticilerden organik bileşikler, klorinat çözücüler, herbisitler ve fenollerin giderimini sağlamak amacıyla kullanılan, kirletici giderme

amaçlı tekniktir. Bu teknikte alg, hibrit kavaklar, siyah söğüt ve servi kullanılabilmektedir (Hamutoğlu et al., 2012; Tiryaki & Potur, 2017; Sertkahya, 2025).

Fitovolatilizasyon, organik ve inorganik kirleticilerin ortamdan alınarak bitki bünyesinde daha az toksik bir forma dönüştürülmesi ya da aynı formda atmosfere salınımıdır. Fitovolatilizasyon; toprak, sediment, çamur ve yer altı suyunda uygulanan, kirleticilerden klorinat çözücüler ve bazı inorganiklerin (Se, Hg, As) giderimini sağlamak amacıyla kullanılan, kirleticiyi buharlaştırma amaçlı uygulanmaktadır. Bu teknikte kullanılan bitkilere; kavaklar, yonca ve hindistan hardalı örnek olarak gösterilebilir. (Sangeeta Mukhopadhyay & Maiti, 2010; Adiloğlu, 2018).

Hidrolik kontrol, bitkiler vasıtasıyla yer altı sularındaki kirleticilerin birikimi ve taşmasını önlemek ve veya istenen düzeyde tutmak için uygulanan yöntemi ifade etmektedir. Hidrolik kontrol yönteminde yeşil ıslak yöntemlerinin birden fazlası aynı anda kullanılır. Avantajı ıslah etki alanının çok geniş olmasıdır. Mevsim ve iklim şartlarına göre su alınımının değişmesi ise bu yöntemin dezavantajı olarak öne çıkmaktadır. Yüzey suyu ve yer altı suyunda uygulanan, kirleticilerden suda çözünen organik ve inorganiklerin giderimini sağlamak amacıyla kullanılan, kirletici bozunumu amaçlamaktadır. Bu teknikte kullanılan bitkilere; hibrit kavaklar ve söğüt örnek olarak gösterilebilir (Vanlı, 2007; Hamutoğlu et al., 2012; Adiloğlu, 2018; Sertkahya, 2025)

Vejetatif örtü sistemleri, toprak içindeki kirleticilerin yüzeydeki bitki sistemi ile kontrol edilmesi işlemidir. Bu yöntem topraktaki su kaybını azaltmayı ve su tutumunu maksimize etmeyi amaçlar ve yeşil ıslah amacıyla kullanılmaktadır. Sistem bitkiyi bir örtü olarak kullanarak su infiltrasyonunu azaltır ve alt tabakalarda bulunan kirliliği oluşturan maddelerin bozunuma uğratmaktadır. Suyun dikey akışının toprak altındaki kirleticiye ulaşımının bitki tarafından engellenmesini sağlayan vejetatif örtü sistemleri; toprak, sediment ve çamurda uygulanan, kirleticilerden organik ve inorganik bileşiklerin giderimini sağlamak amacıyla kullanılan, erozyon kontrolü içinde kullanılmaktadır. Bu teknikte kullanılan bitkilere; kavaklar ve çimler örnek olarak gösterilebilir (Adiloğlu, 2018; Yeşilyurt & Gurgan, 2023)

Kıyı tampon şeritleri, akarsulara doğru akmakta olan yer altı suları ve yüzey sularındaki kirletici faktörlerin giderimini sağlamak için kıyı boyunca şeriler şeklinde bitkilerin ekimidir. Bu yöntemde amaç kirliliğin çevreye ve taban sularına bulaşını önlemektir. Yapılan bazı çalışmalara göre buffer strips yöntemi toprak erozyonunu %90 seviyesinde azaltmış ve herbisit akışını %42-70 oranlarında önlemiştir. Ek olarak suda bulunan sediment, fosfor, azot, fekal koliformlar ve pestisitlerde de azalma meydana gelmiştir. Kirleticilerin su ile dere vb. akarsulara taşınmasının engellenmesini sağlayan kıyı tampon şeritleri; yüzey ve yer altı suyunda uygulanan, kirleticilerden suda çözünen organik ve inorganiklerin giderimini sağlamak amacıyla kullanılan, kirletici gidermeyi amaçlamaktadır. Bu teknikte kavaklar kullanılabilmektedir (Vanlı, 2007; Hamutoğlu et al., 2012; Adiloğlu, 2018; Yeşilyurt, 2023).

Akümülatör Bitkiler

Akümülatör bitkiler, yüksek kirletici konsantrasyonunun olduğu alanlarda yetişebilen ve bu kirleticileri kökleri aracılığıyla kök ya da diğer doku ve organlarında depolayabilen bitkilere akümülatör ya da hiperakümülatör bitkiler denir (Güneş & Bozkurt, 2021).

Fitoremediasyon teknolojilerinde akümülatör bitki olarak Poaceae, Brassicaceae, Fabaceae, Salicaceae, Asteraceae, Chenopodiaceae, Cyperaceae, Careophylaceae, Cannabaceae, Amaranthaceae, Cannaceae, Pontederiaceae ve Typhaceae; familyaları en çok kullanılan familyalardır. Her bir familya grubu kendi içinde avantaj ve dezavantajlara sahiptir. Kontamine olan alanlarda giderim yapılacak alana göre uygun familya seçimi yapılarak fitoremediasyon yöntemleri uygulanır. (Gawronski & Gawronska, 2007).

Fitoremediasyon çalışmalarında hem otsu hem de odunsu pek çok bitki türü ağır metal, organik kirletici ve besin fazlalığı gibi çevresel sorunların giderilmesinde etkin rol oynamaktadır. Derin ve yoğun kök yapısına sahip Vetiver grass (*Vetiveria zizanioides*), ağır metal toleransı yüksek olması nedeniyle geniş çaplı toprak iyileştirme uygulamalarında öne çıkarken; Bermuda grass (*Cynodon dactylon*), Bahia grass (Paspalum notatum) ve Switch grass (*Panicum virgatum*) gibi çim türleri hem metal stabilizasyonunda hem de hidrokarbon bozunumunda kullanılan dayanıklı türlerdir. Ağır metal fitoekstraksiyonunda klasik model bitkilerden olan Sunflower (*Helianthus annuus*) ve Indian mustard (*Brassica juncea*) özellikle Pb, Cd ve Zn gibi toksik elementleri bünyelerine alma kapasiteleriyle dikkat çekmektedir. Benzer şekilde Periwinkle (*Catharanthus roseus*), Nightshade (*Solanum nigrum*) ve Lambsquarters (*Chenopodium berlandieri*) gibi türlerin hiperakümülatör özellikleri, kirlenmiş alanların hedef metal seçiciliği gerektiren iyileştirme çalışmalarında önem taşımaktadır. Sulak alan ve atıksu arıtımında yaygın kullanılan *Typha angustifolia, Eichhornia crassipes, Lemna minor* ve *Phragmites australis* gibi hidrofiller hem ağır metalleri hem de organik kirleticileri yüksek verimle uzaklaştırma yetenekleri sayesinde doğal arıtma sistemlerinin temel bileşenleri hâline gelmiştir. Odunsu türlerden Poplar (*Populus* spp.), hızlı büyümesi ve kök bölgesinde organik kirleticilerin biyodegradasyonunu hızlandırması nedeniyle özellikle klorlu solvent ve petrol türevlerinin bulunduğu alanlarda kullanılmaktadır. Ayrıca *Kochia scoparia, Hordeum jubatum, Andropogon gerardii, Sorghastrum nutans, Elymus canadensis, Agropyron cristatum, Festuca arundinacea, Thinopyrum elongatum* ve *Chloris gayana* gibi kuraklığa ve tuzluluğa dayanıklı türler, ağır metalce zengin bozulmuş topraklarda bitkisel örtünün yeniden tesis edilmesine katkı sağlamaktadır. Besin fazlasının uzaklaştırılması ve toprak kalitesinin yükseltilmesi açısından *Medicago sativa, Lathyrus sylvestris* gibi baklagiller ile *Daucus carota* gibi bazı tarımsal türler de hem fitostabilizasyon hem de toprak-biyota etkileşimlerini düzenlemede önemli bir ekolojik işlev üstlenmektedir. Bu geniş tür çeşitliliği, fitoremediasyonun farklı kirletici türlerine ve farklı ekosistem koşullarına uyarlanabilir, maliyeti düşük ve çevre dostu bir biyoteknoloji olduğunu açıkça göstermektedir (Sinha et al., 2007; Adiloğlu and Pamay, 2021; Yeşilyurt, 2023).

Mikroplastiklerin, bitki kökleri tarafından emilerek toprak üstü aksamlara taşınabileceğini de belirterek, topraklardan mikroplastik gideriminin kök immobilizasyonu ya da ekstraksiyonu yoluyla mümkün olduğunu savunmuşlardır. Kök immobilizasyonunun mikroplastikleri ortamdan uzaklaştırmadığını ancak hareketliliklerini sınırlayarak biyoyararlanımlarını azalttığını ve ekolojik riskleri düşürdüğü ifade edilmiştir. Su ortamlarında bulunan *Thalassia testudinum, Lemna minor, Fucus vesiculosus* gibi su bitkilerinin mikroplastikleri absorbe ederek hareketliklerini sınırlandığını çalışmalarında belirtmişlerdir. Mikroplastik gideriminde ekstraksiyonun (fitoekstraksiyon), immobilizasyonun aksine mikroplastikleri ortamdan uzaklaştırdığını ifade edilmiştir. Yabani otlar ve su mercimeği (*Lemna minor*) gibi vasküler bitkilerin mikroplastikleri biriktirilebildiği ve plastik ayrıştırıcı mikroorganizmaların mikroplastik yüzeylerinde kolonize olarak mikroplastiklerin karbon omurgalarını depolimerize ettiğini, mikrobiyal olarak güçlendirilmiş fitoremediasyon yöntemi ile mikroplastik gideriminde kullanılabileceğini belirtmişlerdir (Li et al., 2024)

SONUÇ

Mikroplastiklerin tarım topraklarına karışması, yalnızca toprak yapısını ve ekolojik fonksiyonları bozmakla kalmayıp, bitkilerin kök bölgesine, tarımsal ürünlere ve çeşitli canlılara geçişiyle birlikte besin zinciri boyunca ilerleyen ciddi bir çevresel ve sağlık sorununa dönüşmektedir. Mikroplastiklerin insan vücuduna kadar taşınabilmesi ve çeşitli fizyolojik ile metabolik sorunlara yol açabilmesi, bu kirliliğin göz ardı edilemeyecek kadar önemli olduğunu açıkça göstermektedir. Ancak literatür incelendiğinde, mikroplastiklerin topraktan giderimine yönelik çalışmaların sınırlı olduğu ve özellikle bitki temelli arıtım yaklaşımlarının yeterince

araştırılmadığı görülmektedir. Oysa fitoremediasyonun bilinen mekanizmaları ve akümülatör bitkilerin kirletici biriktirme kapasitesi dikkate alındığında, bu bitkilerin topraktaki mikroplastiklerin azaltılmasında potansiyel bir çözüm sunabileceği anlaşılmaktadır. Bu çalışma, akümülatör bitkilerin mikroplastik kirliliğinin gideriminde kullanılabileceğine ilişkin bilimsel bir farkındalık oluşturmuş ve bu alandaki bilgi eksikliğine dikkat çekmiştir. Gelecekte yapılacak kapsamlı deneysel çalışmaların, mikroplastik-fitoremediasyon ilişkisini daha iyi aydınlatması, yöntemlerin geliştirilmesi ve sürdürülebilir tarım uygulamalarına katkı sağlaması beklenmektedir. Böylece toprak ekosistemlerinin korunması ve insan sağlığının güvence altına alınması adına önemli ilerlemeler kaydedilebilecektir.

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EVALUATION OF TRANSITION EFFORTS OF TÜRKİYE TO ORGANIC AGRICULTURE: AN APPLICATION WITH THE MSD BASED RAWEC METHOD

Assoc. Prof. Dr. Semin TOPALOĞLU PAKSOY

Çukurova University, Faculty of Economics and Administrative Sciences, Department of Econometrics, Adana-Türkiye

ORCID ID: https://orcid.org/0000-0003-1693-0184

Dr. Emine Kokaçya DUVAN

Scientific Researcher, Kadirli/Osmaniye-Türkiye

ORCID ID: https://orcid.org/0000-0002-9180-9651

ABSTRACT

In recent years, the negative effects of industrial agriculture on the environment and health and the problems originating from climate change, in addition to the already emerging major problem of habitat loss, have led to an increase in global problems such as poverty, difficulty in accessing food, hunger and inadequate and/or unhealthy nutrition. These destructions demonstrate the importance and necessity of protecting ecological resources, necessary to continue food production in the future. Organic agriculture stands out as an alternative solution to these problems. Because organic agriculture is a form of agricultural production that does not harm human health and the environment and does not use chemical inputs in production. Therefore, it aims to produce high-quality and nutritious food that contributes to preventive health services and well-being. Therefore, the aim of the current study is to analyse Türkiye's performance in organic agriculture since the year 2019. Data for the period 2019-2023 was considered. The analysis is conducted using the RAWEC method, which is one of the MCDM methods. For the method, countries that have applied to become members of the EU are selected as alternatives and as the indicators; organic farming area, organic area share of total agricultural land, number of organic producers and processors, pesticide use per capita, and agricultural production use per value were determined. The analysis results show that there have no any changes in the rankings of candidate countries' performance for the period 2019-2023. While Türkiye maintains its first-place position in all years, its RAWEC score decreased the most in 2023 compared to 2019. Albania, while the country with the greatest performance improvement, has not made significant progress in changing its ranking. This situation highlights the need for candidate countries to embrace the organic production, and to allocate resources to all strategies and training to ensure compliance. Both the supply and demand for organic agriculture in our country must increase, and access to healthy food must be ensured and expanded. Turkey's efforts to adapt to EU norms in this regard will be a valuable opportunity to protect its ecology and develop its foreign trade.

Keywords: Organic agriculture, RAWEC method, modified standard deviation procedure, comparison analysis, performance evaluation

ÖZET

Son yıllarda, endüstriyel tarımın çevre ve sağlık üzerindeki olumsuz etkileri ve iklim değişikliğinden kaynaklı sorunlar, habitat kaybı olarak şimdiden ortaya çıkan büyük sorunun yanı sıra, küresel ölçekte karşılaşılan yoksulluk, gıdaya erişim zorluğu, açlık ve yetersiz ve/veya sağlıksız beslenme gibi sorunların giderek artmasına neden olmaktadır. Bu tahribatlar, gelecekte gıda üretimini devam ettirmede gerekli olan ekolojik kaynakları korumanın önemini ve gerekliliğini göstermektedir. Organik tarım bu sorunlara bir çözüm alternatifi olarak öne çıkmaktadır. Çünkü organik tarım, insan sağlığına ve çevreye zarar vermeyen ve üretimde kimyasal girdi kullanılmadan tarımsal üretim yapma biçimidir. Bu nedenle üretimde, koruyucu sağlık hizmetlerine ve refaha katkıda bulunan yüksek kaliteli ve besleyici gıda üretmeyi amaçlamaktadır. Bu nedenle mevcut çalışmanın amacı, Türkiye'nin organik tarım konusunda sergilediği performansı, 2019 yılından itibaren analiz etmektir. Analizde 2019-2023 dönemine ait veriler ele alınmıştır. ÇKKV yöntemlerinden biri olan RAWEC yöntemi ile yapılan analizlerde, alternatif olarak AB'ye üye olmak üzere başvuruda bulunmuş ülkeler; kriter olarak da bu ülkelere ait olan; Organik tarım alanı, Toplam tarım arazisinin organik alan payı, Organik üretici ve Organik işlemci sayısı, Kişi başına pestisit kullanımı ve Tarımsal üretimin değer başına kullanımı göstergeleri belirlenmiştir. Analiz sonuçları, 2019-2023 periyodunda aday ülke performanslarının sıralamalarında hiç bir değişikliğin olmadığını göstermektedir. Türkiye, birinci sıradaki konumunu korumakla birlikte, 2019 yılına göre 2023 yılında RAWEC skoru en fazla zayıflayan ülke olmuştur. Arnavutluk, performansını en fazla artıran ülke olmakla beraber sıralamasını değiştirebilecek bir ilerleme kaydedememiştir. Bu durum, aday ülkelerin organik üretim gibi güncel tarımsal üretim anlayışını benimsemesi ve bunlara uyulması konusunda her türlü strateji ve eğitime kaynak ayırması gerektiğini vurgulamaktadır. Organik tarım arzı kadar talebinin de ülkemizde artması, sağlıklı gıdaya erişimin sağlanması ve yaygınlaştırılması gerekmektedir. Türkiye'nin bu konuda AB normlarına adapte olmaya çaba sarf etmesi, sahip olduğu ekolojisini koruma ve dış ticaretini geliştirme açısından değerli bir fırsat olacaktır.

Anahtar Kelimeler: Organik tarım, RAWEC yöntemi, modifiye edilmiş standart sapma prosedürü, karşılaştırma analizi, performans değerlendirme

GİRİŞ

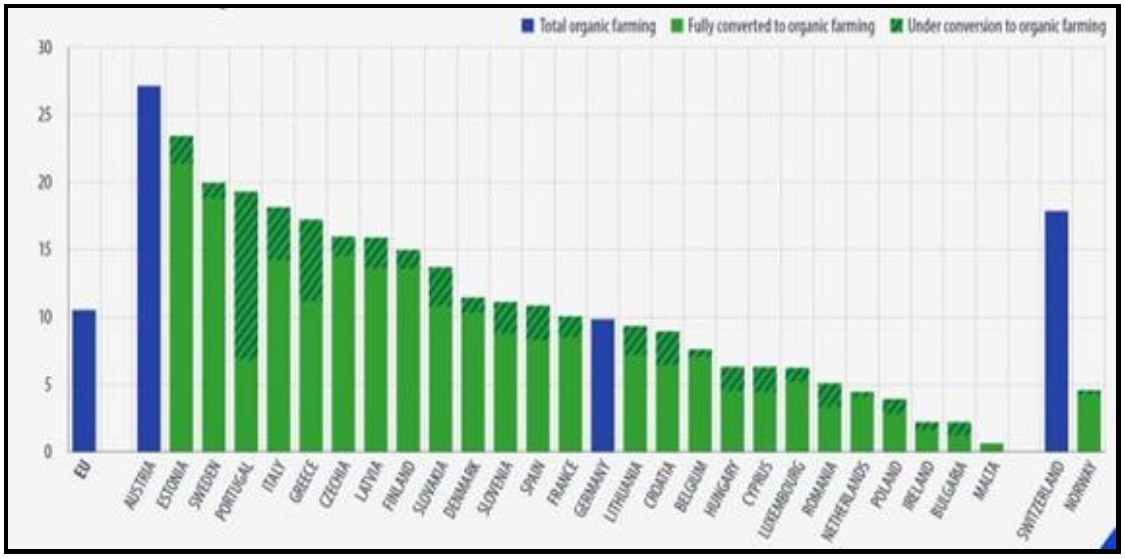
Organik tarım; toprakların, ekosistemlerin ve insanların sağlığını koruyan bir üretim sistemidir. Zira olumsuz etkileri olan girdileri kullanmak yerine, yerel koşullara uyarlanmış ekolojik süreçlere, biyoçeşitliliğe ve döngülere dayanmaktadır. Organik tarım; gelenek, yenilik ve bilimi bir araya getirerek tüm paydaşlar için adil ve faydalı ilişkiler sağlamaktadır (IFOAM General Assembly, 2008). Organik tarım ile toprak, bitki, hayvan, insan ve gezegenin sağlığı bir ve bölünmez bir bütün olarak ele alınmaktadır. Organik tarım, özellikle koruyucu sağlık hizmetlerine ve refaha katkıda bulunan yüksek kaliteli ve besleyici gıda üretmeyi amaçlamaktadır. Bu bağlamda, olumsuz sağlık etkileri olabilecek gübre, pestisit, hayvansal ilaç ve gıda katkı maddelerini kullanmaktan vazgeçilmelidir (IFOAM General Assembly, 2008). 2023 yılında tarımda kullanılan toplam pestisit miktarı 3,73 milyon ton aktif bileşend2 katı artık söz konusudur en oluşmakta olup, 2022'ye kıyasla %2 azalma olmuştur. Ancak, on yılda %14 artış, 1990 yılına kıyasla 2 katı olduğu görülmektedir (FAO, 2023).

Organik tarım gibi tarımda sürdürülebilir sistemler, büyüyen bir nüfus için sağlıklı, besleyici gıdalar ve diğer doğal ürünler üretmek açısından önemlidir. Aynı zamanda çiftçilerin adil bir yaşam sürmelerini, toprak verimlilik ve biyolojik çeşitliliği yenilemelerini ve artırmalarını, kıt su kaynaklarını korumalarını ve yenilemelerini, iklim değişikliğini azaltmalarını ve olumsuz

etkilenen insanların iklim değişikliğine uyum sağlamalarına ve daha dirençli hale gelmelerine yardımcı olurlar (IFOAM Organics International, 2025b).

Tüm dünya ülkelerinin pek çoğunda olduğu gibi Avrupa Birliğinde (AB) de organik tarıma önem verilmekte ve birlik ülkelerinin uyması için geliştirilen standartlar ve yaptırımlar ile güçlü bir şekilde desteklenmektedir (Çukur ve Işın, 2024). AB Ortak Tarım Politikası, tarımda çevresel, ekonomik ve sosyal sürdürülebilirliği sağlamak amacıyla tek Avrupa kıtası felsefesine uygun olarak geliştirilen bir politikadır (European Commission, 2020). Özellikle 2004 yılındaki AB genişleme sürecinde, Orta ve Doğu Avrupa ülkelerinin de birliğe katılmaları sonucunda, birlik üyeleri arasında ekonomik ve sosyal konular başta olmak üzere her alanda farklılıklar büyümüştür. Özellikle bu tarihten itibaren, artan farklılıkları ortadan kaldırmak amacıyla üye ülkelerden, geliştirilen ülke stratejileri doğrultusunda ilerleme kaydetmeleri ve sürdürülebilir kalkınma hedeflerine uyum sağlamaları beklenmektedir. Ayrıca, uyum çalışmalarında etkili ilerlemelerin sağlanması amacıyla üye ülkelerin 2024 yılı itibarıyla yıllık performans raporu sunmaları ve Komisyon ile yıllık inceleme toplantısı yaparak gerektiğinde specifik takip eylemleri talep edilecektir (European Commission, 2023).

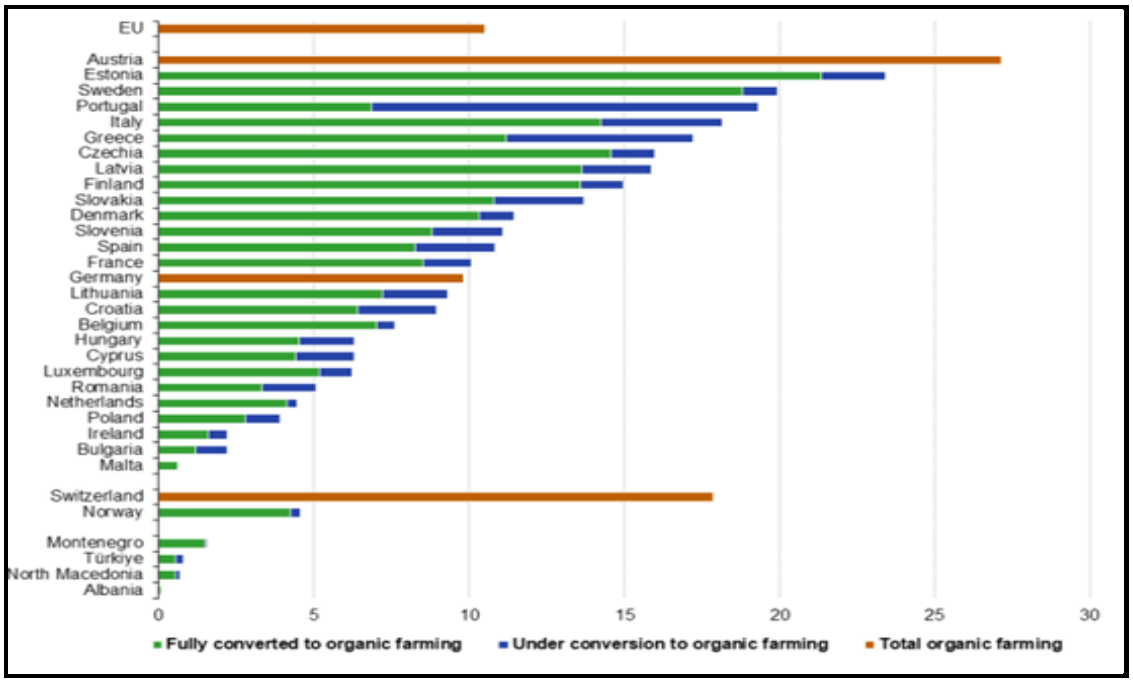
AB ülkelerinin, toplam tarım arazisinin organik alan payı bilgisi aşağıda Şekil 1 ile gösterilmektedir. Ekonomik olarak gelişmiş AB ülkelerinin bazılarının (Lüksemburg, Hollanda ve İrlanda gibi) AB ortalamasının altında kaldığı görülmektedir. Şekil 1'de pek çok üye ülkenin AB ortalaması üstünde tam organik tarımı yakaladığı, ancak 2004 genişleme sürecinde üye olan ülkelerin (Polanya, Romanya ve Malta gibi) bu seviyenin altında kaldığı; 2013 yılında birliğe üye olan Hırvatistan'ın ise AB ortalamasına yaklaşarak iyi performans sergilediği görülmektedir.



Şekil 1. AB üye ülkelerinde toplam tarım arazisinde organik tarım alan payı (2022)

Kaynak: Eurostat, 2024

Şekil 2'de yeşil renk, organik tarıma geçilmiş alanı; mavi renk organik tarıma geçilmekte olan alanı ve kırmızı renk organik tarıma tamamen geçilmiş alanları göstermektedir. Türkiye'nin ise AB üye ülkelerinin çok gerisinde olduğu ve aday ülkeler klasmanında yer aldığı görülmektedir. Avusturya ve İsviçre'nin tamamen organik tarıma geçen alanı çok yüksek olan ülkeler olarak öne çıktığı görülmektedir. Türkiye'nin ise Malta ve Kuzey Makedonya'nn önünde, sondan 3. sırada yer aldı görülmektedir.



Şekil 2. AB üye ve bazı aday ülkelerinin toplam tarım arazisinde organik tarım alanı payı (2022)

Kaynak: Eurostat, 2024.

Sürdürülebilir tarımsal gıda sistemlerini geliştirmek için Gıda ve Tarım Örgütü (FAO) ile stratejik ortaklığı bulunan IFAOM – Organics International'a göre dünya, küresel ölçekte yoksulluk, gıdaya erişim zorluğu ve hatta açlık ve yetersiz beslenme ile karşıya karşıya kalmıştır. Dünyada 800 milyondan fazla insan açlıkla karşı karşıya kalmakta ve yaklaşık 2 milyar insan yetersiz beslenmektedir. Küresel yetişkin nüfusun yaklaşık %30'u aşırı kilolu veya obez ve dünya çapında üretilen gıdanın yaklaşık %30'u da israf edilmektedir. İklim değişikliğinden kaynaklı sorunların yanı sıra endüstriyel tarımın çevre ve sağlık üzerindeki olumsuz etkileri ile doğa, insanlık tarihinde eşi benzeri görülmemiş ölçüde tahrip olmaya devam etmekte, ekilebilir alanlar azalmaktadır (IFOAM Organics International, 2025a). Bunların sonucu olarak çiftçilere makul bir gelir sağlayamama ve fosil yakıtlara yüksek derecede bağımlılık şeklinde ortaya çıkan sorunlar nedeniyle tarımda değişime olan ihtiyaç meydana gelmiştir. Ayrıca şimdi ve gelecekte gıda üretimi için gerekli olan ekolojik kaynakları korumanın gerekliliği zorunluluktur. Bu noktada organik tarım mevcut soruna bir çözüm alternatifi olarak öne çıkmaktadır.

Diğer taraftan AB komisyonu tarafından 2019 yılında kabul edilen Avrupa Yeşil Mutabakatı ile 2050 yılına kadar karbon-nötr hedefi sağlanmaya çalışılmaktadır. Mutabakatta sürdürülebilirliği, çok yönlü ve geniş bir şekilde geliştirilen ortak stratejilerin geliştirilmesi gerektiği prensibine dayanmaktadır. Tek bir kıtanın yalnız başına kurtarılamayacağı ve bu nedenle, özellikle ticarete yaptığı ve üye olmayan ülkelerin de bu felsefeye bağlı olması yönünde kararlar ile stratejik ortaklıkları benimsediği görülmektedir. Bu bağlamda, özellikle aday ülkeler başta olmak üzere AB ile ticaret yapan ülkeleri de kapsayan ve konuyla ilgili yaptırımların takip edilmesi ve uyum çabalarının artırılmasının önemi ortadır.

Bu çalışmada amaç, sürdürülebilirliğin önemli bir parçası olan organik tarımda, Türkiye'nin AB üye ve aday ülkeleri ile muhtemel farklılıkları ortaya çıkarmaya çalışmaktır. Bu bağlamda organik tarım ürünleri üretimi açısından önemli görülen ve erişilebilen değişkenler olarak;

organik tarım alanı, toplam tarım alanın içinde organik üretim yapılan alanın payı, organik tarım üretimi yapan üretici sayısı, organik tarım ürünleri işlemci sayısı, kişi başına düşen pestisit kullanımı ve tarımsal üretimin değer başına kullanımı değişkenleri dikkate alınarak Türkiye ve AB ülkelerinin performansları karşılaştırılmaktadır. Yapılan karşılaştırma ile Türkiye'nin organik tarıma yönelik çabası, objektif bir şekilde değerlendirilebilecektir. Ayrıca göreli olarak yeni bir ÇKKV metodu olan RAWEC yöntemi, bu alanda ilk kez uygulanarak literatüre katkı sağlanması beklenmektedir.

Veri ve Yöntem

Bu araştırmada kullanılan veri, Organik Tarım Araştırma Enstitüsü (Research Institute of Organic Agriculture (FiBL)) ve FAO (Food and Agricultural Organization) istatistik veri tabanından yararlanılmıştır. Çalışmanın yapıldığı dönemde en güncel veri 2023 yılına ait olduğundan, araştırmada 2019-2023 dönemine ait veriler ele alınmıştır. Çalışmada alternatif olarak belirlenen ülkeler Tablo 1, kriter olarak belirlenen değişkenler Tablo 2 ile gösterilmektedir. Çalışmada değişken ve ülkelerde veri kısıtı olmayan kayıtlara yer verilmiştir. Tablo 1'de de görüldüğü üzere Türkiye yaklaşık 40 yıl, Ukrayna ise yaklaşık 4 yıl önce üyelik başvurusu yapmıştır. Bu ülkeler en eski ve en yeni üyelik başvurusunda bulunan ülkeler olarak dikkat çekmektedir.

Tablo 1. AB 'ye aday ülkeler ve üyelik başvuru tarihleri

Ülkeler	***Üyelik Başvuru Tarihi***	***Adaylık Tarihi***	***Müzakerelere Başlama Tarihi***	***Fasıl Sayısı***
Arnavutluk	24 Nisan 2009	27 Haziran 2014	19 Temmuz 2022	-
Bosna - Hersek	15 Şubat 2016	15 Aralık 2022	-	-
Gürcistan*****	3 Mart 2022	14 Aralık 2023	-	-
Karadağ *****	15 Aralık 2008	17 Aralık 2010	29 Haziran 2012	33/3
Kuzey Makedonya	22 Mart 2004	15-16 Aralık 2005	19 Temmuz 2022	-
Moldova*****	3 Mart 2022	24 Haziran 2022	25 Haziran 2024	-
Sırbistan	22 Aralık 2009	1 Mart 2012	21 Ocak 2014	22/2
Türkiye	14 Nisan 1987	11 Aralık 1999	3 Ekim 2005	16/1
Ukrayna	28 Şubat 2022	24 Haziran 2022	25 Haziran 2024	-

*Eksik veri içeren ülkeler **Kaynak:** TC. Dışişleri Bakanlığı (2025).

Tablo 2. Kriter olarak kullanılan değişkenler

Değişken Kodu	**Değişken Açıklaması**	**Birim**
X1	Organik tarım alan	ha
X2	Toplam tarım arazisinin organik alan payı	%
X3	Organik üretici sayısı	Kişi sayısı
X4	Organik işlemci sayısı	Kişi sayısı
X5	Kişi başına pestisit kullanımı	Kg/kişi
X6	Tarımsal üretimin değer başına kullanımı	g/Int$[1]

[1] Toplam üretim miktarı (gr) / Toplam üretim değeri (uluslararası $)

Kaynak: statistics.fibl.org ve fao.org

Modifiye Edilmiş (Değiştirilmiş) Standart Sapma (Modified Standard Deviation -MSD) Prosedürü

Puška vd. (2022) tarafından geliştirilen MSD prosedürü, standart sapma (SD) tekniğinin bir uzantısıdır. SD yaklaşımına iki adım eklenmiştir. İlk adım, sütun toplamını hesaplamaktır. İkinci adım, standart sapma değerini bu göstergeye göre düzeltmektir. Bu prosedür aşağıdaki adımları içermektedir (Puška vd. 2022; Akbulut ve Aydın, 2024):

Adım 1. Karar matrisinin oluşturulması. Karar matrisi Y, Eşitlik (1) ile gösterildiği şekilde oluşturulmaktadır. Matriste m; alternatifleri, n ise kriter sayılarını ifade etmektedir. The decision matrix (Y) is prepared as in Eq. (1). This matrix includes m alternatives, K1,…,Km based on the n criteria, D1,…, Dn.

Y= $\left[y_{ij}\right]_{mxn}$ y_{ij}: i. alternatifin j. kriter altındaki değeridir. (1)

Adım 2. Y matrisi, kriterlerin fayda ve maliyet özellikleri göz önünde bulundurularak, Eşitlik (2) ve (3) yardımıyla normalleştirilmektedir.

$$V_{ij}= \frac{y_{ij}}{\max\{y_{ij}|i=1,2\ldots m\}} \quad \text{fayda kriterleri için} \tag{2}$$

$$V_{ij}= \frac{\min\{y_{ij}|i=1,2\ldots m\}}{y_{ij}} \quad \text{maliyet kriterleri için} \tag{3}$$

Adım 3. Her kriterin standart sapması (σ_n) hesaplanmaktadır.

Adım 4. Sütunların toplamının toplamı hesaplanmaktadır.

Adım 5. Standart sapmanın modifiye edilmiş (düzeltilmiş) değeri, Eşitlik (4) yardımıyla hesaplanmaktadır.

$$\sigma' = \frac{\sigma}{\sum_j^n y_{ij}} \tag{4}$$

Adım 6. Kriterlerin nihai ağırlıkları Eşitlik (5) yardımıyla hesaplanmaktadır.

$$w_j^{MSD} = \frac{\sigma_j'}{\sum_{j=1}^n \sigma_j'} \tag{5}$$

RAWEC Yöntemi

Çok kriterli karar verme (ÇKKV) yöntemlerinden biri olan RAWEC yöntemi, Puška vd.(2024) tarafından literatüre kazandırılan ve hayli yeni olan bir yöntemdir (Akbulut ve Aydın, 2024). Diğer birçok ÇKKV yaklaşımıyla karşılaştırıldığında basit, uygulanması kolay ve etkilidir. Yöntem, çift normalizasyona ve ideal ve anti-ideal değerlerden sapmaların hesaplanmasına dayanmaktadır. Bu yöntem aşağıda verilen işlem adımlardan oluşmaktadır (Puška vd, 2024).

Adım 1. Problemin Eşitlik (1) ile gösterilen karar matrisi oluşturulmaktadır.

Adım 2. Normalleştirilmiş karar matrisi, Eşitlik (6) ve (7) uygulanarak oluşturulmaktadır. Eşitliklerde de gösterildiği üzere karar matrisinin normalleştirilmesinde, çift normalizasyon işlemi uygulanmaktadır.

$$V_{ij}= \frac{y_{ij}}{\max\{y_{ij}|i=1,2\ldots m\}} \text{ ve } V'_{ij}= \frac{\min\{y_{ij}|i=1,2\ldots m\}}{y_{ij}} \text{ fayda kriteri için} \quad (6)$$

$$V_{ij}= \frac{\min\{y_{ij}|i=1,2\ldots m\}}{y_{ij}} \text{ ve } V'_{ij}= \frac{y_{ij}}{\max\{y_{ij}|i=1,2\ldots m\}} \text{ maliyet kriteri için} \quad (7)$$

Adım 3. Kriter ağırlığından sapmayı elde etmek için denklem (8) ve (9) uygulanmaktadır.

$n_{ij}= \sum_{i=1}^{m} w_j \ .(1- V_{ij})$, w_j; j. kriter ağırlığıdır. (8)

$n'_{ij}= \sum_{i=1}^{m} w_j \ .(1- V'_{ij})$ (9)

Adım 4. Her alternatife ait Ω_i değeri Eşitlik (10) yardımıyla hesaplanmaktadır.

$$\Omega_i = \frac{n'_{ij}-n_{ij}}{n'_{ij}+n_{ij}} \quad (10)$$

RAWEC yönteminde $\Omega_i \in [-1,1]$ 'dir. En yüksek Ω_i değerine sahip i. alternatif, en iyi alternatifi göstermektedir.

BULGULAR

Analizde ilk aşamada MSD prosedüründen yararlanılarak her yıl için kriterlerin ağırlıkları hesaplanmıştır. Tablo 3'de 2019-2023 yıllarına ait kriter ağırlıkları gösterilmekte ve ağırlıkların genel olarak her yıl için 0,14-0,20 aralığında yer aldığı görülmektedir. Tüm yıllarda X1 kriterinin en yüksek, X6 kriterinin en düşük önem derecesine sahip olduğu görülmektedir. X2, X3 ve X4 kriterlerinin hemen hemen birbirine yakın önem derecelerine sahip olduğu dikkat çekmektedir.

Tablo 3. Yıllara göre kriter ağırlıkları

Ağırlıklar	X1	X2	X3	X4	X5	X6
$W_j^{MSD-2019}$	0,20	0,17	0,17	0,17	0,15	0,14
$W_j^{MSD-2020}$	0,20	0,17	0,17	0,17	0,15	0,15
$W_j^{MSD-2021}$	0,20	0,16	0,18	0,15	0,16	0,15
$W_j^{MSD-2022}$	0,20	0,17	0,17	0,16	0,16	0,15
$W_j^{MSD-2023}$	0,19	0,16	0,17	0,17	0,16	0,15

Ağırlıkların hesaplanmasından sonra, RAWEC yönteminin işlem adımları uygulanarak kriterler ve hesaplanan ağırlıkları ile ülkeler değerlendirilerek her yıl için RAWEC skorları hesaplanmaktadır. Ülkelerin yıllara göre RAWEC skorlarları (Ωi), Tablo 4'de gösterilmektedir.

Tablo 4. Yıllara göre RAWEC skorları (Ω_i) ve sıralamaları

Ülkeler	Ω_i	$Rank_{2019}$	Ω_i	$Rank_{2020}$	Ω_i	$Rank_{2021}$	Ω_i	$Rank_{2022}$	Ω_i	$Rank_{2023}$
Arnavutluk	-0,60	6	-0,54	6	-0,40	6	-0,54	6	-0,39	6
Bosna Hersek	-0,26	5	-0,21	5	-0,31	5	-0,21	5	-0,24	5
Kuzey Makedonya	-0,06	4	0,03	4	-0,08	4	0,03	4	-0,07	4
Sırbistan	0,00	3	0,07	3	0,05	3	0,07	3	0,03	3
Türkiye	0,60	1	0,57	1	0,45	1	0,57	1	0,42	1
Ukrayna	0,12	2	0,13	2	0,18	2	0,13	2	0,15	2

Sıralamada ilk 3'de yer alan ülkeler; Türkiye, Ukrayna ve Sırbistan'dır. Bu ülkelerin tüm periyod boyunca pozitif, diğerlerinin negatif RAWEC skorlara sahip olduğu görülmektedir. Tüm periyot boyunca en düşük skorları ile 6. sırada yer alan ve istikrarlı bir şekilde RAWEC skorunu artırma trendinde olan tek ülke Arnavutluk'tur. Diğer tüm ülkelerin inişli çıkışlı skorlara sahip olduğu, buna rağmen sıralamadaki konumlarının değişmediği görülmektedir. Bu durum, ülkelerin RAWEC skorları ile kayda değer ilerlemeler sergilemediği ve organik tarıma hak ettiği önemi yeterince vermediğinin bir işareti olarak yorumlanabilir.

SONUÇ ve ÖNERİLER

Analiz sonuçları, 2019 yılından 2023 yılına kadar aday ülke performanslarının sıralamalarında hiç bir değişikliğin olmadığını göstermektedir. Türkiye, birinci sıradaki konumunu korumakla birlikte, 2019 yılına göre 2023 yılında performansı en fazla zayıflayan ülke olmuştur. Arnavutluk performansını en fazla artıran ülke olmakla beraber sıralamasını değiştirebilecek bir ilerleme kaydedememiştir. Bu durum, aday ülkelerin organik üretim konusunda gerek yaptırımlar gerekse bunlara uyulması konusunda her türlü strateji ve eğitime kaynak ayırması, bu konuda AB normlarına adapte olmaya çaba sarf etmesi ekolojiyi koruması ve dış ticaretini geliştirmesi açısından faydalı olacaktır. Özellikle tarımda modern teknolojilere erişimin olmadığı veya zayıf olduğu AB'ye aday olan bu ülkelerde, organik tarımın yaygınlaştırılması, yerel kaynakların optimum kullanılmasına katkı sağlama potansiyeli oluşturacaktır.

Diğer taraftan, iklim krizi aşırı hava dalgalanmalarına sebep olmakta ve giderek tarım için artan bir tehdit oluşturmaktadır. Oysa organik sistemlerin, şiddetli kuraklık ve sel gibi stres koşullarında geleneksel sistemlerle karşılaştırıldığında, iklim değişikliğine karşı daha istikrarlı ve dirençli olduğu görülmektedir. Bu nedenle ülkelerin organik tarım alanında sergiledikleri performansı artırmaları, gerek üretici gerekse tüketiciler açısından fayda sağlayacaktır. Aynı zamanda sağlığının korunması, çevre kirliliğinin önlenmesi gibi faydalı etkileri en büyük kazanç olacaktır. Bu nedenle ülkelerin tarım politikalarında organik tarıma dönüşüm stratejilerini belirlemeleri ve gerekli teşvikleri sağlayarak çiftçilerin organik üretim yapmaları sağlamaları gerekmektedir. Türkiye'nin de, ABD de 1970'de AB üye ülkelerinde 1975-1980 yıllarında başladıkları adaptasyon düzenlemelerini (FAO, 2025), daha fazla gecikmeden çıkarıp uygulamaya başlaması gerekmektedir.

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THE STUDIES ON BOSCALID-RESISTANCE IN *ALTERNARIA* SPP. IN PLANT PROTECTION

Prof. Dr. Aysun CAVUSOGLU

Kocaeli University, Faculty of Agriculture, Department of Plant Protection, 41285, Kocaeli, Türkiye

Prof. Dr. Mehmet Erhan GÖRE

Bolu Abant İzzet Baysal University, Faculty of Agriculture, Department of Plant Protection, 14030, Bolu, Türkiye

ABSTRACT

Boscalid is an active substance as a fungicide, a member of the succinate dehydrogenase inhibiting (SDHI) group in the Fungicide Resistance Action Committee (FRAC) list, and is frequently used in spraying programs in crop protection against Ascomycota members such as *Alternaria* spp.. Resistance towards the active ingredient is an emerging problem in *Alternaria* populations via mutations in some crop cultivars. The *Alternaria* genus includes numerous phytopathogen species that affect a wide range of crops. *Alternaria* spp. are predominantly recognized as necrotrophic pathogens responsible for diseases like early blight, brown spot, leaf and fruit lesions, and necrosis of various plant parts, including underground storage organs. These pathogens, which are mostly anamorphic members of the Ascomycota phylum, exhibit a wide geographical distribution and substantial host diversity. It appears that these studies, on the emerging problem of boscalid-resistance in *Alternaria* spp. in different commercial crops, are beginning to increase. Boscalid resistance issues against the disease, *Alternaria* spp., in plants such as *Solanum lycopercicum*, and *S. tuberosum*, which are members of the Solanaceae family, *Vaccinium* spp., which are members of the Ericaceae family, and *Pistacia vera*, which is a member of the Anacardiaceae family, which are exposed to *Alternaria* spp., have been studied and proven in the scientific field. These studies were conducted *in vitro* and/or *in vivo* environments to evaluate the results of using boscalid alone or in combination with other active substances. In this review article, information about these studies is compiled, the importance of the subject is emphasized, and attention is drawn to the issue of Boscalid resistance.

Keywords: *Alternaria* spp., boscalid, fungal pathogens, resistance

INTRODUCTION

With the increase in the world population, there has been a transition from small production areas to intensive commercial production areas, and the previously used handmade organic or inorganic chemicals have been replaced by intensively used and commercially produced pesticides. One of the most used pesticide groups is fungicides.

From the point of view of fungicides, copper sulphate, sulphur, mercurous chloride, etc. were the most well-known active substances until the 1940s, but after the 1940s, active substances such as thiram, captan, dodine, etc. came into use. As we approach the present day, especially

in the last 50 years, active ingredients such as iprodione, carbendazim, metalaxyl, etc. have taken their place in the market and have begun to be used extensively (Beckerman et al., 2023; Russel, 2005).

Excessive use of some of the fungicides, at inappropriate times, and using inappropriate methods has ultimately led to resistance problems. In fact, mutations introduced by the pathogen in the affected target area or the changes in the pathogen population play crucial roles in this problem. For all these reasons, resistance to lots of active ingredients has occurred in the combat against fungal diseases seen in many plant species (Grabke et al., 2014; Hu et al., 2015; Lucas et al., 2015 Wang et al., 2022).

Fungi are found in plants as pathogens, besides being saprophytes, and endophytes. The most important issue in plant production is to overcome phytopathological problems and protect the crops with sustainable methods. However, due to many reasons stated above, sustainability may not be possible in the use of a product obtained as a result of many research and development studies (Abubakar et al., 2020; Beckerman et al., 2023).

The *Alternaria* genus has also phytopathogenic species as members of the Ascomycota phylum and affects dozens of commercially important plant groups. Many organic and inorganic active substances have been identified against *Alternaria* spp., boscalid being one of them. Boscalid is also an active substance that has been obtained and tested as a result of many studies. Boscalid is also now facing resistance issues in some plants to the plant pathogen, which is associated with *Alternaria* diseases. This review article will address the issue of boscalid resistance in commercially produced plants suffering from the pathogens *Alternaria* spp..

CHARACTERISTICS AND USES OF BOSCALID

Boscalid controls a broad range of phytopathogenic fungi in cultivated plants via inhibition of fungal development. The inhibited development stages are germ tube elongation, appressoria formation, and mycelial growth. The active ingredient is transported via translaminar and acropetal ways (Stammler et al., 2008). Boscalid was registered in Chile, Korea, the UK in 2002, and the USA in 2002 (Anonymous, 2025a).

Boscalid is an active substance as a fungicide, a member of the SDHI group in the Fungicide Resistance Action Committee (FRAC) list (FRAC, 2025), and is frequently used in spraying programs in crop protection against Ascomycota members. Boscalid was registered alone with 50% active ingredient to control *Penicillium* spp., *Botrytis cinerea*, *Monilia fructigena*, *Alternaria alternata* f. sp. *citri* in apple, pistachio, tangerine, and grape. In addition, boscalid usage is registered in combination with other substances to control *Erysiphe corylacearum*, *Sphaerotheca macularis*, *Leveillula taurica*, *Puccinia porri*, etc. in hazelnut, vegetables, strawberry, etc. in Türkiye (Anonymous, 2025b), and in some of the other countries (Anonymous, 2025c; Anonymous, 2025d).

Before resistance studies, there were numerous studies about the boscalid effects on fungal diseases on crop protection. In a study on the sensitivity of *Botrytis cinerea* from vegetables to boscalid in a greenhouse (Zhang et al., 2007), it was found out that boscalid inhibited mycelial growth and conidial germination in appropriate and over-doses. In addition, the study emphasized that resistance was lower than for prymethanil. Secondly, synergism between boscalid and kresoxim-methyl was pointed out. Another study was about boscalid effects on *Sclerotinia sclerotiorum* isolates in oilseed rape and beans to observe differences in sensitivity on the isolates from boscalid-treated fields or not treated fields (Stammler et al., 2007). The results indicated that the frequency distribution of the ED50 values was similar for both types of isolates. In a study on boscalid and fluazinam treatment for controlling *Sclerotinia minor* in

peanuts was shown that the fungicides are effective when applied before infection (Smith et al., 2008). *Penicillium digitatum* is an important pathogen at the post-harvest stage in citrus. Boscalid was applied to 189 isolates of the pathogen and the results indicated that the active substance has fungicidal action against *P. digitatum* in the study (Xu et al., 2020). These studies show that the active ingredient boscalid has a place and value in crop protection against fungal diseases.

CHARACTERISTICS OF THE *ALTERNARIA* SPP. AND ITS DAMAGES TO PLANTS

The species belonging to the genus *Alternaria* hold particular importance due to their wide host range and capacity to cause significant damage both economically and ecologically among fungal plant pathogens. These pathogens can induce diseases such as stem cankers, tuber decay, leaf blight, seed necrosis, and fruit rot in a variety of crop species (Goetz & Dugan, 2006; Adongo et al., 2015; Matić et al., 2020).

The cultivated plant families, such as Apiaceae, Cucurbitaceae, Ericaceae, Fabaceae, Rosaceae, Rutaceae, Solanaceae, etc., represent major groups affected by *Alternaria* spp.. These crops occupy large global cultivation areas and contribute significantly to global food security (FAOSTAT, 2025). Consequently, understanding protection and remedy methods against *Alternaria* in cultivated plant families is of critical importance for plant protection efforts worldwide.

In the last decades, lots of studies have demonstrated that different *Alternaria* spp. can be pathogens in various crops. For example, *Alternaria jingzhouensis* was found on leaves of *Citrullus lanatus*, and *A. momordicae* was found on *Momordica charantia* leaves as weak pathogens, but these were highly pathogenic on some other cucurbits (Aung et al., 2024). In a study on cucurbit leaf spot, *Alternaria alternata*, *A. arborescens*, and *Curvularia* sp. were found in different degrees of pathogenicity (Paredes-Machado et al., 2025). Nanofungicides with selenium and silicon were applied against *Alternaria alternata*, which is a pathogen in *Phaseolus vulgaris* L. (Taha et al., 2023).

Anwaar et al. (2020) evaluated the effects of some fungicides and biopesticides for the control of *Alternaria citri* in citrus, which causes black necrotic lesions on branches, young leaves, and fruits. The Apiaceae family also has an important role as a source of vegetables and aromatic plants. Bessadat et al. (2025) found that new species of the *Alternaria* genus and, emphasized that the family can be a reservoir for the *Alternaria* genus.

The conclusion emerging from these studies is that *Alternaria* spp. can be found in many plant families, and new species within the families have been identified day by day. In addition to identifying the pathogen species, these studies also address preventative and control measures.

BOSCALID RESISTANCE IN THE COMBAT AGAINST *ALTERNARIA* SPP.

Resistance mechanisms for the SDHI group have been studied among phytopathogen fungi such as *Aspergillus* sp., *Botrytis cinerea*, *Didymella* sp, *Blumeriella* sp., *Fusarium* sp., *Erysiphe* sp., etc., and well documented in a review articles (Yin et al., 2023; Kovacevik et al., 2025). Although not many years have passed since the introduction of boscalid to the market, studies on its resistance or sensitivity to *Alternaria* spp. have begun.

Alternaria alternata is one of the main pathogens on medicinal plant *Fritillaria thunbergii*, and the main protection method is the use of chemical fungicides in China. Procymidone resistance occurred in the main growing fields in recent years, and research showed that the resistance

caused a cross-resistance between the active ingredient and iprodione and between boscalid and pydiflumetofen. In addition, four types of mutations were found in boscalid-resistant isolates (Wang et al., 2025).

Boscalid resistance has been studied by Avenot et al. (2008; 2014) and Avenot & Michailides (2020) for *Alternaria alternata* in pistachio orchards. The boscalid resistance at different levels, SDHD mutations in *Alternaria* sp., cross or multiple resistance between the other applied active ingredients, and rapid development in *Alternaria* sp. resistance to boscalid were indicated in the studies.

Blueberry species are popular due to their health benefits and their taste. *Alternaria* fruit rot is one of the postharvest problems affecting the yield. The growers chose fungicide application before harvest in crop protection to overcome the disease. In a study seven fungicides, including boscalid, were assessed for fungicide resistance profiles. The results showed that nineteen of forty-three *Alternaria alternata* isolates were resistant to boscalid (Beg et al., 2025). In addition, one *A. tenuissima* and one *A. limoniasperae* isolate were found resistant to boscalid.

Prunus dulcis is an important fruit and is affected by *Alternaria* spp. in late spring or early summer. Boscalid resistance was assessed from 520 isolates of *A. alternata*. 204 of them found resistance to boscalid, and they showed that the resistance developed within a short time after its registration for almonds. They emphasized that applications of other fungicides in different modes of action in mixed or rotated ways can be a management method for the disease (Förster et al., 2022).

Broccoli seeds can be infected naturally by *Alternaria brassicicola*, and the isolates of the pathogen showed reduced sensitivity to azoxystrobin in a study (Kaur et al., 2025). In continuation of the study, nine of the fifty-eight isolates of the pathogen showed reduced sensitivity to the SDHI group fungicides, boscalid and penthiopyrad, in broccoli seeds.

At the same time, the boscalid resistance or reduced sensitivity to *Alternaria* spp. has been studied in other crops such as strawberries (Li et al., 2025), tomatoes (Shi et al., 2015), and potatoes (Kokaeva et al., 2025), etc. Within the scope of the present review, the boscalid resistance was associated with the SDHI resistance mutations, cross or multiple resistance in fungicides that share the same group, location of pathogens, or differences in the pathogen species.

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A DIFFERENT EXTRACTION PROCEDURE IN OLIVE OIL PRODUCTION

ZEYTİNYAĞI ELDESİNDE FARKLI BİR SIKIM PROSEDÜRÜ

Dr. Cansu DÖLEK

Çukurova Üniversitesi Kozan Meslek Yüksekokulu, Bahçe Tarımı Programı, Kozan, Adana, Türkiye

ORCID ID: 0000-0001-7628-0676,

Prof. Dr. Mücahit TAHA ÖZKAYA

Ankara Üniversitesi Ziraat Fakültesi, Bahçe Bitkileri Bölümü,

ORCİD: :0000-0002-6571-5985

ÖZET

Ülkemiz zeytin ve zeytinyağı açısından büyük önem taşımaktadır. Zeytinyağının en önemli bileşenleri fenollerdir. Zeytinyağının elde edilme yöntemlerine göre miktarları değişiklik göstermektedir. Türk Gıda Kodeksi Zeytinyağı Ve Pirina Yağı Tebliği'ne göre zeytinyağları asitlik derecesi açısından doğrudan tüketime uygun veya tüketilemez şekilde 2 grupta bulunur. Bu durumu etkileyen en önemli faktörler çeşit, ekoloji, bakım koşulları ve hasat zamanını yanı sıra işleme teknolojisidir. Zeytinyağında kalitenin belirlenmesi ile ilgili çalışmalarda genellikle soxhelet yöntemi kullanılmaktadır. Fakat bu yöntem sırasında yüksek sıcaklık ve sürtünme etkisi nedeniyle fenolik bileşenler miktarının tam net tespit edilemediği düşünülmektedir. Zeytinyağı miktarının az olduğu çalışmalarda Abencor sistemi kullanılarak yapılan araştırmalarda, yağ kalitesi daha doğru bir şekilde tespit edilebilmektedir. Fakat bu makinenin yüksek fiyatlarda olması nedeniyle bulunması zordur. Aynı zamanda literatürde laboratuvar koşullarında zeytinyağı çıkarmak için farklı çalışmalarda bildirilmiştir. Bu çalışmada zeytinyağı ekstraksiyon yöntemleri üzerinde durulmuş, sanayi tipi ve laboratuvar koşullarında ekstraksiyon olmak üzere iki ana başlıkta incelenmiştir. Bunun yanı sıra çalışmada laboratuvarda küçük miktarlarda zeytin örnekleri için geliştirdiğimiz yağ çıkarma metodu literatüre kazandırılmak istenmiştir. Bu şekilde daha kısa sürede ve büyük makinelere ihtiyaç duymadan araştırma çalışmalarında kullanılabilecek küçük ölçekli bir metot hazırlanmıştır. Geliştirilen bu metodun akademik çalışmalara kolaylık sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Abenkör, Ekstraksiyon, Soğuk Sıkım, Soxhelet, Zeytinyağı.

ABSTRACT

Our country holds significant importance in terms of olive and olive oil production. The most important components of olive oil are phenolic compounds. The quantity of these compounds varies depending on the method of olive oil extraction. According to the Turkish Food Codex Communiqué on Olive Oil and Pomace Oil, olive oils are classified into two groups in terms of acidity level: those suitable for direct consumption and those not suitable. The most critical

factors affecting this classification include variety, ecology, cultivation conditions, harvest time, and processing technology.

In studies related to the determination of olive oil quality, the Soxhlet method is generally employed. However, due to the high temperature and friction effects involved in this method, it is believed that the exact amount of phenolic compounds cannot be accurately determined. In studies involving small amounts of olive oil, the Abencor system allows for more accurate determination of oil quality. Nevertheless, due to the high cost of this equipment, it is not readily accessible. Additionally, various other laboratory-based olive oil extraction methods have been reported in the literature.

This study focuses on olive oil extraction methods and examines them under two main headings: industrial-scale and laboratory-scale extractions. Moreover, it introduces a new oil extraction method developed for small quantities of olive samples in laboratory settings. In this way, a small-scale method that does not require large machinery and can be used in research studies within a shorter time frame has been developed. It is believed that this method will facilitate academic research.

Keywords: Abencor, Cold Press, Extraction, Olive Oil, Soxhlet.

GİRİŞ

Zeytin ağacının yayılış alanı, hem kuzey hem de güney yarım kürelerde 30° ve 45° enlemleri arasında bulunmaktadır. Zeytin, kurak ve sıcak ekolojilere adapte olmuş Akdeniz iklimi bitkisidir (Pansiot and Rebour,1964). Ülkemiz zeytin ve zeytinyağı açısından büyük önem taşımaktadır. Zeytinyağının en önemli bileşenleri fenollerdir. Zeytinyağının elde edilme yöntemlerine göre miktarları değişiklik göstermektedir. Rodis vd. (2002) mevcut meyve fenollerinin yalnızca %1-2'sinin zeytinyağına aktarıldığını, geri kalanının (%98) atıklarla birlikte kaybolduğunu bildirmiştir. Zeytin fenolleri, antioksidan, antimikrobiyal, antikanser ve diğerleri gibi çeşitli biyoaktiviteleri nedeniyle son birkaç on yılda artan bir ilgi görmüştür ve bunları en değerli ve umut verici diyet bileşiklerinden biri olarak belirlemiştir (Obied vd. 2007; Obied vd. 2005; Jerman Klen vd. 2015).

Natürel zeytinyağları, zeytin ağacı meyvesinden, doğal özelliklerini değiştirmeyecek bir sıcaklıkta sadece mekanik veya fiziksel işlemler uygulanarak elde edilen, berrak, yeşilden sarıya değişebilen renkte, kendine özgü tat ve kokuda olan doğal halinde gıda olarak tüketilebilen yağlardır. Natürel zeytinyağları diğer nebati yağlardan farklıdır. Bu farklılığa neden olan en temel iki özellikten ilki; zeytin meyvesinin doğasından kaynaklanmaktadır. İkincisi ise eğer hammadde, yani zeytin, iyi kalitede ise tamamen mekanik yollarla elde edilen yağın anında yenilebilir nitelikte olmasıdır (Göğüş ve Yıldırım. 2009).

Zeytin meyvelerinin soğuk preslemeyle ekstraksiyonuyla elde edilen sızma zeytinyağı (EVOO), önemli bir bileşendir. EVOO'nun kimyasal bileşimi karmaşıktır ve aralarında fenolik bileşiklerin ve polifenollerin bulunduğu heterojen bir bileşik karışımı içerir. Polifenoller, fenolik asitler, fenolik alkoller, sekoiridoidler, lignanlar ve flavonoidler gibi farklı maddeleri içerir. Fenolik bileşikler, mükemmel bir antioksidan kaynağı oldukları için incelenmiştir ve özellikleri kronik hastalıkların önlenmesinde insan sağlığına faydalar sağlar (Tripoli vd. 2005).

Zeytinyağı sıkım prosedürü, yıkama ve yabancı maddelerden ayırma, kırma, yoğurma (malaksasyon), katı-sıvı faz ayrımı (dekantör) ve sıvı-sıvı faz ayrımı (seperasyon) kısımlarından oluşmaktadır. Bu aşamalarda zeytin hamuru ve yağın kalış süresi ve sıcaklık derecesi yağ miktarı ve içerik bileşimi açısından önem arz etmektedir. Zeytinyağının oluşumu sırasında etkili olan faktörler ve sistemler aşağıda açıklanmıştır.

Sızma zeytinyağı kalitesi zeytin çeşidi, iklim özellikleri, bitki besleme, hasat, depolama ve işleme teknikleri gibi farklı faktörlere bağlıdır. Pouyafard vd. (2016) zeytin ağaçlarında su stresinde bazı fizyolojik ve morfolojik değişimler olduğunu bildirmiştir. Bu durum aynı şekilde zeytinyağı kalitesini de etkilemektedir. Zeytin kırma, sızma zeytinyağının organoleptik ve besinsel nitelikleri üzerinde önemli bir etkiye sahiptir. Metalik kırıcılar kullanıldığında, yağlar şiddetli etki nedeniyle daha yüksek fenolik bileşik içeriğine sahiptir ve daha acı ve keskindir. Zeytin ezmesi yoğurma işlemi yağ verimini ve ayrıca yağın antioksidan içeriğini etkiler. Uzun süreli yoğurma ile yağ verimi genellikle artarken yağların fenol içeriği azalır. Zeytin ezmesinin katı ve sıvı fazlarından yağın ayrılması basınç, süzme veya santrifüjleme sistemleri kullanılarak gerçekleştirilir (Di Giovacchino vd. 2002a).

Hamur yoğrulurken makinelerin dışına su verilerek zeytin hamuru ısıtılır. Verilen suyun sıcaklığı 27 ^{0}C'den düşükse soğuk sıkım zeytinyağı, 27-50 ^{0}C arasında ise sıcak sıkım zeytinyağı olarak değerlendirilir. Sıcak su kullanılarak katı hamurdan daha fazla yağın ayrılması ve yağ oranını arttırmak hedeflenmektedir (Anonim, 2024a). Üretim sırasında zeytinyağının kalitesine en fazla etki eden şartlar malaksiyon işlemi sırasında oluşur. Malaksiyon kırılıp parçalanan zeytinin hamur haline getirilerek yoğurulması işlemidir. Bu işlem sırasında yağın daha fazla çıkması için zeytin hamuruna verilen su 40-45 °C'lere kadar çıkabilir. Kalua vd. (2006), hamur ısısının belli bir sıcaklığın üzerine çıkmasının elde edilen zeytinyağı kalitesini bozduğunu belirtmiştir (Erinç vd. 2018; Kızılaslan ve Birsin, 2022). Salas ve Sánchez (1999) geleneksel basınç yağ çıkarma prosedüründe, ikinci adım olan malaksasyon genellikle 30 °C'de 30 dakika boyunca gerçekleştirildiğini, ancak bu parametrelerin hamurun özelliklerine bağlı olarak değişebildiğini belirtmişlerdir. Diğer taraftan, günümüzde daha yaygın olan sürekli santrifüjleme yağ çıkarma prosedürü daha uzun malaksasyon sürelerini içerir. Sıcaklık bu derecenin üstüne çıktığında ise enzimlerin de etkisiyle zeytinyağında kusurlar oluşmaya başlamaktadır.

Gıdalardaki yağ miktarı, süt ve süt ürünlerinde Gerber yöntemiyle, bunun dışında kalan gıdalarda ise sokselet (soxhelet) yöntemiyle saptanmaktadır. Sokselet (soxhelet) ekstraksiyon cihazı kullanılarak uygun bir çözücü ile örnekteki yağın ekstrakte edilmesi ilkesine dayanır. Bu yöntemde çözücü olarak normal pentan veya hekzan kullanılır. Bu şekilde örnekten elde edilen yağ miktarı, yöntemde belirtilen şartlarda ekstrakte edilen maddenin tümüdür ve % olarak ifade edilir. Analiz edilecek örneğin nem oranının %10'un altında olması için örnek bir kurutma kabına konarak 80 ^{0}C'den fazla olmayan sıcaklıkta etüvde kurutulur. Yağ ekstraksiyonu, öğütmeden sonra 30 dakika içinde tamamlanmalıdır. Daha önce etüvde kurutulmuş ve desikatörde soğutulmuş olan ve içinde iki tane cam boncuk bulunan balon 1 mg duyarlılıkta tartılarak darası alınır. Örnek öğütüldükten sonra yaklaşık 5-10 g ± 0.5 mg duyarlılıkta tartılır. Tartılan numune, çözücü ile ıslatılmış küçük bir parça pamuk tampon kullanılarak kartuşa konur. Kartuş ekstraktöre yerleştirilir. Balona yeterli miktarda (yaklaşık 150 ml-1.5 sifon hacmi) çözücü ilave edilir. Balon, ekstraktör ve soğutucu birbirine bağlanır. Su banyosu veya ısıtıcılı tabla üzerine yerleştirilir. 6-8 saatlik ekstraksiyon uygulanır. Balonun içerisindeki çözücünün büyük bir kısmı damıtılarak geri alınır. Bu işlem sırasında yağ balonu içerisinde toplanan yağın yanmamasına dikkat edilmelidir (Anonim, 2025b).

Sokseletin (SE'nin), diğer geleneksel katı numune hazırlama teknikleriyle karşılaştırıldığında en ciddi dezavantajları şunlardır: (1) ekstraksiyon için gereken uzun süre ve sadece atılması pahalı olmakla kalmayıp aynı zamanda ek çevre sorunlarına da neden olabilen büyük miktarda ekstraktant atığı; (2) geleneksel Soxhlet ekstraktörü, adımı hızlandıracak olan çalkalamayı sağlayamaz; (3) kullanılan büyük miktarda çözücü nedeniyle, ekstraksiyondan sonra bir buharlaştırma/konsantrasyon adımı zorunludur (López-Bascón and De Castro, 2020).

Yeni numune hazırlama tekniklerini geliştirmenin ve mevcut numune hazırlama tekniklerini iyileştirmenin temel hedefleri şunlardır: (1) insan müdahalesini önlemek veya en aza indirmek

için otomasyon; (2) mümkün olan en kısa sürede çok sayıda numunenin işlenmesini sağlamak için hızlandırma; ve (3) çözücü ortadan kaldırma veya mümkün değilse daha az toksik çözücülerin azaltılmış hacimlerinin kullanılmasıdır (de la Guardia and Garrigues, 2012; Rı´os vd. 2009; López-Bascón and De Castro, 2020).

"Abenkör" zeytinyağı üretiminde kalite ve verim değerlendirmesi için kullanılan küçük ölçekli bir ekstraksiyon sistemi olarak tanımlanabilir ve özellikle araştırma ve kalite kontrol çalışmalarında tercih edilmektedir. Abenkör sistemi, zeytinlerin laboratuvar ortamında kontrollü koşullarda işlenmesini sağlar. Sistem, zeytinlerin ezilmesi, hamurun karıştırılması ve santrifüj yoluyla yağın ayrıştırılması aşamalarını içermektedir. Bu sayede, farklı zeytin çeşitlerinin, hasat zamanlarının veya işleme yöntemlerinin zeytinyağı kalitesi ve verimi üzerindeki etkileri detaylı olarak incelenebilir (Uyanık and Gümüşkesen, 2024).

Zeytin meyvesi nemi, EVOO'nun fenolik içeriğini olumsuz yönde etkiliyor gibi görünmektedir; yağa fenolik transfer oranı daha düşük olan bu çeşitler, zeytin meyvelerinde yüksek oranda nem sunmuştur (Talhaoui vd. 2016). %50'den fazla nem içeriğinin, yağ çıkarma için "zor" zeytin ezmesine neden olduğu düşünülmüştür (Di Giovacchino, 1991; Cecchi vd. 2019). Fenolik bileşikler esas olarak zeytin ezmesinin su ve yağ fazları arasında dağılmıştır. Fenolik bileşiklerin su fazına olan daha büyük afinitesi, zeytin meyvelerinde bulunan fenollerin yalnızca %0,05-1'inin yağa aktarıldığı anlamına gelir (Cecchi vd. 2018). EVOO'nun fenolik bileşik içeriğini artırmak için yağ çıkarma sırasında su temininin sınırlandırılması önerilebilir (Cecchi vd. 2019).

MATERYAL VE YÖNTEM

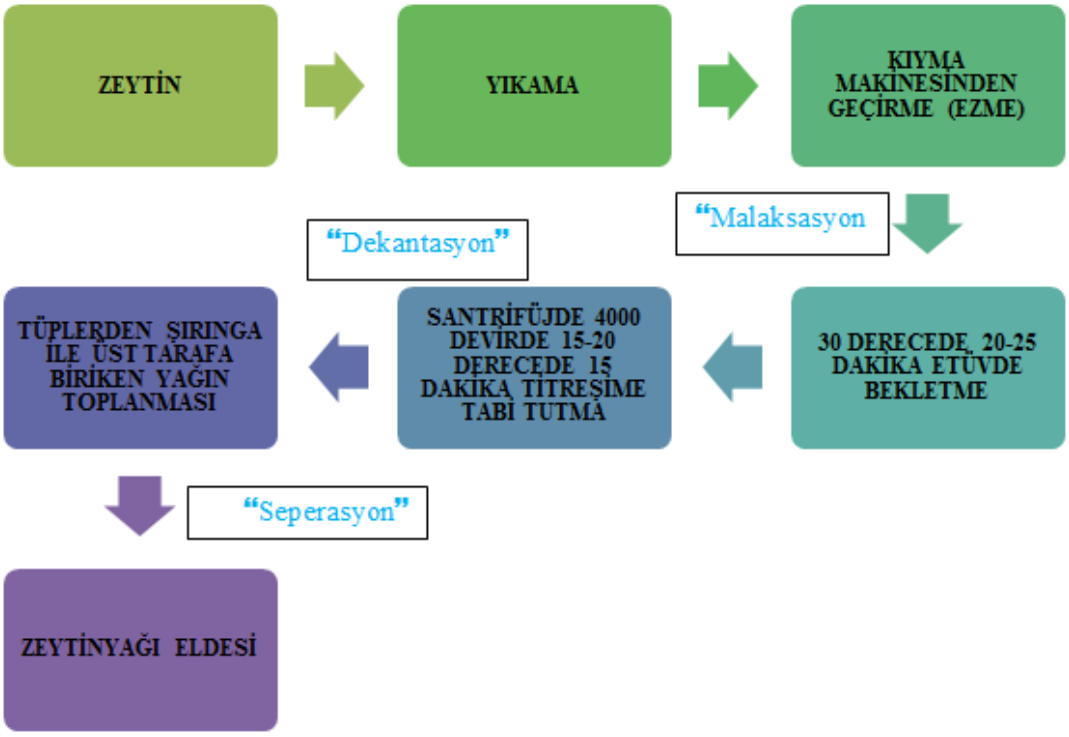
Zeytinyağının soğuk sıkım olarak elde edilmesi için yeni bir ekstrasyon tekniği geliştirilmiştir. Bu sayede küçük ölçekli çalışmalarda zeytinyağı sıkımı için yeni bir bakış açısı sunulmuştur. Rengi dönmeye başlayan zeytinler toplandıktan sonra aynı gün laboratuvara getirilir. Buzdolabında +4 ^{0}C de 2-3 gün kadar bekletilebilir. Fakat gün içerisinde tamamlanacak kadar miktarla ilerlenirse daha fazla yağ elde etmek için uygun olacaktır. Zeytinler yabancı maddelerden ayrıştırmak ve tozunu gidermek için yıkanır. Suyunun tamamen akıtılması sağlanır. Daha sonra meyveler kıyma makinesinden geçirilir. Meyve miktarının fazla olması ve çekirdeklerin küçük olması kıyma makinesinden geçişi kolaylaştırmaktadır. Çekirdeklerin makineyi tıkamamasına dikkat edilmelidir. Zeytinler fazla bekletilmeden kıyma makinesinden geçirilerek behere alınır. Ardından ağzı kapalı bir şekilde 30 ^{0}C de etüve konur. Elde edilen hamur 20-25 dakika etüvde bekletilir. Bu aşamaya kadar kısım fabrikadaki malaksör aşamasını içermektedir. Daha sonra 16'lık tüplere koyularak santrifüj için hazırlanır. Hamur tüpün yarısı kadar doldurulur. Santrifüj içerisine karşılıklı olarak yerleştirilir. 4000 devirde 15-20 ^{0}C de 15 dakika boyunca titreşime tabi tutularak yağın üst tarafta birikmesi sağlanır. Bu aşama ise katı sıvı faz ayırma aşaması olan dekantör görevi görmektedir. Sonrasında şırınga ile üst tarafa biriken yağ bir kaba tüpe doldurulur. En son aşama separatör aşamasıdır ve yağ geri kalan maddelerden ayrılarak saf hale getirilir (Şekil 1, 2). Analiz edilmek üzere +4 ^{0}C de buzdolabında saklanır. Eğer daha uzun süre bekletilecekse -22 ^{0}C de bekletilmelidir. Sıcak sıkım ile düşük değerlere sahip olacak fenolik bileşenler bu yöntemle birlikte daha doğru sonuçlar verecek ve yağa daha iyi bir şekilde geçebilecektir.



Şekil 1. Zeytinyağı eldesinde yeni yöntemin ilerleme aşamaları

BULGULAR VE TARTIŞMA

Çalışmada geliştirilen metot ile birlikte laboratuvar koşulllarında kısa sürede ve kolay bir şekilde yağ çıkarma imkanı sağlanmıştır. Zeytinyağı sıkım prosedürü aşağıdaki şema ile gösterilmiştir. Bu sayede herhangi bir kimyasal veya yüksek sıcaklık uygulaması olmadan işleme gerçekleşmektedir. Fakat çıkarılan yağ miktarı diğer yöntemlere göre daha az olmaktadır.



Şekil 2. Zeytinyağı eldesinde prosedürün akış şeması

Bir zeytinyağı değirmeni basınç sistemiyle donatıldığında, zeytin kırma genellikle 20-30 dakika boyunca granit değirmen taşları (2-6 taşlı) tarafından gerçekleştirilir. Elde edilen zeytin ezmesi daha sonra bir hidrolik presle sıkılır. Bu şekilde iyi yağ çıkarma verimleri elde edilir (Di Giovacchino and Solinas, 1987). Bir zeytinyağı değirmeni santrifüjleme sistemiyle donatıldığında, zeytin kırma genellikle mobil veya sabit çekiçler, dişli diskler, koniler veya silindirler gibi metalik kırıcılar tarafından gerçekleştirilir (Munoz Aranda and Alba Mendoza, 1980). Zeytin ezme işleminden sonra elde edilen zeytin ezmesi, sonraki yağ ayırma adımı için iyi bir şekilde hazırlanması ve daha iyi bir ekstraksiyon verimi elde edilmesi için malakslanmalıdır. Basınç sistemiyle çalışan bir zeytinyağı değirmeninde, zeytin ezmesi için malaksasyon süresi 10-20 dakikadır ve sıcaklık 20-25 °C'den yüksek değildir. Genel olarak, zeytin ezmesi malaksasyonunun süresi ve sıcaklığı arttıkça yağ oranında bir artış olduğu bildirilmiştir (Di Giovacchino, 1991). Yoğurma süresi ayrıca, laboratuvar ölçeğinde bitkilerle yapılan bazı araştırmalarda (Montedoro vd. 1994; Servili vd., 1992; Lercker vd. 1999; Angerosa vd. 2001; Angerosa vd. 1998) veya endüstriyel zeytinyağı fabrikalarında Di Giovacchino vd. (2002a)' nin bildirildiği gibi, yağların uçucu maddelerinin bileşimini de etkilemektedir.

Yağın toplam fenol içeriği, yalnızca malaksasyon sırasında zeytin ezmesinin sıcaklığı arttığında değişebilir. Küçük laboratuvar tesislerinde gerçekleştirilen bazı araştırmalarda, malaksasyon adımı sırasında zeytin ezmesinin sıcaklığındaki artışın, yağın toplam fenol içeriğinde bir azalmaya yol açtığı belirtilmiştir [Montedoro vd. 1994; Servili vd. 1992; Angerosa vd. 2001;

Servili vd. 1994). Bu durumda, laboratuvar ölçeğinde gerçekleştirilen testlerden elde edilen sonuçların bazen endüstriyel bir zeytinyağı fabrikasında elde edilecek sonuçları tahmin etmede yararlı olmadığı açıktır (Di Giovacchino vd. 2002b). Geliştirilen yöntem ile ezme sonucunda elde edilen hamur yumuşak dokulu olmakta, çelik bıçaklar sayesinde büyük parçalar kalmamaktadır. Etüvde ise uygun sıcaklık derecesi sağlandığından yağların açığa çıkması kolaylaşmakta ve hamura su eklemeye gerek kalmamaktadır. Nitekim bu durum, diğer yöntemlerde ortaya çıkan problemi engellemektedir. Eğer kullanılan meyvelerde su oranı az olursa odunsuluğu önlemek amacıyla 20-25 ^{0}C civarında bir miktar su eklenmesi mümkün olabilmektedir.

Çekirdekleri kırmak için gereken güç, yüksek enerji dağılımı ve kütlenin önemli ölçüde ısınması ile şoklar, vurmalı çalkantılar, ezme ve şiddetli darbeler üretir (Romaniello vd. 2017; Squeo vd. 2017). Bu durumda meyve kuru ise ve içeri su da verilmiyorsa fazla sürtünme ve ısı artışına bağlı olarak yağda odunsu bir his tespit edilebilir. Bu etkiler, EVOO'nun son miktarını ve fenolik ve uçucu profillerini etkileyen endojen enzimatik aktivitelerde önemli bir rol oynar (Servili and Montedoro, 2002; Servili vd. 2011). Caponio vd. (2003), çekiçli değirmenin taş değirmenlere göre bitki dokularından daha fazla miktarda fenol çıkarmayı mümkün kıldığını ve sonuç olarak çekiçli kırıcı ile üretilen yağın taş değirmenlerle elde edilenden daha acı ve daha yüksek antioksidan kapasiteye sahip olduğunu bulmuşlardır. Zeytin çekirdeği, tüm çekirdekte yüksek düzeyde peroksidaz (POX) aktivitesi içerir (Luaces vd. 2007; Servili vd. 2007), bu da fenollerin oksidatif reaksiyonlarını etkiler ve VOO fenolik içeriğini belirlemede önemli bir rol oynamaktadır (Garcia-Rodriguez vd. 2015). Tohum dokularının hafif bir şekilde bozulması veya bir çekirdek ayırma makinesinin kullanımı nedeniyle POX'un sınırlı aktivitesi, mekanik ekstraksiyon işlemi sırasında VOO'ların fenolik bileşiklerinin iyileştirilmesine ilişkin sonuçları doğrulamaktadır (Garcia-Rodriguez vd. 2015; Tamborrino vd. 2020; Amirante vd. 2006; Angerosa and Di Giacinto, 1995; Manganiello vd. 2021, Taticchi vd. 2014; Tamborrino vd. 2022).

Zeytinyağı üretim aşamalarında kullanılan suyun sıcaklığı soğuk sıkım ve sıcak sıkım gibi iki kavramı ortaya çıkarmıştır. Üretim tekniği açısından zeytinin yağa dönüşene kadar geçirdiği evreler aynı olmakla birlikte farklılığı yaratan sadece suyun derecesidir. Bu durum soğuk sıkımda zeytinyağı kalitesinin yüksek olmasını sağlar. Bunun yanı sıra en önemli faktörlerden diğeri ise meyvelerin erken hasat edilmiş ve en kısa sürede tesise ulaşmış olmasıdır. Sıcak veya soğuk su kullanımı yoğurma aşamasında hamur ve yağın birbirinden ayrılması için kullanılmaktadır.

Nebioğlu (2020) sızma zeytinyağının duyusal özellikleri ve biofenol miktarının depolama koşullarına ve süresine göre değişiklik gösterdiğini belirtmiştir. Yaptığı çalışmada Gemlik çeşidinde biofenol miktarlarında değişen malaksasyon sıcaklık ve sürelerinde genel olarak düşüş gözlenmekle birlikte sıcaklığın 50°C'ye çıkması ile bir miktar yükseldiği gözlemlenmiştir. Ancak en yüksek biofenol miktarı 30°C ve 30 dakikalık (G1) malaksasyon sonucu elde edilen üründe tespit edilmiştir (227 kg/mg). Garcıa-Ayuso and De Castro, (1999) çalışmalarında soxhelet yöntemini kullanmış ve ortaya çıkabilecek olumsuz durumlara karşı öneri getirmişlerdir. Sızdırma işleminin hızlandırılması için ekstraksiyon haznesinde odaklanmış mikrodalgalarla desteklenen geleneksel bir Soxhlet ekstraktöründen oluşan bir prototip, tohumlardan (zeytin) yenilebilir yağın çıkarılmasına uygulanarak kontrol edilmiştir. Soxhlet ekstraksiyonunun tipik özelliği olan, numunenin taze çözücüyle sürekli teması, ekstraksiyon dengesini sürekli olarak bozar ve böylece bu yaklaşım, ekstraksiyon adımı boyunca numuneyle önceden belirlenmiş bir hacimde ekstraktantın temas halinde tutulduğu kapalı yöntemlerden daha etkili hale gelmektedir.

Zeytinyağı miktarının az olduğu çalışmalarda Abencor sistemi kullanılarak yapılan araştırmalarda, yağ kalitesi daha doğru bir şekilde tespit edilebilmektedir. Otağ ve Gümüşkesen

(2023) Ayvalık ve Memecik zeytin çeşitlerinden Abencor yöntemi kullanarak zeytinyağı elde etmişlerdir. Bu sistemle yapılan çalışmada, zeytinyağı üretiminde verim artırıcı maddelerin (örneğin doğal mikronize talk ve enzimler) kullanımının yağ verimi ve kalitesi üzerindeki etkilerini incelemiştir. Sonuçlar, %1 oranında doğal mikronize talk kullanımının yağ verimini artırdığı ve zeytinyağı kalitesinde olumsuz değişiklik yaratmadığını göstermiştir. Başka bir çalışmada Uyanık ve Gümüşkesen (2024) Urla/İzmir bölgesinde organik ve geleneksel yöntemlerle yetiştirilen Erkence çeşidi zeytinlerden, Abencor sistemi kullanılarak elde edilen zeytinyağlarının kimyasal ve duyusal özelliklerini incelemişlerdir. Bu çalışma, zeytinin olgunlaşma düzeyi ve yetiştirme yöntemlerinin yağ kalitesi üzerindeki etkilerin belirlenmesinde yağ çıkarma yönteminin önemini de ortaya koymuştur.

Yapılan bir çalışmada Cecchi vd. (2019) laboratuvar ölçeğinde, zeytin ezmesi neminin hem yağ çıkarma verimi hem de fenolik içerik ve çıkarılabilir zeytinyağından elde edilen profil üzerindeki etkisini, dondurularak kurutulmuş zeytin ezmesinin geniş bir nem aralığında kademeli olarak seyreltilmesi yoluyla fiziksel ve biyokimyasal olarak incelemiştir. Frantoio ve Leccio del Corno çeşitlerinin zeytin meyveleri hasattan hemen sonra dondurularak kurutulmuş ve ardından öğütülmüştür (Cecchi vd. 2015). Deneyler, ekstrakte edilebilir yağda yağ çıkarma veriminin ve fenolik transfer veriminin arttığını ve tam zeytin meyvelerinin öğütülmesi sırasında zeytin ezmesi nem değerlerinden daha düşük zeytin ezmesi nem değerlerinde maksimuma ulaştığını göstermiştir. Veriler ayrıca zeytin ezmesi neminin, çıkarılan yağların fenolik profilini etkileyen enzimatik olaylarda önemli bir rol oynadığını ve meyvelerde bulunmayan veya diğer moleküllere bağlı olan lignanların, enzimlerin ve suyun eş varlığı sayesinde yağ çıkarma sırasında serbest bırakıldığı veya biyosentezlendiği hipotezini doğrulamaktadır (Cecchi vd. 2019).

Yapılan başka çalışmada ise Jerman Klen vd. (Jerman Klen vd. 2015) zeytinyağı işleme sırasında zeytin meyvesi fenollerinin niceliksel davranışını kapsamlı bir şekilde incelemişlerdir. Toplamda, ultra yüksek basınçlı sıvı kromatografisi-diyot dizisi algılama analizi kullanan üç fazlı bir ekstraksiyon hattından 6 zeytin matrisinde 69 fenol niceliksel olarak belirlenmiştir. Çok sayıda meyve, temsili başlangıç meyve materyali olarak rastgele seçilmiş, tartılmış ve dondurularak kurutulmadan önce sıvı nitrojenle dondurulmuştur. Çekirdekleri çıkarılan meyveler, çekirdekler, macun ve posa sıvı nitrojenle dondurularak kurutulmuş, homojenleştirilmiş ve analiz edilene kadar -25 °C'de saklanmıştır (Jerman vd. 2010; Jerman Klen and Mozetič Vodopivec, 2011; Jerman Klen and Mozetič Vodopivec, 2012). Dondurularak kurutulmuş örneklerin kuru madde ölçümleri gravimetrik olarak gerçekleştirilmiş ve fenol transferi/bölüşüm hesaplamalarının temelini oluşturmuştur. Kabuk ve posa birlikte toplam meyve fenollerinin %95'ini sınırlarken, çekirdek yalnızca %5'ini sınırlanmıştır (Lesage-Meessen vd. 2001).

Sıvı-sıvı ekstraksiyonunda (LLE), iki karışmayan çözücünün karışımı, analitin iki faz arasında dağıtılması yoluyla ayırma işlemini yönlendirmek için seçilir. Zeytinyağının polifenol ekstraksiyonunun özel durumunda, su ve n-hekzan içinde seyreltilmiş metanol veya etanol gibi çözücüler önerilir (Bonoli vd. 2003; International Olive Council, 2009; Pirisi vd. 2000). Ancak, bu teknik pahalı ve tehlikeli organik çözücüler ve analiz başına uzun bir zaman gerektirir ve bu da fenolik bileşiklerin stabilitesini ve nihai toplam konsantrasyonlarını etkileyebilir. Chávez Ramos vd. (2020) son yıllarda, yeni ekstraksiyon yöntemlerinin araştırılmasının giderek daha önemli hale geldiğini ve sıvı faz mikroekstraksiyon (LPME) ve mikroteknolojiye yönelme gerçekleştiğini bildirmiştir (Monasterio vd. 2013; Spietelun vd. 2014).

Zeytinyağında kalitenin belirlenmesi ile ilgili çalışmalarda genellikle soxhelet yöntemi kullanılmaktadır. Fakat bu yöntem sırasında yüksek sıcaklık ve sürtünme etkisi nedeniyle fenolik bileşenler miktarının tam net tespit edilemediği düşünülmektedir. Aynı zamanda bu yöntemle kimyasal kullanımı da olduğundan yağın içerisindeki bileşenleri ve antioksidan

kapasiteyi değiştirebilmektedir. Zeytinyağı fabrikasında soğuk sıkım zeytinyağı eldesi ile sağlık bileşenleri yüksek bir yağ elde etmek mümkündür. Sıcak sıkım tekniği ise zeytinyağında çabuk bozulma etkisi vermekte, yağ miktarı artarken, içeriğindeki bileşenler düşmektedir. Laboratuvar çalışmalarında gıda olarak tüketim olmayacağı için zeytinyağında bu durum yok sayılabilmektedir ve uygulamalar arasındaki farklılıklar değerlendirilmektedir. Bu değerlerde daha net sonuçlar ortaya koyabilmek ve bundan sonraki çalışmalar için karşılaştırmalı analiz yapılabilmesi için bu soğuk sıkım metodu geliştirilmiştir.

SONUÇ

Bu çalışmada farklı zeytinyağı çıkarımı yöntemleri açıklanmış ve yeni bir metot eklenerek, elde olan imkanlarla daha kolay bir şekilde zeytinyağı eldesi literatüre kazandırılmak istenmiştir. Soxhelet yönteminin kimyasal ve yüksek sıcaklık içermesinden dolayı zeytinyağının içerisindeki bileşimi tam olarak ortaya koyamama, soğuk sıkım yapan tesislerin ise büyük makineler ve yüksek oranda meyveye ihtiyaç duyulması problemi olduğu düşünülerek yeni geliştirilen bu yöntem az miktarda örneğin değerlendirilmesinde oldukça önemli görülmektedir. Çalışmada laboratuvarda küçük miktarlarda zeytin örnekleri için geliştirdiğimiz yağ çıkarma metodu literatüre kazandırılmak istenmiştir. Bu yöntemde zeytinyağı eldesinde kıyma makinesi, etüv ve santrifüj kullanılarak malaksör, dekantör ve seperatör basamakları tamamlanmaktadır. Bu şekilde daha kısa sürede ve büyük makinelere ihtiyaç duymadan araştırma çalışmalarında kullanılabilecek küçük ölçekli bir metot hazırlanmıştır. Geliştirilen bu metodun akademik çalışmalara kolaylık sağlayacağı düşünülmektedir.

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A MULTI-TEMPORAL ANALYSIS OF THE CORRELATION BETWEEN NDVI AND NDMI IN REMOTE SENSING-BASED PRECISION AGRICULTURE

UZAKTAN ALGILAMA TABANLI HASSAS TARIMDA NDVI VE NDMI ARASINDAKİ KORELASYONUN ÇOK ZAMANLI ANALİZİ

Dr. Öğretim Üyesi Mesut ÇOŞLU

Burdur Mehmet Akif Ersoy Üniversitesi, Fen-Edebiyat Fakültesi, Hassas Tarım ve Tarımsal Robotlar Bölümü

Doç. Dr. İlker ÜNAL

Burdur Mehmet Akif Ersoy Üniversitesi, Fen-Edebiyat Fakültesi, Hassas Tarım ve Tarımsal Robotlar Bölümü

ÖZET

Uydu tabanlı uzaktan algılama, bitki ve toprak koşullarının izlenmesinde sürekli, nesnel ve geniş alanları kapsayan veri sağlaması nedeniyle hassas tarım uygulamalarında temel bir araç olarak kullanılmaktadır. Bu çalışmada, tarım alanlarındaki bitki örtüsü dinamikleri ile nem içeriği arasındaki ilişkinin çok zamanlı olarak analiz edilmesi amaçlanmıştır. Çalışmada Nisan, Mayıs ve Haziran aylarına ait 12 farklı tarihli Sentinel-2 uydu görüntülerinden hesaplanan Normalize Fark Bitki İndeksi (NDVI) ve Normalize Fark Nem İndeksi (NDMI) kullanılmıştır. Ayrıca, istatiksel analizlerde kullanmak amacıyla tarım alanı olduğu bilinen 100 adet nokta formatında yer gerçeği vektör verilerinden yararlanılmıştır. NDVI ve NDMI verilerinin istatistiksel analizinde normallik testleri ve korelasyon analizleri gerçekleştirilmiştir. Veri setinin normal dağılım gösterip göstermediği çarpıklık-basıklık değerleri, histogramlar ve Shapiro–Wilk testi sonuçları ile kontrol edilmiştir. Buna göre verilerin normal dağılmadığı tespit edilmiş ve korelasyon analizlerinde Spearman'ın korelasyon katsayısı hesaplanmıştır. Analiz sonuçları, tüm dönemler için NDVI ve NDMI arasında pozitif ve yüksek düzeyde anlamlı bir ilişki bulunduğunu ortaya koymuştur. En yüksek korelasyon katsayıları 20 Mayıs 2025 (ρ=0.96) ve 23 Mayıs 2025 (ρ=0.96) tarihlerinde elde edilmiştir. Elde edilen bulgular, Nisan–Haziran büyüme dönemi boyunca bitki örtüsü ve nem göstergeleri arasında anlamlı ve tutarlı bir ilişki olduğunu göstermektedir. Bu ilişki, çok zamanlı uydu uzaktan algılama verilerinin ürün gelişimi takibi, sulama planlaması ve sürdürülebilir su yönetimi süreçlerinde karar destek mekanizmalarını güçlendirme potansiyelini vurgulamaktadır.

Anahtar Kelimeler: Bitki Örtüsü İzleme, CBS, Çok Zamanlı Analiz, Hassas Tarım, Uzaktan Algılama.

ABSTRACT

Satellite-based remote sensing has become a fundamental tool in precision agriculture due to its ability to provide continuous, objective, and large-scale data for monitoring vegetation and soil conditions. This study aims to analyze, on a multi-temporal basis, the relationship between vegetation dynamics and moisture content in agricultural areas. The study utilized Normalized

Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) values derived from 12 Sentinel-2 satellite images acquired between April, May, and June 2025. Additionally, 100 ground truth vector points known to represent agricultural land were used for statistical analyses. Normality tests and correlation analyses were performed on the NDVI and NDMI datasets. The distribution of the data was assessed using skewness–kurtosis values, histograms, and the Shapiro–Wilk test. Since the datasets did not exhibit normal distribution, Spearman's rank correlation coefficient (ρ) was calculated to examine the correlation. The analysis results revealed a positive and highly significant correlation between NDVI and NDMI across all periods. The highest correlation coefficients were obtained on 20 May 2025 (ρ=0.96) and 23 May 2025 (ρ=0.96). The findings demonstrate that there is a significant and consistent relationship between vegetation vigor and moisture content throughout the April–June growing season. This relationship highlights the potential of multi-temporal satellite remote sensing data to strengthen decision-support mechanisms for crop growth monitoring, irrigation scheduling, and sustainable water resource management in precision agriculture.

Keywords: GIS, Multi-Temporal Analysis, Precision Agriculture, Remote Sensing, Vegetation Monitoring.

GİRİŞ

Hassas tarım teknolojileri, veri odaklı yaklaşımlar ile mahsul, toprak ve kaynak yönetimini optimize ederek üretimde verimliliği artırmayı, aynı zamanda işletme maliyetlerini düşürmeyi ve çevresel etkiyi en aza indirmeyi de amaçlamaktadır (Saha vd., 2025). Bu kapsamda değerlendirildiğinde hassas tarım, tarımsal üretimi artırmak ve girdi kayıplarını en aza indirmek amacıyla girdilerin en uygun şekilde yönetilmesini sağlayan bir teknoloji bütününün uygulanmasını gerektirmektedir. Hassas tarımın önemli faktörlerinden biri, bitki örtüsü sağlığını ve durumunu izleyebileceğimiz uzaktan algılama teknolojileridir. Son yıllarda hassas tarımda uzaktan algılama teknolojilerinin kullanımı önemli ölçüde artmıştır. Mekânsal, spektral ve zamansal açıdan yüksek çözünürlüklü uydu görüntülerinin günümüzde daha erişilebilir hale gelmesi özellikle mahsul izleme, sulama planlaması, besin yönetimi, hastalık ve zararlı takibi ile verim tahmini gibi çok sayıda hassas tarım uygulamasında uzaktan algılamanın kullanımını önemli ölçüde teşvik etmiştir (Sishodia vd., 2020; Giovos vd., 2021).

Hassas tarımda ve genel olarak tarımda kullanılan uzaktan algılama sistemleri, sensör platformuna ve sensör tipine göre sınıflandırılmaktadır. Bu kapsamda kullanılan sensörler genellikle uydu, hava ve yer tabanlı platformlara monte edilmektedir. Her ne kadar bulut örtüsü, yüksek maliyet ve isteğe bağlı görüntüleme çözümleri bakımından dezavantajları bulunsa da günümüzde geniş kapsama alanları ve yüksek çözünürlüklü veriler sunan uydu tabanlı uzaktan algılama sistemleri tarımsal uygulamalarda aktif bir şekilde kullanılmaktadır (Sishodia vd., 2020).

Bitki örtüsü indeksleri, birden fazla spektral bantta ölçülen yansıma değerlerini bir araya getirerek bitkinin büyüme durumu, canlılığı, biyokütlesi ve klorofil miktarı gibi özelliklerini değerlendirmeye imkân veren matematiksel ifadelerdir. Bitki sağlığı hakkında nicel veriler sağlayan bu indekslerin haritalanması, tarım alanlarındaki mekânsal ve zamansal değişkenliği ortaya koymak açısından hassas tarım uygulamalarında kritik önem taşımaktadır (Sishodia vd., 2020; Radočaj vd., 2023). Bu bitki örtüsü indeksleri içerisinde multispektral sensör tabanlı hesaplanan NDVI, hassas tarımda en sık kullanılan bitki örtüsü indeksidir (Giovos vd., 2021; Radočaj vd., 2023). Bunun yanı sıra NDMI, bitkilerdeki nem, su stresi durumu ve sulama altındaki alanları tespit etmek amacıyla kullanılan bir indekstir. Bu indeks sonucu elde edilen nicel veriler ile tarım alanları farklı su ihtiyacı olan bölgelere ayrılıp, gerektiğinde hassas sulama uygulamaları kapsamında planlama çalışmaları yapılabilmektedir (Gaznayee vd., 2023;

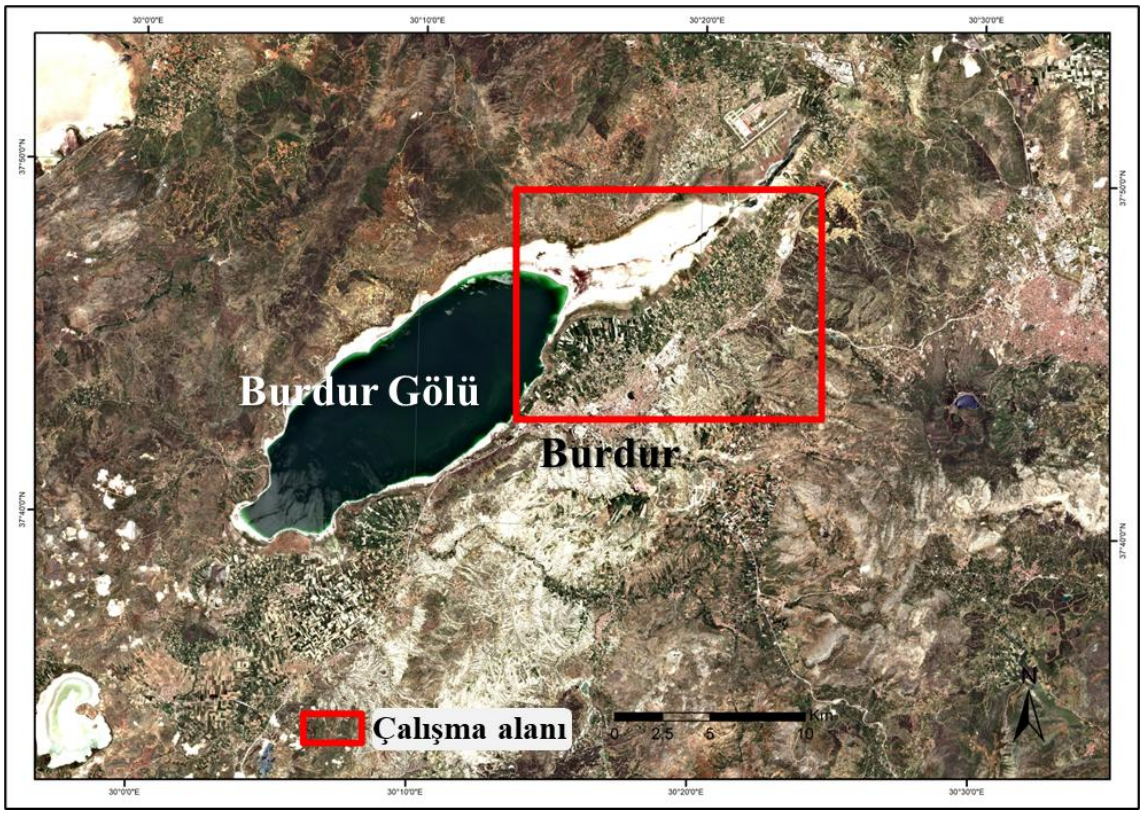
Koohikeradeh vd., 2025). NDVI ve NDMI, bitki örtüsü sağlığını nicel olarak ortaya koyarak tarla içinde ek izleme veya yönetimsel müdahale gerektirebilecek alanların belirlenmesine önemli katkılar sağlamaktadır. NDVI ve NDMI'nın eşzamanlı analizi, bitki sağlığı ve toprak nemindeki zamansal eğilimlerin kapsamlı bir şekilde anlaşılmasını sağlar; NDVI bitki örtüsü canlılığını ortaya koyarken, NDMI ise bitki ve toprak nemi içeriğine ilişkin önemli bilgiler sunar. NDVI ve NDMI haritalarını oluşturmak için uydu görüntülerini kullanmak, zaman içinde büyük alanların izlenmesine imkân tanıyan uygun maliyetli ve verimli uygulamalardır (Varouchakis vd., 2025). Tarım alanlarında nicel veriler sunma kabiliyetine sahip bu iki indeks kullanılarak yapılan önemli çalışmalar bulunmaktadır. Bu kapsamda yapılan çalışmalara Gaznayee vd. (2023) tarafından ideal sulama sistemi performans senaryolarını değerlendirmek ve Bchir ve Masmoudi-Charfi (2024) tarafından bitki örtüsü ve nem indekslerini tahmin etmek ve haritalamak amacıyla gerçekleştirilen araştırmalar örnek olarak verilebilir.

Günümüzde bitki örtüsü sağlığı ile nem koşullarının birlikte değerlendirilmesi, tarımsal üretim süreçlerinin izlenmesi ve optimize edilmesinde kritik bir öneme sahiptir. Bu bağlamda, NDVI ve NDMI gibi spektral indekslerin çok zamanlı olarak incelenmesi, bitki gelişimi ile nem dinamikleri arasındaki etkileşimin daha kapsamlı ve nicel bir biçimde ortaya konmasına olanak tanımaktadır. Özellikle Sentinel-2 gibi yüksek konumsal, zamansal ve spektral çözünürlüklere sahip uydu platformları, tarım alanlarının büyüme dönemi boyunca izlenmesi için önemli fırsatlar sunmaktadır. Bu çalışma, Nisan–Haziran dönemine ait çok zamanlı NDVI ve NDMI verilerini temel alarak tarımsal alanlardaki bitki örtüsü değişimleri ile nem içeriği arasındaki ilişkiyi istatistiksel olarak incelemeyi amaçlamakta; böylece uzaktan algılama temelli indekslerin sulama yönetimi, ürün gelişimi izleme ve sürdürülebilir hassas tarım uygulamalarındaki karar destek süreçlerine katkı potansiyelini ortaya koymaktadır.

MATERYAL VE YÖNTEM

Çalışma alanı ve veri

Çalışma alanı Burdur şehir merkezinin kuzeyinde ve Burdur Gölü'nün doğusunda yer almaktadır (Şekil 1). Türkiye'nin güneybatısında ve Akdeniz Bölgesi'nin batısında yer alan Burdur İli, 29° 24' ve 30° 53' doğu boylamları ile 36° 53' ve 37° 40' kuzey enlemleri arasında konumlanmaktadır. Burdur ilinin güneyinde Antalya, batısında Denizli, güneybatısında Muğla, doğu ve kuzeyinde Isparta ve Afyonkarahisar illeri yer almaktadır. Ayrıca Burdur'un güney kesiminde Toros Dağları'nın uzantıları yer alırken, ilin önemli bir bölümü kapalı havza niteliğindeki Burdur Gölü ve çevresindeki plato ve tepelerden oluşmaktadır (Burdur Valiliği, 2021).



Şekil 1. Çalışma alanı

Burdur'da kışlar soğuk ve yağışlı, yazlar sıcak ve kurak geçmekte olup geçiş iklimi özellikleri göstermektedir. Yağışların büyük bölümü kış aylarında gerçekleşmekte; ilk donlar Kasım'da, son donlar ise Nisan ayının ikinci yarısında görülmektedir (Burdur İl Tarım ve Orman Müdürlüğü, 2025). 1932–2024 uzun dönem verilerine göre en düşük ortalama sıcaklık Ocak ayında 2.60 °C, en yüksek ortalama sıcaklık ise Temmuz–Ağustos döneminde 24.60 °C'dir. Yıllık ortalama sıcaklık 13.30 °C, ortalama yıllık yağış miktarı 428.10 mm ve yağışlı gün sayısı 88.20 olarak belirlenmiştir (MGM, 2025). Burdur Havzası'nda toprakların önemli bir bölümünü kestanerengi topraklar oluşturmakta (%22.65) olup bu topraklar Burdur Gölü çevresinde kumtaşı, kiltaşı, çamurtaşı ve konglomera üzerinde gelişmiş ve organik maddece zengindir. Ayrıca gölün güneybatısında yaygın kırmızı kahverengi orman toprakları ile ayrışma kökenli kireçsiz kahverengi orman toprakları da havzanın karakteristik diğer toprak gruplarıdır (Tarım ve Orman Bakanlığı, 2020).

Çalışmada kullanılan temel veri seti Sentinel-2 uydu görüntüleridir (Çizelge 1). Sentinel-2, geniş kapsama alanı, yüksek çözünürlüklü ve multispektral görüntüleme ile özellikle toprak, su ve bitki örtüsünün izlenmesine yönelik çalışmalarda kullanılmaktadır.

Çizelge 1. Sentinel-2 uydusunun mekânsal ve spektral özellikleri

Spektral Bant	Merkezi Dalga Boyu (nm*)	Mekânsal Çözünürlük (m**)
B1: Ultra mavi (kıyı, aerosol)	443	60
B2: Mavi	490	10
B3: Yeşil	560	10
B4: Kırmızı	665	10
B5: Kırmızı kenar 1	705	20
B6: Kırmızı kenar 2	740	20
B7: Kırmızı kenar 3	783	20
B8: Yakın kızılötesi (NIR)	842	10
B8A: Yakın kızılötesi-dar	865	20
B9: Su buharı	945	60
B10: Kısa dalga kızılötesi (SWIR)	1375	60
B11: Kısa dalga kızılötesi (SWIR)	1610	20
B12: Kısa dalga kızılötesi (SWIR)	2190	20

**nanometre ve **metre*

Bu çalışma kapsamında Nisan, Mayıs ve Haziran aylarına ait 12 farklı tarihli Sentinel-2 uydu görüntüleri kullanılmıştır (Çizelge 2).

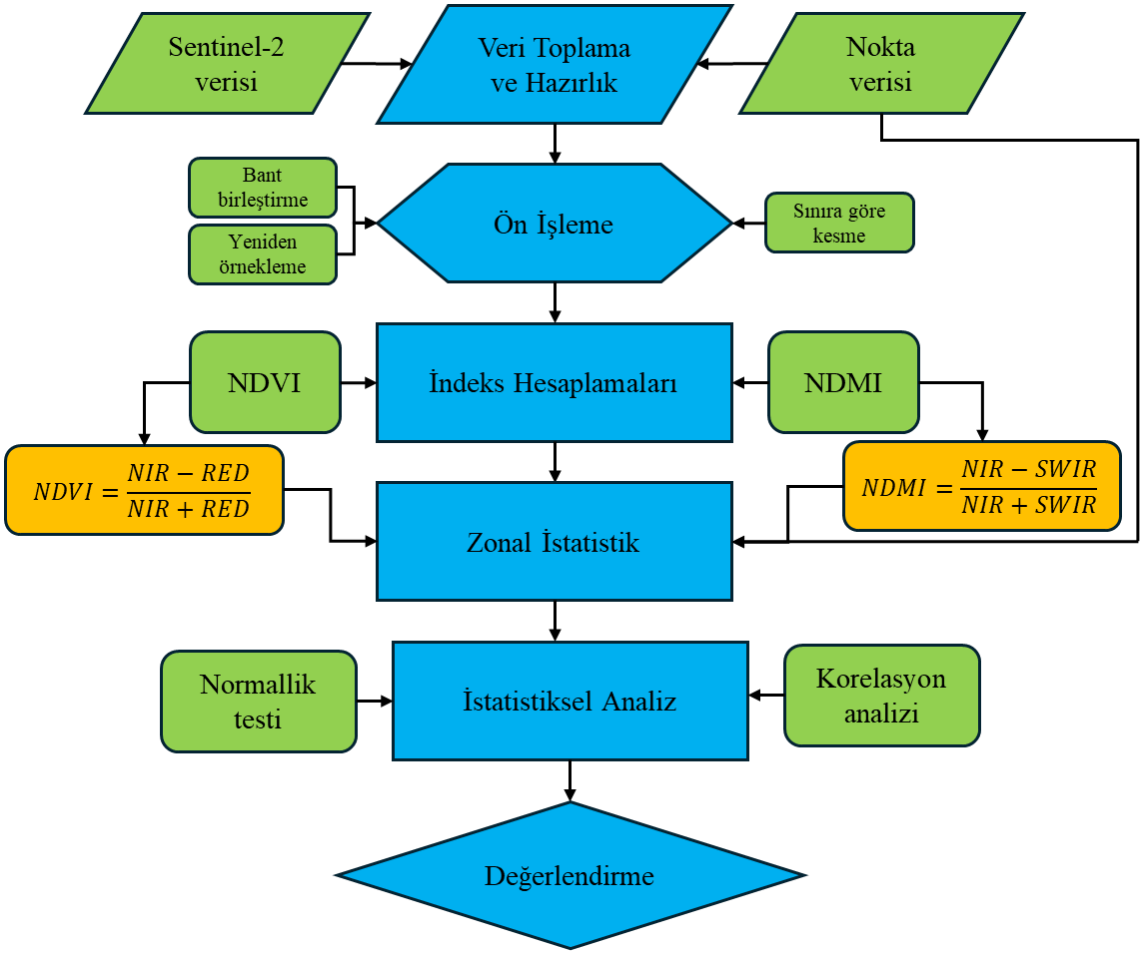
Çizelge 2. Çalışmada kullanılan Sentinel-2 uydu görüntüleri

Sentinel-2 Platformu	Görüntü Tarihi
S2A_MSIL2A_T36STG	10 Nisan 2025
S2C_MSIL2A_T36STG	15 Nisan 2025
S2B_MSIL2A_T36STG	20 Nisan 2025
S2B_MSIL2A_T36STG	23 Nisan 2025
S2C_MSIL2A_T36STG	15 Mayıs 2025
S2A_MSIL2A_T36STG	20 Mayıs 2025
S2B_MSIL2A_T36STG	23 Mayıs 2025
S2C_MSIL2A_T36STG	28 Mayıs 2025
S2C_MSIL2A_T36STG	04 Haziran 2025
S2A_MSIL2A_T35SQB	09 Haziran 2025
S2C_MSIL2A_T35SQB	14 Haziran 2025
S2A_MSIL2A_T35SQB	19 Haziran 2025

Çalışmada kullanılan bir diğer veri, istatistiksel analizlerde kullanmak amacıyla tarım alanı olduğu bilinen 100 adet nokta verisidir. Bu veri, yüksek çözünürlüklü Google Earth Pro ve Sentinel-2 uydusunun yanlış renk kombinasyonları üzerinden kontrol edilerek CBS ortamında vektör veri olarak üretilmiştir.

Yöntem

Çalışma veri toplama ve hazırlık, ön işleme, indeks hesaplamaları, zonal istatistik, istatiksel analizler ve değerlendirme aşamalarından oluşmaktadır (Şekil 2).



Şekil 2. İş akışı

Çalışmanın ilk aşaması olan veri toplama ve hazırlık aşamasında ilgili tarihlere ait Sentinel-2 verileri, Avrupa Birliği Uzay Programı Copernicus'tan indirilmiştir. Bu aşamada, çalışma alanındaki tarım alanları yüksek çözünürlüklü Google Earth Pro üzerinden belirlenmiştir (.kml formatında). Daha sonra bu noktaların CBS ortamında projeksiyon dönüşümleri gerçekleştirilmiş ve shapefile (.shp) formatına dönüştürülmüştür. Bu noktalar Sentinel-2'nin doğru ve yanlış renk kombinasyonları üzerinden kontrol edilerek gerekli düzeltmeler sağlanmıştır. Ön işleme aşamasında görüntülere sırasıyla yeniden örnekleme (resample), bant birleştirme (composite bands) ve alan sınırına göre kesme (clip) işlemleri uygulanmıştır. Bu aşamada, özellikle mekânsal çözünürlüğü daha düşük olan SWIR bandı (20 m), 10 m

çözünürlüklü bantlarla (kırımızı, yeşil, mavi ve yakın kızılötesi) uyumluluk sağlamak üzere yeniden örneklenmiştir. Ayrıca ön işleme aşamasında ek bir atmosferik düzeltme veya bulut giderme işlemi uygulanmamıştır. Bunun nedeni, kullanılan verilerin hâlihazırda atmosferik olarak düzeltilmiş L2A düzeyinde ürünler olması ve veri indirme sürecinde %10 bulutluluk eşiğinin filtreleme kriteri olarak belirlenmesidir. Çalışmanın indeks hesaplamaları aşamasında, Eşitlik 1 ve Eşitlik 2'de verilen NDVI (Rouse vd., 1974) ve NDMI (Gao, 1996) indeksleri kullanılmıştır.

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

$$NDMI = \frac{NIR - SWIR}{NIR + SWIR} \tag{2}$$

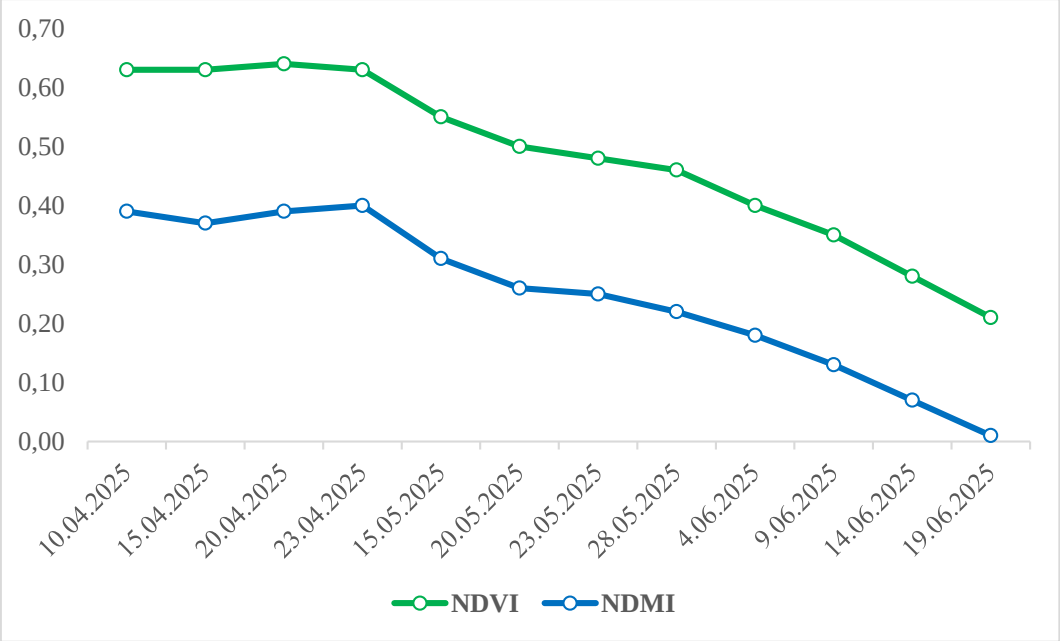
burada RED görünür bölgedeki kırmızı, NIR yakın kızılötesi ve SWIR ise kısa dalga kızılötesi bölgedeki yansımadır. NDVI, yaygın olarak kullanılan bitki örtüsü indekslerinden biri olup -1 ve +1 arasında bir değer almaktadır. NDVI için negatif değerler su kütleleri varlığına işaret ederken, sıfıra yakın değerler çıplak toprak, kaya, kuraklık veya zararlılar nedeniyle meydana gelen bitki örtüsü yokluğunu göstermektedir. NDVI'da olduğu gibi -1 ve +1 arasında bir değer alan NDMI ise, bitki örtüsündeki nem durumunu tespit etmek için kullanılmaktadır. Buradaki SWIR bant, bitki örtüsünün su içeriğine duyarlı olup bitkilerdeki su stresinin güvenilir bir göstergesi olarak kullanılmaktadır (Nicoletti vd., 2024; Varouchakis vd., 2025).

Yer gerçeği olarak kullanılan 100 adet noktaya ait NDVI ve NDMI değerleri zonal istatistik aracı kullanarak çıkarılmıştır. Daha sonra bu noktalar istatiksel analizlerde kullanmak üzere excel dosyası olarak düzenlenerek kaydedilmiştir. Çalışmanın istatiksel analiz aşamasında, öncelikle verilerin normal dağılım gösterip göstermediği test edilmiştir. Bu kapsamda her bir tarih ve indeks için histogramlar, çarpıklık-basıklık değerleri ve Shapiro-Wilk testi hesaplamaları gerçekleştirilmiştir. Bu işlem adımından sonra elde edilen değerlere göre her ne kadar bazı tarihlerde veri seti NDVI ve NDMI için normal dağılım göstermiş olsa da tamamı üzerinden değindirildiğinde genel olarak normal dağılım göstermediği belirlenmiştir. Bu nedenle NDVI ve NDMI arasındaki ilişkinin belirlenmesinde Spearman's korelasyon katsayısı hesaplanmıştır. Makuya vd. (2024) tarafından yapılan çalışmada, değişkenler arasında doğrusal olmayan bir ilişki belirlenmiş ve bu nedenle Spearman'ın korelasyon katsayısı kullanılmıştır. Spearman'ın korelasyon katsayısı, iki değişken arasındaki ilişkiyi ve bu ilişkinin yönünü belirlemede kullanılan parametrik olmayan bir yöntemdir. Bu analiz türü, özellikle mekânsal bilimler alanında araştırmacılar tarafından sıkça tercih edilmektedir (Çubukçu, 2015). Çalışmanın son aşamasında, iki değişken arasındaki ilişkinin zaman içerisindeki değişimi analiz edilerek bitki örtüsünün dönemsel dinamikleri ile yüzey nem koşulları arasındaki ilişki sistematik olarak değerlendirilmiştir.

BULGULAR VE TARTIŞMA

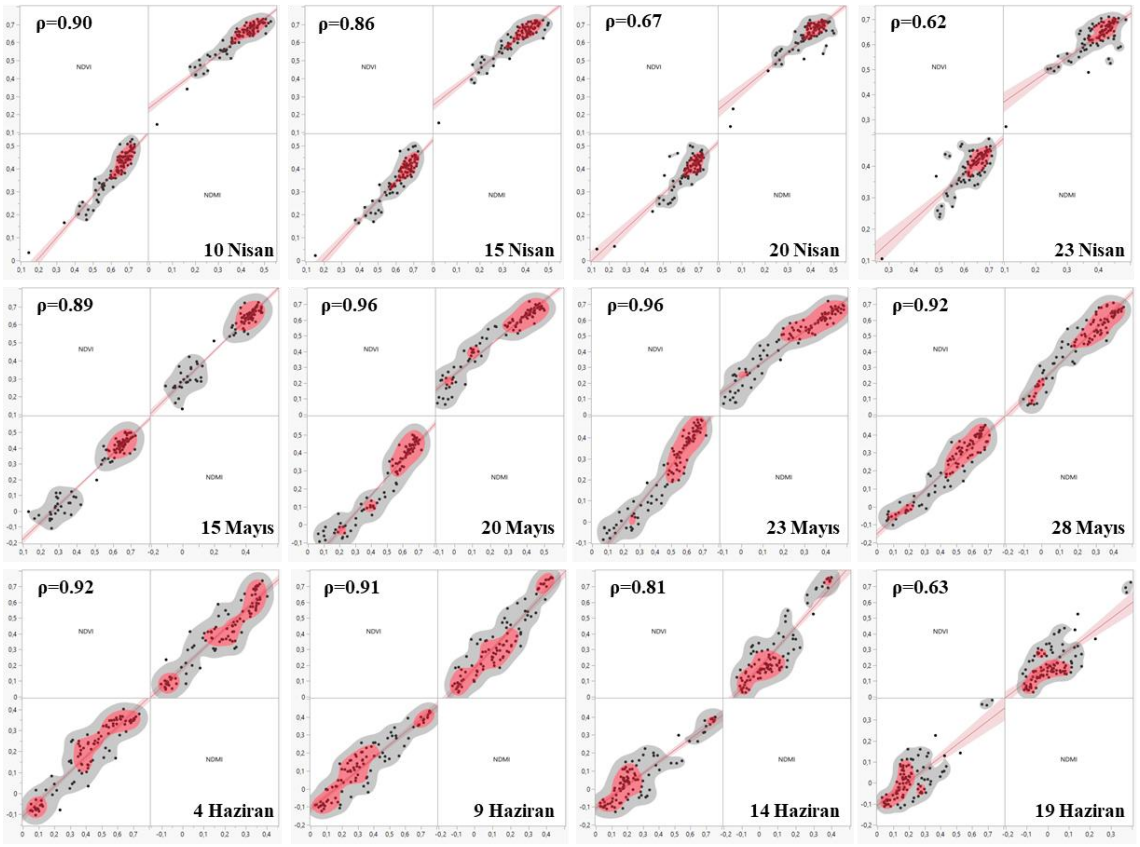
Çalışma alanında yürütülen çok zamanlı analiz sonucunda, 10 Nisan-19 Haziran 2025 dönemine ait NDVI ve NDMI ortalama değerlerinde belirgin bir azalma eğilimi tespit edilmiştir (Şekil 3). Şekil incelendiğinde, en yüksek ortalama NDVI değerinin 20 Nisan 2025 tarihinde, en düşük NDVI değerinin ise 19 Haziran 2025 tarihli analiz sonucunda elde edildiği görülmektedir. Örnek tarım alanlarındaki en yüksek ortalama NDMI değeri 23 Nisan 2025'te,

en düşük NDMI değeri ise NDVI ile benzer şekilde 19 Haziran 2025 tarihinde kaydedilmiştir. Çalışma alanındaki ürün türleri bilinmemekle birlikte, alanın tarımsal kullanımda olduğu göz önünde bulundurulduğunda her iki göstergedeki paralel düşüş; bitki örtüsünün mevsimsel gelişim döngüsüne, artan su stresine veya vejetasyon yoğunluğunun azalmasına işaret edebilecek bir durum olarak değerlendirilebilir. Ayrıca NDVI'daki kademeli azalma bitki canlılığının ve yeşil biyokütlenin zaman içerisinde gerilediğini gösterirken, NDMI'daki daha belirgin düşüş ise toprak ve bitki nemi koşullarının aynı dönemde daha hızlı zayıfladığını ortaya koymaktadır. Bu bulgular, çalışma alanındaki NDVI-NDMI eğilimlerinin tarımsal dinamikler ve alanın olası su gereksinimleri hakkında önemli ipuçları sunduğunu göstermektedir.



Şekil 3. Ortalama NDVI ve NDMI değerleri

Çalışma kapsamında gerçekleştirilen istatiksel analizler sonucunda, 12 farklı tarihli NDVI-NDMI korelasyon analizi grafikleri elde edilmiştir (Şekil 4). Analiz sonuçları, çalışma alanında bitki ve nem içeriği ilişkilerinin izlenmesi açısından NDVI ve NDMI indekslerinin birlikte değerlendirilmesinin önemli bir avantaj sağladığını göstermektedir. Böylece tarımsal üretim süreçlerinde stres tespiti, sulama planlaması ve verim tahmini gibi uygulamalara katkı sunabilecek bir izleme yaklaşımı ortaya çıkmaktadır.



Şekil 4. Dönemlere ait korelasyon grafikleri

NDVI ve NDMI arasındaki korelasyonu gösteren çok zamanlı grafikler incelendiğinde, Nisan–Haziran döneminde bitki örtüsü ve nem koşulları arasındaki ilişkinin oldukça düzenli bir zamansal desen izlediği görülmektedir. Bu kapsamda değerlendirildiğinde genel olarak tüm tarihlerde pozitif ve yüksek düzeyde anlamlı bir ilişki olduğu tespit edilmiştir (ρ=0.62-0.96). Nitekim tarım alanlarında yapılan bir çalışmada Bchir ve Masmoudi-Charfi (2024), bu iki indeks arasında yüksek korelasyon olduğunu ortaya koymuştur. Ayrıca araştırmacılar tarafından bitki örtüsünün olgunlaşma döneminde NDMI'nın nem değişimlerini daha iyi tespit edebildiği ve bu dönemde korelasyonun düşüş eğilimine girdiği belirtilmiştir. Bir başka çalışmada ise kentsel yeşil alanda çok zamanlı analiz sonucunda NDVI ve NDMI arasında pozitif yönlü yüksek bir ilişki olduğu ve farklı yıllardaki değişkenliğin sıcaklıktan kaynaklanmış olabileceği değerlendirilmiştir (Strashok vd., 2022). Çalışmadan elde edilen bulgular literatürde yer alan benzer araştırma sonuçları ile paralellik göstermektedir. Bu kapsamda değerlendirildiğinde NDVI ve NDMI'nın eşzamanlı analizinin, bitki sağlığı ve nem durumundaki zamansal eğilimlerin kapsamlı bir şekilde anlaşılmasını sağlayabileceği ortaya konmuştur. Varouchakis vd. (2025), NDVI'nın bitki örtüsü canlılığını; NDMI'nın ise nem içeriğini ortaya koymada tamamlayıcı bir role sahip olduğunu belirtmiştir. Bu kapsamda her iki indeksin birlikte kullanımı, özellikle rehabilite edilen alanlarda bitki örtüsü sağlığının izlenmesinde önemli bir araç olarak vurgulanmıştır. Bu bulgular, mevcut çalışmalarda gözlenen pozitif ve güçlü korelasyonlar ile uyumlu olup benzer ekolojik süreçlerin farklı çalışma alanlarında da geçerli olabileceğini göstermektedir.

Çalışmadan elde edilen bulgular, Nisan döneminde alandaki vejetasyon heterojenliği nedeniyle korelasyonun orta ve yüksek (ρ=0.62-0.90), Mayıs döneminde yoğun bitki örtüsü ve yüksek nem içeriği nedeniyle NDVI-NDMI arasında maksimum korelasyon (ρ=0.89-0.96) ve Haziran döneminde ise sıcaklığın belirgin bir şekilde artması ve alandaki bazı bitki örtüsü için hasat

zamanının gelmesi; dolasıyla kuruma ve doygunluk etkisi gibi nedenlerle zayıflayan bir korelasyon (ρ=0.63-0.92) olduğunu göstermiştir. Bu bulgular, NDVI ve NDMI arasındaki ilişkinin bitkilerin fenolojik evreleri ile yakından ilişkili olduğunu ve su stresinin arttığı dönemlerde bu ilişkinin zayıfladığını ortaya koymaktadır. Nitekim Gaznayee vd. (2023) tarafından yapılan çalışmada uzaktan algılama tabanlı NDVI ve NDMI analizlerinin, alan düzeyinde sulama suyunun izlenmesi ile su gereksinimlerinin mekânsal ve zamansal dağılımına ilişkin değerli bilgiler sağlayabildiği; ayrıca nem içeriği ile NDVI değerleri arasında anlamlı ilişkiler bulunduğu tespit edilmiştir. Bu doğrultuda elde edilen bulgular, NDVI ve NDMI'nın eşzamanlı kullanımının bitki-su etkileşimlerinin çözümlemesinde bütüncül ve güvenilir bir çerçeve sunduğunu ortaya koymakta; böylece tarımsal su yönetimi, bitki sağlığının izlenmesi ve ekosistem dinamiklerinin değerlendirilmesine yönelik gelecekte yapılacak çalışmalara önemli bir bilimsel temel sağlamaktadır.

SONUÇ

Uydu tabanlı uzaktan algılama teknolojisinin hassas tarım uygulamaları kapsamında kullanımına odaklanan bu çalışmada, Nisan–Haziran dönemine ait çok zamanlı Sentinel-2 uydu görüntülerinden üretilen NDVI ve NDMI kullanılarak tarım alanlarında bitki örtüsü dinamikleri ile nem içeriği arasındaki ilişki analiz edilmiştir. Analiz sonuçları, tüm çalışma dönemleri boyunca NDVI ve NDMI indeksleri arasında pozitif ve yüksek düzeyde anlamlı bir ilişki bulunduğunu göstermiştir. Özellikle 20 Mayıs 2025 ve 23 Mayıs 2025 tarihlerinde elde edilen değerler (ρ=0.96), bitki örtüsü gelişimi ile yüzey nemi arasındaki güçlü korelasyonu açıkça ortaya koymaktadır. Elde edilen bulgular, büyüme sezonu boyunca bitki sağlığı ve nem dinamiklerinin uyumlu bir şekilde değiştiğini ve her iki indeksin tarımsal izleme süreçlerinde birlikte kullanılmasının karar verme süreçlerine önemli katkılar sağlayabileceğini göstermektedir. Çalışmanın sonuçları, ürün gelişiminin izlenmesi, sulama zamanının belirlenmesi ve su kaynaklarının daha verimli kullanılmasına yönelik planlamalarda uydu tabanlı uzaktan algılama verilerinin yüksek bir potansiyel taşıdığını göstermektedir. Gelecek çalışmalarda, belirli ve farklı ürün türlerine yönelik karşılaştırmalı analizlerin yapılması, meteorolojik verilerin çalışmalara daha etkin bir şekilde entegrasyonu ve makine öğrenmesi tabanlı modellerle ilişki düzeylerinin daha ayrıntılı olarak incelenmesi, elde edilen bulguların hem doğruluğunu hem de uygulama alanlarını genişleteceği değerlendirilmektedir.

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HOST INTERACTIONS AND DAMAGE MECHANISMS OF ERIOPHYID MITES (ACARI: ERIOPHYIDAE)

ERIOPHYID AKARLARIN (ACARİ: ERİOPHYİDAE) KONUKÇU ETKİLEŞİMLERİ VE ZARAR MEKANİZMALARI

Nihal KILIÇ

Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/0000-0002-7538-7444

Kübra KOÇ

Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/0009-0009-2442-3116

ÖZET

Eriophyid akarlar (Acari: Trombidiformes: Eriophyidae), mikroskobik boyutları, oldukça basitleşmiş vücut yapıları ve dar konukçu seçicilikleri nedeniyle bitkilerle ilişkili türler arasında dikkat çeker. Çoğu yalnızca tek bir bitki türünde yaşar ve bu durum onların bitkiye yüksek düzeyde uyum sağladığını gösterir. Çok küçük olmaları yalnızca fark edilmelerini zorlaştırmaz; aynı zamanda genç ve savunması düşük bitki dokularına hızla yerleşmelerine imkân verir. Bu özel yaşam şekli, oluşturdukları zarar tiplerinin gelişimini, şiddetini ve bitki fizyolojisine etkilerini doğrudan belirler. Bu çalışma, eriophyid akarların konukçu seçimini, başlıca zarar şekillerini ve bu zararların tarım ile doğal ekosistemlerdeki sonuçlarını bütüncül bir bakışla ele almaktadır.

Gall oluşturan türler, bitkinin büyüme noktalarında anormal doku gelişimine neden olarak sürgünlerin şeklini ve işlevini bozar. Söğütte *Aceria salicis* sürgün uçlarında kozalak benzeri yapılar oluşturur; bu yapılar yeni sürgün gelişimini sınırlar ve yıllık büyümeyi zayıflatır. Kuş üzümünde *Cecidophyopsis ribis* tomurcuk içini doldurarak çiçeklenmeyi ve meyve tutumunu ciddi biçimde düşürür. Fındıkta *Phytoptus avellanae* kozalak şeklindeki tomurcuk deformasyonlarıyla sürgün gelişimini ve verimi olumsuz etkiler.

Eriophyid akarlar beslenme sırasında tükürükleriyle bitki dokularına kimyasal sinyaller iletir ve bu sinyaller bitkinin fitohormon dengesini değiştirir. Bu değişim, gall ve erinoz gibi anormal doku gelişimlerinin ortaya çıkmasına neden olur. Böylece akarlar, doğrudan bitkiyi öldürmeseler bile büyüme düzenini bozarak fizyolojik kapasitenin düşmesine yol açar. Erinoz oluşturan türlerde yaprak alt yüzeyinde keçemsi bir tabaka oluşur ve bu tabaka ışık geçişini azaltarak fotosentezi zayıflatır. Asmada *Colomerus vitis* hem erinoza hem de tomurcuk deformasyonlarına neden olur ve üzüm verimini azaltır. Gall oluşumu, akarların genç dokularda hücre bölünmesi ve farklılaşmasını değiştiren kimyasal sinyaller göndermesiyle başlar. Bitkinin fitohormon dengesi değişir ve içi yumuşak, dışı koruyucu bir tabakayla çevrili özel bir yapı oluşur. Bu yapı akar için hem beslenme alanı hem de korunaklı bir mikrohabitat sağlar.

Eriophyid zararlarının en önemli yönü, bitkiyi öldürmeden fakat fizyolojik kapasitesini yavaş ve kalıcı biçimde azaltmalarıdır. Sürgün kısalması, çiçeklenme azalması, büyüme geriliği ve kalite düşüşü gibi biriken etkiler ekonomik kayıpları artırır. Bu nedenle erken teşhis, doğru tür belirlenmesi ve popülasyon değişimlerinin düzenli izlenmesi, entegre mücadele stratejilerinin başarısı için kritik öneme sahiptir.

Anahtar Kelimeler: Eriophyidae; konukçu seçiciliği, gal oluşumu, entegre mücadele.

ABSTRACT

Eriophyid mites (Acari: Trombidiformes: Eriophyidae) attract attention among plant-associated arthropods due to their microscopic size, highly simplified body structure, and narrow host specificity. Most species live on only a single plant species, which reflects their high level of adaptation to their hosts. Their extremely small size not only makes them difficult to detect but also enables them to settle rapidly on young and weakly defended plant tissues. This specialized lifestyle directly shapes the development, severity, and physiological impact of the damage they cause. This study provides an integrated overview of host selection in eriophyid mites, their main damage types, and the consequences of these damages for agricultural and natural ecosystems.

Gall-forming species cause abnormal tissue development at plant growth points, altering the shape and function of shoots. In willow, *Aceria salicis* produces cone-like structures at shoot tips that restrict new shoot formation and weaken annual growth. In currant, *Cecidophyopsis ribis* fills the interior of buds, markedly reducing flowering and fruit set. In hazelnut, *Phytoptus avellanae* induces cone-shaped bud deformities that hinder shoot development and decrease yield.

During feeding, eriophyid mites deliver chemical signals into plant tissues through their saliva, altering the plant's phytohormone balance. This shift leads to abnormal tissue developments such as galls and erinea. Thus, although they do not kill the plant directly, they disrupt normal growth and reduce physiological capacity over time. In erinea-forming species, a felt-like layer develops on the lower leaf surface, reducing light penetration and weakening photosynthesis. In grapevine, *Colomerus vitis* induces both erinea and bud deformities, lowering grape yield. Gall formation begins when mites send chemical signals that alter cell division and differentiation in young plant tissues. The plant's phytohormone balance changes, producing a structure with a soft, nutrient-rich interior and a protective outer layer. This structure provides both a feeding site and a sheltered microhabitat for the mite.

A major characteristic of eriophyid damage is that it weakens the plant gradually and persistently without causing direct mortality. Shortened shoots, reduced flowering, growth suppression, and quality loss collectively increase economic damage. Therefore, early detection, accurate species identification, and regular monitoring of population dynamics are essential for the success of integrated pest management strategies.

Keywords: Eriophyidae; host specificity, gall formation; integrated pest management

GİRİŞ

Eriophyoid akarlar (*Acari: Eriophyoidea*), bitkilerle sıkı ilişkili yaşam biçimleri, iki çift bacak taşımaları ve son derece küçülmüş vücut yapılarıyla fitofag eklembacaklılar içinde özel bir grubu temsil eder (Lindquist et al., 1996). Bu akarlar, konukçu bitkilerde oluşturdukları belirti tiplerine bağlı olarak Türkçe literatürde yaygın biçimde "gal akarları", "erinoz akarları" ve "pas

(bronzlaşma) akarları" olarak adlandırılmaktadır. Bu kullanım, eriophyoidlerin bitkilerde meydana getirdiği karakteristik zarar şekillerini doğrudan tanımlamaya yöneliktir.

Eriophyoidea üst grubunun en türce zengin familyası olan Eriophyidae, konukçu bitkinin epidermisi, tomurcukları ve iletim demetleri çevresinde beslenerek bitki fizyolojisini doğrudan etkileyen çok sayıda türü içerir. Bu etkileşimler yaprak deformasyonları, büyüme anomalileri, erinoz oluşumu, bronzlaşma ve özellikle gal gelişimi gibi belirgin belirtilerle ortaya çıkmakta; tarımsal üretimde ve doğal ekosistemlerde önemli ekonomik ve ekolojik kayıplara yol açmaktadır (de Lillo et al., 2018).

Son yıllarda yapılan çalışmalar, eriophyid akarların aşırı derecede sadeleşmiş morfolojik yapıları ve dünya genelindeki yetersiz örnekleme nedeniyle büyük ölçüde eksik tanımlandığını göstermektedir. Morfolojik olarak birbirine çok benzeyen türlerin klasik yöntemlerle ayırt edilmesi güçleşirken, moleküler çalışmalar birçok türün genetik olarak ayrışmış tür komplekslerinden oluştuğunu ortaya koymuştur (Amrine et al., 2003; Navia et al., 2010; Carew et al., 2009). Bu nedenle, tanımlanmış yaklaşık 4.400 eriophyoid türe karşın gerçek tür zenginliğinin çok daha yüksek olduğu kabul edilmektedir (Skoracka & Kuczyński, 2012).

Eriophyoid akarların en ayırt edici özelliklerinden biri, son derece dar konukçu seçiciliğidir. Küresel analizler, türlerin yaklaşık %80'inin yalnızca tek bir bitki türünde, %95'inin ise tek bir bitki cinsi içinde sınırlı kaldığını göstermektedir (Skoracka et al., 2010). Bu yüksek özgüllük, konukçu–fitofag ilişkileri ve gal oluşumu gibi karmaşık doku yanıtlarının anlaşılmasında Eriophyidae'yi önemli bir grup hâline getirmektedir.

Türkiye'de eriophyid akarlar üzerine yapılan çalışmalar çoğunlukla tarımsal ürünlerle sınırlıdır. Fındıkta *Phytoptus avellanae* (fındık kozalak akarı), bağlarda *Colomerus vitis*, zeytinde *Aceria oleae*, süs bitkilerinde ise *Eriophyes tiliae* gibi türler yaygın olarak rapor edilmiştir (Çobanoğlu, 2002; Akyazı & Ecevit, 2008; Bayram & Çobanoğlu, 2013). Buna karşın yabancı otlar ile doğal ve yarı doğal bitki örtüsü üzerindeki eriophyid faunası büyük ölçüde ihmal edilmiştir. Son yıllarda özellikle yabancı otlar üzerinde yapılan sınırlı çalışmalar, Türkiye'de çok sayıda yeni kayıt ve potansiyel yeni tür bulunduğuna işaret etmektedir (Denizhan et al., 2022).

Bu çalışma, Eriophyidae familyasındaki tür çeşitliliğini, konukçu bitki özgüllüğünü ve gal oluşumunun morfolojik, fizyolojik ve moleküler temellerini güncel literatür ışığında ele almaktadır.

TAKSONOMİ, FİLOGENİ VE TÜR ÇEŞİTLİLİĞİ

Eriophyoidea Üst Familyasının Taksonomik Konumu

Eriophyoid akarlar, *Acari* içinde *Acariformes* alt sınıfına bağlı *Trombidiformes* takımı içerisinde yer alan ve yalnızca iki çift bacağa sahip olmalarıyla diğer akar gruplarından belirgin biçimde ayrılan özel bir gruptur. Son derece küçülmüş ve sadeleşmiş morfolojik yapıları, bitki dokuları üzerinde ve içinde yaşamaya uyum sağlamış gelişimsel ve ekolojik bir özelleşmenin sonucu olarak değerlendirilmektedir (Lindquist et al., 1996). Bu özellikler, eriophyoidlerin hem tanılanmasını güçleştirmekte hem de sistematik çalışmalar açısından ayrı bir önem kazanmalarına neden olmaktadır.

Eriophyoidea üst familyası, güncel taksonomik sınıflandırmaya göre üç ana familyadan oluşmaktadır: *Eriophyidae, Phytoptidae* ve *Diptilomiopidae*. Bu aileler arasında *Eriophyidae*, tür ve cins sayısı bakımından açık ara en geniş grubu oluşturmakta ve aynı zamanda ekonomik önemi en yüksek olan eriophyoid türlerin büyük çoğunluğunu barındırmaktadır (de Lillo et al., 2018).

Eriophyidae Familyasının Morfolojik Tanı Kriterleri

Eriophyid akarlar, ince, uzun ve kurtçuğu andıran vücut şekilleriyle diğer bitkiyle beslenen akar gruplarından kolayca ayırt edilir. Gövdeleri çok küçük ve uzamış yapıdadır ve halka halka dizilmiş segmentlerden oluşur (Şekil 1). Besin alma organlarının bulunduğu gnathosoma bölgesi öne doğru uzamıştır ve beslenmeye uyumlu bir yapı gösterir. Dorsal ve ventral yüzeyde yer alan kalkanların şekli ve üzerindeki yapılar, cins ve türlerin ayırt edilmesinde önemli ipuçları sağlar. Ayrıca bacak uçlarındaki duyu yapıları (tarsal sensilla), vücut üzerindeki kıl dizilimleri (setalar) ve kütikula üzerindeki mikroskobik desenler, eriophyidlerin doğru tanılanmasında taksonomik açıdan kritik öneme sahiptir (Amrine & Stasny, 1994; de Lillo & Skoracka, 2010).



Şekil 1. Eriophyidae familyasının morfolojik tanısı (Science Photo Library, Media ID: 798412).

Tür Zenginliği

Dünya genelinde tanımlanmış eriophyoid tür sayısı yaklaşık 4.400 olup, bunların 3.200'den fazlası *Eriophyidae* familyası içinde yer almaktadır (Skoracka & Kuczyński, 2012). Ancak bu sayıların, grubun gerçek küresel çeşitliliğini tam olarak yansıtmadığı konusunda güçlü bir görüş birliği bulunmaktadır (Lindquist et al., 1996; Amrine et al., 2003).

Gerçek tür sayısının düşük görünmesinin başlıca nedenleri arasında eriophyidlerin dünya genelinde sınırlı ölçüde araştırılmış olması, özellikle tropik ve subtropik bölgelerde yetersiz örnekleme yapılması ve mikroskobik, aşırı sadeleşmiş vücut yapılarının morfolojiye dayalı tür ayrımını güçleştirmesi yer almaktadır (Navia et al., 2010; Krantz & Walter, 2009; de Lillo & Skoracka, 2010). Bu durum, birçok genetik olarak ayrışmış soyun tek bir takson altında değerlendirilmesine yol açmaktadır.

Ayrıca eriophyid türlerin büyük bir bölümünün yalnızca tek bir konukçu bitki türünde ve sınırlı popülasyonlar hâlinde bulunması, tespit ve örnekleme süreçlerini zorlaştırmaktadır (Skoracka et al., 2010). Moleküler çalışmalar, daha önce geniş konukçu spektrumlu tek tür olarak kabul edilen bazı taksonların gerçekte çoklu tür komplekslerinden oluştuğunu ortaya koymuştur (Carew et al., 2009; Skoracka & Kuczyński, 2012).

Konukçu bitki türü başına düşen ortalama eriophyoid tür sayısı yaklaşık 0,8 olarak hesaplanmakla birlikte, bu değerin dünya florasının büyük bölümünün henüz ayrıntılı olarak incelenmemiş olması nedeniyle muhtemelen bir alt sınırı temsil ettiği düşünülmektedir (Skoracka et al., 2010; de Lillo et al., 2018).

KONUKÇU BİTKİ SEÇİCİLİĞİ VE KONUKÇU–AKAR ETKİLEŞİMLERİ

Eriophyidae'de Konukçu Özgüllüğünün Önemi

Eriophyidae familyası, bitki–akar etkileşimleri içinde bilinen en dar konukçu spektrumuna sahip gruplardan biridir. Küresel ölçekte eriophyoid türlerin yaklaşık %80'inin yalnızca tek bir bitki türünde, %95'inin ise tek bir bitki cinsi içinde sınırlı kaldığını ortaya koymaktadır (Skoracka et al., 2010). Bu yüksek konukçu seçiciliği, eriophyidlerin bitki dokularına son derece özgül uyumlar geliştirmesinin bir sonucudur ve özellikle gal oluşumu gibi karmaşık doku değişimlerinin ortaya çıkmasında belirleyici rol oynar. Konukçuya bu denli sıkı bağlılık, eriophyoid akarları bitki gelişimi, konukçuya adaptasyon süreçleri ve bitki etkileşimlerinin mekanizmalarını anlamak açısından önemli bir grup hâline getirmektedir.

Monofaji, Oligofaji ve Nadir Geniş Konukçu Kullanan Türler

Eriophyid akarların büyük çoğunluğu monofag olup yaşam döngülerini yalnızca tek bir konukçu bitki türü üzerinde tamamlar. Bu durum, özellikle *Aceria*, *Eriophyes*, *Cecidophyopsis* ve *Phyllocoptes* gibi türce zengin cinslerde belirgin şekilde görülmekte ve eriophyidlerin konukçu bitkiye yüksek düzeyde uyum sağladığını ortaya koymaktadır (Lindquist et al., 1996; Amrine & Stasny, 1994).

Bununla birlikte, sınırlı sayıda türün yakın bitki türleri arasında gelişebilen oligofag popülasyonlar oluşturabildiği bilinmektedir. Bu durum genellikle aynı bitki cinsi veya yakın akraba bitki grupları içinde gözlenmekte ve dar sınırlar içinde değişebildiğini göstermektedir (Skoracka et al., 2010; Skoracka & Kuczyński, 2012).

Gerçek anlamda geniş konukçu spektrumuna sahip eriophyid türler ise son derece nadirdir ve bu türlerin büyük kısmı, ayrıntılı moleküler çalışmalar sonucunda morfolojik olarak birbirine çok benzeyen ancak genetik olarak ayrışmış gizli tür kompleksleri olarak yeniden değerlendirilmiştir (Carew et al., 2009; Skoracka & Kuczyński, 2012).

Konukçu Seçimi ve Konukçu–Akar Etkileşimleri

Dünya genelinde tanımlanmış yaklaşık 4.400 eriophyoid tür bulunmasına karşın, bu sayının grubun gerçek küresel çeşitliliğini yansıtmadığı yaygın olarak kabul edilmektedir (Skoracka & Kuczyński, 2012; Lindquist et al., 1996). Sınırlı örnekleme, özellikle tropik bölgelerdeki araştırma eksikliği ve eriophyidlerin mikroskobik, oldukça sadeleşmiş vücut yapıları, morfolojiye dayalı tür ayrımını zorlaştırmakta ve birçok genetik olarak ayrışmış soyun tek takson altında değerlendirilmesine yol açmaktadır (Amrine et al., 2003; Navia et al., 2010; de Lillo & Skoracka, 2010). Türlerin büyük bölümünün yalnızca tek bir konukçu bitki türünde ve sınırlı populasyonlar hâlinde bulunması, bu durumu daha da belirginleştirmektedir (Skoracka et al., 2010). Moleküler çalışmalar, bazı taksonların gerçekte tür komplekslerinden oluştuğunu göstermiştir (Carew et al., 2009). Eriophyid akarlar, konukçu bitkilerde yalnızca beslenmeye bağlı doku kayıplarına değil; epidermal bronzlaşma ve pas benzeri belirtiler (*Aculops*, *Aculus*), erinoz oluşumu (Şekil 2) ve özellikle gal gelişimi gibi, bitki dokularının gelişimsel ve fizyolojik işleyişini değiştiren karmaşık etkileşimlere neden olur (Oldfield & Proeseler, 1996; 1996; Paponova et al., 2017; de Lillo et al., 2018).



Şekil 2. Eriophidlerin neden olduğu pas, erinoz, gal oluşumları

ERIOPHYIDLERİN BİTKİDE OLUŞTURDUĞU YAYGIN BELİRTİ TİPLERİ

Eriophyid akarlar, konukçu bitki dokularında oluşturdukları yapısal ve fizyolojik değişimlere göre belirgin belirtiler meydana getirir. Bu belirtiler, bitki dokusunun nasıl etkilendiğine bağlı olarak dört ana grupta toplanmaktadır. Bu sınıflandırma hem teşhis hem de zarar değerlendirmesi açısından temel bir çerçeve sunar.

Gal Oluşturan Eriophyidler

Gal oluşturan eriophyid akarlar, konukçu bitki dokularında hücre bölünmesini (hiperplazi) ve hücre büyümesini (hipertrofi) tetikleyerek normal dokudan farklılaşmış, yapısal ve işlevsel olarak özgün oluşumlar meydana getirir. Bu grubun en ayırt edici özelliği, konukçu bitkiye son derece dar bir bağlılık göstermeleridir; türlerin büyük çoğunluğu yalnızca tek bir bitki türünde gal oluşturabilmektedir (Skoracka et al., 2010; Skoracka & Kuczyński, 2012).

Gal gelişimi özellikle genç ve meristematik dokularda gerçekleşir ve hücre döngüsünün yeniden etkinleştirilmesi, doku polaritesinin bozulması ve yaprak yüzey kimliğinin değişmesiyle ilişkilidir. Beslenme sırasında eriophyid akarların tükürükleriyle bitki dokularına ilettiği kimyasal sinyaller, bitki içindeki fitohormon dengesini ve gelişim düzenleyici maddeleri etkileyerek dokuların normal gelişim seyrini değiştirir (Oldfield & Proeseler, 1996).

Gal dokusu içinde damar yapılarının yeniden düzenlenmesi sonucunda şeker ve aminoasit akışı artar; bu durum galin, akar için hem besince zengin hem de çevresel etkilere karşı korunaklı bir mikrohabitat hâline gelmesini sağlar (Jeppson et al., 1975; Childers et al., 2020).

Gal Tipleri, Morfolojik Çeşitlilik ve Gal Oluşturan Başlıca Cinsler

Gal oluşturan eriophyid akarlar, konukçu bitki grubuna bağlı olarak farklı morfolojik özellikler gösteren gal tipleri meydana getirir. Bu yapılar, bitki dokusunun hangi bölgesinin etkilendiğine ve dokusal yeniden düzenlenmenin derecesine bağlı olarak belirgin biçimde ayrışır. Literatürde eriophyid kaynaklı galler genellikle dört ana morfolojik grupta ele alınmaktadır (Amrine & Stasny, 1994; Lindquist et al., 1996; de Lillo et al., 2018).

Cepli galler, yaprak yüzeyinde kese ya da çukur şeklinde odacıklar hâlinde gelişir ve çoğunlukla yaprağın fotosentetik yüzeyini daraltır. Bu tip gallerin klasik örneği, ıhlamurda görülen *Eriophyes tiliae*'dir (Şekil 3). Tür, yaprak yüzeyinde kırmızımsı, içe doğru çökük cepli galler oluşturarak fotosentezi sınırlar ve erken yaprak yaşlanmasına neden olur. Benzer şekilde *Eriophyes pyri,* armut yapraklarında cepli gal oluşumuyla yaprak deformasyonları ve büyüme geriliği meydana getirir (Lindquist et al., 1996; Oldfield & Proeseler, 1996).



Şekil 3. Ihlamur yapraklarında *Eriophyes tiliae* zararı (Fotoğraf: Rosser1954 Roger Griffith, *Eriophyes tilae tilae* detail.JPG, Holger Krispile:Galle Lindengallmilbe Eriophyes tiliae.JPG Wikimedia Commons)

Çok odacıklı galler, damar dokusunun belirgin biçimde yeniden düzenlendiği ve yoğun hücre bölünmesiyle şekillenen karmaşık yapılardır. Bu gal tipi özellikle *Aceria* cinsi içinde yaygındır. *Aceria anthocoptes*, devedikeni üzerinde çok odacıklı galler oluşturarak sürgün gelişimini sınırlar (Şekil 4) ve bitkinin rekabet gücünü azaltır. Bu türde zarar, besin akışının gal dokusuna yönlendirilmesiyle bitkinin genel gelişim dengesinin bozulması şeklinde ortaya çıkar (Navia et al., 2010; de Lillo et al., 2018).



Şekil 4. *Aceria anthocoptes'*in meydana getirdiği çok odacıklı galler

Tomurcuk galler, tomurcukların anormal büyümesi ve sürgün deformasyonlarıyla karakterizedir ve çoğunlukla *Cecidophyopsis* cinsine ait türler tarafından oluşturulur. Kuş üzümünde yaygın olarak görülen *Cecidophyopsis ribis*, tomurcuk içini tamamen dolduran büyük böbrek şeklindeki gallerle tomurcuğun normal gelişimini engeller. Bu durum çiçeklenmenin azalmasına, meyve tutumunun düşmesine ve uzun vadede bitkinin zayıflamasına yol açar (Lindquist et al., 1996; Navia et al., 2010). Tomurcuk gallerine en önemli örneklerden biri de fındıkta görülen *Phytoptus avellanae*'dir (Kaya, et. al., 2023) ve tomurcuklarda kozalak benzeri gal yapıları oluşturmaktadır (Şekil 5).



Şekil 5. *Phytoptus avellanae* fındık kozalak akarının oluşturduğu galler ve gal oluşturan bireyler (Fotoğraf: Gilles San Martin (Wikimedia Commons), File:Phytoptus avellanae.jpg)(

Fotoğraf: Stephen James McWilliam (Wikimedia Commons), File:Phytoptus avellanae (Liverpool, UK).jpg

Damar galleri (damar kalınlaşmaları); yaprak ana veya yan damarları boyunca şişkinlik ve kalınlaşma şeklinde ortaya çıkar yaprak mimarisini doğrudan etkiler. Kavakta görülen *Aceria parapopuli*, damar dokuları boyunca oluşturduğu gallerle yaprak formunu bozar (Şekil) ve büyüme performansını düşürür. Bu tip gallerde damar dokusunun yeniden düzenlenmesi, gal içindeki besin birikimini artıran temel mekanizmadır (Amrine & Stasny, 1994; de Lillo et al., 2018).



Şekil 6. *Aceria parapopuli* nin oluşturduğıu galleri

Gal Oluşturan Türlerin Tarımsal Önemi

Gal oluşturan eriophyid akarlar, tarımsal sistemlerde hem doğrudan hem de dolaylı etkileri nedeniyle önemli zararlılar arasında yer alır. Yaprak, sürgün ve tomurcuk dokularında meydana gelen yapısal deformasyonlar fotosentez kapasitesini azaltır, bitkinin büyüme dengesini bozar ve uzun vadede belirgin verim kayıplarına yol açar. Bu etkiler özellikle odunsu kültür bitkilerinde daha belirgin hâle gelmektedir.

Türkiye koşullarında gal oluşturan eriophyidlere ait en dikkat çekici örneklerden biri, fındıkta yaygın olarak görülen fındık kozalak akarı *Phytoptus avellanae*'dir. Bu tür, tomurcuklarda kozalak benzeri galler oluşturarak sürgün gelişimini engeller, çiçek tomurcuğu oluşumunu sınırlar ve doğrudan verim kaybına neden olur. Oluşturduğu yapılar, tomurcuk galinin tipik bir örneği olup gal oluşturan eriophyidler grubunda değerlendirilir (Lindquist et al., 1996; Navia et al., 2010).

Benzer şekilde, Türkiye'de park ve süs bitkilerinde yaygın olan ıhlamur ağaçlarında *Eriophyes tiliae*, yapraklarda ceplik galler oluşturarak yaprak yüzeyinin işlevsel alanını daraltır ve erken yaprak yaşlanmasına yol açar. Kavakta görülen *Aceria parapopuli* ise yaprak damarları boyunca gelişen gallerle yaprak mimarisini bozarak büyüme performansını düşürür. Bu türlerin ortak özelliği, zararlarının belirli konukçu bitkilerde yoğunlaşması ve bitkinin fizyolojik kapasitesini kademeli olarak azaltmasıdır (Lindquist et al., 1996; de Lillo et al., 2018).

Türkiye tarımı açısından en önemli örneklerden biri de fındıkta görülen *Phytoptus avellanae*'dir (Kaya, et. al, 2023). Bu tür, tomurcuklarda kozalak benzeri gal yapıları oluşturarak sürgün gelişimini sınırlar, çiçek tomurcuğu oluşumunu azaltır ve doğrudan verim kaybına yol açar.

Gal oluşturan eriophyidlerin tarımsal önemi yalnızca doğrudan doku deformasyonlarıyla sınırlı değildir. Bazı türler aynı zamanda bitki virüslerinin taşınmasında rol oynayarak dolaylı zarar oluşturur. Bu durum, gal oluşumunun yanı sıra epidemiyolojik risklerin de dikkate alınmasını gerektirir. Bu nedenle tarımsal üretimde erken teşhis, düzenli izleme ve doğru tür tanımlaması

açısından özel dikkat gerektiren bir grup olarak değerlendirilmektedir (Smith et al., 2010; de Lillo et al., 2018).

Erinoz Oluşturan Eriophyidler

Erinozun Tanımı ve Genel Özellikleri

Erinoz, eriophyid akarların konukçu bitki yapraklarında oluşturduğu, çoğunlukla yaprak alt yüzeyinde gelişen yoğun ve keçemsi tüylenme tabakası ile karakterize bir belirti tipidir. Bu yapı, gerçek bir gal oluşumundan farklı olarak kapalı bir doku yapısı içermez; ancak bitki dokusunda belirgin anatomik ve fizyolojik değişimlere yol açar. Erinoz oluşumu, özellikle yaprak epidermisi ve mezofil dokusunun yeniden düzenlenmesiyle ilişkilidir (Lindquist et al., 1996; de Lillo et al., 2018).

Erinoz Oluşum Mekanizması, Morfolojik ve Anatomik Özellikleri

Erinoz oluşumu, eriophyid akarların beslenme sırasında bitki dokularına ilettiği kimyasal sinyallerin, bitki içindeki fitohormon dengesini ve aynı zamanda bitki içindeki gelişim düzenleyici maddeleri etkilemesiyle başlar. Bu etki sonucunda trikom gelişimi uyarılır ve normalden çok daha yoğun, sık ve düzensiz bir tüylenme tabakası ortaya çıkar. Erinoz tabakası genellikle yaprak alt yüzeyinde gelişir ve yaprağın doğal yüzey mimarisini belirgin biçimde değiştirir (Oldfield & Proeseler, 1996).

Erinozlu yapraklarda epidermal hücrelerde kalınlaşma, trikom yoğunluğunda artış ve mezofil dokusunda düzensiz hücre dizilimi gözlenir. Erinoz tabakası, yaprak yüzeyinde hava akışını ve ışık geçirgenliğini azaltarak fotosentez kapasitesinin düşmesine neden olur. Ayrıca bu yapı, yaprak yüzeyinde nem tutulumunu artırarak mikroklimatik koşulları değiştirir ve yaprak dokusunun fizyolojik dengesini bozar (Lindquist et al., 1996; Childers et al., 2020).

Erinoz Oluşturan Başlıca Cins ve Türler

Erinoz oluşturan eriophyid türler belirli cinslerde yoğunlaşmaktadır. *Aceria (Eriophyes) tiliae,* ıhlamur ağaçlarında yaygın olarak görülür ve yaprak alt yüzeyinde yoğun erinoz tabakası oluşturarak yaprakların solunum ve fotosentez kapasitesini belirgin biçimde azaltır. *Aceria oleae,* zeytinde erinoz benzeri yoğun tüylenme ve yaprak deformasyonlarına yol açarak ağacın fizyolojik dengesini ve verim potansiyelini düşürür. *Colomerus vitis,* asma yapraklarında erinozun en iyi bilinen örneklerinden biridir; bu tür hem yapraklarda erinoz oluşumuna hem de tomurcuk gelişiminde bozulmalara neden olur (Şekil 7) ve salkım oluşumunu olumsuz etkiler (Lindquist et al., 1996; Oldfield & Proeseler, 1996; de Lillo et al., 2018).



Şekil 7. *Colomerus vitis'in* meydana getirdiği erinoz zararı (https://www.dreamstime.com/photos-images/colomerus-vitis.html)

Erinozun Bitki Fizyolojisi ve Verim Üzerine Etkileri

Erinoz oluşumu, bitkide genellikle doğrudan doku kaybı yaratmaz; ancak fotosentez kapasitesinin azalması, gaz alışverişinin kısıtlanması ve yaprak dokusunun erken yaşlanması gibi kümülatif etkilerle verim düşüşüne neden olur. Uzun süreli ve yoğun erinoz varlığı, bitkinin büyüme dengesini bozar ve özellikle çok yıllık bitkilerde yıllar içinde belirgin performans kayıplarına yol açar (de Lillo et al., 2018; Childers et al., 2020).

Erinoz oluşturan eriophyidler, özellikle bağ, zeytinlik ve süs bitkileri gibi sistemlerde ekonomik açıdan önem taşır. Belirtiler çoğu zaman gözden kaçabildiği için zarar geç fark edilir ve bu durum kayıpların artmasına neden olur. Bu nedenle erinoz belirtilerinin doğru tanımlanması, türün doğru teşhisi ve popülasyonların izlenmesi, entegre mücadele stratejilerinin planlanmasında kritik rol oynar (Oldfield & Proeseler, 1996; de Lillo et al., 2018).

Pas / Bronzlaşma Oluşturan Eriophyidler

Genel Tanım ve Zararın Niteliği

Pas veya bronzlaşma oluşturan eriophyid akarlar, konukçu bitkilerin özellikle yaprak epidermisi üzerinde yüzeysel beslenme yoluyla hücresel bütünlüğü bozan türlerden oluşur. Bu grupta gal veya erinoz gibi belirgin doku proliferasyonları yerine, epidermal hücrelerin çökmesi, klorofil kaybı ve kütikula yapısının bozulması ön plandadır. Sonuç olarak yapraklarda pas rengi, bronz tonlar veya matlaşma şeklinde görsel belirtiler ortaya çıkar (Lindquist et al., 1996; de Lillo et al., 2018).

Bu zarar tipi genellikle bitkinin fotosentetik kapasitesinde azalma, su dengesinde bozulma ve uzun vadede büyüme geriliği ile ilişkilidir. Pas ve bronzlaşma belirtileri, özellikle yüksek popülasyon yoğunluklarında bitkinin genel fizyolojik performansını belirgin biçimde düşürmektedir.

Zarar Mekanizması

Pas oluşturan eriophyidler beslenme sırasında epidermal hücrelerin içeriğini emerek hücre duvarlarında mikroskobik hasara neden olur. Bu süreçte:

- Epidermal hücrelerde çökme ve nekroz benzeri yapısal bozulmalar,
- Kloroplastların işlev kaybı ve klorofil degradasyonu,
- Kutikula bütünlüğünün zayıflaması ve yüzeyin değişmesi gözlenir. Bu fizyolojik bozulmalar yaprak yüzeyinde pas veya bronz renkli bir görünüm oluşturur. Zarar genellikle ilerleyici nitelikte olup, yaprağın tamamına yayılabilir (Jeppson et al., 1975; Childers et al., 2020).

Başlıca Türler ve Konukçu Bitkiler

Pas / bronzlaşma oluşturan eriophyidlerin önemli bir bölümü *Aculops, Aceria* ve *Phyllocoptes* cinslerinde yoğunlaşmaktadır.

Aculops lycopersici: Domateste görülen en önemli pas akarlarından biridir. Yapraklarda hızlı bronzlaşma, yaprak kıvrılması, gövde ve meyvelerde matlaşma oluşturur (Şekil 8). Yüksek yoğunluklarda bitkide genel çöküşe kadar ilerleyebilen zarar meydana getirir (Jeppson et al., 1975; Lindquist et al., 1996).



Şekil 8. *Aculops lycopersici*. Domates yaprağında bronzlaşma oluşturan ergin birey (Fotoğraf: Gilles San Martin (Wikimedia Commons), CC BY-SA 4.0.

Aculus schlechtendali: Elmada yaprak üst yüzeyinde pas renkli görünüm ve matlaşma oluşturur (Şekil 9) Fotosentez kapasitesinin azalmasına bağlı olarak meyve iriliğinde düşüş ve yıllık sürgün gelişiminde zayıflama görülür (Childers et al., 2020; de Lillo et al., 2018).



Şekil 9. *Aculus schlechtendali*. Ergin bireyler, elma yaprağında ve meyvesinde bronzlaşma ve pas benzeri zarar belirtileri. Fotoğraf: (https://treefruit.wsu.edu/crop-protection/opm/apple-rust-mite/).

Phyllocoptes gracilis: Bazı odunsu bitkilerde yaprak yüzeyinde bronzlaşma ve epidermal bozulmalara neden olur. Zarar çoğunlukla estetik ve fizyolojik kalite kaybı şeklinde ortaya çıkar (Lindquist et al., 1996).

Türkiye'de bağ, elma ve sebze alanlarında bronzlaşma belirtileriyle ilişkili eriophyid türlerin varlığı bildirilmiş; özellikle *Aculus ve Aceria* türlerinin yaygın olduğu belirtilmiştir (Çobanoğlu, 2002; Akyazı & Ecevit, 2008).

Tarımsal Önemi

Pas ve bronzlaşma oluşturan eriophyidler, gal oluşturan türlere kıyasla daha az dikkat çekici belirtiler oluştursa da kümülatif ve süreklilik gösteren zararları nedeniyle tarımsal açıdan son derece önemlidir. Fotosentez kaybı, yaprak erken yaşlanması ve ürün kalitesinde düşüş bu grubun başlıca etkileridir.

Özellikle sebze ve meyve üretiminde bronzlaşma belirtileri, pazar değerini doğrudan düşürmekte; yüksek popülasyonlarda ise bitkinin genel gelişimini baskılamaktadır. Bu nedenle pas oluşturan eriophyidler, entegre mücadele programlarında erken teşhis ve düzenli izleme gerektiren bir zarar grubunu temsil eder (de Lillo et al., 2018).

GAL OLUŞUM MEKANİZMALARI

Eriophyidae türlerinin gal oluşturma kapasitesi, bitki–akar etkileşimleri içinde en karmaşık gelişimsel düzenleme örneklerinden birini oluşturur. Gal oluşumu; akarların beslenme sırasında

bitki dokusuna aktardığı tükürük salgılarıyla başlar ve bitki içindeki fitohormon ile gelişim düzenleyici maddeleri etkilediği bilinen sinyallerin yönlendirilmesiyle ilerler. Bu süreçte hücre döngüsü yeniden düzenlenir, damar dokusu gal yapısına doğru yönlendirilir ve savunma yanıtları gal bölgesinde yerel olarak baskılanır (Lindquist et al., 1996; de Lillo et al., 2018; Paponova et al., 2017).

Gal gelişimi çoğunlukla kışlayan dişi akarların genç ve meristematik dokularda beslenmeye başlamasıyla tetiklenir. Tükürük salgıları, bitki hücrelerinde fizyolojik dengeyi bozarak yoğun hücre bölünmesini başlatır ve bu etki akar beslenmesi sürdüğü sürece devam eder. Beslenmenin kesilmesiyle birlikte gal gelişiminin durması, sürecin doğrudan akar varlığına bağlı olduğunu göstermektedir (Oldfield & Proeseler, 1996; Paponova et al., 2017).

Bu aşamada özellikle auksin ve sitokinin dengesindeki değişimler belirleyici rol oynar. Auksin dağılımındaki bozulmalar hücre polaritesinin kaybına ve yönsüz büyümeye yol açarken, sitokininler yoğun hücre bölünmesini ve çok odacıklı gal yapılarının oluşumunu destekler. Aynı zamanda jasmonat ve salisilik asit temelli savunma yanıtlarının yerel olarak baskılanması, gal dokusunun stabil biçimde gelişmesini kolaylaştırır (Paponova et al., 2017; Childers et al., 2020; Desnitskiy et al., 2023).

Gal olgunlaştıkça bitki dokusunda belirgin anatomik ve histolojik değişimler ortaya çıkar. Yoğun hücre çoğalması, parankim dokusunun genişlemesi ve damar dokusunun gal içine doğru yeniden yönlendirilmesi, galin besince zengin bir yapı hâline gelmesini sağlar. Epidermal tabakanın kalınlaşması ve antosiyanin gibi pigmentlerin birikimi ise gal dokusuna mekanik ve fizyolojik koruma kazandırır. Özellikle *Eriophyes tiliae* tarafından oluşturulan gallerde görülen kırmızı renklenme, bu koruyucu sürecin tipik bir göstergesidir (Lindquist et al., 1996; de Lillo et al., 2018; Desnitskiy et al., 2023).

SONUÇ

Eriophyidae familyası, dar konukçu seçiciliği ve bitki dokularında oluşturduğu gal, erinoz ve pas benzeri belirtilerle bitki–akar etkileşimleri içinde özel bir konuma sahiptir. Bu akarların zararları, yalnızca beslenmeye bağlı doku kaybı değil; bitkinin gelişimsel ve fizyolojik süreçlerinin yeniden yönlendirilmesiyle ortaya çıkan kalıcı etkiler şeklinde gerçekleşmektedir. Mevcut veriler, eriophyid çeşitliliğinin dünya genelinde ve özellikle Türkiye'de büyük ölçüde eksik tanımlandığını göstermektedir. Bu nedenle, doğru tür teşhisi, erken tanı ve biyoloji temelli entegre mücadele yaklaşımlarının geliştirilmesi kritik öneme sahiptir. Gelecekte yapılacak çalışmaların, gal oluşum mekanizmaları ve konukçu–akar etkileşimlerinin moleküler temellerine odaklanması hem temel hem de uygulamalı akaroloji açısından önemli katkılar sağlayacaktır.

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DRIED FRUIT MITE *CARPOGLYPHUS LACTIS*: BIOLOGY, FOOD CONTAMINATION AND PROSPECTS FOR SUSTAINABLE CONTROL

KURU MEYVE AKARI *CARPOGLYPHUS LACTİS*: BİYOLOJİ, GIDA KONTAMİNASYONU VE SÜRDÜRÜLEBİLİR MÜCADELE POTANSİYELLERİ

Nihal KILIÇ

Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/0000-0002-7538-7444

Eylül Duru YÜCEL

Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/ 0009-0007-7343-3287

ÖZET

Carpoglyphus lactis (Astigmata: Carpoglyphidae), şekerce zengin depolanmış ürünlerde hızla çoğalarak kalite kaybına ve gıda güvenliği sorunlarına yol açan, yaygın olarak "kuru meyve akarı" olarak bilinen önemli bir zararlıdır. Türün kuru incir, kayısı, üzüm ve hurma gibi geleneksel kuru meyvelere ek olarak reçel, bal, polen, arı ekmeği, pekmez ve sirke gibi fungus ve maya açısından zengin ortamlarda da bulunabilmesi, onun fermente ürünlere de kolaylıkla uyum sağlayabilen bir zararlı olduğunu göstermektedir. *C. lactis* ürünlerde sindirim artıkları, salgıları ve ölü bireylerin kalıntılarıyla fungus gelişimini hızlandırarak istenmeyen tat ve koku oluşumuna, renk kararmasına ve doku bozulmasına neden olur. Özellikle kuru kayısılarda üründe yumuşama ve yapışkanlık ürünün ticari değerini belirgin şekilde düşürmektedir.

Yapılan araştırmalarda kuru incirlerin bazı örneklerinde akarın kilogram başına 10.000'i aşan yoğunluklara ulaşabildiğini bildirilmektedir. Bu durum türün depolama sürecinde sürekli bir risk oluşturduğunu ve uygun koşullar altında çok hızlı popülasyon artışı sergileyebildiğini göstermektedir. Öte yandan bazı kimyasal fumigantların yasaklanması, direnç sorunları ve tüketicilerin kalıntı konusundaki hassasiyeti, alternatif mücadele yöntemlerinin önemini artırmıştır.

Son yıllarda yapılan çalışmalar, *C. lactis*'in oksijen ve nem düzeylerine duyarlı olduğunu ortaya koymuş; ozon gazı, ferrik oksit, kalsiyum klorür ve silika jel gibi fiziksel ajanların paketli kuru kayısıda etkili kontrol sağladığı belirlenmiştir. Ozon kısa sürede yüksek ölüm oranı oluştururken, ferrik oksit oksijen seviyesini düşürerek etkili olmaktadır. Bunun yanında, yerli diatomlu toprak uygulamalarının akarın dış kutikula tabakasını aşındırarak hızlı su kaybına yol açtığı ve farklı sıcaklık koşullarında popülasyon gelişimini başarıyla baskıladığı bildirilmiştir.

Bu çalışma, *C. lactis*'in biyolojisini, ekolojisini, bazı organizmalarla etkileşimini ve çevre dostu alternatif mücadele yöntemlerini bütüncül bir yaklaşımla ele alarak, depolama ekosistemlerinde sürdürülebilir ve güvenli yönetim stratejileri geliştirmek için güncel bir bilimsel çerçeve sunmayı amaçlamaktadır.

Anahtar Kelimeler: *Carpoglyphus lactis,* depo akarları, gıda kontaminasyonu, alternatif mücadele; diatom toprağı.

ABSTRACT

Carpoglyphus lactis (Astigmata: Carpoglyphidae), commonly known as the "dried fruit mite," is an important pest that rapidly proliferates in sugar-rich stored products, causing quality degradation and food safety concerns. The presence of this species not only in traditional dried fruits such as figs, apricots, grapes, and dates but also in fungus- and yeast-rich substrates including jam, honey, pollen, bee bread, molasses, and vinegar demonstrates its strong ability to adapt to fermented food environments. *C. lactis* accelerates fungal development through its digestive residues, secretions, and the accumulation of dead individuals, leading to off-flavors, discoloration, and textural deterioration. In dried apricots in particular, product softening and increased stickiness markedly reduce the commercial value of the commodity.

Studies have reported that the mite can reach densities exceeding 10,000 individuals per kilogram in some dried fig samples. This indicates that the species poses a continuous risk during storage and is capable of very rapid population growth under favorable conditions. In addition, the restriction of certain chemical fumigants, resistance problems, and consumer sensitivity to chemical residues have further increased the importance of alternative control methods.

Recent studies have shown that *C. lactis* is sensitive to oxygen and humidity levels, and physical agents such as ozone gas, ferric oxide, calcium chloride, and silica gel have been demonstrated to provide effective control in packaged dried apricots. While ozone induces rapid mortality, ferric oxide is effective by reducing oxygen concentration. Furthermore, the application of locally produced diatomaceous earth has been reported to abrade the mite's cuticular layer, causing rapid water loss and successfully suppressing population growth under various temperature conditions.

This review aims to provide an up-to-date scientific framework by examining the biology, ecology, interactions with certain microorganisms, and environmentally friendly alternative control methods of *C. lactis*, thereby contributing to the development of sustainable and safe management strategies in stored-product ecosystems.

Keywords: *Carpoglyphus lactis*, stored-product mites, food contamination, alternative control, diatomaceous earth.

Giriş

Kuru meyve akarı *Carpoglyphus lactis* (L.) (Acari: Carpoglyphidae), gıda depolama ekosistemlerinde yaygın olarak bulunan ve özellikle kuru incir, kayısı, üzüm, hurma ve pekmez gibi yüksek şeker içerikli ürünlerde hızla çoğalabilen kozmopolit bir türdür. Akarın bu ürünlerde oluşturduğu zarar, yalnızca fiziksel tüketimle sınırlı olmayıp; salgıladığı enzimler, dışkı partikülleri ve kutikula kalıntıları aracılığıyla ürünün kimyasal ve mikrobiyolojik yapısında bozulmalara yol açarak ekonomik kayıplara neden olmaktadır (Hughes, 1976, Hubert et.al, 2015). Bu bozulmalar, meyve yüzeyinde yumuşama, renk değişimi, yapışkanlık artışı ve fermente kokular şeklinde duyusal kalite kayıplarıyla kendini gösterir.

Türkiye'de yapılan kapsamlı bir çalışmada, kuru incir örneklerinin %94,3'ünde akar bulaşıklığının bulunduğu ve *C. lactis*'in bazı partilerde kilogram başına 10.488 bireye kadar ulaşabildiği rapor edilmiştir (Dizlek et al., 2019). Bu bulgular, türün depolama aşamasında hızlı

popülasyon artışı gösterdiğini ve gıda güvenliğini tehdit eden önemli bir kontaminasyon ajanı olduğunu doğrulamaktadır. Türün insan sağlığı açısından da önemi büyüktür; akar parçacıkları ve dışkıları solunum ve gıda kaynaklı alerjenler arasında yer almakta, hassas bireylerde dermatit ve solunum sorunlarına yol açabilmektedir (Colloff, 2009).

C. lactis'in biyolojisi ve ekolojisi, yüksek nem ve şeker içeriği bulunan mikrohabitatlara güçlü bir uyum göstermesiyle karakterizedir. Türün gelişim süresi sıcaklıkla birlikte kısalmakta ve özellikle daha sıcak–daha nemli koşullarda popülasyon artış potansiyeli belirgin biçimde yükselmektedir; örneğin kuru kayısı üzerinde yürütülen yaşam çizelgesi verileri, 28 °C ve %80 bağıl nemde içsel artış hızının en yüksek düzeye çıktığını ve jenerasyon süresinin kısaldığını göstermiştir (Güldalı & Çobanoğlu, 2010). Ayrıca birçok kuru meyvede doğal olarak bulunan maya ve funguslarla etkileşim hâlinde olması, mikrobiyal enzim ve organik asit üretimiyle besin yüzeyinin daha erişilebilir hâle gelmesi üzerinden akarın beslenme verimliliğini artırarak popülasyonun hızla yükselmesine katkı sağlayabilmektedir (Hubert et al., 2021). Bu nedenle *C. lactis*, gıda maddelerinde kimyasal/mikrobiyal bozunma süreçlerinin hem tetikleyicisi hem de hızlandırıcısı olarak değerlendirilebilir.

Depo akarlarının kimyasal fumigantlarla kontrolü geleneksel olarak fosfin, kükürt dioksit ve metil bromür gibi maddelere dayanıyordu; ancak fosfine karşı direnç gelişimi, metil bromürün Montreal Protokolü kapsamında yasaklanması ve gıda güvenliğine ilişkin yasal sınırların sıkılaşması, bu türlere karşı alternatif mücadele yöntemlerinin geliştirilmesini zorunlu kılmıştır (Subramanyam & Roesli, 2000). Güncel araştırmalar, inert tozlar, uçucu yağlar, sıcaklık–nem yönetimi ve atmosfer manipülasyonu gibi kimyasal olmayan uygulamaların *C. lactis* üzerinde yüksek etkinlik sağlayabildiğini göstermiştir.

Bu derlemenin amacı, *C. lactis*'in biyolojisini, ekolojisini, gıda kontaminasyonundaki rolünü ve sürdürülebilir mücadele potansiyellerini güncel bilimsel veriler ışığında değerlendirmek; ayrıca mevcut literatürdeki boşlukları belirleyerek gelecekteki araştırmalara yön verecek kapsamlı bir çerçeve sunmaktır. Depolama zararlıları arasında nispeten ihmal edilmiş olan bu türün, küresel gıda ticaretinde artan ekonomik ve sağlık riskleri nedeniyle ayrıntılı biçimde incelenmesi artık kaçınılmaz görünmektedir.

Taksonomi ve Tanımlama

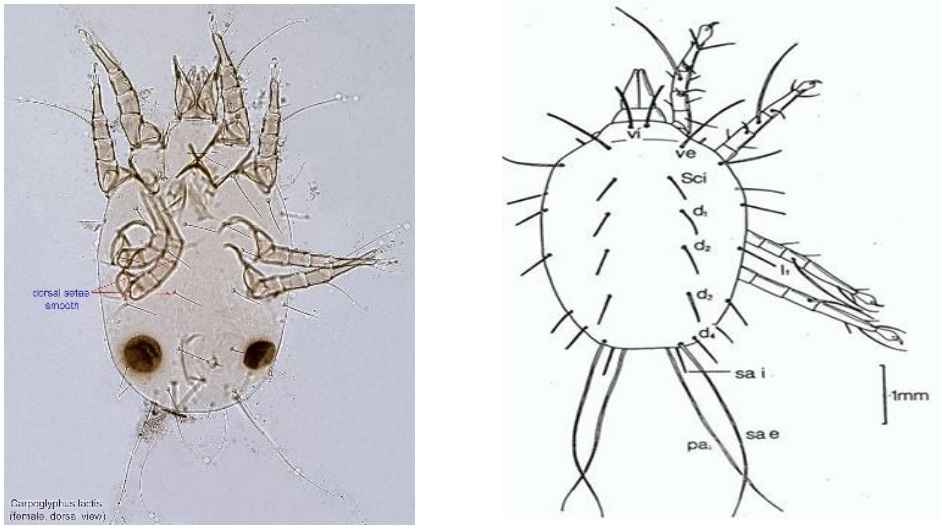
Şube (Phylum): Arthropoda
Sınıf (Classis): Arachnida
Alt sınıf (Subclassis): Acariformes
Takım (Ordo): Sarcoptiformes
Üst aile / Üst grup (Supercohort): Astigmata
Aile (Familia): Carpoglyphidae
Cins (Genus): *Carpoglyphus*
Tür (Species): *Carpoglyphus lactis* (Linnaeus, 1758)

Kuru meyve akarı olarak bilinen *Carpoglyphus lactis*, Arthropoda şubesinin Arachnida sınıfında, Acari alt sınıfının Astigmata üst grubunda yer alan Acaridae familyasına bağlıdır. Familya içinde *Carpoglyphus* cinsi, gıda ve depolama ürünleriyle ilişkili türlerin yoğunlaştığı küçük fakat ekolojik açıdan önemli bir gruptur. *C. lactis,* bu cins içinde en yaygın ve ekonomik önemi en yüksek tür olarak tanımlanmaktadır (Krantz & Walter, 2009).

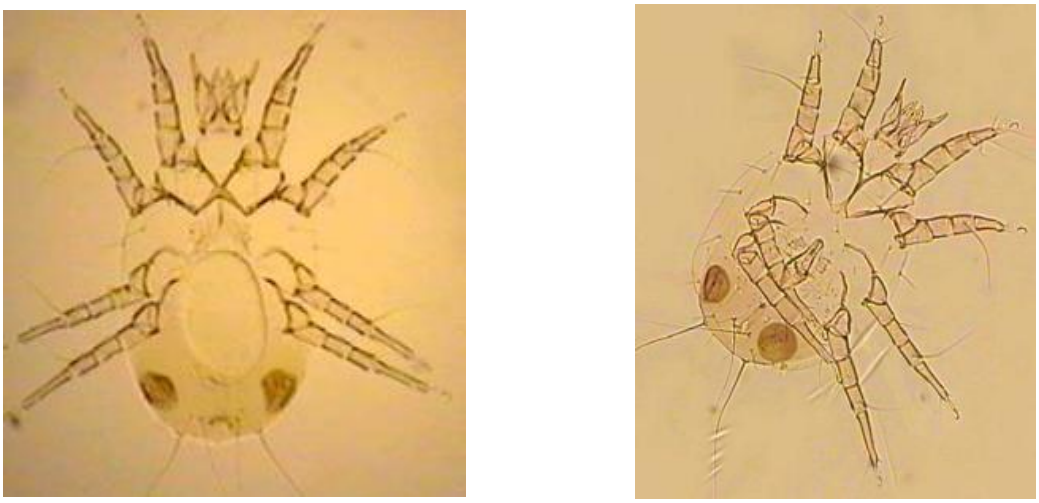
Morfolojik Özellikleri

C. lactis, yumuşak ve ince kutikulalı vücut yapısıyla diğer birçok depolama akarıyla benzerlik göstermekle birlikte, morfolojik açıdan ayırt edici bazı özelliklere sahiptir. Ergin bireyler oval formda olup yaklaşık 300–450 µm uzunluğundadır; (Şekil 1, Şekil 2) vücutları açık krem renginde ve yarı şeffaftır. Larval evre üç çift bacak taşırken, protonimf ve tritonimf

dönemlerinde dört çift bacağa sahip olur. Bu evre değişimleri, tür teşhisinde önemli mikroskobik ipuçları sunar (Hughes, 1976). Kutikulası oldukça ince bir lipid tabakasıyla kaplıdır; bu özellik *C. lactis*'in inert tozlara ve uçucu yağlara karşı yüksek duyarlılığını açıklayan temel anatomik faktörlerden biridir (Krantz, 2009).



Şekil 1. *Carpoglyphus lactis (Vladivostok popülasyonu) dişisinin dorsal görünümü ve* vücut setalarının görünüşü (Hughes 1976). *Fotoğraf: Pavel Klimov, Bee Mite ID – USDA, public domain. https://commons.wikimedia.org/wiki/Category:Carpoglyphus_lactis#/media/File:6-Carpoglyphus_lactis_Vladivostok_female_dors_BF20.jpg,*



Şekil 2. *Carpoglyphus lactis* (Lineé1758) sırasıyla dişi ve erkek bireylerinin genel görünüşü (x20) (güldalı, 2007)

C. lactis'in ince, düşük sklerotize kutikulaya sahip olması, onu hem çevresel streslere hem de fiziksel ve kimyasal mücadele ajanlarına karşı oldukça duyarlı hâle getirir. Lipit tabakasının ince oluşu, inert tozların (diatom toprağı, kaolin, zeolit) kutikula yüzeyindeki koruyucu yağ tabakasını hızla aşındırmasına izin verir; bu da diatom toprağı (DE)'nın bu türde neden çok hızlı mortalite oluşturduğunu açıklar. Aynı zamanda uçucu yağ bileşenlerinin (ör. fenolikler, terpenoidler) kutikula lipitlerini çözerek membran bütünlüğünü bozma etkisi, *C. lactis*'te temas toksisitesinin yüksek olmasının ana nedenlerinden biridir (Isman, 2006).

Kutikulanın su tutma kapasitesinin düşük olması, akarın nem kaybına karşı sınırlı bir toleransa sahip olmasına yol açar. Bu nedenle %60'ın altındaki bağıl nemde ölüm oranları hızla artmakta,

DE gibi desikantlarla birlikte uygulandığında sinerjik kontrol etkisi ortaya çıkmaktadır (Arlian, 1975; Fields & Korunic, 2000).

Biyolojik Özellikleri ve Meydana Getirdiği Zararlar

Biyoloji ve Yaşam Döngüsü

C. lactis hızlı üreyen bir türdür. Dişiler kısa yaşam süreleri boyunca çok sayıda yumurta bırakabilir ve döngü uygun koşullarda birkaç gün içinde tamamlanabilir. Yumurta, larva, protonimf, tritonimf ve erişkin olmak üzere beş temel gelişim evresi bulunur. Yüksek sıcaklık ve nem, yumurta açılma oranını ve nimf evrelerinin hayatta kalma olasılığını artırarak jenerasyon süresinin kısalmasına neden olur. Bu özellik, türün depolarda kısa süre içinde patlayıcı popülasyon artışları oluşturabilmesine zemin hazırlar (Hughes, 1976). Dizlek et al. (2019) tarafından kuru incir depolarında yapılan çalışmada, bazı örneklerde akar yoğunluğunun 10.488 birey/kg seviyesine ulaştığı rapor edilmiştir; bu değer *C. lactis*'in yoğun besin ve elverişli çevre koşulları altında patlama potansiyelini göstermektedir.

Sıcaklık–Nem İlişkisi ve Optimum Koşullar

Kuru meyve akarı gelişimini sıcaklık ve neme son derece duyarlı biçimde sürdüren tipik bir astigmat depolama akarıdır; sıcaklık arttıkça gelişme süresi kısalmakta ve özellikle 25–30 °C aralığında yumurta–ergin dönüşümü hızlanmaktadır. %70–90 bağıl nem, yumurta açılımını ve genç evrelerin yaşama oranını artırırken, düşük nem koşullarında kutikulanın sınırlı su tutma kapasitesi nedeniyle ölüm oranı hızla yükselmektedir (Arlian, 1975). Türkiye'de kuru kayısı üzerinde yürütülen yaşam çizelgesi çalışmalarında, 28 °C ve %80 bağıl nem koşullarında *C. lactis* için en yüksek içsel artış hızı (r_m = 0,37) ve en kısa jenerasyon süresi (8,06 gün) belirlenmiş; gelişme eşiği sıcaklığının 4,90–7,55 °C arasında değişmesi, türün nispeten düşük sıcaklıklarda da gelişimini sürdürebildiğini göstermiştir (Güldalı & Çobanoğlu, 2010). Yüksek şeker içeriği ve doğal mikroflora barındıran kuru meyvelerde oluşan mikro-nem alanları, erken koloni oluşumu ve hızlı popülasyon artışının temel itici gücü olup, depolama sürecindeki sıcaklık ve nem dalgalanmaları, *C. lactis* popülasyon dinamiklerini doğrudan belirleyen kritik faktörler arasında yer almaktadır (Dizlek et al., 2019).

Davranışsal Özellikleri ve Yayılma Potansiyeli

Carpoglyphus lactis, nemli mikro habitatları tercih eden higrofil bir tür olup, özellikle meyve yüzeyindeki nem birikimleri, çatlaklar ve fungus kolonileri içinde yoğunlaşmakta; ışıktan kaçınma eğilimi nedeniyle karanlık ve korunaklı alanlarda daha aktif bulunmaktadır. Hareket kabiliyeti sınırlı olmasına rağmen, kısa mesafeli yüzey yayılımı koloni gelişimi için yeterlidir ve depolama sırasında meyve yüzeyinde oluşan yumuşak, şekerce zengin tabakalar gizli kontaminasyonu kolaylaştırmaktadır (Hughes, 1976; Woolfolk & Rodriguez, 1984). Türün geniş alanlara yayılımında pasif taşınma temel mekanizma olup, kurutma, depolama ve paketleme süreçlerinde kullanılan ekipman ve ambalaj materyalleri akarın ürünler arasında fark edilmeden taşınmasına neden olmakta; ayrıca depolarda bulunan küçük böcekler aracılığıyla phoresy yoluyla taşınma da olasıdır (Krantz & Walter, 2009). Türkiye'de kuru incir işletmelerinde bildirilen yüksek bulaşıklık oranları, yetersiz temizlik ve ekipman kontaminasyonunun akar yayılımında kritik bir rol oynadığını ortaya koymaktadır (Dizlek et al., 2019).

Ürünlere Verdiği Zararlar

C. lactis, kuru meyvelerde doğrudan beslenme yoluyla şeker kristallerini tüketmekte, meyve yüzeyinde mekanik bozulmaya neden olmakta ve ürünün ticari kalitesini düşürmektedir. Akarın beslenmesi sonucu oluşan sindirim artıkları, sekresyonlar ve ölü bireyler, küf ve maya

gelişimini teşvik ederek ürün yüzeyinde sekonder mikrobiyal bozulmayı hızlandırmaktadır (Hughes, 1976; Özer & Toros, 1978; Genç & Özar, 1986). Bu süreç, kuru meyvelerde istenmeyen tat ve koku oluşumuna, renk değişimlerine ve duyusal kalite kaybına yol açmaktadır. Türkiye'de kuru kayısı ve incir üzerinde yapılan çalışmalar, yoğun *C. lactis* bulaşıklığının ürünlerin pazarlanabilirliğini ciddi biçimde azalttığını ve depolama süresince kayıpları artırdığını ortaya koymuştur (Çobanoğlu et al., 1996; Aksoy et al., 2004; Öztekin et al., 2007; Güldalı & Çobanoğlu, 2010).

İnsan Sağlığı İçin Zararları

C. lactis'in kuru kayısılardaki bulaşıklığı, yalnızca ürün kalitesi ve ekonomik kayıplarla sınırlı kalmayıp insan sağlığı açısından da önemli riskler oluşturmaktadır. Kuru meyvelerle temas eden veya bu ürünleri tüketen bireylerde kontakt dermatit, kaşıntı, eritem ve ürtiker benzeri deri reaksiyonları ile gastrointestinal rahatsızlıklar (bulantı, karın ağrısı, ishal) rapor edilmiştir (Hughes, 1976; Özer & Toros, 1978; Genç & Özar, 1986; Özer et al., 1989; Turanlı, 2003). Bu etkiler, büyük ölçüde akarın vücut parçaları, sekresyonları ve sindirim ürünleriyle ilişkili alerjenik proteinler ile ikincil mikrobiyal ve fungal gelişim sonucu ortaya çıkmaktadır.

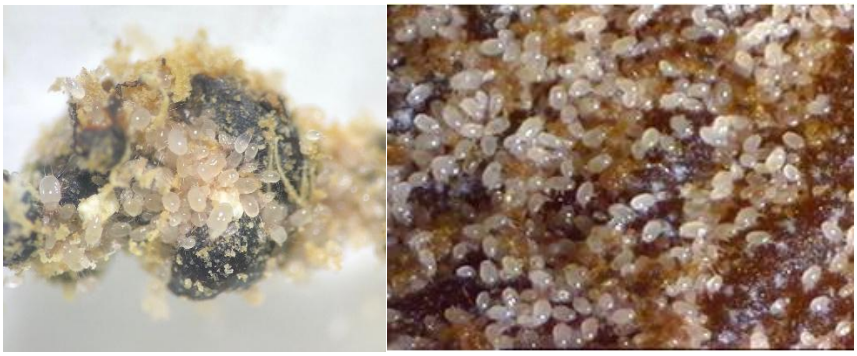
Ayrıca, *C. lactis* ve diğer astigmat depo akarlarının, duyarlı bireylerde alerjik rinit ve astım benzeri solunum semptomlarını tetikleyebildiği, özellikle kuru meyve işleme ve depolama tesislerinde çalışanlar için mesleki bir risk faktörü oluşturduğu bildirilmiştir (Aksoy et al., 2004; Öztekin et al., 2007; Güldalı & Çobanoğlu, 2010; Hubert et al., 2021).

Zarar Verdiği, Beslendiği veya Tespit Edildiği Gıda Maddeleri

Carpoglyphus lactis, şekerce zengin, hafif nemli ve mikrobiyal faaliyetin başladığı gıdalara güçlü uyum gösteren tipik bir depo akarıdır. Hem kurutulmuş meyvelerde hem de işlenmiş şekerli ürünlerde kısa sürede yoğun koloniler oluşturabilmesi, türü gıda güvenliği açısından önemli bir kontaminasyon etmeni hâline getirmektedir.

Kurutulmuş Meyveler: Türün En Sık Rastlandığı Ortam

C. lactis en yoğun olarak kuru incir, kayısı, üzüm, dut, hurma ve keçiboynuzu gibi yüksek fruktoz/sakkaroz içeren ürünlerde rapor edilmiştir. Yüzey neminin artması ve fungus gelişiminin başlaması, popülasyon artışını tetikler (Hubert et.al, 2015). Türkiye'de yapılan bir araştırmada 141 kuru incir örneğinin %34,8'inde *C. lactis* tespit edilirken, bazı örneklerde yoğunluğun 10.488 birey/kg'a kadar çıktığı bildirilmiştir (Dizlek et al., 2019).



Şekil 1. *Carpoglyphus lactis* (Linnaeus, 1758) gün kurusu kayısıda beslenirken (x4) (Kılıç, 2025)

Uluslararası çalışmalar da benzer bir dağılımı doğrulamaktadır: kuru üzüm ve kuru eriklerde maya gelişimi nedeniyle yüksek kontaminasyon riski (Hubert et al., 2021), kuru hurmalarda

şeker kristalleri ve yüzey çatlaklarının yerleşimi kolaylaştırması ve kurutulmuş elma-armut gibi daha düşük kontaminasyonlu ürünlerde mikrobiyal bozulma başladığında popülasyonun hızla artması (Hughes, 1976). Tüm bu ürünlerde şekerli yüzey, mikro çatlaklar ve nem birikimi akar için ideal mikrohabitatlar oluşturmaktadır.

Baharatlar ve Aromatik Ürünler

C. lactis yalnızca meyvelerde değil, tarçın, kimyon, karanfil, kakule ve karabiber gibi aroma bileşiği yüksek baharatlarda da bulunmuştur (Hughes, 1976). Kontaminasyon çoğu zaman öğütme makinelerindeki toz birikimi, paketleme yüzeylerinde kalan nişasta/şeker kalıntıları ve baharatın higroskopik yapısının nem çekmesiyle ilişkilidir. Bazı baharat yağları akarisidal etki gösterse de baharatın lifli yapısı akar için korunaklı mikro alanlar oluşturabilir.

Kuruyemişler ve Yağlı Tohumlar

Fındık, ceviz, badem, yer fıstığı ve Antep fıstığı gibi yağlı tohumlarda da *C. lactis* tespit edilmiştir. Yüzeyde yağ oksidasyonu sonucu oluşan ince yapışkan tabakalar ile fungus gelişimi, akarın yerleşimini kolaylaştırır. Yağ asitlerinden beslenen fungus kolonileri arttıkça akar popülasyonunun da ivme kazandığı bildirilmiştir (Hubert et.al, 2015, Krantz, 2009).

İşlenmiş Şekerli Ürünler: Reçel, Pekmez, Bal ve Şekerlemeler

C. lactis yalnızca kuru gıdalarda değil, şekerce zengin işlenmiş ürünlerde de yaşayabilir:

- Reçel ve marmelat: Kapak altındaki nem ve maya gelişimi kolonizasyonu kolaylaştırır.
- Pekmez ve tahin-pekmez karışımları: Yüzey kabuklanması altında mikro nişler oluşur.
- Bal: Özellikle polenli veya yüksek nemli bal örneklerinde *C. lactis* kaydedilmiştir. Kovan içi organik birikimler akar için uygun yaşam alanı sağlar (Hughes, 1976).
- Şekerlemeler ve lokum: Şurup kalıntıları ve nişasta tozu karışımı akar için son derece uygun mikrohabitatlar oluşturur.

Bu bulgular, *C. lactis*'in yalnızca "kuru meyve akarı" olmadığını; geniş bir şekerli ürün yelpazesinde kontaminasyona neden olabilen çok yönlü bir gıda zararlısı olduğunu göstermektedir.

Fermente Ürünler: Şarap, Sirke ve Maya Karışımları

Bazı çalışmalarda, şarap üretimi sırasında kullanılan kuru üzüm–pekmez karışımlarında *C. lactis* kontaminasyonu kaydedilmiştir. Fermentasyon öncesi yüzeyde gelişen mayalar, CO_2 üretimi ve şeker sızıntıları akarın kolonileşmesini kolaylaştırır (Hubert et al., 2021). Hafif ılık fermentasyon ortamı da gelişmeyi destekler.

Arıcılık Ürünleri, Polen ve Doğal Şeker Kaynakları

En ilginç ekolojik kayıtlardan biri, *C. lactis*'in arı poleni ve kovan içi ürünlerde bulunmasıdır. Polen keklerinin nemli ve şekerli yapısı ile maya gelişimi, akar için uygun bir mikrohabitat sunar (Chmielewski, 1999).). Bu durum türün doğal ekosistemlerde dahi şekerce zengin mikroalanları seçtiğini göstermektedir.

Sonuç olarak, *C. lactis*'in dağılımı tek bir ürün grubuyla sınırlı değildir. Şeker içeriği, nem düzeyi, mikrobiyal aktivite ve yüzey yapısı gibi faktörler bu türün kolonizasyonundaki temel belirleyicilerdir. Bu nedenle tür; kuru meyveler, baharatlar, kuruyemişler, işlenmiş şekerli gıdalar, fermente ürünler ve arıcılık ürünleri gibi çok geniş bir gıda yelpazesinde kontaminasyona neden olabilmektedir.

Mikroorganizmalarla Etkileşim ve Gıda Bozulması Dinamikleri

Fungus, Maya ve Bakteriler ile Etkileşim

C. lactis popülasyonlarının depolanan gıdalarda hızla artmasının temel nedeni, gıda yüzeyinde gelişen maya, fungus ve bakterilerle kurduğu yakın ekolojik ilişkidir. Mikroorganizmaların ürettiği enzimler, meyve dokusunu yumuşatarak karbonhidratları daha erişilebilir hâle getirir ve bu durum akarın beslenme verimliliğini ve popülasyon artışını destekler (Hubert et.al, 2015). Türkiye'de fungal bulaşması yüksek incir örneklerinde *C. lactis* yoğunluğunun 10.488 birey/kg düzeyine ulaştığının bildirilmesi, bu ilişkinin saha koşullarındaki önemini açıkça ortaya koymaktadır (Dizlek et al., 2019).

Akar–Fungus Karşılıklı Etkileşimi

Kuru meyve akarı ile funguslar arasındaki ilişki çoğu durumda karşılıklı yarara dayalıdır. Fungusların pektinaz ve selülaz gibi enzimlerle meyve dokusunu yumuşatması, akar için adeta bir ön sindirim süreci oluştururken; akarın yüzeyi aşındırması, salgıları ve dışkıları ise fungusların tutunması ve yayılması için nemli mikrohabitatlar yaratmaktadır (Hubert et.al, 2015, Krantz, 2009).

Alternatif Mücadele Yöntemleri

Kimyasal fumigantların yasaklanması, fosfine karşı direnç gelişimi ve gıda güvenliği baskıları, *C. lactis* gibi depo akarlarına karşı kimyasal içermeyen stratejilerin önemini artırmıştır. İnert tozlar, bitkisel uçucu yağlar, sıcaklık–nem yönetimi ve atmosfer manipülasyonuna dayalı fiziksel yöntemler hem insan sağlığı hem de ürün kalitesi açısından daha güvenli seçenekler sunmakta ve farklı etki mekanizmaları üzerinden akarı baskılayabilmektedir.

İnert Tozlar (Diatom toprağı, kaolin, zeolit, talk)

İnert tozlar, kutikula üzerindeki lipit tabakasını aşındırarak su kaybını hızlandıran ve ölümle sonuçlanan dehidrasyona yol açan klasik fiziksel mücadele ajanlarıdır (Korunic, 1998; Fields & Korunic, 2000). Yumuşak vücutlu bir tür olan *C. lactis*'te bu mekanizma oldukça hızlı işler.

Taşar et al. (2025), yerli diatom toprağı Detech®'in toz formülasyonunu 20, 25 ve 30 °C sıcaklıklarda ve 0,1–10 g/m² doz aralığında test etmiş; etkinliğin hem doz hem de sıcaklıkla belirgin biçimde arttığını göstermiştir. Orta dozlarda (0,75–2,5 g/m²) 20 °C'de birkaç saat içinde tam mortaliteye ulaşılırken, 30 °C'de ölüm süresi yaklaşık yarıya düşmüştür. Yüksek dozlarda (5–10 g/m²) ise özellikle 30 °C'de ilk saat içinde %100'e varan ölüm oranları rapor edilmiştir.

Bu sonuçlar, sıcaklık artışının diatom toprağının kutikula aşındırıcı etkisini güçlendirdiğini ve *C. lactis* için Detech®'i hızlı etkili, çevre dostu bir biyofiziksel kontrol aracı hâline getirdiğini ortaya koymaktadır.

Kaolin ve benzeri mineraller, yalnızca dehidrasyonla değil, aynı zamanda akarların yüzeyde hareketini zorlaştırarak ve ağız parçalarında irritasyon oluşturarak davranışsal düzeyde de baskılayıcı etki gösterebilir. Kuru incir, kayısı ve hurma gibi pürüzlü yüzeyli ürünler, bu tozların daha iyi tutunmasına ve kalıcı bir fiziksel bariyer oluşturmalarına imkân verir (Phillips & Throne, 2010).

Uçucu Yağlar (EOs)

Bitkisel kökenli uçucu yağlar, depo akarlarında hem sinir sistemi hem de hücresel metabolizma üzerinde çok yönlü etki gösteren doğal bileşiklerdir. Asetilkolinesterazın inhibisyonu, octopamine reseptörlerinin hedef alınması, GABA–klor kanallarının bozulması, kutikula lipid

tabakasının çözünmesi ve oksidatif stres oluşumu, başlıca akarisidal mekanizmalar arasında yer alır (Isman, 2006). Bu süreçler birlikte ele alındığında, uçucu yağlar *C. lactis* gibi yumuşak vücutlu depo akarlarında hızlı mortalite oluşturma potansiyeline sahiptir.

Kekik, adaçayı, karanfil, okaliptus, biberiye ve nane yağlarının çeşitli depo akarları üzerinde yüksek fümigant ve temas etkisi gösterdiği bilinmektedir (Kim et al., 2015; Athanassiou et al., 2005). Fungusla ilişkili türlerde (Hubert et.al, 2015) uçucu yağların antifungal etkisi, akar popülasyonunu dolaylı olarak da baskılayabilmektedir.

Carpoglyphus lactis üzerine yürütülen kapsamlı bir çalışmada Yücel et al. (2025), farklı uçucu yağlara karşı türün belirgin duyarlılık gösterdiğini ortaya koymuştur. Tarçın yağı, %5–10 konsantrasyonlarda birkaç saat içinde %80–100 ölüm ve 80 µL/L fümigant dozda %100 mortalite ile en hızlı ve güçlü etkiyi sergilemiştir. Lavanta yağı, %10 dozda 72 saatte ve 100 µL/L fümigant dozda tam mortalite sağlamıştır. Karanfil yağı orta–yüksek dozlarda kısa sürede %100 ölüme ulaşırken; kekik ve portakal yağları daha yavaş ancak anlamlı düzeyde ölüm oranları ile tamamlayıcı akarisit adayları olarak öne çıkmıştır. Bu bulgular, özellikle tarçın ve lavanta yağlarının *C. lactis* için güçlü biyopestisit adayları olduğunu, karanfil ve kekik yağlarının ise olası kombinasyon formülasyonlarında değerlendirilebileceğini göstermektedir.

Sıcaklık, Nem ve Çevresel Faktörlere Dayalı Fiziksel Kontrol

Akarlar, yüksek sıcaklık ve düşük neme karşı fizyolojik olarak son derece hassastır. Bu nedenle sıcaklık ve nem yönetimine dayalı fiziksel yöntemler, *C. lactis* gibi depo akarlarında kimyasal içermeyen ancak etkili bir mücadele aracı sunar. Subramanyam & Roesli (2000), 45–50 °C arası kısa süreli sıcaklık uygulamalarının birçok depo zararlısında hızlı mortalite sağladığını; Fields (1992) ise bu etkinin protein denatürasyonu, hücre zar bütünlüğünün bozulması ve hızlanan su kaybı ile ilişkili olduğunu bildirmiştir. Kuru meyvelerin kısa süreli ısı stresine dayanabilmesi, hızlı ısıtma veya sıcak hava uygulamalarını *C. lactis* için uygulanabilir kılmaktadır.

Nem, astigmat akarların yaşamında belirleyici bir faktördür. Arlian (1975), birçok türün %60'ın altındaki bağıl nemde yaşam sürelerinin dramatik biçimde kısaldığını göstermiştir. Düşük nem yalnızca üremeyi yavaşlatmakla kalmaz, diatom toprağı gibi inert tozların etkinliğini de artırır; zira düşük nemde kutikula lipidleri daha hızlı çözünür ve tozların aşındırıcı etkisi güçlenir (Fields & Korunic, 2000; Athanassiou et al., 2005). Dolayısıyla düşük nem, yüksek sıcaklık ve DE uygulamasının birlikte kullanıldığı entegre fiziksel yaklaşımlar, *C. lactis* kontrolünde özellikle avantajlıdır.

Ozon, Oksijen Azaltıcılar ve Nem Tutucularla Atmosfer Yönetimi

C. lactis'in yüksek neme ve yeterli oksijen düzeyine bağımlı fizyolojisi, atmosfer bileşiminin değiştirilmesine dayalı fiziksel mücadele yöntemlerini depolarda uygulanabilir hâle getirmektedir. Turgu & Kumral (2019), ozon, ferrik oksit, kalsiyum klorür ($CaCl_2$) ve silika jelin kuru kayısı üzerinde C. lactis'e karşı etkinliğini nicel olarak değerlendirmiş ve bu ajanların doza–zamana bağlı şekilde anlamlı mortalite oluşturduğunu göstermiştir .

Ferrik oksit, paket içi oksijeni hızla absorbe ederek hipoksik bir ortam oluşturur. Astigmat akarların düşük O_2'ye toleransı sınırlı olduğundan (Bell & Conyers, 2002), Turgu & Kumral (2019) birkaç gün içinde %90–100 mortalite bildirmiştir. $CaCl_2$ ve silika jel ise nemi azaltarak uzun süreli dehidrasyon baskısı oluşturur; $CaCl_2$ daha hızlı, silika jel ise daha yavaş ancak kalıcı bir etki sağlamaktadır. Bu bulgular, kısa süreli ozon uygulamasını, oksijen absorbanları (ferrik oksit) ve nem tutucular ($CaCl_2$ veya silika jel) ile destekleyen çok aşamalı atmosfer yönetimi modelinin, *C. lactis'e* karşı kimyasal kalıntı bırakmayan etkili bir fiziksel mücadele aracı olabileceğini göstermektedir.

Ayrıca modifiye atmosferde oksijenin azaltılması + CO_2'nin artırılması, solunum asidozu ve enerji metabolizmasının çökmesiyle birçok depo zararlısında mortaliteyi yükseltmektedir (Bell & Conyers, 2002). *C. lactis* için sınırlı veri olsa da türün düşük O_2 ve düşük neme duyarlılığı bu yaklaşımın uygulanabilirliğini desteklemektedir.

Modifiye Atmosfer ile Fiziksel Mücadele ve Paket İçi Ortam Yönetimi

Modifiye atmosfer (MA) uygulamaları, *C. lactis* gibi düşük oksijen ve yüksek CO_2 koşullarına hassas türler için etkili, kalıntı bırakmayan fiziksel kontrol araçlarıdır (Bell & Conyers, 2002).

Astigmat akarlar hipoksiye toleransı düşük organizmalardır. O_2 seviyesi düştüğünde solunum yavaşlar, enerji üretimi azalır ve birkaç gün içinde yüksek mortalite görülebilir (Bell & Conyers, 2002). Paket içi oksijen bağlayıcılar (ör. ferrik oksit), depolama boyunca bu düşük O_2 ortamını koruyarak akar çoğalmasını kalıcı biçimde baskılar.

Düşük nem, C. lactis'in yaşam süresini kısaltır ve atmosfer manipülasyonunun stres etkisini güçlendirir (Arlian, 1975). Nem azaldığında su kaybı hızlanır hem hipoksinin hem CO_2 stresinin öldürücü etkisi artar.

MAP teknolojileri (O_2 absorbanlı ambalajlar, CO_2 üretici sistemler, düşük geçirgenlikli filmler) kuru meyve ve şekerli ürünlerde *C. lactis*'in hem kısa vadede ölmesini hem de yeniden çoğalamamasını sağlayan pratik çözümler sunar. Kimyasal kalıntı riski olmaması nedeniyle ihracata yönelik ürünlerde özellikle avantajlıdır.

Biyolojik Mücadele

Depo ekosistemlerinde *C. lactis* popülasyonlarını doğal olarak baskılayan çeşitli avcı akar türleri bulunmaktadır. Türkiye'de kuru incir örneklerinin %77'sinde *Blattisocius tarsalis'in* saptanması, bu predatörün özellikle *C. lactis*'in yumurta ve genç evreleriyle beslenerek popülasyon artışını sınırlayabildiğini göstermektedir (Dizlek et al., 2019). *B.mali* ve diğer Blattisociinae üyeleri de depo ortamlarında astigmat akarlarının önemli doğal düşmanları olarak tanımlanmıştır (Krantz & Walter, 2009). Depolarda yaygın görülen bir diğer avcı grup Cheyletidae türleridir. *Cheyletus eruditus,* yüksek av kapasitesi sayesinde astigmat akar yoğunluğunu belirgin biçimde azaltabilmekte; *C.malaccensis'in* de benzer şekilde depo akar popülasyonlarını baskıladığı bildirilmektedir (Hughes, 1976).

Bununla birlikte, biyolojik mücadelenin depolarda doğrudan uygulama potansiyeli sınırlıdır. Predatör akarların salımı hijyen ve tüketici algısı açısından uygun görülmemekte; ayrıca sıcaklık ve nem dalgalanmaları predatör etkinliğini azaltabilmektedir. Bu nedenle biyolojik mücadele, doğal predatör faunasının korunması ve kimyasal olmayan yöntemlerle entegre zararlı yönetimini destekleyen ekolojik bir bileşen olarak değerlendirilmektedir (Athanassiou et al., 2005; Athanassiou & Arthur, 2018).

Kimyasal Mücadele

Depolama akarlarının kontrolünde fumigantlar uzun yıllardır kullanılmakla birlikte, kimyasal kalıntı riski, işçi sağlığı ve ihracat kısıtları nedeniyle bu uygulamalar giderek sınırlandırılmaktadır. *C. lactis* gibi astigmat akarlar üzerinde çeşitli kimyasal ajanlar denenmiş olsa da etkinlik ve güvenlik açısından önemli sınırlılıklar bulunmaktadır.

Fosfin (PH_3), depolama zararlılarına karşı yaygın kullanılan bir fumiganttır; ancak astigmat akarların fosfine duyarlılığı değişken olup bazı türlerde düşük duyarlılık ve tolerans bildirilmiştir (Kučerová et al., 2003; Bell & Nayak, 2012). Ayrıca fosfin kullanımında ürünlerde

koku ve kalıntı riski ile fungus ve maya yükünü tam baskılayamama gibi sorunlar öne çıkmaktadır; bu nedenle *C. lactis* için güvenilir tek yöntem olarak değerlendirilmemektedir.

Geçmişte yaygın kullanılan kükürt fümeleme, keskin koku oluşumu ve tüketici tercihleri nedeniyle büyük ölçüde terk edilmiş; temas etkili piretroit ve organofosfatlar ise mikro çatlaklara nüfuz edememeleri ve kalıntı riski taşımaları nedeniyle depolarda sınırlı kullanım alanına sahiptir (Krantz & Walter, 2009; Arthur & Zettler, 2011).

Bu nedenlerle güncel yaklaşım, kimyasal fumigasyonun yalnızca son çare olarak kullanılması ve mücadelenin kimyasalsız yöntemlerle (inert tozlar, uçucu yağlar, nem yönetimi ve modifiye atmosfer uygulamaları) desteklenmesidir. Literatür, direnç gelişimi ve kalıntı riskleri nedeniyle kimyasal yöntemlerden uzaklaşılmasının sürdürülebilir depo yönetimi için kaçınılmaz olduğunu ortaya koymaktadır (Athanassiou & Arthur, 2018).

Entegre Mücadele (IPM) Yaklaşımı

Carpoglyphus lactis için tek bir mücadele yönteminin uzun vadeli ve güvenilir kontrol sağlamadığı bilinmektedir. Bu nedenle, depolama zararlıları literatüründe kimyasal baskının azaltıldığı, fiziksel, biyolojik ve biyoteknik yöntemlerin birlikte uygulandığı Entegre Zararlı Yönetimi (IPM) yaklaşımı önerilmektedir (Arthur & Athanassiou, 2018). *C. lactis* gibi mikrobiyal aktiviteyle yakından ilişkili astigmat depo akarlarının kontrolünde IPM'nin temelini önleyici hijyen, düzenli izleme ve çoklu kontrol araçlarının entegrasyonu oluşturmaktadır.

Depolama alanlarında gıda kırıntıları, şekerli yüzey kalıntıları ve nem birikimi, *C. lactis* kolonizasyonu için ideal koşullar yaratmaktadır. Bağıl nemin %60'ın altında tutulması, astigmat akarların çoğalma kapasitesini belirgin biçimde düşürmektedir (Arlian, 1975). Bu nedenle nem kontrolü, yüzey temizliği, çatlak ve yarıkların kapatılması ile ekipman hijyeni IPM'nin temel ve vazgeçilmez unsurlarıdır. Akarların çıplak gözle fark edilmesinin zor olması, düzenli örnekleme ve stereomikroskop altında izlemeyi zorunlu kılmakta; erken tespit, müdahalenin zamanında ve düşük maliyetle yapılmasını sağlamaktadır (Dizlek et al., 2019).

IPM yaklaşımının etkinliği, fiziksel ve biyolojik yöntemlerin birlikte uygulanmasıyla önemli ölçüde artmaktadır. Düşük nem koşullarının, diatom toprağı (DE) gibi inert tozların etkinliğini belirgin biçimde artırdığı; bu sinerjinin akarların su dengesini bozarak hızlı ölüm oluşturduğu gösterilmiştir (Fields & Korunic, 2000). Benzer şekilde, kısa süreli ısı uygulamaları, tek başına yüksek ölüm oranları sağlamakta; DE ile kullanıldığında kutikula hasarını artırarak etkiyi güçlendirmektedir (Subramanyam & Roesli, 2000). Ayrıca, oksijenin azaltılması ve/veya CO_2'nin artırılmasına dayalı modifiye atmosfer uygulamaları, hipoksiye duyarlı olan astigmat akarlar üzerinde uzun süreli baskılama sağlamaktadır (Bell & Conyers, 2002).

Depo ekosistemlerinde bulunan avcı akarların korunması, IPM açısından önemli bir ekolojik avantaj sunmaktadır. *Blattisocius tarsalis* ve *Cheyletus eruditus* gibi türler, *C. lactis*'in yumurta ve genç evreleriyle beslenerek popülasyon artışını doğal olarak sınırlandırabilmektedir (Dizlek et al., 2019). Buna karşılık, fosfin ve diğer fumigantlar, yalnızca ağır bulaşıklık durumlarında ve kısa süreli acil müdahale aracı olarak önerilmekte; IPM'nin temel hedefi, kimyasal kullanımı en aza indirerek fiziksel ve ekolojik yöntemleri birincil kontrol stratejisi hâline getirmektir (Athanassiou & Arthur, 2018).

Sonuç

Bu çalışma, kuru meyve akarının özellikle yüksek nem ve mikrobiyal aktivitenin yoğun olduğu depo koşullarında hızla çoğaldığını ve gıda kalitesi açısından ciddi riskler oluşturduğunu

göstermektedir. Kimyasal yöntemlerin sınırlılıkları dikkate alındığında, türün kontrolünde Entegre Zararlı Yönetimi (IPM) yaklaşımı esas alınmalıdır. Bu kapsamda, nem yönetimi ile diatom toprağı (DE) kullanımı, akarların su dengesini bozarak etkili ve kalıntı riski düşük bir kontrol sağlamaktadır. Gerektiğinde uçucu yağların (fumigant veya itici etki) fiziksel yöntemlerle birlikte değerlendirilmesi, kimyasal fumigantlara olan bağımlılığı azaltabilecek çevre dostu bir seçenek sunmaktadır.

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VOLATILE COMPOUNDS OF *HYPERICUM ORIENTALE*
HYPERİCUM ORİENTALE'NİN UÇUCU BİLEŞİKLERİ

Research Assistant Dr. Haydar KÜPLEMEZ

Recep Tayyip Erdoğan University, Faculty of Agriculture, Field Crops Department, Rize, Türkiye

Prof. Dr. Fatih SEYİS

Recep Tayyip Erdoğan University, Faculty of Agriculture, Field Crops Department, Rize, Türkiye

ABSTRACT

Hypericum orientale L., a common perennial plant that grows wild on igneous slopes and rocky outcrops at high altitudes, is one of the Hypericum species found in Türkiye. It has been used for traditional therapeutic purposes in Turkish folk medicine. Recent studies reporting the high concentration of bioactive compounds *in H. orientale* underpin its effectiveness as a promising medicinal plant. There are few previous studies on the chemical composition of *H. orientale*. Collected samples were analyzed using SPME supported GC-MS device. Compounds were detected using Shimadzu FFNSC (Flavour & Fragrance Natural & Synthetic Compounds GC/MS Library) library. Results: Hendecane (9.34%), β-Chamigrene (9.63%), σ-Cadinene (8.05%), β-Farnesene (7.89%), 10-β(H)-Cadina-1(6),4-diene (7.79%), α-Amorphene (6.53%) and α-Copaene (5.83%), were detected in high amounts.. Factors affecting volatile oil yield and composition include plant genetics, growth stage, geographical and environmental conditions (like climate, altitude, and soil type), agricultural methods and practices (plant density, water availability, and harvesting time), plant part used, extraction method, and storage condition

INTRODUCTION

There are more than 490 species of Hypericum L. (Hypericaceae) worldwide. In Türkiye, there are 94 taxa (78 species) that belong to this genus. There are roughly 43 indigenous species of Hypericum. Hypericum species, particularly *H. perforatum* L., are referred to as "binbirdelikotu, kılıçotu, kantaron" in Turkish and St. John's Wort in English (Baytop, 1999; Hışıl et al., 2005; Güner et al., 2000; Güner et al., 2012).

Because of their many therapeutic qualities, the species of this genus have been utilised as healing agents for hundreds of years. In Turkish traditional medicine, hypericum species are also employed as sedatives, antiseptics, and antispasmodics (Cirak et al., 2012).

One of the Hypericum species found in Turkey is *Hypericum orientale* L. The stems can be erect or decumbent, range in length from 7 to 45 cm, and occasionally have adventitious roots. 10–40 mm, oblong, elliptic-oblong, or oblanceolate leaves. Sepals can be broadly elliptic to obovate or narrowly oblong and oval. Complete, 10–18 mm petals without black dots. Ovoid to ovoid-cyclindric capsule, 7–14 mm (Davis 1988).

METHODOLOGY

Plant Material and Pre-Analysis Preparation

The samples collected from İkizdere/Rize, 40°44'03"N - 40°46'43"E Cimil Highland, 2002-meter altitude (Figure 1).

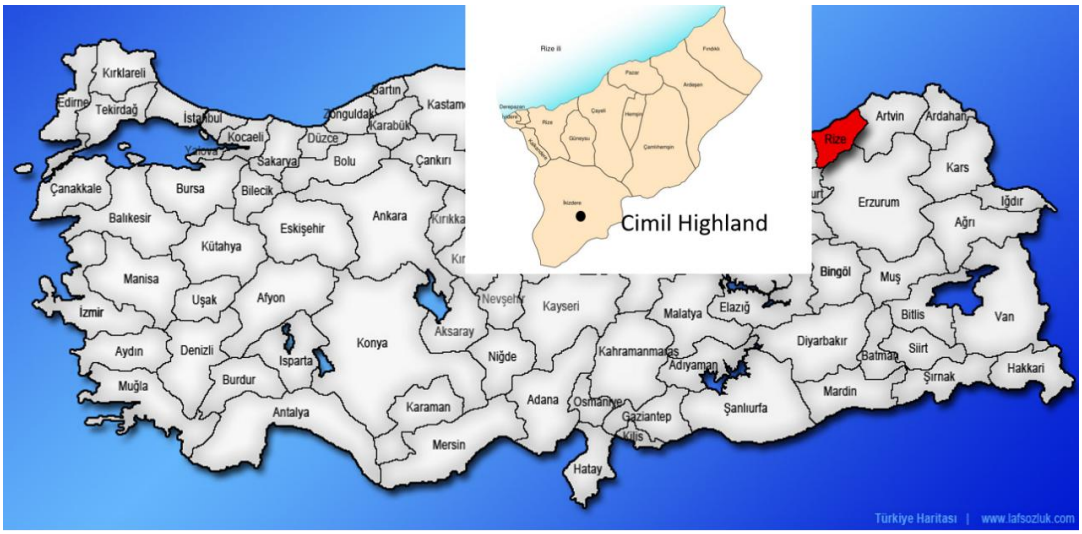


Figure 1. The geographic location where the plant specimen was collected

Coordinate information of the location where the plants were collected was taken with the Garmin etrex 30x device.

The samples were dried in a fan oven until they reached constant weight (40°C for 3 days). The dried samples were then stored in a cold storage facility (+4°C). After being ground in a grinder, the dried samples were weighed to 0.2 grams for volatile component analysis.

GC/MS Analysis

Volatile component analysis was performed using the SPME (Solid Phase Microextraction) method on a Shimadzu GC/MS-OP2020 instrument located in the Plant Analysis Laboratory of the Faculty of Agriculture at Recep Tayyip Erdoğan University. SPME analysis is a convenient method performed with a ground, dry sample without the need for solvents. The method is based on the absorption of essential oils by a fused silica fiber coated with a polymeric stationary phase, followed by desorption of the absorbed substances by heating at the injection port.

Helium (1 mL/min) was used as the carrier gas in GC-MS analyses performed by electrospray ionization (EI) with the CP 5MS (30 m × 0.25 mm internal diameter, 0.25 µm film thickness). The oven was set to operate at a rate of 2 ℃/min from 40 ◦C to 240 ℃ and then at an isothermal temperature of 220 ℃ for 20 minutes. The temperature of the injector and detector was 240 °C. The compounds were identified by comparing their linear retention indices (LRIs) with a series of n-hydrocarbons and by comparing their retention times with those of pure original samples. The alkane series is C8-C24 or 2.5. Mass spectra were taken at 70 eV, and area normalization was used to calculate the percentage composition. After the compounds were separated on the gas chromatography column, each ion-mass spectrum was recorded, and the compounds were identified using the Shimadzu FFNSC library (Flavor & Fragrance Natural & Synthetic Compounds GC/MS Library).

RESULTS

The volatile oil composition of *H. orientale* collected from İkizdere-Cimil Highland is given in Table 1.

Table 1: Volatile oil composition of *H. orientale* collected from İkizdere-Cimil Highland

Rank	Compound (%)	
1	**Hendecane**	**9.34**
2	Tridecane	1.58
3	σ-Elemene	0.42
4	α-Cubebene	1.56
5	Cyclosativene	1.26
6	**α-Copaene**	**5.83**
7	β-Bourbonene	2.17
8	α-Gurjunene	0.48
9	β-Cedrene	3.45
10	α-Patchoulene	1.00
11	α-Humulene	0.90
12	**(E)-β-Farnesene**	**7.89**
13	Aromadendrene	2.22
14	**α-Amorphene**	**6.53**
15	**10-β(H)-Cadina-1(6),4-diene**	**7.79**
16	β-Chamigrene	3.05
17	β-Selinene	4.17
18	**β-Chamigrene**	**9.63**
19	Muurolene	2.89
20	(E,E)-α-Farnesene	1.30
21	γ-Cadinene	4.56
22	**σ-Cadinene**	**8.05**
23	Germacrene B	4.22
24	Spathulenol	1.61
25	(E)-2-tridecenal	0.67
26	Viridiflorol	0.76
27	epi-γ-Eudesmol	0.92
28	epi-α-Muurolol	1.19
29	(Z)-trans-α-Bergamotol	0.81
30	Heptadecane	1.06
31	Phytone	1.67
32	Nonadecane	1.02
Total		**100**

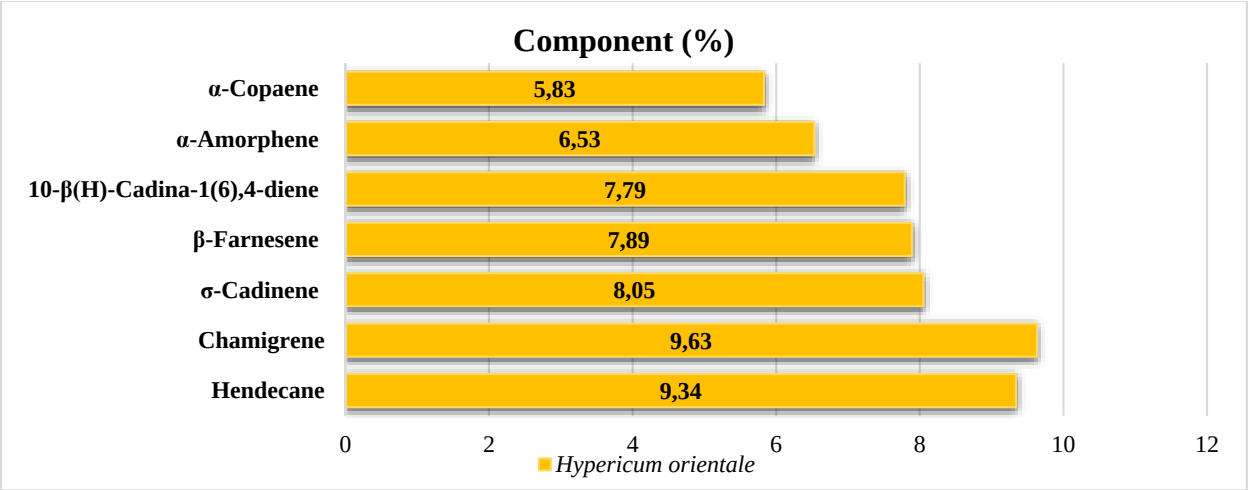


Figure 2: Prominent volatile oil components of H. orientale collected from Cimil Highland/Rize

Totally 32 different volatile oil components could be detected. Hendecane (9.34%), β-Chamigrene (9.63%), σ-Cadinene (8.05%), β-Farnesene (7.89%), 10-β(H)-Cadina-1(6),4-diene (7.79%), α-Amorphene (6.53%) and α-Copaene (5.83%), were detected in high amounts.

CONCLUSION AND DISCUSSION

β-selinene (37.1%), β-caryophyllene (9.7%), γ-muurolene (4.4%), cadinene (6.1%) was detected in *H. orientale* (Bertoli et al., 2018).

Cirak and Seyis (2024) detected 64 different volatile components in three different saples of *H. orientale* collected from Rize. They detected remarkable amounts of p-Menthone, Pulegone, α-Santalene, γ-Cadinene, Spathulenol and Caryophyllene oxide.

The altitude of the natural growth location affects several environmental elements, such as mean temperature, wind speed, precipitation, snowfall duration, soil, temperature extremes, radiation intensities, and length of the vegetative phase (Camas et al., 2014). Higher UV-B radiation and lower temperatures at high altitudes are two environmental conditions that have long been thought to have an impact on secondary metabolism in plants.

Factors influencing the yield and composition of volatile oil encompass plant genetics, growth stage, geographical and environmental conditions (such as climate, altitude, and soil type), agricultural practices (including plant density, water availability, and harvesting timing), the specific plant part utilised, extraction techniques, and storage conditions (Mugao, 2004).

The present investigated sample was collected from one location. *H. orientale* should be collected from more locations to give more information about the chemical composition of this species.

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DETERMINATION OF MORPHOGENETIC VARIABILITY ON VOLATILE COMPOUNDS OF *Rhododendron caucasicum*

Research Assistant Dr. Haydar KÜPLEMEZ

Recep Tayyip Erdoğan University, Faculty of Agriculture, Field Crops Department, Rize, Türkiye

Prof. Dr. Fatih SEYİS

Recep Tayyip Erdoğan University, Faculty of Agriculture, Field Crops Department, Rize, Türkiye

ABSTRACT

Rhododendron is a large genus that contains species that have been used in traditional medicine to treat a variety of ailments, including inflammation, discomfort, gastrointestinal issues, the common cold, asthma, and skin diseases etc. Collected samples were analyzed using SPME supported GC-MS device. Stem parts of *Rhodoendron caucasium* contained high amounts of Seychellene (32.55%), σ-Cadinene (10.52%), α-Amorphene (6.40%) and α-Muurolene (6.17%). In leaf parts α-Cedrene (31.06%), 16-hydroxy-hexadec-6-enoic acid (17.77%) and Phytone (4.92%) were detected in high amounts. High amounts of 16-hydroxy-hexadec-6-enoic acid (8.07%), α- Patchoulene (6.75%), Isoborneol (6.82%) and α-Curcumene (5.56%) were detected in flower parts of *Rh. caucasicum*. All investigated plant parts contained components displaying important biological activities. The GC-MS analysis of leaves, stem and flower parts of *R. caucasicum* showed high amounts of Seychellene in stem part and 16-hydroxy-hexadec-6-enoic acid in flower and leaf parts. The results have shown the presence of diverse of compounds having pharmacological and industrial importance.

Key Words: *Rhododendron caucasicum*, GC/MS, morphogenetic variability

INTRODUCTION

Over 600 species of Rhododendron can be found worldwide. Asia is home to more than 400 of them. In high, cool, and wet regions of Europe, North America, and Australia, the smaller percentage grows. Rhododendron is a member of the Ericaceae family and is usually referred to as rosemary, black poison, or komar. *R. luteum, R. ponticum, R. smirnovii, R. caucasicum*, and *R. ungerni* are the five Rhododendron species that grow natively in Turkey, particularly in the East Black Sea region (Davis, 1982).

Turkey is divided into three major flora regions. These are Euro-Siberian, Irano-Turanian and Mediterranean. City of Rize stands at the Colchis part of Euro-Siberian flora region (Usta et al., 2011).

Rh. aucasicum is known as "mountain kumarı" in the Eastern Black Sea Region (Güner and Duman, 1998). Its white or cream-colored flowers are edible. This Rhododendron, which can grow up to 1 or 1.5 meters tall, is found in the acidic soils (pH 3-4) of the Black Sea region, especially on the northern slopes of mountainous areas. While it forms scattered communities

in the undergrowth of beech, beech-fir, or beech-spruce forests, it is stated that the best growing conditions are in the subalpine and alpine zones (Stevens, 1978; Browicz, 1983). Therefore, the Caucasian rhododendron is also defined as a high-mountain species. It has a wide distribution area, starting from the northwest of the Great Caucasus Mountains and extending to the upper reaches of the Samur River in western Azerbaijan and Dagestan, from where it takes its name from the Caucasus Mountains.

Rh. caucasicum collected from Rize was analyzed regarding volatile oil components in different plant parts.

METHODOLOGY

Plant Material and Pre-Analysis Preparation

The samples collected from Çamlıhemşin/Rize, 40°48'04"N 41°56'47"E Çiçekli highland, 2402-meter altitude (Figure 1).



Figure 1. *R. caucasicum* in its natural habitat in Çiçekli highland/Rize

Coordinate information of the location where the plants were collected was taken with the Garmin etrex 30x device.

The samples were dried in a fan oven until they reached constant weight (40°C for 3 days). The dried samples were then stored in a cold storage facility (+4°C). After being ground in a grinder, the dried samples were weighed to 0.2 grams for volatile component analysis.

GC/MS Analysis

Volatile component analysis was performed using the SPME (Solid Phase Microextraction) method on a Shimadzu GC/MS-OP2020 instrument located in the Plant Analysis Laboratory of the Faculty of Agriculture at Recep Tayyip Erdoğan University. SPME analysis is a convenient method performed with a ground, dry sample without the need for solvents. The method is based on the absorption of essential oils by a fused silica fiber coated with a polymeric stationary phase, followed by desorption of the absorbed substances by heating at the injection port.

Helium (1 mL/min) was used as the carrier gas in GC-MS analyses performed by electrospray ionization (EI) with the CP 5MS (30 m × 0.25 mm internal diameter, 0.25 μm film thickness). The oven was set to operate at a rate of 2 ℃/min from 40 ◦C to 240 ℃ and then at an isothermal temperature of 220 ℃ for 20 minutes. The temperature of the injector and detector was 240 °C. The compounds were identified by comparing their linear retention indices (LRIs) with a series of n-hydrocarbons and by comparing their retention times with those of pure original samples.

The alkane series is C8-C24 or 2.5. Mass spectra were taken at 70 eV, and area normalization was used to calculate the percentage composition. After the compounds were separated on the gas chromatography column, each ion-mass spectrum was recorded, and the compounds were identified using the Shimadzu FFNSC library (Flavor & Fragrance Natural & Synthetic Compounds GC/MS Library).

RESULTS

The volatile oil composition of *Rh. caucasicum* collected from İkizdere-Cimil Highland is given in Table 1.

Table 1: Volatile oil composition of *Rh. caucasicum* stem parts collected from Çiçekli highland/Rize

Rank	**Compound (%)**	
1	Cyclosativene	1.38
2	α-Copaene	3.19
3	α-Gurjunene	3.83
4	**Seychellene**	**32.55**
5	cis-Thujopsene	0.32
6	α-Himachalene	0.75
7	α-Humulene	3.67
8	Alloaromadendrene	4.73
9	**α-Amorphene**	**6.40**
10	α-Zingiberene	4.44
11	10-β(H)-Cadina-1(6),4-diene	1.47
12	β-Chamigrene	1.09
13	**α-Muurolene**	**6.17**
14	γ-Cadinene	3.68
15	**δ-Cadinene**	**10.52**
16	β-Sesquiphellandrene	0.97
17	γ-Undecalactone	0.42
18	Nerolidol	0.71
19	Hexadecane	1.99
20	Caryophyllene oxide	1.31
21	Methyl dihydrojasmonate	0.56
22	epi-α-Muurolol	1.49
23	Octyl furan-2-carboxylate	0.61
24	α-Bisabolol	0.35
25	Heptadecane	1.89
26	Octyl Caprylate	0.51
27	Octadecane	1.09
28	Nonadecane	0.59
29	16-hydroxy-hexadec-6-enoic acid	1.40
30	Isophytol	1.16
31	Eicosane	0.76
Total		**100**

Stem parts of *Rh. caucasium* contained high amounts of Seychellene (32.55%), σ-Cadinene (10.52%), α-Amorphene (6.40%) and α-Muurolene (6.17%) (Table 1).

Table 2: Volatile oil composition of *Rh. caucasicum* leaf parts collected from Çiçekli highland/Rize

Rank	**Compound (%)**	
1	trans-Linalool oxide	2.85
2	α-Copaene	0.86
3	α-Gurjunene	2.62
4	**α-Cedrene**	**31.06**
5	cis-Thujopsene	0.95
6	Geranyl butyrate	4.10
7	Alloaromadendrene	1.99
8	α-Amorphene	1.54
9	α-Patchoulene	0.94
10	α-Curcumene	0.92
11	(E)-β-ionone	2.28
12	Pentadecane	1.74
13	α-Muurolene	1.58
14	δ-Cadinene	2.05
15	γ-Cadinene	1.09
16	Germacrene B	1.32
17	Hexadecane	2.88
18	Caryophyllene oxide	0.70
19	Octyl 2-furoate	0.63
20	Heptadecane	2.89
21	Octyl Caprylate	0.54
22	Pentadecanol	0.95
23	Octadecane	1.56
24	Neophytadiene	1.69
25	**Phytone**	**4.92**
26	Nonadecane	1.34
27	**16-hydroxy-hexadec-6-enoic acid**	**17.77**
28	Isophytol	1.74
29	Ethyl Palmitate	3.60
30	Heneicosane	0.94
Total		**%100**

In leaf parts α-Cedrene (31.06%), 16-hydroxy-hexadec-6-enoic acid (17.77%) and Phytone (4.92%) were detected in high amounts (Table 2).

Table 3: Volatile oil composition of *Rh. caucasicum* flower parts collected from Çiçekli highland/Rize

Rank	Compounds (%)	
1	**Isoborneol**	**6.82**
2	β-Caryophyllene	4.28
3	Aromadendrene	5.72
4	10-β(H)-Cadina-1(6),4-diene	1.16
5	**α-Patchoulene**	**6.75**
6	**α-Curcumene**	**5.56**
7	β-Selinene	1.07
8	Pentadecane	3.45
9	(E,E)-α-Farnesene	3.96
10	Viridiflorene	1.15
11	δ-Cadinene	2.02
12	ɣ-Cadinene	4.96
13	Isoamyl nonanoate	1.08
14	Germacrene B	4.99
15	Citronellyl butyrate	2.24
16	ɣ-Undecalactone	1.24
17	Tridecyl alcohol	1.16
18	Hexadecane	5.23
19	Methyl dihydrojasmonate	1.90
20	Octyl furan-2-carboxylate	2.59
21	Myristic alcohol	3.36
22	Heptadecane	5.17
23	Farnesal	1.19
24	Pentadecanol	1.18
25	Octadecane	2.18
26	Phytone	2.27
27	Nonadecane	1.58
28	**16-hydroxy-hexadec-6-enoic acid**	**8.07**
29	Isophytol	2.33
30	Civetone	2.13
31	Heneicosane	2.18
32	Tetracosane	1.04
Total		**100**

High amounts of 16-hydroxy-hexadec-6-enoic acid (8.07%), α- Patchoulene (6.75%), Isoborneol (6.82%) and α-Curcumene (5.56%) were detected in flower parts of *Rh. caucasicum* (Table 3). All investigated plant parts contained components dispalying important biological activities.

CONCLUSION AND DISCUSSION

Belousova et al. (2017) detected 8(14),15 pimaradiene, calarene, allo-aromadendrene, linalool and muurolol in *Rh. caucasicum*.

Fandakli et al. (2019) determined a total of twenty-five and thirty-one compounds using HD and SPME, respectively. The main volatile constituents of R. caucasicum were found to be calarene (46.13% (HD) and 54.91% (SPME) and sandaracopimaradiene (25.93% (HD) and 8.16% (SPME).

A number of environmental factors, including mean temperature, wind speed, precipitation, snowfall duration, soil, temperature extremes, radiation intensities, and the duration of the vegetative phase, are influenced by the altitude of the natural growth location (Camas et al.,

2014). It has long been believed that two environmental factors that affect secondary metabolism in plants are more UV-B radiation and lower temperatures at high elevations.

Plant genetics, growth stage, geographic and environmental factors (such as climate, altitude, and soil type), agricultural practices (such as plant density, water availability, and harvesting timing), the particular plant part used, extraction methods, and storage conditions are all factors that affect the yield and composition of volatile oil (Mugao, 2004).

According to Sangwan et al. (2001), volatile oils are stored in the plant's unique oil cells and oil tubes and can be found in a variety of plant parts, including leaves, flowers, roots, and stems. The volatile oil that many plants contain is what gives them their distinctive smells. Numerous internal (plant genetics, provenance, etc.) and external (temperature, growing circumstances, drying techniques and extractions, distillation time, and analysis conditions) elements have been found to have an impact on volatile oil components (Moghaddam and Mehdizadeh, 2017). The amount of bioactive compounds derived from secondary metabolites exhibits morphogenetic variation based on the plant's organs, ontogenetic change based on the plant's life cycle, and harvest/collection time.

The present investigated sample was collected from one location. *Rh. caucasicum* should be collected from more locations to give more information about the chemical composition variation of this species.

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PASSIFLORA CULTIVATION IN TÜRKİYE: POTENTIAL, PRACTICES, AND FUTURE PERSPECTIVES

Recep BALKIÇ

Akdeniz University, Elmalı Vocational School, Department of Plant and Animal Production, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0002-1212-9501

Lokman ALTINKAYA

Akdeniz University, Kumluca Vocational School, Department of Plant and Animal Production, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0002-8163-2530

Hamide GÜBBÜK

Akdeniz University, Department of Horticulture, Faculty of Agriculture, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0003-3199-0660

ABSTRACT

Passiflora cultivation has recently emerged as a rapidly developing tropical fruit sector in Türkiye, gaining increasing commercial attention and agricultural significance. Passiflora species were officially introduced into the country for the first time in 2013 through a collaborative project conducted by Akdeniz University, the West Mediterranean Agricultural Research Institute, and the Antalya Provincial Directorate of Agriculture and Forestry. Within this project, several tropical fruit species including mango, pitaya, litchi, longan, and guava were evaluated for adaptation performance, and Passiflora was identified as one of the most promising species due to its high adaptability, productive potential, and rising market demand. Cultivation has since expanded along the Mediterranean coastline as well as the Coastal regions of Muğla and İzmir, where ecological conditions are highly suitable for the species. Key factors contributing to the increasing interest in Passiflora include its ability to produce fruit twice a year under favorable conditions, its ease of vegetative propagation, and the aromatic and attractive qualities of its fruit, which appeal strongly to consumers. In addition to fresh consumption, the use of Passiflora as a raw material in various food industries further strengthens its production potential. Moreover, with more than 500 recognized species and highly ornamental flowers, Passiflora also holds considerable value as an ornamental plant alongside fruit production. This study aims to present the current status, potential, and future prospects of Passiflora cultivation in Türkiye. Considering the growing producer interest, suitable ecological conditions, and diverse utilization opportunities, Passiflora stands out as a strong candidate for becoming an important alternative fruit crop in Türkiye’s agricultural landscape.

Key Words: Passiflora; Adaptation; Tropical Fruits; Possum Purple; Fruit quality

INTRODUCTION

The genus Passiflora (Passifloraceae) comprises a large group of plant species distributed mainly in tropical and subtropical regions and includes taxa of considerable economic, nutritional, and pharmacological importance. The family Passifloraceae contains approximately 700 species, of which nearly 60 produce edible fruits (Feuillet & MacDougal, 2007; Schotsmans & Fischer, 2011). Among the genus Passiflora, the most widely cultivated and economically important species include *Passiflora edulis* Sims, *Passiflora ligularis* Juss., *Passiflora quadrangularis* L., *Passiflora setacea* DC., *Passiflora alata* Curtis, and *Passiflora incarnata* L. (Rodríguez Carlosama et al., 2020). These species are utilized not only for fresh consumption but also for industrial processing and ornamental purposes, while some species are particularly valued for the development of pharmaceutical products. As noted above, although the cultivation of Passiflora species is widespread in tropical and subtropical regions, the highest production levels are reported in Brazil, followed by other Latin American countries such as Colombia and Peru. Among these species, *Passiflora edulis* is native to Brazil and represents the most widely cultivated and commercially valuable species worldwide. The cultivation of Passiflora edulis is of strategic importance not only for fresh fruit consumption but also for juice production, the food industry, and the development of functional products. In practice, the term Passiflora edulis is commonly used to refer to the yellow-fruited form; however, purple-fruited forms are also included within the same species. Approximately 95% of commercial production is based on the yellow-fruited form (*P. edulis* Sims f. *flavicarpa*), whereas the purple-fruited form (*P. edulis* Sims f. *edulis*) is cultivated on a much more limited scale (Fonseca et al., 2022). The yellow-fruited form is characterized by larger fruit size and higher juice content, making it particularly suitable for the juice processing industry. In contrast, the purple-fruited forms produce smaller fruits; however, due to their intense aroma and superior quality, they are preferred for fresh consumption and in the pastry industry (Li et al., 2011). While the average yield of the yellow-fruited form is approximately 5 tons per decare, the yield of the purple-fruited form generally ranges between 1.0 and 1.5 tons per decare (Fonseca et al., 2022). Furthermore, the cultivation of the yellow-fruited *P. edulis* Sims f. *flavicarpa* is predominantly widespread in tropical regions, whereas the cultivation of the purple fruited *P. edulis* Sims f. *edulis* is mainly concentrated in more limited areas characterized by temperate subtropical and microclimatic conditions.

In this study, the cultivation potential of *P. edulis* Sims f. *edulis* in Türkiye, current practices within the country, and future perspectives are presented.

PASSIFLORA CULTIVATION AND PRODUCTION POTENTIAL IN TÜRKİYE

The first official studies on Passiflora in Türkiye were initiated in 2012. Within the scope of a project conducted through the collaboration of the Antalya Provincial Directorate of Agriculture, Forestry and Food, the Western Mediterranean Agricultural Research Institute, and the Faculty of Agriculture of Akdeniz University, Passiflora seedlings were imported from California for the first time, and adaptation studies were initiated in the Gazipaşa and Alanya districts of Antalya (Gübbük, 2017). The Passiflora cultivars introduced to Türkiye included ‘Possum Purple’ belonging to *P. edulis* Sims f. *edulis* and ‘Sweet Sunrise’ belonging to *P. edulis* Sims f. *flavicarpa*. As a result of the adaptation studies, ‘Possum Purple’ was identified as one of the cultivars showing the best adaptation to the region (Gübbük, 2017). As mentioned above, the yellow-fruited cultivar ‘Sweet Sunrise’ is adversely affected by low temperatures under Turkish conditions, and although the plants flower, fruit set does not occur. In contrast, the cultivar ‘Possum Purple’ can be successfully cultivated, particularly along the coastal zones of the Mediterranean and Aegean regions.

Since Passiflora is a climbing plant species with a vine-like growth habit, it requires a support system during cultivation. These training systems should be established prior to orchard installation. When setting up training systems, attention should be paid to ensuring that they are both economically feasible and capable of supporting the plant canopy and fruit load. Globally, the most commonly used training systems in passiflora cultivation are the hedge (trellis) and T systems. In the hedge system, two wires are installed between the posts, with one wire positioned approximately 10 cm below the top of the posts and the second wire placed 70 cm below the first. In the commonly preferred T training system, posts are installed at a height of 1.5–2.0 m and spaced approximately 4 m apart. In this system, a 50 cm-long T shaped crossarm is mounted on each post, and three wires are installed (McCarthy & Dick, 1995). In Türkiye, the hedge system is the most widely used training system in passiflora cultivation; however, in some studies, the T system, modified T system, and Y system have also been applied. Balkıç (2022), investigated the effects of different training systems on the yield and quality of passiflora under open-field and protected cultivation conditions in Antalya and reported that each training system has its own advantages and disadvantages. The author emphasized that cultivation and training systems should be selected according to the intended production objectives.

Passiflora is classified among minor fruit crops worldwide (Altendorf, 2018). In Türkiye, interest in passiflora cultivation has begun to increase, as observed for other tropical fruit species. The growing interest in this crop is primarily attributed to its ease of propagation, ability to produce fruit twice a year, and early bearing shortly after planting. However, cultivation is generally not carried out on large-scale agricultural lands but is instead limited to small scale and hobby oriented production. In the Mediterranean and Aegean coastal regions, where tropical fruit cultivation is practiced, the most important limiting factors are the high cost of land and the preference for crop species that provide higher economic returns per unit area. Nevertheless, the widespread use of passiflora in the ice cream and pastry industries, as well as its preference by hotels operating within the tourism sector, demonstrates that passiflora is a high value-added fruit species with significant economic potential. In Türkiye, passiflora is cultivated as a main crop in only a few locations. Due to its climbing growth habit, this species is also commonly preferred as a hedge plant, particularly along fences installed at the borders of orchards or greenhouses (Figure 1).



a. **b.**

Figure 1. General view of plants grown as hedge plants (a) and fruits (b).

Many tropical fruit species are imported into Türkiye, resulting in significant foreign exchange losses for the agricultural sector. Increasing domestic production of tropical fruit species that can be cultivated under local conditions would help reduce external dependency while simultaneously expanding product diversity within national agriculture. In this context, passiflora occupies a priority position among these species due to its favorable agronomic and commercial characteristics. In particular, if production increases beyond a certain level, passiflora has considerable potential for utilization in the juice industry and in various fruit blends, owing to its distinctive high aroma and flavor profile.

PRACTICES, AND FUTURE PERSPECTIVES IN TÜRKİYE

Passiflora can be rapidly propagated by cuttings, tissue culture, and seeds. The ease of propagation is one of the key factors contributing to the increasing interest in passiflora cultivation. Propagation by cuttings and tissue culture represents vegetative propagation methods, whereas seed propagation, which is also widely practiced in Türkiye, is a generative propagation method. In fruit species propagated by seeds, genetic segregation occurs, resulting in non-uniform plants and the absence of true to type fruit production. Although propagation by cuttings in passiflora is easy and can be widely applied, many growers prefer to produce seedlings from seeds extracted from harvested fruits and establish orchards using these seed derived plants. This practice leads to variability not only in fruit characteristics but also in the level of tolerance of plants to abiotic stress factors. Figure 2 illustrates the effects of low winter temperatures on plants in an orchard established from seed propagated passiflora in Serik/Antalya. Within the orchard, a large number of plants were observed to be affected by frost damage, whereas only a limited number of plants survived. These findings demonstrate

that passiflora plants propagated from seeds may exhibit pronounced differences in physiological characteristics.



a. **b.**

Figure 2. General view of plants within the orchard showing frost-affected (a) and unaffected (b)individuals.

In Türkiye, passiflora cultivation is predominantly carried out under open-field conditions; however, protected cultivation practices are also applied. Protected passiflora cultivation offers an earlier production model compared to open-field conditions. In open-field cultivation, pollination and fertilization in passiflora, which has showy flowers, are generally achieved by insects, and no significant problems are encountered in this process. In contrast, under protected cultivation, limitations in natural pollinators may result in insufficient pollination and fertilization. This situation leads to significant reductions in fruit set and, consequently, yield. Therefore, in protected cultivation, the use of bumblebees or the application of manual pollination is required. In addition, high temperatures encountered during the summer period may adversely affect fruit quality. To prevent such negative effects, careful attention should be paid to seasonal climate control practices (such as shading and misting) and appropriate irrigation management in protected cultivation.

Since Passiflora is a plant with a climbing growth habit, the use of a support and training system is essential in its cultivation. As observed worldwide, the most commonly used training system in passiflora cultivation in Türkiye is the hedge (trellis) system. In addition, the pergola system and the T training system are also applied to a certain extent in Türkiye. Furthermore, passiflora is widely utilized in Türkiye not only as a main crop but also as a hedge plant. In particular, its cultivation as a hedge plant along wire-fenced orchard and field boundaries highlights the potential of this species to provide additional income alongside the main crop.

Passiflora has also begun to be considered as an intercrop in perennial fruit species that share similar ecological requirements and have a late bearing habit. In particular, the early bearing characteristic of passiflora allows it to be cultivated in combination with other fruit species. Avocado cultivation can be given as an example of this practice. Figure 3 illustrates the status of passiflora plants planted between avocado rows in 2021 and 2023. During the period until avocado plants reach economic yield, approximately 4–5 harvests can be obtained from passiflora plants, thereby covering a significant portion of the production costs.



a. b.

Figure 3. Views of passiflora plants intercropped between avocado seedlings in 2021 (a) and 2023 (b).

Türkiye's climatic diversity and ecological advantages for subtropical fruit cultivation indicate a significant future potential for passiflora. The identification of suitable species and cultivars, particularly the expansion of adaptation studies focusing on *Passiflora edulis* Sims f. *edulis*, will play a key role in the widespread adoption of this crop. In addition, the integration of passiflora into fresh consumption markets, the food industry, and the tourism sector will further enhance its economic value. With the development of standardized seedling production, grower training programs, and strengthened marketing infrastructure, passiflora is considered to have the potential to become a high value-added alternative fruit species for Türkiye.

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EFFECTS OF IBA SOLUTIONS PREPARED WITH DIFFERENT ALCOHOL CONCENTRATIONS ON ROOTING IN PASSIFLORA EDULİS

Recep BALKIÇ

Akdeniz University, Elmalı Vocational School, Department of Plant and Animal Production, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0002-1212-9501

Lokman ALTINKAYA

Akdeniz University, Kumluca Vocational School, Department of Plant and Animal Production, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0002-8163-2530

Hamide GÜBBÜK

Akdeniz University, Department of Horticulture, Faculty of Agriculture, Antalya, Turkey

ORCID ID: https://orcid.org/0000-0003-3199-0660

ABSTRACT

Passiflora is among the tropical fruit species whose commercial potential is rapidly increasing in Türkiye. Vegetative propagation by cuttings is widely used in seedling production, and rooting success may vary depending on the growth regulators applied and the methods used in their preparation. Scientific data on the effects of the alcohol concentration used in preparing Indole-3-butyric acid (IBA) solutions on hormone efficacy and on the treated cuttings are limited. This study aimed to determine the effects of preparing a 1000 ppm IBA solution with different alcohol concentrations (30%, 40%, and 50%) on the rooting performance of semi-hardwood cuttings of *Passiflora edulis*. In the study, semi-hardwood cuttings of the "Possum Purple" cultivar, each approximately 20 cm in length and containing at least three nodes, were used. In addition to the control treatment, three Indole-3-butyric acid (IBA) solutions prepared with different alcohol concentrations (30% alcohol + 70% water, 40% alcohol + 60% water, and 50% alcohol + 50% water) were applied. The experiment was designed with three replicates, each consisting of 10 cuttings, for a total of 120 cuttings. Perlite was used as the rooting medium. The trial was conducted over a period of 60 days in an unheated glass rooting greenhouse, where the misting system was set to operate for 15 seconds every hour. The rooting percentage showed clear differences among the treatments, with the highest value obtained from the control group (95.23%). This was followed by the 30% alcohol (70.00%) and 40% alcohol (53.33%) treatments. The 50% alcohol treatment produced the lowest rooting percentage (33.33%). Although the highest number of primary roots was recorded in the 50% alcohol treatment (20.4 roots), root quality and root thickness were reduced in this group. Average root length was highest in the control (12.95 cm) and 30% alcohol (12.92 cm) treatments. Root fresh and dry weights also varied among treatments. The control and 30% alcohol treatments exhibited the highest root fresh and dry weights, whereas increasing alcohol

concentrations caused a noticeable decline in these parameters. The findings indicate that the alcohol concentration used in preparing the IBA solution has a significant effect on rooting success. Although higher alcohol levels increased the number of roots in semi-hardwood cuttings, they negatively affected both the rooting percentage and overall root quality. The most balanced and horticulturally favorable results were obtained from the control and 30% alcohol treatments. This study provides practical insights for optimizing IBA preparation protocols in the propagation of *Passiflora edulis* seedlings.

Key Words: Propagation; Cutting; Passiflora; Rooting; Indole-3-butyric acid

INTRODUCTION

Interest in tropical fruit species has been increasing steadily in recent years. Fruit crops such as banana, mango, pineapple, and papaya, which have high production volumes, also account for substantial levels of international trade. In contrast, fruit species classified within the minor fruit group, including passion fruit, longan, litchi, and mangosteen, are produced in relatively smaller quantities and have more limited commercial circulation compared to major tropical fruits (Altendorf, 2018).

Within the minor fruit group, the genus Passiflora particularly *Passiflora edulis* is known to comprise more than 500 species (Cerqueira-Silva et al., 2018). Among these, purple passion fruit (*Passiflora edulis* f. *edulis* Sims), yellow passion fruit (*Passiflora edulis* f. flavicarpa), and granadilla (*Passiflora quadrangularis* L.) are the most widely cultivated species (Balkıç, 2022). With respect to utilization patterns, yellow passion fruit is predominantly preferred for processing purposes, whereas purple passion fruit is commonly consumed fresh in addition to its use in processed products (Deshmukh et al., 2017).

The first official scientific study aimed at evaluating the adaptation of tropical fruit species to the ecological conditions of Türkiye was conducted through a collaborative effort involving the Antalya Provincial Directorate of Agriculture and Forestry, the West Mediterranean Agricultural Research Institute, and the Faculty of Agriculture at Akdeniz University. Within the scope of this project, adaptation trials were initiated in 2012 in the Alanya and Gazipaşa districts of Antalya for several tropical fruit species, including passion fruit, guava, mango, longan, litchi, and pitaya (Gübbük, 2017). Among these species, passion fruit and pitaya emerged as particularly promising crops, and their cultivation has increased progressively in recent years. Under Türkiye growing conditions, the ability of passion fruit to flower and bear fruit twice a year, its ease of propagation, and its early onset of fruiting after planting have played a significant role in the expansion of its cultivation.

Passiflora species can be readily propagated vegetatively through stem cuttings; however, propagation by seed and tissue culture is also possible. Among vegetative propagation methods, cutting propagation is widely practiced, and plant growth regulators are frequently used to stimulate adventitious root formation. Studies conducted in this context have reported that both the rooting substrate and the type of growth regulator applied play a decisive role in rooting success.

Boboc et al. (2020) investigated the effects of different rooting substrates and biostimulant applications on the rooting performance of stem cuttings of *Passiflora caerulea* and *P. quadrangularis*. Their results indicated that cuttings treated with 1000 ppm indole-3-butyric acid (IBA) and rooted in vermiculite achieved the highest rooting percentage (74.47%). Similarly, Bemkaireima et al. (2012) evaluated the effects of different node numbers (two-, three-, and four-node cuttings) and IBA concentrations (250, 500, 750, and 1000 ppm) on the rooting of purple passion fruit (*Passiflora edulis* var. *edulis* Sims) under Manipur (India)

conditions. Based on all evaluated parameters, the authors concluded that 750 ppm IBA was the most effective concentration for promoting rooting. In another study conducted in India, Parse et al. (2018) examined the effects of indole-3-butyric acid (IBA), naphthaleneacetic acid (NAA), salicylic acid, and ethanol applications on the rooting success of passion fruit cuttings. The results demonstrated that, compared to the control treatment, 1000 ppm IBA produced the most favorable outcomes with respect to both root and shoot growth parameters. Under Turkiye conditions, Uzunoğlu & Mavi (2016), evaluated the rooting performance of *Passiflora caerulea* cuttings grown in a pumice substrate under different IBA concentrations (500, 1000, 2000, and 3000 ppm). Measurements taken 45 days after planting revealed that the highest rooting percentage, root number, root length, and callus formation rate were obtained with the 1000 ppm IBA treatment.

In recent years, the use of biologically based inputs, in addition to growth regulators, has gained increasing attention in the rooting of passion fruit cuttings. Altınkaya et al. (2024) investigated the effects of different rooting substrates (perlite and vermiculite) and biostimulant applications on the rooting performance of the passion fruit cultivar ‘Possum Purple’ under Antalya (Türkiye) conditions. In this study, biostimulant treatments included IBA and a microbial fertilizer commercially known as Best-doll, applied either alone or in combination with IBA. The microbial fertilizer contained *Penicillium bilaii*, *Bacillus megaterium*, *Azospirillum brasilense*, *Arthrobacter viscosus*, *Azotobacter vinelandii*, *Azotobacter chroococcum*, and *Pseudomonas* spp., with a total microbial density of 2×10^7 cfu mL^{-1}. The results indicated that the highest rooting percentages were obtained in the control, microbial fertilizer, and microbial fertilizer + 750 ppm IBA treatments.

As outlined above, numerous studies have investigated the rooting of passion fruit cuttings. While these studies have consistently reported the positive effects of different IBA concentrations on rooting performance, the proportion of alcohol and distilled water used in the preparation of IBA solutions has generally not been specified. Passion fruit cuttings are semi-hardwood in nature, and it is therefore presumed that high alcohol concentrations in IBA solutions may cause damage to living tissues, potentially impairing rooting success. For these reasons, the present study was designed to evaluate the effects of IBA solutions prepared with different alcohol concentrations on the rooting performance of the passion fruit cultivar ‘Possum Purple’.

MATERIALS AND METHODS

This study was conducted between 2019 and 2020 in the glass mist-propagation greenhouse located at the Research and Experimental Fields of the Faculty of Agriculture, Akdeniz University. In the experiment, 3 nodes semi-hardwood cuttings of the passion fruit cultivar ‘Possum Purple’ (*Passiflora edulis* f. *edulis*) were used. Except for the control treatment, prepared cuttings were treated for 10 seconds with 1000 ppm IBA solutions prepared using three different alcohol concentrations. For the preparation of IBA solutions, three separate batches were prepared by dissolving 0.1 g of pure IBA, weighed using a precision balance, in different volumes of absolute ethyl alcohol, followed by dilution with distilled water to a final volume of 100 ml. The treatments were as follows:

1. Control (distilled water only)
2. 1000 ppm IBA (30 ml absolute ethyl alcohol + 70 ml distilled water)
3. 1000 ppm IBA (40 ml absolute ethyl alcohol + 60 ml distilled water)
4. 1000 ppm IBA (50 ml absolute ethyl alcohol + 50 ml distilled water)

After treatment, the cuttings were planted in trays filled with perlite, placed under an intermittent misting system, with a spacing of 5 cm within rows and 10 cm between rows. The cuttings were allowed to root for 60 days, and the misting system was programmed to operate for 15 seconds every hour.

At the end of the rooting period, the following parameters were evaluated in the rooted cuttings:

Rooting percentage (%): Calculated as the ratio of rooted cuttings to the total number of cuttings and expressed as a percentage.

Primary roots number (count.): Determined by counting the number of primary roots formed on each rooted cutting.

Average root diameter (mm): The diameter of five randomly selected roots from each rooted cutting was measured near the root collar, and the mean value was calculated.

Average root length (cm): The length of five randomly selected roots from each rooted cutting was measured, and the mean value was calculated.

Longest root length (cm): Determined by measuring the length of the longest root on each rooted cutting.

Fresh root weight (g): Roots were excised at the root collar and weighed using a precision balance to determine fresh weight.

Fresh Leaf weight (g): Leaves were detached from rooted cuttings and weighed using a precision balance to determine fresh weight.

Dry root weight (g): Roots excised at the root collar were oven-dried at 65 °C until constant weight was achieved, after which dry weights were recorded.

Dry leaf weight (g): Leaves detached from rooted cuttings were oven-dried at 65 °C until constant weight was achieved, and final dry weights were recorded.

The experiment was arranged with three replications, each consisting of 10 cuttings, resulting in a total of 120 cuttings. All data obtained were subjected to analysis of variance (ANOVA) using the XLSTAT statistical software. Mean comparisons were performed using the least significant difference (LSD) test. In addition, principal component analysis (PCA) was conducted to evaluate the relationships among the measured variables, also using the XLSTAT program.

RESULT AND DISCUSSION

The effects of IBA solutions prepared with different alcohol concentrations on rooting percentage, number of primary roots, average root diameter, average root length, and longest root length in passion fruit cuttings are presented in Table 1. With respect to rooting percentage, the highest rooting rate (95.24%) was recorded in the control treatment, followed by the IBA solution prepared with 30% alcohol (70.00%), 40% alcohol (53.33%), and 50% alcohol (33.33%), respectively. In contrast, the number of primary roots exhibited an inverse relationship with rooting percentage, as clearly shown in Table 1. Accordingly, the highest number of primary roots (20.42) was observed in the treatment with IBA prepared using 50% alcohol, which also resulted in the lowest rooting percentage.

Table 1. The effects of IBA prepared with different alcohol concentrations on rooting rate, primary root number, average root diameter, average and maximum root length in Passiflora.

Treatment	Rooting Percentage (%)	Primary Root Number (count)	Average Root Diameter (mm)	Average Root Length (cm)	Longest Root Length (cm)
Control	95.24 a*	10.57 b	1.22 a	11.11 b	25.26 b
IBA (%30 Alc.)	70.00 b	19.85 a	0.95 b	13.35 a	17.47 a
IBA (%40 Alc.)	53.33 c	19.00 a	0.88 c	8.95 c	14.22 b
IBA (%50 Alc.)	33.33 d	20.42 a	0.80 d	11.99 ab	15.05 b
$LSD_{\%5}$	10.928	1.863	0.048	1.415	1.594

*: ($P<0.05$)

The lowest number of primary roots (10.57 roots per cutting) was recorded in the control treatment. The highest average root diameter was observed in the control treatment (1.22 mm), whereas the lowest root diameter (0.80 mm) was determined in the treatment with IBA prepared using 50% alcohol (Table 1). Both the average root length and the longest root length were highest in the treatment with IBA prepared using 30% alcohol (Table 1).

The effects of IBA solutions prepared with different alcohol concentrations on root fresh and dry weights as well as leaf fresh and dry weights of passion fruit cuttings are presented in Table 2. As shown in Table 2, IBA solutions prepared with different alcohol concentrations did not have a statistically significant effect on root fresh and dry weights, whereas their effects on leaf fresh and dry weights were significant. The highest leaf fresh weight (6.67 g) and leaf dry weight (1.75 g) were recorded in the control treatment, which also exhibited the highest rooting percentage. In contrast, the lowest leaf fresh weight (2.97 g) was observed in the treatment with IBA prepared using 40% alcohol. Additionally, the lowest leaf dry weight was recorded in the treatment with IBA prepared using 50% alcohol (Table 2).

Table 2. The effects of IBA prepared with different alcohol concentrations on root fresh/dry weight and leaf fresh/dry weight in Passiflora.

Treatment	Fresh Root Weight (g)	Dry Root Weight (g)	Fresh Leaf Weight (g)	Dry Leaf Weight (g)
Control	3.57	0.73	6.67 a	1.75 a
IBA (%30 Alc.)	4.05	0.71	4.23 b	1.01 b
IBA (%40 Alc.)	3.57	0.58	2.97 c	0.75 c
IBA (%50 Alc.)	3.76	0.50	3.29 c	0.72 c
$LSD_{\%5}$	N.S.**	N.S.	0.751	0.233

*: ($P<0.05$), **N.S.: Non Significant

The (PCA) performed on all obtained data is presented in Figure 1.

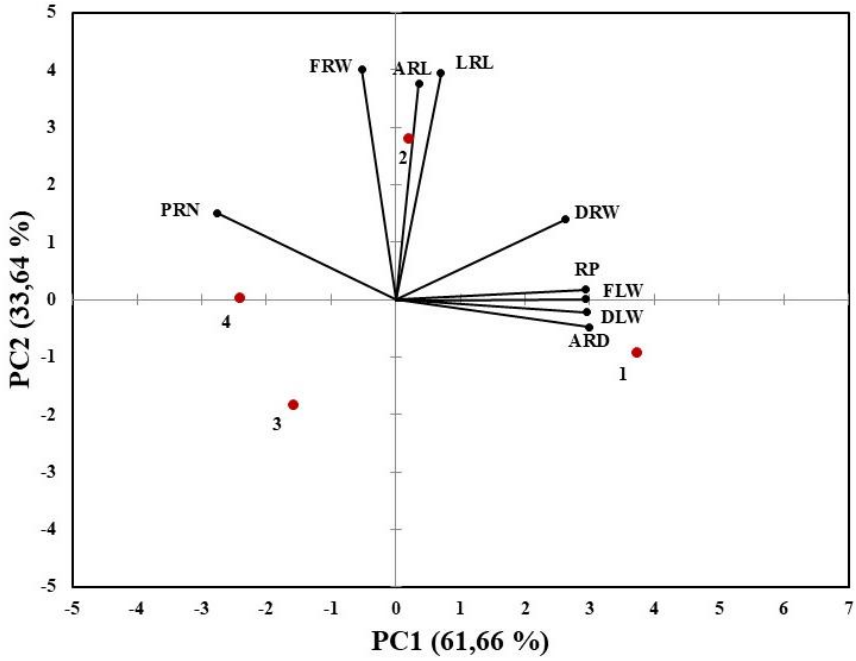


Figure 1. Biplot graph of rooting percentage (RP), primary root number (PRN), average root diameter (ARD), average (ARL) and longest root length (LRL), fresh (FRW) and dry root weight (DRW), and fresh (FLW) and dry leaf weight (DLW) in response to IBA treatments prepared with different alcohol concentrations. (1: Control, 2: IBA (%30 Alc.), 3: IBA (%40 Alc.), 4: IBA (%50 Alc.))

The principal component analysis (PCA) revealed that the first two components (PC1 and PC2) together explained 95.30% of the total variance. As illustrated in Figure 1, increasing the alcohol concentration used in the preparation of the IBA solution resulted in a decline in the evaluated parameters. Rooting percentage, root length, root diameter, and leaf fresh and dry weights were positively correlated with each other, whereas these parameters exhibited a negative correlation with the number of primary roots, as shown in Figure 2.

Numerous studies on the vegetative propagation of Passiflora species have reported that indole-3-butyric acid (IBA) applications enhance rooting success (Bemkaireima et al., 2012; Parse et al., 2018; Boboc et al., 2020; Uzunoğlu & Mavi, 2016). However, in the present study, the highest rooting percentage was obtained in the control treatment, while a marked decrease in rooting was observed with increasing alcohol concentration, indicating that semi-hardwood passion fruit cuttings are sensitive to high alcohol levels. In particular, the reduced rooting percentages observed in IBA solutions prepared with 40% and 50% alcohol suggest that alcohol may exert phytotoxic effects on living tissues. Although this finding appears to contrast with the high IBA efficiencies reported in the literature, the lack of detailed information regarding the solvent composition used in IBA solution preparation in most studies may represent a major reason for this discrepancy. Indeed, McCracken (1987), emphasized that the choice of solvent used in the preparation of auxin-based rooting hormones should be made with caution. This perspective supports the findings of the present study and highlights the importance of considering alternative solvents or lower alcohol concentrations when applying IBA, particularly in green and semi-hardwood cuttings. In this study, while the highest rooting percentage was recorded in the control treatment, the lowest rooting percentage was observed at the highest alcohol concentration. The results further revealed an inverse relationship between rooting percentage and the number of primary roots. Nevertheless, the reduction in primary root number was accompanied by increases in root diameter and root length, indicating that fewer roots developed more robustly. As the number of primary roots decreased, individual

roots became longer and thicker. This response is consistent with the findings of Hartmann et al. (2011), who reported that under conditions where a limited number of adventitious roots are formed, plants tend to allocate carbon resources to fewer roots, thereby promoting the development of thicker and longer roots. The higher leaf fresh and dry weights recorded in the control treatment further indicate that overall plant growth was healthier under conditions associated with higher rooting percentages. These results are in agreement with the findings of Altınkaya et al. (2024), who demonstrated that alternative approaches beyond chemical applications can positively influence rooting success and seedling quality.

CONCLUSION

This study demonstrated the effects of IBA solutions prepared with different alcohol concentrations on the rooting success and root development of Passiflora edulis f. edulis 'Possum Purple' cuttings. The results showed that increasing alcohol concentration led to a marked reduction in rooting percentage, whereas decreases in root number were accompanied by increases in root diameter and length. High alcohol concentrations were found to exert phytotoxic effects on semi-hardwood passion fruit cuttings, thereby negatively affecting rooting performance. These findings indicate that the effectiveness of IBA in rooting is dependent not only on hormone concentration but also on the alcohol content of the solution. Therefore, careful optimization of the alcohol concentration used in the preparation of IBA solutions is recommended for the vegetative propagation of passion fruit.

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USE OF CANONICAL CORRELATION ANALYSIS IN ASSESSING THE RELATIONSHIP BETWEEN BODY MEASUREMENTS AND CARCASE CHARACTERISTICS IN AWSSI SHEEP

İVESİ KOYUNLARINDA VÜCUT ÖLÇÜLERİ İLE KARKAS ÖZELLİKLERİ ARASINDAKİ İLİŞKİNİN DEĞERLENDİRİLMESİNDE KANONİK KORELASYON ANALİZİNİN KULLANILMASI

Prof. Dr. Ömer Cevdet BİLGİN

Atatürk Üniversitesi, Fen Fakültesi

Prof. Dr. Nurinisa ESENBUĞA

Atatürk Üniversitesi, Ziraat Fakültesi

ÖZET

Koyunlarda morfometrik ölçüler ile karkas verimi arasındaki ilişkinin doğru şekilde belirlenmesi, besi yönetimi, seleksiyon stratejileri ve verim tahminlerinin geliştirilmesi açısından büyük önem taşımaktadır. Bu çalışmada, İvesi ırkı erkek kuzularda çeşitli ağırlık ve vücut ölçüleri ile karkas ağırlık ve ölçüleri arasındaki ilişkinin incelenmesi ve karkas ağırlığı ve ölçülerini en iyi açıklayan morfometrik özelliklerin belirlenmesi amaçlanmıştır. Araştırmada temel yöntem olarak kanonik korelasyon analizi kullanılmıştır. Çalışmanın hayvan materyalini 15 baş İvesi erkek kuzusu oluşturmuştur. Kuzulardan kesimden önce alınan 6 adet vücut ölçüsü ile kesimden sonra alınan karkas ağırlık ve ölçüm verileri analizlerde kullanılmıştır. Canlı vücut ölçüleri ile karkas verileri arasındaki çok değişkenli ilişkileri ortaya koymak amacıyla kanonik korelasyon analizi (CCA) uygulanmış; ayrıca kanonik yükler, standart kanonik katsayılar ve çapraz yükler hesaplanmıştır. Analiz sonuçlarının desteklenmesi amacıyla ikili korelasyonlar değerlendirilmiş ve yorumlamada birinci kanonik varyete çifti dikkate alınmıştır. İlk kanonik varyete çifti için kanonik korelasyon katsayısı 0,97 olarak bulunmuş ve vücut ölçüleri ile soğuk karkas ağırlığı arasında yüksek düzeyde bir ilişki saptanmıştır. Bu varyeteyle karkas ağırlığındaki varyansın yaklaşık %90'ı, vücut ölçülerindeki varyansın ise %60'ı açıklanmıştır. Kanonik yükler incelendiğinde but çevresi, omuz yüksekliği ve göğüs derinliğinin vücut ölçüleri setine en fazla katkı sağlayan özellikler olduğu görülmüştür. Elde edilen bulgular, İvesi kuzularında canlı dönemde kolayca ölçülebilen bazı morfometrik özelliklerin soğuk karkas ağırlığını yüksek doğrulukla tahmin edebildiğini ortaya koymuştur. Özellikle but çevresi, omuz yüksekliği ve göğüs derinliği, karkas verimini belirleyen temel fenotipik göstergeler olarak öne çıkmaktadır. Örnek sayısının sınırlılığı istatistiksel anlamlılığı kısıtlasa da, kanonik korelasyonun yüksekliği pratik önem taşımaktadır. Sonuç olarak, İvesi koyunlarında karkas veriminin erken dönemde tahmin edilmesinde vücut ölçülerinin etkili bir kriter olarak kullanılabileceği belirlenmiştir.

Anahtar kelimeler: İvesi koyunu, Vücut ölçüleri, Karkas ölçüleri, Kanonik korelasyon

ABSTRACT

Accurately determining the relationship between morphometric measurements and carcass yield in sheep is crucial for improving livestock management, selection strategies, and yield predictions. This study aimed to investigate the relationship between various weight and body measurements and carcass weight and measurements in Awassi male lambs and to identify the morphometric traits that best explain carcass weight and measurements. Canonical correlation analysis was used as the primary method in the study. The animal material for the study consisted of 15 Awassi male lambs. Six pre-slaughter body measurements and post-slaughter carcass weight and measurement data were used in the analyses. Canonical correlation analysis (CCA) was applied to reveal multivariate relationships between live body measurements and carcass data; canonical loadings, standard canonical coefficients, and cross-loadings were also calculated. Pairwise correlations were evaluated to support the analysis results, and the first canonical variety pair was considered in the interpretation. The canonical correlation coefficient for the first canonical variety pair was 0.95, indicating a strong relationship between body measurements and cold carcass weight. This variety explained approximately 90% of the variance in carcass weight and 60% of the variance in body measurements. Examining the canonical loadings revealed that leg circumference, shoulder height, and chest depth contributed most to the set of body measurements. The findings revealed that some morphometric traits, easily measured at live age in Awassi lambs, can predict cold carcass weight with high accuracy. Leg circumference, shoulder height, and chest depth, in particular, stood out as key phenotypic indicators of carcass yield. While the limited sample size limits statistical significance, the high canonical correlation is of practical importance. In conclusion, body measurements can be used as an effective criterion for early-stage carcass yield prediction in Awassi sheep.

Key Words: Awassi sheep, Body measurements, Carcass measurements, Canonical correlation

GİRİŞ

Koyun yetiştiriciliğinde karkas verimi ve karkasın yapısal özellikleri, ekonomik değeri belirleyen en önemli unsurlar arasında yer almaktadır. Ancak karkas özelliklerinin doğrudan ölçülmesi yalnızca kesim sonrasında mümkün olduğundan, kesim öncesi dönemde kolay ve düşük maliyetle elde edilebilen canlı vücut ölçülerinin karkas verimiyle olan ilişkilerinin ortaya konulması büyük önem taşımaktadır (Bilgin ve Esenbuğa, 2009). Bu bağlamda, canlı morfometrik ölçülerin karkas özelliklerini ne ölçüde yansıtabildiğinin belirlenmesi, seleksiyon kararlarının desteklenmesi ve besi–kesim planlamasının daha etkin biçimde yapılabilmesi açısından önemli bir yaklaşım sunmaktadır. Canlı ağırlık, vücut uzunluğu, sağrı ve ekstremiteye ait ölçüler gibi temel morfometrik özelliklerin, koyunlarda büyüme performansı ve karkas verimiyle yakından ilişkili olduğu daha önce yapılan birçok çalışmada ortaya konulmuştur. Özellikle canlı ağırlık ve göğüs çevresi gibi ölçülerin, karkas ağırlığının güvenilir göstergeleri olduğu bildirilmektedir (Atta and El Khidir, 2004; Shehata, 2013). Benzer şekilde, farklı koyun ırklarında yapılan çalışmalarda canlı vücut ölçüleri ile karkas özellikleri arasında anlamlı ve güçlü ilişkiler saptanmış, bu ölçülerin karkas tahmininde kullanılabileceği vurgulanmıştır (Bautista-Díaz et al., 2020; Gomes et al., 2021).

Canlı ölçümler ile karkas özellikleri arasındaki ilişkilerin değerlendirilmesinde klasik tek değişkenli yöntemler sınırlı kalabilmekte, bu nedenle çok sayıda değişkenin birlikte ele alınabildiği çok değişkenli istatistiksel yöntemlere ihtiyaç duyulmaktadır. Bu kapsamda, kanonik korelasyon analizi (CCA), iki farklı değişken seti arasındaki ilişki yapısını bütüncül biçimde ortaya koyabilen etkili bir yöntem olarak öne çıkmaktadır. Nitekim, koyunlarda kesim öncesi canlı ölçümler ile kesim sonrası karkas özellikleri arasındaki ilişkilerin

değerlendirilmesinde kanonik korelasyon analizinin başarıyla kullanıldığı çeşitli çalışmalar bulunmaktadır (Bilgin ve Esenbuğa, 2009; Cankaya et al., 2009; Roberto et al., 2024). Türkiye'de yerli koyun ırkları üzerinde yapılan çalışmalar, canlı vücut ölçülerinin karkas parça ağırlıkları ve karkas yapısı ile olan ilişkilerinin ortaya konulmasında kanonik korelasyon analizinin önemli avantajlar sunduğunu göstermektedir. Morkaraman kuzularında yürütülen çalışmalarda, canlı dönemde ölçülen bazı vücut özelliklerinin karkas parçalarını yüksek doğrulukla temsil edebildiği bildirilmiştir (Bilgin ve Esenbuğa, 2009). Bununla birlikte, farklı ırklarda ve yetiştirme koşullarında bu ilişkilerin yeniden değerlendirilmesi gerektiği de vurgulanmaktadır.

İvesi (Awassi) koyunu, Türkiye'nin özellikle Güneydoğu Anadolu Bölgesi'nde yaygın olarak yetiştirilen, et ve süt verimi bakımından önemli bir ırk olmasına rağmen, bu ırkta canlı vücut ölçüleri ile karkas özellikleri arasındaki ilişkilerin çok değişkenli yöntemlerle ele alındığı çalışma sayısı sınırlıdır. Bu nedenle, İvesi erkek kuzularında canlı dönemde ölçülen vücut ölçüleri ile kesim sonrası karkas özellikleri arasındaki ilişkinin kanonik korelasyon analizi ile ortaya konulması hem bilimsel literatüre katkı sağlamak hem de uygulamaya dönük pratik sonuçlar üretmek açısından önem taşımaktadır (Bilgin et al. 2010).

Bu çalışmanın amacı, İvesi erkek kuzularında canlı dönemde ölçülen sınırlı sayıdaki vücut ölçüsü ile karkas verimi ve yapısını temsil eden temel karkas özellikleri arasındaki ilişkiyi kanonik korelasyon analizi kullanarak değerlendirmek ve karkas potansiyelini en iyi yansıtan canlı morfometrik ölçüleri belirlemektir.

MATERYAL ve METOD

Hayvan Materyali

Araştırmanın hayvan materyalini, aynı işletme koşullarında yetiştirilen toplam 15 baş İvesi erkek kuzusu oluşturmuştur. Kuzular yaklaşık olarak benzer yaş ve besi döneminde olup, çalışma kapsamındaki tüm ölçümler aynı bireylerden elde edilmiştir. Ölçümler, kesim öncesi canlı dönemde ve kesim sonrası karkas değerlendirmesi sırasında alınmıştır. Kesimden bir gün önce her bir kuzudan toplam 6 adet vücut ölçüsü alınmıştır. Ölçümler standart yöntemlere göre gerçekleştirilmiştir. Canlı ağırlık dijital hayvan tartısında, diğer vücut ölçüleri ise cetvel ve ölçü çubuğu kullanılarak elde edilmiştir. Ölçülen morfometrik özellikler şunlardır: Canlı ağırlık (kg), vücut uzunluğu (cm), arka dirsek yüksekliği (cm), incik çevresi (cm), son sağrı genişliği (cm), alın uzunluğu (cm). Kesim sonrası karkaslar 24 saat boyunca +4 °C'de soğutulmuş ve ardından toplam 6 karkas özelliği değerlendirilmiştir (Soğuk karkas ağırlığı (kg), karkas uzunluğu (cm), but iç uzunluğu (cm), but derinliği (cm), göğüs çevresi (cm), göğüs derinliği (cm)). Karkas ölçümleri, soğutulmuş karkas üzerinde, standart anatomik referans noktaları kullanılarak alınmıştır.

Kanonik Korelasyon Analizi (CCA): Canlı vücut ölçüleri (X seti) ve karkas parametreleri (Y seti) analiz öncesinde aşağıdaki adımlarla işlenmiştir: Eksik veri kontrolü yapılmış ve tüm bireylerde tam veri seti bulunduğu doğrulanmıştır. Tüm değişkenler ortalaması 0, varyansı 1 olacak şekilde standartlaştırılmıştır. Aykırı değer analizi yapılmış ve belirgin bir uç değer gözlenmemiştir. Vücut ölçüleri ile karkas özellikleri arasında çok değişkenli doğrusal ilişki yapısını belirlemek için Kanonik Korelasyon Analizi uygulanmıştır. CCA, X ve Y değişken setleri için aşağıdaki fonksiyonlar oluşturulmuştur (Tabachnick & Fidell 2013; Härdle & Simar 2015):

$$U = a_1X_1 + a_2X_2 + \ldots + a_pX_p$$
$$V = b_1Y_1 + b_2Y_2 + \ldots + b_qY_q$$

Burada U ve V, iki veri seti arasındaki maksimum korelasyonu temsil eden kanonik değişkenlerdir. Analizde: p = 6 (vücut ölçüleri), q = 6 (karkas ölçüleri), n = 15 (birey sayısı) olacak şekilde kanonik varyete çiftleri değerlendirilmiştir. CCA kapsamında şu istatistikler hesaplanmıştır: Kanonik korelasyon katsayısı, standart kanonik katsayılar, kanonik yükler ve açıklanan varyans oranları. Tüm analizler SAS paket programı kullanılarak gerçekleştirilmiştir.

BULGULAR ve TARTIŞMA

İvesi koyunlarında iki değişken grubuna ait ortalama ve standart sapmalar Çizelge 1'de sunulmuştur. İvesi erkek kuzularında kesimden önce ölçülen altı temel vücut ölçüsü ile kesim sonrası belirlenen altı karkas özelliği arasındaki ilişki yapısı kanonik korelasyon analizi ile incelenmiştir (Tablo 2). Analiz sonucunda birinci kanonik değişken çifti (U_1–V_1) için elde edilen yüksek kanonik korelasyon katsayısı (RC = 0.985), canlı morfometrik yapı ile karkas özellikleri arasında çok güçlü bir doğrusal ilişki bulunduğunu ortaya koymuştur (Tablo 2). İlk kanonik değişken çifti, iki değişken seti arasındaki ortak varyansın %97'sini açıklamış olup, indirgenme indeksinin yüksek olması canlı vücut ölçülerinin karkas özelliklerini yüksek doğrulukla temsil edebildiğini göstermektedir. Benzer şekilde, koyunlarda canlı ölçümler ile karkas özellikleri arasındaki ilişkilerin çok değişkenli yöntemlerle ele alındığı çalışmalarda ilk kanonik fonksiyonun yüksek açıklama gücüne sahip olduğu bildirilmektedir (Bilgin ve Esenbuğa, 2009; Cankaya et al., 2009; Kunene et al., 2009; Roberto et al., 2024).

Tablo 1. Araştırmada kullanılan değişkenlerin ortalama ve standart sapmaları

Bağımsız değişkenler	$\overline{X}$	$S_{\overline{x}}$	*Bağımlı değişkenler*	$\overline{X}$	$S_{\overline{x}}$
Canlı ağırlık (CA)	59.17	2.00	Soğuk karkas ağırlığı (SKA)	26.99	1.16
Vücut uzunluğu (VU)	74.47	3.74	Karkas uzunluğu (KU)	61.67	1.73
Arka dirsek yüksekliği (ADY)	22.73	1.90	But iç uzunluğu (BIU)	20.82	2.55
İncik çevresi (IN)	16.47	1.56	But derinliği (BD)	20.19	6.86
Alın uzunluğu (AU)	8.00	0.93	Göğüs derinliği (GD)	20.37	1.00
Son sağrı genişliği (SSG)	24.23	1.35	Göğüs çevresi (GÇ)	79.37	3.64

Canlı ölçümlerden oluşturulan U_1 kanonik değişkeninin yapısı incelendiğinde, son sağrı genişliği, incik çevresi ve canlı ağırlığın, karkasla ilişkili morfolojik profili en güçlü biçimde temsil eden değişkenler olduğu belirlenmiştir. Bu değişkenlerin hem kanonik ağırlıklarının hem de kanonik yüklerinin yüksek olması, arka vücut gelişimini yansıtan ölçümlerin karkas verimi açısından belirleyici olduğunu göstermektedir. Canlı ağırlık ve vücut uzunluğu da U_1 değişkeninde anlamlı yükler sergileyerek, genel beden büyüklüğünün karkasın kütlesel ve yapısal özellikleriyle bütüncül bir ilişki içinde olduğunu desteklemiştir. Arka vücut ve ekstremiteye ait ölçülerin öne çıkması, karkasın et verimi bakımından en değerli bölgesi olan but gelişimiyle biyolojik olarak uyumlu bir sonuçtur. Nitekim literatürde sağrı genişliği, bacak çevresi ve canlı ağırlık gibi ölçülerin karkas ağırlığı ve but gelişimiyle güçlü ilişkiler gösterdiği bildirilmektedir (Atta and El Khidir, 2004; Shehata, 2013; Bautista-Díaz et al., 2020; Atac and Altincekic, 2023).

Tablo 2. Canlı vücut ölçüleri ve karkas ölçüleri arasındaki Kanonik Korelasyon Analizinin özet sonuçları

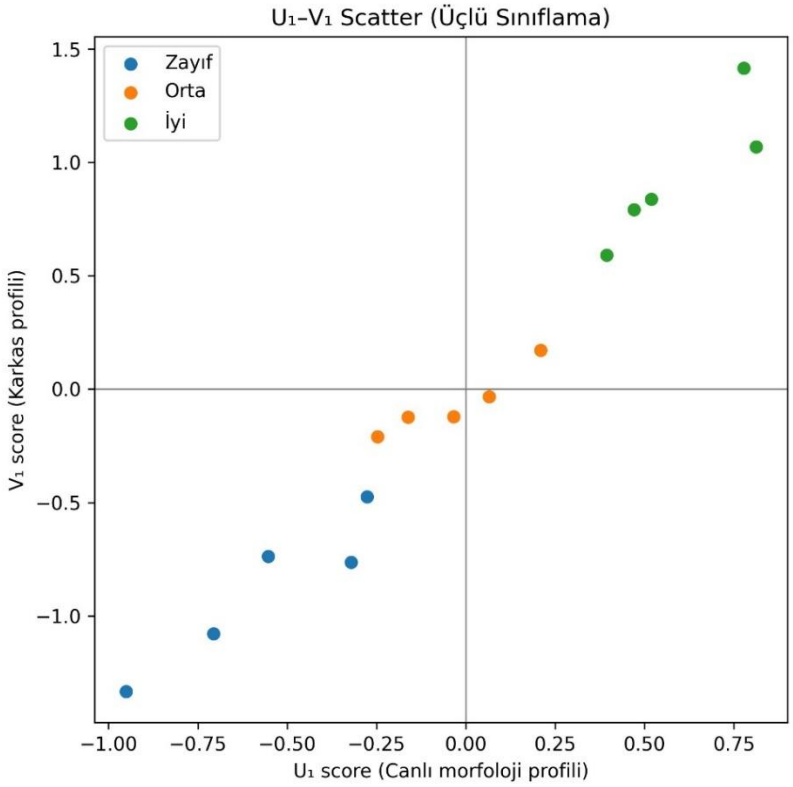
Kanonik Değişken Çiftleri	Kanonik Korelasyon (R_C)	Kanonik Korelasyonun Karesi (R_C^2)	F	Önemlilik Durumu	Olabilirlik Oranı (likelihood ratio)	İndirgenme İndeksi
$U_1 – V_1$	0.985	0.970	7.16*	0.341	0.030	0.970
$U_2 – V_2$	0.860	0740	2.57	0.742	0.260	0.740
$U_3 – V_3$	0.742	0.550	2.63	0.852	0.450	0.550
$U_4 – V_4$	0.662	0.439	2.35	0.523	0.561	0.439
$U_5 – V_5$	0.478	0.229	2.75	0.684	0.771	0.229
$U_6 – V_6$	0.099	0.01	2.54	0.984	0.990	0.01

Karkas ölçümleri setinde ise soğuk karkas ağırlığı, karkas uzunluğu ve göğüs çevresi, V_1 kanonik değişkeninin oluşumunda en yüksek kanonik yük ve ağırlıklara sahip değişkenler olarak öne çıkmaktadır. Bu bulgu, karkasın hem kütlesel (ağırlık) hem de boyutsal (uzunluk ve çevre ölçüleri) özelliklerinin canlı dönemdeki morfolojik yapı ile birlikte şekillendiğini göstermektedir. Karkas uzunluğu ve göğüs çevresinin yüksek yükler sergilemesi, bu ölçülerin karkas kompozisyonu ve kas dağılımını yansıtan temel göstergeler olduğunu ortaya koymaktadır. Benzer sonuçlar, farklı koyun ırklarında yapılan çalışmalarda da rapor edilmektedir (Gomes et al., 2021; Roberto al., 2024).

Tablo 3. Canlı vücut ölçüleri ve karkas ölçüleri icin hesaplanan standize edilmiş kanonik ağırlıklar ve yükler

Bağımsız değ.	Ağırlıklar	Yükler	Bağımlı değ.	Ağırlıklar	Yükler
CA	0.128	0.351	SKA	0.530	0.472
VU	-0.047	0.023	KU	-0.470	-0.671
ADY	-0.196	-0.425	BIU	-0.446	0.159
IN	0.521	0.211	BD	-0.153	-0.321
AU	0.457	0.278	GD	-0.523	-0.511
SSG	0.680	0.243	GÇ	0.054	0.057

Kanonik ağırlıklar ve kanonik yükler birlikte değerlendirildiğinde, canlı ölçümlerin kanonik değişkenin matematiksel yapısına katkısı ile biyolojik yorum gücü arasındaki fark daha net biçimde ortaya çıkmaktadır. Bu çalışmada, özellikle son sağrı genişliği ve incik çevresinin hem yüksek ağırlık hem de yüksek yük değerleri göstermesi, bu ölçümlerin karkasla ilişkili morfolojik yapıyı temsil etmede istatistiksel olarak güçlü ve biyolojik olarak anlamlı göstergeler olduğunu düşündürmektedir. Literatürde, kanonik ağırlıkların değişkenlerin modele katkısını, kanonik yüklerin ise biyolojik yorumu daha güvenilir biçimde yansıttığı vurgulanmakta olup, bu çalışmada elde edilen sonuçlar söz konusu yaklaşımı destekler niteliktedir (Salako, 2006; Yakubu and Ibrahim, 2011).



Grafik 1. Canlı vücut ölçülerinden elde edilen U_1 skorları ile karkas özelliklerinden elde edilen V_1 skorları arasındaki ilişki

U_1 ve V_1 skorları kullanılarak yapılan bireysel düzeyde değerlendirmede, kuzular İyi, Orta ve Zayıf olmak üzere üç gruba ayrılmışlardır. "İyi" grupta yer alan kuzuların hem pozitif U_1 hem de pozitif V_1 skorlarına sahip olduğu ve canlı morfolojik yapılarının karkas özellikleriyle yüksek düzeyde uyum gösterdiği belirlenmiştir. Buna karşılık, "Zayıf" gruptaki kuzuların her iki skor açısından da negatif değerlere sahip olduğu ve karkas potansiyelinin daha düşük olduğu görülmüştür. U_1–V_1 saçılım grafiğinde (Grafik 1) gruplar arasındaki belirgin ayrışma, kanonik skorların yalnızca teorik bir istatistiksel çıktı değil, aynı zamanda birey düzeyinde sınıflama ve karar destek aracı olarak da kullanılabileceğini göstermektedir. Benzer şekilde, kanonik skorların birey düzeyinde sınıflama ve seleksiyon amacıyla kullanılabileceği daha önce farklı hayvan materyallerinde de rapor edilmiştir (Bilgin ve Esenbuğa, 2009; Gomes et al., 2021; Roberto et al., 2024).

SONUÇ

Bu çalışmada, İvesi erkek kuzularında canlı dönemde ölçülen sınırlı sayıdaki vücut ölçüsünün karkas verimi ve yapısını ne ölçüde yansıtabileceği kanonik korelasyon analizi ile ortaya konulmuştur. Canlı vücut ölçüleri ile karkas özellikleri arasında çok güçlü bir ilişki bulunmuş, birinci kanonik değişken çifti iki değişken seti arasındaki ortak varyansın %97'sini açıklamıştır. Bu bulgu, canlı dönemde kolay ve düşük maliyetle elde edilebilen morfometrik ölçümlerin, kesim sonrası karkas özelliklerinin güvenilir birer göstergesi olabileceğini ortaya koymaktadır. Kanonik ağırlıklar ve yükler birlikte değerlendirildiğinde, özellikle son sağrı genişliği ve incik çevresinin, karkasla ilişkili yapıyı temsil etmede öne çıkan canlı ölçümler olduğu belirlenmiştir. Karkas tarafında ise soğuk karkas ağırlığı, karkas uzunluğu ve göğüs çevresi, karkasın hem kütlesel hem de yapısal gelişimini en iyi yansıtan özellikler olarak ön plana çıkmaktadır. Bu sonuçlar, arka vücut gelişimini temsil eden ölçülerin karkas verimi açısından kritik önem

taşıdığını ortaya koymaktadır. Ayrıca U1–V1 saçılım grafiğinde gruplar arasındaki belirgin ayrışma, kanonik skorların seleksiyon, besi planlaması ve karar destek süreçlerinde pratik bir araç olarak kullanılabileceğini göstermektedir. Sonuç olarak, İvesi erkek kuzularında sınırlı sayıda seçilmiş canlı vücut ölçüsüne dayalı kanonik korelasyon yaklaşımı, karkas verimi ve yapısının öngörülmesinde etkili, uygulanabilir ve saha koşullarına uygun bir yöntem sunmaktadır. Bu yaklaşımın, özellikle erken dönemde seleksiyon kararlarının desteklenmesi ve yetiştiricilikte verimliliğin artırılması açısından önemli katkılar sağlayabileceği düşünülmektedir.

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COMPARISON OF LACTATION CURVE MODELS IN TUJ SHEEP

TUJ KOYUNLARINDA LAKTASYON EĞRİSİ MODELLERİNİN KARŞILAŞTIRILMASI

Prof. Dr. Nurinisa ESENBUĞA

Atatürk Üniversitesi, Ziraat Fakültesi

ORCID NO: 0000-0002-2036-8369

Prof. Dr. Ömer Cevdet BİLGİN

Atatürk Üniversitesi, Fen Fakültesi

ORCID NO: 0000-0003-3805-3848

ÖZET

Laktasyon eğrilerinin doğru modellenmesi, koyunlarda süt veriminin yönetimi, ıslah planlaması ve verim tahminlerinin güvenilir şekilde yapılabilmesi açısından büyük önem taşımaktadır. Bu çalışmada, Tuj koyunlarının 3–27. haftalar arasında ölçülen süt verimlerine dört farklı matematiksel modelin uygulanması, modellerin tahmin performanslarının karşılaştırılması ve Tuj koyunlarının laktasyon eğrisini en iyi temsil eden modelin belirlenmesi amaçlanmıştır. Çalışmanın hayvan materyalini 31 baş Tuj koyunu oluşturmuştur. Tuj koyunlarının laktasyon eğrileri Wood (WD), Cobby and Le Du (CD), Morant and Gnanasakthy (MG) ve Gipson and Grossman (GG) modelleri kullanılarak değerlendirilmiştir. Karşılaştırmalar MSPE, R^2 ve Durbin–Watson (DW) kriterleri dikkate alınarak yapılmıştır. WD modeli veriye yüksek düzeyde uyum göstermiş (MSPE=0.00041, R^2=0.9899) ve en düşük hata değerlerinden birini üretmiştir. MG modeli benzer biçimde güçlü bir performans sergilemiş (MSPE=0.00046, R^2=0.9886) ve gözlenen değerlere yakın tahminler yapmıştır. CD modeli diğer modellere kıyasla düşük açıklama gücüyle (MSPE=0.1063, R^2=0.703) en zayıf uyumu göstermiştir. Altı parametreli GG modeli istatistiksel olarak yüksek uyum sağlamakla birlikte, parametre karmaşıklığı nedeniyle uygulanabilirliği ve stabilitesi diğer modellere göre daha sınırlı bulunmuştur. Dört model birlikte değerlendirildiğinde WD ve MG modellerinin Tuj koyunlarının laktasyon eğrisini temsil etmede en yüksek doğruluk ve istikrarı sunduğu belirlenmiştir. CD modeli düşük performans sergilediğinden uygun görülmemiştir. GR modeli istatistiksel olarak başarılı olmasına rağmen, çok parametreli yapısı ve hesaplama zorlukları sebebiyle pratik uygulamalarda kullanımının sınırlı olabileceği tespit edilmiştir. Sonuç olarak, Tuj koyunlarının laktasyon eğrisinin güvenilir şekilde modellenebilmesi için WD modelinin birincil, MG modelinin ise güçlü bir alternatif olarak kullanılabileceği sonucuna varılmıştır

Anahtar kelimeler: Tuj koyunu; Laktasyon eğrisi; Matematiksel modelleme

ABSTRACT

Accurate modeling of lactation curves is crucial for sheep milk yield management, breeding planning, and reliable yield prediction. This study aimed to apply four different mathematical models to milk yields measured between weeks 3 and 27 in Tuj sheep, compare their predictive performance, and determine the model that best represents the lactation curve of Tuj sheep. The

animal material for the study consisted of 31 Tuj sheep. Lactation curves of Tuj sheep were evaluated using the Wood (WD), Cobby and Le Du (CD), Morant and Gnanasakthy (MG), and Gipson and Grossman (GG) models. Comparisons were made using the MSPE, R^2, and Durbin–Watson (DW) criteria. The WD model showed a high fit to the data (MSPE=0.00041, R^2=0.9899) and produced one of the lowest error values. The MG model performed similarly strongly (MSPE=0.00046, R^2=0.9886) and produced predictions close to the observed values. The CD model showed the poorest fit, with low explanatory power compared to the other models (MSPE=0.1063, R^2=0.703). While the six-parameter GG model provided a statistically high fit, its applicability and stability were found to be more limited than the other models due to parameter complexity. When the four models were evaluated together, it was determined that the WD and MG models offered the highest accuracy and stability in representing the lactation curve of Tuj sheep. The CD model was deemed unsuitable due to its poor performance. Although the GR model was statistically successful, its multi-parameter structure and computational challenges limited its use in practical applications. Consequently, it was concluded that the WD model could be used as the primary model for reliable modeling of the lactation curve of Tuj sheep, while the MG model could be used as a strong alternative.

Keywords: Artificial Intelligence, Autonomous Systems, Ethics, Reliability, Openness.

GİRİŞ

Laktasyon eğrilerinin modellenmesi, koyunlarda süt veriminin biyolojik yapısını açıklamak, verimliliği karşılaştırmak, yönetim ve seleksiyon kararlarını yönlendirmek açısından modern hayvancılık araştırmalarında önemli bir yer tutmaktadır. Laktasyon eğrisi; yükseliş, pik ve düşüş olmak üzere üç temel fazdan oluşmaktadır ve bu fazların şekli ırk, besleme düzeyi, sağım yönetimi, iklim ve genetik yapı gibi faktörlerden güçlü biçimde etkilenmektedir (Guevara et al., 2023a; Guevara et al., 2023b; Barani et al., 2025).

Sığır ve koyunlarda laktasyon eğrilerinin modellenmesinde en yaygın kullanılan yöntemlerden biri Wood (1967) tarafından geliştirilen eksik gamma fonksiyonudur. Wood modeli (WD), basit yapısı ve biyolojik olarak yorumlanabilir parametreleri nedeniyle bireysel olarak ve sürü düzeyinde güvenilir tahminler sağlayabilmektedir. Nitekim Pérez-Segura et al. (2025), Rambouillet koyunlarında yaptıkları çalışmada WD modelinin laktasyon performansındaki değişimleri başarılı biçimde temsil ettiğini ve pik zamanı ile laktasyon persistensisini yüksek doğrulukla tahmin edebildiğini bildirmişlerdir. Bununla birlikte son yıllarda, özellikle Latin Amerika'daki sürülerden elde edilen verilerin heterojen yapıları nedeniyle nonlineer karışık modellerin (NLME) kullanımlarıda yaygınlık kazanmıştır. Guevara et al. (2023a), 42 farklı laktasyon modelini test ettikleri kapsamlı çalışmalarında, Morant & Gnanasakthy (MG), Wood (WD), Papajcsik–Bodero ve Sikka modellerinin öne çıktığını, ancak model uygunluğunun verinin tamlığı, birey sayısı, sağım başlangıç zamanı ve sürü yönetimi koşullarına göre değişebildiğini göstermişlerdir. Özellikle MG ve Sikka modellerinin yüksek uyum sağladığı, ancak bazı bireylerde yakınsama problemleri oluşturduğu da vurgulanmıştır (Guevara et al., 2023a). Benzer şekilde son dönemlerde yapılan çalışmalar, koyun laktasyon eğrilerinin klasik modellerle her zaman tam olarak açıklanamayabileceğini göstermektedir (Castillo-Hernández et al., 2025). Tekel et al. (2019), Awassi koyunlarında klasik modellerden hiçbirinin R^2 değerinin 0.85'i aşamadığını, en iyi uyumun yüksek dereceli polinom modellerle sağlandığını bildirmişlerdir. Ayrıca metabolomik düzeyde yürütülen yeni araştırmalar, enerji dengesi ve glukoneogenez gibi metabolik süreçlerin laktasyon eğrilerinin şeklini doğrudan etkilediğini göstermektedir. Pérez-Segura et al. (2025), calcium propionate takviyesinin hem laktasyon eğrisini hem de metabolik yolakları değiştirdiğini, süt üretiminde belirgin artışa neden olduğunu ortaya koymuştur. İncelediğimiz çalışmalar, laktasyon eğrisinin yalnızca

matematiksel bir ilişki olmadığını; aynı zamanda hayvanın metabolik, genetik ve çevresel koşullarını yansıtan biyolojik bir süreç olduğunu göstermektedir. Bu nedenle, belirli bir koyun genotipi için en uygun eğriyi seçmek bilimsel açıdan ve yetiştiricilik uygulamaları açısından kritik öneme sahiptir (Angele-Hernandez et al., 2013; Barani et al., 2025; Castillo-Hernández et al., 2025).

Bu çalışmanın amacı, Tuj koyunlarının laktasyon eğrilerini modellemek amacıyla dört farklı modelin (Wood modeli, Cobby–Le Du modeli, Morant–Gnanasakthy modeli ve Gipson–Grossman) karşılaştırılarak, bu ırka özgü en uygun model yapısının belirlenmesidir.

MATERYAL ve METOT

Hayvan Materyali

Araştırmada, Tuj koyunlarına ait tamamlanmış laktasyon kayıtları kullanılmıştır. Örneklem büyüklüğü olarak 31 baş Tuj koyununun laktasyon verileri değerlendirmeye alınmıştır. Tüm koyunlar benzer yönetim ve besleme koşulları altında tutulmuş; kuzular doğumu takiben yaklaşık 2.5 aylık olana dek annelerini emmiş ve bu sürenin sonunda sütten kesim yapılmıştır. Sağım verileri laktasyon boyunca düzenli aralıklarla (haftalık ortalamalar şeklinde) kaydedilmiştir.

Matematiksel Modeller

Laktasyon eğrisini tanımlamak için literatürde yaygın olarak kullanılan dört farklı model seçilmiş ve kullanılan modeller Tablo 1'de sunulmuştur. Her bir model, Tuj koyunlarının bireysel süt verim değerlerine uygulanmıştır. Parametre tahminleri ve standart hataları, SAS yazılımının *NLIN (Nonlinear Regression)* prosedürü kullanılarak Gauss-Newton iterasyon algoritması ile elde edilmişlerdir. Model uyumunun değerlendirilmesinde üç temel performans kriteri kullanılmıştır: (1) Ortalama kareler hatası (MSPE), (2) Düzeltilmiş Belirleme Katsayısı (R^2) ve (3) Durbin–Watson istatistiği (DW). MSPE, modelin tahmin ettiği değerlerin gözlemlerden sapmalarının kareler ortalamasını ifade eder ve daha düşük MSPE değeri daha iyi uyumu göstermektedir. R^2 değerleri, modelin verideki toplam varyasyonu açıklama oranını belirtir. DW istatistiği ise model artıklarında (hatalarında) otokorelasyon olup olmadığını test etmek için kullanılmıştır. DW değerinin 2'ye yakın olması artığın rastgele dağılım gösterdiğine (otokorelasyon olmadığına) işaret eder. 2'den düşük değerler pozitif otokorelasyona, 2'den yüksek değerler ise negatif otokorelasyona işaret etmektedir

Table 1. The models for describing lactation curves.

Name	Source	Function of t	Number of parameters
WD	Wood (1967)	$Y_{(t)}=at^{b}e^{-ct}$	3
CD	Cobby and Le Du (1978)	$Y_{(t)}=a - bt - a\ e^{-ct}$	3
MG	Morant and Gnanasakthy (1989)	$Y_{(t)}=e^{(a + bt + ct2 + d/t)}$	4
GG	Gipson and Grossman (1989)	$Y_{(t)}= a_1b_1\,(1\text{-}\tanh^2(b_1(t\text{-}c_1))) + a_2b_2\,(1\text{-}\tanh^2(b_2(t\text{-}c_2)))$	6

BULGULAR

Tuj koyunlarına ait süt verimlerine yukarıda tanımlanan dört model (Wood, Morant–Gnanasakthy (MG), Gipson–Grossman (GG) ve Cobby–Le Du (CD)) ayrı ayrı uygulanmış ve her model için MSPE, R^2 ve DW değerleri hesaplanarak Tablo 2'de sunulmuştur.

Table 2 Tuj koyunlarının laktasyon eğrilerini tanımlamak için modellerin uyum iyiliği istatistiklerinin karşılaştırılması

Models	N	MSPE	R^2	DW
		**	**	N.S.
WD	31	0.0004±0.007^{c}	0.99±0.0004^{a}	3.39±0.22
CD	17	0.106±0.010^{a}	0.70±0.094^{c}	3.63±0.25
MG	9	0.00046±0.008^{c}	0.98±0.056^{a}	3.37±0.28
GG	24	0.013±0.005^{b}	0.94±0.0012^{b}	3.56±0.23

Modellerin performansı, tahmin edilen değerlerin gözlenen süt verimleriyle uyumu üzerinden MSPE ve R^2 ölçütleriyle karşılaştırılmış, ayrıca modellerin yakınsama başarısı ve uygulama kolaylığı da dikkate alınmıştır. WD modeli, tüm bireylerde başarılı bir şekilde çözümleme sağlamış ve genel olarak dengeli bir performans sergilemiştir. Modelin hata değeri (MSPE = 0.0004) oldukça düşük çıkmış, belirleme katsayısı (R^2) 0.99 olarak belirlenmiştir. Tuj koyunlarının haftalık süt verimleri, WD modeline göre istikrarlı şekilde tahmin edilmiş ve model, eğrinin başlangıcından sonuna kadar biyolojik açıdan tutarlı tahminler vermiştir. Parametre tahminleri de istikrarlı bulunmuş; model hiçbir laktasyonda yakınsama sorunu yaşamamıştır.

Morant–Gnanasakthy (MG) modeli, teorik olarak daha esnek bir yapıya sahip olmasına rağmen, veri setinde sınırlı sayıda laktasyonda yakınsama sağlamıştır. Yakınsama sağlanan bireylerde MG modeli WD modelinden sonra en iyi uyumu gösteren model olmuş ve MSPE değeri 0.00046, R^2 değeri ise 0.98 olarak hesaplanmıştır. Bununla birlikte modelin bireylerin önemli bölümünde başarısız olması, tüm sürü bazında kullanılabilirliğini sınırlandırmaktadır.

Table 3. Dört farklı modele ait laktasyon eğrisi parametreleri, pik verim ve pik zamanı için en küçük kare ortalamaları ve standart hatalar

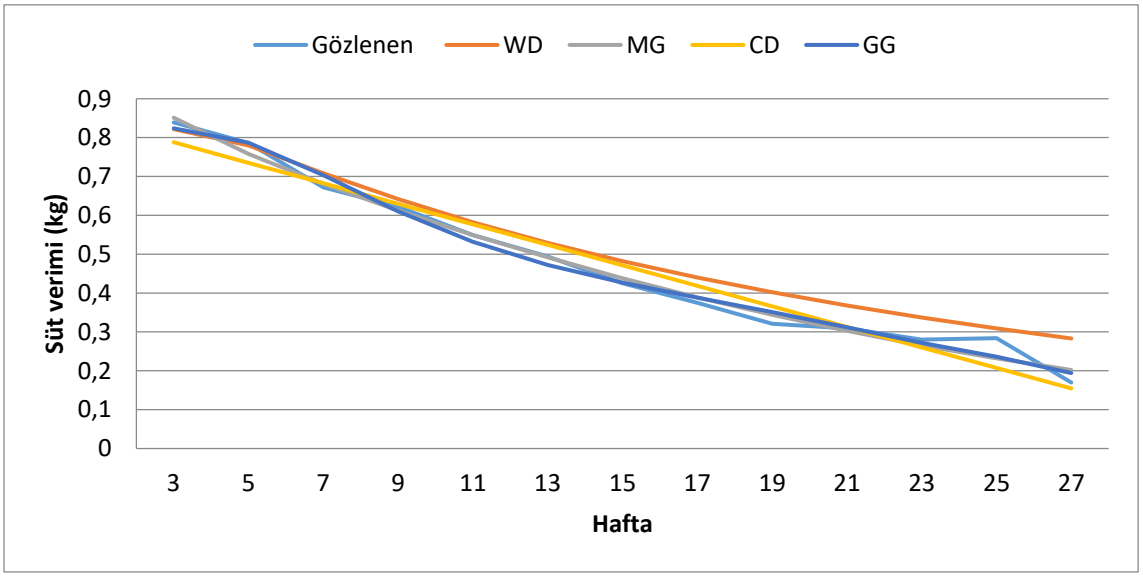
	N	a Mean±S.E.	b Mean±S.E.	c Mean±S.E.	Pik verimi (kg)	Pik zamanı (week)
		**	**	**	**	*
WD	31	0.82±0.13^{ab}	1.30±0.10^{a}	0.28±0.11^{c}	0.902±0.08^{b}	0.90±0.09^{a}
CD	17	0.87±0.28^{ab}	0.026±0.07^{c}	7.33±0.98^{a}	0.845±0.081^{b}	0.68±0.08^{b}
MG	9	-0.095±0.007^{c}	-0.041±0.005^{d}	-0.0006±0.00001^{d}	3.0±0.65^{a}	0.85±0.025^{ab}
GG	24	5.00±0.57^{a}	0.13±0.01^{b}	2.21±0.82^{b}	0.704±0.10^{b}	0.10±0.01^{c}

Gipson–Grossman (GG) modeli iki fazlı yapısıyla laktasyon eğrisinin kompleks dinamiklerini yakalamada istatistiksel olarak güçlü bir uyum göstermiştir. MSPE değeri 0.013 ve R^2 değeri 0.94 ile WD ve MG modellerinden sonra oldukça yüksek bir açıklama gücüne ulaşmıştır. Ancak parametre sayısının fazlalığı nedeniyle model ancak 24 bireyde yakınsama sağlayabilmiştir. Bu durum GG modelinin pratikte sınırlı kullanımına işaret etmiştir. Yakınsama sağlanan bireylerde elde edilen eğriler son derece hassas olsa da modelin aşırı uyum (overfitting) eğiliminde olduğu gözlenmiştir (Grafik 1).

Cobby–Le Du (CD) modeli, diğer modellere kıyasla daha kısıtlı bir uyum sergilemiştir. MSPE değeri 0.106, R^2 değeri ise 0.70 olarak belirlenmiştir. Model özellikle laktasyonun düşüş evresini yeterince doğru temsil edememiş ve doğrusal azalış bileşeni nedeniyle eğrinin doğal eğriselliğini yakalamakta zayıf kalmıştır. Bunun sonucu olarak CD modeli, Tuj koyunlarının laktasyon yapısını tanımlamada diğer modellere göre daha düşük bir başarı göstermiştir.

Model artık analizleri, incelenen modeller için ciddi bir otokorelasyon sorunu olmadığını göstermiştir. Dört modelin de ortalama Durbin–Watson istatistikleri 3 civarında bulunmuştur (3.39–3.63 aralığında). DW değerlerinin 2'nin belirgin üzerinde olması, pozitif yönlü otokorelasyonun olmadığını ve hatta hafif negatif korelasyon eğilimi olabileceğini düşündürmektedir. Kısacası, tüm modeller artıklar açısından bağımsızlık varsayımını büyük ölçüde sağlamışlardır; model tahmin hataları arasında anlamlı bir pozitif ilişki saptanmamıştır. Bu bulgu, özellikle GG modeli için beklenen bir sonuçtur; zira GG modeli otokorelasyonu azaltmak amacıyla iki fazlı yapı önermektedir. Ancak WD ve diğer modellerde de veri doğası gereği artık korelasyonunun sorun teşkil etmediği görülmüştür.

Genel olarak dört model karşılaştırıldığında (Tablo1, Tablo 2), MG modeli WD modeline yakın bir şekilde istatistiksel olarak en düşük hatayı üretmesine karşın, sınırlı uygulanabilirliği nedeniyle tüm sürü için ideal bir seçenek olarak değerlendirilememiştir. GG modelinin uyumu yüksek olmasına rağmen benzer şekilde yakınsama sorunları nedeniyle pratikte uygulamada sorunlar çıkarabilmektedir. CD modeli, hem hata değerleri hem açıklama gücü bakımından en zayıf model olmuştur. WD modeli ise hem yüksek uyum, hem istikrarlı parametre tahmini hem de tüm bireylere uygulanabilirlik açısından en dengeli performansı sunmuş ve Tuj koyunları için en uygun model olarak ortaya çıkmıştır (Grafik 1).



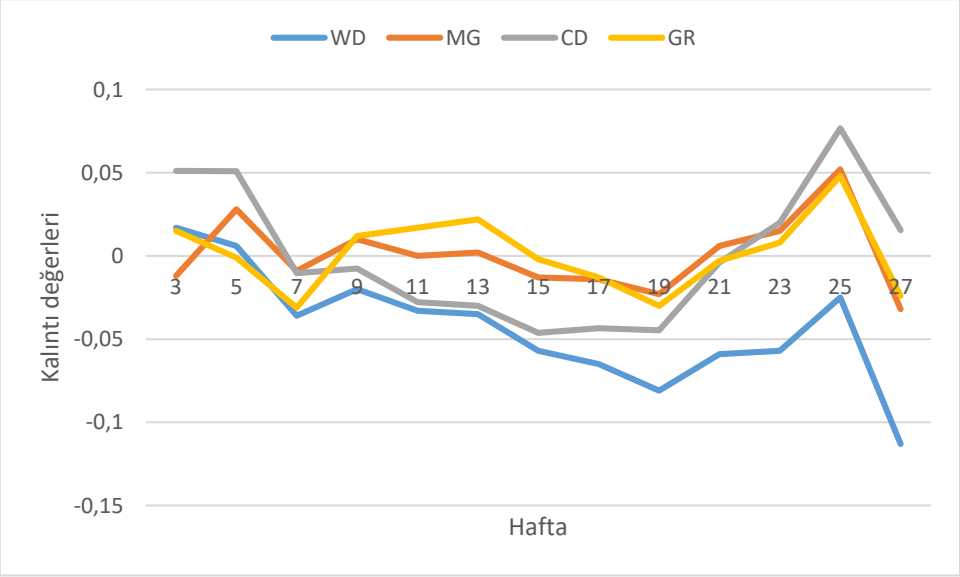
Çizelge 1. Tuj koyunlarında gerçek süt verimleri ve farklı modeller ile tahmin edilen laktasyon eğrileri

TARTIŞMA

Bu çalışmada Tuj koyunlarının laktasyon eğrilerini modellemek amacıyla kullanılan dört farklı eğri fonksiyonunun performansı, model tercihinde hem istatistiksel uyum hem de pratik uygulanabilirlik açısından önemli farklılıklar olduğunu göstermiştir (Grafik 1, 2). Elde edilen sonuçlar, koyunlarda laktasyon eğrisi modellemesine ilişkin son yıllarda yapılan uluslararası

çalışmalarla karşılaştırıldığında tutarlı bir bilimsel çerçeve sunmaktadır. WD modeli, bu çalışmada yüksek R^2, ve düşük MSPE değerleri ve tüm bireysel laktasyonlarda sorunsuz yakınsama sağlamasıyla en dengeli model olarak öne çıkmaktadır. Bu sonuç, Guevara et al. (2023a) tarafından bildirilen bulgularla örtüşmektedir. Söz konusu çalışmada 42 farklı model test edilmiş ve WD modeli, özellikle rastgele etkiler eklenerek yeniden değerlendirildiğinde, biyolojik yorumlanabilirlik ve kararlılık açısından en tutarlı sonuçları vermiştir. Ayrıca Pérez Segura et al. (2025) tarafından Rambouillet koyunlarında yürütülen çalışmada laktasyon eğrisi WD modeli ile başarıyla temsil edilmiş; araştırmacılar model parametrelerinin laktasyon biyolojisi ile doğrudan ilişkili olduğunu, bu nedenle saha koşullarında modelin güvenilir bir araç olarak kullanılabileceğini vurgulamışlardır. WD modelinin bu tür popülasyonlarda üstünlük göstermesinin temel nedenlerinden biri, eğrinin pik sonrası süt verimindeki nonlineer azalışı başarılı şekilde temsil etmesidir. Nitekim Tekel et al., (2019) Awassi koyunlarında WD modelinin klasik eğriler içinde en stabil performansı sergilediğini, ancak daha yüksek uyum isteyen durumlarda polinom temelli esnek modellerin öne çıkabileceğini bildirmişlerdir. Bununla birlikte, bu tür esnek modellerin biyolojik anlamlandırılmasının güç olduğu, bu nedenle özellikle seleksiyon ve yönetim kararlarında WD eğrisinin hala en rasyonel seçenek olduğu belirtilmektedir.

MG modeli, teorik olarak eğrinin hem yükseliş hem düşüş fazını daha ayrıntılı temsil eden esnek yapısıyla dikkat çekmektedir. Bizim çalışmamızda da MG modeli, konverjans sağlanan bireylerde WD modelinden sonra en düşük hatayı ve en yüksek R^2'ye sahip model olmuştur. Bu bulgu, Pollott & Gootwine (2000) tarafından koyunlarda yapılan çalışma ile paralellik göstermektedir. Araştırmacılar MG eğrisinin özellikle süt verimi daha düzenli olan populasyonlarda yüksek doğruluk sunduğunu bildirmişlerdir. Ancak hem bizim çalışmamızda hem de literatürde (Bilgin et al., 2010; Guevara et al., 2023a) belirtildiği gibi MG modelinin en büyük sınırlılığı, yakınsama sorunları ve parametre kararsızlığıdır. Guevara et al., (2023a), MG modelinin özellikle laktasyonun başlangıç döneminin eksik olduğu veya düzensiz sağım verisine sahip koyun popülasyonların da güvenilirliğini kaybettiğini, bazı bireylerde biyolojik açıdan gerçekçi olmayan eğriler oluşturduğunu göstermiştir. Bu nedenle MG modeli yüksek istatistiksel uyum sağlasa bile, sürü genelinde pratik kullanılabilirliği WD modelinin gerisinde kalmaktadır (Grafik 2).



Çizelge 2. Farklı modeller için elde edilen kalıntı değerleri

GG modeli, iki fazlı yapısıyla teoride daha detaylı bir laktasyon dinamiği sunabilmektedir. Bu çalışma, GG modelinin MSPE açısından oldukça güçlü olduğunu ortaya koysa da modelin yüksek parametre sayısı ve bazı bireylerde yakınsama sağlayamaması, literatürle uyumlu şekilde pratik sınırlamayı göstermektedir. Nitekim Grossman & Koops (1988) ile Bilgin et al. (2010) GG modelinin bireysel hayvan düzeyinde sıkça overfitting yarattığını, özellikle düşük verimli ırklarda modelin ikinci fazı gereksiz şekilde zorlayarak anlamsız eğriler ortaya koyduğunu belirtmişlerdir. Bu durum, Tuj gibi toplam laktasyon verimi düşük olan ırklarda modelin biyolojik gerçekliğini yakalamakta zorlanmasına yol açabilmektedir. GG modeli yüksek doğruluk potansiyeline karşın, pratikte en düşük güvenilirliğe sahip modellerden biri olarak değerlendirilebilir.

CD modeli, pik sonrası dönemi doğrusal varsayması nedeniyle Tuj koyunlarının eğrisel azalış paterniyle uyum sağlayamamıştır. Bu durum literatürde de sıkça rapor edilmektedir. Rambouillet koyunları üzerinde yapılan bir çalışmada (Pérez Segura et al., 2025), laktasyonun pik sonrası fazının doğrusal olmadığını, çevresel ve fizyolojik faktörlerin etkisiyle non-lineer bir düşüş sergilediği gösterilmiştir. Benzer şekilde, Guevara et al. (2023a) CD'nin özellikle kısa laktasyonlu sürülerde yetersiz uyum sergilediğini, WD modelinin ise çok daha tutarlı sonuç verdiğini belirtmişlerdir.

Bu literatür bulguları ışığında, Tuj koyunlarında laktasyon eğrisini temsil etmek için WD modelinin hem teorik hem pratik açıdan en uygun model olduğu söylenebilir. WD modeli en düşük hata ve en yüksek R^2 değerlerine sahip olmasının yanında, tüm bireylerde güvenilir yakınsama sağlayarak sürü düzeyinde en güvenilir tahminleyici olarak öne çıkmaktadır. Güncel çalışmalar (Guevara et al., 2023a; Pérez Segura et al., 2025) koyun popülasyonlarında WD eğrisinin önemini koruduğunu göstermektedir. Öte yandan model seçimi çalışmanın amacına bağlıdır. Tahmin doğruluğunun kritik olduğu durumlarda spline tabanlı eğriler veya yüksek dereceli polinomlar tercih edilebilirken, biyolojik yorumlanabilirlik, seleksiyon uygulamaları ve saha yönetimi söz konusu olduğunda WD modeli en rasyonel ve güvenilir seçenek olmayı sürdürmektedir.

SONUÇ

Bu çalışmada Tuj koyunlarının laktasyon eğrilerini modellemek amacıyla dört farklı fonksiyon (Wood, Morant–Gnanasakthy, Gipson–Grossman ve Cobby–Le Du) karşılaştırılmış ve modellerin istatistiksel uyum ölçütleri ve pratik uygulanabilirlikleri birlikte değerlendirilmiştir. Elde edilen bulgular, her modelin farklı güçlü yönleri olsa da Tuj koyunlarının laktasyon yapısı göz önüne alındığında en dengeli ve güvenilir performansın WD modeli tarafından sağlandığını göstermiştir. Genel olarak değerlendirildiğinde, WD modelinin tüm bireylere sorunsuz uygulanabilmesi, istikrarlı parametre kestirimleri üretmesi ve hata ölçütleri açısından diğer modellerden daha iyi değerlere sahip olması nedeniyle pratik kullanım açısından öne çıktığı tespit edilmiştir.

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EFFECTS OF FUNGICIDES ON NON-TARGET FUNGAL COMMUNITIES IN THE PLANT PHYLLOSPHERE

FUNGİSİTLERİN BİTKİ FİLLOSFERİNDEKİ HEDEF DIŞI FUNGUS TOPLULUKLARI ÜZERİNE ETKİLERİ

Araş. Gör. Ömer Ümit OKÇU

Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Plant Protection, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/0000-0002-4809-4398

Prof. Dr. Nuray ÖZER

Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Plant Protection, Tekirdağ, Türkiye

ORCID ID: https://orcid.org/0000-0001-6876-7580

ABSTRACT

The plant phyllosphere has a complex microbial community that includes epiphytic and endophytic fungi. Beneficial fungi within this community play important roles in various ecological processes such as surface competition, biofilm formation, support of the nutrient cycle and limitation of pathogen colonization. However, the fungicides commonly applied in agricultural production have the potential to affect not only target fungal pathogens but also the beneficial fungal populations that are naturally present in the phyllosphere. Fungicide applications may selectively alter fungal diversity and community composition on the phyllosphere, leading to reductions in certain epiphytic or endophytic fungi. Conversely, competitive epiphytic groups that exhibit resistance or tolerance to fungicide treatments may remain unaffected by some active ingredients and thus gain importance as potential biological control agents. Consequently, in fungicide use strategies, non-target effects need to be taken into consideration, chemical applications need to be optimized in terms of dose, timing, and selectivity, and integrated approaches compatible with biological control need to be developed. This review article presents the ecological roles of epiphytic and endophytic fungal communities in the plant phyllosphere and the effects of fungicide applications on non-target groups in light of current studies.

Key Words: Phyllosphere, Fungal Community, Beneficial Fungi, Fungicide Impact, Non-Target Effects

ÖZET

Bitki filosferi, epifitik ve endofitik fungusları içeren karmaşık bir mikrobiyal topluluğa sahiptir. Bu topluluk içinde yer alan yararlı funguslar; yüzey rekabeti, biyofilm oluşumu, besin döngüsünün desteklenmesi ve patojen kolonizasyonunun sınırlandırılması gibi çeşitli ekolojik

süreçlerde önemli roller üstlenmektedir. Ancak tarımsal üretimde yaygın olarak kullanılan fungisitler, yalnızca hedef fungal patojenleri değil, aynı zamanda fillosferde doğal olarak bulunan yararlı fungal popülasyonları da etkileyebilmektedir. Fungisit uygulamaları, fillosferdeki fungal çeşitliliği ve topluluk kompozisyonunu seçici biçimde değiştirebilmekte; bazı epifitik ya da endofitik yaşayan fungusların azalmasına yol açabilmektedir. Buna karşılık, fungisit uygulamalarına karşı direnç veya tolerans gösteren rekabetçi epifitik gruplar, bazı etkili maddeli fungisitlerden etkilenmemeleri nedeniyle potansiyel biyolojik mücadele ajanları olarak önem kazanmaktadır. Bu nedenle fungisit kullanım stratejilerinde hedef dışı etkilerin dikkate alınması, kimyasal uygulamaların doz, zamanlama ve seçicilik açısından optimize edilmesi ve biyolojik mücadele ile uyumlu entegre yaklaşımların geliştirilmesi gerekmektedir. Bu derleme makalesi, bitki fillosferindeki epifitik ve endofitik fungus topluluklarının ekolojik rollerini ve fungisit uygulamalarının hedef dışı gruplar üzerindeki etkilerini mevcut çalışmalar ışığında sunmaktadır.

Anahtar Kelimeler: Fillosfer, Fungal Topluluk, Yararlı Funguslar, Fungisit Etkisi, Hedef Dışı Etkiler

GİRİŞ

Bitki fillosferi, bitkinin toprak üstü organlarını kaplayan ve hem yüzeyde hem de iç dokularında çok çeşitli mikroorganizmaların yaşadığı karmaşık bir ekosistemdir. Yaprak yüzeyini ve iç dokularını kapsayan bu bölge, besin açısından sınırlı fakat mikrohabitat çeşitliliği bakımından oldukça zengin, dinamik bir mikrobiyal yaşam alanı olarak tanımlanmaktadır (Osono, 2006). Kütikula, epidermis, stomalar ve farklı tipte tüylerden oluşan yaprak yüzeyi, mikroorganizma kolonizasyonunun gerçekleştiği heterojen bir ortam sağlamaktadır (Sivakumar et al., 2020). Bunlar arasında salgı üreten tüyler; polisakkarit tuzları, lipitler, uçucu bileşikler ve proteinler gibi bileşikleri salgılayarak mikroorganizma kolonizasyonuna doğrudan katkıda bulunurken, salgı üretmeyen tüyler ışık emilimi, su geriliminin düzenlenmesi ve kuraklığa dayanıklılık gibi fiziksel özellikleriyle dolaylı bir etki oluşturmaktadır (Hirano & Upper, 1983). Benzer şekilde, kütikula yüzeyinin kimyasal bileşimi ve stomaların morfolojik özellikleri, fillosferde kolonize olabilen mikroorganizma topluluklarının bileşimini şekillendirmektedir. Bu topluluklar arasında, özellikle biyotik ve abiyotik streslere karşı dayanıklılık sağlayan yararlı mikroorganizmaların ekolojik ve işlevsel önemi giderek daha iyi anlaşılmaktadır.

Fillosferde yer alan yararlı funguslar, yaşam biçimlerine göre epifitik ve endofitik olmak üzere iki temel grupta değerlendirilmektedir. Epifitik funguslar bitki dokusuna girmeden yaprak yüzeyinde kolonize olmakta; yüzeyde biriken organik maddeleri, mumsu kütikula bileşenlerini ve bitkiden sızan karbon kaynaklarını kullanarak hem kendi gelişimlerini sürdürmekte hem de besin döngüsüne katkı sağlamaktadır. Endofitik funguslar ise konukçu bitkinin iç dokularına giren, çoğu durumda belirti oluşturmadan gelişebilen ve simbiyotik özellikler gösterebilen organizmalardır (Osono, 2006; Sivakumar et al., 2020). Birçok fillosfer fungus türü ekolojik açıdan esneklik gösterebilmekte; uygun koşullarda epifitik yaşamdan endofitik faza geçiş yapabilmekte veya tersine dönebilmektedir (Kharwar et al., 2010; Porras-Alfaro & Bayman, 2011; Thomas et al., 2024). Ayrıca toprak, bitkinin toprak üstü organlarına taşınarak fillosfere yerleşebilen endofitik funguslar için önemli bir inokulum kaynağı oluşturabilmektedir (Zarraonaindia et al., 2015).

Son yıllarda fillosfer kökenli yararlı mikroorganizmaların sentetik mikrobiyal topluluklar (SynComs) hâlinde yeniden yapılandırılarak bitkilere uygulanması, bitki koruma alanında yeni ve umut vadeden bir yaklaşım olarak öne çıkmaktadır (Sarver et al., 2025). Bu çalışmalar, epifitik ve endofitik yararlı fungusların patojen baskılama, savunma reaksiyonlarının uyarılması ve kolonizasyon direncinin artırılması gibi işlevlerinin, kontrollü mikrobiyal

topluluklar aracılığıyla güçlendirilebileceğini göstermektedir. Bazı yararlı fungus türlerinin fillosfer ortamında kolonize olabilme kapasitesi, SynCom yaklaşımının fungus temelli biyolojik kontrol stratejilerine uyarlanabileceğine işaret etmektedir.

Tarımsal üretimde yaygın olarak kullanılan fungisitler, hedef patojenlerin kontrolünde etkili olmakla birlikte, fillosferde yer alan yararlı epifitik ve endofitik fungus toplulukları üzerinde belirgin hedef dışı etkilere yol açabilmektedir. Fungisit uygulamaları; fungal çeşitlilikte azalma, duyarlı türlerin baskılanması, toleranslı türlerin öne çıkması ve mutualistik ağların zayıflaması gibi sonuçlar doğurabilmektedir (Teixidó et al., 1999; Moulas et al., 2013; Karlsson et al., 2014; Knorr et al., 2019; Noel et al., 2022; Sumbula et al., 2022; Wu et al., 2023). Endofitik fungus topluluklarının sistemik fungisitlerle baskılanması konukçu savunmasının zayıflamasına; epifitik fungus topluluklarının azalması ise yüzey patojenlerinin daha kolay kolonize olmasına zemin hazırlayabilmektedir. Dolayısıyla fungisit uygulamalarının fillosfer mikrobiyotası üzerinde dolaylı fakat önemli etkiler yarattığı açıktır. Fillosferdeki yararlı fungus topluluklarının korunması, sürdürülebilir hastalık yönetimi ve biyolojik kontrol stratejilerinin etkinliği açısından kritik önem taşımaktadır (Karlsson et al., 2014).

Bu derleme, tarımda kullanılan fungisitlerin fillosferde bulunan yararlı epifitik ve endofitik fungus toplulukları üzerindeki etkilerini ekolojik, fonksiyonel ve uygulamaya dönük bir bakış açısıyla değerlendirmeyi amaçlamaktadır. Bu kapsamda, fillosferde yer alan fungusları etkileyen abiyotik ve biyotik faktörler ile farklı bitkilerde hedeflenen ve hedef dışı fungusların fungisitlere verdikleri yanıtlar mevcut literatür ışığında ele alınmıştır.

FİLLOSFERDE BULUNAN FUNGUSLARI ETKİLEYEN FAKTÖRLER

Abiyotik Faktörler

Fillosferdeki epifitik ve endofitik fungus topluluklarının kompozisyonu, doğrudan dış çevreye maruz kalmaları nedeniyle sıcaklık, UV radyasyonu, yağış, nem ve rüzgâr gibi çeşitli iklimsel faktörler tarafından güçlü biçimde etkilenmektedir (Gomes et al., 2018). Mevsimsel değişiklikler özellikle rüzgâr hızı ve ortalama sıcaklık üzerinden belirleyici olurken, güneş ışığının yoğun olduğu yaprak bölgelerinde UV'ye daha dayanıklı koyu renkli fungus türlerinin baskın hâle gelebildiği bildirilmektedir (Gessler et al., 2014; Kembel & Mueller, 2014). Genellikle ilkbaharda epifitik ve endofitik fungus çeşitliliği sonbahara kıyasla daha yüksek olmakta (Collado et al., 1999; Osono, 2008), yağışlı dönemlerde ise yaprak yüzeyinde oluşan su tabakası spor çimlenmesini kolaylaştırırken yoğun yağışların fungusların çoğalma yapılarının yaprak yüzeyinden uzaklaşmasına neden olabildiği belirtilmektedir (Collado et al., 1999; Gomes et al., 2018). Yaprak yüzeyinin heterojen bir yapıya sahip olması fungusların yüzeye tutunma, gelişme ve rekabet etme kapasitesini önemli ölçüde şekillendirmektedir (Beattie, 2011; Vorholt, 2012). Bitkiye özgü yapısal özellikler, özellikle kütikula yapısı, yüzey dokusu, tüy yoğunluğu ve stomaların konumu, epifitik ve endofitik fungusların fillosferdeki yerleşim başarısını doğrudan etkilemektedir. Ayrıca tüylerin kimyasal bileşimi ve salgı üretme özellikleri, belirli bölgelerde fungal birikimi artırarak bazı türlerin kolonizasyon kapasitesini güçlendirebilmektedir (Hirano & Upper, 1983). Bitkinin farklı organları fungus türlerini belirleyen diğer yapısal faktörlerdendir. Yaprak ve sürgün gibi organlarda bulunan epifitik ve endofitik fungus topluluklarının hem tür zenginliği hem de baskın türler açısından belirgin biçimde farklılaştığı ve bu farklılıkların organlara özgü doku yapısı ile kimyasal bileşimden kaynaklandığı bildirilmektedir (Gomes et al., 2018). Güneş alan veya gölge konumlar arasındaki çevresel farklılıklar belirli ölçüde varyasyon yaratsa da fillosfer fungal kompozisyonunu şekillendirmede asıl belirleyici unsurun organ tipi olduğu ve organların kendilerine özgü fungal topluluklara sahip olduğu belirtilmektedir (Laforest-Lapointe et al., 2016). Fenolojik süreçler de fillosferdeki fungus topluluklarının dinamiklerini etkileyen önemli

bir diğer faktördür. Yaprak yaşlanmasıyla birlikte doku bütünlüğünün zayıflaması ve besin içeriğinde meydana gelen değişimler, bazı endofitik fungusların yaprak içi dokularda daha hızlı çoğalmasına olanak tanımaktadır. Birçok fillosfer fungusunda epifitik, endofitik ve saprofitik evreler arasında geçişlerin yaşlanan yapraklarda daha belirgin hâle geldiği belirtilmektedir (Osono, 2006). Yine yaprak dökümü sonrasında endofitik türlerin baskınlığının azalmasıyla bazı epifitik funguslar iç dokuları kolonize edebilmektedir (Cabral, 1985; Stone, 1987).

Biyotik Faktörler

Fillosferde bulunan yararlı epifitik ve endofitik funguslar, patojen funguslarla aynı yaşam alanını paylaşarak bitki sağlığının sürdürülmesinde önemli biyotik düzenleyiciler hâline gelmektedir. Bu hedef dışı funguslar, yaprak yüzeyindeki sınırlı besin kaynaklarına ve yararlı fungal topluluklar tarafından oluşturulan kolonizasyon alanlarına hızla yerleşerek patojenlere karşı belirgin bir besin ve alan rekabeti yaratmakta; özellikle karbon içeren yüzey salgıları ve hücreler arası boşluklardaki besinlere erişimde üstünlük sağlayabilmektedir (Sohrabi et al., 2023). Yararlı epifitik türlerin erken ve yoğun yüzey kolonizasyonu, patojen fungusların tutunma ve çimlenmesini sınırlandırarak güçlü bir kolonizasyon direnci oluşturmaktadır (De Mandal & Jeon, 2023). Endofitik funguslar ise bitki dokuları içinde patojenlerle rekabet ederek ve konukçu savunmasını uyararak dolaylı bir koruma sağlamaktadır (Sivakumar et al., 2020).

FUNGİSİTLERİN FİLLOSFERDE BULUNAN HEDEF DIŞI FUNGUSLARA ETKİSİ

Tarımsal üretimde fungisitlerin temel kullanım amacı, hedef patojenleri baskılayarak hastalık kontrolünü sağlamaktır. Ancak yapılan çalışmalar, fungisit uygulamalarının hedef patojenlere etkili olurken, bitki fillosferinde doğal olarak bulunan epifitik ve endofitik hedef dışı fungus topluluklarını da farklı düzeylerde etkileyebildiğini ortaya koymaktadır. Oysa fillosferde bulunan yararlı funguslar; patojenlerle rekabet, antagonizm, besin döngüsü ve savunma reaksiyonlarının teşviki gibi mekanizmalar yoluyla bitki sağlığının korunmasında kritik bir rol üstlenmektedir. Bu nedenle hedef patojen baskısının sağlandığı sistemlerde, fungisit uygulamalarının bu yararlı mikrobiyal dengeyi ne ölçüde ve hangi yönde değiştirdiğinin ortaya konulması, sürdürülebilir ve çevreyle uyumlu bitki koruma yaklaşımları açısından özel bir önem taşımaktadır. Çeşitli bitki türlerinde hedef patojene karşı kullanılan fungisitlerin fillosferde bulunan hedef dışı fungus türleri üzerindeki etkilerini birlikte değerlendiren başlıca çalışmalar ve elde edilen bulgular Tablo 1'de sunulmuştur.

Tablo 1. Fungisitlerin hedef fungal patojen ve fillosferdeki hedef dışı fungal topluluklar üzerine etkileri

Bitki	**Fungisitler**	**Hedef fungal patojenler / baskılanma durumu**	**Hedef dışı funguslar /baskılanma durumu**	**Kaynak**
Elma	Kükürt + captan; boraks + kükürt; flusilazol	Depo çürüklük etmenleri *Penicillium expansum* ve *Botrytis cinerea* / sezon boyunca çok düşük yoğunlukta izole edilmiştir	**Baskılanan:** *Cladosporium* spp.; G**eçici olarak baskılanan,** çekirdek çürüklüğü ile ilişkili latent patojen *Alternaria* spp.. **Daha az etkilenen mayalar**: *Candida* spp., *Cryptococcu*s spp. *Debaryomyces* spp., *Hansenula* spp., *Pichia* spp. (beyaz), *Rhodotorula* spp., *Sporobolomyces* spp.(pembe)	Teixidó et al., 1999

Tablo 1. (Devamı)

Bitki	**Fungisitler**	**Hedef fungal patojenler / baskılanma durumu**	**Hedef dışı funguslar /baskılanma durumu**	**Kaynak**
Buğday	Azoxystrobin, bixafen, cyprodinil, difenoconazole, fenpropimorph, metrafenone, picoxystrobin, prochloraz, propiconazole, prothioconazole, pyraclostrobin	*Zymoseptoria tritici* (Septoria yaprak lekesi), *Blumeria graminis* (külleme) / tutarlı bir azalma görülmemiş; *Puccinia striiformis* (sarı pas). / belirgin biçimde baskılanmıştır.	**Baskılanan:** *Aureobasidium pullulans*, *Dioszegia* sp., *Leucosporidium golubevii*. **Göreceli bolluğu artan tür:**: *Phaeosphaeria juncophila*	Karlsson et al., 2014
	1.Epoxiconazole + pyraclostrobin + boscalid, 2.Epoxiconazole + fluxapyroxad, 3.Prothioconazole + bixafen	**Baskılanan***: P. striiformis* (3. karışım hariç). *Z. tritici* (1. karışım hariç), *Parastagonospora nodorum* (yaprak ve başak yanıklığı), *Didymella exitialis* (yaprak lekesi), *B. graminis.* **Artan:** *Pyrenophora tritici-repentis* (sarı yaprak lekesi); *Microdochium nivale* (kar küfü)	**Baskılanan***: Lewia infectoria* (patojen olmayan), *Dioszegia hungarica* (1. karışım hariç) **Artan**: *Cladosporium* spp., *Sporobolomyces* sp., *C. victoriae* (1. karışım hariç), *C. tephrensis, C. stepposus* (3. karışım hariç), *Udeniomyces pannonicus*	Knorr et al., 2019
Biber	Metalaxyl (fungisit, toprak ve yapraktan);	**Etkilenmeyen:** *Erysiphe sp.* (külleme etmeni) ve *Cladosporium sp.* (yaprak patojeni)	Saccharomycetes sımıfı ile ilişkili bir moleküler birim ve endofitik fungus *Periconia macrospinosa* uyarılmıştır	Moulas et al., 2013
Domates	Propineb, iprodione + carbendazim	**Azalma:** *Alternaria alternata* (erken yaprak yanıklığı etmeni); Ayrıca yaprak hastalıklarıyla ilişkili patojenik cinsler olarak bildirilen *Cladosporium*, *Corynespora* ve *Pseudocercospora* da tespit edilmiştir	**Azalma:** *Acremonium* ve *Malassezia* (iprodione + carbendazim uygulamasında); *Coprinopsis* (propineb uygulamasında)	Sumbula et al., 2022

Hıyar	Tebuconazole (sentetik triazol); kükürt (inorganik fungisit)	**Azalma:** Külleme etmeni *Podosphaera xanthii* her iki fungisit tarafından da baskılanmıştır. Bu azalma kükürt uygulamasında daha belirgin olmuştur. Ancak *Podosphaera* ile birlikte hıyarda yaprak hastalıklarıyla ilişkili patojenik cinsler *Alternaria*, *Curvularia* ve *Cladosporium* da tespit edilmiştir.	**Tebuconazole:** Hedef dışı etki daha belirgin olup *Fereydounia*, *Moesziomyces* ve *Phaeosphaeria*'nın topluluktaki oranı azalmış, fırsatçı/patojenik potansiyeli bulunan *Nigrospora*'nın topluluktaki oranı artmıştır; *Sympodiomycopsis* cinsi ise tebuconazole uygulamasında toplulukta oran artışı göstermiştir. **Kükürt:** Hedef dışı fungal topluluk üzerinde daha sınırlı etki gözlenmiş, *Iodophanus* başta olmak üzere çoğu cinsin topluluktaki oranı büyük ölçüde korunmuştur.	Wu et al., 2023

Fungisit uygulamalarıyla baskılanan bazı hedef dışı epifitik ve endofitik fungusların, patojenlere karşı biyokontrol potansiyeline sahip olduğu bilinmektedir. Bu türlerden yüksek düzeyde etki gösterenlerden bazıları (≥%70) Tablo 2'de verilmiştir. Söz konusu yararlı funguslar; besin ve yer için rekabet, biofilm oluşumu, uçucu bileşik, toksin ve litik enzim üretimi ile mikoparazitizm gibi çeşitli etki mekanizmalarının büyük bir kısmına sahiptirler (Avis et al., 2001; Castoria et al., 2001; Buxdorf et al., 2013; Öztekin et al., 2023).

Tablo 2. Bazı fillosfer kökenli fungusların farklı patojen funguslara karşı antagonistik etkileri

Fillosfer fungusu	**Etkili olduğu patojen fungus**	***In vitro***	***In vivo***	**Kaynak**
Aureobasidium pullulans	*Botrytis cinerea*	+	+	Lima et al., 1997
	Blumeria graminis f. sp. *tritici*	–	+	De Curtis et al., 2012
	Aspergillus tubingensis	+	+	Pantelides et al., 2015
Candida spp.	*Penicillium* spp.	+	–	da Cunha et al., 2018
Debaryomyces spp.	*Mucor circinelloides*	+	–	Medina-Córdova et al., 2018
	Aspergillus sp.	+	–	
	Fusarium proliferatum	+	–	
	Fusarium subglutinans	+	–	
	Monilinia fructicola	+	+	Czarnecka et al., 2019
Moesziomyces spp. (syn. *Pseudozyma*)	*Podosphaera fuliginea*	+	–	Avis et al., 2001
	Botrytis cinerea	+	+	Buxdorf et al., 2013
Rhodotorula spp.	*Aspergillus carbonarius*	+	–	Tryfinopoulou et al., 2020
	Moniliophthora roreri	+	–	Estrela Junior et al., 2022

SONUÇ

Bitki fillosferi, epifitik ve endofitik funguslardan oluşan ve bitki sağlığının korunmasında önemli ekolojik işlevler üstlenen dinamik bir mikrobiyal ekosistemdir. Ancak fungisitler, patojenleri baskılamadaki etkinliklerine karşın, çoğu zaman fillosferdeki yararlı fungal toplulukları da olumsuz etkileyerek mikrobiyal çeşitliliğin azalmasına ve topluluk dengesinin bozulmasına yol açabilmektedir. Bu durum, doğal biyolojik kontrol potansiyelinin zayıflamasına ve fırsatçı türlerin baskınlaşmasına neden olabilmektedir. Bu nedenle fungisit kullanımının, yalnızca hedef patojenler değil, hedef dışı yararlı funguslar da dikkate alınarak planlanması gerekmektedir. Daha seçici fungisitlerin tercih edilmesi, uygulama sıklığının ve zamanının optimize edilmesi ve biyolojik kontrol stratejilerinin kimyasal uygulamalarla entegre edilmesi, fillosfer mikrobiyal dengesinin korunması açısından kritik öneme sahiptir. Sürdürülebilir bitki sağlığı yönetimi, patojen kontrolü ile birlikte fillosferdeki yararlı epifitik ve

endofitik fungal toplulukların korunmasını da esas alan ekolojik temelli yaklaşımlarla mümkün olacaktır.

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INVESTIGATION OF MORPHOLOGICAL, PHYSIOLOGICAL AND AGRONOMIC CHARACTERICTICS OF TRITICUM SPELTA AND TRITICUM MACHA HEXAPLOID WHEAT SPECIES

Büşra İrem ÖZTEKİN

Eskişehir Osmangazi University, Agricultural Faculty, Field Crops Department

Prof. Dr. İmren KUTLU

Eskişehir Osmangazi University, Agricultural Faculty, Field Crops Department

ABSTRACT

Triticum spelta and *Triticum macha* are among the ancient cultivated wheat species and differ significantly from modern wheat species in terms of their morphological and physiological diversity, spike structure and adaptability. While *T. spelta* is generally a tall plant height, glume-like elongated spikes with low processing yields, *T. macha* is shorter, has a distinctive compact spike morphology, and is particularly prevalent in the Caucasus. This diversity results in significant differences between the two species in spike and flag leaf morphology, yield components, and some physiological traits, making them valuable genetic resources for breeding studies. In this study, 19 *T. spelta* and 28 *T. macha* accessions were evaluated for their morphological, physiological, and agronomic characteristics. The study aimed to examine the variation of the mentioned traits in two wheat species and to reveal the relationships between these variables using descriptive statistics and principal component analysis (PCA). Descriptive statistics revealed a wide variation in spike traits, flag leaf measurements, physiological traits, and yield components in both species. High variability (CV 37–55%) was observed, particularly in grain yield and biological yield. Mean spike length and flag leaf morphology were higher in *T. spelta*, while mean spikelet fertility, grain number per spike and flag leaf chlorophyll content were higher in *T. macha*. PCA results on *T. spelta* accessions revealed that the first two components explained 50.2% of the total variance, while the first five explained 79.3% where the eigenvalue is greater than 1. Variables related to yield components such as spike length, spike weight, grain weight per spike, grain number per spike, and flag leaf area in PC1 carried high positive loadings. PC2 was associated with flag leaf width and length and physiological indicators. In *T. spelta*, yield components and flag leaf morphology accumulate variance along two separate axes. In the PCA results for *T. macha* accessions, the first two components explained 49.7% of the total variance, while the first six explained 83.9% with greater than 1 eigenvalue. PC1 again showed a strong relationship with spike traits and yield components. PC2 was determined by flag leaf width, length, area, and physiological traits. Furthermore, in PC6, the flag leaf chlorophyll content variable was found to be a single, a unique discriminating variable in *T. macha* with a high loading value. In conclusion, PCA demonstrated that yield-related spike components and flag leaf morphology were clearly separated along different axes in both wheat species. These findings provide valuable insights into the selection of high-yielding traits in breeding programs. The pronounced differences between *T. spelta* and *T. macha* further highlight the strong influence of genetic background on morphological and physiological variation.

Keywords: Chlorophyll Content, NDVI, Spike Characteristics, Grain Yield, Leaf Morphology.

INTRODUCTION

Triticum aestivum L. is hexaploid form of wheat and one of the most globally cultivated crop as a staple food in numerous countries (Tadesse et al., 2019). Ancient subspecies within the primary gene pool of hexaploid wheat, especially spelt forms such as T. *macha* and T. *spelta* can be considered valuable genetic materials for new and potentially advantageous alleles. Ancient spelt wheats constitute an alternative source of genetic diversity that has been lost during the intensification of modern agriculture and breeding processes (Fu, 2015). Hexaploid spelt wheats exhibit significant variations in spike architecture, including spike shape, density, and grain form (Fan et al., 2019).

T. macha is the primitive hexaploid ancestor of other spelt forms and endemic to Georgia (Bedoshvili et al., 2021). Although *T. macha* is a spelt variety, its spikelets are not as densely arranged as those of other spelt wheat varieties. *T. macha* is hypothesized to be the ancestor of soft wheat varieties, transforming into modern bread wheat through human-induced selection due to its easy threshing and strong rachis characteristics (Jorjadze et al., 2014). In *T. macha*, the stems typically range from 40 to 100 cm in height, excluding the spikes, thin-walled or thick, hollow, and rarely hairy. The leaf blade is 8–32 cm × 8–12 mm, hairless or sparsely hairy, erect in young plants, drooping when mature; green or gray-green in color. Spikes are 7–12 cm long, erect or slightly inclined, moderately dense or sparse, awned or awnless, and white, red or blue-gray. The rachis (spike axis) is brittle, so the spikelet splits into two parts after threshing. The spikelets remain attached to the rachis joint (Feldman and Levy, 2023).

T. spelta has long been cultivated mainly in southwestern Germany, the valleys of the Austrian Alps, Switzerland, and a few other regions in Europe (Grausgruber, 2018). *T. spelta* stalks are erect, stiff, 60–120 cm tall excluding the heads, hairy or hairless, hollow, and thin-walled. The leaf sheaths are sparsely hairy or hairless; the auricles are very large, curved, fringed, and long-hairy. The leaf blades are 30–60 cm long, hairless or sparsely hairy, dark green and narrow in young plants, and pale greenish-yellow and broader in older stems. The spikes are quite long (10–15 cm), sparse (lax), straight or slightly curved, and may be white, red, gray-blue, or black-blue in color; they are distinctly pointed and awned or awnless. Each spike contains 16–22 spikelets, which are usually distinctly separated from each other on the axis. The rachis is flat and smooth; the rachis joints are semi-brittle and break easily under pressure (during threshing). Spikelets are oval and 12–16 mm long, solitary at the nodes, and hairy or haieless. The uppermost spikelet is fertile and positioned perpendicular to the plane of the lateral spikelets. In each spikelet, those in the middle of the spike carry 2 grains, while those at the base and tip are usually single-grained. The two glumes of each spikelet are similar in length, 8–12 mm, and may be white, yellow, red, brown, or black-blue. The glumes are shorter than the spikelet and may be bristly or bristle-free. The grains are reddish, 7–10 mm long, with a hard endosperm and pointed at both ends. The apex is covered with a white tuft of hairs and is tightly enclosed by the palea-lemma, forming a glume-like structure. The grain groove is shallow. The thousand-grain weight is 50–58 g (Feldman and Levy, 2023).

Both *T. macha* and *T. spelta* are gaining renewed interest today due to the increasing demand for healthy and diverse products in nutrition (Longin et al., 2023). Compared to bread wheat, they have superior agronomic performance under low-input conditions or challenging ecological environments. Therefore, they are highly suitable species for marginal areas and organic production systems (Konvalina et al., 2014; Magistrali et al., 2020). Furthermore, *T. macha* and *T. spelta* have significant genetic variation in many agronomic traits and disease resistance. Therefore, they are important genetic resources widely used in wheat breeding programs (Longin and Würschum, 2014; Wang et al., 2024).

Scientific studies on *T. macha* and *T. spelta* are limited and most involve a one-sided approach. These varieties are known as grains with high protein content and relatively low demands on growing conditions. Their ability to grow even in nutrient-poor mountain soils is a significant advantage. Furthermore, when provided with adequate mineral nutrition, they do not tend to shed grain after heading, eliminating the need for growth regulators. Their high resistance to heavy rainfall and excessive moisture during the tillering stage, their reduced susceptibility to fungal diseases due to their spelt structures, and their ability to germinate with their glume are among their notable characteristics. For these reasons, *T. macha* and *T. spelta* are becoming an increasingly important focus of interest for both researchers and farmers. As they are valuable genetic resources for breeding studies and for inclusion in agricultural production for different purposes, this study comprehensively examined the morphological, physiological, and agronomic characteristics of *T. macha* and *T. spelta*.

MATERIALS and METHODS

The experiment included 28 *Triticum macha* and 19 *Triticum spelta* wheat genotypes obtained from the USDA gene bank as plant material. Table 1 presents a comprehensive overview of the wheat genotypes utilized in this study.

The soil in the experimental field had a considerable amount of lime (7.2%) and a low organic matter content (2.3%). The pH level of the soil was 7.8, indicating a mild alkaline and non-saline nature. Clay, in particular, was identified as the predominant soil texture class. During the trial year, the mean temperature was 9.9°C, the mean humidity was 65.9%, and the total precipitation was 208.5 mm.

The seeds of wheat were sowed in rows that were one meter in length, with a spacing of 30 cm between rows and 5 cm within each row. The fixed fertilizer dose applied to the plants was 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}, with all phosphorus applied at planting and half of the nitrogen applied at planting and the other half during the tillering period. Two supplementary irrigations were performed during the stem elongation and flowering periods.

The flag leaf area was determined by measuring the flag leaf width and length with a ruler and then multiplying by a factor of 0.75 according to the method of Kalayci et al. (1998). Flag leaf chlorophyll content was measured during the heading stage using a chlorophyll meter called “Spectrum Field Scout CM 1000.” An infrared thermometer was used to measure canopy temperature. Spectral reflectance from the canopy expressed as NDVI was measured using the GreenSeeker active optical sensor. Red (656 nm) and near-infrared (774 nm) self-illumination systems are built within the sensor. More red light is absorbed, and NIR light is largely reflected by a healthy plant.

The harvesting of plants that had reached full maturity was conducted through manual selection of the plants in the designated plots. The harvested spikes of plants whose biological performance was being measured were threshed by being compressed between plates covered with a rough rubber surface to separate the grains from their husks.

Table 1. List of hexaploid wheat genotypes used in the study

Genoty	Plant ID	Plant name	Collected From	Genoty	Plant ID	Plant name	Collected
M1	PI 278660	Gen-2708	United Kingdom	SP1	PI 225271	Gen-85	Iran
M3	PI 355508	69Z5.187	Former, Soviet Union	SP2	PI 225295	Gen-109	Iran
M4	PI 355509	69Z5.188	Former, Soviet Union	SP3	PI 306550	Gen-2943	Romania
M6	PI 355511	69Z5.190	Sankt-Peterburg, Russian	SP4	PI 306551	Gen-2944	Romania
M7	PI 355512	69Z5.191	Former, Soviet Union	SP5	PI306552	Gen-2945	Romania
M8	PI 355513	69Z5.192	Former, Soviet Union	SP7	PI 306555	Gen-2948	Romania
M9	PI 355514	69Z5.193	Switzerland	SP10	CItr14138	CI 14138	Unknown
M10	PI 361862	DN-2378	Denmark	SP12	PI 295059	Deutchland	Bulgaria
M11	PI 428148	G1260	Stavropol'skij kraj,	SP13	PI 221402	Fuchsii	Serbia
M13	PI 428177	G524	Uppsala län, Sweden	SP16	PI 295060	Hinducusc	Bulgaria
M16	PI 675002	GE.2013-15	Samtskhe-Javakheti,	SP17	PI 295062	Italien	Bulgaria
M17	PI675003	GE.2013-16	Samtskhe-Javakheti,	SP19	PI 591904	Liestal 11	Bulgaria
M18	PI 675004	GE.2013-17	Samtskhe-Javakheti,	SP20	PI 591903	Muri 6	Germany
M19	PI 295057	Gruzia	Bulgaria	SP21	PI 591901	Rotenburg	Niedersachsen
M20	PI 572908	H Tri	Rach'a-Lechkhumi-	SP23	PI 591894	Ruefenach	Germany
M21	PI 611470	H Tri	Rach'a-Lechkhumi-	SP24	PI 591902	Steiners	Germany
M22	PI 572911	H Tri	Imereti, Georgia	SP25	PI 295061	Ungarn-1	Bulgaria
M23	PI 572913	H Tri	Imereti, Georgia	SP26	PI 295063	Ungarn-2	Bulgaria
M24	PI 572912	H Tri	Imereti, Georgia	SP29	PI 591899	White	England,
M25	PI 542466	H86-708	Oregon, United States				
M26	PI 272554	I-1-2710	Pest, Hungary				
M27	PI 290507	I-1-2710	Pest, Hungary				
M28	PI 272555	I-1-3544	Pest, Hungary				
M29	PI 352466	Letshchumicu	Former, Soviet Union				
M30	PI 572906	WIR 28168	Georgia				
M31	PI 572907	WIR 28214	Georgia				
M32	PI 572905	WIR 29576	Georgia				
M33	PI 323436	Unknown	Wien, Austria				

The following metrics were recorded for each five plant in each parcel after harvest: spike length (cm), the number of spikelets per spike, the number of grains per spike, the total weight of grains per spike (g), the number of grains per spikelet, the spike density, and the spike index. Spike density (SD) and spike index (SI) were calculated as follows: The first ratio, SD, is calculated by dividing the number of spikelets by the length of the spike. The second ratio, SI, is determined by dividing the spike weight by the grain weight per spike.

The biological yield and grain yield of the plants harvested from each plot were determined in grams, and the harvest index was calculated as a percentage by dividing the grain yield by the biological yield.

The mean, minimum, and maximum values are displayed using boxplots, while descriptive statistics including variance, coefficient of variation, kurtosis, and skewness were calculated using the Minitab 16 statistical software. Furthermore, a principal component analysis (PCA)

based on the correlation matrix was applied to determine the relationships among the 17 examined features. The first five and six factors with eigenvalues greater than 1.0 were considered effective for interpreting the results. The first two components, which contained the majority of the variability, were presented as bi-plot arrangements of the following: *T. macha*, *T. spelta*, and all genotypes evaluated together and the examined traits.

RESULTS AND DISCUSSION

The morphology of flag leaves, including their width, length, and area, is a critical factor in determining the plant's photosynthetic capacity and, consequently, the final wheat yield (Zanella et al. 2023). Modifying the structure of flag leaves to maximize photosynthetic assimilation during the grain-filling stage is a desirable objective for wheat breeding programs. Various photosynthetic component traits, including flag leaf morphology, have demonstrated genetic variation despite their quantitative nature and have been consistently heritable. This renders them suitable for phenotypic selection, a process that is imperative for the breeding of superior wheat varieties (Poland 2015). The descriptive statistics concerning the morphological and physiological characteristics of the flag leaf examined in the study are presented in Table 2 and Figure 1. The descriptive statistics of the characteristics indicated a significant variation in the differences between *T. macha* and T. *spelta*. The flag leaf width of *T. macha* exhibited a more heterogeneous distribution, characterized by high variance and CV values, and a more expansive box structure. Genotypes such as M29 and M10 were particularly noteworthy for their elevated values, while *T. spelta* demonstrates a more constrained variation. As illustrated in Table 2, *T. spelta* had high variance in flag leaf length, a finding corroborated by Figure 2, which identified SP1 and SP19 as notable examples of long-leaved individuals. In the flag leaf area variable, *T. macha* presented higher variance and CV, and Figure 2 demonstrated that genotypes such as M7 and M28 broadened the distribution.

Selecting genotypes with a large flag leaf area is a sound approach due to its positive contribution to yield. However, in flag leaf area-based breeding programs, large leaves should be prioritized in regions without water limitations, while narrow leaves should be selected for arid environments. Genotypes with smaller flag leaf areas have better tolerance to drought and heat, so they should be considered. *T. macha* had a wider variation in flag leaf area, and there was a high probability of finding genotypes suitable for all conditions. Given that *T. spelta* comprises individuals with relatively narrower flag leaf areas, narrow-leaved genotypes can be selected for arid and hot areas.

Table 2. Descriptive statistics of the physiological characteristics examined in the study

	Variance			CoefVar			Skewness			Kurtosis		
Variable	*T. macha*	*T. spelta*	*All*	*T. macha*	*T. spelta*	*All*	*T. macha*	*T. spelta*	*All*	*T. macha*	*T. spelta*	*All*
Flag leaf width	0.05	0.02	0.05	13.79	8.90	13.12	-0.01	0.07	0.42	-0.30	0.81	0.03
Flag leaf length	9.25	15.33	15.12	11.42	12.84	13.79	0.45	-0.68	0.20	0.68	0.56	-0.48
Flag leaf area	53.23	27.88	42.39	21.28	14.97	18.77	0.20	-0.17	0.06	-1.29	-0.19	-1.01
Flag leaf chlorophyll index	4104.2	5976.4	5468.7	13.17	17.88	15.91	-0.80	-0.04	-0.51	0.00	-0.70	-0.60
Canopy temperature	0.13	0.12	0.65	2.34	2.06	5.09	0.06	-0.35	0.27	0.92	0.65	-1.28
NDVI	0.02	0.02	0.02	14.75	18.20	16.03	-1.30	-2.10	-1.70	1.12	4.81	3.00

This study revealed significant physiological differences between *T. macha* and *T. spelta* species based on findings obtained from flag leaf chlorophyll index, canopy temperature, and NDVI values. The literature indicates that flag leaf chlorophyll index is a strong indicator of photosynthetic capacity and carbon assimilation during the grain filling period (Noor et al., 2022). It is known that genotypes with high chlorophyll content have more stable photosynthetic activity both under optimal conditions and under stress. Chlorophyll content reflects the plant's photosynthetic efficiency and nitrogen use efficiency; high chlorophyll levels have been reported to be positively correlated with yield, especially under well-watered conditions (Ahmad et al., 2022; An et al., 2022; Sorwar Jahan et al., 2025). In our study, the fact that *T. macha* exhibited a wider variation in chlorophyll index and stood out with high-value genotypes such as M29 and M21 indicates that this species has different physiological strategies in terms of photosynthetic capacity (Figure 1). In contrast, although the variance was high in *T. spelta*, the distribution remains narrower, suggesting that this species exhibits a more homogeneous structure in terms of chlorophyll (Table 2).

Canopy temperature is widely regarded as one of the most sensitive indicators of drought stress, given its direct correlation with the plant's water status and stomatal behavior (Pinter et al., 1990). The findings of this study suggest that the low variation in canopy temperature values within species indicates that the population generally utilizes similar water use strategies. However, when all genotypes are evaluated collectively, high variance and variation coefficients indicate high interspecies variability, suggesting significant differences in canopy temperature between the two species (Table 1). However, the observation that *T. macha* displayed a lower canopy temperature distribution compared to *T. spelta* in Figure 1 suggested the existence of drought- and heat-tolerant genotypes within this species, thereby indicating potential candidates for selection. M6 and M25 stand out as particularly prominent genotypes.

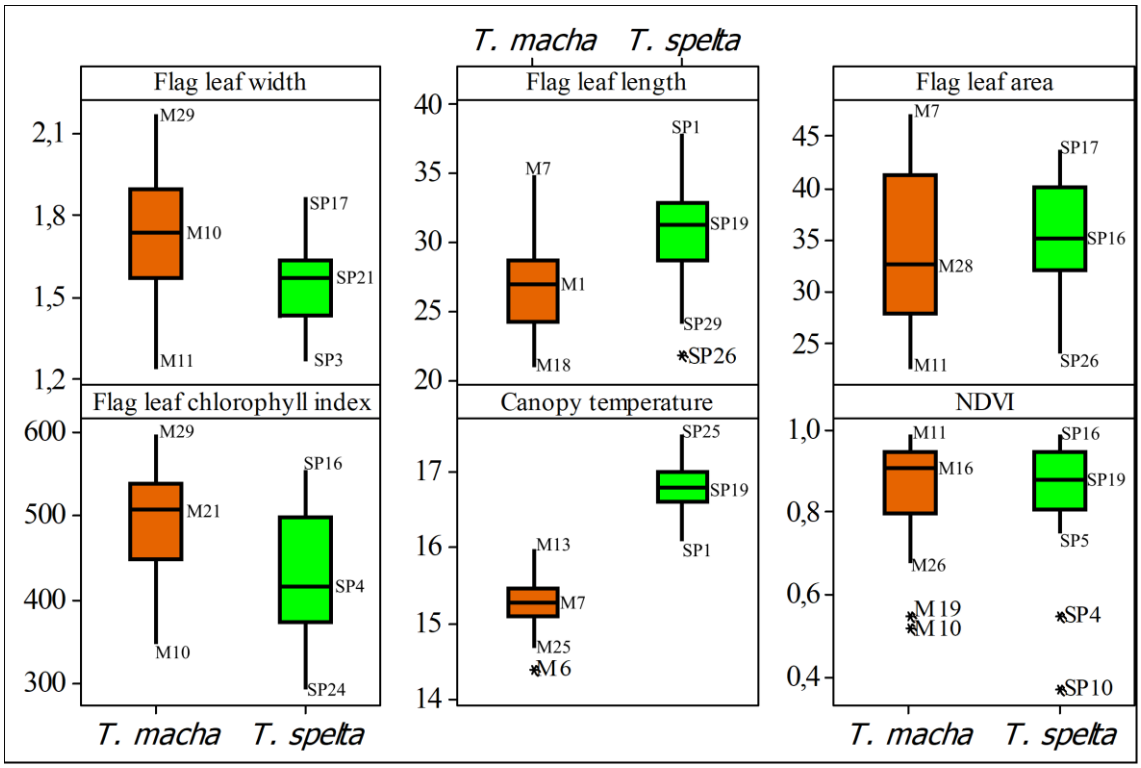


Figure 1. Minimum, maximum and mean values of the physiological characteristics examined in the study

NDVI values, the extent of green tissue, the biomass level, and overall physiological vitality in plants are critical factors for estimating yield (Hassan et al., 2019; Qiu et al., 2022). In this study, the wide NDVI variation observed in *T. spelta* reflects different levels of stress tolerance within the species. Moreover, the observation that certain genotypes with notably low NDVI values also manifest other stress indicators, such as low chlorophyll or high canopy temperature, reinforces the significance of NDVI as a comprehensive indicator of physiological stress. The low variance in NDVI values between the two species indicated that vegetative development is generally homogeneous (Table 2). However, the higher negative skewness and more pronounced extreme values in *T. spelta* indicated that the species possesses genotypes that may respond more variably to stress conditions. *T. spelta* exhibited distinctive characteristics in NDVI values, characterized by high skewness and extreme kurtosis. The boxplot graph demonstrated that the distinct low values of SP4 and SP10 corroborated this statistical finding (Figure 1).

Grain yield per spike is determined by the number of spikelets per spike, the number of grains per spike and/or spikelet, and grain size. On the other hand, grain yield per spike is calculated by the number of grains per spike, grain weight, and the number of spikes per area. The thousand-grain weight and number of grains per spike are significantly influenced by spikelet number, grain weight, and number of grains per spikelet (Philipp et al., 2018). These traits are directly associated with the genetic composition of wheat and is used in the identification of varieties. In this study, *T. macha* and *T. spelta* genotypes were compared in terms of spike morphology and yield components; variance, coefficient of variation, skewness, and kurtosis values (Table 3) were evaluated, and the maximum, minimum, mean, and range of the values were presented as boxplot graphs (Figure 2). A comparison of the genotypes of *T. macha* and *T. spelta* revealed that these two species exhibited distinctly different distributions in terms of spike architecture and yield components.

Table 3. Descriptive statistics of the spike characteristics examined in the study

	Variance			CoefVar			Skewness			Kurtosis		
	T. macha	T. spelta	All	T. macha	T. spelta	All	T. macha	T. spelta	All	T. macha	T. spelta	All
Spike length	4.70	4.85	6.36	20.59	16.72	21.75	0.84	-0.96	0.13	-0.41	2.00	-1.09
Spike weight	0.18	0.44	0.29	17.95	30.00	23.16	0.45	0.34	0.15	0.11	-0.15	0.19
Spikelet number per spike	16.95	5.79	17.73	17.42	12.74	19.39	-0.03	-0.68	0.40	-0.54	1.33	-0.25
Grain number per spike	84.85	37.46	97.85	20.47	18.35	24.55	-0.36	-1.39	0.06	0.08	1.40	-0.13
Grain number per spikelet	0.10	0.05	0.08	16.21	12.81	15.53	-0.77	0.40	-0.26	1.79	0.12	0.77
Grain weight per spike	0.08	0.11	0.09	20.26	24.14	21.70	0.88	-0.34	0.23	1.48	-0.94	0.39
Spike density	0.37	0.02	0.42	26.18	9.44	32.77	-0.37	0.25	0.56	-1.25	-0.61	-1.30
Spike index	55.70	92.23	71.18	12.53	15.32	13.87	0.78	2.20	1.63	1.34	7.24	5.31

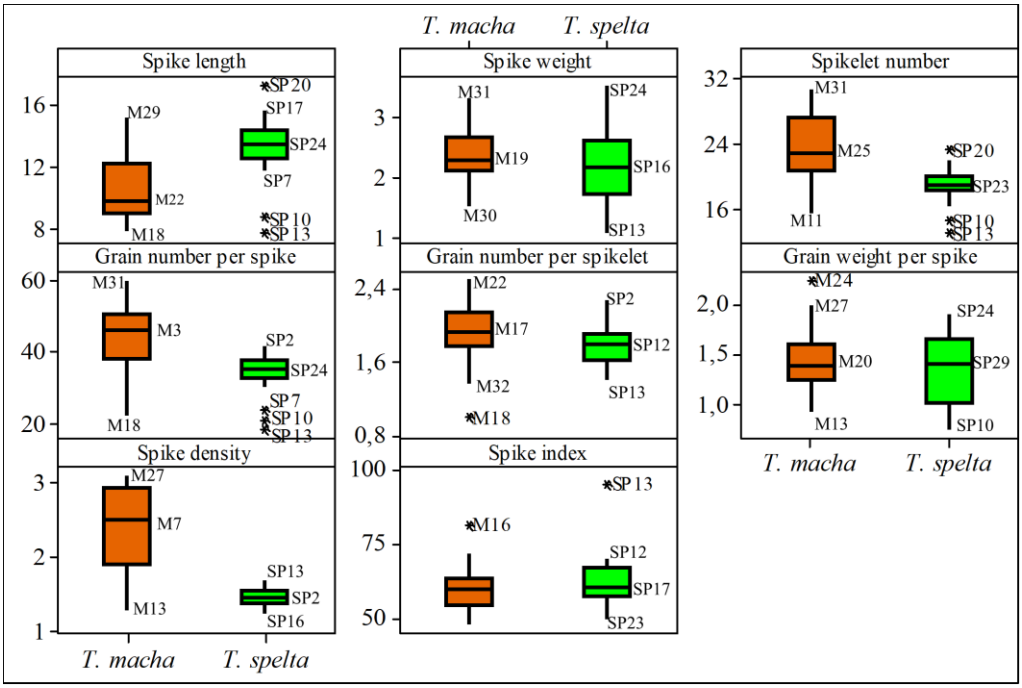


Figure 2. Minimum, maximum and mean values of the spike characteristics examined in the study

The boxplot graphs demonstrated that *T. spelta* achieves higher values, particularly in spike length and spike weight, while *T. macha* exhibited a wider range of variation in traits such as grain and spikelet number per spike (Figure 2). Descriptive statistics supported these differences; *T. macha* had a more heterogeneous population structure with higher variance and skewness-kurtosis values closer to a normal distribution for most traits, while *T. spelta* had extremely low variance and a highly stable structure for the spike density trait, and a structure with high variance, extreme skewness, and extreme values for the spike index trait (Table 3). In *T. spelta*, negative skewness in spike length and weight indicated a homogeneous structure away from low values, while in *T. macha*, positive skewness or near-symmetric distributions revealed a wider genetic variation. The higher variance evidenced by *T. macha* genotypes in traits such as spikelet number per spike, grain number per spike, and spike density confirms that this species originates from a more polymorphic population with greater genetic mixing, as reported by Barabaschi et al. (2025). Conversely, in the *T. spelta*, more limited and compressed distribution in certain traits suggests a more stable morphological structure in the hulled form (Szewczyk, 2013). The results indicated that *T. macha* had a more heterogeneous genetic structure, while *T. spelta* had a genetic structure that varies based on traits but was quite stable in some morphological characters.

T. macha is characterized by abundant leaf mass and robust stems, and it tolerates excessive moisture well (Samadashvili, 2024). *T. spelta*, on the other hand, is popular because of its good tolerance to growing conditions and its ability to withstand natural and climatic environmental factors, allowing it to be grown without excessive use of plant protection products. *T. spelta* can yield stable crops without strict adherence to production technology and can be a great alternative to soft wheat (Babenko et al., 2018). Despite the reported positive characteristics and their satisfactory biological yield, their production is limited due to low grain yields. Significant differences were observed between *T. macha* and *T. spelta* genotypes in terms of biological yield, grain yield, and harvest index. The variance in biological yield was quite high in *T. macha* (101,385) and much lower in *T. spelta* (34,814). Furthermore, the CV value of *T. macha* was 45.7%, which was more than twice that of *T. spelta* (Table 4).

Table 4. Descriptive statistics of the yield characteristics examined in the study

	Variance			CoefVar			Skewness			Kurtosis		
	T. macha	T. spelta	All	T. macha	T. spelta	All	T. macha	T. spelta	All	T. macha	T. spelta	All
Biological Yield	101385.6	34814.0	89975.9	45.70	19.47	37.38	-0.04	-0.70	-0.54	-0.53	1.02	-0.27
Grain yield	4430.1	3178.8	4487.24	66.49	37.28	55.46	1.51	0.62	0.83	4.08	0.71	1.29
Harvest index	18.66	18.46	18.96	31.19	27.48	29.88	0.18	-0.06	0.07	0.07	-0.94	-0.46

T. spelta had higher median values in biological yield and exhibited a narrower distribution among genotypes, while *T. macha* showed wider variance and a more heterogeneous structure (Figure 3). These findings indicated that *T. macha* had a more variable population structure in terms of biomass production. A similar difference was noticeable in grain yield; while *T. spelta* showed higher yield levels in the boxplot, the Table 4 results revealed that *T. macha* had much higher variance (4.430) and skewness (1.51) in this trait. The high positive skewness in *T.*

macha's grain yield indicated that some genotypes had extremely low yield values, whereas *T. spelta* showed a more balanced distribution. In terms of harvest index, the two species showed a more similar variation structure; the fact that the variances of both species were very close to each other (18.66–18.46) and the skewness is close to zero indicated that this trait was more stable between species. However, the boxplot graph showed that *T. spelta* tended to have slightly higher values in the harvest index.

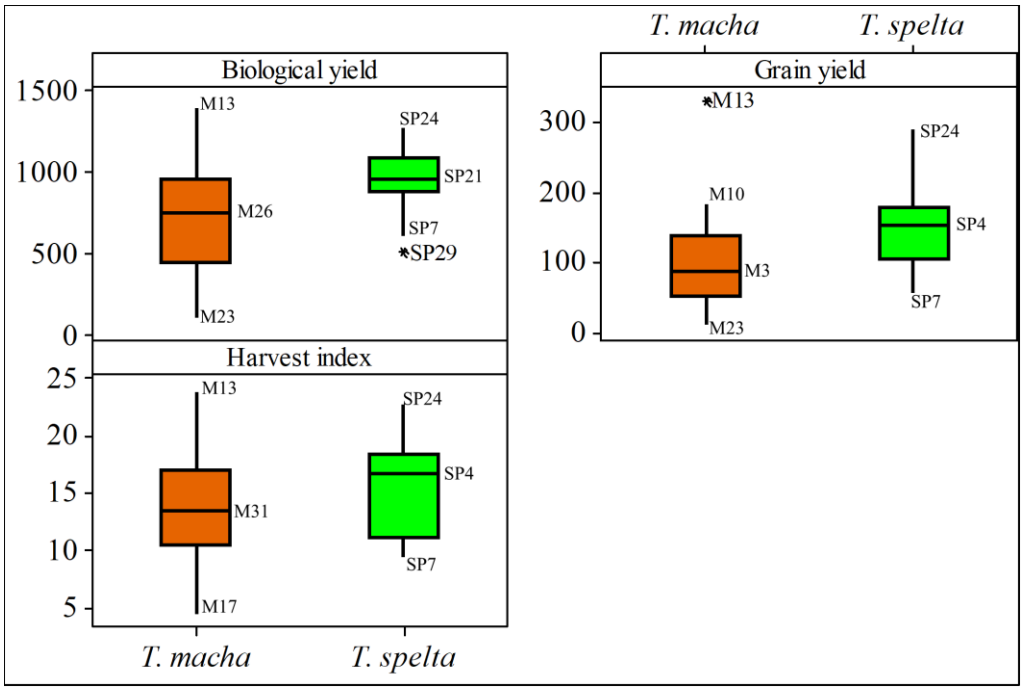


Figure 3. Minimum, maximum and mean values of the yield characteristics examined in the study

Overall, these results revealed that *T. macha* had a population structure with wider variation and extreme values in terms of biomass and grain yield, while *T. spelta* exhibited a more stable, higher biological and grain yield and a more homogeneous character in terms of distribution.

The findings revealed that *T. macha* was more heterogeneous and diverse, while *T. spelta* had a more stable structure in terms of certain morphological characteristics; these differences also affect the potential use of the species in breeding programs. In general, *T. spelta* offers a more advantageous structure in terms of characteristics that enhance physiological performance, while *T. macha* is characterized by more heterogeneous morphological variation. These results revealed that the difference between the species was not morphological but was mainly evident in physiological productivity indicators. Consequently, these distinct differences in the distribution characteristics of the two species stem from differences in evolutionary history, breeding history, reproductive system, and selection pressures.

The PCA loadings of *T. macha* and *T. spelta* genotypes revealed that the relationships between the morphological and physiological traits of the two species show fundamentally similar trends, but that some characters created species-specific differentiation (Table 5). In both species, the PC1 axis largely represented spike morphology and yield components; traits such as spike weight (SW), grain number per spike (GNS), grain weight per spike (GWS), flag leaf area (FLA), and spikelet number (SN) were the variables that gave the highest positive loadings to PC1. This indicated that, regardless of species differences, the variation in basic morphological structures related to yield determines the first component.

Table 5. Factor loadings obtained from the principal component analysis

	T. macha						T. spelta					All genotypes					
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC4	PC5	PC6
SL	0,10	0,42	0,22	0,01	0,08	0,12	0,38	0,09	-0,18	-0,12	0,02	-0.18	-0.34	-0.03	-0.40	-0.09	0.02
SW	0,39	-0,03	-0,04	0,20	0,27	-0,05	0,37	-0,04	0,17	0,24	0,02	0.25	-0.34	0.11	-0.10	-0.02	-0.37
SN	0,31	-0,27	-0,23	0,12	0,08	0,13	0,34	0,17	-0,11	-0,12	0,29	0.39	-0.05	0.22	0.07	0.00	-0.17
GNS	0,38	-0,11	0,11	-0,25	0,14	0,01	0,39	0,03	-0,13	-0,21	0,06	0.40	-0.14	0.02	-0.15	0.16	0.16
GNSp	0,14	0,16	0,42	-0,47	0,15	-0,13	0,28	-0,12	-0,09	-0,21	-0,16	0.16	-0.17	-0.21	-0.40	0.23	0.45
GWS	0,38	-0,17	-0,05	-0,18	0,15	-0,13	0,37	-0,09	0,21	0,02	-0,12	0.27	-0.31	0.02	0.03	0.35	-0.25
SD	0,12	-0,44	-0,31	0,05	-0,04	0,04	-0,28	0,04	0,19	0,06	0,35	0.36	0.20	0.17	0.30	0.06	-0.11
SI	0,04	-0,27	0,01	-0,63	-0,17	-0,09	-0,22	-0,06	0,14	-0,43	-0,42	-0.05	0.10	-0.19	0.29	0.72	0.19
FLW	0,34	0,17	-0,04	0,14	-0,32	0,09	0,18	-0,19	-0,25	0,37	0,02	0.25	-0.26	-0.03	0.10	-0.30	0.21
FLL	0,31	0,06	0,22	0,15	0,09	-0,00	-0,03	-0,44	0,27	-0,14	0,04	-0.10	-0.28	-0.42	0.26	0.08	-0.11
FLA	0,39	0,14	0,09	0,16	-0,16	0,05	0,08	-0,49	0,08	0,11	0,04	0.12	-0.38	-0.32	0.25	-0.14	0.06
FLCI	-0,04	-0,06	-0,11	-0,21	0,24	0,83	-0,02	0,13	-0,10	-0,45	0,55	0.15	0.15	0.25	-0.11	-0.00	0.45
CT	-0,16	0,15	-0,22	-0,11	0,54	-0,16	-0,04	0,34	-0,13	0,46	-0,11	-0.37	-0.12	0.02	-0.00	0.12	-0.24
NDVI	-0,07	-0,05	0,39	0,16	0,26	0,33	0,09	0,18	-0,17	-0,21	-0,49	0.01	0.06	-0.09	-0.51	0.24	-0.26
BY	0,11	0,36	-0,27	-0,24	-0,33	0,19	0,21	-0,05	0,51	0,01	0,03	-0.20	-0.35	0.16	0.19	-0.01	0.29
GY	0,08	0,39	-0,38	-0,13	-0,03	0,07	0,12	0,29	0,51	0,05	-0,03	-0.22	-0.30	0.42	0.12	0.09	0.14
HI	0,08	0,23	-0,34	0,00	0,40	-0,19	0,04	0,45	0,29	-0,02	-0,04	-0.13	-0.17	0.53	-0.01	0.25	-0.05

In *T. macha*, PC2 and PC3 appear to be more related to flag leaf traits (FLW, FLL, FLA) and spike density (SD) and plant structure, while in *T. spelta*, flag leaf traits gave the highest negative loadings to the PC2 axis, and PC3 represented yield components (BY, GY, GWS) more. This situation showed that in *T. spelta* genotypes, the variation in leaf traits was clearly reflected in the second component, while yield traits shaped the third component.

In both species, PC4 and PC5 were related to physiological variables representing the environmental response. In particular, spike index (SI), canopy temperature (CT), and NDVI showed high load values on these axes. In *T. spelta*, SI occupied high negative loadings in both PC4 and PC5, indicating that it was an important discriminating factor in the variance structure of spike yield in this species. In *T. macha*, the very high positive loading (0.83) of FLCI on PC6 indicated that the chlorophyll index formed an independent axis of variation in this species.

When all genotypes were analyzed together, morphological traits such as GNS, SN, SD, and FLA were again dominant on the PC1 axis, while leaf traits and spike density stood out on PC2, and yield traits and harvest index stood out on PC3. The high loadings of NDVI and CT, particularly on PC4 and PC5, indicated that physiological responses contribute to the variance structure explained in later components, independent of species differences. In the joint analysis of all genotypes, these distinctions were more balanced, with morphological-yield components forming the primary source of variation and physiological indicators forming the secondary source of variation.

PCA distributions showed that a large portion of the variation in both *T. macha* and *T. spelta* genotypes was explained by spike morphology and yield components (Figure 4). In the *T. macha* genotypes in the upper panel, grain number per spike (GNS), grain weight per spike (GWS), spikelet number (SN), spike weight (SW), and flag leaf area (FLA) contributed most strongly to the PC1 (29%) axis. The fact that the arrows of these traits point in the same direction indicated that high-yield components in *T. macha* genotypes increase alongside similar morphological traits. In contrast, the PC2 (21%) axis was shaped more by physiological variables such as canopy temperature (CT), NDVI, and FLCI. The distribution of *T. macha* genotypes showed that some genotypes, particularly M13, M14, and M18, differ from others in terms of physiological responses.

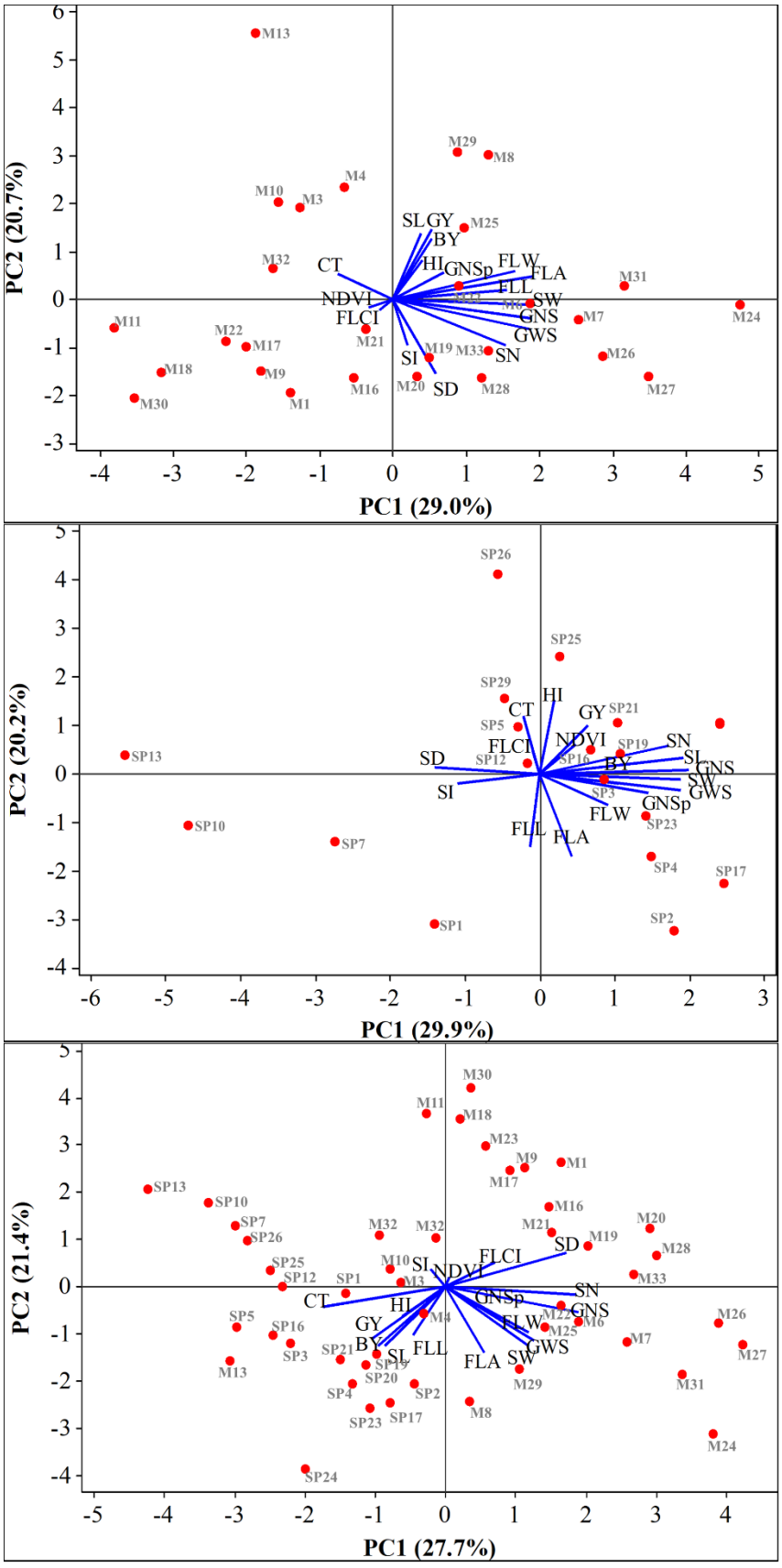


Figure 3. Bi-plot graph obtained from PCA analysis

The distribution of *T. spelta* genotypes in the middle panel showed that PC1 (29.9%) again represents yield and spike structure, but in *T. spelta*, PC2 (22.2%) was more clearly related to

flag leaf traits (FLW, FLL, FLA) and spike density (SD). In particular, the negative positioning of genotypes such as SP7, SP10, and SP13 on the PC1 axis indicated that these genotypes had low values for yield and spike components; conversely, the positive clustering of genotypes such as SP24 and SP21 indicated that high yield components were concentrated in a narrower group of genotypes in *T. spelta*. Furthermore, the shorter arrows of physiological variables in *T. spelta* genotypes indicated that these traits did not determine the variation structure as strongly as *T. macha*.

In the lower panel, when all genotypes were evaluated together, it was seen that the PC1 (27.7%) axis again represented yield components, while the PC2 (21.4%) axis was determined by both flag leaf characteristics and physiological indicators. When examining the distribution of the two types of genotypes in the field, it was seen that *T. macha* genotypes generally cluster closer to the center of the axis, while *T. spelta* genotypes showed a wider spread. This supported the idea that variation in *T. spelta* was particularly high in traits such as flag leaf characteristics and spike density. Furthermore, the fact that the spearhead lengths of variables related to yield, such as GNS, GWS, SW, and SN, were highest in all genotypes revealed that these traits explained the largest portion of the total variance in the study and were the fundamental determinants of inter-genotypic distinctiveness.

Overall, when the three PCA graphs were evaluated together, *T. macha* genotypes exhibited a more homogeneous variation structure, while *T. spelta* genotypes showed a wider distribution, particularly in morphological traits. In contrast, yield components remained the main source of variation in both species. Physiological variables (CT, NDVI, FLCI) more strongly separated the variation structure in *T. macha*, while their effects were more limited in *T. spelta*. This indicated that the species had different strategies in their physiological responses and yield determinants.

CONCLUSION

This study revealed that *T. macha* and *T. spelta* genotypes exhibited distinct variation patterns in terms of morphological, physiological, and yield components. In general, *T. macha* showed wider variance, more balanced distributions, and a more heterogeneous population structure in spike architecture (SN, GNS, GWS, SD), flag leaf morphology (FLW, FLA), and some yield components. In contrast, *T. spelta* had higher average values and better performance in traits that particularly increased yield and physiological capacity, such as spike length, spike weight, grain yield, flag leaf length, chlorophyll index, and NDVI. *T. spelta*'s low variance in some traits (e.g., spike density, canopy temperature) indicated a more stable morphological structure; however, high skewness and kurtosis values in other traits suggested yield potential in certain genotypes.

PCA analyses revealed that the main determinants of variation in both species were spike structure and yield components; however, physiological variables (NDVI, CT, FLCI) more strongly separated variation in *T. macha*, while remaining more limited in *T. spelta*. Genotype distributions showed that *T. macha* clustered in a more compact genetic variation space, while *T. spelta* exhibited a wider spread in yield and physiological traits, clearly revealing superior-performing genotypes. In terms of yield, *T. spelta* genotypes generally had higher biological and grain yields, while *T. macha* genotypes showed a more variable structure at the species level, even though they included high-yielding individuals.

When all findings were evaluated together, *T. macha* stands out as an important resource for increasing genetic diversity and morphological variation in breeding studies, while *T. spelta* offers valuable genotypes, particularly in terms of its potential to improve photosynthetic

capacity and yield components. The complementary characteristics of these two species are strategically important for creating a robust genetic pool in modern wheat breeding, both in terms of adaptation and yield.

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VIRTUAL REALITY AS A TOOL FOR FARMER TRAINING IN BIODIVERSITY-FRIENDLY PRACTICES

Oluwadamilola Peace AGOI

Federal University of Agriculture Abeokuta, Ogun Nigeria.

Moses Adeolu AGOI

Lagos State University of Education, Lagos Nigeria.

ORCID ID: 0000-0002-8910-2876

Samuel Olayiwola AJAGA

Lagos State University of Education, Lagos Nigeria.

Oluwanifemi Opeyemi AGOI

Obafemi Awolowo University, Osun Nigeria.

Abstract

Virtual Reality (VR) is increasingly recognized as a transformative tool for training farmers in sustainable and biodiversity-friendly agricultural practices. As global agriculture faces mounting challenges, including biodiversity loss, soil degradation, and climate variability, there is an urgent need for training approaches that can effectively convey complex ecological interactions and sustainable management strategies. VR provides a unique opportunity to immerse farmers in highly realistic, interactive environments where they can explore, observe, and practice biodiversity-enhancing techniques without incurring real-world risks. By situating learners within simulated farm landscapes, VR facilitates experiential learning that traditional extension methods often struggle to achieve. This paper examines how VR-based training environments can strengthen farmers' understanding of ecological processes, improve decision-making, and encourage behavioural change toward biodiversity-positive practices. It draws on recent advancements such as VR-enabled decision-support systems for climate-smart farm planning, immersive agricultural education frameworks like the VRFARM model, and VR applications in ecosystem visualization and landscape ecology. These developments demonstrate VR's potential to help farmers visualize long-term ecological outcomes, such as habitat restoration, species interactions, and carbon sequestration, while comparing the economic implications of different land-use choices. We further propose a mixed-methods evaluation framework that integrates quantitative learning assessments, behavioural intention measures, and qualitative reflections to assess VR's effectiveness as a training tool. Despite its promise, VR adoption faces several constraints. High hardware costs, limited technological infrastructure in rural areas, and digital literacy gaps can restrict equitable access to immersive training. Moreover, ensuring ecological accuracy in virtual simulations requires interdisciplinary collaboration and continuous updates. Ultimately, VR represents a promising yet evolving approach to promoting biodiversity-friendly agriculture. While early evidence highlights its potential to enhance ecological literacy and lower barriers to knowledge transfer, further research is needed to evaluate long-term impacts, improve accessibility, and tailor VR solutions to diverse farming contexts.

Keywords: Biodiversity, Immersive Learning, Virtual Reality.

INTRODUCTION



Agriculture today faces unprecedented pressure to balance productivity with ecological sustainability as global environmental challenges intensify. Biodiversity loss, declining soil fertility, and accelerating climate change continue to undermine the stability and long-term viability of conventional farming systems. These challenges highlight the urgent need to transition toward agricultural models that protect and restore ecological functions while supporting food security. Achieving this transition requires equipping farmers with practical knowledge, technical skills, and adaptive capacities necessary for implementing biodiversity-friendly practices such as agroforestry, intercropping, cover cropping, conservation agriculture, and regenerative soil management. However, traditional agricultural extension approaches, typically dependent on field demonstrations, printed manuals, and one-off workshops, often struggle to meet current demands. Limitations such as high or recurrent costs, difficulties reaching remote communities, constraints on scalability, and the risks associated with experimenting in real fields can impede widespread adoption of sustainable innovations. Virtual Reality (VR) offers a promising technological alternative that addresses many of these barriers. VR creates immersive, interactive learning environments in which farmers can visualize, model, and experiment with ecological practices without incurring the real-world costs, uncertainties, or potential losses associated with trial-and-error learning. Through carefully designed simulations, farmers can observe how biodiversity-enhancing interventions, such as planting native tree belts, adjusting crop rotations, or establishing pollinator habitats, affect ecological dynamics and long-term productivity. VR has also enabled the development of advanced “decision-support environments” that integrate biophysical and economic models, allowing users to simulate different land-use scenarios and immediately compare their ecological and financial outcomes. This capability helps farmers better understand trade-offs, evaluate risk, and make more informed decisions regarding biodiversity-sensitive management. In addition to decision support, VR-based educational frameworks such as the VRFARM model demonstrate the pedagogical value of immersive technologies in agriculture. The VRFARM framework emphasizes facilitation, application, reflection, and measurement, showing how immersive learning strengthens agricultural literacy, engagement, and awareness, particularly among learners with limited formal education or technical experience. By enabling learners to explore virtual representations of farms, ecosystems, and species interactions, VR fosters a deeper ecological understanding that traditional extension methods often fail to deliver. Against this background, this paper investigates the emerging role of VR as a training tool for promoting biodiversity-friendly agricultural practices. We provide a comprehensive review of existing literature, outline methodological approaches for evaluating VR-based training interventions, examine the realized and potential impacts of immersive

learning on farmers' ecological knowledge and behaviour, and identify critical gaps that future research must address.

LITERATURE REVIEW

Greig et al. (2024) make a substantial contribution to VR-based agricultural education by introducing the VRFARM framework, an integrated, structured model for designing and assessing virtual reality (VR) learning experiences in the classroom. The VRFARM model comprises four interrelated components: Facilitation, Application, Reflection, and Measurement, each mapping onto and expanding Biggs' classic "3P" (presage, process, product) pedagogical model (Biggs, 2003). Specifically, "Presage" becomes Facilitation, emphasizing the role of student and teacher characteristics, the learning environment, and scaffolding of VR experiences; "Process" translates to Application, the direct engagement of learners in VR activities; and "Product" is reconceptualised as both Reflection (learners revisiting and internalizing their experiences) and Measurement (systematic evaluation of learning outcomes). In their empirical and methodological analysis, Greig et al. (2024) detail how each component can be operationalized in an agricultural education setting. For example, under Facilitation, they examine teacher readiness, student prior agricultural literacy, and the infrastructure required (hardware, software, and instructional design). For Application, they propose immersive virtual field trips, interactive simulations, and skill-based VR modules, which enable students to "walk through" production environments, simulate farm management, or visualize ecological processes (Greig et al., 2024). Reflection involves guided debriefs, peer discussion, and journaling, while Measurement uses both qualitative methods (interviews, focus groups) and quantitative assessments (pre-/post-tests) to gauge changes in agricultural literacy, engagement, and awareness (Greig et al., 2024). This structured framework is essential: the authors argue that VR's introduction into curricula without systematic scaffolding risks superficial novelty without meaningful learning. By applying mixed-methods interventions, VRFARM allows educators not only to deliver immersive experiences but also to rigorously evaluate their pedagogical impact, ensuring that VR translates into real comprehension and behavioural intent. In a complementary but distinct direction, Chatterjee et al. (2025) explore how VR simulation can be tailored for farmer training rather than formal classroom settings. Their study covers multiple agricultural domains, including crop simulation, livestock management, and even supply chain logistics, showing that VR can bolster experiential competencies among farmers. According to their findings, farmers using VR were better able to visualize complex interactions, anticipate outcomes of different management strategies, and make more informed decisions. These simulations help in internalizing ecological trade-offs, for instance, between productivity and conservation, thereby strengthening their capacity to adopt eco-friendly farming practices. A particularly compelling application of VR lies in decision-support systems. Lasseur et al. (2023) pioneered a VR-based decision-support tool developed in Unreal Engine that links realistic farm visualizations with biophysical and economic models. In their proof-of-concept study on a 400-hectare pastoral farm in New Zealand, farmers can "enter" a virtual representation of their land and experiment by planting different tree species in various locations. The system dynamically computes carbon sequestration, profitability, establishment costs, and aesthetic outcomes, allowing users to compare strategies side by side (Lasseur et al., 2023). This immersive modeling offers a tangible way to plan biodiversity-enhancing interventions, such as planting native species corridors or agroforestry buffers, while optimizing for both ecological and financial goals. Beyond farm planning, VR has also been harnessed for ecological modeling and environmental education more broadly. Landscape ecologists have developed immersive virtual ecosystems that represent endangered habitats, such as the Box Gum Grassy Woodland, to communicate

reference ecological conditions and species interactions to land managers. Users report that these simulations feel "believable" and help them grasp spatial and ecological relationships in ways that static diagrams or text cannot. Such immersive experiences can deepen understanding of ecosystem structure, connectivity, and function. In the realm of broader conservation education, VR360 environments are increasingly employed to teach about ecosystem dynamics, indigenous knowledge, and cultural conservation. For instance, Herwidiah et al. (2022) developed a VR360 platform designed to communicate indigenous environmental wisdom and biodiversity concepts to broader audiences. Participants navigate virtual landscapes, observe species behaviours, and learn traditional ecological narratives, fostering greater ecological empathy and conservation awareness. Looking beyond VR, the broader category of Extended Reality (XR), which includes Augmented Reality (AR) and Mixed Reality (MR), has considerable promise for sustainable farming education and practice. Naudé et al. (2024) proposed an XR-AgriEdu framework for higher education that emphasizes three core pillars: agricultural determinants, curriculum development, and facilitating conditions (e.g., infrastructure, instructor training). Their framework illustrates how XR can bridge the gap between theoretical agricultural science and real-world applications, especially for students who lack farm backgrounds. XR enables virtual field trips, overlaying soil-nutrient maps, or holographic visualizations of crop growth, making complex agricultural concepts accessible and experiential (Naudé et al., 2024). Moreover, XR can support *in-field decision-support* and precision farming: as noted by recent systematic reviews, XR tools can visualize soil moisture, nutrient distributions, and forecasted crop outcomes, enabling farmers to overlay data in real time and simulate sustainable scenarios like intercropping or agroforestry in a risk-free, virtual setting (Bigonah et al. 2025). Such immersive decision-support has the potential to accelerate adoption of biodiversity-friendly practices. However, despite these advances, the literature also points to persistent challenges. Hardware costs, especially for high-end VR headsets or powerful computers, remain a major barrier (Bigonah et al., 2025; Greig et al., 2024). In many rural or under-resourced farming communities, infrastructure limitations such as unreliable internet, limited electricity, or lack of technical support hinder deployment. Moreover, acceptability among farmers is not guaranteed: digital literacy, cultural perceptions, and trust in technology affect uptake (Chikene, Singisetti, & Pradhan, 2025). In their discussion, Greig et al. (2024) underscore the importance of teacher training, community buy-in, and equity considerations when implementing VR in educational or extension contexts. Finally, there is an emerging need for ongoing research to validate and refine these frameworks. Systematic reviews show that although XR technologies are proliferating in agriculture, evaluation of long-term learning outcomes, behavioural change, and ecological impact is still limited (Bigonah et al., 2025). Also, cross-cultural adaptation and inclusivity remain underexplored: how do VR and XR trainings translate in different geographical settings, socio-economic contexts, or linguistic backgrounds? Addressing these gaps will be crucial to scaling immersive technology interventions in biodiversity-friendly farming.

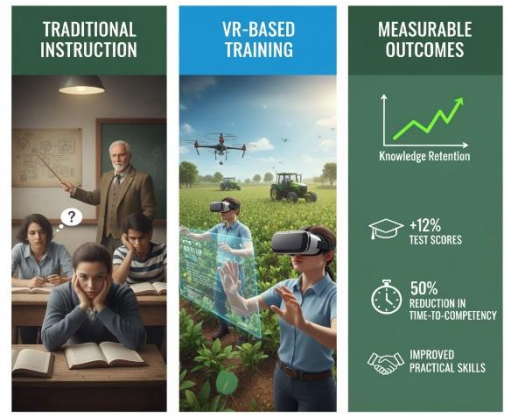
MATERIALS AND METHODS

To evaluate the effectiveness of VR-based farmer training in biodiversity-friendly practices, the study adopts a comprehensive methodological approach that begins with the design of immersive VR training scenarios using advanced game-engine platforms such as Unreal Engine to simulate realistic farm landscapes featuring agroforestry plots, native species corridors, and intercropping systems. These virtual environments integrate biophysical and economic models, including growth simulations, carbon sequestration estimates, and profitability analyses, following the approach demonstrated by Lasseur et al. (2023), while participatory co-design with farmers, agronomists, and ecological experts ensures contextual relevance and ecological

accuracy. The study recruits a diverse sample of farmers across multiple ecological zones and assigns participants to either a control group receiving traditional training or a treatment group receiving VR-based instruction. Evaluation follows a mixed-methods framework inspired by the VRFARM model (Greig et al., 2024), incorporating presage variables such as participant demographics, baseline ecological knowledge, and prior attitudes; process measures including VR interaction logs, time spent in modules, and decisions made during simulations; and product outcomes involving learning gains, shifts in attitudes, and intentions to adopt biodiversity-enhancing practices. Data collection includes reflective interviews and focus-group discussions, as well as quantitative pre- and post-tests of ecological literacy, decision-making ability, and sustainability adoption readiness. Analytical procedures combine statistical tests such as paired t-tests and ANOVA to assess changes over time with qualitative thematic analysis of narrative data, complemented by economic modeling of potential adoption scenarios to estimate real-world impacts. Ethical considerations guide the entire process, ensuring informed consent, data privacy, and sensitivity to participants' varying levels of digital literacy, while providing technical support and on boarding for those unfamiliar with VR technologies.

RESULTS AND DISCUSSION

Learning Outcomes and Ecological Literacy



Building on prior studies, we anticipate that participants exposed to VR-based training will demonstrate substantially greater gains in ecological literacy than those receiving conventional instruction, and several empirical and evaluative reports bolster this expectation. Greig et al.'s VRFARM framework emphasizes not only immersive application but also structured facilitation, guided reflection, and rigorous measurement, creating the scaffolding necessary for VR experiences to translate into durable learning gains (Greig et al., 2024). Evidence from domain-specific VR training further supports measurable improvements: a controlled pilot at Poltava State Agrarian University found that students trained with a Unity-based VR simulator for tractor-plough setup scored higher on theoretical tests (mean = 3.60 vs. 3.36 for control) and made fewer critical mistakes during real-world procedures, demonstrating transfer from virtual practice to tangible performance (Kanivets et al., 2025). Large sectoral evaluations likewise report consistent improvements in engagement, retention, and test scores when VR replaces or supplements traditional training, Walmart and other industry adopters documented test-score improvements of roughly 10-15% in corporate training comparisons, and government reviews conclude that VR reduces time-to-competency while increasing accessibility (Australian Dept. of Agriculture review, 2020). Specifically for biodiversity and farm-planning education, Lasseur et al. (2023) demonstrated a geospatial VR "digital twin" that allows farmers to stand in a realistic 400-ha virtual landscape, plant different tree species in 30×30 m grid cells, and immediately inspect modelled carbon sequestration and profitability outcomes, an approach that operationalizes ecological concepts (habitat placement, connectivity, species choice) into decision tasks that learners can practice and iterate on without real-world costs (Lasseur et al., 2023). By converting complex ecological processes into manipulateable, visual scenarios, such systems scaffold understanding of species interactions, edge effects, and ecosystem services in ways that static diagrams cannot. Systematic and scoping reviews of XR in agriculture and

education report similar patterns: immersive systems excel at visualising spatial ecological relationships and at promoting active experimentation, both of which are strong predictors of deeper conceptual change and behavioural intention. Mechanisms explaining these gains include "presence" and embodied interaction, VR induces a sense of being in the environment which increases attentional focus and the salience of ecological feedback loops, plus the ability to repeat scenarios, receive immediate model-based feedback, and reflect in structured debriefs (components emphasized in VRFARM). Taken together, the peer-reviewed prototypes, controlled pilots, and sector reviews create a convergent empirical case: immersive VR training, if implemented within a deliberate pedagogical framework and supported with evaluation metrics, produces measurable improvements in ecological literacy, practical competence, and adoption readiness for biodiversity-friendly farming. Future trials should prioritize randomized designs with long-term follow-up to quantify retention, behavioural adoption, and on-farm biodiversity outcomes.

Decision-making and Adoption Intention



Embedding decision-support models within immersive VR environments gives farmers an unprecedented, practice-oriented way to see and weigh trade-offs between biodiversity outcomes and farm profitability, and emerging empirical work shows this capability can meaningfully reduce perceived risk and increase adoption confidence. For example, Lasseur et al. (2023) built a geospatial VR "digital twin" of a New Zealand pastoral farm that lets users place trees in a 30 × 30 m grid and instantly view modelled outputs such as carbon sequestration, establishment costs, and projected profitability; by converting abstract ecological functions into immediate, visible consequences, the tool turns strategic choices (where and what to plant) into repeatable experiments rather than one-time, risky investments. This "try-before-you-plant" affordance matters because perceived uncertainty and fear of loss are major barriers to on-farm adoption of biodiversity-friendly measures (e.g., agroforestry, native corridors). VR reduces that uncertainty by enabling rapid scenario iteration and side-by-side comparisons of outcomes under differing assumptions (growth rates, discounting, maintenance costs), which helps farmers internalize both short- and long-term trade-offs and better estimate payback horizons. Beyond intuitive reasoning, immersive systems also shape psychological drivers linked to adoption. Experimental and quasi-experimental studies in environmental VR show that high presence and embodied interaction increase risk salience and pro-environmental intent: participants exposed to immersive climate or biodiversity scenarios report greater perceived personal relevance, stronger emotional engagement, and higher willingness to adopt mitigation or conservation behaviours than those in non-immersive conditions (Santoso & Bailenson, 2024; Hurrell, 2024). Translating this to agriculture, a VR decision-support environment that visualizes both ecological gains (e.g., increased habitat area, connectivity, carbon sequestration) and economic impacts (e.g., net present value, opportunity cost) can thus simultaneously strengthen ecological literacy and reduce the psychological barrier that often prevents trial adoption. Empirical sector reports and pilot studies also suggest measurable practical benefits. Case studies of VR and XR training in agricultural and technical domains report improvements in confidence, faster time-to-competency, and greater inclination to try new techniques after immersive training sessions (industry and university pilots summarized in systematic reviews).

For instance, controlled pilots in vocational agricultural settings (tractor operation, agronomic decision modules) document higher post-test scores and fewer critical mistakes when learners had virtual rehearsal opportunities, indicating that virtual practice can transfer to safer real-world action. From a decision-support design perspective, the effectiveness of VR hinges on a few practical features: integration of credible, locally calibrated biophysical and economic models; transparent presentation of assumptions (growth rates, discount factors); the ability to run sensitivity analyses within the VR session; and structured debriefing that links virtual choices to on-farm implementation steps. Lasseur et al. highlight the importance of linking immersive visualization to robust underpinning models so that users receive trustworthy feedback rather than mere graphical impressions. Finally, macro-level analyses of digital agriculture show that when farmers perceive clear economic benefits and lower implementation risk, adoption rates increase, digital decision tools that make benefits and costs explicit therefore serve a dual role: they inform better decisions and act as a de-risking mechanism that increases uptake of biodiversity-friendly practices (Geng et al., 2024). Taken together, the current empirical literature supports the contention that VR decision-support, by making trade-offs visible, repeatable, and emotionally salient, can raise farmer confidence and accelerate the experimentation and adoption of biodiversity-positive land-use choices. Future research should prioritize randomized field trials that measure not only attitudinal shifts but actual on-farm adoption and ecological outcomes over multi-year horizons.

Ecological Validity and Realism



The success of VR as a tool for farmer training hinges critically on ecological realism, that is, how faithfully a virtual ecosystem reproduces the visual, spatial, temporal, and functional properties of the real landscape it represents. Empirical evaluations show this is not merely aesthetic: believable virtual ecosystems increase immersion, credibility, and the perceived usefulness of the tool among expert users and stakeholders, which in turn affects uptake, learning transfer, and the likelihood that virtual choices are translated into on-farm action. For example, Chandler et al. (2022) built a proof-of-concept virtual Box Gum Grassy Woodland and evaluated it with 27 domain experts (ecologists, land managers, policy practitioners). In that expert panel 21 of 27 participants (78%) reported feeling immersed in the VR scenes, and a striking 88% judged the simulation to be *believable* (Chandler et al., 2022). Participants specifically flagged features that supported believability, animated plant models, seasonally-accurate flowering, spatially varying light and shadow, and layered soundscapes (bird calls, wind), while also suggesting improvements (e.g., more understory heterogeneity and fauna) to increase ecological fidelity (Chandler et al., 2022). These concrete assessment numbers show that expert buy-in depends on careful ecological modelling, not just photorealism. Technical design choices materially affect realism and performance. Chandler et al. experimented with model creation approaches (artist-crafted 3D species models vs. LiDAR/photogrammetry) and concluded that carefully sculpted models often offer a pragmatic balance between botanical fidelity and rendering performance (Chandler et al., 2022). Similarly, Lasseur et al. (2023) emphasise that credible decision-support VR must be anchored in robust, locally calibrated biophysical and economic models so that the visual feedback users receive corresponds to scientifically defensible outcomes. Their Unreal Engine prototype for a 400-ha New Zealand

farm linked spatial NDVI layers, carbon accounting, and profitability calculations, enabling users to "stand in" a virtual farm and immediately see modelled carbon sequestration and profit implications when planting trees in 30×30 m grid cells (Lasseur et al., 2023). Lasseur et al. report that the tool helped reconcile farmers' tacit knowledge with scientific data, a critical function for trust and adoption (Lasseur et al., 2023). Landscape-scale realism also requires attention to spatial patterning and connectivity, core concerns of landscape ecology, because biodiversity outcomes (species movement, habitat patchiness, and edge effects) hinge on landscape configuration as much as on local species lists. Recent reviews of computational methods in landscape ecology stress that spatial resolution, connectivity metrics, and simulation models (e.g., neutral landscape generators, resistance surfaces) are central to predicting ecological processes and must feed VR models to make them ecologically meaningful (Hesselbarth et al., 2024). In practice, this means VR developers should integrate open-source landscape tools (e.g., NLMR, landscape metrics) or pre-processed remote-sensing layers so the virtual scene reflects real heterogeneity rather than uniform "green everywhere" textures (Hesselbarth et al., 2024). Given these empirical and methodological findings, good practice for maximizing ecological realism and usefulness includes: (1) co-design with local ecological experts (botanists, wildlife ecologists) and farmers to ensure species composition, structure, and management scenarios are locally relevant (Chandler et al., 2022); (2) use of multi-source spatial data (remote sensing, DEMs, soil maps) and transparent model assumptions (growth rates, species niches) so users can query and trust outputs (Lasseur et al., 2023); (3) iterative expert evaluation (heuristic testing, expert panels) to quantify believability and identify gaps, Chandler et al.'s expert trial is a model (78-88% immersion/believability metrics); and (4) performance-aware modelling that balances botanical accuracy with rendering efficiency (e.g., level-of-detail methods, selective fauna animations) to keep VR usable on accessible hardware (Chandler et al., 2022; Hesselbarth et al., 2024). Ultimately, ecological realism is not optional: it is the coupling mechanism that converts immersive experience into domain knowledge, managerial confidence, and, eventually, biodiversity-friendly decisions on the ground.

Implications for Extension and Policy

VR can meaningfully complement traditional extension services, particularly in remote and underserved regions, by offering scalable, low-risk, and repeatable training that augments, rather than replaces, human-led advisory systems. Immersive VR modules permit farmers to experience simulated management actions (e.g., planting agroforestry belts, installing riparian buffers, or trailing intercropping layouts) and immediately view modelled ecological and economic outcomes; this experiential "trial run" helps reduce perceived implementation risk and can accelerate willingness to experiment on-farm (Lasseur et al., 2023). Empirical evidence supports this claim: a recent PLOS ONE demonstration linked a VR decision-support "digital twin" to biophysical and carbon-accounting models for a 400-ha New Zealand pastoral property and found that the immersive tool aided farmers in reconciling tacit local knowledge with scientific model outputs, improving planning confidence and scenario comparison (Lasseur et al., 2023). Large institutional programs show VR and digital training have scale potential when integrated into extension networks. The FAO's digital-extension guidance and summary of virtual trainings demonstrates that centrally coordinated virtual training can reach thousands of practitioners efficiently: FAO reports training ~1,350 national-level staff from 118 countries through virtual training modalities during 2020-2024, illustrating how centralized digital delivery can rapidly disseminate technical content at scale and at low marginal cost per participant. Pilot studies of VR for extension content also provide favourable empirical outcomes: a pilot on VR 360° tours for manure and mortality management documented statistically significant increases in awareness after viewing VR modules ($p < 0.0001$), with

participants rating the format as engaging and likely to be recommended to peers, evidence that remote immersive media can improve technical understanding without in-person field visits. From a policy and delivery standpoint, several implementation models have emerged that governments and donors could support. Shared-resource VR hubs (community centres, district extension offices, or mobile VR vans) can lower hardware barriers by providing scheduled access points where farmers gather for facilitated sessions; FAO and development reviews note such hub-and-spoke models as effective for digital extension rollouts. Subsidies or cost-sharing for hardware and local facilitation, plus funding for locally calibrated content development, can further enhance equity and uptake: policy analyses on agricultural modernization emphasize that targeted subsidies for extension infrastructure and training often yield strong returns in adoption and productivity when paired with capacity building (JRC/World Bank reviews). Systematic reviews of XR in agriculture underscore both promise and caveats: XR/VR consistently improves engagement, retention, and skill rehearsal across agricultural and technical domains, but gaps remain in long-term impact evaluations and in accessible, low-cost hardware solutions suitable for rural deployment (Anastasiou et al., 2023). To maximize benefit, policy design should therefore combine (a) content subsidies and shared hubs to ensure equitable access, (b) capacity building for extension agents so they can facilitate VR debriefs and link virtual choices to on-farm steps (the pedagogical element crucial to the VRFARM model), and (c) monitoring & evaluation funding to measure behavioural adoption and ecological outcomes over multi-year horizons. When implemented this way, VR becomes a powerful multiplier for extension: scalable, pedagogically robust, and able to lower the economic and psychological barriers that often prevent farmers from trailing biodiversity-friendly practices.

CONCLUSION

Virtual Reality (VR) represents a highly promising and innovative pathway for strengthening farmer training in biodiversity-friendly agricultural practices. Through immersive, interactive environments linked to biophysical and economic models, VR enables farmers to engage directly with simulated ecosystems, experiment with alternative land-use strategies, and visualize both short- and long-term ecological outcomes. This experiential mode of learning helps demystify complex concepts such as habitat connectivity, species interactions, and ecosystem service provision, while simultaneously illustrating the economic trade-offs associated with different management choices. Evidence from educational research, including VRFARM applications, and VR-based decision-support systems demonstrates notable improvements in ecological literacy, learner engagement, and farmers' intention to adopt biodiversity-enhancing practices. These findings suggest that VR has the potential to transform conventional extension by lowering barriers to experimentation and fostering more informed, confident decision-making. Yet, several challenges must be addressed for VR to reach its full potential in biodiversity-positive farming. Issues of hardware cost, digital access, rural connectivity, and technical training can limit equitable participation, particularly in underserved farming communities. Furthermore, the effectiveness of VR tools depends heavily on their ecological realism and contextual adaptation, which requires interdisciplinary collaboration with local ecologists, agronomists, and farmers. Continuous evaluation is equally essential to ensure that VR interventions translate not only into knowledge gains but also into sustained behavioural changes and measurable on-farm biodiversity outcomes. With thoughtful design, inclusive implementation strategies, and long-term assessment, VR could become a powerful catalyst for scaling agro ecological practices, accelerating the adoption of biodiversity-friendly innovations, and strengthening conservation efforts within agricultural landscapes.

Future Research

Future research should prioritize longitudinal studies to evaluate whether farmers trained through VR actually adopt biodiversity-friendly practices and the resulting ecological impacts, such as changes in species richness and soil health over time. Investigations into access and equity are essential, including strategies to reduce cost barriers through shared VR hubs, mobile units, or low-cost hardware, as well as digital literacy interventions to support marginalized groups like women, older farmers, and low-income participants. Research should also focus on contextual adaptation by tailoring VR modules to diverse agro-ecological zones, cultural settings, and biodiversity priorities, assessing how these factors influence engagement and uptake. Technological innovation offers further opportunities, such as integrating VR with augmented and mixed reality for hybrid virtual–on-field training and incorporating real-time farm data from IoT and sensors to ensure immersive scenarios reflect current conditions. Finally, studies should examine economic and policy mechanisms that facilitate scaling VR-based training, including incentive structures, extension partnerships, public-private models, and cost-benefit analyses comparing VR approaches with conventional biodiversity training methods.

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BEHAVIORS AND ATTITUDES OF ACADEMIC AND ADMINISTRATIVE STAFF AND UNIVERSITY STUDENTS TOWARDS DOGS

Hürü Ceyda TÜM

M.S. Scholar, Department of Pathology, Faculty of Veterinary Medicine, Erciyes University, Kayseri, Turkey.

ORCID: 0009-0000-4138-6112

Assoc. Prof. Dr. Davut BAYRAM

Advisor, Department of Animal Breeding and Husbandry Science, Faculty of Veterinary Medicine, Erciyes University, Kayseri, Turkey.

ORCID: 0000-0003-1495-1248

ABSTRACT

This research was conducted to evaluate the attitudes, behaviors, and ownership tendencies of academic and administrative staff and students in universities towards dogs through a holistic approach. The study aims to analyze the level of awareness regarding dogs, experiences of pet ownership, frequency of interaction with dogs, and attitudes towards the environments in which dogs live, within the axis of socio-demographic variables and psychological factors. This descriptive study was carried out using quantitative data collection techniques via face-to-face and online survey methods.

The study population comprises academic and administrative staff working at universities in Turkey, as well as undergraduates. The sample consists of 1,033 volunteer participants working and studying at eight universities located in different geographical regions, primarily Erciyes University (including Burdur Mehmet Akif Ersoy, Afyon Kocatepe, Aydın Adnan Menderes, Hatay Mustafa Kemal, Kafkas, Bursa Uludağ, and Selçuk University). The survey form used as the data collection tool consists of six main sections: demographic information, attitudes towards dogs, ownership and care, health, training and human-dog relationships, and dogs' reactions to environmental stimuli and social interaction needs.

The obtained data were analyzed using R 4.5.2 and JMP Pro 16.01 statistical software packages. In addition to descriptive statistics, Spearman correlation, chi-square tests, Cramér's V effect size analyses, and Kruskal-Wallis tests were used to examine the relationships between variables. Furthermore, multivariate logistic regression models were established to determine the factors defining dog ownership.

The findings indicate that participants generally exhibit an empathetic, sensitive, and welfare-oriented approach towards dogs. Variables such as gender, age, profession, income level, pet ownership, and psychological awareness were determined to have significant effects on attitudes. It was observed that female participants exhibited a more protective and empathetic approach towards dogs, whereas male participants displayed a more pragmatic and distant attitude; additionally, the love for animals was found to be stronger in younger individuals.

Awareness regarding animal care and a professional approach were more prominent in individuals with high income levels, while emotional attachment was more distinct in individuals with lower income levels. One of the most critical results of the study is that even individuals with high levels of knowledge can show behavioral inconsistencies in practice—a situation defined as the "knowledge-action gap"—and that application rates for procedures such as neutering remain low even among the educated segment.

“This research is summarized from thesis project number 13972, supported by the Erciyes University Research and Development Unit as a Master's thesis.”

Keywords: Animal Welfare, Attitude, Dog, Human-Animal Interaction, University Community

INTRODUCTION

Today, cats, dogs, and birds, characterized as stray animals living in public spaces, exist outside the state's sphere of interest—except for measures taken during extraordinary periods—but are intertwined with society. With the transition to settled life, animals have reached an indispensable position in every aspect of human life. Dogs occupy an important position in social life, both because they have a special place in individuals' lives as pets and because they are one of the species frequently encountered in public spaces with their identity as stray animals. Archaeological findings indicate that the dog was the first domesticated animal species and has lived with human communities for approximately 15,000 years.

Today, dogs serve not only as domestic companions but also in many fields such as security, guidance, therapy, and search and rescue. However, especially in developing countries, dogs constitute a significant portion of stray animal populations and have become indispensable actors in public spaces in city life. In countries with high stray animal populations like Turkey, dogs have become an integral part of daily life. Therefore, attitudes toward dogs are critically important, not only for determining behaviors at the individual level but also for shaping social peace, animal welfare policies, and local government practices.

Particularly on university campuses, dogs have become a natural part of daily life for students and employees who are in contact with them, and this situation directly affects individuals' perceptions and attitudes towards dogs. While some individuals evaluate dogs as living beings that require love, compassion, and protection, others may perceive them as a threat or risk factor. University communities serve as an important social laboratory for observing these attitudes as they bring together individuals from different socio-cultural backgrounds. While students, representing the young population, are indicators of future social perceptions and behavioral patterns, academic staff are effective in shaping social views through their knowledge and awareness levels, and administrative staff contribute to the process with their practical experiences in campus life.

Research on dogs in Turkey has mostly focused on population control, welfare, or interactions of stray animals with humans; studies that reveal the attitudes of university communities towards dogs in a holistic manner are quite limited. This situation points to a significant gap in the literature. Investigating attitudes towards dogs is important not only for understanding behavioral patterns at the individual level but also for guiding social policies. For instance, the presence of stray animals on campuses can sometimes lead to security concerns and at other times to an increase in adoption and protection behaviors among students. This situation directly affects the policies of university administrations towards campus animals. Therefore, examining the attitudes of university communities towards dogs will fill a scientific gap and

provide an opportunity to develop strategies that will contribute to regulatory practices for university life and social animal welfare policies.

In this context, the primary aim of this research is to examine the behaviors and attitudes of academic and administrative staff and university students towards dogs, to reveal similarities and differences between different groups, to determine positive or negative tendencies towards dogs, and to evaluate the potential reflections of these attitudes on social life, university administrations, and animal welfare policies. Thus, the findings to be obtained are expected to provide both a scientific basis for animal welfare studies and guidance for university administrations' regulatory practices regarding campus life.

GENERAL INFORMATION

2.1. The Place and Importance of Dogs in Human Society Throughout human history, dogs, as one of the earliest domesticated animals, have assumed a significant role in cultural, economic, and social life. Archaeological and genetic findings show that dogs were domesticated from wolves approximately 15,000 years ago and undertook functions such as hunting, protection, herding, and guarding in different societies. In the historical process, dogs have been evaluated not only as functional helpers but also as symbols of friendship and loyalty. Today, besides being considered pets that can establish emotional bonds with family members, dogs contribute to human life in many fields, such as police, guide, and therapy dogs. However, stray dogs appear as a noteworthy social phenomenon, particularly in urban life, triggering different attitudes and behaviors in individuals. In this context, university campuses are among the spaces where dogs experience intense interaction with humans. Therefore, the place of dogs in human society necessitates their examination not only as biological entities but also as a socio-cultural phenomenon.

History of domestication and cultural importance: The association of domestic animals with human life began with the domestication of the dog, continued with farm animals over time, and has expanded to species called "exotic animals," such as iguanas, snakes, and spiders, today. The concept of "pet" generally refers to animals whose feeding, care, and breeding are under human control. The process of dog domestication began approximately 20,000 to 40,000 years ago, during the period when humans subsisted on hunting and gathering. As the first domesticated animal species, the association of humans with dogs dates back 12-14 millennia according to archaeological sources, while genetic sources trace this development back to 100,000 years ago. Animals have existed in people's lives since the early times of civilization and have appeared many times as figures representing religion in addition to being domestic animals. With different breeds emerging since the day they were domesticated, dogs serve humans in many fields, such as search and rescue, herding, guard protection, guidance, hunting, and companionship. Animals have sometimes been friends we look after in our homes and gardens, and sometimes companions with whom we share our loneliness. Related to this, Ainsworth (1985) introduced the concept of "affectional bonds." This concept expresses not only the attachment felt towards the mother but also the attachment to pets.

The ancestors of the dog descended from species belonging to the Canidae family, a predatory mammal that appeared approximately 15 million years ago. Since the ancestors of modern dogs share a common ancestor with wolves (Canis lupus), important clues regarding the evolution of the dog also focus on the evolutionary history of wolves. The genus *Canis*, located in the evolutionary process of wolves, evolved approximately 2–3 million years ago in a way that would lead to the ancestors of modern dogs. The dog is one of the oldest and closest domestic animals in human history. From hunter-gatherer communities to modern societies, dogs have assumed both domestic and functional roles, becoming vitally important creatures for humans.

The domestication of dogs not only led to the evolutionary transformation of a species but also caused an increase in the genetic diversity of dogs and the emergence of very different breeds. Genetic diversity has been shaped in line with different environmental conditions and human needs; this situation has led to significant diversification in the physical characteristics and behaviors of dogs.

Sociological and psychological aspects of dog–human relationships: Throughout history, the relationship between animal and human health has shown similarities. Aristotle's examinations of human and animal bodies revealed parallels between anatomical structures and functions. Human-animal interactions have been at the center of not only cultural but also social and economic transformations in the historical process. Pets, especially dogs, constitute a significant part of these relationships. Among the main reasons for adopting pets, factors such as accepting animals as individuals in the family or adopting them as friends sharing the loneliness at home reveal people's social sharing needs in pet ownership. Especially after the 17th century, it is stated that animals were seen as a means of socialization, and the general attitude towards animals and nature evolved in a more positive direction compared to other ages.

As one of the oldest domesticated animals in human history, dogs have become an inseparable part of human life not only in domestic life but also in many fields such as security, therapy, guidance, and social support. It is known that the presence of animals plays an important role in reducing the feeling of loneliness and making the individual feel peaceful. Furthermore, in studies conducted with children in the home environment, specifically those accompanied by dogs, it is determined that these children have lower blood pressure levels compared to others. The first documented treatment regarding the use of animals' close relationship with humans to improve human health was applied by William Tuke in the late 18th century to patients with psychological disorders. In the 19th and 20th centuries, research on the animal-human relationship and the use of animals for therapeutic purposes showed an increasing trend. Today, these relationships show that human and animal health are interconnected within the framework of the "One Health" approach and should be addressed in an integrated manner with ecosystem health.

The place of dogs in urban life (stray dogs, adoption, shelters): The concept of "stray animal" is perceived differently in different societies. However, the term "stray animal," expressing this different perception, is used in daily life. Generally, the expression "stray animals" is a term used for homeless street animals. This expression brings to mind especially cats and dogs, which are encountered in greater numbers. Stray animals are animals that are condemned to live on the streets generally due to reasons such as people's temporary interests, lack of responsibility awareness, inability to allocate time or cash, health problems, and, unfortunately, natural disasters.

We define stray animals in three ways: 1) Free-ranging animals that do not have an owner but are fed by people and are not under control; 2) Animals without an owner; 3) Animals belonging to wildlife, abandoned to nature, and accustomed to humans can also be defined as stray animals, but their breeding for humans is not appropriate.

Kruk (2021) defined the concept of "stray animal" in his study as pets that are not at home or within the owner's boundaries and are out of the control of the owner or caregiver. Turkey accepted the European Convention for the Protection of Pet Animals in 2003. Humans beginning to dominate nature and transitioning to settled life led to the domestication of many wild animals and, subsequently, the emergence of stray animal status. In the historical process, these animals assumed functional roles within society. Cats contributed to the control of rodents, birds to pests, and dogs to garbage; additionally, dogs played a warning role in the

security of neighborhoods. Cats, dogs, and birds, which are characterized as stray animals and live in the public sphere today, have lived intertwined with society, outside the state's sphere of interest except for measures taken during extraordinary periods. While the number of people living in cities increased in the 1950s when there was intense migration from villages to cities in Turkey, the increase in the number of stray animals parallel to this trend came inevitable. Basically, the stray animal problem, formed through stray dogs, has been characterized and discussed as an urban problem in Turkey for a long time.

RESEARCH AND FINDINGS

Research Design: The aim of this research is to evaluate the attitudes and behaviors of academic and administrative staff and students in at universities toward dogs. The study a seeks to evaluate the degree of awareness concerning dogs, experiences of pet ownership, frequency of interactions with dogs, and attitudes towards the environments in which dogs reside this descriptive study was intended to be carried out using quantitative data collection techniques via face-to-face and online survey methods.

Universe and Sample: The universe of this research consists of academic and administrative staff working at universities in Turkey and students studying at the undergraduate level. The sample consists of volunteer participants working and studying at eight universities located in different geographical regions, primarily Erciyes University.

Institutional Permissions: Within the scope of the study, official institutional permission applications were made to a total of 15 universities for the survey implementation. As a result of these applications, positive feedback was received from the 8 universities listed below, and survey implementations were carried out only in these universities:

- Erciyes University (Central Anatolia)
- Burdur Mehmet Akif Ersoy University (Mediterranean)
- Afyon Kocatepe University (Aegean)
- Aydın Adnan Menderes University (Aegean)
- Hatay Mustafa Kemal University (East/Southeast)
- Kafkas University (East/Southeast)
- Bursa Uludağ University (Marmara)
- Selçuk University (Central Anatolia)

Academic and administrative staff and undergraduates working/studying at these universities formed the study sample. The sample selection acted on a voluntary basis. Individuals participating in the study were informed about the purpose and scope of the survey and were included in the process after obtaining their consent.

Data Collection Tool: Research data were collected through face-to-face and online survey methods. In both methods, participant confidentiality was protected, and participation was ensured on a voluntary basis.

Face-to-Face Surveys: Face-to-face survey applications were carried out for academic and administrative staff and undergraduates working on university campuses. Surveys were administered by researchers assigned to determined campus areas using the one-on-one interview method. Participants were informed about the purpose and scope of the research and the conditions of participation based on voluntariness, and the data collection process was initiated after their approval was obtained.

Online Surveys: The online survey method was used to obtain data from academic and administrative staff and students working at universities outside the institution. The survey form was prepared via Google Forms and delivered to participants via the official e-mail addresses of the relevant institutions. Explanations regarding the purpose of the study, confidentiality principles, and voluntariness were included at the beginning of the survey link.

The applied survey form consists of six sections:

1. Demographic Information: Includes questions regarding participants' socio-demographic characteristics such as age, gender, occupation, educational status, and monthly household income.

2. Attitude Towards Dogs: Consists of statements aimed at evaluating participants' attitudes towards stray dogs and keeping dogs at home.

3. Adoption and Care: Includes questions regarding participants' dog ownership status, reasons for adoption, gender of owned dogs, and health status.

4. Health: Consists of statements aimed at measuring dogs' health status, vaccination frequency, and feeding habits.

5. Training and Human–Dog Relationships: Contains questions regarding dogs' training processes, forms of social interaction, and general behavioral characteristics.

6. Dogs' Reaction to Environmental Stimuli and Social Interaction Needs: Consists of statements aimed at evaluating dogs' reactions to environmental factors, social interaction requirements, and coping with stress.

Data Collection Process: Survey applications were conducted between December 2024 and January 2025. The data collection process was carried out for academic and administrative staff and undergraduates working at universities where official permission was obtained within the scope of the research. Survey forms were administered by the researcher both in printed media and online via Google Forms. Face-to-face surveys were conducted by the researcher using the one-on-one interview method on permitted campuses; online forms were delivered to participants via the official e-mail addresses of the relevant institutions. All participants were informed before participating in the research, and voluntary participation consent was obtained. Surveys were administered anonymously, and no personal or identity information was collected. Scientific ethical principles were fully observed throughout the research process, and an "Ethics Committee Exemption Certificate" was obtained from the Erciyes University Institute of Social Sciences (Document Date: April 30, 2024, Application No: 173).

Data Analysis: After defining categorical and continuous variables, the obtained data were evaluated in the JMP Pro 16.01 statistical software package and the R 4.5.2 platform. Analyses were performed in terms of distributions, differences, and correlations. Relationships between categorical variables were evaluated with the Pearson Chi-Square test and Cramér’s V effect size; differences of continuous variables on categorical attitude structures were tested with the nonparametric Kruskal–Wallis test. Relationships between variables were examined with Spearman correlation.

FINDINGS

In this section, findings regarding the attitudes, behaviors, and adoption tendencies of individuals in the university community towards dogs are presented in percentage distributions. The data are based on the responses of 1,033 individuals participating in the research. The obtained results were evaluated using descriptive statistics and chi-square analyses. Within the scope of the findings, participants' demographic characteristics, dog ownership status, attitudes towards stray dogs, and evaluations regarding dogs' care, welfare, and behavioral requirements were examined in detail.

Demographic Findings: Findings regarding participants' demographic characteristics (gender, age, occupation, and income) are detailed below:

Gender: Of the total 1,033 individuals participating in the research, 55.57% (n=574) are female and 44.43% (n=459) are male. This distribution shows that female participants are represented at a slightly higher rate than males in the sample. This difference in gender distribution suggests that female participation is higher in the overall study, thus forming a significant basis for examining gender differences in some variables regarding dog attitudes and behaviors.

Age Range: When participants' age ranges are examined, it is seen that the 18–25 age group provided the highest participation by a clear margin (84.80%; n=876). This is followed by the 26–33 age range at 6.97% (n=72) and the 34–41 age range at 4.16% (n=43). The rate of participants in the 42–49 age range was determined as 2.32% (n=24), and those aged 50 and over as 1.74% (n=18). This finding indicates that the study sample consists largely of young individuals, especially university students, and therefore the results represent the attitudes of the young adult population.

Occupation: When the occupational distribution of participants is examined, students formed the largest group by a clear margin (92.16%; n=952). The academic staff rate was determined as 4.45% (n=46), and the administrative staff rate as 3.39% (n=35). This result confirms that the target group of the study is university students; however, it shows that there is also significant participation from academic and administrative staff. This diversity provides valuable data for comparing the perceptions of individuals in different roles within the university community towards dogs.

Monthly Income (TL/Month): When participants' monthly household income levels are examined, those with an income of 45,000 TL and above formed the highest group with 33.01% (n=341). This was followed by individuals in the income group of 15,000 TL and below at a rate of 27.40% (n=283). Distributions were observed in the middle-income groups as 15,001–25,000 TL (16.07%; n=166), 25,001–35,000 TL (12.39%; n=128), and 35,001–45,000 TL (11.13%; n=115). Findings show that a significant portion of participants are in the middle-upper income group, but the low-income group is also strongly represented in the study.

Findings on Pet Ownership and Attitudes: Presence of Pets at Home: Approximately half of the participants (49.27%; n=509) stated that they currently keep a pet at home. Additionally, 19.65% (n=203) stated that they very much want to adopt a pet in the future, while 30.11% (n=311) stated that they do not have any pets. A rate of 0.97% (n=10) of participants stated that they do not consider adopting a pet. This result reveals that the potential for pet ownership is quite high and there is a general acceptance tendency towards pets in society.

Monthly Expenditure for Pet: When the average monthly expenditure levels of participants with pets (n=326) are examined, the highest rate is in the 2,001–5,000 TL range with 45.71% (n=149). This is followed by the range of 2,000 TL and below with a rate of 41.10% (n=134). Those spending in the 5,001–10,000 TL range were 9.82% (n=32), those in the 10,001–15,000 TL range were 2.45% (n=8), and those spending over 15,000 TL took place at a rate of 0.92%

(n=3). These findings show that most pet owners spend at a moderate level, and those making high expenditures constitute a very limited group.

Attitude Towards Stray Dogs: Participants' attitudes towards stray dogs are quite varied. More than half of the participants (51.21%; n=529) chose the statement "I love them, and I am not afraid." The rate of those saying "I love them, but I am afraid" is 23.43% (n=242). Among more negative attitudes, responses included "They should be collected" at 12.58% (n=130), "They should be put to sleep" at 7.26% (n=75), and "I have no idea" at 2.71% (n=28). This finding shows that a love-based but cautious approach towards stray dogs prevails in society in general.

Thought of Keeping a Dog at Home: When participants' views on keeping a dog are examined, 46.95% (n=485) gave the response "I would like to feed one provided it is in the garden (outside the house)." While 25.46% (n=263) said, "I would like to keep one at home," 10.65% (n=110) stated that they currently keep a dog. The rates of those expressing negative views are 7.16% (n=74) "I do not want to" and 4.55% (n=47) "I definitely do not want to." These results show that although there is generally a positive approach to the idea of keeping a dog in society, the vast majority tend to keep the dog outside the house.

Findings Regarding Dog Ownership and Care Processes: Dog Ownership Status: 68.25% (n=705) of the participants stated that they had never owned a dog, 18.59% (n=192) that they currently own a dog, and 13.17% (n=136) that they owned a dog in the past. This distribution shows that dog ownership is widespread in a limited segment of society, but individuals who have experienced ownership in the past are present in a substantial ratio.

Knowledge and Opportunity Regarding Dog Adoption and Care: Of the 412 participants responding to this question, 60.68% (n=250) considered themselves sufficient regarding dog adoption and care. 28.16% (n=116) stated they were not sufficient, while 11.17% (n=46) gave the response "I am eager; we can cope with this situation together with my dog." This finding reveals that although the desire to adopt a dog is high, a significant portion of the participants feel a lack of knowledge or resources.

Reasons for Adoption: When participants' reasons for dog adoption are examined, the most frequently stated reason was friendship or companionship (47.24%; n=257). This is followed by protection/security purposes (24.45%; n=133) and hobby/activity (17.83%; n=97). Moving away from people (7.17%; n=39) and treatment or guidance purposes (3.31%; n=18) were stated at lower rates. This result shows that dogs are primarily considered social and emotional companions, and functional reasons (such as protection or therapy) remain in the background.

Effective Factors in Adoption Decisions: When factors affecting the dog adoption decision were evaluated, the vast majority of participants (72.93%; n = 256) gave the response, I decided without being influenced by anyone." Parents having a dog (20.51%; n=72) ranked second, while friend influence (3.42%; n=12), child's request (1.99%; n=7), and media influence (1.14%; n=4) were seen at quite low rates. This finding shows that the adoption decision is mostly an individual preference, and social circle or media influence remains limited.

Place of Adoption: When examining where participants adopted their dogs, the highest rate was the "gifted" option with 36.31% (n=118). This was followed by adoption from a breeder (31.08%; n=101) and adoption from a shelter (24.00%; n=78). Adoption rates from pet shops (5.54%; n=18) and veterinary clinics (3.08%; n=10) are at low levels. Findings show that shelter-sourced adoption exhibits a positive trend, but gift and breeder-sourced adoption are still widespread.

Adoption Cost: When the status of paying any fee during adoption was examined, 68.03% (n=217) of the participants gave the response, “No, I adopted completely free of charge." In contrast, 31.97% (n=102) stated that they paid a fee, such as for food, vaccine, or service, for

the dog they adopted. This result shows that adoption largely takes place through a voluntary process far from the expectation of financial gain.

Dog's Pedigree Status: When the pedigree statuses of participants' dogs are examined, 69.26% (n=223) stated that their dog did not have a pedigree document, while 30.75% (n=99) stated that a pedigree document was present. These rates show that registered purebred dogs are found in a limited ratio in our country, and adoptions mostly consist of undocumented dogs.

Pedigree Importance Level: When the levels of importance participants attach to pedigree or being purebred were evaluated, 80.30% (n=269) selected the response "never important." In contrast, only 19.70% (n=66) said "yes, important." This finding shows that the majority of participants evaluate the dog on the basis of emotional bonding rather than as a status indicator or breed-based preference element.

Place of Owned Dogs in Society: Looking at participants' views on the place of owned dogs in society, 67.38% (n=696) said, "They provide positive contributions to society." While 20.62% (n=213) responded "they have neither positive nor negative effects," 8.81% (n=91) said "I am undecided," and 3.20% (n=33) said "there are negative effects." This result shows that owned dogs are generally perceived as a positive element in society.

Place of Stray Dogs in Society: When the social perception regarding stray dogs was evaluated, 46.08% (n=476) of the participants said, "They have negative effects for society." In contrast, 18.97% (n=196) staff participants stated that "stray dogs provide positive contributions to society," while 18.10% (n=187) were "undecided," and 16.84% (n=174) believed that "stray dog save no effect." These findings reveal that stray dogs are perceived more as a risk element within society.

Dog Breed: When the distribution regarding dog breeds is examined, it is seen that Kangal mix dogs are at the highest rate by a clear margin (72.45%; n=894). This is followed by Kangal (6.30%; n=72), Terrier (2.67%; n=33), and Akbaş (2.67%; n=33). Other breeds (Rottweiler, Golden Retriever, Labrador, Cocker Spaniel, etc.) were represented at much lower rates. This finding shows that native breeds—especially Kangal and its mixes—are dominant in regional adoptions.

Dog's Age: When the age distribution of dogs is examined, dogs in the 1–5 age range are at the highest rate by a clear margin (50.78%; n=163). The rate of dogs under one year old was determined as 13.71% (n=44), 6–10 years old as 16.20% (n=52), over 10 years old as 9.66% (n=31), and those who do not know the age as 9.66% (n=31). This finding shows that most owned dogs are in the young adult age group.

Dog's Gender: According to the declarations of dog owners, 63.45% (n=184) of the dogs they own are male; 36.55% (n=106) are female. This distribution shows that the rate of adopting male dogs is higher.

Neutering Status: When the neutering status of dogs is examined, 7227.65% (n=81) of owners neutered their dog, while 72.36% (n=212) did not This result shows that neutering rates are quite low and points to the necessity of awareness studies on the subject.

Place Where Neutering Was Performed: 50% (n=52) of the participants (n=104) who had their dog neutered stated that the procedure was done at the veterinary clinic they regularly visit. 28.85% (n=n = 30) marked the option "I have no information about the subject"; 8.65% (n = 9) marked "at a municipal facility," 6.73% (n = 7) marked "at another recommended clinic," and 5.77% (n = 6) marked at a university hospital." Findings show that neutering procedures are mostly carried out in private veterinary clinics.

Status of Having Offspring Before Neutering: 41.77% (n=66) of the 158 participants who had their dog neutered gave the response "We neutered before giving birth." 39.24% (n=62) used the expression "I have no information about the subject," 12.66% (n=20) "gave birth once," 5.06% (n=8) "gave birth twice," and 1.27% (n=2) "gave birth three times." This result shows that most dog owners tend to neuter before birth.

Reasons for Not Neutering: According to the statements of 192 participants who did not neuter their dog, the most common reason, with a rate of 35.05% (n=102), was "I might consider neutering; I haven't had a problem yet." This is followed by "I don't want it to feel pain" (17.87%; n=52) and "empathy/emotional reasons" (17.87%; n=52). Also, 12.03% (n=35) gave the response "I think it is a practice against nature," 7.56% (n=22) "an unhealthy practice," and 5.15% (n=15) "religious or conscientious reasons." These findings reveal that the reasons for not neutering are mostly based on emotional and moral foundations.

Dog's Health Status: When responses regarding the health status of dogs are examined, the highest rate belongs to the response "has no health problems" with 45.73% (n=193). 31.52% (n=133) stated "I have it vaccinated regularly," 5.92% (n=25) "have a chronic disease," 4.03% (n=17) "I have it vaccinated irregularly," and 2.61% (n=11) "unvaccinated." 4.27% (n=18) said, "I am not knowledgeable." These findings show that the vast majority of owned dogs are subjected to regular health checks.

Fear of Dogs Before Adoption: When the fear status of dog owners before adopting a dog was examined, 89.35% (n = 260) gave the response, "No I had no fear." 8.59% (n = 25) said, "I did; I overcame the fear when I adopted," and 2.06% (n = 6) said, "I did, but I still fear after adoption." This result shows that pre-adoption fears largely disappear with experience.

Order of Ownership: When the ownership order of the dogs owned by the participants was evaluated, 64.51% (n = 189) gave the response, "I am the first owner." 21.84% (n=64) marked the options. "I am the second owner." 11.26% (n=33) "I don't know," and 2.39% (n=7) "I am the third owner." This result shows that a large portion of the dogs were adopted by their first owner.

Age at Adoption: When the age at which the dog was adopted is examined, 46.23% (n=135) of the participants stated that they adopted in the "suckling period–3 months" range. 26.71% (n=78) said "4–6 months," 12.33% (n=36) "I adopted without knowing the age," 8.22% (n=24) "6–12 months," 4.11% (n=12) "1 year old," and 2.40% (n=7) "2 years old." This finding reveals that dog adoptions mostly take place in the puppy period.

Number of Daily Food Meals: When the number of daily food meals given to dogs is examined, 49.48% (n=143) of the owners stated that they feed their dog twice a day, and 22.15% (n=64) stated that they feed "ad libitum" (free access). 20.42% (n=59) marked the option "three meals," and 7.96% (n=23) "one meal." Findings show that the vast majority of dogs are fed regularly at two meals.

Number of Daily Water Meals: Findings regarding the amount of water given to dogs show that the vast majority of owners, 88.62% (n=257), provide their dogs with "ad libitum" (continuous access) opportunity. Apart from this, 5.17% (n=15) reported giving water three times a day, 4.83% (n=14) twice a day, and 1.38% (n=4) once a day. This result shows that most dog owners exhibit an ideal approach regarding water supply.

Findings on Behavior, Training, and Welfare: Dog's Training Status: Examining participants' responses about their dogs' training levels, we found that 57.75% (n=164) said their dog was "trained by the owner." 28.52% (n=81) of participants responded that their dog "received no training," 10.56% (n=30) indicated their dog was "trained by an amateur trainer," and 3.17%

(n=9) reported their dog was "trained by a professional trainer." Findings show that an owner-based approach is more common in dog training than professional support.

Type of Collar Used: When the types of collars used by dog owners are examined, 52.65% (n=149) stated that they use a "neck collar." This was followed by the options "harness/chest collar" at 29.33% (n=83), "I do not use a collar" at 15.19% (n=43), and "choke/training collar" at 2.83% (n=8). This finding shows that a large portion of owners prefer standard collar models, prioritizing the dog's comfort.

Attitude Towards Other Family Members: When dogs' attitudes towards other individuals in the family are examined, 60.65% (n=168) of the participants stated that their dog behaves "very well" and 31.05% (n=86) "well." Responses of "unresponsive" were 3.97% (n=11), "bad" 2.89% (n=8), and "very bad" 1.44% (n=4). This finding reveals that the intra-family harmony of owned dogs is high.

Attitude Towards Children at Home: When dogs' attitudes towards children are examined in households with children under 14 years of age, 62.08% (n=149) were evaluated as "very good" and 27.08% (n=65) as "good." "Unresponsive" was stated as 5.83% (n=14), "bad" as 3.33% (n=8), and "very bad" as 1.67% (n=4). Findings show that dogs generally exhibit a positive and compatible attitude towards children.

Attitude Towards Guests: When dogs' attitudes towards guests coming to the house are examined, responses were 35.64% (n=98) "good," 35.27% (n=97) "very good," 16.73% (n=46) "bad," 8.00% (n=22) "unresponsive," and 4.36% (n=12) "very bad." This distribution shows that a large portion of dogs are socially accustomed to accepting guests, but a certain group may show protective or shy behaviors.

Attitude Towards People Outside: When the attitudes of participants' dogs towards people they encounter outside are examined, they were reported as "good" by 36.46% (n=101), "very good" by 23.47% (n=65), "unresponsive" by 21.30% (n=59), "bad" by 12.99% (n=36), and "very bad" by 5.78% (n=16). This result reveals that most dogs can establish positive interactions with people in the external environment, but some may show shy or protective reactions.

Attitude Towards Other Dogs Outside: When dogs' behaviors towards other dogs outside were examined, they were evaluated as "good" by 40.22% (n=111) and "very good" by 17.39% (n=48). In contrast, responses of "bad" (25.00%; n=69), "unresponsive" (11.23%; n=31), and "very terrible(6.16%; n=17) were received. This finding shows that while social tolerance among dogs is generally positive, aggressive or shy behaviors can also be seen at a certain rate.

Ability to Stay Alone at Home: When dogs' skills to stay alone at home are examined, 55.20% (n=154) gave the response "can stay alone for a full day." 20.43% (n = 57) said "up to half a day," 16.13% (n = 45) said "up to 6 hours," and 8.24% (n = 23) said "no, I can't stay alone." Findings show that most owned dogs adapt to being alone.

Status of Damaging Household Goods and Clothes: When dogs' behaviors towards household goods and clothes are evaluated, 48.72% (n=133) marked the option "has no habit of damaging." Responses of "sometimes, especially when bored or left alone" were 23.81% (n=65), "rarely but plays with toys" 20.51% (n=56), and "frequently causes damage" 6.96% (n=19). This result shows that destructive behaviors are at a low level in most dogs but may increase in situations such as loneliness or boredom.

Level of Meeting Dog's Daily Emotional Needs: When the level of meeting emotional needs such as play, attention, and walking is examined, 53.96% (n=150) of the participants responded "sufficiently met," 37.05% (n=103) "partially met," 6.84% (n=19) "not sure," and 2.16% (n=6)

"not met." This result shows that a large portion of dog owners pay attention to their animals' emotional welfare.

Housing Type: When the type of housing where dogs live is examined, 66.08% (n=187) marked the option "detached house with garden," 28.27% (n=80) "apartment," and 5.65% (n=16) "detached house with common area." This finding shows that owned dogs mostly live in houses with access to open space and points to a positive condition in terms of dog welfare.

Number of Daily Walks: Data regarding the frequency of taking dogs outside show that 31.64% (n=87) gave responses of "at irregular intervals during the week," 30.18% (n=83) "twice a day," 21.46% (n=59) "three times or more," and 16.73% (n=46) "once a day." This distribution reveals that most dogs engage in regular daily exercise, but irregularity is observed in some.

Average Duration of Each Walk: Evaluated in terms of the duration of each walk, 59.56% (n=162) of dog owners stated that they walk their dog between half an hour and one hour. 22.06% (n=60) responded "less than half an hour" and 18.38% (n=50) "longer than two hours." This finding shows that most owned dogs access sufficient physical activity daily.

Walking Area Preferences: When the areas where participants walk their dogs most frequently are evaluated, the highest rate was "parks and green areas" with 27.59% (n=168). This was followed by "surroundings of the house" (19.70%; n=120), "rural areas and fields" (17.41%; n=106), "forested areas" (12.15%; n=74), "city streets" (11.82%; n=72), and "dog parks" (5.42%; n=33). This distribution shows that dog owners tend to prefer natural areas.

Quality of Social Interactions: When dogs' forms of social interaction are examined, 41.50% (n=122) gave responses of "interaction with family members and friends," 23.13% (n=68) "encountering people and other animals on walks," 20.07% (n=59) "regular play and socialization with other dogs," 7.14% (n=21) "mostly at home," and 7.14% (n=21) "very little social interaction." This result shows that dogs' social needs are mostly met through human-centered interactions.

Reaction to Environmental Stimuli: When dogs' reactions to environmental stimuli are evaluated, 59.06% (n=163) were reported as "gives very positive reactions," 23.55% (n=65) "shows interest but is shy," 11.59% (n=32) "shows fear or aggressiveness," and 5.80% (n=16) "generally uninterested or unresponsive." Findings reveal that dogs are generally curious and react positively to the environment.

Reaction to Learning and Training Processes: When dogs' learning speeds and reactions to training processes are examined, 40.28% (n=114) were reported as "interested but learning speed is average," 39.93% (n=113) ""learns very quickly and eager for training," 10.25% (n=29) "struggles to learn, requires extra encouragement," and 9.54% (n=27) "uninterested or resistant." This finding shows that a large portion of owned dogs are open to learning and motivated.

Stress Coping Level: When dogs' ways of coping with stressful situations are examined, 48.73% (n=134) responded "takes some time but calms down," 39.27% (n=108) "calms down easily and quickly," 6.18% (n=17) "becomes uncontrollable, aggressive, or fearful," and 5.82% (n=16) "remains stressful for a long time." Findings show that the vast majority of dogs possess the skill to cope with stress.

View on Keeping Dogs at Home: Of the 305 participants responding to this question, 48.85% (n=149) gave responses of "I am in favor of feeding only in houses with gardens," and 44.59% (n=136) said, "I am pleased to keep at home; I find it positive." 4.26% (n=13) expressed the view, "I cannot bear the responsibility of keeping a dog." 1.64% (n=5) said, "I definitely do not find it appropriate," and 0.66% (n=2) said, "I am against keeping dogs." This distribution

reveals that a positive attitude generally prevails towards dog ownership, but living space conditions are a determining factor.

Belief Level in Cognitive Features in Dogs: When participants' beliefs regarding whether dogs possess cognitive features (intelligence, emotion, reasoning, curiosity, etc.) are examined, 80.00% (n = 244) gave the response, "Yes, I believe they exist." 16.07% (n=49) used the expression "I think some features exist partially." 2.62% (n=8) said, "No, I think these features do not exist," and 1.31% (n=4) said, "I am not sure." This result reveals that the vast majority of participants view dogs as living beings with cognitive capacity.

Level of Caring About Dog Psychology: When the level of importance dog owners attach to dog psychology is evaluated, 46.36% (n=140) gave responses of "very high," 35.76% (n=108) "high," 17.22% (n=52) "medium," and 0.66% (n=2) "very low." This finding proves that a significant portion of dog owners show high sensitivity to the dog's mental and emotional state.

Knowledge Level About Dogs' Psychological Welfare and Behaviors: When participants' knowledge levels regarding dogs' psychological welfare and behaviors were examined, they were reported as "medium level" by 36.96% (n=112), "high" by 35.97% (n=109), "very high" by 21.12% (n=64), "low" by 4.62% (n=14), and "very low" by 1.32% (n=4). This result shows that participants' awareness regarding the subject is generally strong.

Regular Veterinary Checks: When the status of taking dogs for regular veterinary checks is examined, 55.44% (n=158) gave responses of "yes, regularly," 36.84% (n=105) "only, when necessary," and 7.72% (n=22) "no, I do not." Findings show that a large portion of owned dogs are subjected to regular veterinary control.

Types of Food the Dog is Fed: When the types of food dogs are fed were evaluated with multiple choice, the most frequently reported type was high-quality dry food (33.10%; n=139). This was followed by homemade meals (29.76%; n=125), economic dry food (17.62%; n=74), raw feeding—BARF type (10.95%; n=46), and canned food (8.57%; n=36). These results show that dog owners attach importance to balanced nutrition and supplement ready-made foods with traditional foods.

Supplementary Foods Given Besides Kibble: When supplementary foods given to dogs besides kibble are evaluated, responses were received as "cooked meat or fish" (30.27%; n=181), "special dog treats" (19.06%; n=114), "butcher's by-products" (14.38%; n=86), "fresh vegetables and fruits" (12.21%; n=73), "uncooked bones" (11.20%; n=67), "grains or rice" (9.36%; n=56), and "I give no supplementary food" (3.51%; n=21). This distribution shows that most owners supplement dog nutrition with various natural foods.

Preference for Leaving the Dog on Vacation: When dog owners' practices regarding their dogs during vacation periods are examined, 39.93% (n=107) gave responses of "I leave it to my friend." 26.49% (n=71) "I take it with me," 24.25% (n=65) "I cannot leave it to anyone; I do not go on vacation." 4.85% (n=13) "I leave it to the veterinary clinic," and 4.48% (n=12) "I leave it to a boarding facility." Findings reveal that owners tend to leave their dogs with a trusted circle or take them along with them.

Effect of Dog Adoption on Social Circle: When the effects of dog adoption on social circle relationships are examined, 35.21% (n=94) gave the response "no change occurred; they remained neutral." 31.46% (n=84) stated "their social circle was "affected very positively, with increased interest and support," 28.46% (n=76) reported it was "affected positively but with some reservations," 4.12% (n=11) indicated it was "affected negatively, with increased anxiety and criticisms," and 0.75% (n=2) said it was affected very negatively." This result shows that dog adoption generally finds a positive response in the social circle.

Effect of Dog Adoption on Family Budget: When the economic effects of dog adoption are evaluated, 45.76% (n=124) gave the response "no significant change occurred. "This is followed by the options 'did not affect at all, I can cover the costs easily' (23.62%; n=64), 'affected negatively to some extent, small budget changes occurred' (21.03%; n=57), 'affected negatively in a serious manner' (5.53%; n=15), and 'affected positively, made the budget more planned' (4.06%; n=11). Findings show that dog adoption has an effect at a manageable level economically.

Regret Felt from Dog Adoption: Findings regarding the level of regret felt from the dog adoption decision show that 48.54% (n=133) of the participants gave the response "no, I am very happy; my life changed positively." 22.99% (n=63) gave responses of "I encountered partial difficulties, but generally I am happy." 22.99% (n=63) said, "I am not regretful; I find my decision positive," and 5.47% (n=15) said, "Yes, I am regretful." This result shows that dog adoption generally contributes positively to individuals' life satisfaction.

Comparative and Advanced Statistical Findings:

Findings Related to Gender: A statistically significant and strong relationship was found between gender and attitudes towards stray dogs ($\chi^2 = 186.61$, $p < 0.001$, Cramér's $V = 0.425$). While 58% of women gave the response, "I love them, and I am not afraid," this rate remained at 42.7% for men. 29.3% of men chose the statement, I support them being collected." This result indicates that women exhibit a more empathetic and protective attitude towards stray dogs. Additionally, a strong relationship was determined between gender and the thought of keeping a dog at home ($\chi^2 = 51.36$, $p < 0.001$, Cramér's $V = 0.410$), indicating that acceptance levels of women and men differ significantly.

Findings Related to Age Groups: A significant difference was determined among age groups in attitude towards stray dogs ($\chi^2 = 56.12$; $p < 0.001$; Cramér's $V = 0.27$). 59.4% of individuals in the 18–25 age group marked the option "I love them and I am not afraid," whereas this rate fell to 41.8% in the 36–45 age group. The response "I am afraid, and I stay away" was observed at a rate of 22.5% in those aged 46 and over. This finding shows that the young age group exhibits a more positive and sensitive attitude towards stray dogs.

Factors Determining Dog Ownership (Logistic Regression): The logistic regression model developed to examine determinants affecting dog ownership showed that the presence of pets at home (OR=0.17; $p<0.001$), attitude regarding the social role of stray dogs (OR=2.59; $p=0.001$), and desire to keep a dog at home (OR=0.09; $p<0.001$) form significant and strong effects on ownership. Ownership significantly decreases in those without pet experience at home.

Spearman Correlation Analyses: Knowledge—Psychology: "Participants with higher knowledge about dogs' psychological welfare and behaviors also report a higher level of caring about dog psychology" ($r = 0.24$). This relationship is a direct and consistent finding.

Age–Income: A limited increase is observed in income levels as participants' ages increase ($r = 0.21$).

In general, relationships between the examined demographic (age, income) and ownership variables and psychological welfare and attitude indicators are at a weak level.

Analyses in Dog Owners Subgroup: In analyses performed in the dog owner's subgroup, the only significant result is the difference between the dog's training level and the dog owner's age ($p < 0.001$). While young owners (18–35 years) reported their dogs more in the "received training" category, the training level decreases as age progresses. This finding shows that dog training is an age-sensitive behavioral investment.

DISCUSSION&CONCLUSION

Discussion

The findings of this research show that the attitudes and behaviors of academic and administrative staff and students in universities towards dogs are generally positive but carry significant differences in terms of different variables. Data obtained from 1,033 individuals participating in the research revealed that empathy and awareness regarding dogs are high in the educated segment of society, yet knowledge level is not always reflected in practical behaviors.

Attitudes and Behaviors According to Gender Variable: Findings indicate that gender creates a significant difference in attitudes towards dogs. While female participants preferred the statement "I love them and I am not afraid" at a rate of 58%, this rate remained at 42.7% in males. In contrast, it was determined that male participants showed a greater tendency towards negative judgments such as "should be collected" and "should be put to sleep." This result shows that women generally exhibit a more empathetic, emotional, and protective apattitude towardogs. Studies conducted by Yılmaz, Özcan, and Şen (2021) and Herzog (2007) in the literature also emphasize that women's compassion level towards animals is higher than men's, based on biological and social learning foundations. In societies like Turkey, where emotional care is culturally attributed more to women, it is seen that these tendencies are also reflected in relationships established with animals.

Attitudes and Behaviors According to Age Range: According to research findings, the vast majority of participants (84.80%) are in the 18–25 age range. Young adults used the expressions "I love them" and "I am not afraid" more frequently, showing a high potential for establishing an emotional bond towards dogs. It was observed that positive attitudes towards dogs decreased as age increased, and the rate of responses such as "should be collected" or "I am afraid" rose in middle-age groups. Evaluated in terms of behavioral sciences, the high levels of animal love in young participants can be explained by social learning, emotional development, and social modeling in the campus environment. The tendency of individuals in advanced age groups to maintain physical distance from dogs generally stems from life experiences or negative observations.

Attitudes and Behaviors According to Occupation Variable: Significant differences were observed in dog attitudes according to the occupation variable. While academic staff exhibited a more conscious approach with high emphasis on ethical responsibility regarding "animal welfare" and "owned–stray dog distinction," students approached more on the basis of emotional bonding and desire for adoption. It was determined that administrative staff had a more pragmatic and distant tendency. This situation is compatible with the study of Erdoğan and Yıldız (2020), showing that academic education develops not only cognitive knowledge but also ethical sensitivity.

Attitudes and Behaviors According to Income Level: It was determined that individuals in the high-income group had higher awareness regarding dog ownership, dog care, and dog welfare, whereas those in the low-income group had strong emotional orientations despite low adoption rates. While professional care and welfare-oriented attitudes are seen in high-income individuals, emotional closeness and desire for protection stand out in middle- and low-income groups. Although income level affects behaviors towards dogs quantitatively, it is not the sole determinant qualitatively in terms of emotional attachment.

Status of Pets Present at Home: It was determined that the attitudes of individuals with pets at home towards dogs were significantly more positive. While pet owners selected the statement "I love them and I am not afraid" at a higher rate, statements of "should be collected" and "I am

afraid" increased in individuals without pets. This situation shows parallelism with the study of Ergin, Pekşen, and Diker (2011), showing that pet ownership increases empathy levels and reduces fear/prejudice rates.

Attitudes Towards Stray Dogs: It was seen that a love-based but cautious approach towards stray dogs prevails in society. While more than half of the participants expressed positive views, there is also a significant segment carrying security concerns. This situation reveals that the social attitude towards stray dogs possesses a dual structure (love and fear).

Knowledge-Action Gap: One of the most striking discussion points of the study is the gap between knowledge and practice. Although the vast majority of participants stated that they care about dog care and welfare, the low rates of neutering (27.65%) and the training level being far from professionalism (mostly training by the owner) show that the level of consciousness does not always transform into action.

Conclusion

This research addressed the attitudes of academic and administrative staff and students in universities towards dogs with a holistic approach. Findings show that participants generally exhibit an empathetic, sensitive, and welfare-oriented approach towards dogs.

Key Results:

Gender Effect: Female participants exhibit a more protective and empathetic attitude compared to males.

Age Effect: Love for animals and positive attitude are stronger in young individuals (18-25 years); cautious approach increases as age progresses.

Income and Profession Effect: While a knowledge-based and professional approach is dominant in high-income and academic staff groups, emotional attachment is at the forefront in students and low-income groups.

Ownership Effect: Pet ownership is one of the strongest determinants of positive attitudes towards dogs.

Knowledge-Action Inconsistency: It was determined that even individuals with high levels of knowledge show behavioral inconsistencies in practice (e.g., regarding neutering) ("knowledge-action gap").

Recommendations:

Education and Awareness: Seminars and elective courses on "Animal Welfare and Behavioral Psychology" should be organized in universities, and all staff and students should be included in these processes.

Campus Animal Policies: University administrations should turn feeding, shelter, and health services for stray animals into institutional policies and carry out these practices in cooperation with volunteer student communities.

Neutering Consciousness: The importance of neutering for balancing the owned and stray dog population should be emphasized; informational activities should be carried out in cooperation with veterinary faculties.

Social Empathy: Content that will reduce false perceptions regarding dogs and highlight empathy and scientific knowledge should be produced in mass media tools.

Future Research: It is suggested that future studies examine individuals' emotional bonds and ethical approaches in more detail with qualitative methods (in-depth interviews, etc.).

In conclusion, universities taking an active role in education and social responsibility areas that reinforce this consciousness will be the key to reaching a sustainable social structure in terms of dog welfare.

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IMPACT OF MELOXICAM ON OXIDATIVE STATUS IN REPRODUCTIVE TISSUES OF MALE RATS

Assoc. Prof. Dr. Caner ÖZTÜRK

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray, Türkiye

ORCID ID: https://orcid.org/0000-0003-0566-0684

Assoc. Prof. Dr. Neşe Hayat AKSOY

Aksaray University Faculty of Veterinary Medicine, Department of Biochemistry, Aksaray, Türkiye

ORCID ID: https://orcid.org/0000-0001-9039-555X

Lect. Dr. Erkan ÖZKAN

Aksaray University Faculty of Veterinary Medicine, Department of Parasitology, Aksaray, Türkiye

ORCID ID: https://orcid.org/0000-0002-5251-2302

Res. Asst. Ramazan ARSLAN*

Aksaray University Faculty of Veterinary Medicine, Department of Reproduction and Artificial Insemination, Aksaray, Türkiye

ORCID ID: https://orcid.org/ 0009-0000-6275-5861

ABSTRACT

Introduction and Purpose: This study aimed to investigate whether meloxicam alters oxidative status in the cauda epididymis and testicular tissues of rats.

Materials and Methods: Six male Wistar rats weighing 220 ± 20 g were used. All animals were housed under controlled conditions, received standard pellet feed and water ad libitum, and were monitored twice daily for general health. The rats were randomly assigned to two groups: the treatment group received meloxicam at 2 mg/kg/day intraperitoneally for five consecutive days, whereas the control group was administered physiological saline via the same route and schedule. At the end of the treatment period, tissue samples were collected and immediately homogenized. Total Antioxidant Status (TAS) and Total Oxidant Status (TOS) were quantified using validated colorimetric methods, and the Oxidative Stress Index (OSI) was calculated from these measurements. Descriptive statistics were generated for each parameter. Depending on distribution characteristics, differences between the control and meloxicam groups were analyzed using either independent samples t-tests or the Mann–Whitney U test.

Results: In the cauda epididymis, meloxicam administration resulted in a marked rise in TAS values compared with the control group ($p < 0.05$). OSI values were significantly lower in the treated animals ($p < 0.05$), while TOS levels did not differ between groups. These findings indicate a shift toward an enhanced antioxidant environment in the epididymal tissue following meloxicam exposure. In contrast, TAS, TOS, and OSI values in testicular tissue showed no significant differences between groups ($p > 0.05$), suggesting that the impact of meloxicam on oxidative regulation may be tissue-specific and more pronounced in the epididymis than in the testis.

Discussion and Conclusion: Overall, short-term meloxicam treatment appears to reinforce antioxidative capacity in the cauda epididymis and may exert a localized protective effect. These results contribute to the understanding of how NSAIDs influence oxidative processes within reproductive tissues and highlight the need for studies with larger sample sizes to further clarify these observations.

Keywords: Meloxicam, Oxidative Stress, Epididymal and Testicular Tissue, Wistar Rat Model

INTRODUCTION

Reactive oxygen species (ROS) are inevitable by-products of aerobic metabolism and play a dual role in male reproductive physiology. At physiological concentrations, ROS participate in normal cellular signaling processes that regulate spermatogenesis, epididymal sperm maturation, capacitation, and acrosome reaction (Agarwal et al., 2014; Dutta et al., 2021). In particular, the epididymis provides a specialized microenvironment where spermatozoa acquire motility and fertilizing capacity under strict redox regulation (O'Flaherty, 2019). However, when ROS production exceeds the buffering capacity of antioxidant defense systems, oxidative stress develops, leading to lipid peroxidation, protein oxidation, and DNA damage in sperm cells, ultimately impairing male fertility (Aitken & Baker, 2006; Agarwal et al., 2014).Oxidative stress in the male reproductive tract is therefore a critical factor in male infertility and is often intertwined with inflammation and other pathologies Dutta et al., 2021).

The epididymis is especially vulnerable to oxidative imbalance because spermatozoa exiting the testis lose the protection of Sertoli cell-derived antioxidants and become reliant on luminal antioxidant mechanisms (O'Flaherty, 2019). Although the testis possesses robust intrinsic antioxidant defenses and a blood–testis barrier that limits exposure to systemic insults, prolonged oxidative stress or pharmacological interference may still disrupt spermatogenesis (Dutta et al., 2021).

Non-steroidal anti-inflammatory drugs (NSAIDs) are widely used in both human and veterinary medicine for their analgesic, antipyretic, and anti-inflammatory properties. Meloxicam is a preferential cyclooxygenase-2 (COX-2) inhibitor that reduces prostaglandin synthesis and inflammatory mediator release (Alemán-Laporte et al., 2022). Prostaglandins play important regulatory roles in testicular blood flow, steroidogenesis, and immune modulation; therefore, COX inhibition may influence reproductive physiology beyond pain control (Uzun et al., 2015). Experimental studies have shown that long-term or high-dose meloxicam exposure can impair spermatogenesis, reduce sperm quality, and induce oxidative damage in testicular tissue (Haroun et al., 2020; Uzun et al., 2015).

Conversely, emerging evidence suggests that under certain conditions, meloxicam may exert protective effects by limiting inflammation-driven ROS production. In large animal models, meloxicam administration has been associated with reduced sperm lipid peroxidation and improved semen quality following inflammatory stress (Gupta et al., 2025). These findings indicate that the impact of meloxicam on oxidative balance may depend on tissue type, dose,

and duration of exposure. Notably, the effects of short-term meloxicam treatment on epididymal oxidative status remain poorly characterized.

Therefore, the present study aimed to investigate whether short-term meloxicam administration alters oxidative stress parameters in the cauda epididymis and testicular tissues of Wistar rats. Total antioxidant status (TAS), total oxidant status (TOS), and the oxidative stress index (OSI) were evaluated to determine whether meloxicam induces tissue-specific modulation of redox balance.

MATERIALS and METHODS

Animals and Experimental Design

Six adult male Wistar rats (body weight 220 ± 20 g) were obtained from the university's laboratory animal center. The rats were housed in standard cages under controlled conditions (12 h light/12 h dark cycle, 23 ± 2°C, with free access to commercial pellet chow and water). Animals were acclimated for one week and monitored twice daily for health and wellbeing. The experiment was conducted in accordance with ethical guidelines for animal research, and all procedures were approved by the Institutional Animal Care and Use Committee. The rats were randomly divided into two equal groups (n = 3 per group) for a 5-day treatment period as follows:

Meloxicam group

Rats received meloxicam at 2 mg/kg/day, administered intraperitoneally for five consecutive days. The meloxicam dosing and schedule were based on prior analgesic regimen studies in rodents adjusted to achieve an anti-inflammatory dose commonly used in laboratory practice.

Control group

Rats received an equivalent volume of physiological saline (0.9% NaCl) via intraperitoneal injection once daily for five days, to account for handling and injection effects. No other treatments were given during this period.

Sample Collection

Twenty-four hours after the final injection (Day 6), rats were anesthetized (ketamine/xylazine overdose, IP) and euthanized. A midline laparotomy was performed, and the reproductive organs were immediately exposed. From each animal, the testes and the cauda epididymides were carefully dissected out. The cauda epididymis (distal region of the epididymis where mature sperm are stored) was chosen because of its importance in sperm storage/maturation and its potential sensitivity to systemic treatments. Tissue samples were gently rinsed in ice-cold saline to remove blood and blotted dry. The supernatants were collected and stored at –80°C until analysis. All preparation steps were carried out quickly to minimize artifactual oxidation.

Biochemical Assays

Total Antioxidant Status (TAS) and Total Oxidant Status (TOS) were measured in tissue homogenate supernatants using validated colorimetric methods. TAS was determined by the automated ABTS radical cation decolorization method described by Erel (2004). In this assay, antioxidants in the sample reduce the blue-green $ABTS^{+}$ radical to a colorless form; the magnitude of decolorization (measured at 660 nm) is proportional to the total antioxidant capacity and is calibrated with Trolox equivalent units.

TOS was measured by the ferrous ion oxidation–xylenol orange (FOX) assay in an automated format according to Erel (2005). In the TOS assay, oxidants present in the sample oxidize ferrous ions to ferric ions, which then bind xylenol orange to produce a colored complex measured at 560 nm; hydrogen peroxide is used as the standard and results are expressed in micromolar H_2O_2 equivalents. For both TAS and TOS assays, we followed kit or literature protocols with appropriate controls and calibrators, and all measurements were performed in duplicate for accuracy.

An *Oxidative Stress Index (OSI)* was calculated to provide an integrated measure of oxidative balance, defined as the ratio of TOS to TAS, expressed as a percentage (OSI = TOS / TAS × 100). In essence, a higher OSI indicates a condition of relatively higher oxidant burden to antioxidant capacity (greater oxidative stress), whereas a lower OSI suggests a more antioxidative or protected state.

Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for TAS, TOS, and OSI in both tissues. Prior to group comparisons, the normality of data distribution was assessed using the Shapiro–Wilk test. TAS and OSI values were found to be normally distributed in both experimental groups, and therefore, differences between groups for these parameters were evaluated using an independent samples t-test. In contrast, TOS values did not meet the assumption of normality in the control group; accordingly, comparisons between the meloxicam-treated and control groups were performed using the non-parametric Mann–Whitney U test. A p value < 0.05 was considered statistically significant for all comparisons.

RESULTS

Oxidative Stress Parameters in the Cauda Epididymis

Descriptive statistics and intergroup comparisons of oxidative stress parameters measured in the cauda epididymal tissue are summarized in Table 1. Total Antioxidant Status (TAS) values were significantly higher in the meloxicam-treated group compared with the control group (2123.19 ± 32.71 vs. 1170.29 ± 215.71 µmol/L, $p < 0.05$).

Total Oxidant Status (TOS) values did not differ significantly between the groups, although a numerical decrease was observed in the meloxicam-treated rats compared with controls (21.40 ± 7.67 vs. 26.67 ± 8.18 µmol/L, $p > 0.05$).

In parallel with the increase in TAS, the Oxidative Stress Index (OSI) was significantly lower in the meloxicam group than in the control group (1.01 ± 0.345 vs. 2.31 ± 0.648, $p < 0.05$), indicating a shift toward a more favorable antioxidative balance in the cauda epididymal tissue following meloxicam administration.

Table 1. Descriptive statistics and intergroup comparisons of oxidative stress parameters (TAS, TOS, and OSI) measured in the cauda epididymal tissue of control and meloxicam-treated rats.

Group	TAS (µmol/L) (Mean ± SD)	TOS (µmol/L) (Mean ± SD)	OSI (Mean ± SD)
Control	1170.29 ± 215.71	26.67 ± 8.18	2.31 ± 0.648
Meloxicam	2123.19 ± 32.71	21.40 ± 7.67	1.01 ± 0.345
	*	-	*

* Indicates a statistically significant difference compared with the control group ($p < 0.05$).

Oxidative Stress Parameters in Testicular Tissue

The descriptive statistics and group comparisons of oxidative stress parameters measured in testicular tissue are presented in Table 2. No statistically significant differences were detected between the meloxicam-treated and control groups for TAS, TOS, or OSI values ($p > 0.05$ for all comparisons).

Although TAS values tended to be higher and OSI values tended to be lower in the meloxicam-treated group compared with controls, these differences did not reach statistical significance. Testicular TOS values were also comparable between the groups. Overall, short-term meloxicam administration did not significantly alter the oxidative status of testicular tissue under the conditions of the present study.

Table 2. Descriptive statistics and intergroup comparisons of oxidative stress parameters (TAS, TOS, and OSI) measured in testicular tissue of control and meloxicam-treated rats.

Group	TAS (µmol/L) (Mean ± SD)	TOS (µmol/L) (Mean ± SD)	OSI (Mean ± SD)
Control	1429.71 ± 689.55	6.84 ± 0.37	0.542 ± 0.398
Meloxicam	2248.55 ± 80.12	6.32 ± 2.73	0.309 ± 0.009
	-	-	-

DISCUSSION

Our pilot data suggest a tissue-specific redox response to short-term meloxicam exposure. Meloxicam increased TAS and reduced OSI in the cauda epididymis, indicating a shift toward an enhanced antioxidant environment in this compartment. In contrast, TAS, TOS, and OSI in testicular tissue did not differ significantly between groups, although numerical trends were observed. Together, these findings imply that the epididymis may be more responsive to short-term COX inhibition–related modulation of oxidative balance than the testis under baseline (non-inflammatory) conditions.

Our study adds to a growing body of literature indicating that nonsteroidal anti-inflammatory drugs (NSAIDs) can influence oxidative stress and reproductive health in males. Uzun et al. (2015) reported that subchronic meloxicam treatment in rats significantly depressed testicular antioxidant defenses – including reduced activities of superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx), and glutathione levels – accompanied by histopathological damage to the seminiferous tubules. In their work, meloxicam (as well as naproxen, another NSAID) led to decreased sperm count and motility and clear structural injury in the testes without altering systemic hormone levels. Our observations of increased OSI and altered TAS/TOS in the testes are consistent with this mechanism suggesting that even short-term COX-2 inhibition can tip the pro-oxidant/antioxidant balance towards oxidative stress in testicular tissue. Notably, Haroun et al. (2020) likewise found that chronic high-dose meloxicam (8 mg/kg for 63 days) induced marked testicular toxicity in rats, characterized by decreased testis weight, impaired sperm parameters, and diminished antioxidant activity in the testis, along with severe tubular degeneration. Co-administration of the antioxidants curcumin or ascorbic acid effectively mitigated these changes, reinforcing the notion that meloxicam's deleterious effects on the testis are largely mediated by oxidative stress and can be counteracted by bolstering antioxidant defenses.

The epididymal findings from our study merit discussion in light of the epididymis's unique role and protection mechanisms. The epididymis is richly endowed with enzymatic antioxidants

– including SOD, CAT, GPx (such as the secreted GPX5), peroxiredoxins, and others – which collectively maintain a low ROS environment vital for sperm maturation. This robust antioxidant system is evolutionarily tuned to shield maturing spermatozoa from oxidative damage during their transit and storage in the epididymis (O'Flaherty, 2019). It is therefore notable that short-term meloxicam did not provoke as large a shift in OSI in the epididymis as in the testis (as suggested by our tissue-specific data). One interpretation is that the epididymal antioxidant network may buffer against transient oxidative perturbations, rendering the epididymal tissue more resilient to a 5-day meloxicam exposure. However, evidence from longer exposures indicates that the epididymis can indeed be adversely affected by NSAID-induced oxidative stress. For instance, Owumi et al. (2020) showed that a 14-day course of diclofenac in rats elevated lipid peroxidation and ROS/RNS levels and diminished antioxidant enzyme activities in both epididymal and testicular tissues. Such oxidative stress resulted in impaired sperm parameters and lower serum testosterone, whereas selenium co-treatment prevented these effects by suppressing nitrosative and oxidative stress in the reproductive tract. Similarly, Rodrigues et al. (2024) reported that oral meloxicam (1 mg/kg for 15 days) significantly reduced serum testosterone and sperm production, and lowered sperm counts in the proximal epididymal regions (caput/corpus) of rats. Interestingly, meloxicam in that study did not change cauda epididymal sperm count but did delay sperm transit and attenuate noradrenaline-induced contractions of the distal epididymal duct. Taken together, these findings indicate that while the epididymis has potent antioxidant safeguards, NSAID exposure (including meloxicam) can still disrupt epididymal function – whether via direct oxidative damage or indirectly through altered androgen levels and smooth muscle activity. The relatively modest oxidative changes we observed in the epididymis after 5 days of meloxicam may therefore represent the early stages of a process that, with prolonged exposure, could culminate in significant epididymal oxidative injury and functional deficits.

It is also important to consider the interplay between inflammation, ROS generation, and the antioxidant response in our model. Under physiological conditions, the testes exhibit an immune-privileged status with controlled inflammatory activity, whereas acute inflammatory insults can trigger significant ROS production and tissue damage. By virtue of its anti-inflammatory action, meloxicam might be expected to *reduce* oxidative stress in scenarios where inflammation is a driving factor (e.g. infection, torsion, or ischemia-reperfusion injuries). In line with this, therapeutic COX-2 inhibition has shown protective effects in models of testicular torsion – an extreme case of inflammation and oxidative injury. Gürocak et al. (2011) observed that meloxicam treatment attenuated tissue damage in an experimental torsion/detorsion model, significantly lowering malondialdehyde (MDA) levels (a lipid peroxidation marker) in ischemic testes. They concluded that aggressive management of the inflammatory response (including use of a COX-2 inhibitor like meloxicam) helps salvage testicular tissue by curbing inflammation-induced oxidative stress. Similarly, COX inhibitors such as ibuprofen have been reported to reduce oxidative injury in acute testicular ischemia-reperfusion when given prophylactically (Dokmeci et al., 2007; Özgür et al., 2022). These findings underscore a nuanced context-dependence: in pathological inflammatory states, meloxicam's antioxidant effect (via dampening inflammation) can outweigh its potential pro-oxidant side effects, resulting in net protection. In our study, however, healthy rats were treated in the absence of any overt inflammatory challenge. Under such normal conditions, systemic COX-2 inhibition may offer little anti-oxidative benefit and can instead tilt the balance toward oxidative stress by disrupting normal prostaglandin-mediated homeostasis. It is conceivable that in our short-term regimen, meloxicam induced a mild "oxidative inflammation" at the cellular level perhaps by subtle activation of immune cells or by causing transient drops in antioxidant enzyme expression – even though no clinical inflammation was present. Indeed, the testis contains resident macrophages and germ cells that can produce ROS; altering the COX-

2/PGE_2 axis might influence these cells' redox signaling and lead to an accumulation of oxidants.

CONCLUSION

In conclusion, short-term meloxicam administration appears to reinforce antioxidative capacity in the cauda epididymis, while no statistically significant changes were detected in testicular oxidative status under the present conditions. Given the limited sample size, these findings should be considered preliminary and warrant confirmation in larger, mechanistically oriented studies.

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AGE-DEPENDENT VARIATIONS IN SERUM AMH AND FSH LEVELS IN AWASSI EWES DURING AND OUTSIDE THE BREEDING SEASON

Özlem BEDİR

Harran University, Faculty of Veterinary Medicine, Department of Histology and Embryology, Şanlıurfa, Turkiye

ORCID ID: https://orcid.org/0000-0002-2558-1599

Deniz KORKMAZ

Harran University, Faculty of Veterinary Medicine, Department of Histology and Embryology, Şanlıurfa, Turkiye

ORCID ID: https://orcid.org/0000-0002-1257-4816

Ömer KORKMAZ

Harran University, Faculty of Veterinary Medicine, Department of Obstetrics and Gynecology, Şanlıurfa, Türkiye

ORCID ID: https://orcid.org/0000-0001-5179-2181

Aytaç AKÇAY

Ankara University, Faculty of Veterinary Medicine, Department of Animal Science and Nutrition, Department of Veterinary Biostatistics, Ankara, Türkiye

ORCID ID: https://orcid.org/0000-0001-6263-5181

Ayfer GÜLLÜ YÜCETEPE

Harran University, Faculty of Veterinary Medicine, Department of Microbiology, Şanlıurfa, Türkiye

ORCID ID: https://orcid.org/0000-0002-9842-3305

ABSTRACT

Introduction and Purpose: Reproductive efficiency in sheep has a direct impact on flock sustainability and productivity. Identifying reliable hormonal markers is essential for evaluating ovarian activity and selecting high-fertility females. Anti-Müllerian hormone (AMH), secreted by granulosa cells of preantral and small antral follicles, reflects the ovarian reserve, while follicle-stimulating hormone (FSH), produced by the anterior pituitary, regulates follicle recruitment and growth. Age, reproductive status, and season may alter their physiological

levels. However, limited data exist on these parameters in native Awassi (İvesi) ewes. This study aimed to determine age-dependent variations in serum AMH and FSH levels during and outside the breeding season. This study represents the preliminary phase of a TÜBİTAK 1001-funded project investigating molecular and histological aspects of ovarian function in Awassi ewes.

Materials and Methods: Blood samples were obtained from 200 clinically healthy female Awassi sheep, categorized into three age groups: 1 week old, 6 months old, and 1–5 years old (n = 20 per group). Sampling was conducted during both the breeding (autumn–winter) and non-breeding (spring–summer) seasons. Serum AMH and FSH levels were measured using ELISA. Statistical analyses were performed using t-tests and the Kruskal–Wallis test ($p < 0.05$).

Results: No significant differences were detected between 1-week-old and 6-month-old animals. During the breeding season, both AMH and FSH levels varied significantly among age groups ($p < 0.001$), with the highest concentrations observed in 5-year-old ewes. AMH was also elevated in the 1-, 2-, and 5-year-old groups compared to the 3- and 4-year-old groups. In the non-breeding season, hormone levels remained relatively stable ($p > 0.05$).

Discussion and Conclusion: Age and reproductive season have a significant influence on circulating AMH and FSH levels in Awassi ewes. Higher concentrations during the breeding season may indicate increased follicular activity and ovulatory potential. The stability of hormone levels outside the breeding season supports photoperiodic control of reproduction. AMH and FSH appear to be promising non-invasive biomarkers for improving reproductive management and selection strategies in sheep breeding programs.

Key Words: Awassi ewe; AMH; FSH; Breeding season; Ovarian activity

RETROSPECTIVE ANALYSIS OF CLINICOPATHOLOGICAL FEATURES OF GLOMUS TUMORS

Gamze ERKILINÇ

Bakircay Unıversıty Faculty of Medıcıne, Department of Medıcal Pathology, Izmir, Turkey,

ORCID ID: https://orcid.org/0000-0003-4704-7415

ABSTRACT

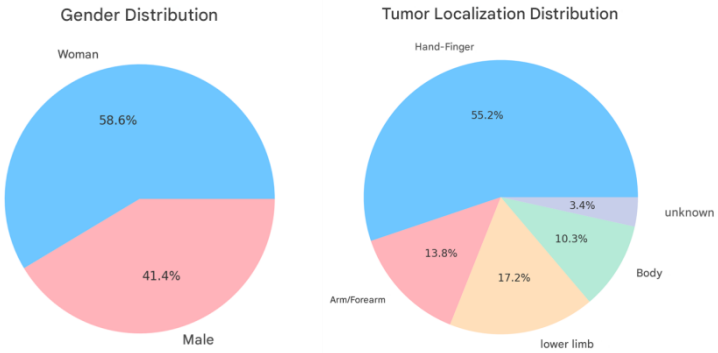
Introduction and Purpose: Glomus tumors are benign perivascular neoplasms that are frequently seen in the distal extremities, particularly in the nail beds, but can also be observed in other locations such as the trunk and abdomen. This study aimed to retrospectively evaluate the clinicopathological features of cases diagnosed with glomus tumors and to discuss the findings in light of current literature.

Materials and Methods: A total of 29 cases histopathologically diagnosed with glomus tumors between 2005 and 2025 were included in the study. H&E (Hematoxylin & Eosin) stained sections and, if available, immunohistochemical (IHC) stained preparations of materials routinely examined in our Department of Medical Pathology were retrospectively re-evaluated. Data on clinical findings, age, gender, tumor size, and location were obtained from the hospital automation system. The relationship between histopathological findings and clinical data was analyzed.

Results: Of the 29 cases included in the study, 17 were female (58.6%) and 12 were male (41.4%). The age range for all cases was 16–81 years, with a mean age of 47.6 years. The mean age was 45.1 years for women and 51.2 years for men. In terms of localization, the most common tumors were the hands and fingers. Fingers/nail beds were present in 16 cases (55.2%), the skin of the arms and forearms in 4 cases (13.8%), the lower extremities (thighs, legs, feet) in 5 cases (17.2%), and the trunk (gluteal region, back, coccyx) in 3 cases (10.3%). The location was not specified in the file in 1 case (3.4%). A multifocal glomus tumor was observed in 1 patient (3.4%). Tumor sizes ranged from 0.1 to 3.5 cm, with a mean tumor size of 0.7 cm. No statistically significant correlation was found between tumor size, gender, or tumor location ($p>0.05$). In patients with a clinical complaint, the most common presentation was pain. Immunohistochemical examination was performed in a total of 8 cases, and SMA, calponin, and vimentin were positive in all (n=8, 100%). CD34 staining was positive in tumor cells in 3 (3/8, 37.5%) of these cases. In these cases, the Ki-67 proliferation index was found to be between 1 and 2%. Histomorphological and/or immunohistochemical findings in all cases were consistent with benign glomus tumors; no evidence of malignancy was observed.

Discussion and Conclusion: Glomus tumors are benign perivascular tumors, most commonly seen in middle-aged women, as in our series, and most commonly located in the fingers and nail beds. Clinically, they most commonly present with pain and/or a small, palpable mass. Surgical excision is the mainstay of treatment, and the prognosis is quite good in cases where excision is performed with adequate surgical margins. However, our study demonstrates that glomus tumors can also occur in atypical and less expected locations, such as the arm, forearm, lower extremity, trunk, and coccyx. Therefore, glomus tumors should be considered in the differential diagnosis of chronic localized pain and small soft tissue masses.

Key Words: Glomus tumors, distal extremities, histopathology, perivascular tumors



EPIDEMIOLOGICAL RISK FACTORS AND MORTALITY IN ADULT CANCER PATIENTS WITH CARBAPENEM-RESISTANT *KLEBSIELLA PNEUMONIAE* BACTEREMIA

Gülsüm KAYA

Yalova University, Faculty of Medicine, Department of Medical Microbiology, Yalova, Turkey

ORCID ID: https://orcid.org/0000-0003-2517-5512

Aslı YILDIRIM

Yalova University, Faculty of Medicine, Department of Department of Medical Oncology, Yalova, Turkey

ORCID ID: https://orcid.org/0000-0002-2511-478X

Hasan ERGENÇ

Yalova University, Faculty of Medicine, Department of Department of Internal Medicine, Yalova, Turkey

ORCID ID: https://orcid.org/0000-0003-0519-0264

ABSTRACT

Introduction and Purpose: Carbapenem resistant *Klebsiella pneumonia* (CRKP) induced bloodstream infections in oncology patients constitute a significant problem worldwide. The aim of this study was to investigate the epidemiological risk factors and mortality rates associated with CRKP bloodstream infections in cancer patients.

Materials and Methods: This is a retrospective study conducted in the oncology clinic of a tertiary education and research hospital (January 2023–November 2025). Case records of patients treated for oncological malignancies and diagnosed with CRKP bacteremia were evaluated. For each patient, the first episode of CRKP bacteremia was included in the study. Demographic, clinical, and laboratory data were analyzed through the hospital information system. The obtained data were analyzed using SPSS 22.

Results: The mean age of the patients was 68.2 ± 12.5 years, and 64% were male. The most common malignancies were colon (26%), lung (16%), breast (14%), and prostate cancer (12%). Nearly half of the cohort (48%) had stage IV disease at the time of evaluation. The overall mortality rate was 72%. The mean length of hospital stay was 35.6 days, and CRKP bacteremia developed on average by day 25.4 of hospitalization. Hypertension (60%) and diabetes mellitus (44%) were the most prevalent comorbidities, while 52% of patients were receiving immunosuppressive therapy, 46% were undergoing chemotherapy, and 58% required total parenteral nutrition. Invasive device use was widespread: 86% had a urinary catheter, 72% required mechanical ventilation, 72% had a nasogastric tube, and 68% had a central venous catheter. Patients who developed CRKP bacteremia had a mean APACHE II score of 23.1 ±

8.3, indicating a high severity of illness. Laboratory findings demonstrated pronounced systemic inflammation, with markedly elevated CRP levels (156.1 ± 79.3 mg/L) and procalcitonin (13.1 ± 25.5 ng/mL), alongside anemia (Hgb 9.0 ± 1.5 g/dL) and lymphopenia.

Conclusion: CRKP bacteremia in adult cancer patients is associated with advanced age, high comorbidity burden, widespread use of invasive devices, and severe systemic inflammation. The observed 72% mortality underscores the critical risk and poor prognosis in this population, highlighting the urgent need for targeted preventive and early management strategies.

Key Words: Carbapenem resistant *Klebsiella pneumonia*; Bacteremia; Cancer patıents; Risk factors; Mortality

ETIOLOGY AND CLINICAL MANAGEMENT OF PAPILLEDEMA

PAPİLÖDEMİN ETİYOLOJİSİ VE TEDAVİSİ

Anıl Selim APA

Department of Ophtalmology, Isparta City Hospital, Isparta, Türkiye

Orcid ID: 0000-0002-3580-0062

ÖZET

Papil ödem birçok sebebe bağlı olarak kafa içindeki basıncın yükselmesi sebebiyle optik sinirin intraoküler bölümünün ödemlenmesidir. Optik siniri oluşturan retina ganglion hücresi aksonları, skleral lamina kribrozadan geçer ve görsel veriyi beyinde oksipital kortekse iletir. Lamina kribroza düzeyinde bu aksonların kompresyona uğraması, doku ödeminin gelişmesine ve hücreler arası matriks basıncının artmasına neden olur. İntrakranial basınç ile beyin omurilik sıvısı (BOS), kan ve beyin dokusu hacimleri ile serebral perfüzyon basıncı arasındaki basınç-hacim dinamiği Monro–Kellie doktrini ile açıklanır. Kafatası içindeki kan, BOS ve beyin dokusunun toplam hacmi sabit olduğu için, bu bileşenlerden herhangi birinin hacminde meydana gelen artış, diğerlerinde eşzamanlı bir hacim azalması ile dengelenmediğinde intrakranial basınç yükselir. İntrakranial yer kaplayan lezyonlar, serebral kanamalar, menenjit, travma, hidrosefali, idiyopatik intrakranial hipertansiyon gibi hastalıklarda da intrakranial basınç artışına bağlı papil ödem görülmektedir. Papil ödemin tanısı için binoküler biyomikroskopi ile fundus muayenesi oldukça önemlidir. Papil ödem akut dönemde fundus muayenesinde, optik disk sınırlarında silinme ve belirsizleşme, disk başında hiperemi, optik disk çukurluğunda kayıp ve optik disk etrafında kıymık tarzı hemoraji ile karşılaşılabilir. Görme kaybının temel mekanizmasının, aksoplazmik akımın bozulmasına bağlı olduğu düşünülmektedir. Yüksek intrakraniyal basınç, optik sinirleri çevreleyen BOS basıncında yükselmeye sebep olarak, göz içi basıncı ile retrolaminar basınç arasındaki basınç gradyanını bozmaktadır. Optik sinir içindeki artan doku basıncı ve bu nedenle oluşan iskemik ortam sebebiyle, aksoplazmik akımın düzenlenmesinde bozukluğa yol açmaktadır. Papilödem genellikle asemptomatik olabilir, fakat hastalarda baş ağrısı, bulantı ve kusma şikayetleri olabilir. Daha şiddetli olgularda intrakranial basıncın fazla yükselmesine bağlı olarak fokal nörolojik bulgular veya bilinç bulanıklığı gibi semptomlar görülebilir. Akut papil ödem olgularında optik siniri etkileyen diğer hastalıklara göre görme düzeyi çoğunlukla daha iyi düzeyde izlenir. Akut evrede papil ödem olgularında çoğu zaman görme alanı testinde kör noktanın genişlediği görülür. Çekilen RNFL (Retinal Nerve Fiber Layer) ile akut dönemde artış görülebilirken kronik dönemde eğer optik atrofi geliştiyse azalma da izlenebilir. Tedavide esas amaç altta yatan hastalığın tanısını koyarak uygun tedavi yöntemini seçmektir. Semptomları rahatlatmak amacıyla analjezikler ve antiemetikler kullanılabilir. İntrakranial hipertansiyonda BOS basıncının azaltılması amacıyla asetozolamid gibi diüretik tedavi başlanabilir. Ayrıca gerekli olgularda BOS drenajı, shunt cerrahisi ve kitle olan vakalarda kitlenin eksizyonu gibi cerrahi tedavi seçenekleri mevcuttur. Aşırı kilolu hastaların diyet programı ile kilo vermesi de önerilmektedir. Sonuç olarak papil ödemin asemptomatik olabilirken, hayatı tehdit edebilecek düzeye kadar ciddi sonuçları olabilen birçok hastalığın neticesinde ortaya çıkabilmektedir.

Hastalar detaylı anamnez ile muayene edilmelidir. Tedavide oftalmolog, nörolog ve beyin sinir cerrahlarının birlikteliği gerekmektedir.

Anahtar Kelimeler: Optik sinir, Papil ödem, Optik sinir ödemi

ABSTRACT

Papilledema is the swelling of the intraocular portion of the optic nerve due to an elevation in intracranial pressure secondary to various causes. The axons of the retinal ganglion cells that form the optic nerve pass through the scleral lamina cribrosa and transmit visual data to the occipital cortex in the brain. Compression of these axons at the level of the lamina cribrosa leads to the development of tissue edema and an increase in interstitial matrix pressure. The pressure-volume dynamics between intracranial pressure and the volumes of cerebrospinal fluid (CSF), blood, and brain tissue, along with cerebral perfusion pressure, are explained by the Monro–Kellie doctrine. Since the total volume of blood, CSF, and brain tissue within the skull is constant, an increase in the volume of any of these components results in elevated intracranial pressure when not compensated by a simultaneous volume reduction in the others. Papilledema associated with increased intracranial pressure is also seen in diseases such as intracranial space-occupying lesions, cerebral hemorrhages, meningitis, trauma, hydrocephalus, and idiopathic intracranial hypertension. Diagnosis of papilledema is highly dependent on fundus examination with binocular biomicroscopy. In the acute stage, fundus examination may reveal blurring and indistinctness of the optic disc margins, hyperemia of the disc head, loss of the optic cup, and splinter-like hemorrhage around the optic disc. The underlying mechanism of visual loss is thought to be related to the impairment of axoplasmic flow. High intracranial pressure causes an elevation in the CSF pressure surrounding the optic nerves, disrupting the pressure gradient between the intraocular pressure and the retrolaminar pressure. This leads to a defect in the regulation of axoplasmic flow due to the increased tissue pressure within the optic nerve and the resulting ischemic environment. Papilledema can often be asymptomatic, but patients may experience complaints such as headache, nausea, and vomiting. In more severe cases, symptoms such as focal neurological findings or confusion may occur due to excessive elevation of intracranial pressure. In cases of acute papilledema, the level of vision is often observed to be better compared to other diseases affecting the optic nerve. In the acute phase of papilledema cases, visual field testing often shows enlargement of the blind spot. While an increase may be seen in the measured Retinal Nerve Fiber Layer (RNFL) thickness in the acute phase, a decrease may also be observed in the chronic phase if optic atrophy has developed. The main goal of treatment is to identify the underlying disease and select the appropriate treatment method. Analgesics and antiemetics can be used to alleviate symptoms. In intracranial hypertension, diuretic therapy such as acetazolamide may be initiated to reduce CSF pressure. Furthermore, surgical treatment options are available in necessary cases, such as CSF drainage, shunt surgery, and excision of the mass in cases with lesions. Weight loss through a diet program is also recommended for overweight patients. In conclusion, papilledema can arise as a result of numerous diseases, with serious consequences ranging from an asymptomatic level to potentially life-threatening conditions. Patients must be examined with a detailed history. Treatment requires the collaboration of ophthalmologists, neurologists, and neurosurgeons.

Keywords: Optic Nerve, Papilledema, Optic Nerve Edema

BACTERIAL INFECTIONS IN NEWBORNS

İNTERLEUKİN-33 AS A POTENTİAL BİOMARKER OF

Nazrin HUSEYNOVA
Scientific - Research Institute of Pediatrics
ORCID ID: https://orcid.org/0000-0000-0000-0000

Naila RAHİMOVA
Scientific - Research Institute of Pediatrics
ORCID ID: https://orcid.org/0000-0002-1551-2979

Sabira HUSEYNOVA
Azərbaycan Medical University, Department of I Pediatric Diseases
ORCID ID: https://orcid.org/0009-0003-8086-0317

ABSTRACT

Search for new, prospective diagnostic biomarkers of bacterial systemic infections in newborns is an urgent and important task in modern neonatology. In recent years, new biomarkers of inflammation and tissue damage have been actively studied, and one candidate with prospects is the epithelial "alarmin" IL-33. IL-33 is a cytokine of the IL-1 family, produced by various cell types, including epithelial cells, endothelial cells, and fibroblasts. IL-33 consists of 270 amino acids with a relative molecular weight of approximately 30,000. Its gene is located on Chromosome 9p24.1.

Objective: To determine changes in interleukin-33 (IL-33) levels in newborns with bacterial infections.

Study Material & Methods: A prospective study that was conducted from 2023 to 2025 included 142 infants of different gestational ages. Gestational ages ranged from 25 to 41 weeks. Of these, 83 (58.5%) were boys and 59 (41.5%) were girls. The infants were divided into two groups. The main group included 116 newborns with neonatal bacterial infections: perinatal infections (16), neonatal sepsis (56), and pneumonia (44). The control group included 26 newborns with no signs of infection. IL-33 was measured using a standard solid-phase (sandwich) enzyme-linked immunosorbent assay (ELISA) using a commercial Sunred Bio (Shanghai) kit manufactured by Algen Diagnostic Medical LTD (Ankara, Turkey) on a BioScreen MS 500 analyzer (Stat Faxs USA).

Results & Discussion: The main clinical syndromes observed in the newborns included signs of respiratory, cardiovascular, and gastrointestinal damage. Upon admission to the hospital, the general condition of the newborns in the main group was severe in 56 (39.4%), very severe in 61 (43%), and preagonal in 2 (1.4%). In the main group, elevated levels of C-reactive protein (CRP) (41.8±3.6 g/L), procalcitonin (4.2±1.5 g/L), and presepsin (670.5±70.6 pg/mL) were observed. According to our study, serum IL-33 levels varied widely, from 2.14 to 136 ng/L. In newborns with bacterial infections, IL-33 levels reliably increased by 6.4 times compared to healthy newborns, averaging 29.7±2.5 ng/L ($p>0.001$).

Conclusions: Obtained data indicate evident activation of the innate immune system in newborns with bacterial infections. IL-33, as an “alarmin”, may reflect the degree of epithelial

damage and the systemic inflammatory response. In combination with traditional markers (CRP, presepsin, procalcitonin), IL-33 can improve the accuracy of early diagnosis of neonatal sepsis and pneumonia. However, studies of IL-33 in newborns are currently limited by small sample sizes, a lack of multicenter prospective data, validated reference intervals for different gestational ages, and insufficient information about the dependence of IL-33 levels on the type of pathogen and the type of sepsis.

Thus, elevated IL-33 serum levels in newborns with bacterial infections confirm its significant role in the pathogenesis of neonatal inflammatory conditions and indicate the potential for its use as an additional biomarker for early detection. Clinical implementation requires large multicenter studies, standardization of detection methods, and evaluation of the diagnostic efficacy of IL-33 in combination with existing laboratory markers.

Keywords: interleukin-33, newborns, bacterial infections.

RESULTS OF ANTIBIOTIC SENSITIVITY IN PATIENTS USING DOXYCYCLINE-ABSORBED COLLAGEN SPONGE

Kosayeva G.A.

Department of Surgical Diseases, Azerbaijan Medical University, Baku, Azerbaijan

ORCID: 0000-0003-0029-5833

Kosayev A.A.

Department of Surgical Diseases, Azerbaijan Medical University, Baku, Azerbaijan

ABSTRACT

Introduction: Pilonidal sinus disease is a common condition that primarily affects young adults. It is most frequently observed in individuals between the ages of 15 and 30, with a higher prevalence in males. Since the earliest descriptions of the disease, most clinicians believed that a pilonidal sinus was congenital in origin. The global incidence of infected pilonidal disease is approximately 25 cases per 100,000 individuals, affecting an estimated 0.7% of the population. At present, surgical excision of the pathological tissue remains the definitive treatment. However, despite advances in medical and surgical techniques – such as abscess drainage, open wound healing, and minimally invasive procedures – unsatisfactory outcomes, including high recurrence rates and postoperative complications, remain significant challenges. The main concerns in treatment are wound healing rate, infection prevention, postoperative pain management, and reducing recurrence rates.

Objective: This study aims to evaluate the effect of doxycycline-absorbed collagen sponges in conjunction with skin plastic surgery on the treatment outcomes for pilonidal sinus, with a particular focus on antibiotic sensitivity to enhance treatment efficacy.

Materials and Methods: A total of 105 patients with pilonidal sinus were enrolled and divided into two groups based on the treatment method. Group I (control) consisted of 54 patients who received conventional surgical treatment, while Group II (main group) included 51 patients who underwent surgery with doxycycline-absorbed collagen sponges combined with skin plastic surgery. Microbiological testing was conducted on all patient samples to evaluate antibiotic sensitivity.

Results: In the main group, surgical operations were performed on 51 patients with pilonidal sinus, using skin plastic surgery in combination with doxycycline-absorbed collagen sponges. The use of doxycycline-absorbed collagen sponges resulted in fewer inflammatory-infiltrative changes in the wound and surrounding soft tissues. The regression rate of the process was also faster in these patients. All microbiological samples taken from patients were tested for doxycycline sensitivity, and all were found to be sensitive to doxycycline. The five antibiotics showing the highest sensitivity were: Doxycycline (51 patients), Piperacillin/Tazobactam (50 patients), Cefuroxime (48 patients), Levofloxacin (46 patients), and Cefixime (46 patients). The three antibiotics with the lowest sensitivity were: Cefepime (32 patients), Ampicillin (33 patients), and Amikacin (34 patients). The 3 antibiotics with the lowest sensitivity: Cefepime (32 patients), Ampicillin (33 patients), Amikocin (34 patients)

Conclusion: Wound healing after pilonidal sinus surgery remains a challenge, with recurrent infections and unsatisfactory outcomes being common. The use of doxycycline-impregnated collagen sponge resulted in fewer inflammatory-infiltrative changes within the wound and in the surrounding soft tissues in the main group of patients, and in patients where such changes were observed, the rate of regression was faster. This study highlights the potential benefit of using doxycycline-absorbed collagen sponges in combination with skin plastic surgery as a promising treatment approach. However, further research is required to refine this technique and improve patient outcomes in the management of pilonidal sinus.

Keywords: Pilonidal sinus, doxycycline, microbiological results, antibiotic sensitivity

TRICHOMONIASIS AND ADVERSE BIRTH OUTCOMES

Elnara BAYRAMOVA

Department of Obstetrics and Gynecology, Azerbaijan Medical University, Baku, Azerbaijan, OrcİD: 0000-0001-7960-7865

Nurlana HASANOVA

Department of Obstetrics and Gynecology, Azerbaijan Medical University, Baku, Azerbaijan

Sevinj KARIMOVA

Department of Obstetrics and Gynecology, Azerbaijan Medical University, Baku, Azerbaijan, OrcİD: 0009-0001-7569-0152

Lala MUSAYEVA

Department of Obstetrics and Gynecology, Azerbaijan Medical University, Baku, Azerbaijan, OrcİD: 0009-0002-7408-0851

ABSTRACT

Introduction and Purpose. Trichomoniasis is the most common non-viral sexually transmitted infection (STI) worldwide. Approximately 156 million new cases occur worldwide annually among women and men aged 15–49 years. Given the burden of trichomoniasis experienced by women of child bearing age, the impact of this infection in pregnancy, particularly with regard to adverse birth outcomes (ABOs), is important to consider. Preterm delivery (PTD) occurred in 10% of all U.S. live births in 2018 and can be complicated by respiratory distress and death in infants.

Several prospective observational cohort studies in the 1980s investigated relationships between ABOs and trichomoniasis in pregnant women, noting associations between infection and PTD, LBW, and PROM. This literature influenced clinical practice, leading some providers to screen asymptomatic pregnant women for trichomoniasis in the absence of guidelines recommending this practice. However, in 2001, one study described increased risk of PTD in asymptomatic pregnant women receiving metronidazole (MTZ) for trichomoniasis, compared to placebo. This study raised concerns about trichomoniasis screening in pregnant women, leading current guidelines to only recommend testing for symptomatic pregnant women. Given that 70%−85% of infected women are asymptomatic, and untreated infections can last 3 months or longer, a better understanding of the perinatal effects of untreated trichomoniasis in pregnant women is essential.

Randomised studies and observational studies, including longitudinal cohort, case-control, and retrospective designs, conducted in any country were considered for inclusion without language restrictions. Case reports, case series, and other systematic reviews and meta-analyses were excluded. Articles presenting secondary analyses of already included studies were excluded.

Material and methods. Measures of association (odds ratio [OR], risk ratio [RR], hazard ratio [HR]) and precision (standard error, 95% CI) were extracted from included studies or calculated using reported raw data, if provided. When raw data included a cell with a value of zero, 0.5 was added to all cells to calculate a measure of association. Both crude and adjusted measures were extracted. In the event both were provided, the adjusted effect estimate was used for analysis. Given our rare outcomes, RRs were assumed to be approximate yet conservative estimates of the ORs.In studies where testing for T. vaginalis was performed at multiple points during pregnancy, data were collapsed across time points where data were provided. When data were not provided, results from one time point were selected.

Conclusion. In conclusion, trichomoniasis may be a major source of female reproductive morbidity given its association with PTD, PROM, and LBW.

Key Words: Trichomoniasis, adverse birth outcomes, non-viral sexually transmitted infection

MONOCLONALITY IN B CELL LYMPHOMA USING BIOMED-2 MULTIPLEX POLYMERASE CHAIN REACTION

Hind ALAIOUAT

Mohamed V University, Faculty of medicine and pharmacy, Department of pathology, Ibn Sina University Hospital, Rabat, Morocco

ORCID ID: https://orcid.org/0009-0003-0927-4251

Zakia BERNOUSSI

Mohamed V University, Faculty of medicine and pharmacy, Department of pathology, Ibn Sina University Hospital, Rabat, Morocco

ORCID ID: https://orcid.org/0009-0008-6628-4882

ABSTRACT

Introduction and Purpose: B cell lymphoma are a heterogeneous group of malignancies, and pose significant diagnostic challenges due to their clinical and molecular diversity. BIOMED-2 multiplex polymerase chain reaction (PCR) assessment of clonal immunoglobulin (IG) gee rearrangements has great potential to support the diagnosis of B cell lymphoma. This retrospective study aims to tested clonality rearrangements of IGH and incomplete IGH D-J, on formalin-fixed paraffin embedded (FFPE) tissue of patients with B cell lymphoma.

Materials and Methods: This study retrospectively analyzed 34 patients with FFPE specimens of patients with B cell lymphoma from one center. IGH and incomplete IGH D-J clonal gene rearrangements were analyzed using standard multiplex PCR and heteroduplex techniques.

Results: In our research, we were identified a total positive monoclonality in (32/34) of cases for IGH and in (13/34) of cases for incomplete IGH D-J. The positive clonality was detected in three frameworks (FRI, II, III) of IGH revealed in (16/34) of cases, in (10/34) and in (6/34) of cases to FRIII, FRII and FRI, respectively. Analysis of incomplete IGH D-J showed (10/34) and (3/34) rates of positive clonality for DH1–6-JH and DH7-JH, respectively. In the (2/34) of cases was no detected any gene rearrangements in both of incomplete IGH D-J and IGH genes.

Discussion and Conclusion: Detection of B-cell monoclonality using the polymerase chain reaction (PCR) is becoming crucial in diagnostic of B cell lymphoma. In our investigation, we were analyzing the usefulness of the BIOMED-2 protocols in the clonality detection of B cell lymphoma cases and compared findings with previous publications. Evans et al. revealed 79% monoclonal gene rearrangements, which consisted of FRI (68%), FRII (61%), FRIII (50%). Contradictory with our results, clonality gene rearrangements were detected by Catherwood et al. in 100% of cases. Other studies showed lower frequencies of IGH monoclonality (ranged between 40% - 80%). In conclusion, analysis of molecular clonality gene rearrangements is a helpful and credible technique for clonality detection in diagnosis of B cell lymphoma.

Key words: BIOMED-2, DLBCL, IGH clonality, Lymphoma

COLLATERAL SENSITIVITY PROFILE OF MULTIDRUG RESISTANT BACTERIA: *BACILLUS SUBTILIS*

Fardin Ahmed
Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh
Department of Life Sciences, Independent University, Bangladesh, Dhaka - 1229, Bangladesh

Noor Haliza Mahmud
Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh
Department of Life Sciences, Independent University, Bangladesh, Dhaka - 1229, Bangladesh

Snigdha Bhowmik
Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh
Department of Life Sciences, Independent University, Bangladesh, Dhaka - 1229, Bangladesh

Sharmin Zaman Emon
Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh

Md. Latiful Bari
Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh

Jannatul Ferdous
Department of Life Sciences, Independent University, Bangladesh, Dhaka - 1229, Bangladesh

ABSTRACT

Introduction: The emergence of multidrug-resistant microorganisms poses a serious threat to global health security. Collateral sensitivity, a phenomenon in which resistance to one antibiotic promotes susceptibility to another, suggests a possible technique for combating antimicrobial resistance. This study investigates collateral sensitivity in *Bacillus subtilis* to 28 regularly used antibiotics.

Objectives: To investigate collateral sensitivity, and compare the analyses of the control organism and drug-adapted strains of the same bacterium to investigate the resistance mechanisms.

Methods: The strain was separately cultured in serial passaging system, independently adapted with chloramphenicol (50 μg/ml), ampicillin (50 μg/ml) and rifampicin (50 μg/ml) supplemented Tryptone Soya Broth (TSB). And then, antibiotic sensitivity testing by Kirby Bauer method was conducted to compare between the control organism and antibiotic adapted ones. After completing independent adaptations, each adapted strain got further adaptation with another antibiotic to ensure multidrug resistance, e.g., a chloramphenicol-adapted strain will be adapted with ampicillin and rifampicin respectively.

Results: This study showed collateral sensitivity of *B. subtilis* to multiple drugs. Initially, the control showed resistance to 9 antibiotics but after adaptations it showed resistance for different antibiotics for three different antibiotics. It was previously resistant to those drugs, similarly, it

showed increased resistivity or decreased sensitivity for 11 and 7 different antibiotics respectively, where it showed sensitivity previously.

Conclusion: An individual antibiotic is able to change the antibiotic sensitivity pattern of specific bacteria towards multiple directions, and has different impacts on the antibiotic-bacterium series, where there is an opportunity to find alternative drugs that become more effective when a pathogen is resistant to a first-line antibiotic.

Keywords: Collateral sensitivity, multidrug resistance and adaptation.

TRI-FLORAL MEDIATED FABRICATION OF COPPER-DOPED ZINC OXIDE NANOPARTICLES TO CONTROL WOUND INFECTION CAUSED BY *ACINETOBACTER BAUMANNII*

Nandhana R

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Ranjani S

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

S. Hemalatha

School of Life Sciences, B.S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai 600048, India.

Abstract

The rise of multidrug-resistant *Acinetobacter baumannii* has increased the demand for sustainable antimicrobial strategies. In this study, copper-doped zinc oxide (Cu–ZnO) nanoparticles were synthesized by using tri-floral extract derived from *Clitoria ternatea*, *Ipomoea carnea*, and *Pongamia pinnata*, which acted as natural reducing and stabilizing agents, making the process simple, eco-friendly, and cost-effective. A distinct colour changes during synthesis indicated the synthesis of nanoparticles, which was confirmed through physicochemical characterization techniques. UV–Visible spectroscopy revealed characteristic absorption peaks of Cu doped ZnO nanoparticles, while FTIR analysis confirmed the involvement of floral phytochemicals in capping and stabilization of nanoparticles. XRD patterns verified the crystalline wurtzite ZnO structure with successful copper incorporation, and FESEM imaging showed well-defined nanostructures. EDX analysis further confirmed the elemental composition of the synthesized nanoparticles, whereas dynamic light scattering (DLS) and zeta potential analysis provided information on particle size distribution and colloidal stability. The antibacterial potential of the Cu doped ZnO nanoparticles was assessed in *A. baumannii* using MIC (Minimum inhibitory concentration), MBC (Minimum bactericidal concentration), and biofilm inhibition assays. All three techniques demonstrated significant antibacterial and antibiofilm activities, with copper doping likely enhancing antimicrobial effects through increased reactive oxygen species (ROS) generation and disruption of bacterial membranes. The nanoparticles effectively inhibited biofilm formation and maturation, suggesting strong potential to interfere with bacterial adhesion, survival, and biofilm-associated resistance. This study represents the tri-floral-mediated green-synthesized of Cu doped ZnO nanoparticles present a promising and sustainable nanomaterial with high efficacy for controlling *A. baumannii*-induced wound infections.

Keywords: Tri-floral synthesis, *Acinetobacter baumannii*, wound infection, Cu doped Zno nanoparticles, antibacterial activity

BURULI ULCER: A REVIEW

Agomoh, N, G

Ogbonnaya Onu Polytechnic, School of Science and Industrial Technology, Biology/Microbiology Department, Aba, Nigeria

https://orcid.org/0009-0008-0575-4350

Ukwen, C.O

Ogbonnaya Onu Polytechnic, School of Science and Industrial Technology, Biology/Microbiology Department, Aba, Nigeria

https://orcid.org/0009-0009-2500-6138

Abstract

Buruli ulcer, a neglected tropical disease caused by Mycobacterium ulcerans,, continues to affect underserved populations in various rural regions of West and Central Africa, as well as localized areas of Australia and Southeast Asia, Although it is not a parasitic infection, worthy of note is that its ecological links with aquatic environment and vector-related transmission hypotheses place it within conversations commonly shared with parasitic disease research. The progression of the disease is largely attributed to the cytotoxic lipid mycolactone, a potent toxin that gradually destroys skin and subcutaneous tissues. Because this damage often occurs without timely medical intervention, the resulting tissue loss can become extensive and may ultimately cause serious functional limitations in the affected area. Emerging studies have broadened insight into possible transmission routes, examining the contributions of aquatic organisms, small wildlife reservoirs and ecosystem disturbances. Improvements in molecular diagnostics have strengthened environmental monitoring, yet the precise mode of transmission remains unresolved. Clinically, the transition to antibiotic-centred therapy regimens based on rifampicin combination has reduced the dependence on surgical intervention. Nonetheless, obstacles such as delayed case identification, limited diagnostic access, and challenges in long-term wound management persist in endemic communities. Comprehensive strategies that integrate community awareness programs, rapid diagnostic tools, enhanced wound-care practices, and stronger surveillance networks are showing encouraging results. The convergence of Buruli ulcer with environmental shifts, socioeconomic inequities, and health-system constraints underscores the need for interdisciplinary collaboration spanning microbiology, parasitology, ecology, and public health. This seminar presents an updated synthesis of knowledge on the epidemiology, molecular pathology, ecological drivers, and control options for Buruli ulcer, while outlining critical research gaps and opportunities for coordinated action within a One Health perspective.

Keywords: buruli ulcer, pathology, control, One Health.

ANTIBACTERIAL EFFICACY ASSESSMENT OF HAND HYGIENE PRODUCTS COMMONLY USED IN BANGLADESH

Ronia Parvin

Environment Microbiology Laboratory, Department of Botany, University of Rajshahi, Rajshahi-6205, Bangladesh

ORCID ID: 0009-0000-0009-6039

Hasinay Zannat

Environment Microbiology Laboratory, Department of Botany, University of Rajshahi, Rajshahi-6205, Bangladesh

Farzana Ashrafi Neela

Environment Microbiology Laboratory, Department of Botany, University of Rajshahi, Rajshahi-6205, Bangladesh

Abstract

Hands are considered the primary route for transmitting microbes and infections to the individuals. The COVID-19 pandemic has emphasized the importance of hand hygiene in preventing the spread of infectious diseases. There are various types of hand hygiene products available in Bangladesh. Some of these products demand an effectiveness against microorganisms of 99%. Therefore, it was in our interest to know whether the brands that are available in the market can perform according to the manufacturer's instructions. The study was carried out at the Environmental Microbiology Laboratory, Department of Botany, University of Rajshahi, Bangladesh, for the period of March 2024-February 2025. In this study, a total of four liquid hand washes (Santoor, Lifebuoy, Sepnil, and Dettol) and three sanitizers (Savlon, Sepnil, and Hexisol) were used. Isolation of hand wash- and hand sanitizer-tolerant bacteria was done by the handprint method using nutrient agar medium. The effectiveness of hand washes and hand sanitizers against isolated bacteria was determined by the disk diffusion method. A total of 11 hand wash- and sanitizer-tolerant bacteria were identified by 16S rRNA sequencing. Of the 11 identified isolates, 6 were handwash-tolerant, including *Staphylococcus pasteuri*, *Rothia terrae*, two strains of *Staphylococcus hominis*, *Bacillus pumilus*, and *Bacillus safensis*; the remaining 5 isolates were sanitizer-tolerant, which included *Exiguobacterium mexicanum*, *Priestia flexa*, *Bacillus safensis*, *Kocuria flava*, and *Staphylococcus hominis*. The results from the handprint and disk diffusion assays revealed that Santoor handwash and Hexisol and Savlon hand sanitizers demonstrated superior efficacy against bacteria compared to the other products. This study highlights the benefits of using properly active hand sanitizers or liquid hand washes, especially in the context of the post-pandemic world.

Key words: Hand hygiene, COVID-19 pandemic, Bacteria, Hand washes, Hand sanitizers

EVALUATION OF POSTOPERATIVE COMPLICATIONS IN PATIENTS UNDERGOING WIDE PALMAR FASCIAL EXCISION FOR DUPUYTREN CONTRACTURE

GENİŞ PALMAR FASYA EKSİZYONU UYGULANAN DUPUYTREN KONTRAKTÜRÜ HASTALARINDA POSTOPERATİF KOMPLİKASYONLARIN DEĞERLENDİRİLMESİ

Mehmet Sabri BALIK

Recep Tayyip Erdoğan University, Faculty of Medicine, Department of Orthopaedic and Traumatology, Rize-Türkiye

ORCID ID: https://orcid.org/0000-0001-9729-3927

ABSTRACT

Introduction and Purpose: Dupuytren contracture is a fibrotic disorder of the palmar fascia that causes flexion contractures of the fingers, significantly impairing hand function. Surgical treatment is the most effective method to correct the contracture; however, postoperative complications may occur. The aim of this study was to evaluate complications in patients undergoing wide palmar fascial excision for Dupuytren contracture and to correlate these findings with clinical data.

Materials and Methods: This retrospective study included patients who underwent wide palmar fascial excision for Dupuytren contracture at the Orthopedics and Traumatology Clinic of Recep Tayyip Erdoğan University Training and Research Hospital. Demographic data, type of anesthesia, surgical technique, and postoperative complications were recorded. Patients with a history of hand trauma, infection, or peripheral nerve disease were excluded. Complications were classified as intraoperative or postoperative, and early and late postoperative outcomes were separately documented. The severity of complications and the need for additional interventions were also analyzed.

Results: The most common postoperative complications were hematoma, wound healing problems, marginal necrosis, and temporary limitation of motion. One patient with skin necrosis was treated with a full-thickness skin graft. Complications were correlated with patient age, comorbidities, and duration of surgery. No long-term sequelae were observed. The majority of patients achieved functional recovery with appropriate early rehabilitation.

Discussion and Conclusion: Although complications are inevitable in Dupuytren contracture surgery, proper surgical planning, selection of appropriate technique, and postoperative care can minimize these risks. The findings assist surgeons in anticipating complication risks and counseling patients preoperatively. The study demonstrates that wide palmar fascial excision can achieve good functional outcomes without long-term sequelae, emphasizing the importance of postoperative rehabilitation.

Key Words: Dupuytren Contracture; Surgical Treatment; Complications; Hand Surgery

ÖZET

Giriş ve Amaç: Dupuytren kontraktürü, el parmaklarında fleksiyon kontraktürü oluşturan fibrotik bir palmar fasya hastalığıdır ve gelişen kontraktür el fonksiyonlarını ciddi şekilde etkileyebilir. Cerrahi tedavi, kontraktürü düzeltmek için en etkili yöntemlerden biridir; ancak operasyon sonrası komplikasyonlar görülebilir. Bu çalışmanın amacı, Dupuytren kontraktürü nedeniyle geniş palmar fasya eksizyonu uygulanan hastalarda gelişen komplikasyonları değerlendirmek ve bu bulguları klinik verilerle ilişkilendirmektir.

Materyal and Metod: Çalışma, Recep Tayyip Erdoğan Üniversitesi Eğitim ve Araştırma Hastanesi Ortopedi ve Travmatoloji Kliniğinde Dupuytren kontraktürü tanısıyla geniş palmar fasya eksizyonu yapılan hastaların arşiv kayıtları incelenerek retrospektif olarak gerçekleştirilmiştir. Hastaların demografik verileri, anestezi türü, cerrahi teknik detayları ve postoperatif komplikasyonlar kaydedilmiştir. Önceki el travması, enfeksiyon veya periferik sinir hastalığı öyküsü olan hastalar çalışma dışı bırakılmıştır. Komplikasyonlar intraoperatif ve postoperatif olarak sınıflandırılmış, erken ve geç dönem bulguları ayrı ayrı dökümante edilmiştir. Ayrıca komplikasyonların şiddeti ve müdahale gerektirip gerektirmediği analiz edilmiştir.

Bulgular: Cerrahi sonrası en sık gözlenen komplikasyonlar hematom, yara iyileşme problemleri, marjinal nekroz ve geçici hareket kısıtlılığı olarak saptanmıştır. Bir hastada gelişen cilt nekrozu, cilt grefti ile tedavi edilmiştir. Komplikasyonlar, hastaların yaşı, komorbiditeleri ve cerrahi sürenin uzunluğu ile korelasyon göstermiştir. Geç dönemde komplikasyonlara bağlı sekel gelişmemiştir. Hastaların büyük çoğunluğu, erken dönemde uygun rehabilitasyon ile fonksiyonel geri kazanım sağlamıştır.

Tartışma ve Sonuç: Dupuytren kontraktürü cerrahisinde komplikasyonlar kaçınılmaz olmakla birlikte, doğru cerrahi planlama, uygun cerrahi teknik seçimi ve postoperatif bakım ile bu riskler azaltılabilir. Bulgular, cerrahların komplikasyon risklerini önceden değerlendirmesine ve hastaları bilgilendirmesine yardımcı olmaktadır. Çalışma, geniş palmar fasya eksizyonu sonrası komplikasyonlara bağlı sekel gelişmeden iyi fonksiyonel sonuç elde edilebileceğini göstermektedir ve cerrahi sonrası rehabilitasyonun önemini vurgulamaktadır.

Key Words: Dupuytren Kontraktürü; Cerrahi Tedavi; Komplikasyon; El Cerrahisi

HISTOPATHOLOGICAL EVALUATION OF TISSUE SAMPLES IN PATIENTS UNDERGOING SURGICAL TREATMENT FOR CARPAL TUNNEL SYNDROME

KARPAL TÜNEL SENDROMU NEDENİYLE CERRAHİ TEDAVİ UYGULANAN HASTALARDAN ALINAN DOKU ÖRNEKLERİNİN HİSTOPATOLOJİK DEĞERLENDİRİLMESİ

Mehmet Sabri BALIK[1]

Recep Tayyip Erdoğan University, Faculty of Medicine, Department of Orthopaedic and Traumatology, Rize-Türkiye

ORCID ID: https://orcid.org/0000-0001-9729-3927

ABSTRACT

Introduction and Purpose: Carpal tunnel syndrome (CTS) is a clinical condition caused by compression of the median nerve within the carpal tunnel and is one of the most common entrapment neuropathies of the upper extremity. Although repetitive hand and wrist movements, rheumatoid arthritis, pregnancy, and endocrine disorders contribute to its etiology, most cases are idiopathic. CTS is diagnosed based on clinical findings, physical examination, and electromyography (EMG). In addition to conservative treatments, surgical release of the carpal tunnel is a common therapeutic approach. The aim of this study was to evaluate the histopathological characteristics of tissue samples obtained during surgical treatment and to correlate these findings with clinical data.

Materials and Methods: Patients diagnosed with CTS at the Orthopedics and Traumatology Clinic of Recep Tayyip Erdoğan University Training and Research Hospital were included. Diagnosis was confirmed by clinical findings, physical examination, and EMG, and tissue samples were collected during surgical carpal tunnel release. Patients with a history of trauma, previous hand surgery, or peripheral nerve disease were excluded. Tissue samples were histopathologically evaluated for inflammation, fibrosis, synovial hyperplasia, and vascular changes. Clinical data were compared with histopathological findings.

Results: The most common histopathological findings were fibrosis, synovial thickening, and inflammatory changes. These findings correlated with symptom severity and clinical data.

Discussion and Conclusion: Fibrosis, synovial hyperplasia, and inflammatory changes observed in carpal tunnel tissues support the pathophysiological processes resulting from median nerve compression. Findings indicate that CTS is associated not only with mechanical nerve entrapment but also with soft tissue changes, highlighting its multifactorial etiology. Histopathological evaluation may serve as a guiding tool for surgical planning and treatment strategies.

Key Words: Carpal Tunnel Syndrome; Median Nerve; Histopathology; Surgical Treatment

ÖZET

Giriş ve Amaç: Karpal tünel sendromu (KTS), median sinirin karpal tünel içinde basıya uğraması sonucu ortaya çıkan bir klinik tablodur ve üst ekstremitenin en sık görülen tuzak

nöropatilerinden biridir. Tekrarlayıcı el ve el bileği hareketleri, romatoid artrit, gebelik ve endokrin bozukluklar etiyolojide rol oynasa da olguların önemli bir kısmı idiyopatiktir. KTS tanısı; klinik bulgular, fizik muayene ve elektromiyografi (EMG) ile doğrulanmaktadır. Tedavide konservatif yöntemlerin yanı sıra cerrahi olarak karpal tünelin gevşetilmesi de uygulanmaktadır. Bu çalışmanın amacı, cerrahi tedavi sırasında elde edilen karpal tünel doku örneklerinin histopatolojik özelliklerini değerlendirmek ve bu bulguları klinik verilerle ilişkilendirmektir.

Material ve Metod: Bu çalışma, Recep Tayyip Erdoğan Üniversitesi Eğitim ve Araştırma Hastanesi Ortopedi ve Travmatoloji polikliniğine başvuran KTS tanılı hastalar üzerinde gerçekleştirilmiştir. Arşiv kayıtları incelenerek, KTS tanısı klinik bulgular, fizik muayene ve EMG ile doğrulanan ve cerrahi tedavi uygulanarak karpal tünelden doku örnekleri alınan hastalar çalışmaya dahil edilmiştir. Anamnezde travma veya el cerrahisi öyküsü olan, periferik sinir hastalığı bulunan hastalar çalışma dışı bırakılmıştır. Alınan doku örnekleri histopatolojik olarak inflamasyon, fibrozis, sinovyal hiperplazi ve damar değişiklikleri açısından incelenmiştir. Tüm klinik veriler hasta dosyalarından elde edilerek histopatolojik bulgularla karşılaştırılmıştır.

Sonuçlar: Cerrahi sırasında elde edilen doku örneklerinde en sık fibrozis, sinovyal kalınlaşma ve inflamatuvar değişiklikler saptanmıştır. Histopatolojik bulgular, semptom şiddeti ve klinik verilerle uyum göstermiştir.

Tartışma ve Sonuç: KTS tanılı olguların karpal tünelinden alınan doku örneklerinde fibrozis, sinovyal hiperplazi ve inflamatuvar değişikliklerin belirlenmesi, median sinirin basıya uğraması sonucu gelişen patofizyolojik süreci doğrulamaktadır. Literatürdeki benzer çalışmalar, KTS'nin yalnızca sinir sıkışması ile değil, çevresel yumuşak doku değişiklikleri ile de ilişkili olduğunu göstermektedir. Elde edilen histopatolojik bulgular, semptom şiddeti ve klinik verilerle uyumlu bulunmuş olup, KTS'nin multifaktöriyel etiyolojisini vurgulamaktadır. Bu bulgular, cerrahi planlamada ve tedavi stratejilerinde yol gösterici bilgiler sunmaktadır ve yumuşak doku patolojilerinin KTS gelişiminde önemli rol oynadığını göstermektedir.

Anahtar Kelimeler: Karpal Tünel Sendromu; Median Sinir; Histopatoloji; Cerrahi Tedavi

EFFECT OF ER, CR: YSGG LASER ON ADHESION IN BLEACHED DENTIN

BEYAZLATILMIŞ DENTİNDE ER, CR: YSGG LAZERİN ADEZYONA ETKİSİ

Destina KALKAN

Near East University, Department of Restorative, Lefkoşa/KKTC

ORCID ID: https://orcid.org/0009-0009-9432-8181

Tağmaç ÖZBERK

Near East University, Department of Restorative, Lefkoşa/KKTC

ORCID ID: https://orcid.org/0009-0004-3912-6994

ABSTRACT

Introduction and Purpose: This study aimed to evaluate the micro-shear bond strength of a self-etch and a total-etch adhesive after application of Er, Cr: YSGG laser at different powers and durations to bleached dentin.

Materials and Methods: Thirty-six human dentin slices were used. The samples were divided into a negative control group (n=6) and bleached groups (n=30). The bleached groups received Er, Cr: YSGG laser treatments at different powers and durations. Four adhesive systems (Self-etch: SEB, Total-etch: PBNT, Universal adeziv: Adhese Universal, G-Premio Bond) were applied, and bond strength was tested at a speed of 1 mm/min.

Results: Data showed that surface treatment with Er, Cr: YSGG laser could enhance adhesion depending on the type of adhesive used and the laser parameters applied.

Discussion and Conclusion: Er, Cr: YSGG laser treatment may serve as an alternative approach for immediate permanent restoration of devital bleached teeth in clinical practice.

Key Words: bleaching, ErCr: YSGG laser, adhesive system, bond strength.

ÖZET

Giriş ve Amaç: Bu çalışmada, beyazlatma yapılmış dentine farklı güç ve sürelerde uygulanan Er,Cr: YSGG lazer sonrası bir self-etch ve bir total-etch adezivin mikro-makaslama bağlanma dayanımlarının incelenmesi amaçlanmıştır.

Materyal ve Method: Çalışmada 36 adet insan dentin kesiti kullanıldı. Örnekler negatif kontrol grubu (n=6) ve beyazlatma uygulanan gruplara (n=30) ayrıldı. Beyazlatılmış gruplara farklı güç ve sürelerde Er,Cr: YSGG lazer uygulandı. Dört farklı adeziv sistem (Self etch: SEB, Total-

etch: PBNT, Universal adeziv: Adhese Universal, G-Premio Bond) ile bağlanma dayanımları değerlendirildi. Testler 1 mm/dk hızla gerçekleştirildi.

Bulgular: Er,Cr: YSGG laser treatment may serve as an alternative approach for immediate permanent restoration of devital bleached teeth in clinical practice.

Sonuç: Er,Cr: YSGG lazer uygulaması, özellikle devital olarak beyazlatılmış dişlerin aynı seansta daimi olarak restore edilmesi gereken durumlarda diş hekimleri için alternatif bir yöntem olarak değerlendirilebilir.

Anahtar Kelimeler: Beyazlatma, ErCr: YSGG lazer, adeziv sistem, bağlanma dayanımı.

NEW EXPERIMENTAL MODEL OF ACUTE PANCREATITIS WITH ADJUSTABLE DEGREE OF DESTRUCTIVE CHANGES

Hilala Fariz Abbasova

Chief Laboratory Assistant, Doctoral Student of Department of Surgical Diseases 3, Azerbaijan Medical University, Baku, Azerbaijan.

ORCID: https://orcid.org/ 0000-0002-7880-1073

ABSTRACT

Relevance. Studying the pathogenesis of acute pancreatitis and investigating new treatment strategies are among the main scientific directions in emergency surgery. In this context, experimental models of acute pancreatitis remain an important research object. Currently, all experimental models of acute pancreatitis are divided into invasive and non-invasive. Invasive models are more suitable for studying primary necrosis of the pancreas that develops without apparent inflammation and are usually accompanied by the death of animals within 24 hours, which does not allow for dynamics in studying the pathophysiological mechanisms of acute pancreatitis development. The main drawback of non-invasive models is the lack of necrosis in the pancreas parenchyma. They are more suitable for studying the pathophysiological mechanisms underlying the edematous form of acute pancreatitis (Moghassemi, S.; Dadashzadeh, A.,2024)

Study Objective. To create an experimental model of acute pancreatitis that takes into account both the destructive and inflammatory components of the pathological process, allowing for dynamic study of the pathophysiological mechanisms of acute pancreatitis development.

Materials and Methods. The proposed experimental model of acute pancreatitis was created by introducing a special complex consisting of a mixture of bile and chloroform in a ratio of 2:1 at a dosage of 5-10 mg per 100 g of body weight under anesthesia after performing a superior laparotomy. The introduction of 1 ml of the bile and chloroform mixture into the tissue of the pancreas using a syringe with a fine needle was performed at various locations: at the junction of the head and body of the pancreas, as well as at the junction of its body and tail to a depth of 1-3 mm. The introduction of the bile and chloroform mixture into the pancreatic tissue causes inflammation (due to bile) and necrosis (due to chloroform), which allows for the creation of a mixed form of acute pancreatitis (Carrascal, M.; Areny-Balagueró, A.,2022).

The work was conducted in accordance with the rules established by the European Commission overseeing laboratory and other experiments involving experimental animals of various species. Morphological studies were conducted on 48 rabbits in an intact state (12 rabbits), as well as 24, 48, and 72 hours after modeling acute pancreatitis (12 rabbits in each series).

Results and Discussion. Experimental studies showed that within the first 24 hours after modeling acute pancreatitis, against the backdrop of developing microcirculatory blockage, there is simultaneous (parallel) activation of the drainage and transport functions of the micro-lymphatic circulation system. By the third day, a complete blockage of the microcirculatory system occurs, while the micro-lymphatic link, despite the destruction of some lymphatic capillaries, largely continues to perform its drainage and transport functions (Molnar R., Madacsy T.,2020). Experimentally, at the morphological level, it was established in animals with the new model of acute pancreatitis that the pathological activation of autoenzymes in the

parenchyma and ductal system of the pancreas is only a "trigger" moment, while the leading role in the pathogenesis of the development and outcome of this pathology belongs to progressive disorders in intra-organ microcirculation (Zhang, X.; Xie, H.; Liu, Z.; Zhang, J.;2023).

Conclusion. The newly developed model of acute pancreatitis is closely aligned with clinical reality and has no significant drawbacks characteristic of other models, as both inflammatory and destructive components of the etiopathogenesis of this disease have been considered in its creation. The advantages of the proposed model include good reproducibility, simplicity of execution, the ability to extrapolate the pathological process, and control over the mortality rate. Morphological changes in the pancreas with this model, along with the site and depth of injection, also directly depend on the dose of the introduced mixture. The experimenter has the opportunity to "manage" the severity of the disease. Moreover, simple dosage regulation of the degree of inflammatory-destructive impact allows for the creation of various clinical forms of acute pancreatitis – both edematous and destructive – in different experimental animals (small, medium, large), with or without manifestations of parapancreatitis.

Based on the results of the above experimental studies, which demonstrate the differences and certain advantages of the developed new experimental model of acute pancreatitis, we have submitted an application to the Eurasian Patent Organization and obtained Eurasian Patent No. 051244 for the invention.

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PRENATAL EXPOSURE TO ETHANOL INDUCES ALTERATIONS IN PURKINJE NEURONS POTENTIALLY LINKED TO SENSORIMOTOR DEFICITS

Kamal Smimih

Biological Engineering Laboratory, Faculty of Sciences and Techniques (FST), Sultane Moulay Slimane University, Beni Mellal 23000, Morocco;

Fatima Ez-Zahraa Saad

Laboratory of Anthropogenic, Biotechnology and Health, Nutritional Physiopathologies, Neuroscience and Toxicology Team, Faculty of Sciences, Chouaib Doukkali university, El Jadida, 24000, Morocco;

Manal Khanouchi

Laboratory of Anthropogenic, Biotechnology and Health, Nutritional Physiopathologies, Neuroscience and Toxicology Team, Faculty of Sciences, Chouaib Doukkali university, El Jadida, 24000, Morocco;

Mohamed Merzouki

Biological Engineering Laboratory, Faculty of Sciences and Techniques (FST), Sultane Moulay Slimane University, Beni Mellal 23000, Morocco;

Omar El Hiba

Laboratory of Anthropogenic, Biotechnology and Health, Nutritional Physiopathologies, Neuroscience and Toxicology Team, Faculty of Sciences, Chouaib Doukkali university, El Jadida, 24000, Morocco;

ABSTRACT

Prenatal alcohol exposure (PAE) is recognized as a major public health concern due to its profound and lasting effects on the central nervous system (CNS), as well as its capacity to induce a range of physical and mental abnormalities in the developing fetus, ultimately leading to neurobehavioral deficits in affected individuals. The present study aimed to assess the nutritional, biometric, and morphometric consequences of PAE in a mouse model.

Female mice with positive vaginal plugs were divided into 3 groups: group 1: Ethanol+Pyrazole (Et+Pyr), received 1g/kg ethanol i.p. in two doses (D10 and D13 of pregnancy). Group 2: Pyrazole (Pyr), received an i.p. injection of 100mg/kg pyrazole on the same days as the Et+Pyr group, while Group 3: Control (C), received an equivalent volume of saline solution (NaCl 0.9%), in an equal volume on the same days.

Later, offspring were assessed using the CatWalk behavioral test to assess motor function, before undergoing a histological study of the cerebellum. Our data show a clear alteration in locomotor patterns in mice exposed to alcohol prenatally (EPA) compared to the pyrazole and control groups, with a significant difference in performance scores for this test. In addition,

histological examination of the cerebellar Purkinje cell layer revealed signs of neuronal degeneration in mice that received ethanol treatment.

These results highlight the potent neurotoxic effect of a single dose (1 g/kg) of ethanol administered during the prenatal period on locomotor performance and suggest a probable alteration of the neurons controlling locomotion, particularly Purkinje neurons.

Keywords: *prenatal alcohol exposure, CatWalk behavioral test, Purkinje neurons, mice.*

THE COMBINED EFFECTS OF NEUROINFLAMMATION AND AMMONIA NEUROTOXICITY CONTRIBUTE TO COGNITIVE IMPAIRMENT IN CHRONIC HEPATIC ENCEPHALOPATHY

Manal Khanouchi

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco

ORCID ID: https://orcid.org/0000-0002-7935-3049

Bilal EL-Mansoury

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco

ORCID ID: https://orcid.org/0000-0002-2583-7515

Arumugam R. Jayakumar

University of Miami School of Medicine, Miami FL, USA.

Omar El Hiba

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco

ORCID ID: https://orcid.org/0000-0002-0581-4164

ABSTRACT

Introduction and Purpose: Chronic hepatic encephalopathy (CHE) is a major neuropsychiatric complication of chronic liver disease (CLD), characterized by progressive cognitive dysfunction, motor impairment, and neuroinflammation. However, chronic animal models mimicking long-term liver injury remain insufficiently explored. Therefore, the present study aimed to characterize memory deficits and examine microglial activation in a chronic model of HE induced by thioacetamide (TAA) administration.

Materials and Methods: Chronic liver dysfunction was induced in five-month-old male Wistar rats through repeated intraperitoneal injections of thioacetamide (TAA). Liver injury and fibrosis were assessed using biochemical markers including ALT, AST, MMP-3, MMP-9, TIMP-1, and P3NP, and further confirmed by hepatic histopathology. Cognitive performance was evaluated using the Morris Water Maze and Y-maze tests. Microglial activation was examined by Iba1 immunohistochemistry in the cerebral cortex and hippocampal subfields (CA1, CA3, and DG). Inflammatory cytokines (TNF-α, IL-1β, IL-6) and brain ammonia levels were measured to assess neuroinflammatory status and hyperammonemia.

Results: TAA-treated rats exhibited pronounced liver injury, reflected by significant elevations of ALT and AST, decreased serum levels of MMP-3 and MMP-9, and increased TIMP-1 and P3NP, consistent with advanced hepatic fibrosis. Behavioral analyses revealed significant memory impairment in both the Morris Water Maze and Y-maze tests following TAA exposure. Immunohistochemical evaluation showed marked increases in Iba1 immunoreactivity in the cortex and hippocampal regions. Furthermore, CHE rats displayed elevated cortical levels of pro-inflammatory cytokines (TNF-α, IL-1β, IL-6) and a threefold increase in brain ammonia concentration.

Discussion and Conclusion: The current findings demonstrate that chronic TAA-induced liver dysfunction leads to hyperammonemia and pronounced neuroinflammation, which collectively contribute to significant memory deficits. This chronic model of hepatic encephalopathy provides valuable insights into the mechanistic links between persistent liver injury, neuroinflammation, and cognitive impairment, and may serve as a relevant platform for future therapeutic investigations.

Key Words: Ammonia, biochemical analysis, brain cytokines, chronic liver disease, chronic hepatic encephalopathy, cortex, hippocampus, Iba1, memory, microglial activation.

THE COMBINED EFFECTS OF NEUROINFLAMMATION AND AMMONIA NEUROTOXICITY CONTRIBUTE TO COGNITIVE IMPAIRMENT IN CHRONIC HEPATIC ENCEPHALOPATHY

Manal Khanouchi

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco;

Bilal EL-Mansoury

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco;

Arumugam R. Jayakumar

University of Miami School of Medicine, Miami FL, USA.

Omar El Hiba

Laboratory of Anthropogenetics, Biotechnology, and Health, Team Nutritional physiopathology, Neurosciences, and Toxicology, Faculty of Sciences, Chouaib Doukkali University, Av. Des facultés, 24000, El Jadida. Morocco;

Abstract

Chronic hepatic encephalopathy (CHE) is a neuropsychiatric complication of chronic liver disease (CLD) characterized by neuropsychiatric dysfunction, cognitive impairment, and motor abnormalities. This study aimed to characterize memory deficit and examine microglial activation in a chronic model of HE (CHE). Chronic liver dysfunction was induced in five-month-old male Wistar rats through repeated administration of thioacetamide (TAA). Liver injury and fibrosis were evaluated using biochemical markers (ALT, AST, MMP-3, MMP-9, TIMP-1, and P3NP) and confirmed by hepatic histopathology. TAA-treated rats exhibited a marked elevation of ALT and AST, a significant decrease in MMP-3 and MMP-9, and increased serum levels of TIMP-1 and P3NP, consistent with advanced hepatic fibrosis. Cognitive performance was assessed using the Morris water maze and Y-maze tests, which both demonstrated significant memory impairment in TAA-treated animals. In addition, our results showed increased Iba1 immunoreactivity in the cerebral cortex and the hippocampal subfields (CA1, CA3, DG). Interestingly, they have also shown increased inflammatory cytokines (TNF-α, IL-1β, IL-6) in the cortex of CHE rats. Alternatively, CHE rats exhibited a threefold increase in brain ammonia. Together, these findings demonstrated that chronic liver injury induces hyperammonemia, possibly driven by neuroinflammation, leading to significant memory deficits.

Keywords: Ammonia, biochemical analysis, brain cytokines, chronic liver disease, chronic hepatic encephalopathy, cortex, hippocampus, Iba1, memory, microglial activation.

ANTI-INFECTIVE PROPERTIES OF MOROCCAN *MYRTUS COMMUNIS L.* ESSENTIAL OIL

AKHELLOUF Fatima Zahra

Integrative Biology Laboratory, Department of Biology, Faculty of Science Ain Chock, Hassan II University, Casablanca, Morocco.

Department of Parasitology-Mycology, National Institute of Hygiene, Rabat, Morocco.

QASMAOUI Aicha

Medical Bacteriology Laboratory, National Institute of Hygiene, Rabat, Morocco.

OUAKRIM Houcine

Medical Bacteriology Laboratory, National Institute of Hygiene, Rabat, Morocco.

AZZOUZI Maryame

Integrative Biology Laboratory, Department of Biology, Faculty of Science Ain Chock, Hassan II University, Casablanca, Morocco.

ADLAOUI El Bachir

Department of Parasitology-Mycology, National Institute of Hygiene, Rabat, Morocco.

AMARIR Fatima

Integrative Biology Laboratory, Department of Biology, Faculty of Science Ain Chock, Hassan II University, Casablanca, Morocco.

CHAROF Reda

Medical Bacteriology Laboratory, National Institute of Hygiene, Rabat, Morocco.

Abstract

Faced with the problem that has been raised for several years now of the increase in the appearance of multi-resistant pathogenic bacterial strains, many researchers have become interested in the use of natural molecules with powerful antibacterial properties. In addition, changing attitudes and the growing rejection of ‘all things chemical’ are opening the door to a ‘return to nature’. *Myrtus communis L. (M. communis)*, commonly known as myrtle, is an aromatic shrub of the Myrtaceae family, widespread throughout the Mediterranean basin. In Morocco, common myrtle grows spontaneously in the cork oak and kermes oak forests of the Rif, the Central Plateau, the Middle Atlas and the High Atlas. *M. communis* is a plant that has

attracted a great deal of interest among scientists. It is known for its digestive, antiseptic, antimicrobial, astringent and toning properties. Its bioactive compounds, including terpenes, phenolic acids, flavonoids and anthocyanidins in various plant organs, contribute to its haemagglutinating, anti-hyperglycaemic and anti-inflammatory effects. The main objective of this study is to evaluate the antibacterial activity of *M. communis* essential oil (MC-EO) against the opportunistic pathogen *Staphylococcus aureus (S. aureus)*: ATCC strain and nosocomial strain. The antibacterial activity of MC-EO was evaluated using the disc diffusion technique. The results obtained demonstrated that the isolated essential oil has significant antibacterial activity against the bacteria studied. The inhibition zones recorded on *S. aureus* ATCC (12.3±1.1) and S. aureus (12±1) nosocomial strains were almost identical. These results are promising and provide scientific validation for the therapeutic use of this species. Thus, the effect of natural substances extracted from medicinal plants could well rival that of antibiotics.

Keywords: *Myrtus communis L.*, leaves, essential oil, antibacterial activity and *Staphylococcus aureus.*

TITLE: DIETARY TRADE-OFFS IN HIGHER EDUCATION: A QUANTITATIVE COST-NUTRITION MODEL

Palash Kumar Das

Department ofMathematics, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh Place of work : Dormitory 2(D-2) Hall ,(HSTU)

Abstract

This study analyzes the effectiveness of linear programming (LP) methods in minimizing costs within budgets for student nutrition planning and small-scale agribusiness food formulation. In both cases, decision-making within limited resources while maintaining nutritional value is a challenge, where conventional empirical methods are not optimized. In the education-related field, a mathematical model is proposed for residential students, which helps meet nutritional needs at the lowest cost through daily food selection. According to the results, it is possible to implement a balanced diet plan for only 80 taka per day. In the agriculture-based field, since 70% of the production cost of small-scale farm food formulation is related to food, an optimization model is developed using local ingredients. It incorporates information on nutritional value, market prices, and industry practices. The model significantly reduces costs compared to conventional methods and provides insights into realistic decision-making through sensitivity analysis. The two models presented together show that LP-based optimization methods can play a significant role in cost-efficiency and effective use of resources.

Keywords: Nutrition planning; Linear programming (LP) methods; The agriculture-based field; Small-scale farm food formulation; LP-based optimization.

EFFECTS OF ACUTE AND CHRONIC HIGH-INTENSITY INTERVAL TRAINING ON COGNITIVE AND PHYSICAL PERFORMANCE IN HIGH SCHOOL ADOLESCENTS

Rochdi DAIBI
Laboratory of Biology and Health, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

Jihane HILALI
Institute of Sports Professions, Interdisciplinary Laboratory of Sport Sciences, Ibn Tofail University, Kenitra, Morocco

Jaouad ROUANE
Laboratory of Biology and Health, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

Youssef SQALLI HOUSSAINI
Laboratory of Biology and Health, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

El Mokhtar ELOUALI
Institute of Sports Sciences, Hassan I University, Settat, Morocco

Fouad BOUGHANZAI
Laboratory of Electronic Systems, Information Processing, Mechanics and Energy

Walid Bouzid
Institute of Sports Sciences, Hassan I University, Settat, Morocco

Abdelhalem MESFIOUI
Laboratory of Biology and Health, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco

Abstract

Introduction: High-Intensity Interval Training (HIIT) is well established for its physiological benefits; however, its impact on cognitive performance—particularly in adolescents—remains insufficiently investigated. This study aimed to examine both the acute and chronic effects of HIIT on cognitive performance, specifically selective attention, as well as physical performance in high school students.

Methods: Over a 6-week period, the experimental group (n = 23) completed a structured HIIT program, while the control group (n = 10) completed only the Stroop cognitive assessment. Pre- and post-intervention measures were collected after each session. Selective attention was assessed using the EncephalApp Stroop test, with OffTime and OnTime representing reaction times without and with Stroop interference, respectively. In the experimental group, mean age was 17.91 years, mean BMI was 21.03 kg/m², mean resting heart rate was 82.13 bpm, and mean VO_2max was 39 ml/min/kg. The control group presented a mean age of 17.4 years, mean BMI of 20.65 kg/m², and mean resting heart rate of 78.7 bpm.

Results: A significant improvement in cognitive performance was observed following HIIT, reflected by reduced reaction times in the experimental group (OffTime: $p = 0.050$; OnTime: $p = 0.163$). Wilcoxon tests indicated significant improvements in both Stroop conditions during interventions 01 and 03, except for OnTime1 ($p = 0.078 > 0.05$). Regarding chronic effects, no significant between-group difference was found in OffTime performance ($p = 0.863$), whereas a significant improvement in OnTime was observed in both the experimental ($p = 0.043$) and control groups ($p = 0.034$). HIIT significantly enhanced physical performance, particularly sprinting ability ($p = 0.001$) in both sexes within the experimental group, and produced significant physiological changes in BMI ($p = 0.024$) and maximal aerobic speed (MAS) ($p = 0.001$).

Conclusion: This study provides evidence that HIIT induces significant improvements in both cognitive and physical performance among adolescents, supporting its relevance as an effective school-based training modality.

EPIDEMIOLOGICAL PROFILE OF THE COLLECTIVE FOODBORNE TOXI-INFECTIONS IN MOROCCO

Morad Kaddouri
Laboratory of the Engineering and Applied Technologies, Higher School of Technology, Sultan Moulay Slimane University, Beni Mellal 23000, Morocco

Ait Melloul Abdelaziz
Higher Institute of Nursing Professions and Health Technology, ISPITS-Marrakech-Morocco.
Unit of Microbial Biotechnology, Faculty of Sciences Semlalia-Cadi Ayyad University, Marrakesh, Morocco.

Omar Ait El Alia
Laboratory of the Engineering and Applied Technologies, Higher School of Technology, Sultan Moulay Slimane University, Beni Mellal 23000, Morocco

Khalid Boutoial
Laboratory of the Engineering and Applied Technologies, Higher School of Technology, Sultan Moulay Slimane University, Beni Mellal 23000, Morocco

Abstract

Methods. The manuscript presents a comprehensive study on the state of food poisoning in Marrakech city, Morocco, from 2018 to 2022. Data were collected from hospital records, epidemiological surveillance reports, and laboratory-confirmed cases to provide a comprehensive analysis. Microbiological analysis of food poisonings was conducted at the Regional Laboratory for Epidemiological Diagnosis, Marrakech.

Results. During the study period, CFTIs constituted a substantial public health threat, with 67 recorded outbreaks. The majority of outbreaks occurred in urban areas (86.67%) and during summer (76.67%). Most affected were individuals under 30 (56.96%) and females (60%), with children and adolescents being highly vulnerable. Dairy and pastry shops were the primary outbreak sites (44.16%), with vegetables and fruits (31.45%) being the most commonly implicated food items. Causative agents were identified among 77.79% of the outbreaks. E*scherichia coli* (35.56%), yeast and molds (20%), and *Staphylococcus aureus* (16.67%) were the most prevalent, and outbreaks of polymicrobial contamination were reported.

Conclusion. These findings highlight the urgent need to identify contamination sources and enforce hygienic practices. Notably, Morocco demonstrates relatively favorable epidemiological statistics compared to certain European states, alongside marked improvements in food safety indicators versus other developing countries. Enhanced food safety training, improved surveillance systems, and more stringent regulatory controls remain critical to sustain this progress and further reduce outbreak incidence.

Keywords: Epidemiology, Food poisonings, Food Safety, Outbreaks, Risk Factors.

ONE HEALTH EDUCATION, HEALTH LITERACY, "HEALTHY PEOPLE 2030"AND DEVELOPED PROCESES

Professor Shalva Zarnadze, MD, MPH, PhD
TSMU, Deapartement of Nutrition, Aging Medicine, environmental and occupational health
https://orcid.org/0000-0002-6895-9205

Professor Irine Zarnadze, MD, MPH, PhD
TSMU, Department of Public Health, Health care Management, Politicy and Economi;
Tbilisi, Georgia
https://orcid.org/0000-0001-5511-437X

Abstract

Introduction: One Health" is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes that the health of people, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent**.** The approach mobilizes multiple sectors, disciplines and communities at different levels of society to work together to promote well-being and address threats to health and ecosystems, while responding to the collective needs for clean water, energy and air, safe and nutritious food, acting on climate change and promoting sustainable development. Health literacy has been defined as the "degree to which individuals have the capacity to obtain, process and understand basic health information and services needed to make appropriate health decision.

Aim of Research: The aim of the study is to assess the prospects for unified health, the opportunities for implementing digital unified health, and the adaptation of personal and organizational health literacy systems in the Healthy Population 2030 perspective.

Methods of Research: Complex research method. Quantitative and qualitative research. Sociological research using the method of interviewing and questionnaires of the population and experts. Documentary analysis method.

Results: Research shows that the use of digital technologies is important in a unified healthcare system. Digital technologies improve the quality and relevance of information delivery. Many respondents preferred digital technologies for the effectiveness of both individual health literacy and organizational literacy. Adults with limited health literacy obtain less information from disease prevention and control materials and may be less likely to undergo screening or to successfully manage their illness. For example, health literacy is associated with obesity, dietary choices, and exercise. Women with low health literacy are also associated with a lower probability of mammography screening; they are also more likely to report poorer physician-patient communication and higher levels of decision regret about their breast cancer decisions.

Conclusion: Low health literacy is associated with more hospitalizations, greater use of emergency care, decreased use of preventive services, poorer ability to interpret labels and health messages, poorer health status, higher mortality, and higher health care costs. Functional health literacy extends beyond proficiency in reading, writing, and numeracy to include interpretation of images and oral communication.

Keywords: One Health, Health literacy

THE ROLE OF COMMUNITY PHARMACISTS IN VACCINATION PROGRAMS

S.Rubinthara

R.Swathi

E.Praveena

N.ArshadAhamed

D.Aravindhan

R.SriArasuvasan

K.Vaishnavi

K.Dinesh Rajan

K.Vijayalakshmi

Faculty of pharmacy, Bharath institute of higher education and research chennai, India

Abstract

Community pharmacists have become increasingly vital contributors to global vaccination programs, playing a critical role in improving immunization coverage, patient accessibility, and public health outcomes. As one of the most accessible healthcare professionals, pharmacists provide convenient, cost-effective, and timely vaccine services, particularly for populations that may face barriers to traditional healthcare settings. Their involvement extends beyond vaccine administration to include patient education, screening for contraindications, monitoring adverse reactions, and promoting vaccine confidence.Pharmacist-led vaccination initiatives have demonstrated significant success in increasing uptake of influenza, COVID-19, pneumococcal, and travel-related vaccines. By offering extended hours, walk-in services, and easily accessible locations, community pharmacies reduce missed vaccination opportunities and help relieve the burden on primary care clinics. Furthermore, pharmacists are uniquely positioned to identify unvaccinated individuals through routine medication reviews and patient interactions, enabling targeted interventions that support preventive healthcare.The expansion of pharmacist vaccination authority has strengthened public health readiness, especially during pandemics and seasonal outbreaks. However, challenges remain, including regulatory variability, inadequate reimbursement structures, and the need for standardized training and infrastructure. Addressing these barriers will further enhance the effectiveness of community pharmacy-based vaccination programs. Overall, community pharmacists serve as essential partners in advancing immunization efforts, improving public health resilience, and fostering a culture of preventive care.

Keywords: Community pharmacists, vaccination programs, immunization services, public health, vaccine administration, accessibility, preventive care, pharmacy-based vaccination, patient education, vaccine uptake.

WHY DO MEDICAL MALPRACTICE COMPLAINTS POSE A THREAT TO THE HEALTHCARE SYSTEM?

VORONEANU-POPA Rareș-Vasile

”Grigore T. Popa” University of Medicine and Pharmacy of Iași

CONSTANTINESCU Richard

”Grigore T. Popa” University of Medicine and Pharmacy of Iași

Abstract

Medical malpractice complaints have become an undeniable reality in contemporary healthcare. According to current studies in the specialized literature, an increasing number of physicians are being reported by patients for issues related to medical activity. While some complaints are well-founded, a significant proportion of them are unrelated to the quality of medical care itself and instead concern aspects such as hospital conditions, shortages of certain medications, and similar systemic shortcomings.

However, physicians who face such complaints often modify the way they perform their medical duties. Existing research shows that once a doctor becomes involved in legal proceedings, they tend to adopt a defensive approach to medical practice. This may include selecting patients more cautiously, recommending an excessive number of diagnostic tests, and engaging in other forms of defensive behavior.

Defensive medicine poses a genuine risk to the quality and efficiency of healthcare delivery. Under constant pressure related to potential liability, physicians may find themselves unable to provide high-quality medical care. The purpose of this study is to examine the extent to which medical malpractice complaints constitute a threat to the medical profession and the healthcare system as a whole.

Keywords: medical malpractice, medical liability, defensive medicine

IN-VITRO EVALUATION OF NATURAL PHYTOCONSTITUENTS FOR ANTIDIABETIC AND ANTIOXIDANT POTENTIAL

Varun V. Joshi
Department of Pharmacology, SNJB's Shriman Sureshdada Jain College of Pharmacy, Neminagar, Chandwad, Nashik- 423 101, India (MS).

Mayur B. Kale
Department of Pharmacology, Smt. Kishoritai Bhoyar College of Pharmacy, Kamptee, Nagpur, Maharashtra 441 002, India (MS).

Aman B. Upaganlawar
Department of Pharmacology, SNJB's Shriman Sureshdada Jain College of Pharmacy, Neminagar, Chandwad, Nashik- 423 101, India (MS).

Chandrashekhar D. Upasani
Department of Pharmacology, SNJB's Shriman Sureshdada Jain College of Pharmacy, Neminagar, Chandwad, Nashik- 423 101, India (MS).

ABSTRACT

Objective: To assess the in-vitro antidiabetic and antioxidant potential of selected natural phytoconstituents using enzyme inhibition and free-radical scavenging assays.

Background: Postprandial hyperglycemia and oxidative stress are key contributors to diabetic complications. Natural phytoconstituents with enzymatic inhibitory activity and antioxidant capacity represent a promising approach for safer diabetes management. This study evaluates the in-vitro antidiabetic and antioxidant potential of two purified natural compounds.

Methods: In-vitro α-amylase and α-glucosidase inhibition assays were performed using standard microplate procedures at concentrations ranging from 1–20 mg/mL, with acarbose as the reference inhibitor. Antioxidant activity was assessed using the DPPH radical scavenging assay at 10–50 ppm, with ascorbic acid as the standard. Percentage inhibition was calculated from changes in absorbance, and all experiments were performed in duplicate.

Results: Both natural compounds demonstrated dose-dependent enzyme inhibition. Maximum α-amylase inhibition reached **61–64%** at 20 mg/mL, whereas α-glucosidase inhibition ranged from **53–67%** at the same concentration. These values were compared with the standard inhibitor, which showed above **90%** inhibition. In the DPPH assay, the two compounds exhibited strong free-radical-scavenging potential, with inhibition values ranging from 72% to 87% at 50 ppm, compared with 99% for the reference antioxidant.

Conclusion: The tested phytoconstituents exhibit significant inhibition of α-amylase and α-glucosidase, as well as potent antioxidant activity, indicating their potential role in managing hyperglycemia and oxidative stress. These findings provide a scientific basis for advancing these natural compounds into further pre-clinical evaluation for diabetes-related applications.

Keywords: Natural Phytoconstituents, α-amylase, α-glucosidase, DPPH, antidiabetic activity, antioxidant.

MECHANISM OF UMBILICUS HERBAL MOXIBUSTION IN AMELIORATING IDIOPATHIC PULMONARY FIBROSIS VIA THE NRF2/SLC7A11/GPX4 PATHWAY TO INHIBIT OXIDATIVE STRESS

MISS. Yawei Wang

School of Acupuncture and Massage, Hebei University of Chinese Medicine, Shijiazhuang, Hebei, China

ORCID ID: https://orcid.org/0009-0004-5650-8396

ABSTRACT

Introduction and Purpose: The core pathological alteration in idiopathic pulmonary fibrosis (IPF) is the deposition of extracellular matrix. Oxidative stress can stimulate the activation and proliferation of lung fibroblasts, thereby inducing extracellular matrix deposition.The study aims to observed the effects of umbilicus herbal moxibustion (UHM) on pathological changes in rats with idiopathic pulmonary fibrosis(IPF) and to explored its potential mechanism of action from the perspective of regulating the Nrf2/SLC7A11/GPX4 pathway to inhibit oxidative stress, aiming to provide experimental evidence for clinical application.

Materials and Methods: Forty SD rats were randomly divided into the sham group, model group (IPF), IPF + pirfenidone group (PFD), IPF + PDF + UHM group (UHM), and IPF + PDF + bran-cake moxibustion group (BCM), with eight rats in each group. The IPF rat model was generated by intratracheal instillation of bleomycin. Rats in the PFD group were gavaged with pirfenidone ($0.05g \cdot kg^{-1}$). Rats in the UHM and BCM groups were respectively performed herb-partitioned moxibustion or bran-cake-partitioned moxibustion at “Shenque” acupoint (CV8) after gavaged with pirfenidone ($0.05g \cdot kg^{-1}$).Each session consisted of seven moxa cones, performed once daily for 21 consecutive days. Micro-CT was utilized to assess the degree of pulmonary fibrosis. Immunohistochemistry was performed to detect the expression of α-SMA, E-cadherin, vimentin, and FAP. Biochemical assays were conducted to measure the levels of SOD, MDA, GSH, GSH-Px, and NO in lung tissue and serum. Immunofluorescence was used to detect ROS levels in lung tissue. The expression of proteins related to the Nrf2/SLC7A11/GPX4 pathway in lung tissue was detected by western blot.

Results: Compared with the sham group, rats in the IPF group exhibited increased high-density shadows and ground-glass opacities in the lung fields, along with an elevated fraction of non-aerated lung volume ($P< 0.05$), the levels of MDA and NO in both lung tissue and serum were increased ($P< 0.05$), the levels of GSH, GSH-Px and SOD decreased ($P< 0.05$), the expression of ROS, α-SMA, vimentin and FAP in lung tissue elevated ($P< 0.05$), and the expression of E-cadherin, p-Nrf2/Nrf2, GPX4 and SLC7A11 reduced ($P< 0.05$).Compared with the IPF group, rats in the PDF, UHM, and BCM groups showed reduced high-density shadows and ground-glass opacities in the lung fields, as well as a decreased fraction of non-aerated lung volume ($P< 0.05$), the levels of MDA and NO in lung tissue and serum were lower ($P< 0.05$), the levels of GSH, GSH-Px and SOD were higher ($P< 0.05$), the expression of ROS, α-SMA, vimentin and FAP in lung tissue was decreased ($P< 0.05$), and the expression of E-cadherin, p-Nrf2/Nrf2, GPX4 and SLC7A11 was increased ($P< 0.05$).Compared with the PDF group, rats in the UHM and BCM groups demonstrated further reductions in high-density shadows and ground-glass

opacities in the lung fields, as well as a lower fraction of non-aerated lung volume ($P< 0.05$), the levels of MDA and NO in lung tissue and serum were decreased ($P< 0.05$), the levels of GSH, GSH-Px and SOD were increased ($P< 0.05$), the expression of ROS, α-SMA, vimentin and FAP in lung tissue was reduced ($P< 0.05$), the expression of E-cadherin, p-Nrf2/Nrf2, GPX4 and SLC7A11 was elevated ($P< 0.05$).Compared with the UHM group, rats in the BCM group showed increased high-density shadows and ground-glass opacities in the lung fields, along with a higher fraction of non-aerated lung volume ($P< 0.05$), the levels of MDA and NO in lung tissue and serum were elevated ($P< 0.05$), the levels of GSH, GSH-Px and SOD were decreased ($P< 0.05$), the expression of ROS, α-SMA, vimentin and FAP in lung tissue was increased ($P< 0.05$), the expression of E-cadherin, p-Nrf2/Nrf2, GPX4 and SLC7A11 was reduced ($P< 0.05$).

Discussion and Conclusion: Umbilicus herbal moxibustion attenuate pathological changes of IPF in rat and modulate the Nrf2/SLC7A11/GPX4 pathway to suppress oxidative stress to ameliorate IPF.

Key Words: idiopathic pulmonary fibrosis; Oxidative stress; umbilicus herbal moxibustion; Nrf2/SLC7A11/GPX4 pathway

MECHANISM BY WHICH MOXIBUSTION AT CV8 COMBINED WITH PIRFENIDONE AMELIORATES IDIOPATHIC PULMONARY FIBROSIS VIA INHIBITION OF ZBP1-MEDIATED PANOPTOSIS

Mr. Renbin Feng

Hebei University of Chinese Medicine, Department of Acupuncture and Moxibustion School, Shijiazhuang, PR China.

ORCID ID: https://orcid.org/0009-0004-6088-6330

ABSTRACT

Introduction and Purpose: This study aims to observe the combined effects of moxibustion at CV8 and pirfenidone on lung function in rat models of bleomycin-induced idiopathic pulmonary fibrosis (IPF). Additionally, it investigates the potential mechanism of action through the inhibition of ZBP1-mediated PANoptosis in improving IPF.

Materials and Methods: Fifty male SD rats were randomly divided into five groups: sham operation group (Sham), model group (IPF), pirfenidone group (PFD), moxibustion group (QYJ), and pirfenidone + moxibustion group (PFD+QYJ), with 10 rats in each group. Except for the Sham group, which received intratracheal instillation of normal saline, the other groups were established as IPF models through intratracheal instillation of bleomycin (5 mg/kg). Interventions commenced on day 2 post-modeling: the PFD group received pirfenidone suspension (50 mg/kg·d) via gavage; the QYJ group received saline gavage followed by moxibustion at CV8; the PFD+QYJ group first received pirfenidone gavage, followed by moxibustion at CV8 (following the same procedure as the QYJ group); the Sham and IPF groups received equivalent volumes of saline gavage daily. Furthermore, the Sham, IPF, and PFD groups underwent grasping and fixation for durations equivalent to those of the treatment groups. All groups received interventions once daily for 21 consecutive days.

Post-intervention measurements included: pulmonary function-related indicators; HE staining and Sirius red staining of lung tissue; alkaline hydrolysis method for determining hydroxyproline (HYP) content in lung tissue; ELISA for detecting serum and lung tissue levels of IFN-γ, IL-1β, IL-6, and IL-18; immunofluorescence co-localization of NLRP3 and ZBP1 expression in lung tissue; and Western blot analysis of pyroptosis (GSDMD-N), apoptosis (Caspase-3), necroptosis (p-MLKL), and ZBP1 protein expression in lung tissue.

Results: Compared to the Sham group, the IPF group demonstrated significant destruction of lung tissue structure, characterized by extensive infiltration of inflammatory cells and collagen deposition. Pulmonary function parameters, including Rrs, Ers, Rn, and H, were significantly elevated, while Crs and G were notably reduced ($P<0.05$). The ratio of type I to type III collagen and the content of hydroxyproline (HYP) were both significantly increased ($P<0.05$). Levels of inflammatory cytokines, such as IFN-γ, IL-1β, IL-6, and IL-18, were markedly elevated in both serum and lung tissues ($P<0.05$). The expression of pan-apoptosis-related proteins (GSDMD-N, Caspase-3, p-MLKL) and ZBP1 in lung tissues was significantly upregulated ($P<0.05$). Immunofluorescence co-localization analysis demonstrated strong co-localization of ZBP1 with NALP3 in lung tissues affected by IPF. In comparison to the IPF group, all treatment interventions (PFD group, QYJ group, PFD+QYJ group) resulted in improved lung function parameters, specifically Crs and G ($P<0.05$), while Rrs, Ers, Rn, H, the type I/III collagen ratio

in lung tissue, HYP content, and serum and lung tissue levels of IFN-γ, IL-1β, IL-6, IL-18, along with the expression of GSDMD-N, Caspase-3, p-MLKL, and ZBP1 in lung tissue were significantly reduced (P<0.05). Comparisons among the different treatment groups indicated that the QYJ group exhibited less pronounced improvement compared to the PFD group across most indicators (P<0.05), whereas the PFD+QYJ combination therapy group demonstrated the most favorable therapeutic outcomes (P<0.05).

Discussion and Conclusion: Moxibustion at CV8 combined with pirfenidone inhibits ZBP1-mediated pan-apoptosis, alleviates pulmonary inflammatory injury in bleomycin-induced IPF rats, delays the progression of pulmonary fibrosis, and enhances lung function.

Key Words: idiopathic plmonary fbrosis; Moxibustion; CV8; PANoptosis; Inflammation; ZBP1

COMPARISON OF CLINICAL DATA IN PATIENTS WITH ALPHA-FETOPROTEIN-NEGATIVE HEPATOCELLULAR CARCINOMA

Yüksel GÜMÜRDÜLÜ

Çukurova University, Faculty of Medicine, Department of Gastroenterology, Adana, Turkey

ORCID ID: https://orcid.org/0000-0001-8498-8332

Anıl DELİK

Çukurova University, Faculty of Science and Literature, Department of Biology, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-6443-9392

Ümit KARAOĞULLARINDAN

Çukurova University, Faculty of Medicine, Department of Gastroenterology, Adana, Turkey

ORCID ID: https://orcid.org/0000-0003-4309-7845

Yakup ÜLGER

Çukurova University, Faculty of Medicine, Department of Gastroenterology, Adana, Turkey

ORCID ID: https://orcid.org/0000-0003-2999-9308

Sadık DİNÇER

Çukurova University, Faculty of Science and Literature, Department of Biology, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-0298-0917

ABSTRACT

Introduction and Purpose: Alpha-fetoprotein (AFP)-negative hepatocellular carcinoma (HCC) cases present diagnostic and prognostic challenges due to the limited sensitivity of classical biomarkers. In AFP-negative patients, the combined evaluation of clinical features, imaging findings, and comprehensive laboratory profiles can provide guidance for diagnosis and risk stratification. The aim of this study is to investigate the relationships and differences among demographic, clinical, imaging, and extensive laboratory parameters in AFP-negative HCC cases within the dataset, and to assess the prognostic and diagnostic roles of tumor burden, liver function, PVT, and metabolic/immunological indicators.

Materials and Methods: The study is based on a prospective, single-center patient cohort. Cases recorded as AFP-negative and with HCC diagnosis confirmed by imaging or histopathology were included. The variables evaluated in the study were: age, sex, disease type,

etiology, CTP score, presence of ascites, portal PVT, varices, cirrhosis, steatosis on ultrasonography, tumor localization and segment, and the largest tumor size; as well as AFP, complete blood count (WBC, HGB, HCT, PLT), metabolic and biochemical parameters (glucose, Na, K, BUN, creatinine, albumin, total/direct bilirubin, AST, ALT, GGT, LDH, Ca and other basic electrolytes), markers of inflammation and iron metabolism (CRP, erythrocyte sedimentation rate, ferritin), thyroid parameters (TSH, T4), lipid profile (total cholesterol, triglycerides, LDL, HDL), and autoantibodies (ANA, SMA, AMA). Continuous variables were presented as mean ± SD or median (IQR), and categorical variables as frequency (%). Intergroup comparisons were performed using appropriate parametric or nonparametric tests, and multivariate analyses were conducted to investigate independent associations.

Results: Among the 24 patients with hepatocellular carcinoma (HCC) included in the study, 12 constituted the AFP-negative subgroup. Within this group, male patients accounted for n=10 (80%) and female patients for n=2 (20%). The mean age of AFP-negative patients was 72 ± 7.75 years. In this cohort, HBV, MASLD, and cryptogenic etiologies were the most frequently observed causes of AFP-negative HCC. The majority of cases were classified as CTP class A, whereas patients progressing to class B exhibited higher rates of ascites, cirrhosis, and thrombocytopenia. The presence of PVT was significantly associated with larger tumor diameter. Reduced serum albumin levels and lower platelet counts were strongly correlated with cirrhosis. Inflammatory and cellular injury markers (CRP, LDH) demonstrated positive correlations with larger tumor size and advanced BCLC stage. Elevated ferritin levels were observed in selected cases with high tumor burden. Alterations in lipid profile and ultrasonographic evidence of steatosis were more frequently encountered in patients with metabolic etiologies. In multivariate analysis, larger tumor size, presence of PVT, and hypoalbuminemia emerged as independent adverse prognostic indicators.

Discussion and Conclusion: Diagnosis and risk assessment in AFP-negative HCC cannot rely solely on AFP levels. When imaging findings and indicators of liver function (particularly albumin and platelet count) are evaluated together with biochemical markers reflecting tumor burden (LDH, CRP, ferritin), they provide both diagnostic and prognostic information. The association of PVT with tumor size and extent may influence interventional and systemic treatment decisions. Steatosis and lipid abnormalities related to metabolic syndrome further confirm its increasing role in HCC etiology. This study underscores the necessity of a multiparametric approach in AFP-negative HCC patients. Specifically, parameters such as tumor size, presence of PVT, and hypoalbuminemia carry independent clinical significance, while inflammatory and metabolic biomarkers offer complementary insights into tumor burden and etiology. The use of these combined profiles is recommended for early diagnosis and appropriate therapeutic guidance in AFP-negative cases. Validation of these findings in prospective studies with larger cohorts is warranted.

Key Words: Alpha feto protein negative; Hepatosellular carcinoma; Inflammation; clinical; prognosis

HEALTHCARE WORKFORCE DEVELOPMENT IN TURKEY OVER THE YEARS

YILLAR İTİBARİYLE TÜRKİYE'DEKİ SAĞLIK İNSANGÜCÜ GELİŞİMİ

Doç. Dr. Hüseyin ERİŞ
Harran Üniversitesi, Sağlık Hizmetleri MYO, Şanlıurfa, Türkiye
ORCİD: 0000-0002-1685-9819

ÖZET

Sağlık kurumlarında insangücü, hizmetin niteliğini, sürekliliğini ve etkinliğini doğrudan belirleyen temel unsurdur. Sağlık hizmetleri emek yoğun bir yapıya sahip olduğu için insan kaynağının önemi diğer birçok sektöre kıyasla çok daha belirgindir. Sağlık insangücü; hizmet kalitesi ve hasta güvenliği, hizmete erişim ve süreklilik, verimlilik ve kurumsal performans, sağlık politikalarının uygulanabilirliği, hasta memnuniyeti ve kurumsal imaj gibi konular açısından önemlidir. Bu çalışmanın amacı, Türkiye'nin özellikle sağlıkta dönüşüm programıyla geliştirilen sağlık hizmetleri sunumundaki en önemli gücü olan insangücünün yıllar itibariyle gelişimini belirtmektir. 2002–2023 döneminde Türkiye'de sağlık insangücünün tüm meslek grupları itibarıyla belirgin ve sürekli bir artış eğilimi gösterdiğini ortaya koymaktadır. Toplam sağlık personeli sayısı 2002 yılında 380.434 iken, 2023 yılında 1.413.921'e ulaşarak yaklaşık 3,7 katlık bir artış göstermiştir. Bu durum, özellikle 2003 sonrası uygulamaya konulan Sağlıkta Dönüşüm Programı, sağlık hizmetlerine erişimin genişletilmesi ve sağlık altyapısına yapılan yatırımların insangücü üzerindeki doğrudan etkisini yansıtmaktadır. Hekim sayısı 2002–2023 döneminde yaklaşık %125 oranında artmış, ancak bu artış, hemşire/ebe ve diğer sağlık personeline kıyasla daha sınırlı kalmıştır. Hemşire/ebe sayısındaki artışın daha dengeli seyretmesi, sağlık hizmetlerinde ekip temelli hizmet sunumunun güçlendiğine işaret etmektedir. En dikkat çekici artış ise "diğer sağlık personeli" grubunda gözlenmektedir. Bu grubun hızlı büyümesi; sağlık teknikerleri, teknisyenler ve yardımcı sağlık personeline olan ihtiyacın arttığını ve sağlık sisteminin daha karmaşık ve çok disiplinli bir yapıya evrildiğini göstermektedir. Diş hekimi sayısındaki düzenli artış, ağız ve diş sağlığı hizmetlerinin yaygınlaştırılması politikalarının bir sonucu olarak değerlendirilebilir. Bununla birlikte, meslek grupları arasındaki artış hızlarının farklılık göstermesi, niceliksel büyümenin yanı sıra dengeli dağılım ve nitelik tartışmalarını da gündeme getirmektedir.

Anahtar Kelimeler: Sağlıkta Dönüşüm Programı, Sağlık insangücü, Sağlık hizmetleri

ABSTRACT

Human resources in healthcare institutions are a fundamental factor that directly determines the quality, continuity, and effectiveness of services. Since healthcare services are labor-intensive, the importance of human resources is much more pronounced compared to many other sectors. Healthcare human resources are important in terms of service quality and patient safety, access to and continuity of service, efficiency and institutional performance, the applicability of healthcare policies, patient satisfaction, and institutional image. The aim of this study is to

indicate the development of human resources over the years, which is the most important strength in the provision of healthcare services developed in Turkey, particularly with the healthcare transformation program. It reveals that between 2002 and 2023, Turkey's healthcare workforce showed a clear and steady upward trend across all occupational groups. The total number of healthcare personnel increased approximately 3.7-fold, from 380,434 in 2002 to 1,413,921 in 2023. This situation reflects the direct impact on the workforce of the Health Transformation Program implemented after 2003, the expansion of access to health services, and investments in health infrastructure. The number of physicians increased by approximately 125% between 2002 and 2023, but this increase was more limited compared to nurses/midwives and other health personnel. The more balanced increase in the number of nurses/midwives indicates that team-based service delivery in healthcare has been strengthened. The most notable increase, however, is observed in the “other healthcare personnel” group. The rapid growth of this group indicates an increased need for healthcare technicians, technologists, and auxiliary healthcare personnel, and that the healthcare system is evolving into a more complex and multidisciplinary structure. The steady increase in the number of dentists can be considered a result of policies to expand oral and dental health services. However, the differences in the rates of increase between professional groups raise issues of balanced distribution and quality, in addition to quantitative growth.

Keywords: Health Transformation Program, Health workforce, Health services

GİRİŞ

Sağlık kurumlarında insan kaynakları yönetimi (İKY), hizmet sunumunun kalitesi, sürekliliği ve hasta güvenliği üzerinde doğrudan belirleyici bir role sahip olan stratejik bir yönetim alanıdır (World Health Organization [WHO], 2016). Sağlık hizmetlerinin emek yoğun yapısı, sağlık İKY planlanması, seçimi, eğitimi ve performansının daha etkin bir biçimde yönetilmesini zorunlu kılmaktadır (Dubois, McKee, Nolte & Anderson, 2015). Nitelikli sağlık insan gücünün yeterli sayıda ve doğru branşlarda istihdam edilmesi, sağlık sistemlerinin verimliliğini ve erişilebilirliğini artıran temel unsurlar arasında yer almaktadır (OECD, 2023).

Sağlık kurumlarında İKY uygulamaları, çalışan memnuniyeti ve kurumsal bağlılığı güçlendirerek sağlık çalışanlarının hizmet kalitesine olumlu katkı sağlamaktadır (Armstrong & Taylor, 2020). Sağlık kurumlarında iş gücü planlaması, demografik değişimler, hastalık yükü ve teknolojik gelişmeler dikkate alınarak uzun vadeli bir perspektifle yürütülmelidir (WHO, 2020). Eğitim ve sürekli mesleki gelişim faaliyetleri, sağlık çalışanlarının bilgi ve becerilerini güncel tutarak klinik hataların azaltılmasına katkı sunmaktadır (Frenk et al., 2010). Performans değerlendirme sistemleri, bireysel ve kurumsal hedeflerin uyumlaştırılmasını sağlayarak hizmet çıktılarının ölçülmesine olanak tanımaktadır (Armstrong & Taylor, 2020). Adil ücretlendirme ve teşvik mekanizmaları, sağlık personelinin motivasyonunu artırarak kurum içi verimliliği desteklemektedir (Buchan & Dal Poz, 2002).

Sağlık sektöründe tükenmişlik sendromu ve iş stresi, insan kaynakları yönetiminin çalışan refahını önceleyen politikalar geliştirmesini gerekli kılmaktadır (Maslach & Leiter, 2016). Etkili liderlik ve iletişim becerileri, sağlık kurumlarında ekip çalışmasını güçlendirerek hizmet koordinasyonunu iyileştirmektedir (Northouse, 2021). Dijital insan kaynakları uygulamaları, işe alım, performans izleme ve eğitim süreçlerinde hız ve şeffaflık sağlamaktadır (Bondarouk & Brewster, 2016). Türkiye’de sağlıkta dönüşüm süreci, insan kaynakları yönetiminin stratejik önemini artırmış ve sağlık iş gücünün yeniden yapılandırılmasını gündeme getirmiştir (T.C. Sağlık Bakanlığı, 2019). Sonuç olarak, sağlık kurumlarında insan kaynakları yönetimi, sürdürülebilir ve kaliteli sağlık hizmeti sunumunun temel yapı taşlarından biri olarak değerlendirilmektedir (WHO, 2016).

Bu çalışmanın amacı Türkiye'de son yıllarda sağlık insangücündeki gelişim ve nüfusa düşen sağlık insan gücü sayısını belirlemektir.

Metod ve Yöntem

Bu çalışma betimleyici nicel bir çalışmadır. Yıllar itibariyle Sağlık Bakanlığı istatistik yıllıklarında veriler incelenerek hazırlanmıştır.

Tablo 1'de yıllar itibariyle Türkiye'deki sağlık insangücü sayıları meslek türlerine göre verilmiştir.

Tablo 1. Yıllar İtibariyle Türkiye'deki Sağlık İnsangücü Gelişimi

Yıl	Hekim	Hemşire/Ebe	Diş Hekimi	Diğer Sağlık Personeli	Toplam Sağlık Personeli
2002	90.757	116.947	15.866	156.864	380.434
2008	113.151	147.583	19.959	108.771	389.464
2010	123.447	165115	21.432	245121	550.000
2015	141.259	205.889	24.834	415.370	787.352
2020	171.259	286.332	34.830	650.048	1.142.469
2023	204.223	308.037	45.718	855.943	1.413.921

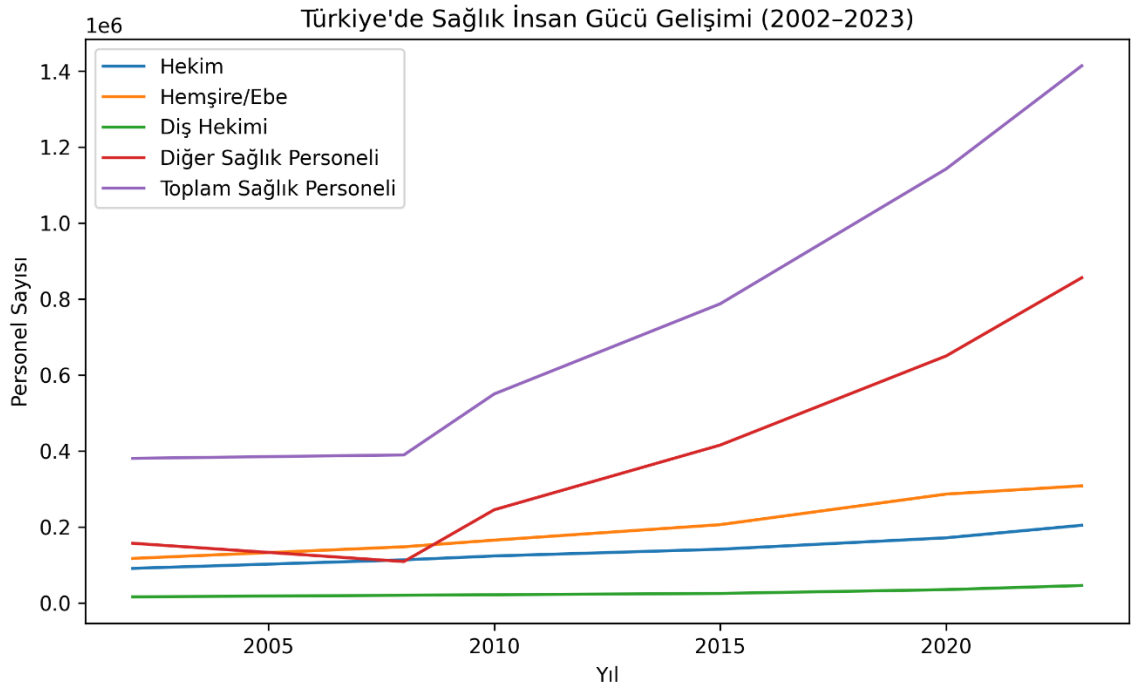
Tablo 1, Türkiye'de sağlık insan gücünün 2002–2023 döneminde niceliksel olarak kayda değer bir artış gösterdiğini ortaya koymaktadır. Toplam sağlık personeli sayısı 2002 yılında 380.434 iken, 2023 yılında 1.413.921'e yükselmiş; böylece yaklaşık **3,7 katlık bir artış** gerçekleşmiştir. Bu artış, özellikle 2003 sonrası uygulamaya konulan Sağlıkta Dönüşüm Programı'nın insan kaynağına yansıyan sonuçlarıyla ilişkilendirilebilir.

Hekim sayısı incelendiğinde, 2002 yılında 90.757 olan sayı 2023'te 204.223'e ulaşmıştır. Bu artış, tıp fakültelerinin kontenjanlarının artırılması ve uzmanlık eğitimine verilen önemin bir sonucu olarak değerlendirilebilir. Benzer biçimde hemşire/ebe sayısı da aynı dönemde 116.947'den 308.037'ye yükselmiş ve sağlık hizmetlerinin ekip temelli yapısının güçlendiğini göstermiştir.

Diş hekimi sayısındaki artış görece daha sınırlı olmakla birlikte, 2002–2023 döneminde yaklaşık **üç katlık** bir büyüme dikkat çekmektedir. Bu durum, ağız ve diş sağlığı hizmetlerinin yaygınlaştırılması ve kamu diş sağlığı merkezlerinin sayısındaki artışla ilişkilendirilebilir.

En dikkat çekici artış ise "diğer sağlık personeli" grubunda görülmektedir. Bu gruptaki personel sayısı 2002 yılında 156.864 iken, 2023'te 855.943'e yükselmiştir. Sağlık teknikerleri, teknisyenler, acil tıp teknisyenleri ve yardımcı sağlık personelinin bu artışı, sağlık hizmetlerinin çeşitlenmesi ve teknolojik altyapının gelişmesiyle uyumludur.

Sonuç olarak tablo 1'de, Türkiye'de sağlık insan gücünün yalnızca sayısal olarak değil, mesleki dağılım açısından da genişlediğini göstermekte; sağlık hizmetlerine erişimin artırılması ve hizmet kapasitesinin güçlendirilmesi yönünde önemli bir yapısal dönüşüme işaret etmektedir.



Şekil.1.

Şekil 1, Türkiye'de sağlık insan gücünün 2002–2023 döneminde tüm meslek gruplarında belirgin ve istikrarlı bir artış eğilimi sergilediğini ortaya koymaktadır. Özellikle 2010 yılı sonrasında toplam sağlık personeli sayısındaki yükseliş ivmesinin belirgin biçimde hızlandığı görülmektedir. Bu eğilim, sağlık sisteminin kurumsal kapasitesinin genişlemesi ve hizmet sunumunun yaygınlaşmasıyla uyumludur.

Hekim sayısındaki artış doğrusal bir seyir izlemekte olup, 2002–2023 döneminde yaklaşık iki katından fazla artış gerçekleşmiştir. Hemşire/ebe grubunda ise hekimlere kıyasla daha yüksek bir artış hızı dikkat çekmektedir. Bu durum, hasta bakım hizmetlerinde hemşirelik ve ebelik rollerinin güçlendiğine ve ekip temelli sağlık hizmeti anlayışının yaygınlaştığına işaret etmektedir.

Diş hekimi sayısındaki artış daha sınırlı bir eğilim sergilemekle birlikte, özellikle 2015 sonrası dönemde yükseliş hızının arttığı görülmektedir. Bu artış, ağız ve diş sağlığı hizmetlerinin birinci basamak sağlık hizmetleriyle entegrasyonunun güçlendirilmesiyle ilişkilendirilebilir.

Grafikte en dikkat çekici artış, "diğer sağlık personeli" kategorisinde gözlenmektedir. 2010 yılı sonrasında bu gruptaki personel sayısında keskin bir yükseliş meydana gelmiş; bu durum sağlık teknikerleri, teknisyenler ve yardımcı sağlık personeline olan ihtiyacın arttığını göstermiştir. Sağlık hizmetlerinde teknolojik kullanımın yaygınlaşması ve hizmet çeşitliliğinin artması, bu grubun hızlı büyümesini açıklayan temel faktörler arasında yer almaktadır.

Tablo 2. Yıllar İtibariyle Türkiye'deki Nüfus Gelişimi Ve Sağlık İnsangücüne Oranı

Yıl	Nüfus	Toplam Sağlık Personeli	Sağlık Personeli / Nüfus (%)
2002	65.022.300	378.551	0,58
2008	71.517.100	389.464	0,54
2010	73.722.988	550.000	0,74
2015	78.741.053	850.000	1,08
2020	83.614.362	1.142.469	1,37
2023	85.372.377	1.470.757	1,72

Tablo 2, 2002–2023 döneminde Türkiye'de nüfus artışı ile toplam sağlık insan gücü gelişimini ve sağlık personelinin nüfusa oranındaki değişimi birlikte ortaya koymaktadır. İncelenen dönemde Türkiye nüfusu yaklaşık %31 oranında artarak 65,0 milyondan 85,4 milyona yükselmiştir. Buna karşılık toplam sağlık personeli sayısındaki artış çok daha yüksek bir hızda gerçekleşmiş ve yaklaşık dört katına çıkarak 378.551'den 1.470.757'ye ulaşmıştır.

Bu farklı büyüme hızları, sağlık personeli/nüfus oranına doğrudan yansımıştır. 2002 yılında %0,58 olan oran, 2008 yılında nüfus artışının sağlık personeli artışını aşması nedeniyle %0,54'e gerilemiştir. Ancak 2010 sonrasında özellikle sağlıkta dönüşüm politikaları, yeni sağlık tesislerinin açılması, üniversitelerin sağlıkla ilgili bölümlerindeki kontenjan artışları ve istihdam politikalarının etkisiyle sağlık insan gücünde belirgin bir ivmelenme gözlenmiştir. Nitekim oran 2010'da %0,74'e, 2015'te %1,08'e ve 2020'de %1,37'ye yükselmiştir.

2023 yılı itibarıyla sağlık personeli/nüfus oranının %1,72'ye ulaşması, Türkiye'de sağlık hizmet sunum kapasitesinin niceliksel açıdan önemli ölçüde güçlendiğini göstermektedir. Bu artış, sağlık hizmetlerine erişimin genişlemesi ve kişi başına düşen sağlık personeli sayısının artması açısından olumlu bir gelişme olarak değerlendirilebilir. Bununla birlikte, oranlardaki iyileşmenin bölgesel dağılım, meslek grupları arasındaki denge ve hizmet kalitesi üzerindeki etkilerinin ayrıca analiz edilmesi, sağlık insan gücü planlamasının etkinliği açısından önem taşımaktadır.

Sonuç

Bu çalışma kapsamında incelenen Tablo 1 ve Tablo 2 bulguları, Türkiye'de sağlık insan gücünün 2002–2023 döneminde hem mutlak sayılar hem de nüfusa oran açısından önemli bir gelişim gösterdiğini ortaya koymaktadır. Toplam sağlık personeli sayısının yaklaşık dört katına yaklaşan bir artış sergilemesi, sağlık sisteminin kurumsal kapasitesinin belirgin biçimde güçlendiğini göstermektedir. Aynı dönemde nüfus artışının daha sınırlı kalması, sağlık insan gücünün büyüme hızının nüfus artış hızının üzerinde gerçekleştiğini ortaya koymaktadır.

Meslek grupları bazında değerlendirildiğinde, hekim ve hemşire/ebe sayılarındaki düzenli artış temel sağlık hizmetlerinin sürdürülebilirliği açısından olumlu bir gelişme olarak değerlendirilmektedir. Bununla birlikte, diğer sağlık personelinin toplam içindeki payının giderek artması, sağlık hizmetlerinin teknolojik, multidisipliner ve ekip temelli bir yapıya doğru evrildiğini göstermektedir. Bu durum, sağlık sisteminin yalnızca klinik hizmetlere değil, tanı, destek ve yardımcı hizmetlere de daha fazla odaklandığını ortaya koymaktadır.

Tablo 2'de yer alan sağlık personeli/nüfus oranları incelendiğinde, 2002–2008 döneminde sınırlı bir gerileme yaşandığı, ancak 2010 sonrasında bu eğilimin tersine dönerek istikrarlı bir artış sürecine girildiği görülmektedir. Özellikle 2015 sonrası dönemde sağlık personelinin nüfusa oranındaki hızlı yükseliş, sağlık politikalarının insan kaynağı planlaması açısından daha

etkin hale geldiğine işaret etmektedir. 2023 yılı itibarıyla ulaşılan oran, sağlık hizmetlerine erişim ve kapasite açısından önceki dönemlere kıyasla önemli bir iyileşmeyi yansıtmaktadır.

Genel olarak elde edilen bulgular, Türkiye'de sağlık insan gücü planlamasının niceliksel açıdan başarılı sonuçlar ürettiğini; ancak bu büyümenin nitelik, dağılım ve verimlilik boyutlarıyla birlikte ele alınması gerektiğini ortaya koymaktadır.

Öneriler

Yıllar itibariyle Türkiye'de sağlık insangücü ve demografik yapıdaki gelişmelerle ilgili veriler incelendikten sonra elde edilen sonuçlara göre tespit edilen eksikliklerin giderilmesi ve daha yüksek kalitede sağlık hizmeti sunumu için yapılması gereken iyileştirmeler şu şekilde sıralanabilir.

İnsan Gücü Planlamasında Nitelik Odaklı Yaklaşımın Güçlendirilmesi

Sağlık insan gücündeki sayısal artışın, hizmet kalitesi ve hasta güvenliğiyle uyumlu şekilde sürdürülebilmesi için mesleki yeterlilik, sürekli mesleki eğitim ve uzmanlaşma alanlarına daha fazla odaklanılması gerekmektedir.

Meslek Grupları Arası Dengeli Dağılımın Sağlanması

Diğer sağlık personelindeki hızlı artış dikkate alınarak, hekim, hemşire/ebe ve yardımcı sağlık personeli arasındaki görev tanımlarının netleştirilmesi ve ekip içi iş bölümünün optimize edilmesi önerilmektedir.

Bölgesel Dengesizliklerin Azaltılmasına Yönelik Politikalar

Ulusal düzeyde artan sağlık insan gücünün, bölgeler ve iller arasında dengeli biçimde dağıtılmasına yönelik teşvik mekanizmaları geliştirilmelidir. Kırsal ve dezavantajlı bölgelerde istihdamı artıracak mali ve mesleki teşvikler önceliklendirilmelidir.

Nüfus Dinamikleriyle Uyumlu Uzun Vadeli Planlama

Sağlık personeli/nüfus oranındaki artışın sürdürülebilirliği için demografik değişimler, yaşlanan nüfus ve kronik hastalık yükü dikkate alınarak uzun vadeli insan gücü projeksiyonları yapılmalıdır.

Veriye Dayalı Politika Üretiminin Güçlendirilmesi

Sağlık insan gücüne ilişkin düzenli, güncel ve ayrıntılı istatistiklerin üretilmesi ve bu verilerin politika yapım süreçlerine entegre edilmesi, kaynakların daha etkin kullanılmasını sağlayacaktır.

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Bilgilerinize arz edilir,

Saygılarımla

Dr. Mirna Fawaz
Committee Member

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Dr. Mustafa Latif EMEK
Yönetim Kurulu adına

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