II. Uluslararası

BERGAMA

Bilimsel Araştırmalar Kongresi

29-30 Haziran 2026
İzmir

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ISARC Academy

INTERNATIONAL SCIENCE AND ART RESEARCH CENTER

INTERNATIONAL **BERGAMA** SCIENTIFIC RESEARCH CONGRESS-II

June 29-30, 2026 Edirne, Türkiye

PROCEEDINGS BOOK

EDITOR

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PROF. DR. MOHAMMED WAHEEB

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CONGRESS TITLE

INTERNATIONAL BERGAMA SCIENTIFIC RESEARCH CONGRESS-II

DATE and PLACE

June 29-30, 2026 İZMİR / TÜRKİYE

PARTICIPATION

Keynote & Invited

PARTICIPANTS COUNTRY

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GENERAL COORDINATOR

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ISARC Academy,Türkiye

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2th INTERNATIONAL BERGAMA SCIENTIFIC RESEARCH CONGRESS
29-30 JUNE İZMİR/TÜRKİYE

Congress Program

Participant Countries:

ALBANİA-ARMANİA-GEORGİA-INDİA-INDONESİA-MOROCCO-NİGERİA-SPAİN-PAKİSTAN –UKRAİNE-VİETNAM

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MEETING ID: 868 5772 2729

PASSCODE: 379941

https://us06web.zoom.us/j/86857722729?pwd=IIuXPIf3Ar3Kq9YgzbEtQwHxNfB1XY.1

29.06.2026 / Hall-1, Session-1

ANKARA LOCAL TIME		**MEETING ID: 868 5772 2729**	
10 ^{00} : 11 ^{30}		**PASSCODE: 379941**	

HEAD OF SESSION: ***Prof. Dr. Gültekin UZUN***

TOPIC TITLE	AUTHORS	AFFILIATION
Synthesıs And Ft-Ir Structural Characterızatıon Of The Phosphorus-Based Flame Retardant Pepa As A Halogen-Free Alternatıve	**Dr. Burcu ARSLAN Çetin TÖREMEN Murat DEMİR Orkan AKKOYUN**	**Viking Temizlik ve Kozmetik Ürün. Paz. San. Tic. A.Ş.**
Effect Of Cemented Carbıde Grades On Cuttıng Tool Performance	**Prof. Dr. Gültekin UZUN Res. Assist. Büşra ÇALIK Taha Metin ALTAY Zehra TUNCABOYLU Cemre KADIOĞLU Emre BOLAT**	**Gazi University/ASELSAN A.Ş.**
Assessıng Generatıve Artıfıcıal Intellıgence Exposure Through Wıthın-Occupatıon Task Structure: A Secondary Analysıs Of The Internatıonal Labour Organızatıon 2025 Data	**Assist. Prof. Dr. Yasal ÖZDEMİR**	**Munzur University**
Dıgıtalızatıon And Automatıon Effects On Job Stress And Job Satısfactıon Of Deck Officers Workıng On Tanker Shıps: A Quantıtatıve Study	**Lect. Hidayet YASA Assoc. Prof. Dr. Murat BAYRAKTAR**	**Bartın Universit/ Zonguldak Bulent Ecevit University**

29.06.2026 / Hall-2, Session-1

ANKARA LOCAL TIME		**MEETING ID: 868 5772 2729**	
10 ^{00} : 11^{30}		**PASSCODE: 379941**	

HEAD OF SESSION: *Prof. Dr. Aliye ÇİLAN AKIN*

TOPIC TITLE	AUTHORS	AFFILIATION
A Lıterature Revıew On Technostress In Work Lıfe And Smartphone Use Outsıde Workıng Hours	Bilge CEPE Assist. Prof. Dr. Nuray Turan	Karamanoğlu Mehmetbey University
Deprem Sonrası Geçici Enkaz Depolama Sahalarının Afet Lojistiğindeki Rolü: Kavramsal Bir Model Önerisi	Ahmet Fatih TAHİROĞLU Prof. Dr. Hanifi Murat MUTLU	Gaziantep University
Impact Of Bank Characteristics On Financial Performance Of Selected Deposit Money Banks In Nigeria	Ibrahim Abubakar Dr. Daniel Marcel	Mudiame University/Modibbo Adama University
Deprem Enkazının Sıfır Atık Yönetimine Entegrasyonu	Ahmet Fatih TAHİROĞLU Prof. Dr. Hanifi Murat MUTLU	Gaziantep University
Tourısm Guıde Students' Perceptıons Of War And Tourısm Wıthın The Context Of Dark Tourısm	Assist. Prof. Dr. Ahmet ÇELİK	Kapadokya University
Evaluatıon Of Naftalan Oıl Therapy In The Context Of Health Tourısm	Prof. Dr. Aliye ÇİLAN AKIN Assist. Prof. Dr. Adnan AKIN	Bolu Abant İzzet Baysal University

29.06.2026 / Hall-3, Session-2

ANKARA LOCAL TIME	**MEETING ID: 868 5772 2729**
10 00 : 11 15	**PASSCODE: 379941**

HEAD OF SESSION: *Assist. Prof. Dr. Tahir ALTUN*

TOPIC TITLE	AUTHORS	AFFILIATION
Development Of A Socıal Judgment Task Based On Traıt Inference	Assist. Prof. Dr. Gaye ÖZEN AKIN Prof. Dr. Sevtap CİNAN	Kırklareli University/Istanbul University
Concurrent Applıcatıon Of Pharmacologıcal Treatment And Physıotherapy In Chıldren Wıth Genetıc Dısorders: A Systematıc Revıew On Motor Functıon And Qualıty Of Lıfe	Assist. Prof. Dr. Tuğba Dere Assist. Prof. Dr. Beyza Nur Durukan Assoc. Prof. Dr. Hanife Abakay	Yozgat Bozok University//Kayseri University/
Investıgatıon Of The Effectıveness Of Motor Imagery Traınıng Combıned Wıth Lsvt Bıg In Patıents Wıth Parkınson's Dısease	Assist. Prof. Dr. Tuğba Dere Assist. Prof. Dr. Beyza Nur Durukan	Yozgat Bozok University/
Demographic And Religious Perspectives In The Transition To The Age Of Artificial Intelligence: A Quantitative Research Example	Lect. Dr. Yeliz AKKAYA TÜRKOL	Hitit University
The Unıty Of Moralıty And Worshıp In The Qur'an	Assist. Prof. Dr. Tahir ALTUN	Kafkas University

29.06.2026 / Hall-4, Session-2

ANKARA LOCAL TIME		**MEETING ID: 868 5772 2729**	
10 ^{00} : 11 ^{30}		**PASSCODE: 379941**	

HEAD OF SESSION: ***PROF. DR. Abdelkarim BOUA***

TOPIC TITLE	AUTHORS	AFFILIATION
The Bhil Tribe Of India: A Journey Through Culture, Heritage And Design	Dr Madan Lal Regar , Drashti Makwana Gunisha Rathi Naynika Mittal	National Institute of Fashion Technology /INDİA
Generative Adversarial Networks For Privacy-Preserving Synthetic Demographic Generation Safe Collaborative Data Pipelines For Cross-Border Academic Studies	MUHAMMAD FAISAL	Ministry of Information & Technology, Pakistan
Some Results For Lie İdeals İnvolving Left Derivations İn 3- Prime Near-Rings	PROF. DR. Abdelkarim BOUA	Sidi Mohammed Ben Abdellah University/MOROCCO
The Scıentıfic Dıscourse On Modern Approaches To Cancer Immunotherapy Explorıng Novel Targets, Combınatıon Therapıes And Future Perspectıves Addressıng Therapeutıc Resıstance, Mechanısms Of Actıon, Adverse Effects And Treatment-Related Toxıcıtıes	Nodar Sulashvili , Irina Imerlishvili , Maia (Maka) Advadze , Margarita Beglaryan , Diego Rada Fernandez de Jauregui , Nana Gorgaslidze , Tamar Didbaridze ,Irine Zarnadze , Maka Buleishvili , Vira Kravchenko , Nato Alavidze , Olga Shapoval , Igor Seniuk, Marika Sulashvili , Nino Abuladze , Lela Grigolia , Kakhaber Robakidze , Marina Giorgobiani , Luiza Gabunia , David Aphkhazava	Georgian Technical University/International Black Sea University/Yerevan State Medical University/University of the Basque/National University of Pharmacy/GEORGİA-SPAİN-ARMANİA-UKRAİNE
Bir Madhkour: Reawakening Petra's Western Commercial Lifeline (Incense Route)	Prof. Mohammed Waheeb	The Hashemite University
Production And Characterization Of Carbon Nanotubes From Biochar Under Microwave Irradiation	Faisal Nazir	THE UNIVERSITY OF AGRICULTURE

29.06.2026 / Hall-5, Session-2

ANKARA LOCAL TIME	MEETING ID: 868 5772 2729
10 ^{00} : 12 ^{00}	PASSCODE: 379941

HEAD OF SESSION: *Dr. Madan Lal Regar*

TOPIC TITLE	AUTHORS	AFFILIATION
Data-Efficient Artificial Intelligence For Sports Injury Prediction: A Transfer Learning Approach	Akinyemi Edward AIYEGBUSI Moses Adeolu AGOI Olayemi Grace ABIMBOLA Rasheed Olatunde AJETUNMOBI	Lagos State University/NİGERİA
"Association of Parent-Specific Coronary Artery Disease History with Myocardial Function and Angiographic Severity"	Dr Sarah Shahid	Khyber Girls Medical College, Peshawar, Pakistan
The Role of Agentic AI in Independent Scientific Discovery	B.Kopika J.Jeyavarshana C.Kirthika Dr.S.Selvam	Nadar Mahajana Sangam S. Vellaichamy Nadar College
Digital Gatekeepers: How AI Controls Job Applications	M. Dhinesh kumar Dr.S.Selvam	Nadar Mahajana Sangam S. Vellaichamy Nadar College
Agentic AI: The Future of Autonomous Intelligent Systems	S. Reashmi Dr.S.Selvam	Nadar Mahajana Sangam S. Vellaichamy Nadar College
Leveraging Retrieval-Augmented Generation to Improve Trustworthiness in AI Chatbots	B.DHARSHINI Dr.S.Selvam	Nadar Mahajana Sangam S. Vellaichamy Nadar College
The Bhutia Tribe: A Review of Traditional Costume, Lifestyle and Contemporary Design	Dr Madan Lal Regar	National Institute of Fashion Technology Jodhpur/INDIA

29.06.2026 / Hall-6, Session-2

ANKARA LOCAL TIME		**MEETING ID: 868 5772 2729**	
10 30 : 12 00		**PASSCODE: 379941**	

HEAD OF SESSION: ***Dr. Edmond Muço***

TOPIC TITLE	AUTHORS	AFFILIATION
Artificial Intelligence and the Future of Islamic Thought: Opportunities, Challenges, and Civilisational Responses in the Digital Age	Aliyu Abdullahi Bello Shehu	Shehu Shagari College of Education
Desıgn Challenges Of Acıd-Stable Transıtıon Metal Oxıde Electrocatalysts For Pem Water Electrolysıs	Yasmine MOUHDA	Laboratory of Advanced Materials Physics and Thermal Science
Band Gap Engineering and Photocatalytic Performance of Lead-Free Cs2TiX6 (X = Cl, Br, I) Vacancy-Ordered Double Perovskites: A DFT Study	Aya Chelh, Boutaina Akenoun, Smahane Dahbi, Hamid Ez-Zahraouy	Mohammed V University
The Ethnographıc Element In The Photography Of The Albanıan Natıonal Renaıssance	Dr. Edmond Muço	University of Shkodra “Luigj Gurakuqi”/ALBANİA
Skateboardıng As Lıfestyle And Socıal Identıty: A Netnographıc And Ethnographıc Case Study Of A Youth Skate Communıty In An Industrıal Cıty, Cıkarang, Indonesıa	Siska Purnama Manurung Revalida Febry Luzen Ricardo Nigita Siboro	President University/INDONESİA
Consumer Trıbes In A Shared Thırd Space: Competıng Status Economıes And Dıgıtal Valıdatıon In Urban Runnıng And Calısthenıcs Communıtıes	Siska Purnama Manurung Aida Sarah Soffitri Airin Ayu Indriani Ningrum Mohammad Shahrul Ramadhan Mohamad Idos Della Alfi	President University/INDONESİA

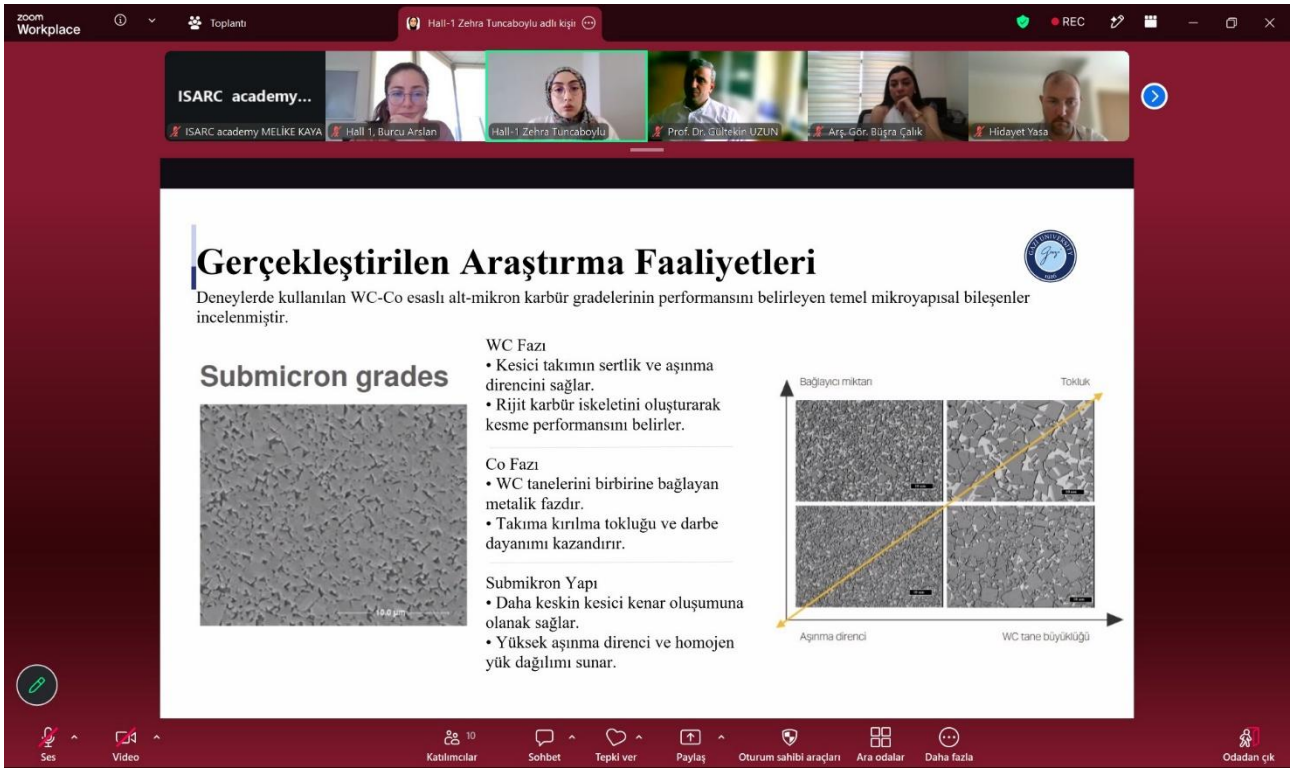
29.06.2026 / Hall-7, Session-3

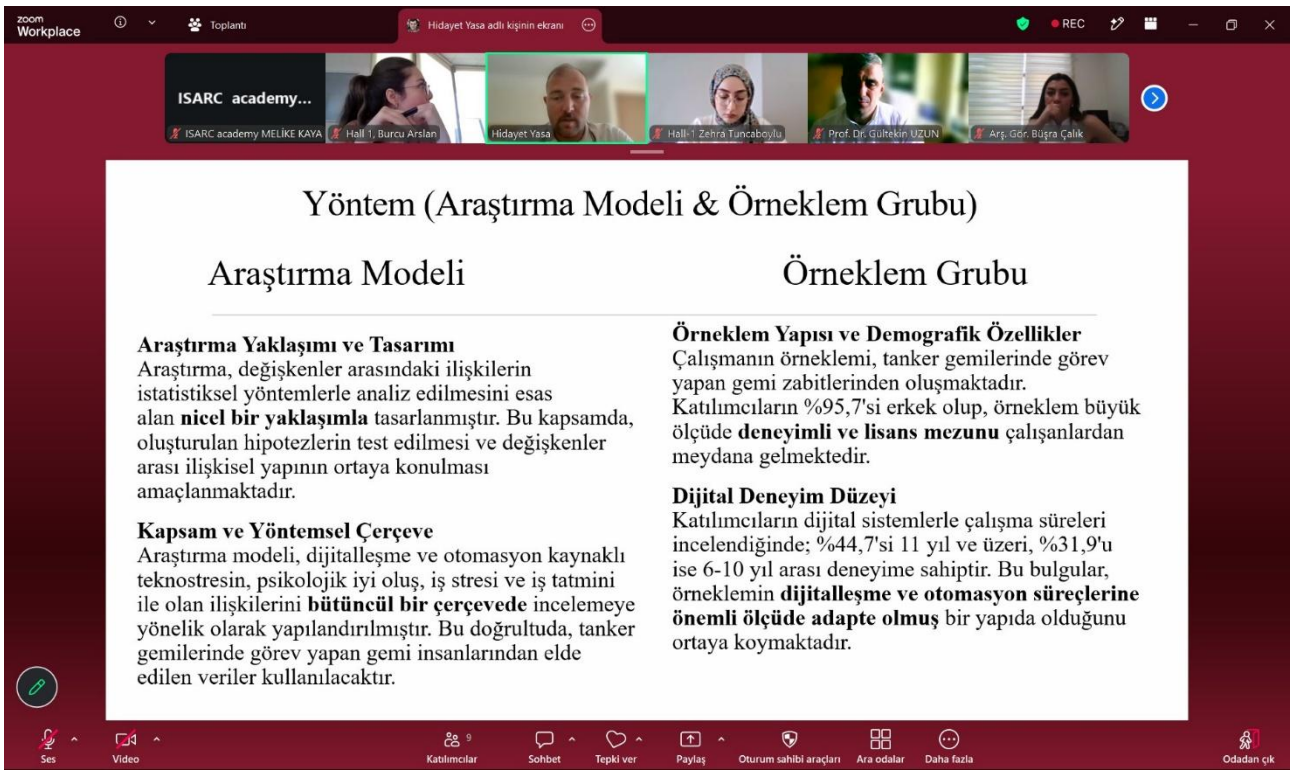
ANKARA LOCAL TIME		MEETING ID: 868 5772 2729	
$10^{30} : 11^{30}$		PASSCODE: 379941	

HEAD OF SESSION: *Le Nguyen Thao Uyen*

TOPIC TITLE	AUTHORS	AFFILIATION
Isolatıon Of Phenols, Flavonoıds, And Saponıns From Boss Yam Peels (Dıoscorea Rotundata) For The Reductıon Of Aflatoxın Growth	Odu Nwamaka Maureen Ganiyu Joan	Federal University
Exceptions to Personal Data Processing Without Consent and the Requirement to Control Legal Power	Hoang Le Buu Le Nguyen Thao Uyen	Thai Binh Duong University/VİETNAM
Occurrence of Klebsiella pneumoniae in Faecal Samples Obtained from Selected Cattle Farms in Ibadan Metropolis, Nigeria	Christianah Afoluke Gegeleso Olutayo Israel Falodun	University of Ibadan
Structural, morphological and optical properties of strontium hexaferrites SrFe 12-x Al x O 19 (x = 1, 1.5, 2, and 2.5) synthesized via sol–gel auto-combustion	Z. Rachyq, Z. Yamkane , M. Sadik , R. Moubah , M. Abdellaoui, M. El Achaby	Hassan II University/Mohammed VI Polytechnic University

PHOTO GALLERY



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Hall-1 Zehra Tuncaboylu
Prof. Dr. Gültekin UZUN
Hall-1 Cemre KADIOĞLU Hal...
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yasal ozdemir
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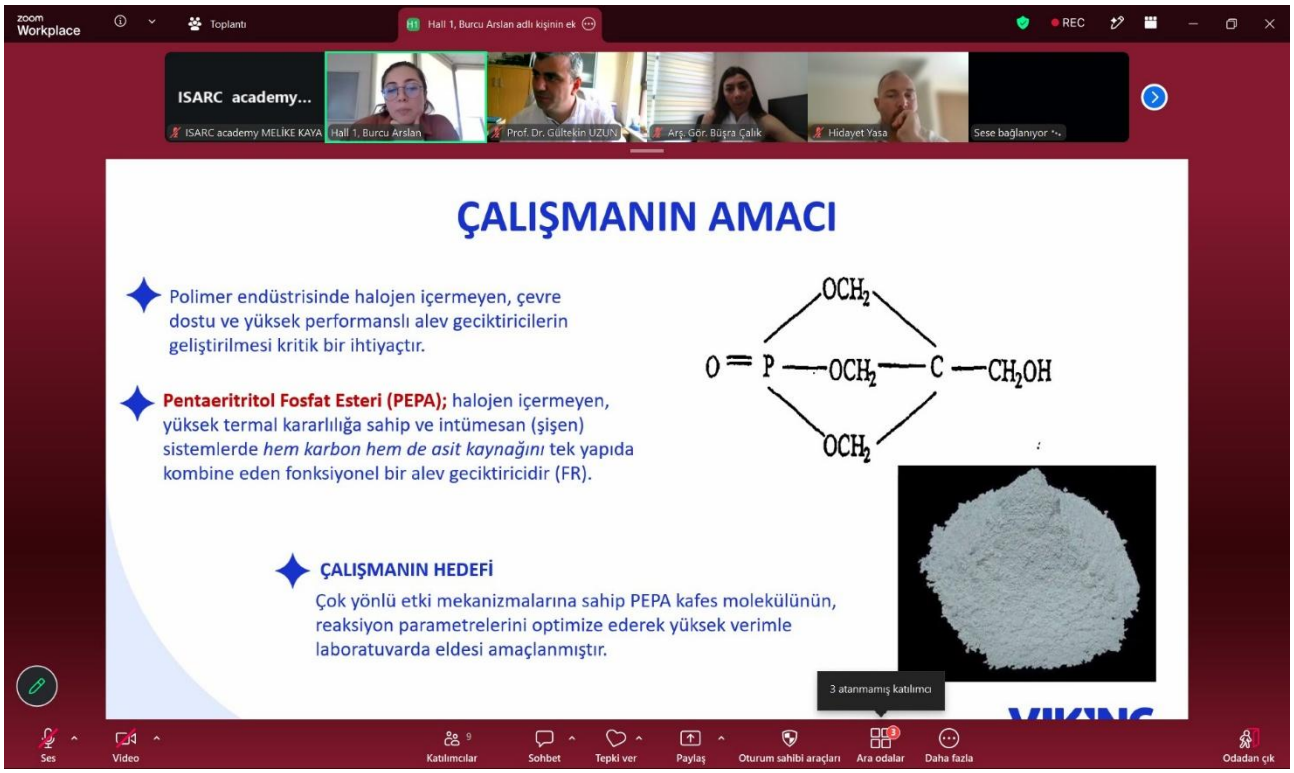
Ara odalar
Daha fazla
Odadan çık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Arş. Gör. Büşra Çalık
Hidayet Yasa
Sese bağlanıyor
ÇALIŞMANIN AMACI
Polimer endüstrisinde halojen içermeyen, çevre dostu ve yüksek performanslı alev geciktiricilerin geliştirilmesi kritik bir ihtiyaçtır.
Pentaeritritol Fosfat Esteri (PEPA); halojen içermeyen, yüksek termal kararlılığa sahip ve intümesan (şişen) sistemlerde hem karbon hem de asit kaynağını tek yapıda kombine eden fonksiyonel bir alev geciktiricidir (FR).
ÇALIŞMANIN HEDEFİ
Çok yönlü etki mekanizmalarına sahip PEPA kafes molekülünün, reaksiyon parametrelerini optimize ederek yüksek verimle laboratuvarda eldesi amaçlanmıştır.
3 atanmamış katılımcı
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Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
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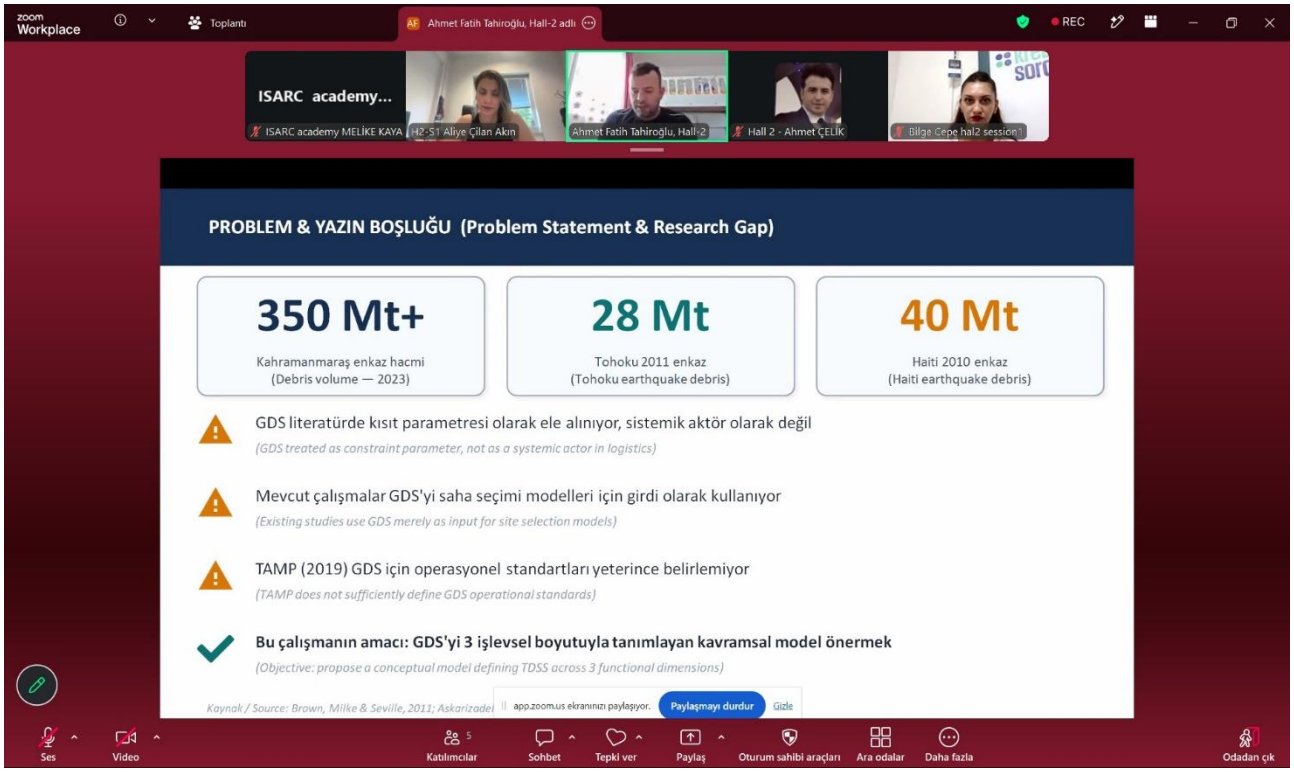
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Ahmet Fatih Tahiroğlu, Hall-2 adlı
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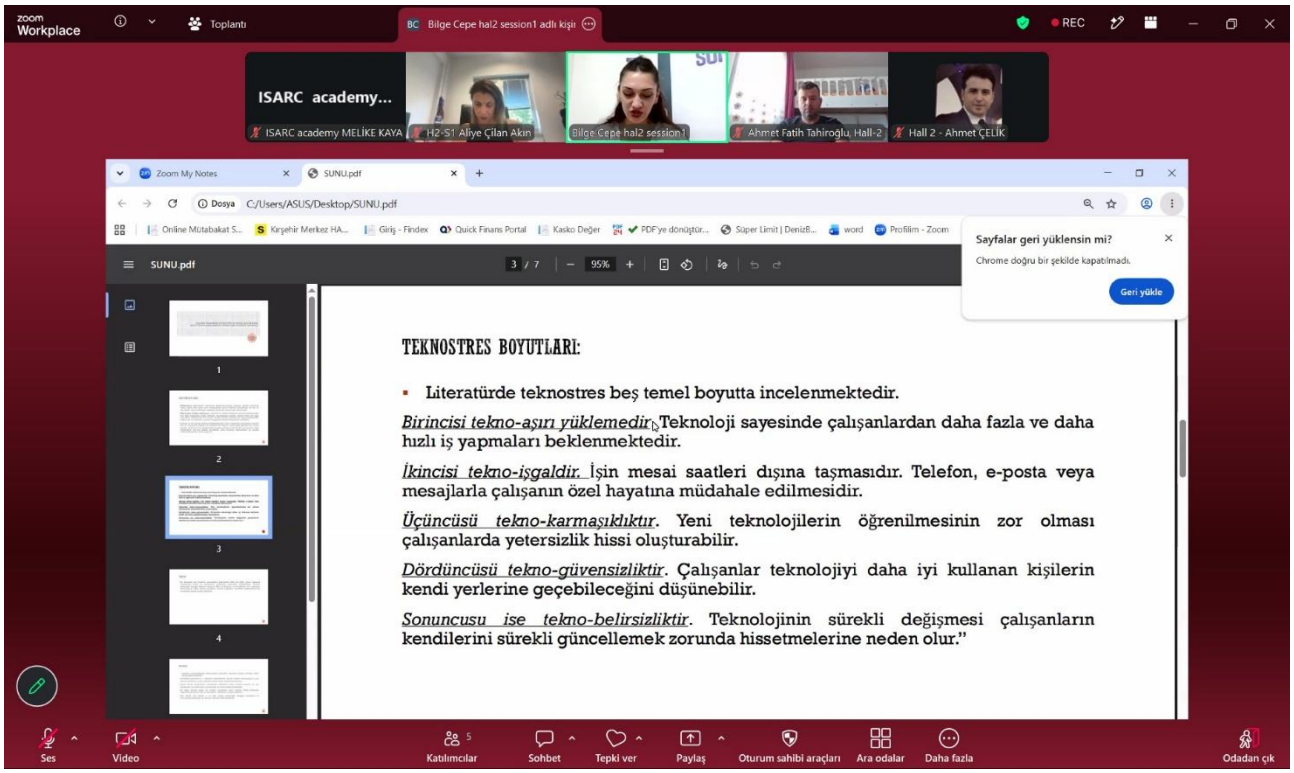
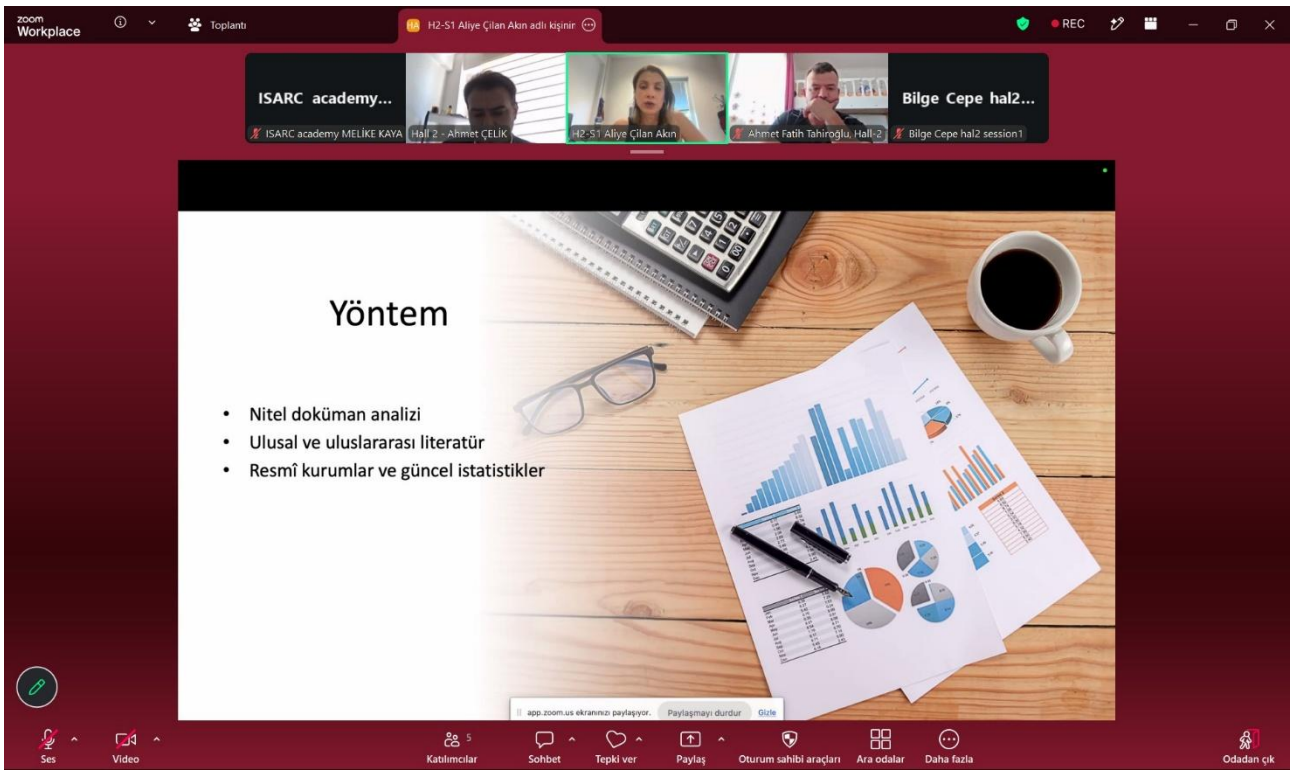
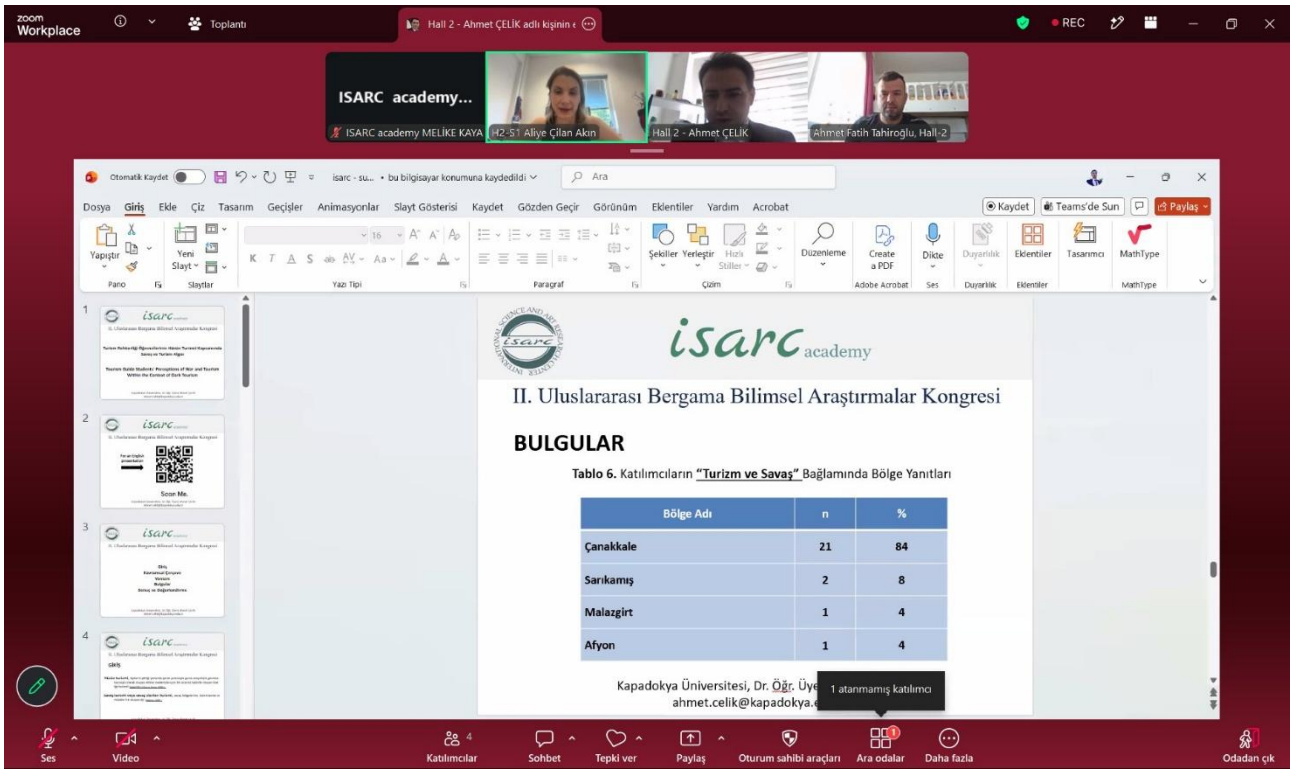
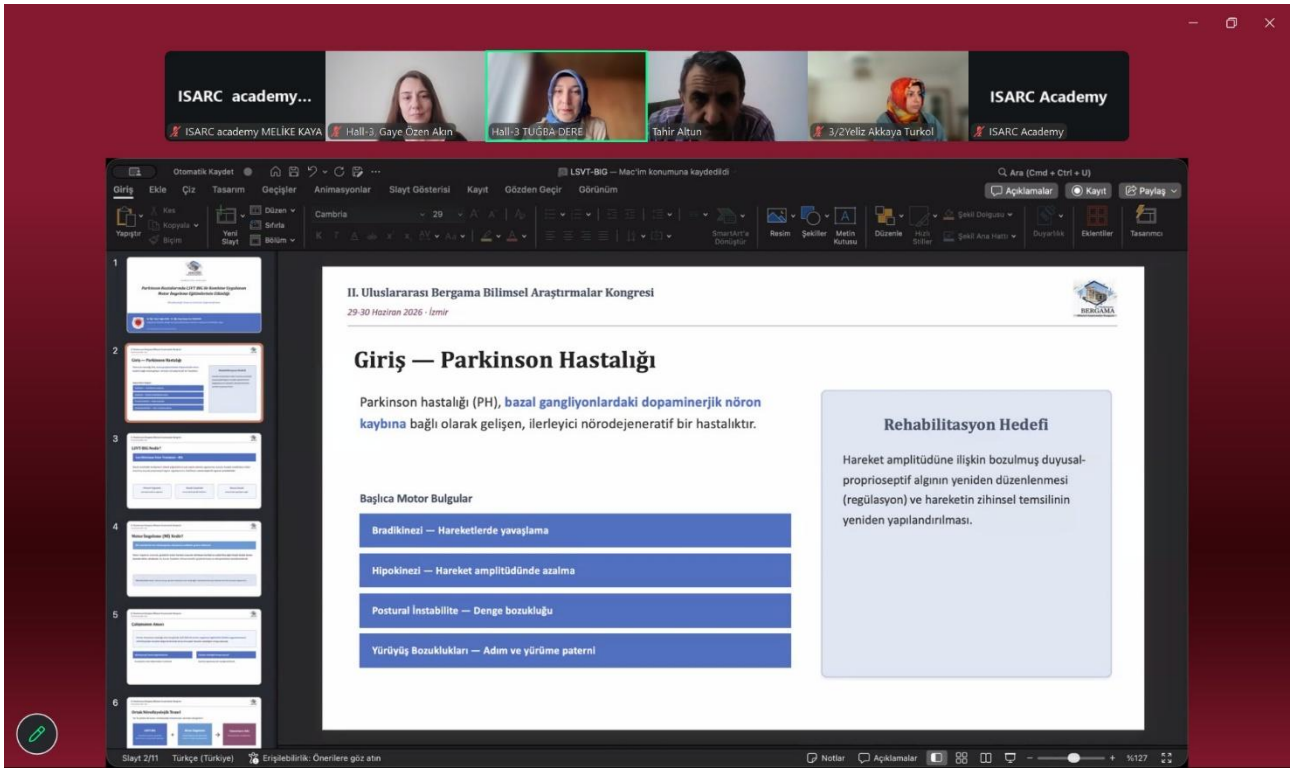
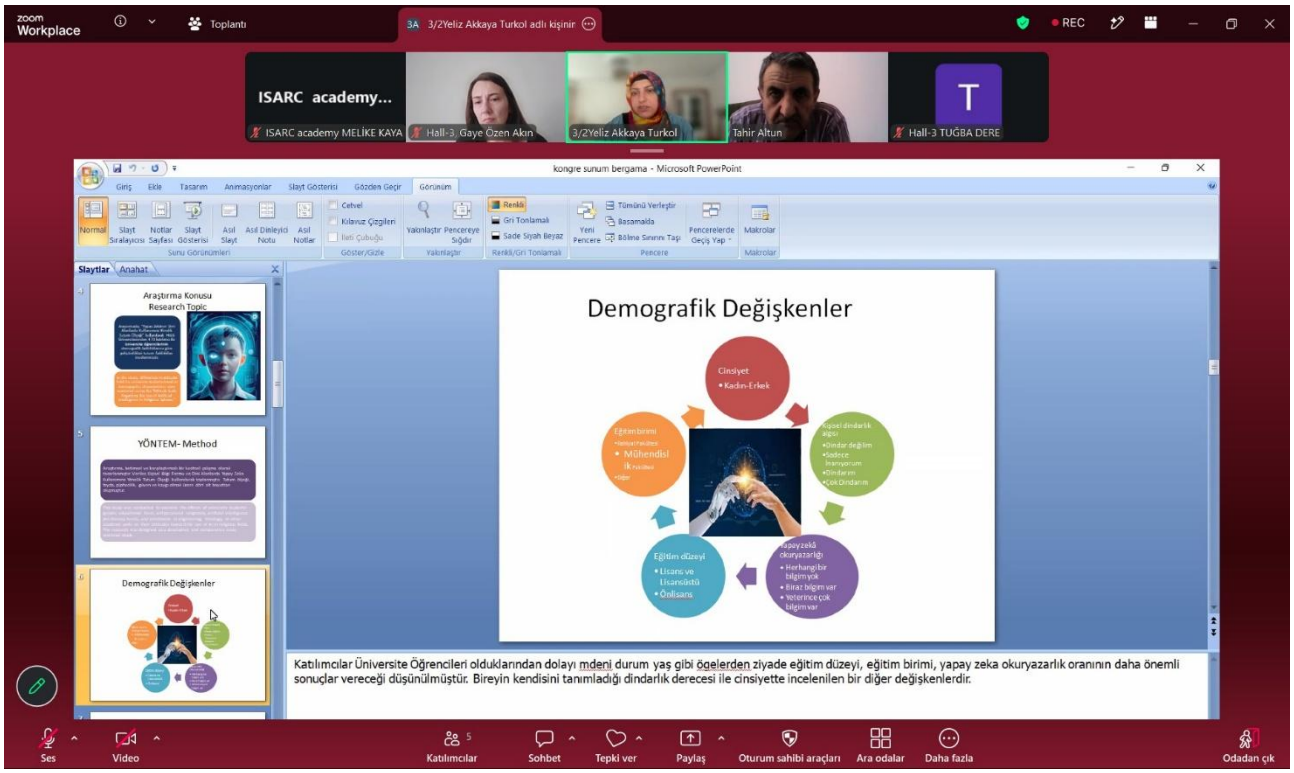
H2-S1 Aliye Çilan Akın
Ahmet Fatih Tahiroğlu, Hall-2
Hall 2 - Ahmet ÇELİK
Bilge Cepe hal2 session1
PROBLEM & YAZIN BOŞLUĞU (Problem Statement & Research Gap)
350 Mt+
Kahramanmaraş enkaz hacmi
(Debris volume — 2023)
28 Mt
Tohoku 2011 enkaz
(Tohoku earthquake debris)
40 Mt
Haiti 2010 enkaz
(Haiti earthquake debris)
GDS literatürde kısıt parametresi olarak ele alınıyor, sistemik aktör olarak değil
(GDS treated as constraint parameter, not as a systemic actor in logistics)
Mevcut çalışmalar GDS'yi saha seçimi modelleri için girdi olarak kullanıyor
(Existing studies use GDS merely as input for site selection models)
TAMP (2019) GDS için operasyonel standartları yeterince belirlemiyor
(TAMP does not sufficiently define GDS operational standards)
Bu çalışmanın amacı: GDS'yi 3 işlevsel boyutuyla tanımlayan kavramsal model önermek
(Objective: propose a conceptual model defining TDSS across 3 functional dimensions)
Kaynak / Source: Brown, Milke & Seville, 2011; Askarizadeh
app.zoom.us ekranınızı paylaşıyor.
Paylaşmayı durdur
Gizle
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık

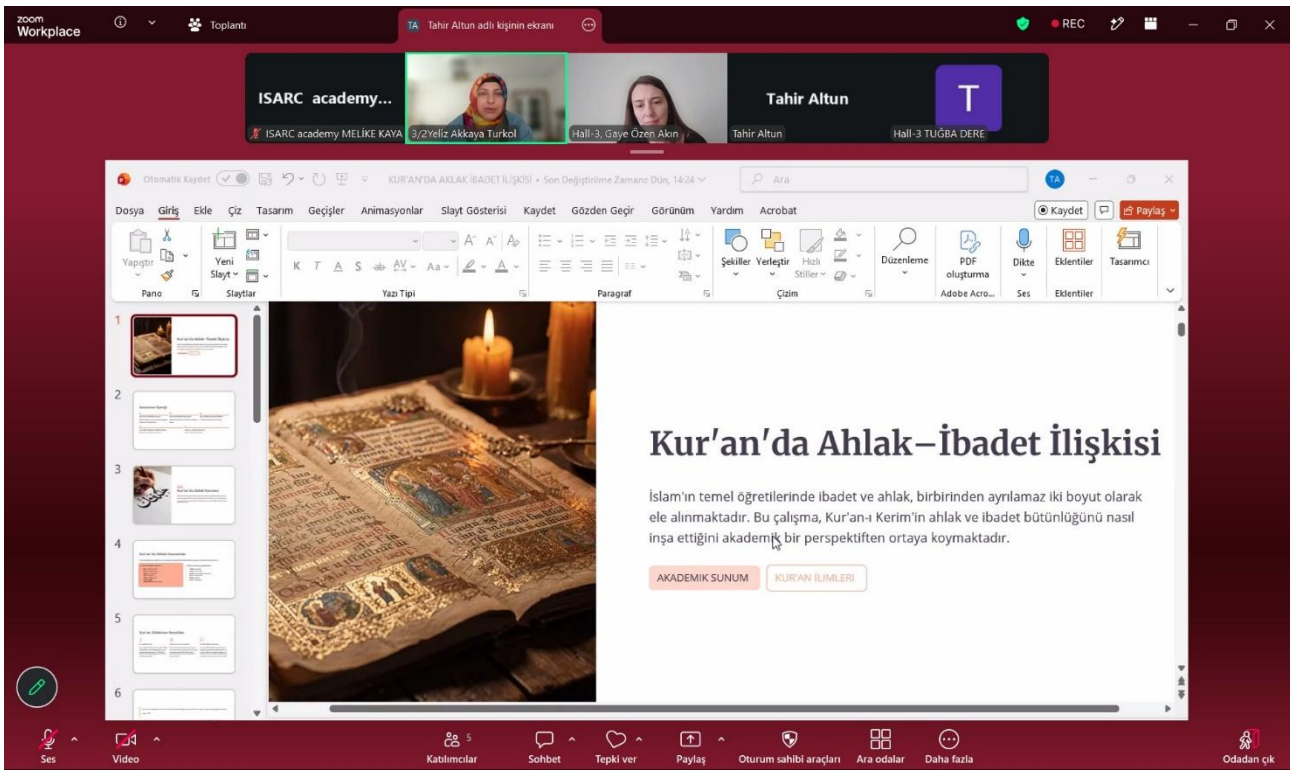

Toplantı
Bilge Cepe hal2 session1 adlı kişi
REC
ISARC academy...
ISARC academy MELİKE KAYA
H2-S1 Aliye Çilan Akın
Bilge Cepe hal2 session1
Ahmet Fatih Tahiroğlu, Hall-2
Hall 2 - Ahmet ÇELİK
Zoom My Notes
SUNU.pdf
C:/Users/ASUS/Desktop/SUNU.pdf
Sayfalar geri yüklensin mi?
Chrome doğru bir şekilde kapatılmadı.
Geri yükle
SUNU.pdf
3 / 7
95%
TEKNOSTRES BOYUTLARI:
Literatürde teknostres beş temel boyutta incelenmektedir.
Birincisi tekno-aşırı yüklemedir. Teknoloji sayesinde çalışanlardan daha fazla ve daha hızlı iş yapmaları beklenmektedir.
İkincisi tekno-işgaldir. İşin mesai saatleri dışına taşmasıdır. Telefon, e-posta veya mesajlarla çalışanın özel hayatına müdahale edilmesidir.
Üçüncüsü tekno-karmaşıklıktır. Yeni teknolojilerin öğrenilmesinin zor olması çalışanlarda yetersizlik hissi oluşturabilir.
Dördüncüsü tekno-güvensizliktir. Çalışanlar teknolojiyi daha iyi kullanan kişilerin kendi yerlerine geçebileceğini düşünebilir.
Sonuncusu ise tekno-belirsizliktir. Teknolojinin sürekli değişmesi çalışanların kendilerini sürekli güncellemek zorunda hissetmelerine neden olur."
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık

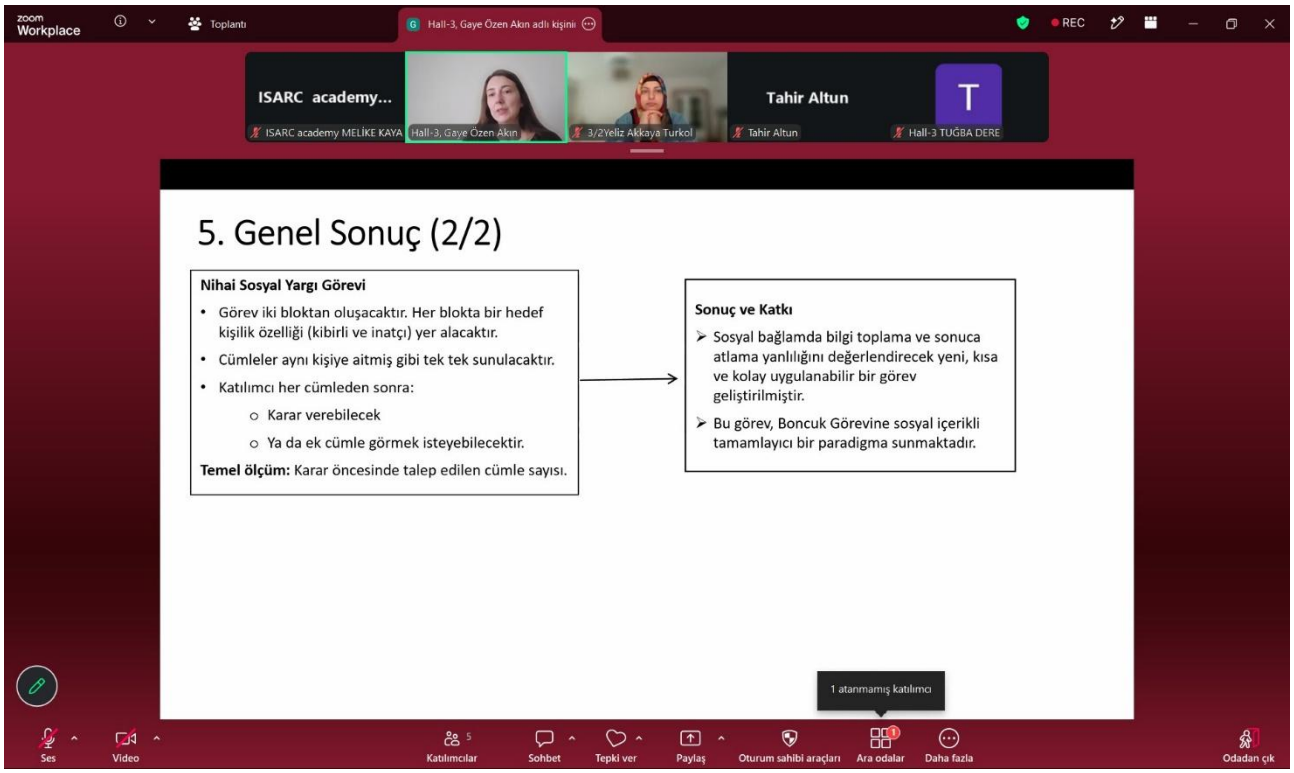

zoom Workplace
Toplantı
H2-S1 Aliye Çilan Akın adlı kişinin
REC
ISARC academy...
ISARC academy MELİKE KAYA
Hall 2 - Ahmet ÇELİK
H2-S1 Aliye Çilan Akın
Ahmet Fatih Tahiroğlu, Hall-2
Bilge Cepe hal2...
Bilge Cepe hal2 session1
Yöntem
Nitel doküman analizi
Ulusal ve uluslararası literatür
Resmî kurumlar ve güncel istatistikler
app.zoom.us ekranınızı paylaşıyor.
Paylaşmayı durdur
Gizle
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık

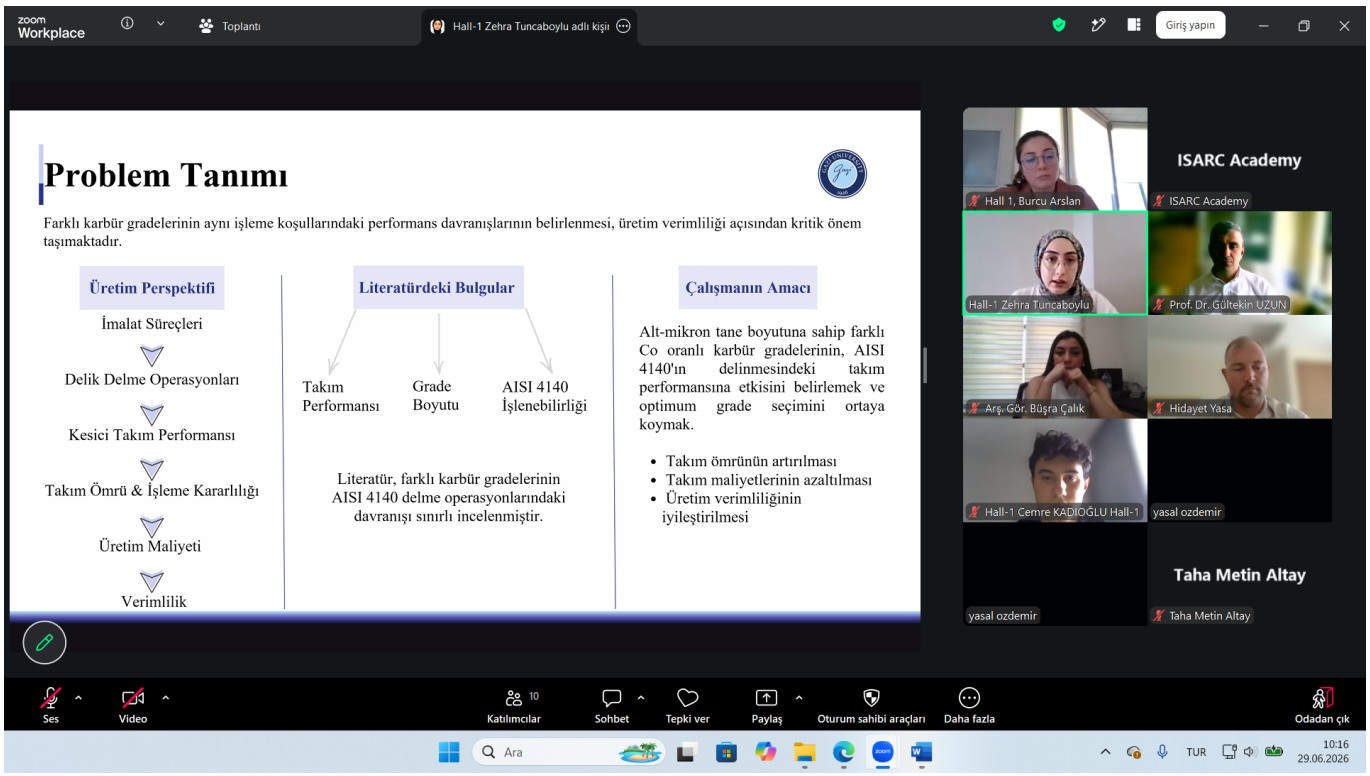

zoom Workplace
Toplantı
Hall 2 - Ahmet ÇELİK adlı kişinin
REC
ISARC academy...
ISARC academy MELİKE KAYA
H2-S1 Aliye Çilan Akın
Hall 2 - Ahmet ÇELİK
Ahmet Fatih Tahiroğlu, Hall-2
isarc academy
II. Uluslararası Bergama Bilimsel Araştırmalar Kongresi
BULGULAR
Tablo 6. Katılımcıların "Turizm ve Savaş" Bağlamında Bölge Yanıtları
Bölge Adı | n | %
Çanakkale | 21 | 84
Sarıkamış | 2 | 8
Malazgirt | 1 | 4
Afyon | 1 | 4
Kapadokya Üniversitesi, Dr. Öğr. Üye
ahmet.celik@kapadokya.
1 atanmamış katılımcı
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık

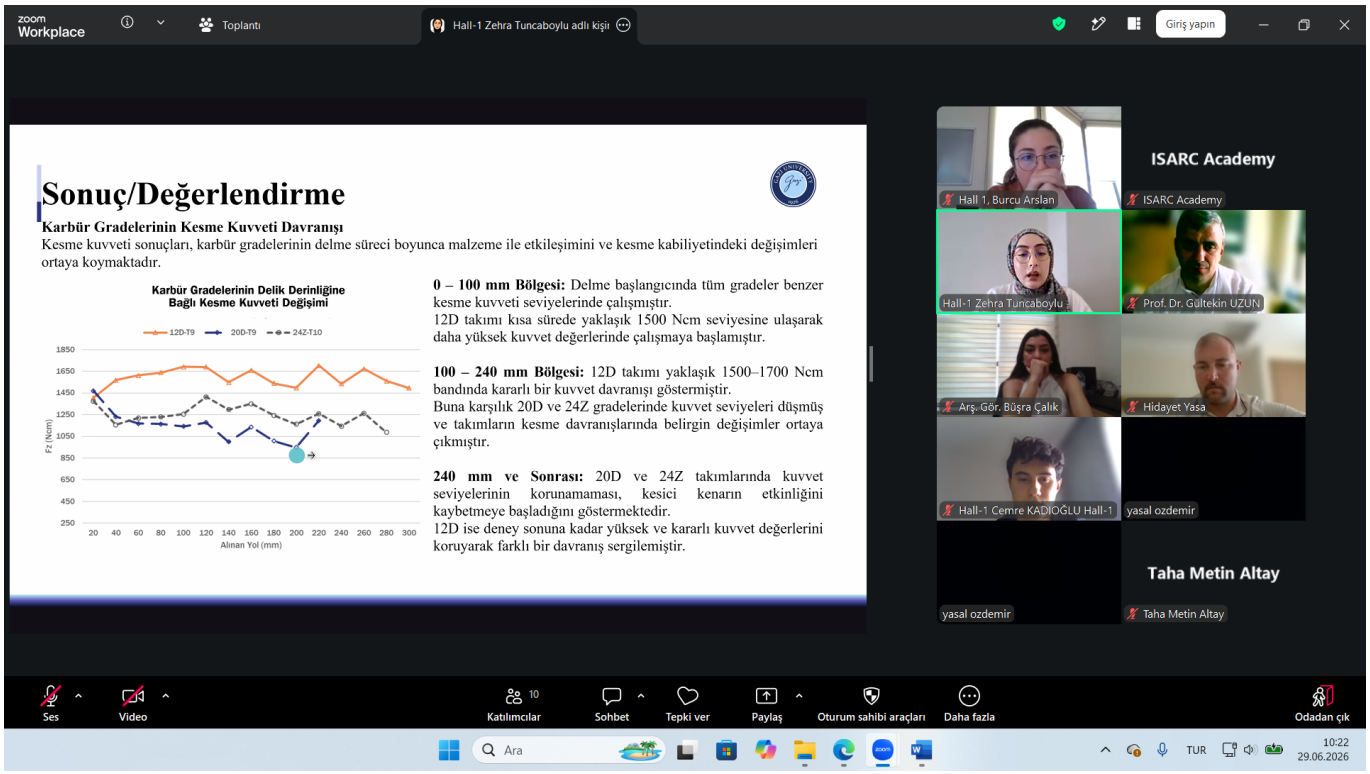

ISARC academy...
ISARC academy MELİKE KAYA
Hall-3 Gaye Özen Akın
Hall-3 TUĞBA DERE
Tahir Altun
3/2Yeliz Akkaya Turkol
ISARC Academy
ISARC Academy
II. Uluslararası Bergama Bilimsel Araştırmalar Kongresi
29-30 Haziran 2026 · İzmir
Giriş — Parkinson Hastalığı
Parkinson hastalığı (PH), bazal gangliyonlardaki dopaminerjik nöron kaybına bağlı olarak gelişen, ilerleyici nörodejeneratif bir hastalıktır.
Başlıca Motor Bulgular
Bradikinezi — Hareketlerde yavaşlama
Hipokinezi — Hareket amplitüdünde azalma
Postural İnstabilite — Denge bozukluğu
Yürüyüş Bozuklukları — Adım ve yürüme paterni
Rehabilitasyon Hedefi
Hareket amplitüdüne ilişkin bozulmuş duyusal-proprioseptif algının yeniden düzenlenmesi (regülasyon) ve hareketin zihinsel temsilinin yeniden yapılandırılması.


zoom Workplace
Toplantı
3A 3/2Yeliz Akkaya Turkol adlı kişinin
REC
ISARC academy...
ISARC academy MELİKE KAYA
Hall-3 Gaye Özen Akın
3/2Yeliz Akkaya Turkol
Tahir Altun
Hall-3 TUĞBA DERE
kongre sunum bergama - Microsoft PowerPoint
Demografik Değişkenler
Cinsiyet
• Kadın-Erkek
Eğitim düzeyi
• Lisans ve Lisansüstü
• Önlisans
Katılımcılar Üniversite Öğrencileri olduklarından dolayı mdeni durum yaş gibi ögelerden ziyade eğitim düzeyi, eğitim birimi, yapay zeka okuryazarlık oranının daha önemli sonuçlar vereceği düşünülmüştür. Bireyin kendisini tanımladığı dindarlık derecesi ile cinsiyette incelenilen bir diğer değişkenlerdir.
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık


Toplantı
Tahir Altun adlı kişinin ekranı
REC
ISARC academy...
ISARC academy MELİKE KAYA
3/2Yeliz Akkaya Turkol
Hall-3, Gaye Özen Akın
Tahir Altun
Hall-3 TUĞBA DERE
Kur'an'da Ahlak–İbadet İlişkisi
İslam'ın temel öğretilerinde ibadet ve ahlak, birbirinden ayrılamaz iki boyut olarak ele alınmaktadır. Bu çalışma, Kur'an-ı Kerim'in ahlak ve ibadet bütünlüğünü nasıl inşa ettiğini akademik bir perspektiften ortaya koymaktadır.
AKADEMİK SUNUM
KUR'AN İLİMLERİ
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık


Toplantı
Hall-3, Gaye Özen Akın adlı kişinin
REC
ISARC academy...
ISARC academy MELİKE KAYA
Hall-3, Gaye Özen Akın
3/2Yeliz Akkaya Turkol
Tahir Altun
Hall-3 TUĞBA DERE
5. Genel Sonuç (2/2)
Nihai Sosyal Yargı Görevi
Görev iki bloktan oluşacaktır. Her blokta bir hedef kişilik özelliği (kibirli ve inatçı) yer alacaktır.
Cümleler aynı kişiye aitmiş gibi tek tek sunulacaktır.
Katılımcı her cümleden sonra:
Karar verebilecek
Ya da ek cümle görmek isteyebilecektir.
Temel ölçüm: Karar öncesinde talep edilen cümle sayısı.
Sonuç ve Katkı
Sosyal bağlamda bilgi toplama ve sonuca atlama yanlılığını değerlendirecek yeni, kısa ve kolay uygulanabilir bir görev geliştirilmiştir.
Bu görev, Boncuk Görevine sosyal içerikli tamamlayıcı bir paradigma sunmaktadır.
1 atanmamış katılımcı
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık


zoom Workplace
Toplantı
Hall-1 Zehra Tuncaboylu adlı kişi
Giriş yapın
Problem Tanımı
Farklı karbür gradelerinin aynı işleme koşullarındaki performans davranışlarının belirlenmesi, üretim verimliliği açısından kritik önem taşımaktadır.
Üretim Perspektifi
İmalat Süreçleri
Delik Delme Operasyonları
Kesici Takım Performansı
Takım Ömrü & İşleme Kararlılığı
Üretim Maliyeti
Verimlilik
Literatürdeki Bulgular
Takım Performansı
Grade Boyutu
AISI 4140 İşlenebilirliği
Literatür, farklı karbür gradelerinin AISI 4140 delme operasyonlarındaki davranışı sınırlı incelenmiştir.
Çalışmanın Amacı
Alt-mikron tane boyutuna sahip farklı Co oranlı karbür gradelerinin, AISI 4140'ın delinmesindeki takım performansına etkisini belirlemek ve optimum grade seçimini ortaya koymak.
Takım ömrünün artırılması
Takım maliyetlerinin azaltılması
Üretim verimliliğinin iyileştirilmesi
ISARC Academy
Hall 1, Burcu Arslan
Hall-1 Zehra Tuncaboylu
Prof. Dr. Gültekin UZUN
Arş. Gör. Büşra Çalık
Hidayet Yasa
Hall-1 Cemre KADIOĞLU Hall-1
yasal ozdemir
Taha Metin Altay
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
TUR
10:16
29.06.2026


zoom Workplace
Toplantı
Hall-1 Zehra Tuncaboylu adlı kişi
Giriş yapın
Sonuç/Değerlendirme
Karbür Gradelerinin Kesme Kuvveti Davranışı
Kesme kuvveti sonuçları, karbür gradelerinin delme süreci boyunca malzeme ile etkileşimini ve kesme kabiliyetindeki değişimleri ortaya koymaktadır.
Karbür Gradelerinin Delik Derinliğine Bağlı Kesme Kuvveti Değişimi
12D-T9
20D-T9
24Z-T10
Fz (Ncm)
Alınan Yol (mm)
0 – 100 mm Bölgesi: Delme başlangıcında tüm gradeler benzer kesme kuvveti seviyelerinde çalışmıştır.
12D takımı kısa sürede yaklaşık 1500 Ncm seviyesine ulaşarak daha yüksek kuvvet değerlerinde çalışmaya başlamıştır.
100 – 240 mm Bölgesi: 12D takımı yaklaşık 1500–1700 Ncm bandında kararlı bir kuvvet davranışı göstermiştir.
Buna karşılık 20D ve 24Z gradelerinde kuvvet seviyeleri düşmüş ve takımların kesme davranışlarında belirgin değişimler ortaya çıkmıştır.
240 mm ve Sonrası: 20D ve 24Z takımlarında kuvvet seviyelerinin korunamaması, kesici kenarın etkinliğini kaybetmeye başladığını göstermektedir.
12D ise deney sonuna kadar yüksek ve kararlı kuvvet değerlerini koruyarak farklı bir davranış sergilemiştir.
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Hall 1, Burcu Arslan
Hall-1 Zehra Tuncaboylu
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Arş. Gör. Büşra Çalık
Hidayet Yasa
Hall-1 Cemre KADIOĞLU Hall-1
yasal ozdemir
Taha Metin Altay
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
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10:22
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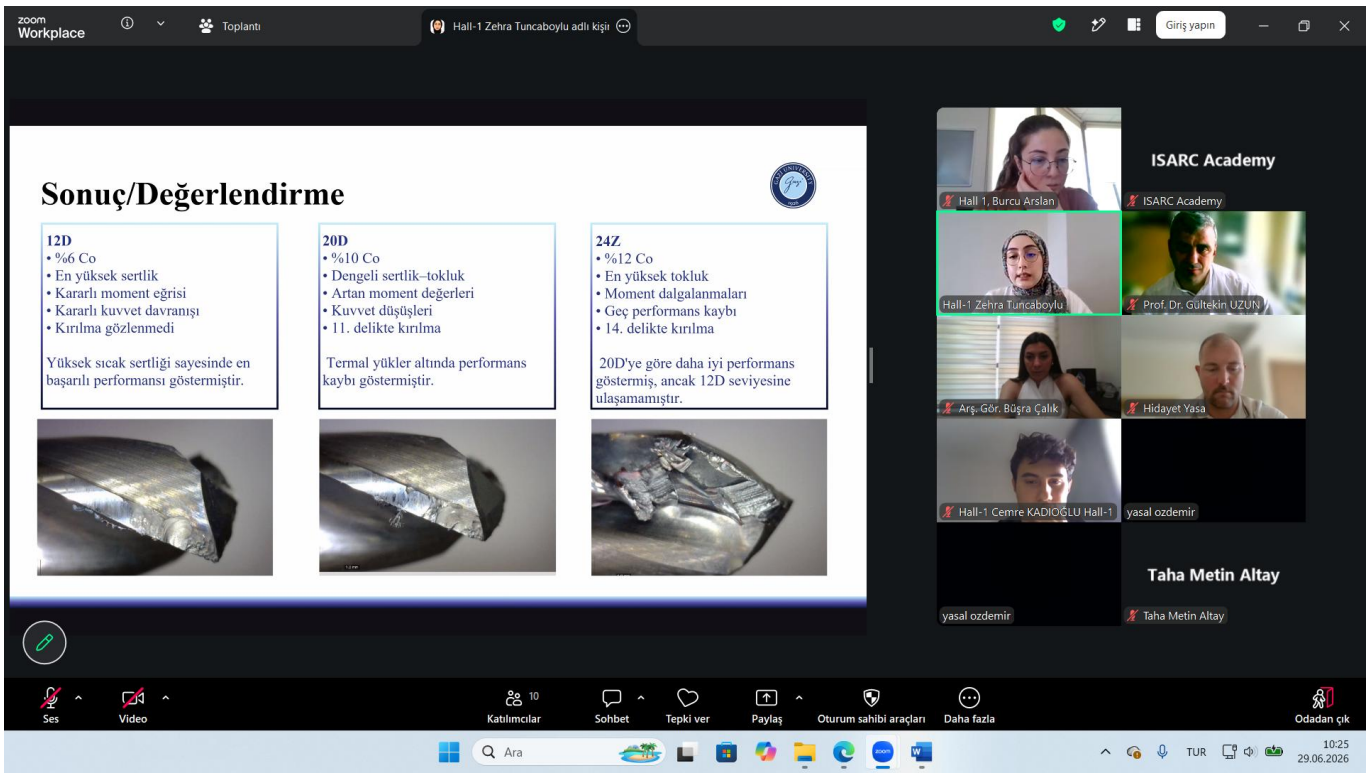
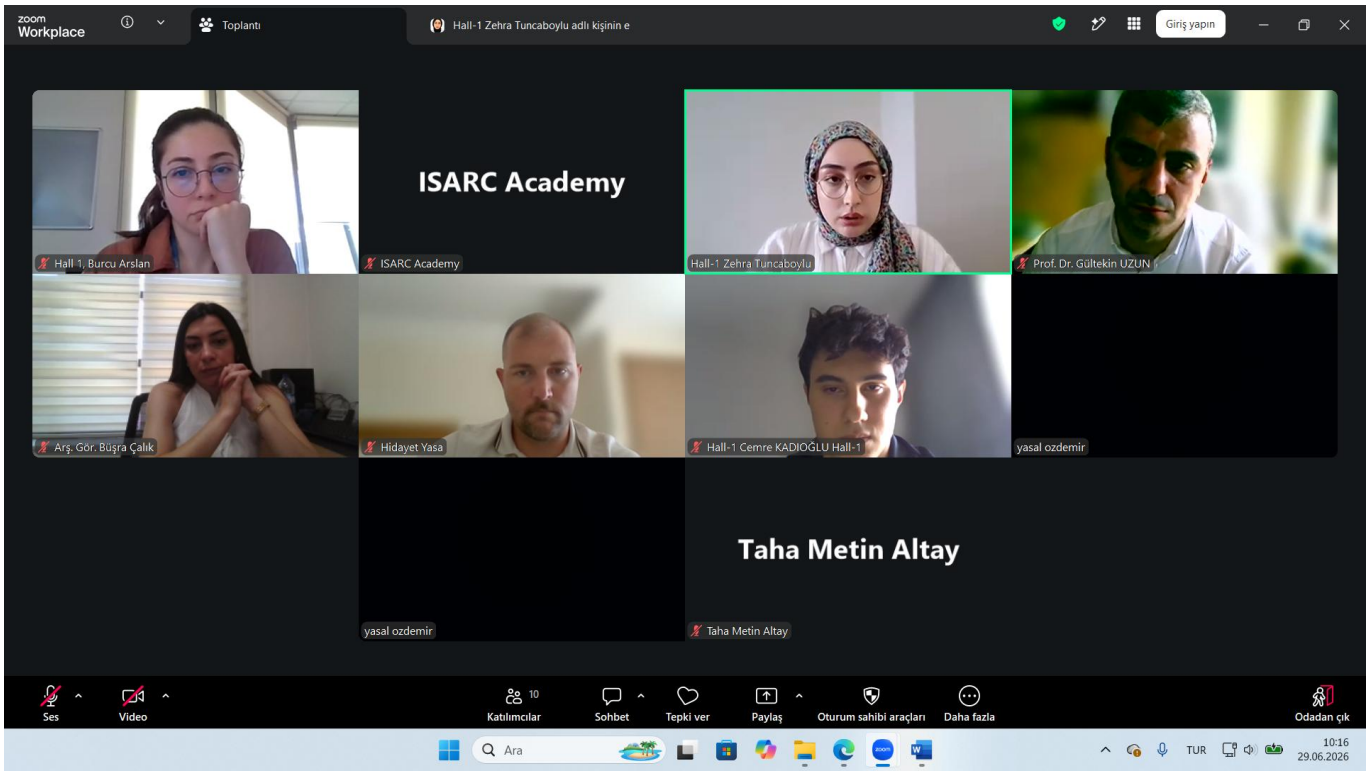
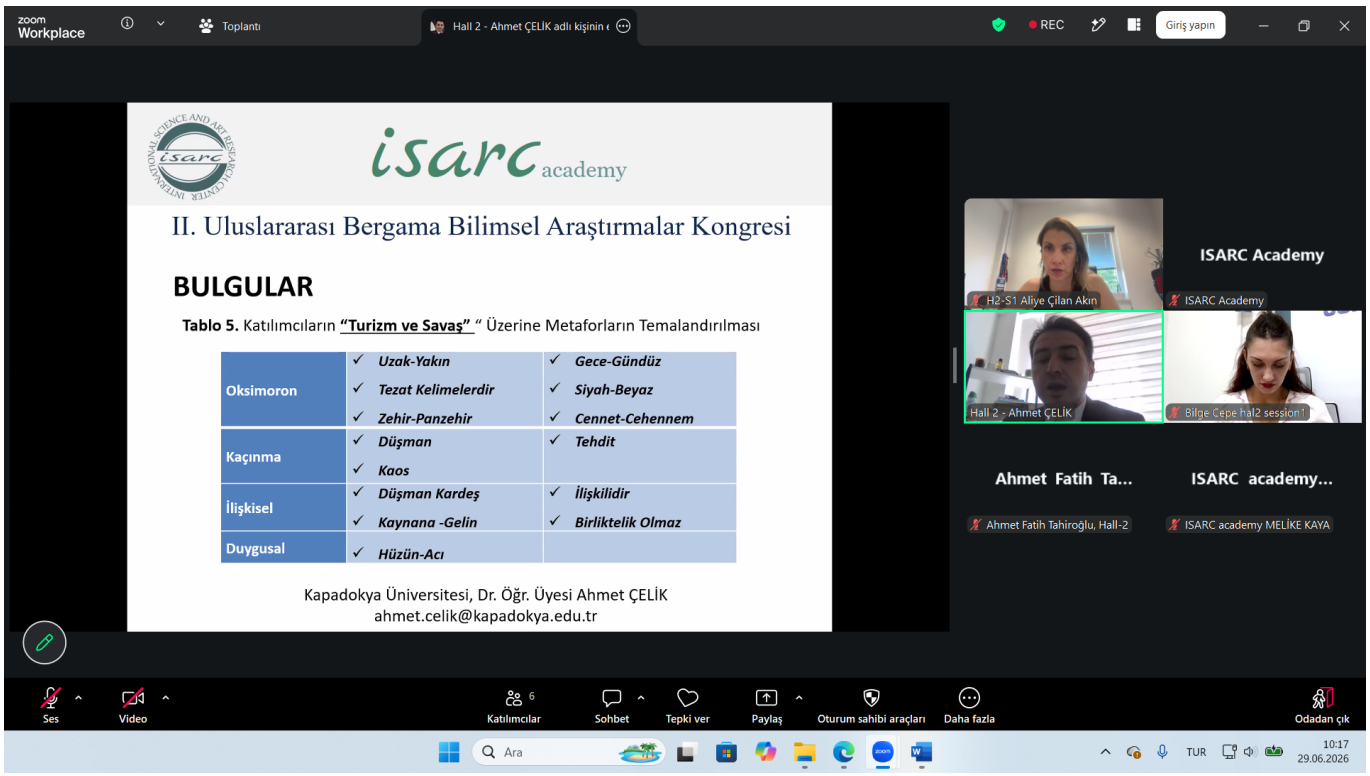
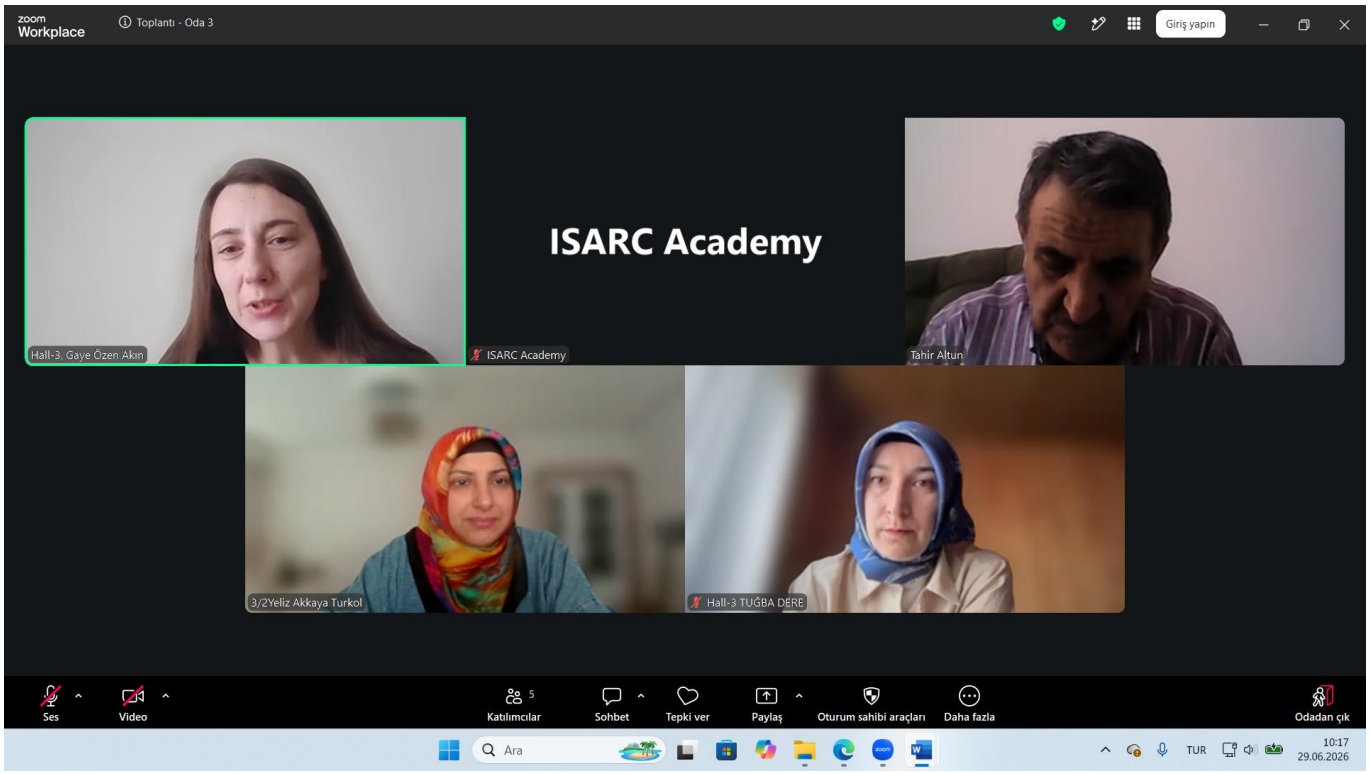
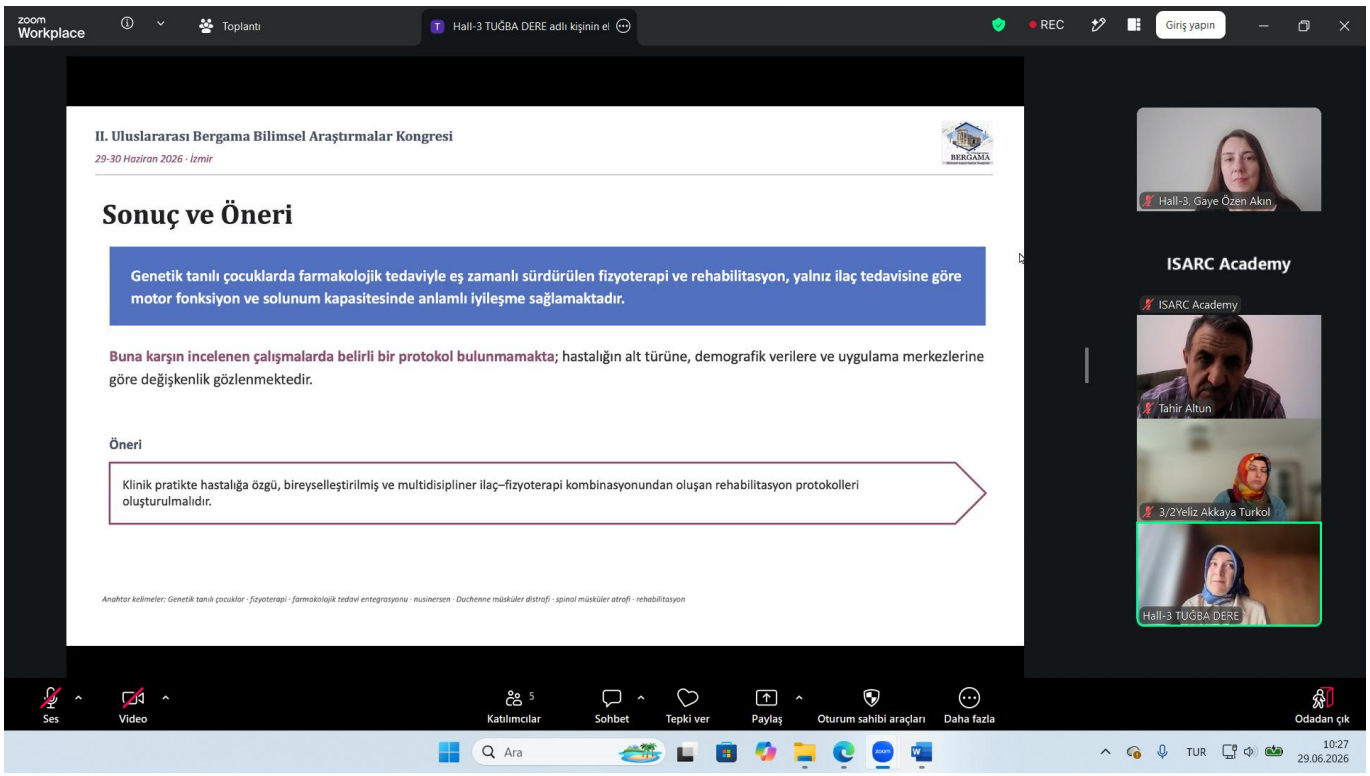
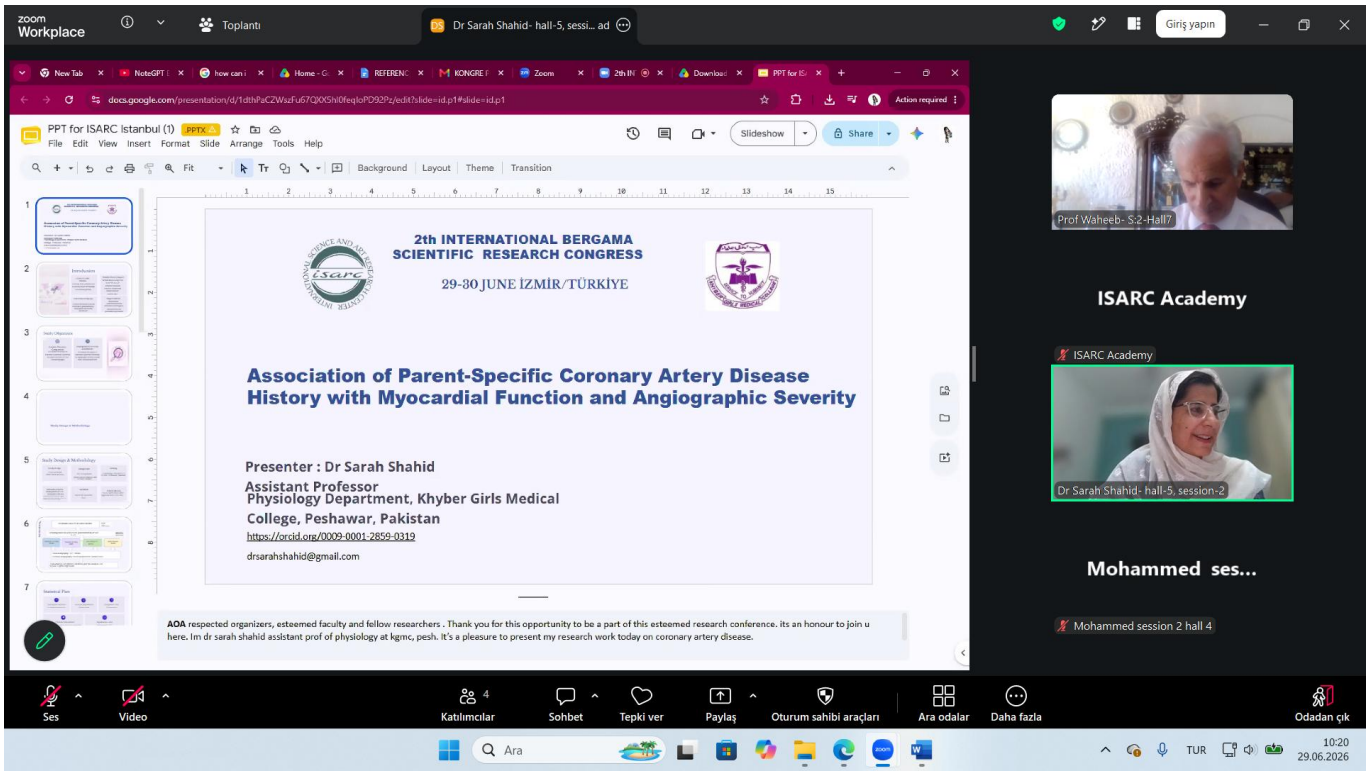

zoom Workplace
Toplantı
Hall-1 Zehra Tuncaboylu adlı kişi
Giriş yapın
Sonuç/Değerlendirme
12D
• %6 Co
• En yüksek sertlik
• Kararlı moment eğrisi
• Kararlı kuvvet davranışı
• Kırılma gözlenmedi
Yüksek sıcak sertliği sayesinde en başarılı performansı göstermiştir.
20D
• %10 Co
• Dengeli sertlik–tokluk
• Artan moment değerleri
• Kuvvet düşüşleri
• 11. delikte kırılma
Termal yükler altında performans kaybı göstermiştir.
24Z
• %12 Co
• En yüksek tokluk
• Moment dalgalanmaları
• Geç performans kaybı
• 14. delikte kırılma
20D'ye göre daha iyi performans göstermiş, ancak 12D seviyesine ulaşamamıştır.
Hall 1, Burcu Arslan
ISARC Academy
Hall-1 Zehra Tuncaboylu
Prof. Dr. Gültekin UZUN
Arş. Gör. Büşra Çalık
Hidayet Yasa
Hall-1 Cemre KADIOĞLU Hall-1
yasal ozdemir
Taha Metin Altay
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
TUR
10:25
29.06.2026

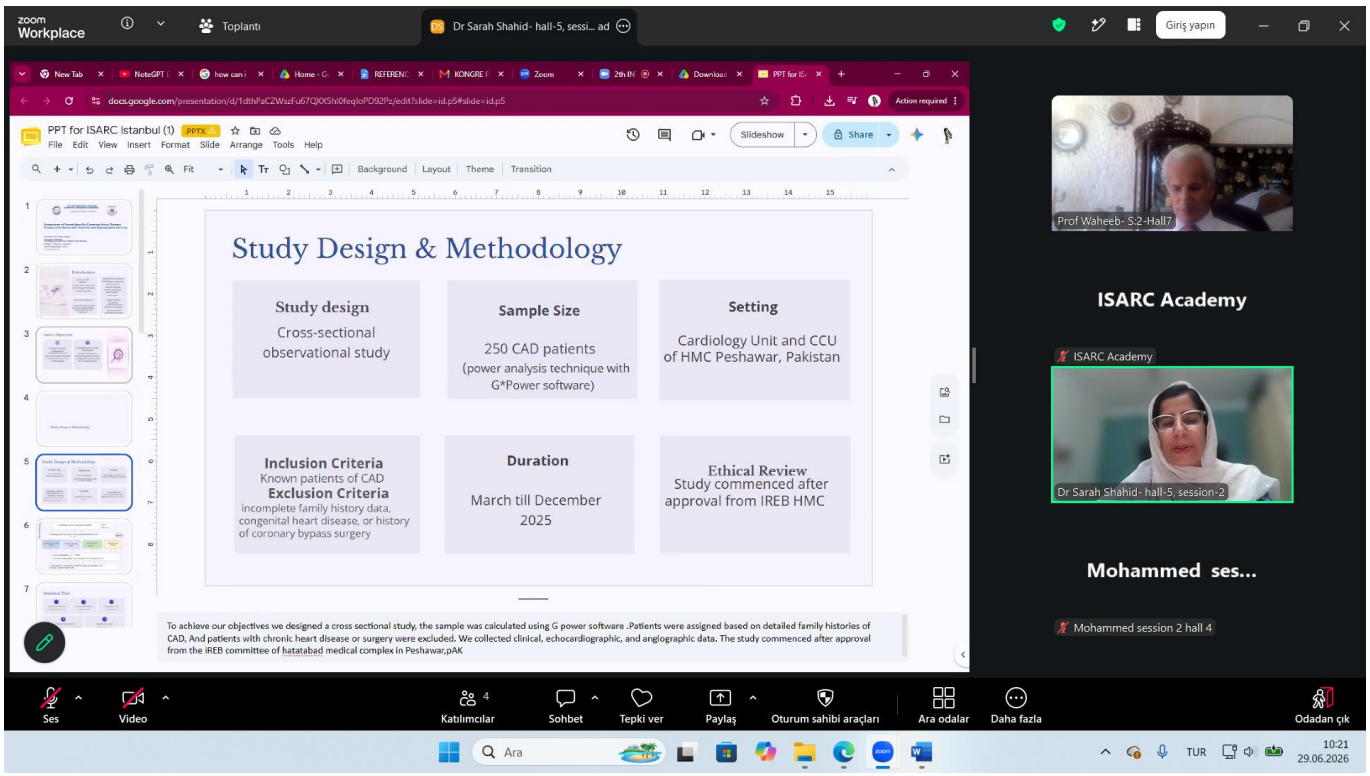

zoom Workplace
Toplantı
Hall-1 Zehra Tuncaboylu adlı kişinin e
Giriş yapın
Hall 1, Burcu Arslan
ISARC Academy
Hall-1 Zehra Tuncaboylu
Prof. Dr. Gültekin UZUN
Arş. Gör. Büşra Çalık
Hidayet Yasa
Hall-1 Cemre KADIOĞLU Hall-1
yasal ozdemir
Taha Metin Altay
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
TUR
10:16
29.06.2026


Toplantı
Hall 2 - Ahmet ÇELİK adlı kişinin
REC
Giriş yapın
isarc academy
II. Uluslararası Bergama Bilimsel Araştırmalar Kongresi
BULGULAR
Tablo 5. Katılımcıların "Turizm ve Savaş" " Üzerine Metaforların Temalandırılması
Oksimoron
Uzak-Yakın
Gece-Gündüz
Tezat Kelimelerdir
Siyah-Beyaz
Zehir-Panzehir
Cennet-Cehennem
Kaçınma
Düşman
Tehdit
Kaos
İlişkisel
Düşman Kardeş
İlişkilidir
Kaynana -Gelin
Birliktelik Olmaz
Duygusal
Hüzün-Acı
Kapadokya Üniversitesi, Dr. Öğr. Üyesi Ahmet ÇELİK
ahmet.celik@kapadokya.edu.tr
H2-S1 Aliye Çilan Akın
ISARC Academy
Hall 2 - Ahmet ÇELİK
Bilge Cepe hal2 session1
Ahmet Fatih Ta...
ISARC academy...
Ahmet Fatih Tahiroğlu, Hall-2
ISARC academy MELİKE KAYA
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
TUR
10:17
29.06.2026


Toplantı - Oda 3
Giriş yapın
Hall-3, Gaye Özen Akın
ISARC Academy
Tahir Altun
3/2Yeliz Akkaya Turkol
Hall-3 TUĞBA DERE
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Daha fazla
Odadan çık
Ara
TUR
10:17
29.06.2026


II. Uluslararası Bergama Bilimsel Araştırmalar Kongresi
29-30 Haziran 2026 · İzmir
Sonuç ve Öneri
Genetik tanılı çocuklarda farmakolojik tedaviyle eş zamanlı sürdürülen fizyoterapi ve rehabilitasyon, yalnız ilaç tedavisine göre motor fonksiyon ve solunum kapasitesinde anlamlı iyileşme sağlamaktadır.
Buna karşın incelenen çalışmalarda belirli bir protokol bulunmamakta; hastalığın alt türüne, demografik verilere ve uygulama merkezlerine göre değişkenlik gözlenmektedir.
Öneri
Klinik pratikte hastalığa özgü, bireyselleştirilmiş ve multidisipliner ilaç–fizyoterapi kombinasyonundan oluşan rehabilitasyon protokolleri oluşturulmalıdır.
Anahtar kelimeler: Genetik tanılı çocuklar · fizyoterapi · farmakolojik tedavi entegrasyonu · nusinersen · Duchenne müsküler distrofi · spinal müsküler atrofi · rehabilitasyon
Hall-3, Gaye Özen Akın
ISARC Academy
ISARC Academy
Tahir Altun
3/2Yeliz Akkaya Turkol
Hall-3 TUĞBA DERE


2th INTERNATIONAL BERGAMA SCIENTIFIC RESEARCH CONGRESS
29-30 JUNE İZMİR/TÜRKİYE
Association of Parent-Specific Coronary Artery Disease History with Myocardial Function and Angiographic Severity
Presenter : Dr Sarah Shahid
Assistant Professor
Physiology Department, Khyber Girls Medical College, Peshawar, Pakistan
https://orcid.org/0009-0001-2859-0319
drsarahshahid@gmail.com
AOA respected organizers, esteemed faculty and fellow researchers . Thank you for this opportunity to be a part of this esteemed research conference. its an honour to join u here. Im dr sarah shahid assistant prof of physiology at kgmc, pesh. it's a pleasure to present my research work today on coronary artery disease.
Prof Waheeb- S:2-Hall7
ISARC Academy
ISARC Academy
Dr Sarah Shahid- hall-5, session-2
Mohammed ses...
Mohammed session 2 hall 4


Study Design & Methodology
Study design
Cross-sectional observational study
Sample Size
250 CAD patients
(power analysis technique with G*Power software)
Setting
Cardiology Unit and CCU of HMC Peshawar, Pakistan
Inclusion Criteria
Known patients of CAD
Exclusion Criteria
incomplete family history data, congenital heart disease, or history of coronary bypass surgery
Duration
March till December 2025
Ethical Review
Study commenced after approval from IREB HMC
To achieve our objectives we designed a cross sectional study, the sample was calculated using G power software .Patients were assigned based on detailed family histories of CAD, And patients with chronic heart disease or surgery were excluded. We collected clinical, echocardiographic, and angiographic data. The study commenced after approval from the iREB committee of hatatabad medical complex in Peshawar,pAK
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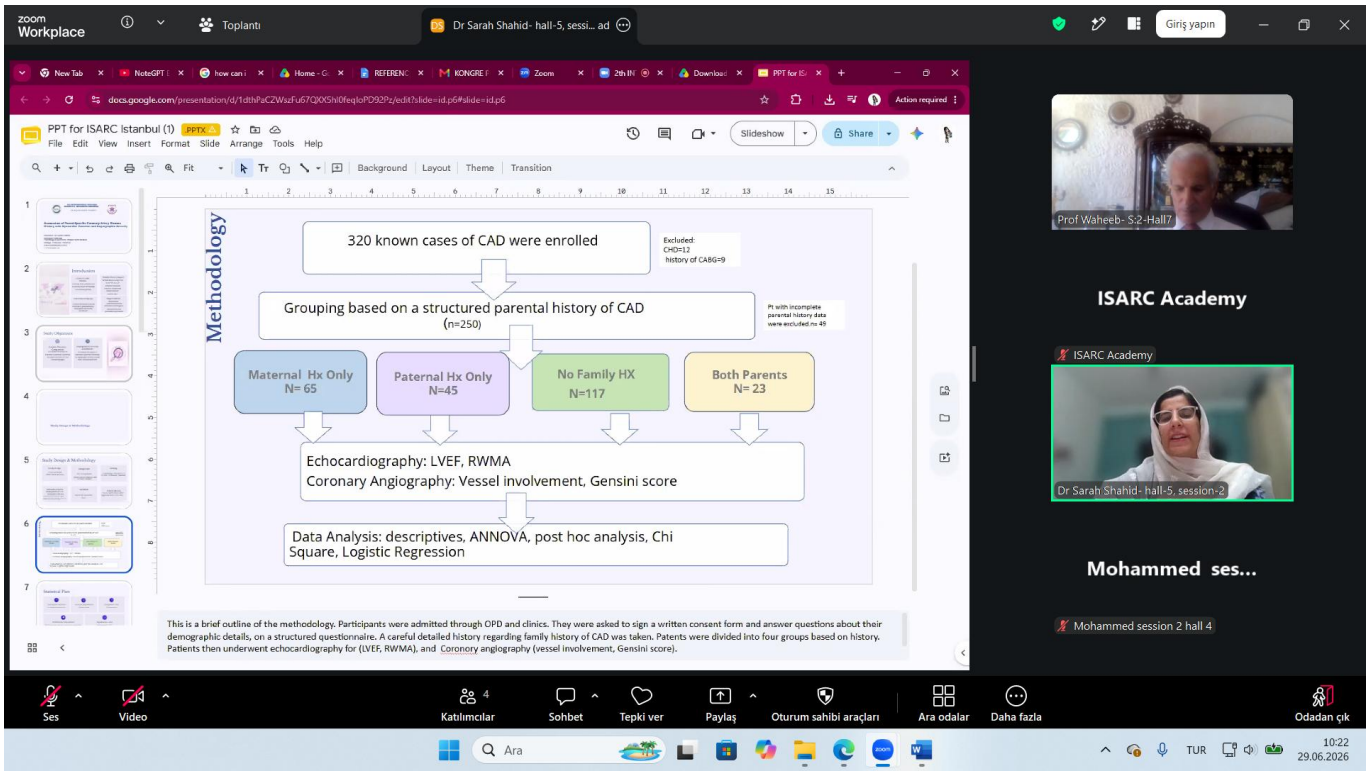
Methodology
320 known cases of CAD were enrolled
Excluded:
CHD=12
history of CABG=9
Grouping based on a structured parental history of CAD
(n=250)
Pt with incomplete parental history data were excluded:n= 49
Maternal Hx Only
N= 65
Paternal Hx Only
N=45
No Family HX
N=117
Both Parents
N= 23
Echocardiography: LVEF, RWMA
Coronary Angiography: Vessel involvement, Gensini score
Data Analysis: descriptives, ANNOVA, post hoc analysis, Chi Square, Logistic Regression
This is a brief outline of the methodology. Participants were admitted through OPD and clinics. They were asked to sign a written consent form and answer questions about their demographic details, on a structured questionnaire. A careful detailed history regarding family history of CAD was taken. Patents were divided into four groups based on history. Patients then underwent echocardiography for (LVEF, RWMA), and Coronory angiography (vessel involvement, Gensini score).
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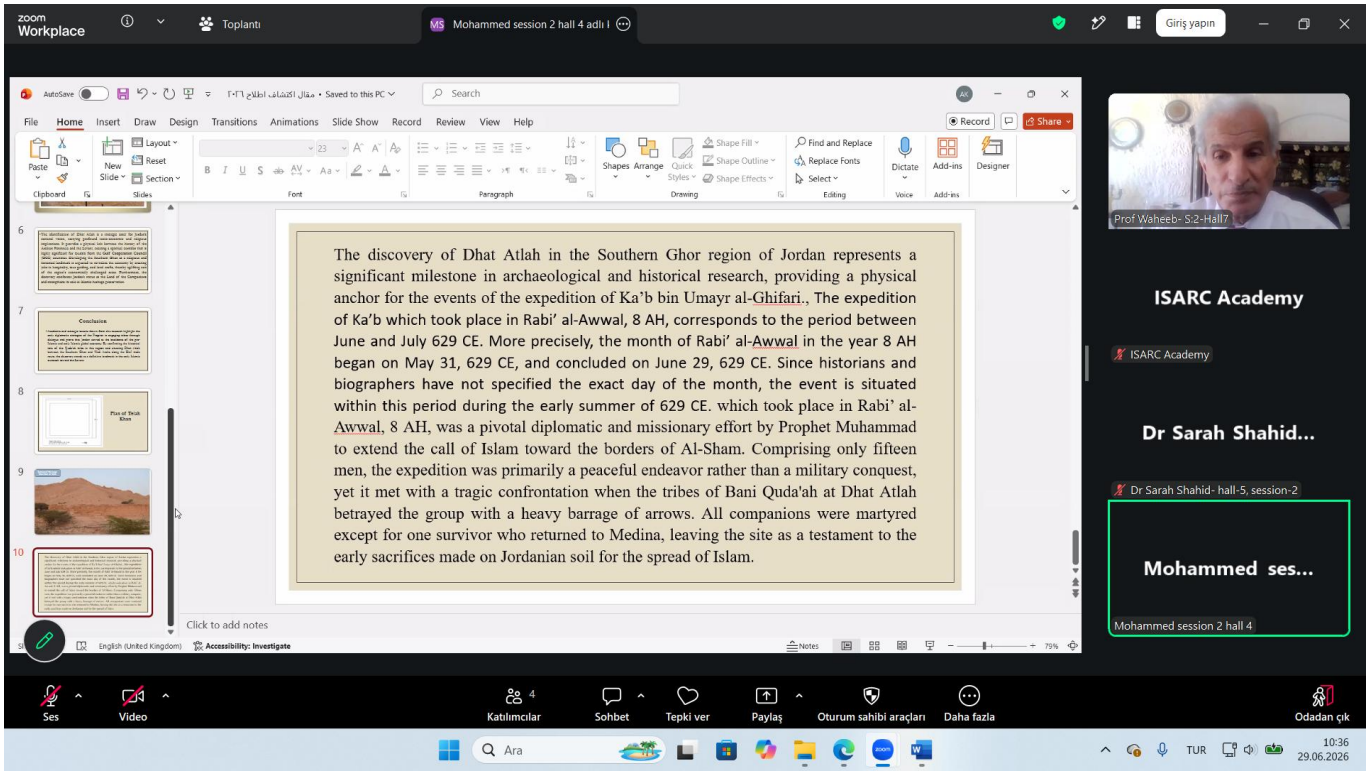
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The discovery of Dhat Atlah in the Southern Ghor region of Jordan represents a significant milestone in archaeological and historical research, providing a physical anchor for the events of the expedition of Ka'b bin Umayr al-Ghifari., The expedition of Ka'b which took place in Rabi' al-Awwal, 8 AH, corresponds to the period between June and July 629 CE. More precisely, the month of Rabi' al-Awwal in the year 8 AH began on May 31, 629 CE, and concluded on June 29, 629 CE. Since historians and biographers have not specified the exact day of the month, the event is situated within this period during the early summer of 629 CE. which took place in Rabi' al-Awwal, 8 AH, was a pivotal diplomatic and missionary effort by Prophet Muhammad to extend the call of Islam toward the borders of Al-Sham. Comprising only fifteen men, the expedition was primarily a peaceful endeavor rather than a military conquest, yet it met with a tragic confrontation when the tribes of Bani Quda'ah at Dhat Atlah betrayed the group with a heavy barrage of arrows. All companions were martyred except for one survivor who returned to Medina, leaving the site as a testament to the early sacrifices made on Jordanian soil for the spread of Islam.
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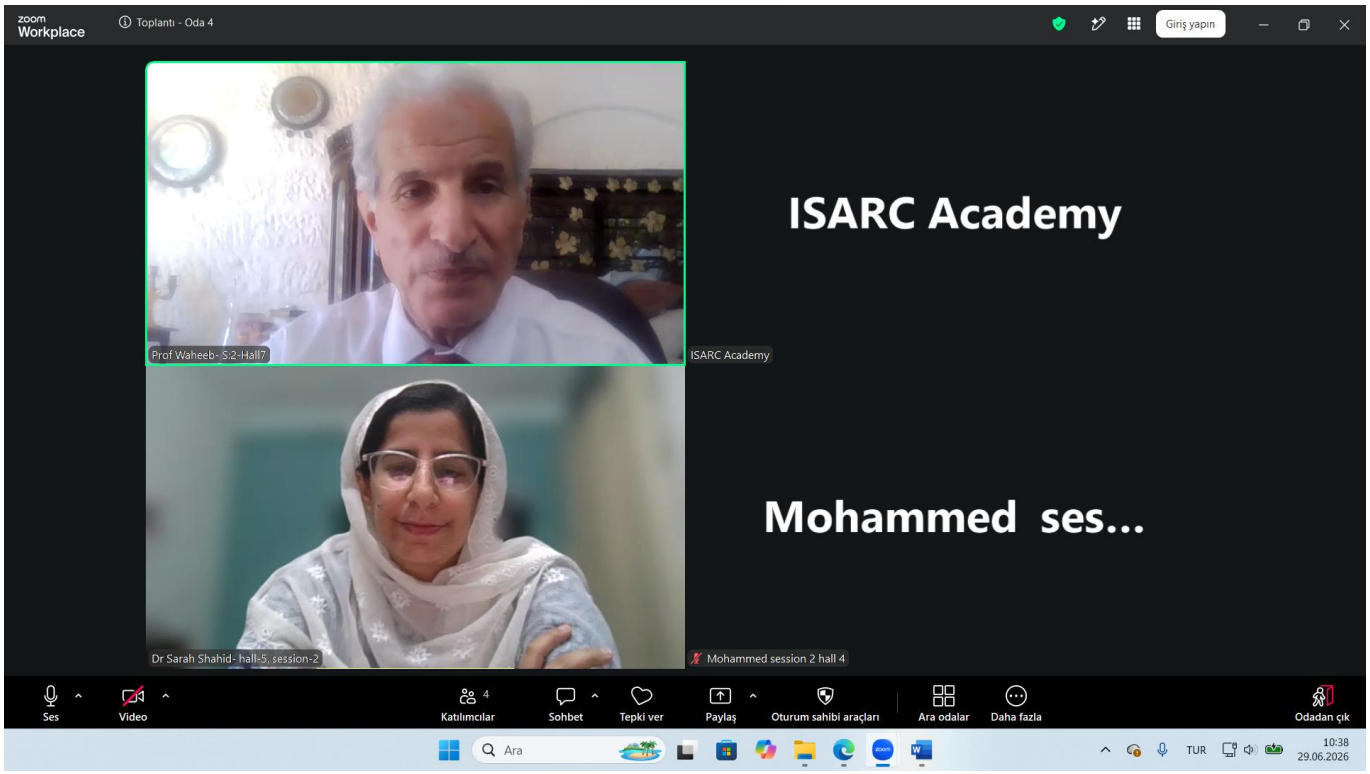
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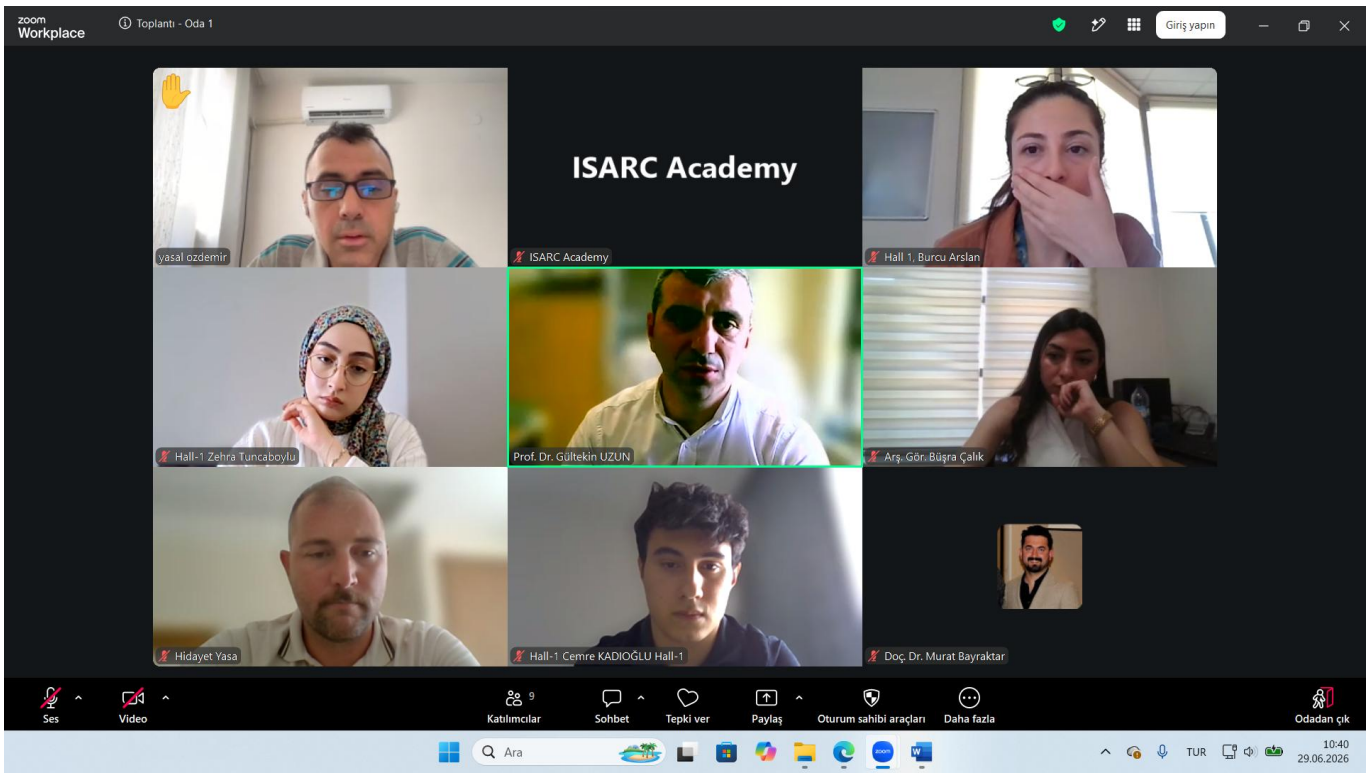
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Hall-1 Cemre KADIOĞLU Hall-1
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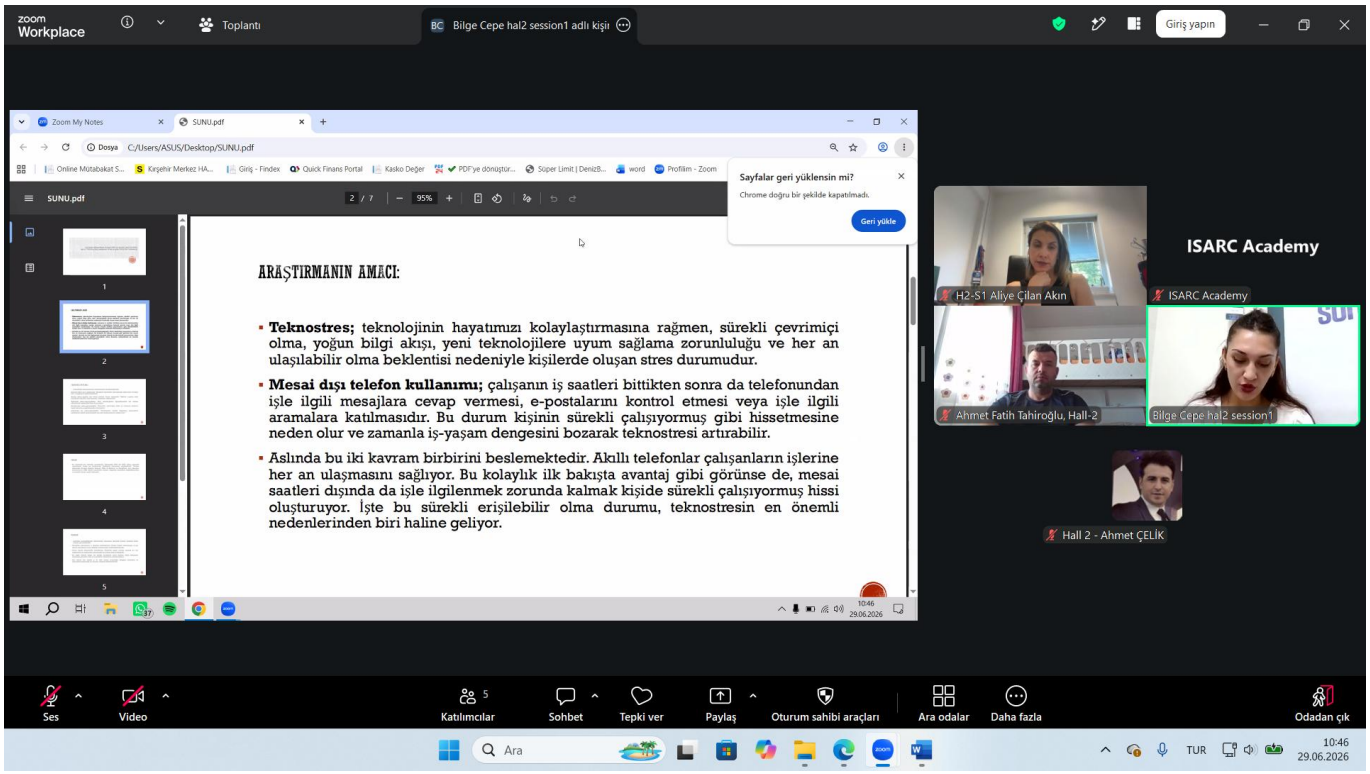
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ARAŞTIRMANIN AMACI:
Teknostres; teknolojinin hayatımızı kolaylaştırmasına rağmen, sürekli çevrimiçi olma, yoğun bilgi akışı, yeni teknolojilere uyum sağlama zorunluluğu ve her an ulaşılabilir olma beklentisi nedeniyle kişilerde oluşan stres durumudur.
Mesai dışı telefon kullanımı; çalışanın iş saatleri bittikten sonra da telefonundan işle ilgili mesajlara cevap vermesi, e-postalarını kontrol etmesi veya işle ilgili aramalara katılmasıdır. Bu durum kişinin sürekli çalışıyormuş gibi hissetmesine neden olur ve zamanla iş-yaşam dengesini bozarak teknostresi artırabilir.
Aslında bu iki kavram birbirini beslemektedir. Akıllı telefonlar çalışanların işlerine her an ulaşmasını sağlıyor. Bu kolaylık ilk bakışta avantaj gibi görünse de, mesai saatleri dışında da işle ilgilenmek zorunda kalmak kişide sürekli çalışıyormuş hissi oluşturuyor. İşte bu sürekli erişilebilir olma durumu, teknostresin en önemli nedenlerinden biri haline geliyor.
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INTERNATIONAL SCIENCE AND ART RESEARCH CENTER

KONU: Kongre Katılımcı Bilgisi **11.07.2026**

İLGİLİ MAKAMA

2.ULUSLARARASI BERGAMA BİLİMSEL ARAŞTIRMALAR KONGRESİ 29-30 HAZİRAN 2026 tarihleri arasında İZMİR ‘de online olarak 11 farklı ülkeden (Türkiye:14 ve diğer Ülkeler:24 Toplam:38 akademisyen/araştırmacıların katılımı ile gerçekleşmiştir. Kongre, 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen ‘’ Tebliğlerin sunulduğu yurt içinde veya yurtdışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışından en az 5 ülkeden farklı tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır. ‘’ değişikliğine ve Doçentlik kriterlerine uygun düzenlenmiştir.

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Saygılarımla

Sefa Salih BİLDİRİCİ
HEAD OF İSARC

CONTENT

HALOJENSİZ BİR ALEV GECİKTİRİCİ OLARAK FOSFOR ESASLI PEPA BİLEŞİĞİNİN SENTEZİ VE FT-IR İLE YAPISAL KARAKTERİZASYONU

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ÖZET

Plastik malzemelerin endüstriyel ve günlük kullanımdaki yaygınlığı, bu malzemelerin yanıcılığından kaynaklanan yangın güvenliği risklerini de beraberinde getirmektedir. Bu riski azaltmak için kullanılan halojenli alev geciktiriciler yüksek etkinlik sunmakla birlikte, yanma sırasında açığa çıkan toksik ve korozif gazlar, çevresel kalıcılıkları ve insan sağlığı üzerindeki olumsuz etkileri nedeniyle giderek kısıtlanmaktadır. Bu durum, halojen içermeyen, çevre dostu ve yerli kaynaklarla üretilebilir alev geciktirici alternatiflerin geliştirilmesini öncelikli hâle getirmiştir. Fosfor esaslı intümesan alev geciktiriciler, yoğun fazda koruyucu bir kömür (char) tabakası oluşturarak ısı ve oksijen transferini sınırlandırmaları sayesinde bu alanda öne çıkan bir yaklaşımdır. Bu çalışmada, pentaeritritol esaslı, kafes yapılı bisiklik bir fosfat olan ve tek molekülünde hem karbon hem de asit kaynağını barındırarak çok fonksiyonlu intümesan etki gösteren PEPA bileşiği sentezlenmiştir. Sentez, pentaeritritol ile fosfor kaynağının doğrudan esterifikasyonu ve reaksiyon suyunun uzaklaştırılması esasına dayanmakta olup, elde edilen ürün saflaştırma ve kurutma işlemlerinin ardından karakterize edilmiştir. Bileşiğin yapısal doğrulaması FT-IR spektroskopisi ile gerçekleştirilmiş; fosfor içeren karakteristik bağ titreşimleri (P=O ve P–O–C) ile hidroksil bölgesindeki beklenen değişimler, hedeflenen yapının başarıyla oluştuğunu göstermiştir. Elde edilen bulgular, halojensiz ve intümesan karakterli bir alev geciktirici adayının erişilebilir hammaddelerle ve yerli üretime uygun bir yaklaşımla sentezlenebildiğini ortaya koymaktadır. Çalışmanın devamında, sentezlenen bileşiğin poliolefin esaslı polimer matrislerine katılarak alev geciktirici performansının değerlendirilmesi hedeflenmektedir.

Anahtar kelimeler: Alev geciktirici, fosfor esaslı, intümesan, PEPA

SYNTHESIS AND FT-IR STRUCTURAL CHARACTERIZATION OF THE PHOSPHORUS-BASED FLAME RETARDANT PEPA AS A HALOGEN-FREE ALTERNATIVE

ABSTRACT

The widespread industrial and everyday use of plastic materials brings with it fire-safety risks arising from their flammability. Although the halogenated flame retardants used to mitigate this risk offer high efficiency, they are increasingly being restricted owing to the toxic and corrosive gases released during combustion, their environmental persistence and their adverse effects on human health. This has made the development of halogen-free, environmentally friendly flame-retardant alternatives that can be produced from domestic resources a priority. Phosphorus-based intumescent flame retardants stand out in this field, as they limit heat and oxygen transfer by forming a protective char layer in the condensed phase. In this study, PEPA — a pentaerythritol-based caged bicyclic phosphate that exhibits a multifunctional intumescent effect by combining both the carbon and the acid source within a single molecule — was synthesized. The synthesis is based on the direct esterification of pentaerythritol with a phosphorus source and the removal of the reaction water; the resulting product was characterized after purification and drying. Structural confirmation was performed by FT-IR spectroscopy, where the characteristic phosphorus-containing vibrations (P=O and P–O–C), together with the expected changes in the hydroxyl region, demonstrated the successful formation of the target structure. The findings show that a halogen-free, intumescent flame-retardant candidate can be synthesized from accessible raw materials through an approach suitable for domestic production. In the continuation of the study, the synthesized compound is intended to be incorporated into polyolefin-based polymer matrices to evaluate its flame-retardant performance.

Keywords: Flame retardant, phosphorus-based, intumescent, PEPA

KARBÜR GRADELERİNİN KESİCİ TAKIM PERFORMANSINA ETKİSİ

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ÖZET

Havacılık ve savunma sanayisinde kullanılan yüksek mukavemetli çeliklerin talaşlı imalatında delik delme operasyonları, kesici takımın maruz kaldığı termomekanik yükler nedeniyle kritik işleme süreçlerinden biridir. Özellikle soğutma sıvısı kullanılmadan gerçekleştirilen kuru delme uygulamalarında oluşan yüksek sıcaklıklar, takım aşınmasını hızlandırmakta ve takım ömrünü doğrudan etkilemektedir. Semente karbür kesici takımların performansı yalnızca kesme parametrelerine değil, takım mikroyapısını oluşturan tungsten karbür tane yapısı ve kobalt bağlayıcı faz oranına da bağlıdır. Kobalt oranındaki değişim, sertlik, sıcak sertlik ve kırılma tokluğu arasındaki dengeyi değiştirerek takımın aşınma davranışını ve kesme performansını etkileyebilmektedir.

Bu çalışmada, AISI 4140 düşük alaşımlı çeliğinin kuru gagalama yöntemiyle delinmesi sırasında, farklı kobalt bağlayıcı oranlarına sahip semente karbür matkapların kesme kuvveti, kesme momenti ve takım ömrü üzerindeki etkileri deneysel olarak incelenmiştir. Deneylerde sırasıyla %6, %10 ve %12 kobalt içeren üç farklı kaplamasız WC-Co karbür matkap kullanılmıştır. Delme işlemleri kuru kesme şartlarında, 80 m/dak kesme hızı ve 0,1 mm/dev ilerleme değerlerinde gerçekleştirilmiştir. Kesme kuvveti ve kesme momenti dinamometre ile ölçülmüş, takım aşınmaları mikroskobik incelemelerle değerlendirilmiştir.

Deney sonuçları, kuru delme şartlarında takım ömrünü belirleyen temel unsurun eksenel kesme kuvvetinden ziyade kesme momenti ve buna bağlı termal yük birikimi olduğunu göstermiştir. %10 kobalt içeren 20D kalite takım 11. delikten sonra, %12 kobalt içeren 24Z kalite takım ise 14. delikte katastrofik kırılmaya uğramıştır. Buna karşılık, %6 kobalt içeren ve 1820 HV30 sertlik değerine sahip 12D kalite takım 15. deliği başarıyla tamamlamıştır. Elde edilen bulgular, AISI 4140 çeliğinin kuru delinmesinde takım ömrünün, oda sıcaklığındaki kırılma tokluğundan çok yüksek sıcaklıklardaki sıcak sertlik davranışı ile ilişkili olduğunu ortaya koymuştur.

Anahtar kelimeler: AISI 4140, Kuru Delme, Semente Karbür, Kobalt Oranı, Takım Ömrü

EFFECT OF CEMENTED CARBIDE GRADES ON CUTTING TOOL PERFORMANCE

ABSTRACT

Drilling operations constitute one of the most critical machining processes in the manufacturing of high-strength steels used in the aerospace and defense industries due to the thermomechanical loads imposed on cutting tools. Particularly in dry drilling applications, where no coolant is employed, the elevated temperatures generated in the cutting zone accelerate tool wear and directly affect tool life. The performance of cemented carbide cutting tools depends not only on cutting parameters but also on the microstructural characteristics of the tool material, namely the tungsten carbide grain structure and cobalt binder content. Variations in cobalt content alter the balance between hardness, hot hardness, and fracture toughness, thereby influencing wear behavior and cutting performance.

In this study, the effects of different cobalt binder contents in cemented carbide drills on cutting force, cutting torque, and tool life were experimentally investigated during the dry peck drilling of AISI 4140 low-alloy steel. Three uncoated WC-Co carbide drills containing 6%, 10%, and 12% cobalt were used in the experiments. Drilling tests were performed under dry cutting conditions at a cutting speed of 80 m/min and a feed rate of 0.1 mm/rev. Cutting force and cutting torque values were measured using a dynamometer, while tool wear was evaluated through microscopic examinations.

The experimental results revealed that the primary factor governing tool life under dry drilling conditions was not the axial cutting force but the cutting torque and the associated thermal load accumulation. The 20D grade drill containing 10% cobalt experienced catastrophic failure after the 11th hole, whereas the 24Z grade drill containing 12% cobalt failed during the 14th hole. In contrast, the 12D grade drill containing 6% cobalt and exhibiting a hardness of 1820 HV30 successfully completed the 15th hole without failure. The findings demonstrate that tool life in

the dry drilling of AISI 4140 steel is governed more by hot hardness behavior at elevated temperatures than by room-temperature fracture toughness.

Keywords: AISI 4140, Dry Drilling, Cemented Carbide, Cobalt Content, Tool Life

1. INTRODUCTION

In the modern manufacturing industry, drilling operations constitute one of the fundamental production stages for critical sectors that require high precision, particularly aerospace. These operations, generally performed at the final stage of part shaping in production lines, have a strategic importance in terms of both part quality and manufacturing costs. Achieving the targets of minimum cost and maximum hole quality in drilling operations depends on the correct combination of workpiece material, cutting parameters, and cutting tool characteristics. Although tool geometry is a known component of this performance equation, the actual element that determines the character of the cutting tool is the composition of the cemented carbide (WC-Co) forming the tool matrix, and particularly the cobalt binder ratio.

At this point, the key to tool performance lies in the compositional balance created by the cobalt binder ratio in the cemented carbide microstructure and the tungsten carbide (WC) grain size. In studies investigating the effect of sintered carbide composition on cutting temperatures, the performances of inserts with different cobalt ratios and grain sizes were examined; it was shown that grades with high thermal conductivity reduce the temperature at the tool tip, and that tool life depends not only on room temperature hardness but also on the balance of hot hardness and thermal conductivity (Vornberger et al., 2020). It has been experimentally proven that the hardness of WC-Co alloys decreases with increasing temperature, cobalt ratio, and grain size, hence the tool behavior at high temperatures is the joint result of these three variables (Milman et al., 1999).

When the isolated effect of the cobalt ratio on mechanical properties is examined; it has been revealed that as the cobalt content increases for the same grain size, the hardness decreases linearly (Saito et al., 2006), while the increase in the binder phase ratio improves the fracture toughness of the material (Cheng et al., 2014). On the grain size front, it has been determined that as the grain size decreases in sub-micron and ultra-fine carbides developed for micro drills, the bending strength increases and the risk of fracture decreases (Gille et al., 2002). However, it has been observed that nanometric (<0.2 µm) grains wear out via micro-chipping due to excessive hardness, whereas sub-micron (0.4-0.8 µm) grains wear more homogeneously, thereby extending tool life (Wachowicz et al., 2025). Under dry cutting conditions, the chemical wear exposed by uncoated carbides also progresses through the cobalt phase: the

strong chemical affinity between the iron (Fe) in the workpiece and the cobalt (Co) in the tool leads to the extraction of cobalt from the tool, triggering the adhesive wear mechanism (Liu et al., 2018).

Studies on the machinability of AISI 4140 low-alloy steel, widely used in aerospace components, reveal that the main indicators determining drilling performance are thrust force and cutting torque. Experimental research focusing on the optimization of cutting parameters in the drilling of AISI 4140 has shown that the feed rate is the most dominant factor on both torque and tool wear, and that torque increases as the feed rate increases (Açay et al., 2020). Similarly, it has been reported that parameters related to tool geometry can be decisive on thrust force in the drilling of carbon and low-alloy steels, while feed rate again stands out as the most effective parameter on torque (Çavuş et al., 2024). In deep hole drilling operations of AISI 4140, it has been shown that cutting speed and feed rate directly determine the drilling torque and thermomechanical load; at high parameters, white layers approximately three times harder than the base material are formed on the hole surface, affecting the fatigue life of the part (Schmidt et al., 2020; Strodick et al., 2020). Studies modeling the drilling process using the finite element method also confirm that the stresses created by the thrust force and torque on the drill are concentrated on the cutting edge and helical flute, hence tool failure is closely related to torque-induced torsional loads (Yıldız et al., 2020).

Performing drilling operations under dry conditions further exacerbates these thermomechanical strains. Experimental studies on the dry drilling of difficult-to-machine alloys have revealed that the primary factor determining performance in dry drilling is the drilling temperature; and that the dominant failure mechanism in carbide tools lacking a coating barrier is adhesive wear (Li et al., 2022). Indeed, it has been determined that in the dry machining of AISI 4140, carbide tools can only remain competitive at low cutting speeds due to high thermal loads, emphasizing that dry and uncooled working environments are a serious limiting factor for carbide tools (Özdemir et al., 2023).

While these findings in the literature indicate that the cobalt ratio is a critical design variable on the hardness-toughness axis in tool selection, they do not provide a direct comparison on the real-time force-torque behavior of uncoated sub-micron carbide drills with different cobalt ratios during the dry peck drilling of AISI 4140. The aim of this study is to experimentally demonstrate the effects of the cobalt ratio on tool performance, cutting force, and cutting torque during the dry peck drilling of AISI 4140 steel using three different uncoated sub-micron carbide drills with 6%, 10%, and 12% cobalt binder ratios, and to offer a directly applicable

result for the machining industry by determining the optimum carbide grade in terms of operational stability.

2. MATERIAL AND METHODS

2.1. Workpiece Material

A In the experimental studies, AISI 4140 low-alloy steel, which is preferred in the manufacturing of critical components requiring high strength, structural integrity, and dynamic fatigue resistance in the aerospace, defense, and space industries, was selected as the workpiece sample. This alloy possesses superior hardenability and toughness values thanks to the carbide-forming elements it contains in its microstructure, such as 0.80-1.10% chromium and 0.15-0.25% molybdenum by weight. Block plates with a thickness of 20 mm were used in the experiments. The chemical composition of the workpiece material by weight percentage is presented in Table 1, and its fundamental mechanical and structural properties are presented in Table 2.

Table 1. Chemical composition of the workpiece material (wt. %)

Element	Value (%)	Element	Value (%)
Carbon	0,38-0,43	Silicon	0,15-0,30
Chromium	0,80-1,10	Phosphorus	Max. 0,035
Manganese	0,75-1,00	Sulfur	Max. 0,040
Molybdenum	0,15-0,25	Iron	Balance

Table 2. Mechanical properties of AISI 4140 alloy

Mechanical properties	Nominal value
Hardness, Brinell (HB) / Rockwell C (HRC)	197 HB / 13 HRC
Tensile strength / Yield strength (MPa)	655 / 415
Modulus of elasticity (GPa) / Poisson's ratio	205 / 0,27-0,30

2.2. Cutting Tools

In order to tribologically analyze the isolated effects of carbide grades on drilling performance, three different cemented carbide (WC-Co) drills in uncoated form with sub-micron grain size were selected. To examine the direct effects of the material's friction and thermal loads on the carbide matrix, all tools were preferred in uncoated form. In cemented carbides, while the WC

phase provides hardness and wear resistance to the tool, the ductile cobalt matrix binds these grains, imparting fracture toughness to the structure (Cheng et al., 2014). The fundamental engineering problem here is the inverse proportion between hardness and toughness: when the amount of cobalt in the structure is increased, even though the tool absorbs impacts better, it loses its hardness and wear resistance (Cheng et al., 2014; Saito et al., 2006). The most important microstructural parameters directly affecting cutting performance and tool life are the WC grain size and the distribution of the cobalt binder between the grains, i.e., the mean free path; when the grain size decreases, the mean free path narrows and the hardness of the material increases significantly (Milman et al., 1999; Saito et al., 2006). The correct combination of grain size and binder ratio not only increases wear resistance but also contributes to the prevention of crack propagation at the microstructural level (Yang et al., 2022).

In this study, drill bits with three different grades were used to investigate the effect of the cobalt binder ratio in the matrix (6%, 10%, and 12%) on the mechanical property limits. The metallurgical and mechanical data of the tools are compiled in Table 3. According to catalog data, 12D is recommended for machining aluminum alloys, composites, and graphite; 20D for alloyed/unalloyed steels, stainless steels, and heat-resistant alloys; and 24Z for machining titanium and heat-resistant alloys (CERATIZIT, 2017).

Table 3. Microstructural and mechanical properties of the tools (CERATIZIT, 2017)

Properties / Parameters	12D	20D	24Z
ISO code	K05-K10	K20-K40	K20-K40
Binder ratio (% Co)	6,0	10,0	12,0
Density (g/cm³)	14,80	14,38	14,10
Hardness (HV30)	1820	1600	1570
Bending strength (MPa)	3600	4000	4000
Fracture toughness (MPa·m$^{1/2}$)	9,3	10,4	11,3

Figure 1. Catalog SEM image of sub-micron WC-Co microstructure (CERATIZIT, 2017)

In the scanning electron microscope (SEM) image taken in backscattered electron mode in Figure 1, the tonal differences are directly related to the atomic number (Z) of the material: light gray angular structures represent high atomic number (Z=74) tungsten carbide grains, while dark gray regions show the low atomic number (Z=27) cobalt matrix phase filling the gaps between the grains. The truncated triangular prism form of the grains, which is characteristic of well-sintered WC-Co systems, contributes to mechanical interlocking and the formation of a rigid carbide skeleton; the fine and homogeneous film formation of the cobalt phase around the grains indicates high production quality and balanced load distribution during operation (González et al., 2020; Yang et al., 2022). Sub-micron grained structures allow obtaining a much sharper cutting edge by reducing micro-fractures occurring at the edge during grinding compared to micron-sized carbides (Gille et al., 2002). In addition, since carbide grains are better supported by the cobalt matrix in closely packed small-grained structures, wear occurs as a slow and controlled surface wear rather than individual detachment of grains, thereby prolonging tool life (Wachowicz et al., 2025).

2.3. Machine Tool

Drilling experiments were carried out on a Haas VF-2SS CNC vertical machining center located in the Manufacturing Engineering Department laboratory of Gazi University Technology Faculty. The machine specifications are given in Table 4.

Table 4. Haas VF-2SS technical specifications

Parameters / Technical specifications	Value
Spindle power	22,4 kW (30 hp)
Maximum rotational speed	12.000 rpm
X / Y / Z axis travel	762 / 406 / 508 mm
Positioning accuracy	±0,005 mm
Control unit	Haas CNC control

2.4. Cutting Parameters and Experimental Setup

Drilling operations were performed in an uncooled (dry) environment, which is one of the conditions that most severely strains tool wear and cutting mechanics tribologically. Since the thermal load arising from machining under dry cutting conditions could not be removed from the environment, the microstructural responses of the tool material could be observed more clearly (Li et al., 2022). In order to accurately compare the performance outputs of all tools, kinematic parameters were kept constant for each hole operation, with the cutting tool grade considered as the sole variable. In the experiments, cutting speed was applied as 80 m/min, feed rate as 0.1 mm/rev, spindle speed as 2547 rpm, and feed speed as 1018 mm/min.

The G81 program code, a standard CNC drilling cycle, was used in the operation; by integrating the Q=2 value into the cycle, the tool was enabled to perform a peck drilling motion. Since it is likely that chips would jam and weld into the helical flutes during the dry drilling of the 20 mm thick high-strength steel, the peck drilling cycle applied every 2 mm of cut allowed the chips to be broken and evacuated, mechanically preventing sudden torque increases caused by jamming. Dynamic cutting force and torque data generated during drilling were collected with a dynamometer, and the average values were calculated by reading the force and torque values for the number of holes in the experiments for each tool via the DynoWare software.

3. RESULTS AND DISCUSSION

When the results obtained from the drilling experiments carried out with uncoated sub-micron carbide tools under dry cutting conditions were evaluated, it was understood that the amount of cobalt in the tool microstructure has a critical level of impact on drilling behavior and tool durability. Contrary to conventional assumptions, it was determined that the fundamental parameter causing the catastrophic fracture of the drill in dry drilling operations is not the axial cutting force (Fz), but the cutting torque (Mz) acting on the tool body (Açay et al., 2020; Yıldız et al., 2020). Among the main reasons for the increase in torque value during the process

leading to fracture are the deterioration of the cutting edge geometry under the effect of high temperature, increased friction on the tool wall, and chip evacuation problems stemming from dry machining conditions. This finding is consistent with the literature revealing that the process leading to tool fracture in the drilling of steels is the sudden torque spikes and torsional stresses created by chip jamming rather than the axial force (Açay et al., 2020; Yıldız et al., 2020).

During the experimental process, the 20D cutting tool fractured after the machining of the 11th hole, and the 24Z cutting tool suffered damage during the 14th hole. In contrast, the 12D cutting tool successfully drilled the 15th hole and completed the experimental process without any fracture occurring.

3.1. Cutting Torque Behavior

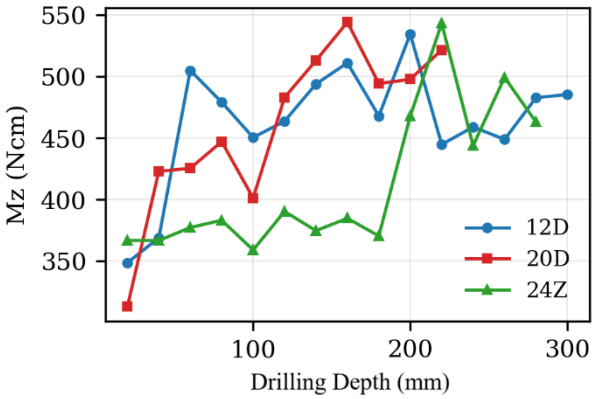

Figure 2. Cutting torque vs. machined length graph

When Figure 2 is examined, it is understood that the behavior of the tools at the moment they enter the part at hole depths of 0-80 mm differs due to their cobalt ratios. The 12D tool, which contains only 6% Co and has the most rigid structure with a value of 1820 HV30, attempted to cut directly without flexing under the effect of its high hardness the moment it started the drilling process; due to this high rigidity, Mz values reached the 500 Ncm band with a sudden increase in the first holes. Conversely, the 20D and 24Z tools, containing 10% and 12% Co respectively, were able to absorb the shocks at the moment of starting to drill thanks to their micro-level more flexible and tough structures, and created a more stable and lower torque curve compared to 12D in the initial 80 mm stage. This initial behavior coincides with literature findings indicating that an increase in cobalt ratio improves fracture toughness (Cheng et al., 2014).

In the 100-240 mm range, however, the intense thermal load accumulated at the drill tip due to dry drilling dramatically differentiated the wear behaviors. Thermal analyses on AISI 4140 show that local temperatures in the cutting zone and related thermal stresses increase rapidly with machining time; uncoated tools lacking the thermal barrier provided by a coating are directly exposed to high frictional temperatures at the tool-chip interface (Arrazola et al., 2009; Kuş et al., 2015). The softening of the binder phase in carbide tools under the influence of increasing temperature in environments where no cooling fluid is used triggers Built-Up Edge (BUE) formation (Li et al., 2022; Liu et al., 2018). Indeed, with the temperature increase, the cutting process gradually diminished in the 20D and 24Z tools, yielding to the behavior of crushing and smearing the material; this situation created the severe peak points seen around 160 mm for 20D and 220 mm for 24Z. Although the 24Z tool was able to tolerate the increasing torque up to 180 mm, when the temperature threshold was exceeded, it completely lost its cutting edge geometry with the sudden detachment of the dense built-up edge at the tool tip. In contrast, the 12D tool, having the lowest cobalt ratio, managed to maintain its hot hardness despite the extreme heat brought by dry cutting; it preserved its cutting edge form without crushing, ensured healthy chip breaking, and successfully completed the process by remaining stable at around the 480 Ncm band up to 300 mm without twisting and breaking. This behavior directly overlaps with studies showing that WC-Co hardness decreases with temperature and cobalt ratio, and that high-temperature performance depends on the hot hardness balance (Milman et al., 1999; Vornberger et al., 2020).

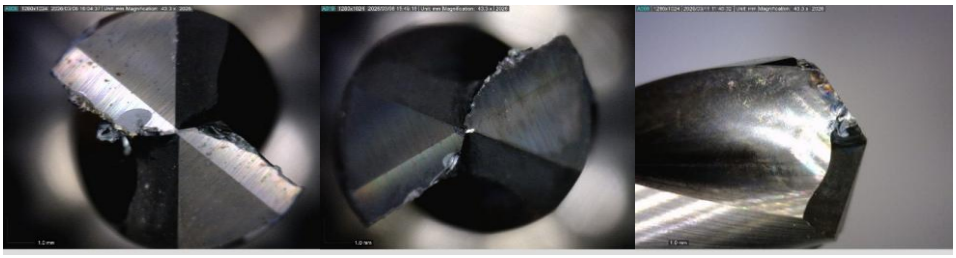

Figure 3. Microscope images of the tools: (a) 12D 2nd experiment, (b) 20D 2nd experiment, (c) 24Z 6th experiment

The integrity formed by the cutting torque curve and the tool wear visuals clearly reveals the instant and characteristic responses of grade differences against torque. Another critical parameter affecting tool performance and stability in drilling operations is the mechanical loads applied in the axial direction.

3.2. Cutting Force Behavior

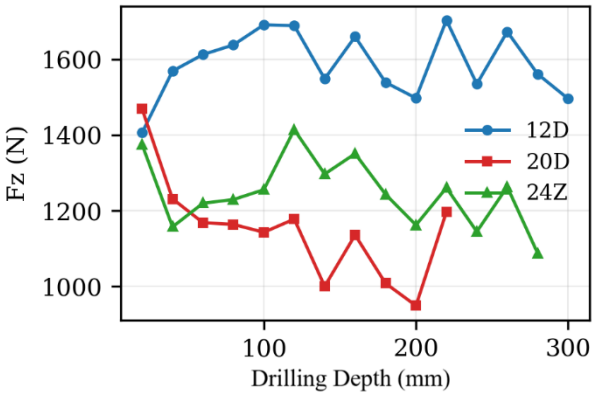

Figure 4. Cutting force vs. machined length graph

The most striking finding in Figure 4 is that the high cobalt-content 20D and 24Z tools experienced a decrease in cutting forces in the 140-200 mm range, contrary to the expected increase. Matrices containing 10% and 12% cobalt underwent thermal softening under high temperature, and the drill tips began to deform and crush. Since these blunted tools could not remove chips, their axial thrust resistance dropped; however, since they started to rub against the wall instead of cutting, the increases seen in the torque curve were experienced. The abrupt termination of the curves for 20D at 200 mm and 24Z at 280 mm proves that the tools could not overcome the thermal barrier formed and failed by fracturing under increasing torque. Mechanical characterization studies reporting drops exceeding 30% in the strength of the WC-Co structure at high temperatures support this sudden failure behavior (González et al., 2020). In contrast, the 12D tool maintained its Fz value stably starting from a depth of 40 mm. This high thrust force curve indicates that the tool tip was not blunted or crushed, and continued the cutting process stably by gripping the workpiece. The excessively hard structure, which seemed like a disadvantage at first, turned into a hot hardness advantage in later stages by preventing the tool from rubbing against the wall.

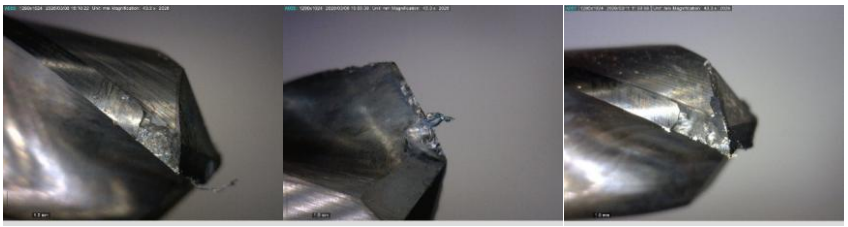

Figure 5. Microscope images of the tools after the 4th experiment: (a) 12D, (b) 20D, (c) 24Z

Figure 6. Microscope images after advanced experimental stages: (a) 12D 8th experiment, (b) 20D 7th experiment, (c) 24Z 8th experiment

3.3. Comparison of Findings with the Literature

When the experimental results are compared with the literature; it is known that increasing the cobalt binder ratio increases fracture toughness, and carbides with 10% or more cobalt content are generally recommended for impact/interrupted operations (Cheng et al., 2014). However, when it comes to the dry drilling of high-strength AISI 4140 steel, these general assumptions lose their validity. The excessive heat that could not be removed in dry cutting caused tools with high cobalt content to exceed their thermal endurance limits. This tool group, whose toughness value is high due to its cobalt content, could not perform its task due to tip deformation and built-up edge before showing the expected flexibility, and broke by twisting under high torque (Liu et al., 2018). Accordingly, the 12D grade with 6% cobalt content, which had the most brittle structure of the experimental set at room temperature and was mainly recommended for abrasive, soft materials such as composites or aluminum in catalog data, was the only tool capable of preserving its structural integrity when exposed to high heat. This indicates that the sole factor determining tool life in the dry drilling operations of difficult-to-machine materials is not the fracture toughness at room temperature, but the hot hardness provided by the cutting edge preserving its form under high temperature (Milman et al., 1999; Vornberger et al., 2020).

4. CONCLUSIONS

In this study, the effects of the cobalt binder ratio (6%, 10%, 12%) of uncoated sub-micron cemented carbide drills on tool performance were experimentally investigated under constant cutting parameters during the dry peck drilling of AISI 4140 low-alloy steel, which is widely used in aerospace manufacturing, and it was determined that the primary factor leading to catastrophic tool failure under dry drilling conditions is not the axial cutting force, but the accumulation of cutting torque and thermal load (Açay et al., 2020); while the 20D and 24Z tools with 10% and 12% cobalt content broke at the 11th and 14th holes respectively due to thermal softening, built-up edge formation, and consequent sudden torque increases despite their high room temperature toughness, the 12D tool with 6% cobalt content, which has the

lowest cobalt ratio and the highest hardness (1820 HV30), preserved its hot hardness and completed the experimental set without breaking, thereby demonstrating that the main factor determining tool life in dry drilling operations of challenging materials is not fracture toughness at room temperature, but hot hardness which enables the cutting edge to maintain its form at high temperatures (Milman et al., 1999; Vornberger et al., 2020). These findings will directly contribute to making grade selection based on hot hardness beyond catalog recommendations in hole drilling operations of AISI 4140-based components in TUSAŞ production lines, thereby enabling the reduction of tool costs, the safe commissioning of sustainable (dry) machining strategies where coolant usage is minimized, and the prevention of line stoppages arising from unplanned tool breakages; and it is anticipated that these results will be expanded in future studies incorporating different cutting parameters, coated equivalent grades, and real-time temperature measurement.

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ÜRETKEN YAPAY ZEKÂ MARUZİYETİNİN MESLEK İÇİ GÖREV YAPISI ÜZERİNDEN DEĞERLENDİRİLMESİ: ULUSLARARASI ÇALIŞMA ÖRGÜTÜ 2025 VERİLERİ ÜZERİNE İKİNCİL BİR ANALİZ

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ÖZET

Üretken yapay zekânın işgücü piyasasına etkisi giderek artarken, tartışmalar çoğunlukla etkiyi mesleğin genel tanımı üzerinden ele almaktadır. Mesleklerin homojen yapılar olmadığı, farklı görevlerden oluştuğu düşünüldüğünde, etkinin yalnızca meslek tanımı üzerinden değil, mesleği oluşturan görevler üzerinden değerlendirilmesi gerekmektedir. Uluslararası Çalışma Örgütü'nün 2023'te hazırladığı, 2025'te geliştirdiği metodoloji, bu değerlendirme için önemli bir zemin oluşturmuştur. Bu çalışmanın amacı, Uluslararası Çalışma Örgütü'nün hazırladığı rapordaki analiz ve yorum çerçevesini genişleterek yeni bulgu, yorum ve içgörü üretmektir. Bu kapsamda 2025'te yayımlanan üretken yapay zekâ maruziyet skorları kullanılarak 427 meslek ve 3.265 görev kaydı için ikincil analizler gerçekleştirilmiştir. Her meslek için yüksek ve çok yüksek maruziyetli görevlerin payı hesaplanmış, üretken yapay zekâ maruziyetinin meslek içi yaygınlığı görev yapısındaki yoğunlaşmayla birlikte değerlendirilmiştir. İncelenen 3.265 görev kaydının %15,1'inin 0,50 ve üzeri, %6,8'inin ise 0,60 ve üzeri maruziyet skoruna sahip olduğu belirlenmiştir. 2023 ve 2025 arası değişim incelendiğinde, görev kayıtlarının %3,8'inin 0,50 eşiğinin altından 0,50 ve üzerine çıktığı, %10,3'ünün ise 0,50 ve üzerinden 0,50 eşiğinin altına indiği görülmüştür. 44 görev kaydının (%1,34) 0,60 eşiğinin altından 0,60 ve üzeri çok yüksek maruziyet düzeyine çıktığı, 474 görev kaydının (%14,5) bu eşiğin altına indiği görülmüştür. Büro destek çalışanlarının 2025 ortalama maruziyet skorunun 0,536 olduğu, bu gruptaki mesleklerin %68,97'sinin yüksek ya da en yüksek maruziyet düzeyinde bulunduğu görülmüştür. Büro destek çalışanlarında 0,50 ve üzeri görev payı ortalaması %68,17 iken, aynı oran profesyonel mesleklerde %26,12, teknisyenler ve yardımcı profesyonellerde %19,72, hizmet ve satış çalışanlarında %9,73, zanaat ve ilgili işlerde %1,95, tarım, ormancılık ve balıkçılık mesleklerinde ise %0,56 düzeyindedir. Meslek bazında incelendiğinde 427 mesleğin 209'unda (%48,9) maruziyetin azaldığı, 186'sında (%43,6) arttığı, 32'sinde (%7,5) değişmediği belirlenmiştir. Çalışma, üretken yapay zekâya maruziyet açısından meslek grupları arasındaki görev bazlı farklılaşmanın çeşitli boyutlarını sayısal verilerle daha somut ve görünür hale getirmektedir.

Anahtar Kelimeler: Üretken yapay zekâ, mesleki maruziyet, görev temelli analiz, meslek içi görev yapısı, seçici görev dönüşümü, işgücü piyasası.

ASSESSING GENERATIVE ARTIFICIAL INTELLIGENCE EXPOSURE THROUGH WITHIN-OCCUPATION TASK STRUCTURE: A SECONDARY ANALYSIS OF THE INTERNATIONAL LABOUR ORGANIZATION 2025 DATA

ABSTRACT

While the impact of generative artificial intelligence on the labour market is increasing, discussions mostly address this impact through the general definition of the occupation. Considering that occupations are not homogeneous structures and consist of different tasks, the impact should be evaluated not only through the definition of the occupation, but also through the tasks that constitute the occupation. The methodology prepared by the International Labour Organization in 2023 and developed in 2025 has provided an important basis for this assessment. The aim of this study is to expand the analysis and interpretation framework in the report prepared by the International Labour Organization and to produce new findings, interpretations and insights. In this context, secondary analyses were carried out for 427 occupations and 3,265 task records by using the generative artificial intelligence exposure scores published in 2025. For each occupation, the share of tasks with high and very high exposure was calculated, and the within-occupation prevalence of generative artificial intelligence exposure was evaluated together with the concentration in task structure. It was determined that 15.1% of the 3,265 task records examined had an exposure score of 0.50 and above, while 6.8% had an exposure score of 0.60 and above. When the change between 2023 and 2025 was examined, it was observed that 3.8% of the task records moved from below the 0.50 threshold to 0.50 and above, while 10.3% moved from 0.50 and above to below the 0.50 threshold. It was observed that 44 task records (1.34%) moved from below the 0.60 threshold to a very high exposure level of 0.60 and above, while 474 task records (14.5%) moved below this threshold. The 2025 average exposure score of clerical support workers was found to be 0.536, and 68.97% of the occupations in this group were found to be at the high or highest exposure level. While the average share of tasks at 0.50 and above among clerical support workers is 68.17%, the same rate is 26.12% in professional occupations, 19.72% in technicians and associate professionals, 9.73% in service and sales workers, 1.95% in craft and related trades, and 0.56% in agricultural, forestry and fishery occupations. When examined on an occupational basis, it was determined that exposure decreased in 209 of 427 occupations (48.9%), increased in 186 (43.6%), and remained unchanged in 32 (7.5%). The study makes

various dimensions of task-based differentiation among occupational groups in terms of exposure to generative artificial intelligence more concrete and visible through numerical data.

Keywords: Generative artificial intelligence; occupational exposure; task-based analysis; within-occupation task structure; selective task transformation; labour market.

DİJİTALLEŞME VE OTOMASYONUN, TANKER GEMİLERİNDE ÇALIŞAN GEMİ ZABİTLERİNİN İŞ STRESİ VE İŞ TATMİNİ ÜZERİNDEKİ ETKİLERİ: NİCEL BİR ARAŞTIRMA

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ÖZET

Denizcilik sektöründe dijital dönüşüm ve otomasyon uygulamalarının yaygınlaşması, gemi operasyonlarının etkinliğini artırırken gemi insanlarının çalışma koşullarında da önemli değişimlere yol açmaktadır. Bu çalışma, gemi insanlarının dijitalleşme ve otomasyon algılarının iş stresi, psikolojik iyi oluş ve iş tatmini üzerindeki etkilerini incelemeyi amaçlamaktadır. Araştırma kapsamında tanker gemilerinde görev yapan gemi insanlarından anket yöntemiyle veri toplanmıştır. Veri toplama sürecinde psikolojik iyi oluşun ölçülmesinde WHO-5 Psikolojik İyi Oluş Ölçeği, iş stresinin değerlendirilmesinde DASS-21 Stres Alt Boyutu, iş tatmininin belirlenmesinde Minnesota İş Tatmini Ölçeği Kısa Formu ve dijitalleşme kaynaklı stres düzeyinin ölçülmesinde Technostress Creators Ölçeği Kısa Formu kullanılmıştır. Araştırmanın analiz süreci iki aşamada gerçekleştirilmiştir. İlk aşamada, katılımcıların demografik özelliklerinin belirlenmesi ve ölçeklerin güvenilirlik düzeylerinin değerlendirilmesi amacıyla IBM SPSS programı kullanılarak tanımlayıcı istatistikler ile Cronbach's Alpha analizleri uygulanmıştır. İkinci aşamada ise değişkenler arasındaki ilişkilerin test edilmesi amacıyla SmartPLS yazılımı aracılığıyla Kısmi En Küçük Kareler Yapısal Eşitlik Modellemesi (PLS-SEM) gerçekleştirilmiştir. Bu kapsamda öncelikle ölçüm modelinin geçerlilik ve güvenilirlik kriterleri değerlendirilmiş, ardından yapısal model üzerinden araştırma hipotezleri sınanmıştır. Elde edilen bulgular, dijitalleşme ve otomasyon kaynaklı stres düzeyinin gemi insanlarının iş stresini anlamlı biçimde artırdığını ve iş tatminini olumsuz yönde etkilediğini ortaya koymuştur. Ayrıca iş stresinin psikolojik iyi oluş üzerinde negatif etkisi olduğu belirlenmiştir. Buna karşılık psikolojik iyi oluşun iş tatminini pozitif yönde etkilediği tespit edilmiştir. Araştırmada öne sürülen aracılık etkilerine ilişkin analiz sonuçları ise iş stresinin aracılık rolünü desteklememiştir. Sonuç olarak, dijitalleşme ve otomasyon süreçlerinin gemi insanlarının çalışma yaşamı üzerindeki etkilerinin yalnızca operasyonel değil, aynı zamanda psikolojik ve örgütsel boyutlarda da değerlendirilmesi gerektiği sonucuna ulaşılmıştır.

Anahtar kelimeler: Denizcilik, Dijitalleşme, Otomasyon, İş Stresi, İş Tatmini, Technostress

DIGITALIZATION AND AUTOMATION EFFECTS ON JOB STRESS AND JOB SATISFACTION OF DECK OFFICERS WORKING ON TANKER SHIPS: A QUANTITATIVE STUDY

ABSTRACT

The growing adoption of digital transformation and automation in the maritime industry is not only enhancing the efficiency of ship operations but also leading to significant changes in the working conditions of seafarers. This study aims to examine the effects of seafarers' perceptions of digitalization and automation on work-related stress, psychological well-being, and job satisfaction. Data were collected via a survey from seafarers working on tanker vessels as part of this research. During the data collection process, the WHO-5 Psychological Well-Being Scale was used to measure psychological well-being, the DASS-21 Stress Subscale was used to assess work-related stress, the Minnesota Job Satisfaction Scale (Short Form) was used to determine job satisfaction, and the Technostress Creators Scale (Short Form) was used to measure stress levels caused by digitalization. The analysis process for this study was conducted in two stages. In the first stage, descriptive statistics and Cronbach's Alpha analyses were performed using IBM SPSS software to determine the participants' demographic characteristics and assess the reliability of the scales. In the second stage, Partial Least Squares Structural Equation Modeling (PLS-SEM) was conducted using the SmartPLS software to test the relationships among the variables. In this context, the validity and reliability criteria of the measurement model were first evaluated, and then the research hypotheses were tested using the structural model. The findings revealed that stress levels resulting from digitalization and automation significantly increased work-related stress among seafarers and negatively affected their job satisfaction. Furthermore, it was determined that work-related stress has a negative impact on psychological well-being. Conversely, it was found that psychological well-being positively influences job satisfaction. However, the results of the analysis regarding the mediating effects proposed in the study did not support the mediating role of work-related stress. In conclusion, it has been determined that the effects of digitalization and automation processes on the working lives of seafarers must be assessed not only from an operational perspective but also from psychological and organizational perspectives.

Keywords: Maritime Industry, Digitalization, Automation, Work Stress, Job Satisfaction, Technostress

1. GİRİŞ

Denizcilik sektörü son yıllarda dijitalleşme ve otomasyon teknolojilerinin etkisiyle önemli bir dönüşüm sürecine girmiştir. Gemi operasyonlarının izlenmesi, veri paylaşımı, karar destek sistemleri, rota optimizasyonu ve uzaktan operasyon uygulamaları; operasyonel verimlilik, emniyet ve sürdürülebilirlik hedeflerini desteklemektedir (UNCTAD, 2020; IMO, 2021). Bununla birlikte bu dönüşüm yalnızca teknik süreçleri değil, gemi insanlarının çalışma biçimlerini ve iş deneyimlerini de etkilemektedir.

Özellikle tanker gemilerinde kullanılan dijital sistemler ve otomasyon teknolojileri, operasyonel süreçlerin daha verimli ve kontrollü yürütülmesine katkı sağlamaktadır. Bununla birlikte bu dönüşümün çalışanlar üzerindeki etkileri yalnızca teknik boyutla sınırlı kalmamakta, iş yaşamına ilişkin psikolojik sonuçları da beraberinde getirebilmektedir.

Denizcilik sektöründe dijitalleşme ve otomasyon süreçlerinin gemi insanları üzerindeki etkilerine ilişkin güncel çalışmalar bulunmaktadır. Bu kapsamda Bayrak ve Muslu (2025), dijitalleşme ve otomasyonun denizcilerde teknostres oluşturduğunu ve bu durumun çalışanların psikolojik sağlıkları ile çalışma yaşamına ilişkin çeşitli sonuçlar doğurabileceğini vurgulamıştır. Araştırmanın sonuç ve önerileri bölümünde, teknostresin çalışanların stres düzeyleri, psikolojik durumları ve çalışma yaşamına yönelik etkilerinin daha ayrıntılı incelenmesine ihtiyaç olduğu ifade edilmiştir. Bununla birlikte, mevcut literatürde dijitalleşme ve otomasyon kaynaklı stresin psikolojik iyi oluş, iş stresi ve iş tatmini ile ilişkisini bütüncül bir çerçevede ele alan çalışmaların sınırlı olduğu görülmektedir. Özellikle bu değişkenler arasındaki ilişkisel yapı ve iş stresinin süreç içerisindeki rolüne yönelik ampirik bulguların daha fazla araştırılmasına ihtiyaç duyulmaktadır. Bu araştırma, tanker gemilerinde görev yapan gemi insanları örnekleminde söz konusu ilişkileri inceleyerek literatüre katkı sunmayı amaçlamaktadır.

2. YÖNTEM VE METHOD

2.1. Veri Toplama Aracı ve Verilerin Analizi

Araştırmada ele alınan değişkenler arasındaki ilişkilerin analiz edilmesi, istatistiksel kavramlara dayanan nicel bir yaklaşımı gerekli kılmaktadır. Bu doğrultuda araştırma tasarımı, değişkenler arasındaki ilişkilerin ortaya konulmasını ve oluşturulan hipotezlerin test edilmesini esas almaktadır (Thomas, Martin, & Silverman, 2023).

Akademik geçerliliği kanıtlanmış ölçekler seçilerek anket formu tasarlanmıştır. Tasarlanan anket formu için gerekli Etik Kurul Onayı alınmıştır.

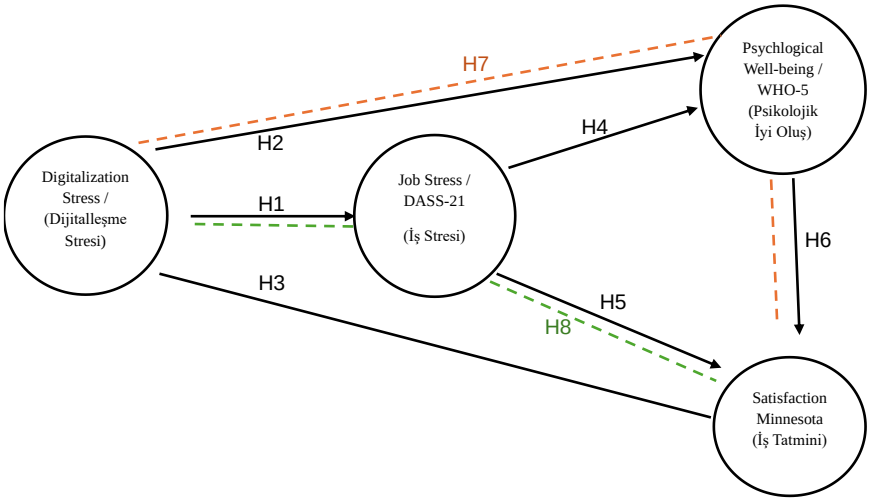

Figure 1 Araştırma Modeli

Araştırma modeli (Figure 1); dijitalleşme stresinin iş stresi, psikolojik iyi oluş ve iş tatmini arasındaki ilişkilerini incelemektedir. Modelde iş stresi aracı-değişken olarak konumlandırılmıştır. Böylece dijitalleşme stresinin iş tatmini üzerindeki doğrudan etkisinin yanı sıra iş stresi ve psikolojik iyi oluş üzerinden oluşan dolaylı etkileri de test edilmektedir. Araştırmada veri toplama aracı olarak, literatürde geçerliliği kanıtlanmış ölçeklerden yararlanılarak bir anket formu hazırlanmış ve uygulama öncesinde gerekli Etik Kurul Onayı alınmıştır. Toplanan veriler öncelikle SPSS programında analiz edilerek tanımlayıcı istatistikler ile geçerlilik ve güvenirlik analizleri gerçekleştirilmiştir. Son aşamada ise SmartPLS programı kullanılarak araştırma modeli test edilmiş ve hipotez analizleri yapılmıştır. Çalışmanın örneklemi, tanker gemilerinde görev yapan gemi zabitlerinden oluşmaktadır. Katılımcıların %95,7'si erkek olup örneklem büyük ölçüde deneyimli ve lisans mezunu çalışanlardan oluşmaktadır. Dijital sistemlerle çalışma süresi açısından katılımcıların %44,7'si 11 yıl ve üzeri, %31,9'u 6-10 yıl arası deneyime sahiptir. Bu durum, örneklemin dijitalleşme ve otomasyon süreçlerine önemli ölçüde adapte olmuş bir yapıya sahip olduğunu göstermektedir.

3. SONUÇ VE TARTIŞMA

Araştırma verilerinin tanımlayıcı istatistikleri ve ön analizleri IBM SPSS Statistics 20.0 paket programı kullanılarak gerçekleştirilmiştir. Ölçeklerin faktör analizine uygunluğu Kaiser-Meyer-Olkin (KMO) ve Bartlett Küresellik Testi ile incelenmiş olup, analiz sonuçları yandaki Tablo 1'de özetlenmiştir.

Table 1 KMO ve Bartlett Küresellik Testi

Faktör 1 (Dijitalleşme Stresi)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,826
Bartlett's Test of Sphericity	Approx. Chi-Square	301,093
	df	55
	Sig.	0,000
Faktör 2 (Psikolojik İyi Oluş)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,888
Bartlett's Test of Sphericity	Approx. Chi-Square	137,479
	df	10
	Sig.	0,000
Faktör 3 (İş Stresi)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,848
Bartlett's Test of Sphericity	Approx. Chi-Square	216,00
	df	21
	Sig.	0,000
Faktör 4 (İş Tatmini)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,780
Bartlett's Test of Sphericity	Approx. Chi-Square	636,040
	df	190
	Sig.	0,000

Tüm ölçeklerin KMO değerlerinin kabul edilebilir sınırların üzerinde ve Bartlett testinin anlamlı olması ($p<0,001$) verilerin analize uygunluğunu kanıtlamıştır. Belirlenen faktör yükü (Kozak, 2014) ve öz değer (Tatlıdil, 1992) kriterlerine göre; Psikolojik İyi Oluş ve İş Stresi tek, Dijitalleşme Stresi iki, İş Tatmini ise dört boyutlu net bir faktör yapısı sergilemiştir.

Katılımcıların demografik bilgileri (Tablo 2) incelendiğinde; katılımcıların %95,7'sinin erkeklerden oluşması tanker taşımacılığının erkek egemen yapısını, %93,6'sının lisans mezunu olması ise personelin yüksek teknik ve mesleki yeterliliğini ortaya koymaktadır.

Table 2 Katılımcıların Demografik Bilgileri

Değişken		Frekans	%
Cinsiyet	Kadın	2	4,3
	Erkek	45	95,7
Eğitim	Ön lisans	2	4,3
	Lisans	44	93,6
	Lisansüstü	1	2,1
Görev	Kaptan	16	34,0
	Başmühendis	13	27,7
	Güverte Zabiti	12	25,5
	Makine Zabiti	5	10,6
	Stajyer	1	2,1
Denizcilikte Deneyim	1-5	7	14,9
	6-10	9	19,1
	11-15	22	46,8
	16-20	4	8,5
	21 ve üzeri	5	10,6
Dijital Sistemlerle Çalışma Süresi	0-2	5	10,6
	3-5	6	12,8
	6-10	15	31,9
	11 ve üzeri	21	44,7

Gemideki görev dağılımında kaptan (%34) ve başmühendis (%27,7) gibi yönetim kademesindeki personelin ağırlıkta olması verilerin operasyonel açıdan güçlü bir temsil yeteneğine sahip olduğunu göstermektedir. Katılımcıların %46,8'inin 11-15 yıl arası sektörel deneyime, %44,7'sinin ise 11 yıl ve üzeri dijital sistem kullanım tecrübesine sahip olması örneklemin mesleki olgunluğu yüksek ve dijitalleşme süreçlerine adapte olmuş uzman bir kitleden oluştuğunu kanıtlamaktadır.

Ölçüm Modeli Güvenilirlik ve Yakınsak Geçerlilik Sonuçları Tablo 3'deki şekilde listelenmektedir. Bu bulgulara göre; Henseler, Ringle ve Sinkovics (2009) tarafından önerilen iki aşamalı model değerlendirme yaklaşımı uyarınca yapılan analizler sonucunda, tüm gizil değişkenlerin Cronbach's Alpha (0,890-0,916), rho_a (0,904-0,941) ve rho_c (0,915-0,932)

değerlerinin 0,70 eşik sınırının üzerinde gerçekleşerek yüksek bir içsel tutarlılık güvenilirliği sağladığı görülmektedir.

Table 3 Ölçüm Modeli Güvenilirlik ve Yakınsak Geçerlilik Sonuçları

	Cronbach's Alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
Dijitalleşme Stresi	0.890	0.904	0.915	0.644
Psikolojik İyi Oluş	0.893	0.941	0.919	0.694
İş Stresi	0.916	0.930	0.932	0.662
İş Tatmini	0.917	0.930	0.930	0.529

Düşük faktör yüküne sahip maddelerin elenmesiyle (Faktör 1'den 3, Faktör 4'ten 7 madde) AVE değerlerinin 0,50 barajını aşması ve dördüncü değişkenin yüksek bileşik güvenilirlik performansı göstermesi, yakınsak geçerliliğin tam olarak sağlandığını ve modelin yapısal analiz (hipotez testleri) aşamasına hazır olduğunu kanıtlamaktadır.

Ölçüm modelinin ayrışma geçerliliği Fornell-Larcker kriteri ve HTMT oranları ile incelenmiş olup, tüm yapıların literatürde öngörülen sınırları karşıladığı ve ayırt edici geçerliliğe sahip olduğu saptanmıştır. Hipotezlerin desteklenme durumu; yol katsayıları (β) ile istatistiksel anlamlılık düzeylerini gösteren p değeri dikkate alınarak değerlendirilmiştir. (Hair, Hult, Ringle, Sarstedt, Danks & Ray, 2021). Söz konusu bulgular Tablo 4'de gösterilmektedir.

Table 4 PLS-SEM Analiz Sonuçları

Hipotezler	Yol	β	p	Sonuç
H1	**Dijitalleşme Stresi → İş Stresi**	0,429	0,000	Kabul
H2	**Dijitalleşme Stresi → Psikolojik İyi Oluş**	-0,012	0,943	Red
H3	**Dijitalleşme Stresi → İş Tatmini**	-0,283	0,037	Kabul
H4	**İş Stresi → Psikolojik İyi Oluş**	-0.408	0,050	Kabul
H5	**İş Stresi → İş Tatmini**	-0,287	0,114	Red
H6	**Psikolojik İyi Oluş → İş Tatmini**	0,295	0,037	Kabul
H7	**Dijitalleşme Stresi → İş Stresi → Psikolojik İyi Oluş**	-0,175	0,089	Red
H8	**Dijitalleşme → İş Stresi → İş Tatmini**	-0,123	0,176	Red

Test edilen sekiz hipotezden H1, H3, H4 ve H6 kabul edilmiş; H2, H5, H7 ve H8 reddedilmiştir. Elde edilen bulgular, dijitalleşme ve otomasyon kaynaklı stresin özellikle iş stresi ve iş tatmini

üzerinde doğrudan etkiler oluşturduğunu; buna karşın iş stresinin aracılık rolünün desteklenmediğini göstermektedir.

4. Değerlendirme

Bu araştırma, tanker gemilerindeki dijitalleşme ve otomasyon kaynaklı stresin iş stresini artırdığını (H1) ve iş tatminini doğrudan düşürdüğünü (H3) ortaya koyarken; teknolojik stresin psikolojik iyi oluş üzerindeki doğrudan etkisini (H2) ve iş stresinin modeldeki tüm aracılık rollerini (H5, H7, H8) anlamsız bulmuştur.

Bulgular, dijital dönüşümün yarattığı bilişsel yükün klasik iş stresi mekanizmalarından bağımsız, doğrudan teknoloji etkileşimi temelli bir baskı unsuru olarak iş tatminini zayıflattığını; psikolojik iyi oluşun ise bu sürecin genel bir iş stresine (H4) dönüşmesiyle olumsuz etkilendiğini göstermektedir. Bu doğrultuda, gemi insanlarının psikolojik refahını korumak adına otomasyon süreçlerinin yanı sıra rol belirsizliklerini azaltan ve teknostresle baş etmeyi kolaylaştıran kurumsal destek mekanizmalarının devreye sokulması kritik bir önem taşımaktadır.

Yüksek risk ve yoğun otomasyon barındıran tanker gemisinde çalışan gemi insanlarını kapsaması yönüyle sınırlı olan bu çalışmanın gelecekte boylamsal tasarımlarla, farklı gemi tipleriyle ve modele örgütsel destek gibi koruyucu değişkenler eklenerek genişletilmesi; denizcilik sektöründe ise insan odaklı dijitalleşme stratejilerinin geliştirilmesi önerilmektedir.

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ÇALIŞMA YAŞAMINDA TEKNOSTRES VE MESAİ SAATİ DIŞINDA AKILLI TELEFON KULLANIMINA YÖNELİK BİR LİTERATÜR TARAMASI

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ÖZ:

Bilgi ve iletişim teknolojilerinde yaşanan hızlı gelişmeler, çalışma yaşamının sınırlarını yeniden şekillendirerek zaman ve mekân bağımsız bir çalışma anlayışını beraberinde getirmiştir. Özellikle akıllı telefonların yaygınlaşması, çalışanların iş süreçlerine sürekli erişimini mümkün kılmış ve bu durum iş-yaşam dengesi üzerinde önemli etkiler yaratmıştır. Her ne kadar bu teknolojiler esneklik, hız ve verimlilik gibi avantajlar sunsa da, çalışanlar üzerinde yeni stres kaynaklarının ortaya çıkmasına da neden olmaktadır. Bu bağlamda teknostres, bireylerin teknoloji kullanımına bağlı olarak yaşadıkları stres ve psikolojik baskı durumu olarak literatürde önemli bir yer edinmiştir.

Bu çalışmanın amacı, teknostres ve mesai saatleri dışında akıllı telefon kullanımına ilişkin mevcut literatürü kapsamlı bir şekilde inceleyerek, bu iki olgu arasındaki ilişkiyi ve çalışma yaşamına olan etkilerini ortaya koymaktır. Literatür taraması kapsamında ulusal ve uluslararası çalışmalar değerlendirilmiş; teknostresin nedenleri, boyutları ve sonuçları ele alınmıştır. Elde edilen bulgular, teknostresin çalışanların iş doyumu, performansı ve psikolojik iyi oluşu üzerinde çoğunlukla olumsuz etkiler yarattığını göstermektedir.

Ayrıca mesai saatleri dışında akıllı telefon aracılığıyla sürdürülen iş ile ilgili iletişimin, çalışanlarda sürekli erişilebilir olma algısını güçlendirdiği, iş ve özel yaşam sınırlarını bulanıklaştırdığı ve tükenmişlik düzeyini artırdığı tespit edilmiştir. Bu doğrultuda, teknostresin bireysel ve örgütsel düzeyde yönetilmesi gereken önemli bir olgu olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler: Teknostres, akıllı telefon kullanımı, iş-yaşam dengesi, dijital stres, literatür taraması

A LITERATURE REVIEW ON TECHNOSTRESS IN WORK LIFE AND SMARTPHONE USE OUTSIDE WORKING HOURS

ABSTRACT

Rapid developments in information and communication technologies have reshaped the boundaries of working life, giving rise to a work structure that is independent of time and place. In particular, the widespread use of smartphones has enabled employees to access work

processes continuously, thereby creating significant implications for work–life balance. Although these technologies provide important advantages such as flexibility, speed, and efficiency, they also give rise to new sources of stress for employees. In this context, technostress has emerged in the literature as a significant concept referring to the psychological pressure and stress experienced by individuals due to technology use.

The aim of this study is to comprehensively examine the existing literature on technostress and smartphone use outside working hours, and to reveal the relationship between these two phenomena and their reflections on working life. Accordingly, national and international studies were evaluated within a systematic framework, and the causes, dimensions, and consequences of technostress were addressed through a holistic perspective. The findings indicate that technostress generally has negative effects on employees' job satisfaction, performance, and psychological well-being.

In addition, it has been determined that work-related communication maintained via smartphones outside working hours strengthens the perception of constant availability among employees, blurs the boundaries between work and private life, and increases the level of burnout. In this regard, technostress is concluded to be a significant phenomenon that needs to be addressed and effectively managed at both individual and organizational levels.

Keywords: Technostress, smartphone use, work–life balance, digital stress, literature review

GİRİŞ:

21. yüzyılın başından itibaren bilgi ve iletişim teknolojilerindeki (BİT) hızlı gelişim, çalışma yaşamının temel dinamiklerini değiştirmiş ve çalışanların iş süreçlerine zaman ve mekân fark etmeksizin erişmelerini mümkün kılmıştır. Bu durum, örgütlerin üretkenlik ve esneklik kazanmasını sağlarken, bireyler üzerinde yeni psikososyal gerilimler ve stres türlerinin ortaya çıkmasına yol açmıştır. Literatürde teknostres, teknoloji kullanımına bağlı olarak ortaya çıkan olumsuz psikolojik ve davranışsal tepkiler bütünü olarak tanımlanmaktadır (Teknostress: A comprehensive literature review, 2024).

Teknostres çalışmaları, teknoloji ile etkileşimin iş ve yaşam üzerindeki etkilerini anlamak üzere çok sayıda araştırma üretmiş; özellikle iş yaşamında bilgi teknolojilerinin kullanımı sonrası çalışanların deneyimlediği "techno-stressors" olarak adlandırılan stres kaynaklarının iş doyumu, verimlilik ve psikolojik iyi oluş üzerinde etkileri incelenmiştir (Teknostress: A comprehensive literature review, 2024). Technostress literatürü, çalışanın teknoloji kullanım düzeyindeki artış ile "techno-overload" (aşırı yüklenme), "techno-invasion" (iş dışı zamanlara

sızma) gibi stresörler arasındaki bağları ortaya koymuştur (Teknostress: A comprehensive literature review, 2024).

Akıllı telefonların yaygınlaşması, çalışanların mesai saatleri dışında da iş ile bağlantı kurmasını kolaylaştırmış ve bu durum iş-yaşam sınırlarının bulanıklaşmasına neden olarak çalışanların sürekli erişilebilirlik algısını güçlendirmiştir. Problemli akıllı telefon kullanımı ile teknostres arasındaki ilişki, teknoloji bağımlılığı ve olumsuz psikolojik etkileşimler bağlamında incelenmiş; problemli akıllı telefon kullanımının teknostres seviyelerini anlamlı biçimde etkilediğine dair bulgular elde edilmiştir (Sayıner, 2022).

Bununla birlikte mevcut literatürde teknostresin ve mesai saatleri dışında akıllı telefon kullanımının birlikte sistematik olarak değerlendirildiği çalışmalar sınırlı kalmaktadır. Çoğu araştırma, teknostresi ya iş yerindeki bilgi teknolojileri ile sınırlı tutarken ya da akıllı telefon kullanımının etkilerini bireysel düzeyde ele almaktadır; ancak her iki olgunun etkileşimini birliteli inceleyen bütüncül çalışmaların sayısı sınırlıdır (Teknostress: A comprehensive literature review, 2024).

Bu çerçevede, 2000–2026 yılları arasında yayımlanmış ulusal ve uluslararası akademik çalışmaların sistematik literatür taraması yapılarak değerlendirildiği bu çalışma, teknostres ve mesai saatleri dışında akıllı telefon kullanımının çalışma yaşamına etkilerini kapsamlı biçimde ortaya koymayı hedeflemektedir.

TEKNOSTRES:

Teknolojiye bağlı olarak bireylerin yaşadığı olumsuz etkiler, ilk olarak Amerikalı psikolog Brod (1984) tarafından "teknostres" olarak tanımlanmıştır. Teknostres, bir çalışanın bilgi ve iletişim teknolojisinin (BİT) sürekli varlığı ve hızlı değişimi nedeniyle deneyimlediği stres olarak açıklanmaktadır (Akman, 2023, s. 73). Bu olgu, yalnızca birçok kurum çalışanını değil, eğitim alanında görev yapan öğretmenleri de etkilemekte; öğretmenlerde teknoloji fobisi ve özyeterlik eksikliği şeklinde kendini gösterebilmektedir (Gökbulut, 2021, s. 2).

Yaygın kabul gören sınıflandırmalara göre teknostres beş temel boyuttan oluşmaktadır: **tekno-aşırı yükleme, tekno-işgal, tekno-karmaşıklık, tekno-güvensizlik ve tekno-belirsizlik** (Kopuz & Aydın, 2020, s. 251). Bu boyutlar, teknolojinin çalışma yaşamındaki sürekli varlığı ve karmaşıklığıyla ilişkili olarak çalışanlarda stres oluşturabilen farklı kaynakları temsil etmektedir.

Teknostresin davranışsal etkileri incelendiğinde, iş performansı, iş kalitesi ve verimlilik gibi önemli örgütsel çıktılar üzerinde olumsuz sonuçlar doğurduğu görülmektedir (Erer, 2021, s. 87). Literatürde teknostresin sonuçları genel olarak **bireysel etkiler** ve **örgütsel etkiler** olmak

üzere iki başlıkta ele alınmaktadır (Özel & Aba, 2023, s. 264). Teknostresin kaynakları arasında ise negatif duygular, ev-iş çatışması, gerginlik, iş yükü, mahremiyet ihlali, rol karmaşası, teknoloji kullanışlılığı ve güvenilirliği, sürekli bulunurluk, anonimlik, değişim baskısı ve iş güvencesi kaygısı gibi faktörler yer almaktadır (Gökaslan, 2022, ss. 360-361).

DİJİTAL STRES:

Stres kavramı, Latince "estrica" sözcüğünden türetilmiş olup, 17. yüzyılda felaket, dert ve baş edilmez sorunlar anlamında kullanılmış; zamanla ise zorluk, baskı, kısıtlanma ve gerilim gibi durumları ifade eden bir kavram hâline gelmiştir (Özyılmaz, 2021, s. 166). Günümüzde dijital teknolojilerin yaygınlaşmasıyla birlikte, stresin bu yeni biçimi "dijital stres" olarak tanımlanmakta ve dijital tükenmişlik ile ilişkili olarak çevreye karşı ilgisizleşme, yorgunluk ve psikolojik sorunları da beraberinde getirmektedir. Bu bağlamda, dijital bağımlılık ve dijital stresin önemli bileşenlerinden biri, bireylerin gelişmeleri kaçırma korkusudur (Sarıçam & Günaydın, 2024, s. 12).

AKILLI TELEFON KULLANIMI:

Pew Research Center tarafından yayımlanan "Haber Medyasının Durumu 2012" raporuna atıfta bulunan Pavlik, mobil cihazların masaüstü ve dizüstü bilgisayarlara kıyasla daha derinlikli bir haber deneyimi sunabildiğini belirtmektedir. Rapora göre Amerikalıların %44'ü akıllı telefon, %22'si ise tablet sahibidir. Ayrıca ABD nüfusunun yaklaşık yarısının mobil iletişim araçlarına sahip olduğu, bu grubun üçte birinin internete kablosuz olarak erişim sağladığı ifade edilmektedir. Mobil kullanıcıların üçte ikisinin cihazlarını haber takibi amacıyla kullanması dikkat çekmekte; haber tüketiminin ise e-posta kullanımından sonra en yaygın ikinci mobil etkinlik olduğu görülmektedir (Değirmencioğlu, 2016: 598).

Bu bulgular, mobil teknolojilerin giderek artan önemini ortaya koyarken, günümüzde akıllı telefonlar ve mobil uygulamaların hem dünya genelinde hem de Türkiye'de hızla yaygınlaştığı gözlemlenmektedir. 2020 yılında yapılan bir araştırma, dünya çapında yaklaşık 3,5 milyar akıllı telefon kullanıcısı bulunduğunu göstermektedir. Aynı araştırmaya göre ABD'de 16–64 yaş aralığındaki bireylerin %77'si akıllı telefon sahibiyken, Türkiye'de bu oran %89'a ulaşmıştır (Subaşı, 2022: 2).

Teknoloji kullanımındaki bu yaygınlaşma yaş gruplarına göre farklılık göstermektedir. Genç yetişkinler arasında akıllı telefon, bilgisayar ve akıllı saat gibi cihazların kullanımı oldukça yaygınken, ileri yaştaki bireyler için bu teknolojiler daha çok sağlıklarını koruma ve yaşam kalitelerini artırma gibi işlevsel amaçlara hizmet etmektedir (Erdoğan, 2025: 67).

LİTERATÜR TARAMASI:

Literatür taraması sürecinde, araştırma konusuyla ilgili daha önce yayımlanmış kitaplar, makaleler, tezler, konferans bildirileri, tarihsel belgeler ve çeşitli raporlar sistemli bir şekilde incelenerek çalışmaya katkı sağlayabilecek veriler elde edilmeye çalışılır (Demirci, 2014: 74). Bu sürecin temel amacı ise araştırmanın hangi kuramsal ve kavramsal çerçevede yürütüleceğini ortaya koymak ve mevcut çalışmaların sentezi yoluyla literatürdeki eksik ya da yeterince ele alınmamış alanları belirleyerek bu boşluklara odaklanmaktır (Köroğlu, 2015: 61).

YÖNTEM:

Bu çalışmada, teknostres ve mesai saatleri dışında akıllı telefon kullanımına ilişkin literatür sistematik bir yaklaşımla incelenmiştir. Araştırma kapsamında 2000–2026 yılları arasında yayımlanmış ulusal ve uluslararası akademik çalışmalar değerlendirmeye alınmıştır. Bu doğrultuda, Google Scholar, Web of Science, Scopus ve DergiPark gibi veri tabanları kullanılarak "teknostres", "dijital stres", "akıllı telefon kullanımı", "iş-yaşam dengesi" ve "çalışanlarda teknoloji kullanımı" anahtar kelimeleri üzerinden tarama yapılmıştır.

Elde edilen çalışmalar; konuya uygunluk, erişilebilirlik ve akademik katkı kriterleri doğrultusunda seçilmiş, tekrar eden ve konu dışı çalışmalar elenmiştir. İncelenen literatür, kavramsal çerçeve, nedenler, sonuçlar ve değişkenler arası ilişkiler açısından analiz edilerek tematik olarak sınıflandırılmıştır.

BULGULAR:

İncelenen literatür, teknostresin ortaya çıkışında başlıca belirleyiciler arasında teknoloji kullanım yoğunluğu, sürekli erişilebilir olma beklentisi ve artan iş yükünün yer aldığını göstermektedir. Özellikle tekno-aşırı yükleme ve tekno-işgal boyutlarının çalışanlar üzerinde önemli düzeyde baskı oluşturduğu; bununla birlikte teknolojik değişim hızına uyum sağlama zorunluluğunun da stres düzeyini artıran temel faktörlerden biri olduğu ifade edilmektedir (Kopuz & Aydın, 2020: 251; Gökaslan, 2022: 360–361). Teknostresin etkileri değerlendirildiğinde, bireysel düzeyde psikolojik iyi oluşun olumsuz yönde etkilendiği; tükenmişlik, kaygı, dikkat dağınıklığı ve iş doyumunda azalma gibi sonuçların ortaya çıktığı görülmektedir. Örgütsel düzeyde ise performans düşüşü, verimlilik kaybı ve işten ayrılma niyetinde artış gibi sonuçların öne çıktığı belirtilmektedir (Erer, 2021: 87; Özel & Aba, 2023: 264).

Mesai saatleri dışında akıllı telefon aracılığıyla sürdürülen iş ile ilgili iletişimin, çalışanlar üzerinde sürekli ulaşılabilir olma algısını güçlendirdiği ve iş ile özel yaşam arasındaki sınırları belirsizleştirdiği anlaşılmaktadır. Bu durum, bireylerin zihinsel olarak işten uzaklaşmasını

zorlaştırarak iş-yaşam çatışmasını artırmakta ve özellikle tükenmişlik düzeyi ile güçlü bir ilişki göstermektedir (Sayıner, 2022: 45–61). Ayrıca problemli akıllı telefon kullanımının teknostres düzeyini anlamlı biçimde artırdığı; iş amaçlı kullanımın mesai saatleri dışına taşmasının ise teknostresin "tekno-işgal" boyutunu daha da belirgin hâle getirdiği ifade edilmektedir (Teknostress: A comprehensive literature review, 2024). Bu bağlamda akıllı telefonların, teknostresin hem ortaya çıkmasında hem de artış göstermesinde etkili bir unsur olduğu sonucuna ulaşılmaktadır.

TARTIŞMA, SONUÇ VE ÖNERİLER:

Bu çalışmada elde edilen bulgular, teknostresin günümüz çalışma yaşamının önemli ve giderek artan bir sorunu hâline geldiğini ortaya koymaktadır. Bilgi ve iletişim teknolojilerinin sağladığı esneklik ve erişilebilirlik avantajlarına rağmen, çalışanların iş süreçlerine sürekli bağlı kalması, iş-yaşam dengesi üzerinde olumsuz etkiler yaratmaktadır. Özellikle mesai saatleri dışında akıllı telefon aracılığıyla sürdürülen iş ile ilgili iletişim, çalışanlarda sürekli ulaşılabilir olma baskısını artırarak iş ve özel yaşam sınırlarının belirsizleşmesine neden olmaktadır. Bu durum, literatürde sıklıkla vurgulanan tekno-işgal ve tekno-aşırı yükleme boyutlarını güçlendirmekte ve bireylerin psikolojik iyi oluşunu olumsuz yönde etkilemektedir.

Araştırma kapsamında incelenen çalışmalar, teknostresin yalnızca bireysel düzeyde değil, örgütsel düzeyde de önemli sonuçlar doğurduğunu göstermektedir. Çalışanların tükenmişlik düzeylerinin artması, iş doyumlarının azalması ve performanslarının düşmesi, örgütler açısından verimlilik kaybı ve iş gücü devri gibi sorunları beraberinde getirmektedir. Bu bağlamda, teknostresin yalnızca bireysel bir sorun olarak değil, aynı zamanda örgütsel bir yönetim meselesi olarak ele alınması gerektiği anlaşılmaktadır.

Öte yandan literatürde dikkat çeken önemli bir eksiklik, teknostres ile mesai saatleri dışında akıllı telefon kullanımının birlikte ele alındığı çalışmaların sınırlı olmasıdır. Mevcut araştırmaların büyük bir kısmı bu iki olguyu ayrı ayrı incelemekte; ancak aralarındaki etkileşimi bütüncül bir bakış açısıyla değerlendiren çalışmaların sayısı oldukça azdır. Bu durum, söz konusu çalışmanın literatüre katkı sağlama potansiyelini artırmakta ve gelecekte yapılacak araştırmalar için önemli bir araştırma alanı ortaya koymaktadır.

Elde edilen bulgular doğrultusunda, teknostresin etkilerini azaltmaya yönelik hem bireysel hem de örgütsel düzeyde çeşitli önlemler alınması gerektiği düşünülmektedir. Bu kapsamda örgütlerin, çalışanların mesai saatleri dışında iş ile ilgili iletişim yükünü sınırlandıran politikalar geliştirmesi, çalışanların sürekli erişilebilir olma beklentisini azaltması ve iş-yaşam dengesini destekleyici uygulamaları hayata geçirmesi önem taşımaktadır. Ayrıca çalışanlara

yönelik dijital farkındalık eğitimleri ve teknoloji kullanımını dengelemeye yönelik uygulamalar (örneğin dijital detoks) teşvik edilmelidir.

Bununla birlikte gelecekte yapılacak çalışmaların, teknostres ve akıllı telefon kullanımını birlikte ele alan ampirik araştırmalara yönelmesi, farklı sektörler ve demografik gruplar arasında karşılaştırmalı analizler yapması ve kültürel farklılıkları dikkate alarak konuyu daha geniş bir perspektiften incelemesi literatüre önemli katkılar sağlayacaktır.

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DEPREM SONRASI GEÇİCİ ENKAZ DEPOLAMA SAHALARININ AFET LOJİSTİĞİNDEKİ ROLÜ: KAVRAMSAL BİR MODEL ÖNERİSİ

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ÖZET

Kentsel alanlarda meydana gelen büyük ölçekli depremler, birkaç dakika içinde milyonlarca ton inşaat ve yıkıntı atığı (İYA) üretmekte; bu enkaz kütlesi kurtarma koridorlarını tıkayarak afet müdahale ve iyileşme süreçlerini doğrudan kısıtlamaktadır. 2023 Kahramanmaraş depremlerinde 350 milyon tonu aşan enkaz hacmi bu tehdidin somut göstergesidir. Afet lojistiği yazınında enkaz yönetimi süreci insani yardım lojistiğinin gölgesinde kalmış; özelde Geçici Enkaz Depolama Sahaları (GDS) kavramsal düzeyde yeterince tartışılmamıştır. Bu çalışma, GDS'nin afet lojistiği sistemi içindeki işlevini teorik bir çerçevede ele almayı ve özgün bir kavramsal model önermeyi amaçlamaktadır. Sistematik yazın taramasına dayanan çalışmada GDS'yi doğrudan ya da önemli ölçüde konu edinen yayınlar analiz edilmiştir. Elde edilen bulgular, GDS'nin enkaz akışını zamansal ve mekânsal olarak düzenleme, nakliye seferlerini konsolide etme ve geri kazanılabilir malzemelerin ön sınıflandırmasını olanaklı kılma bakımından afet lojistiği zincirinde kritik bir ara düğüm olduğunu ortaya koymaktadır. Bu doğrultuda çalışma, GDS'yi üç işlevsel boyutuyla tanımlayan bir kavramsal model önermektedir: (i) enkaz üretim alanları ile kalıcı depolama tesisleri arasında tampon bölge, (ii) nakliye kapasitesini optimize eden lojistik aktarma düğümü ve (iii) geri kazanılabilir malzemelerin ayrıştırıldığı ön işlem alanı. Her boyut, afet öncesi planlama sürecinde farklı kriter setlerini ve kapasite standartlarını gerektirmektedir. Türkiye bağlamında TAMP'ın (2019) GDS için operasyonel standartları yeterince belirlemediği saptanmış; özellikle yüksek sismik riskli kentler için afet öncesi GDS ağı planlamasının öncelikli bir politika ihtiyacı olduğu vurgulanmıştır. Çalışma, önerilen modelin CBS tabanlı çok kriterli saha seçimi çalışmalarıyla sınanmasına yönelik bir araştırma gündemi de sunmaktadır.

Anahtar Kelimeler: Enkaz yönetimi, geçici enkaz depolama sahası, afet lojistiği, deprem

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THE ROLE OF TEMPORARY DEBRIS STORAGE SITES IN POST-EARTHQUAKE DISASTER LOGISTICS: A CONCEPTUAL MODEL PROPOSAL

ABSTRACT

Large-scale urban earthquakes generate millions of tons of construction and demolition waste within minutes, blocking rescue corridors and directly constraining disaster response and recovery operations. The over 350 million tons of debris produced by the 2023 Kahramanmaraş Earthquakes is a concrete illustration of this threat. Within the disaster logistics literature, debris management has remained in the shadow of humanitarian logistics, and Temporary Debris Storage Sites (TDSS) in particular have not been sufficiently examined at the conceptual level. This study aims to address the functional role of TDSS within the disaster logistics system through a theoretical framework and to propose an original conceptual model. Based on a systematic literature review, publications that directly or substantially address TDSS were analyzed. The findings demonstrate that TDSS constitute a critical intermediate node in the disaster logistics chain, serving to regulate debris flows in both temporal and spatial terms, consolidate transport trips, and enable the pre-sorting of recoverable materials. Accordingly, the study proposes a conceptual model that defines TDSS across three functional dimensions: (i) a buffer zone between debris generation areas and permanent disposal facilities, (ii) a logistics transfer hub that optimizes transport capacity, and (iii) a pre-processing area for the separation of recoverable materials. Each dimension requires distinct criteria sets and capacity standards in the pre-disaster planning phase. In the Turkish context, the study finds that TAMP (2019) does not sufficiently define operational standards for TDSS, and emphasizes that pre-disaster TDSS network planning constitutes a priority policy need, particularly for high seismic-risk cities such as Istanbul. The study also presents a research agenda for testing the proposed model through GIS-based multi-criteria site selection studies.

Keywords: Debris management, temporary debris storage site, disaster logistics, earthquake

1. GİRİŞ

Depremler, ani başlangıçlı ve yüksek yıkım kapasiteli doğal afetlerdir. Büyük ölçekli bir kentsel deprem, yalnızca can ve mülk kaybına yol açmakla kalmayıp kısa sürede devasa miktarlarda inşaat ve yıkıntı atığı (İYA) da üretmektedir. 1995 Hanshin-Awaji Depremi yaklaşık 20 milyon ton (Hayashi ve Katsumi, 1996), 2010 Haiti Depremi yaklaşık 40 milyon ton (Brown, Milke ve Seville, 2011) ve 2011 Tohoku Depremi ile Tsunamisi ise yaklaşık 28 milyon ton enkaz meydana getirmiştir (Habib ve Sarkar, 2017). 2023 Kahramanmaraşdepremlerinde ise 350 milyon tondan fazla enkaz oluştuğu tahmin edilmiştir (Doğdu ve Alkan, 2023). Bu ölçekteki enkaz miktarları, mevcut katı atık altyapısını hızla

aşmakta; ulaşım koridorlarını tıkamakta; hem kurtarma operasyonlarını sekteye uğratmakta hem de toplumun iyileşme sürecini onlarca yıl uzatabilmektedir.

Afet sonrası enkaz yönetimi; tahmin, kaldırma, taşıma, geçici depolama, geri kazanım ve nihai bertaraf gibi birbiriyle bağlantılı alt süreçleri kapsayan karmaşık bir lojistik sistemdir. Bu sistemin can damarını oluşturan nakliye operasyonları, altyapı hasarı ve sürücü güvenliği gibi afet koşullarına özgü kısıtlar nedeniyle ciddi biçimde yavaşlamaktadır. Enkaz kaldırma hızı doğrudan toplumun iyileşme kapasitesiyle ilişkilidir: erken evre müdahalede her kaybedilen saat, kapasiteye yakın çalışan sağlık, barınma ve ulaşım altyapıları üzerinde birikimli bir baskı yaratmaktadır.

Afet lojistiği yazınında enkaz yönetimi süreci, insani yardım lojistiğinin gölgesinde kalmış; özelde Geçici Enkaz Depolama Sahaları (GDS — İngilizce literatürde Temporary Debris Management Sites, TDMS olarak da anılmaktadır) kavramsal düzeyde yeterince tartışılmamıştır. Mevcut çalışmaların büyük bölümü GDS'yi, rota optimizasyonu veya tahsis modellerinin bir girdi parametresi olarak ele almakta; sahaya özgü işlevsel, lojistik ve çevresel nitelikleri kavramsal düzeyde irdelememektedir. Bu durum, GDS için operasyonel planlama standartlarının geliştirilmesini güçleştirmekte; özellikle büyük depremlere hazırlık süreçlerinde kritik bir planlama boşluğuna zemin hazırlamaktadır. Bu çalışmanın temel amacı söz konusu boşluğu gidermektir: (i) GDS kavramını afet lojistiği sistematiği içinde net biçimde konumlandırmak, (ii) GDS'nin özgün işlevlerini tanımlayan kavramsal bir model önermek ve (iii) bu modeli afet öncesi planlama uygulamalarına bağlamak. Çalışma; bilimsel veri tabanı taramasından elde edilen bulguların teorik sentezine dayanmaktadır.

2. KAVRAMSAL ARKA PLAN: AFET LOJİSTİĞİ VE ENKAZ YÖNETİMİ

Afet lojistiği; afet öncesi hazırlık, müdahale ve iyileşme aşamalarını kapsayan malzeme, bilgi ve kaynak akışlarının yönetimini ifade etmektedir. Bu alan, insani yardım lojistiği (yiyecek, tıbbi malzeme, barınak) ile enkaz lojistiği (enkaz kaldırma, nakliye, bertaraf) olmak üzere iki temel alt sisteme ayrılmaktadır. Enkaz lojistiği, özellikle büyük ölçekli kentsel depremlerde kapasite baskısı ve zamana duyarlılık açısından insani yardım lojistiğini geride bırakacak düzeyde kritik bir hal almaktadır.

Brown, Milke ve Seville (2011), afet atık yönetimini kapsamlı biçimde incelemiş ve geçici depolama sahaları, geri dönüşüm ile nihai bertaraf gibi teknik yönetim seçeneklerinin literatürde tartışıldığını; ancak bu seçeneklerin afet sonrasında nasıl belirlendiğine dair rehberliğin yetersiz kaldığını saptamıştır. Askarizadeh ve diğerleri (2022) ise sürdürülebilir afet enkaz yönetimine yönelik niceliksel değerlendirme için gerekli veriler arasında enkaz

miktarı ve bileşiminin yanı sıra geçici yönetim sahalarının mevcudiyetini en kritik veri kategorisi olarak belirlemiştir. Bu tespit, GDS'nin soyut bir parametre olmaktan çıkarılıp somut bir planlama nesnesi haline getirilmesi gerektiğine işaret etmektedir.

GDS odaklı metodoloji çalışmaları ağırlıklı olarak 2010 sonrasında hız kazanmıştır. Grzeda, Mazzuchi ve Sarkani (2014), ABD Indiana eyaletinde Coğrafi Bilgi Sistemleri (CBS) ve binom küme analizini entegre ederek çoklu senaryo türleri için potansiyel GDS konumlarını afet öncesinde belirlemiştir. Wang ve diğerleri (2019), GDS seçimi ile hizmet bölgelerini birlikte optimize eden çok amaçlı karma tam sayılı doğrusal programlama yaklaşımı geliştirmiş ve enkaz kaldırma süresinde %33,27'ye varan iyileşme elde edilebileceğini göstermiştir. Habib ve Sarkar (2017) ise Analitik Ağ Süreci (ANP) ve bulanık TOPSIS yöntemlerini birleştirerek GDS seçimi ile enkaz tahsisini eş zamanlı ele alan iki aşamalı bir çerçeve önermiştir.

Türkiye bağlamında en dikkat çekici gelişme, 6 Şubat 2023 Kahramanmaraş Depremleri sonrasında enkaz yönetiminin nasıl kritik bir darboğaz haline geldiğinin açıkça görülmesidir. Yılmaz ve diğerleri (2023) bu deneyimden yola çıkarak emisyon duyarlı bir GDS seçimi yaklaşımı geliştirmiştir. Mevcut Türk afet yönetimi mevzuatı incelendiğinde, Türkiye Afet Müdahale Planı'nın (TAMP, 2019) GDS'ye ilişkin operasyonel standartları yeterince geliştirmediği görülmektedir. Bu eksiklik, yerel yönetimlerin afet öncesinde GDS planlaması yapmasını güçleştirmektedir. Son olarak, Gönül Sezer ve Demirel (2025), İstanbul Avrupa yakası ilçeleri için Çok Özellikli Fayda Teorisi'ne (ÇÖFT — İngilizce literatürde Multi-Attribute Utility Theory, MAUT) dayalı ve sürdürülebilirlik odaklı bir saha seçimi yöntemi önermiştir.

3. GEÇİCİ ENKAZ DEPOLAMA SAHALARININ SAĞLADIĞI FAYDA VE HIZ KAZANIMLARI

GDS'nin afet lojistiği sistemine katkısı yalnızca depolama kapasitesi sağlamaktan ibaret değildir. Doğru konumlandırılmış ve yeterli kapasiteye sahip GDS'ler, enkaz kaldırma operasyonlarının hız, maliyet ve çevresel etki boyutlarında ölçülebilir kazanımlar sunmaktadır. Bu kazanımlar aşağıda dört temel başlık altında ele alınmaktadır.

3.1. Araç Döngüsü Süresinin Kısaltılması

Afet sonrası enkaz taşımacılığında en büyük verimlilik kaybı, araçların enkaz üretim alanından nihai bertaraf tesisine —genellikle kentsel çeperden uzakta yer alan düzenli depolama alanlarına veya dönüşüm tesislerine— yaptığı uzun mesafeli seferlerde yaşanmaktadır. Hasar görmüş ve kapasitesi düşmüş yol ağı koşullarında bu mesafe, araç döngüsü süresini (cycle time) dramatik biçimde uzatmaktadır. GDS'ler, nihai bertaraf tesislerine uzak olan bu ara

noktaları ortadan kaldırarak araçların kısa mesafeli seferler yapmasını sağlar: araçlar enkaz alanından GDS'ye boşaltır, geri döner ve yeni sefer başlatır. Kim, Deshmukh ve Hastak (2014) bu döngü süresindeki kısalmanın saatlik nakliye kapasitesini doğrusal olmayan biçimde artırdığını göstermiştir. Wang ve diğerleri (2019), çok amaçlı optimizasyon modelleriyle GDS konumlarının doğru belirlenmesinin toplam enkaz kaldırma süresinde %33,27 oranında iyileşme sağlayabileceğini hesaplamıştır.

Araç döngüsü etkisini matematiksel olarak sezgisel düzeyde kavramak için sabit araç sayısı ve hızında, seferin ortalama mesafesinin yarıya indirilmesi —diğer koşullar sabit kaldığında— teorik olarak birim zamandaki seferi iki katına çıkarmaktadır. GDS'nin enkaz yoğunluk merkezlerine yakın konumlandırılması, bu etkinin somutlaşmasını sağlar.

3.2. Kapasite Konsolidasyonu ve Nakliye Ölçek Ekonomisi

Deprem alanında enkaz, çok sayıda dağınık noktadan üretilmektedir; hasar görmüş binalar genellikle dar, erişimi kısıtlı sokaklara dağılmış durumdadır. Büyük kapasiteli araçların bu noktalara doğrudan girmesi çoğunlukla mümkün değildir; hem fiziki kısıtlar hem de paralel kurtarma operasyonlarıyla çakışma riskleri bunu güçleştirir. GDS, küçük kapasiteli araçların (kepçe, küçük damperli kamyon) enkaz üretim noktalarından yaptığı mikro seferlerin konsolide edildiği bir aktarma platformu işlevi görür. Konsolide edilen enkaz buradan büyük kapasiteli araçlarla (ağır damperli kamyon, konteyner taşıyıcı) nihai tesislere nakledilir. Bu ölçek ekonomisi mantığı, toplam yakıt tüketimini, sürücü saatini ve yol aşınmasını düşürmektedir.

Konsolidasyon etkisi aynı zamanda trafik yönetimi açısından da kritik önem taşır. Enkaz nakliye araçlarının doğrudan nihai tesislere yönlendirilmesi halinde kentsel arterler çok sayıda ağır araçla dolarak kurtarma araçlarının (ambulans, arama-kurtarma ekipleri, vinç) hareket kabiliyetini kısıtlar. GDS, enkaz trafiğini yoğun müdahale bölgelerinden uzaklaştırarak kurtarma araçları için öncelikli geçiş koridorlarının korunmasını kolaylaştırır.

3.3. Zaman Baskısının Azaltılması ve Operasyonel Esneklik

Afet müdahalesinin ilk 72 saati, hem hayatta kalma oranları hem de ikincil hasar yayılımı açısından en kritik pencereyi oluşturmaktadır. Bu süreçte nihai bertaraf tesislerinin kapasitesinin çabuk dolması ya da erişim yollarının tıkanması, tüm enkaz kaldırma sistemini durdurabilir. GDS, bu türlü tıkanmaları absorbe eden bir tampon katman olarak, nihai tesise bağımlılığı azaltmaktadır. Başka bir deyişle GDS, sistemin 'yedek kapasitesi' rolünü üstlenerek operasyonel sürekliliği sağlar.

Ek olarak GDS, hava koşulları, altyapı hasarı veya personel sirkülasyonu gibi dinamik faktörlerin operasyonu sekteye uğrattığı durumlarda planlama esnekliği sunar. Nihai tesise gitmek yerine enkaz önce GDS'de bekletilebilir; optimum koşullar oluştuğunda transfer gerçekleştirilebilir. Brown, Milke ve Seville (2011), geçici depolama mekanizmalarının bu operasyonel esnekliği sağlamada belirleyici olduğunu vurgulamaktadır.

3.4. Geri Kazanım Kapasitesi ve Ekonomik Fayda

GDS'ler, sahada yürütülen ön sınıflandırma faaliyetleri sayesinde enkaz içindeki metal, beton, ahşap ve plastik gibi geri kazanılabilir malzemelerin ayıklanmasına zemin hazırlar. Bu ön ayırım, nihai bertaraf tesislerine taşınan enkaz hacmini ve ağırlığını önemli ölçüde düşürmekte; tesislerin ömrünü uzatmakta ve bertaraf maliyetlerini azaltmaktadır. Habib ve Sarkar (2017), sürdürülebilir enkaz yönetiminde GDS düzeyindeki sınıflandırma verimliliğinin nihai ekonomik ve çevresel çıktılar üzerinde belirleyici bir değişken olduğunu ortaya koymuştur.

Ekonomik boyutu ise özellikle kalkınmakta olan ülkeler ve sınırlı bütçeli yerel yönetimler açısından kritiktir. GDS'de gerçekleştirilen geri dönüşüm ve yeniden kullanım faaliyetleri; hem enkaz kaldırma maliyetlerini hem de yeniden yapılanma sürecindeki hammadde ihtiyacını azaltabilmektedir. Bu durum, GDS'nin dar anlamda bir 'depolama alanı' olmadığını; aksine değer zinciri içinde aktif bir dönüşüm düğümü olduğunu göstermektedir.

4. KAVRAMSAL MODEL: GDS'NİN ÜÇ İŞLEVSEL BOYUTU

Yazın taramasından elde edilen bulgular ve Bölüm 3'te tartışılan fayda-hız mekanizmaları ışığında bu çalışma, GDS'yi afet lojistiği sistemi içinde üç işlevsel boyutuyla tanımlayan kavramsal bir model önermektedir. Model, GDS'yi salt bir coğrafi nokta ya da kapasite kısıtı olarak değil, enkaz lojistiği zincirinin aktif bir aktörü olarak konumlandırmaktadır.

4.1. Birinci Boyut: Tampon Bölge

GDS'nin birincil işlevi, enkaz üretim alanları ile nihai bertaraf tesisleri arasında bir tampon bölge oluşturmaktır. Büyük ölçekli bir depremde kentsel altyapının ciddi biçimde hasar görmesi nedeniyle enkaz, doğrudan nihai tesislere nakledilemez; taşıma kapasitesi ve altyapı kısıtları bunu fiziken olanaksız kılar. GDS, enkaz akışını coğrafi olarak absorbe ederek yoğunluk dağılımını düzenler ve nakliye sistemine nefes aldırır.

Bu bağlamda potansiyel GDS konumlarının enkaz üretim merkezlerine olan mesafesi ile alan kapasitesi kritik planlama değişkenleri haline gelmektedir. Kim, Deshmukh ve Hastak (2014), tampon işlevinin etkin biçimde gerçekleşebilmesi için GDS'lerin 2 km yarıçap içinde kümelenerek dağıtılmasını önermektedir. Tampon boyutu; GDS'nin ihtiyaç alanlarına kısa

mesafede ve çok sayıda dağıtılmış nokta şeklinde konumlandırılması gerektiğini, tekil büyük saha yerine çok sahalı bir ağ yapısının tercih edilmesini öngörmektedir.

4.2. İkinci Boyut: Lojistik Aktarma Düğümü

GDS'nin ikinci işlevi, enkaz taşımacılığı sistemindeki aktarma düğümleri olarak çalışmasıdır. Bu işlev, lojistik sistemlerde klasik merkez-uç (hub-and-spoke) mantığına benzer biçimde işlemektedir: GDS, dağınık mikro kaynaklardan gelen enkaz akışını konsolide eder ve iri kapasiteli araçların ya da kalıcı depolama sahalarına yönelik rota öbeklerinin oluşturulmasına zemin hazırlar. Bölüm 3.2'de tartışıldığı üzere, Wang ve diğerleri (2019) bu aktarma işlevinin optimize edilmesinin enkaz kaldırma süresi ve maliyeti üzerinde ölçülebilir etkiler yarattığını kanıtlamıştır.

Aktarma düğümü boyutu, GDS'nin iç erişim yolları, manevra alanları, tartım altyapısı ve araç döngüsü kapasitesi açısından belirli minimum standartları karşılaması gerektiğine işaret etmektedir. Bir sahanın yalnızca boş ve geniş olması GDS olarak işlev görmesi için yeterli değildir; saha, aktarma düğümü mantığıyla tasarlanmalı ve donatılmalıdır.

4.3. Üçüncü Boyut: Geri Kazanım Ön İşlem Alanı

GDS'nin üçüncü ve literatürde en az tartışılan işlevi, enkaz akışı içindeki geri kazanılabilir malzemelerin ön sınıflandırmasının ve ilk işlemesinin gerçekleştirildiği alan olmasıdır. Bu ön işlem faaliyeti; hem nihai bertaraf tesislerine binen yükü azaltmakta hem de atık hiyerarşisi ilkeleri (azaltma, yeniden kullanım, geri dönüşüm) açısından sürdürülebilirlik katkısı sağlamaktadır. Habib ve Sarkar (2017), sürdürülebilir enkaz yönetiminde sınıflandırma verimliliğinin belirleyici değişken olduğunu vurgulamaktadır.

Bu boyut; GDS saha planlarının yalnızca depolama kapasitesini değil, sınıflandırma ekipmanı için yeterli manevra alanı ve işlem kapasitesini de içermesi gerektiğini öne çıkarmaktadır. Ön işlem boyutu aynı zamanda GDS personelinin eğitim gereksinimlerini ve güvenlik standartlarını da belirlemektedir.

5. MODELİN UYGULAMA BOYUTU: AFET ÖNCESİ PLANLAMA

Önerilen üç boyutlu kavramsal model, doğrudan afet öncesi planlama uygulamalarına transfer edilebilir niteliktedir. Afet öncesi aşamada GDS saha seçimi, en az üç temel kriter boyutunu eş zamanlı ele almak durumundadır.

Uygunluk kriterleri; GDS'nin enkaz yoğunluk merkezlerine olan mesafesini, mevcut ulaşım altyapısına erişimini ve arazi kullanım özelliklerini kapsamaktadır. Bu kriterler, Grzeda ve diğerleri (2014) tarafından geliştirilen CBS tabanlı yaklaşımlarla haritalanabilmektedir. Depremin etki senaryolarına göre olası enkaz yoğunluk haritalarının üretilmesi ve bu

haritaların GDS aday konumlarıyla örtüştürülmesi, afet öncesi planlama sürecinin vazgeçilmez adımını oluşturmaktadır.

Operasyonel kapasite kriterleri; GDS'nin depolama hacmini, araç döngüsü kapasitesini ve aktarma altyapısını içermektedir. Wang ve diğerleri (2019) bu kriterleri optimizasyon modellerinde karar değişkeni olarak işlemiştir. Sahalar arasında enkaz yükünün nasıl dağıtılacağı ve hangi sahanın hangi ilçeye hizmet edeceği, bu kriterlerin fonksiyonu olarak belirlenmektedir.

Çevresel ve sosyal uygunluk kriterleri; GDS lokasyonunun su kaynakları, yerleşim alanları ve hassas ekosistemlerden uzaklığını kapsamaktadır. Bu kriterlerin ihmal edilmesi, geçici sahaların kalıcı çevre sorunlarına dönüşmesi riskini beraberinde getirmektedir (Brown, Milke ve Seville, 2011). Türkiye özelinde bu değerlendirmeye İstanbul Büyükşehir Belediyesi çevre duyarlılık haritaları ile AFAD tarafından yürütülen sismik risk bölgelendirme çalışmalarının entegre edilmesi önerilmektedir.

Söz konusu üç kriter boyutunun eş zamanlı değerlendirilmesi için Çok Kriterli Karar Verme (ÇKKV) yöntemleri öne çıkmaktadır. Türkiye literatüründe Ağırlıklı Toplam Yöntemi (ATM), Analitik Hiyerarşi Süreci (AHS) ve Çok Özellikli Fayda Teorisi (ÇÖFT) bu amaçla kullanılmaktadır (Gönül Sezer ve Demirel, 2025). Bu yöntemlerin CBS ile entegrasyonu; saha seçimini hem mekânsal hem de çok boyutlu karar mantığıyla ele alan güçlü bir planlama platformu sunmaktadır.

6. SONUÇ VE DEĞERLENDİRME

Bu çalışma, afet lojistiği yazınında kavramsal düzeyde yeterince ele alınmamış bir konuyu — geçici enkaz depolama sahalarının işlevsel niteliğini — yapılandırılmış bir teorik çerçeveye oturtmayı amaçlamıştır. Yapılan yazın taraması ve teorik sentezden elde edilen bulgular çerçevesinde aşağıdaki sonuçlara ulaşılmıştır.

Birincisi, GDS literatürde büyük ölçüde bir kısıt parametresi olarak ele alınmakta; sistemik bir aktör olarak kavramsal düzeyde tanımlanmamaktadır. Bu durum, pratik planlama standartlarının geliştirilmesini güçleştirmektedir.

İkincisi, GDS'nin afet lojistiğine katkısı çok boyutludur: araç döngüsü süresini kısaltması, nakliye kapasitesini konsolide etmesi, nihai tesislere olan bağımlılığı azaltması ve geri kazanım fırsatları sunması bakımından GDS, enkaz lojistiği zincirinin stratejik bir halkasını oluşturmaktadır.

Üçüncüsü, önerilen üç boyutlu kavramsal model (tampon bölge, lojistik aktarma düğümü ve geri kazanım ön işlem alanı), GDS'nin çok işlevli niteliğini görünür kılmakta ve her boyutun farklı planlama kriter setlerini tetiklediğini ortaya koymaktadır.

Dördüncüsü, Türkiye özelinde TAMP (2019) ve ilgili mevzuatta GDS için operasyonel standartların geliştirilmesi, özellikle Marmara bölgesi gibi yüksek sismik risk taşıyan kentsel alanlar açısından öncelikli bir politika ihtiyacı olarak öne çıkmaktadır.

Çalışmanın temel sınırlılığı, önerilen kavramsal modelin ampirik veri ile test edilmemiş olmasıdır. Gelecek araştırmalar için: (i) modelin boyutlarının CBS(Coğrafi Bilgi Sistemleri) tabanlı çok kriterli saha seçimi çalışmalarında ağırlıklandırılması, (ii) İstanbul gibi megakentler için senaryo bazlı GDS ağı optimizasyonu ve (iii) GDS ile kalıcı depolama sahaları arasındaki etkileşimin bütünleşik lojistik sistem modeliyle değerlendirilmesi önerilmektedir. Bu araştırma gündeminin hayata geçirilmesi, Türkiye'nin afet enkaz yönetimi planlamasına hem teorik hem de uygulamalı düzeyde anlamlı katkılar sunacaktır.

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DEPREM ENKAZININ SIFIR ATIK YÖNETİMİNE ENTEGRASYONU

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ÖZET

Depremler, yoğun yapılaşmış metropollerde büyük miktarda inşaat ve yıkıntı atığı üreterek ciddi çevresel, lojistik ve ekonomik sorunlara yol açmaktadır. Türkiye, Kuzey Anadolu Fay Hattı başta olmak üzere birçok aktif fay üzerinde konumlanması nedeniyle bu riskle sürekli yüzleşmektedir. 6 Şubat 2023 Kahramanmaraş Depremlerinin ardından oluşan büyük enkaz, mevcut yönetim yaklaşımlarının yetersizliğini bir kez daha gözler önüne sermiştir. Bu çalışma, deprem enkazının yönetiminde sıfır atık ilkeleri ile döngüsel ekonomi yaklaşımının nasıl entegre edileceğini ele almaktadır. Uluslararası sıfır atık politika çerçevesi ve Türkiye'deki ilgili mevzuat incelenerek geçici enkaz depolama sahalarından (GDS) kalıcı depolama ve geri kazanım tesislerine (KDS) uzanan süreçte atık hiyerarşisinin uygulanabilirliği araştırılmaktadır. Enkaz bileşim analizleri; yıkıntı atıklarının yaklaşık % 60-70'ini betonarme kırıklarının, % 15-20'sini tuğla ve yığma malzemelerin oluşturduğunu ortaya koymaktadır. Geri dönüştürülmüş agrega üretimi, hurda metal kazanımı ve ahşap geri kullanımı başta olmak üzere sistematik bir sınıflandırma altyapısıyla enkaz içindeki ikincil hammaddelerin ekonomiye kazandırılmasının hem çevresel hem de ekonomik açıdan önemli faydalar sağlayabileceği değerlendirilmektedir. Çalışmada önerilen dört aşamalı döngüsel akış modeli; saha bazlı ön ayrıştırmayı, GDS'de ikincil sınıflandırmayı, KDS'de işlemeyi ve ikincil hammaddelerin piyasaya geri dönüşünü kapsamaktadır. Japonya'nın afet atığı yönetimi deneyiminden çıkarılan dersler, Türkiye için uyarlanabilir model unsurları olarak değerlendirilmektedir. Sonuç olarak çalışma, deprem enkazının salt bir temizlik operasyonu olarak değil, kaynak yönetimi süreci olarak konumlandırılması gerektiğini savunmakta; ulusal düzeyde bir Afet Atığı Yönetim Planı oluşturulması, GDS/KDS altyapısının afet öncesi hazırlık aşamasında tamamlanması ve enkaz süreçlerinin dijital izleme sistemleriyle entegre edilmesi başta olmak üzere somut politika önerileri sunmaktadır.

Anahtar Kelimeler: Enkaz Lojistiği, Sıfır Atık, Deprem Yönetimi, Döngüsel Ekonomi

INTEGRATİON OF EARTHQUAKE DEBRİS İNTO ZERO WASTE MANAGEMENT

ABSTRACT

Earthquakes generate large volumes of construction and demolition waste in densely built metropolises, giving rise to serious environmental, logistical, and economic challenges. Türkiye faces this risk on a continuous basis, as it is situated on several active fault lines, most notably the North Anatolian Fault. The huge value of debris produced by the February 6, 2023 Kahramanmaraş Earthquakes once again exposed the inadequacy of existing management approaches. This study examines how zero waste principles and the circular economy approach can be integrated into earthquake debris management. By reviewing the international zero waste policy framework and relevant Turkish legislation, the applicability of the waste hierarchy across the chain from temporary debris storage areas (TDS) to permanent storage and recovery facilities (PDS) is investigated. Debris composition analyses indicate that approximately 60–70% of demolition waste consists of reinforced concrete fragments and 15–20% of brick and masonry materials. It is assessed that the systematic reintroduction of secondary raw materials — primarily through the production of recycled aggregate, scrap metal recovery, and timber reuse — can yield significant environmental and economic benefits. The four-stage circular flow model proposed in this study encompasses on-site pre-sorting, secondary classification at TDS facilities, processing at PDS facilities, and the return of secondary raw materials to the market. Lessons drawn from Japan's disaster waste management experience are evaluated as adaptable model components for Turkey. The study argues that earthquake debris should be positioned not as a mere clearance operation but as a resource management process governed by circular economy principles, and presents concrete policy recommendations including the establishment of a national Disaster Waste Management Plan, the completion of TDS/PDS infrastructure during the pre-disaster preparedness phase, and the integration of debris management processes with digital monitoring systems.

Keywords: Debris Logistics, Zero Waste, Earthquake Management, Circular Economy

1. GİRİŞ

Depremler, doğal afetler arasında yıkıcı etkileri ve uzun süreli sonuçları bakımından en önemli risklerden birini oluşturmaktadır. Türkiye, Kuzey Anadolu Fay Hattı başta olmak üzere birçok aktif fay üzerinde yer alması nedeniyle yüksek sismik risk bölgesinde konumlanmaktadır. 17 Ağustos 1999 Marmara Depremi, 6 Şubat 2023 Kahramanmaraş Depremleri ve ardından gelen diğer afetler; insan kayıplarının yanı sıra muazzam miktarlarda inşaat ve yıkıntı atığı üretmiştir.

Sıfır atık kavramı, atığın oluşumunu kaynağında engellemeyi, kaçınılmaz atıkları ise hiyerarşik bir yaklaşımla en yüksek değerde geri kazanmayı hedefleyen bir yönetim felsefesidir. Bu yaklaşım, hem olağan kentsel yaşamda hem de olağanüstü afet dönemlerinde uygulanabilir niteliktedir. Afet sonrası ortaya çıkan enkaz, doğası gereği heterojen ve tehlikeli unsurlar barındırmakla birlikte, sistematik bir yönetim anlayışıyla değerli ikincil hammadde kaynağına dönüştürülebilir. Beton, metal, ahşap, tuğla ve seramik gibi malzemelerin ayrıştırılarak geri kazanılması; hem çevresel baskıyı azaltmakta hem de yeniden yapım sürecinde hammadde ihtiyacını karşılamaktadır.

Bu çalışma; sıfır atık ilkelerinin deprem enkaz yönetimi süreçlerine nasıl entegre edilebileceğini, Türkiye'deki sıfır atık mevzuatını ve uluslararası sıfır atık hareketini kapsamlı biçimde incelemeyi; enkaz atıklarının geri kazanım potansiyelini değerlendirmeyi ve politika önerileri sunmayı amaçlamaktadır.

2. DÜNYADA SIFIR ATIK HAREKETİ VE DÖNGÜSEL EKONOMİ

2.1. Sıfır Atık Kavramının Kökeni ve Teorik Çerçevesi

Sıfır atık hareketi, 20. yüzyılın sonlarında endüstriyel ekoloji ve döngüsel ekonomi kuramlarının gelişimiyle birlikte şekillenmiştir. Paul Palmer tarafından 1970'lerde kimyasal atıkların yeniden kullanımına yönelik çalışmalar kapsamında ortaya atılan bu kavram, 2000'li yıllarda kentsel yönetim politikalarının gündemine girmiştir. San Francisco (2002), Yeni Zelanda (2003) ve ardından pek çok Avrupa kenti, sıfır atık hedeflerini belediyecilik stratejilerine entegre etmiştir. Sıfır atık; israfı önlemeyi, kaynakların daha etkin kullanılmasını, atık oluşumunun engellenmesi ya da minimize edilmesini ve atığın kaynağında ayrı toplanarak geri kazanılmasını kapsayan bir yönetim felsefesi olarak tanımlanmaktadır. Uluslararası Sıfır Atık İttifakı (Zero Waste International Alliance – ZWIA), sıfır atığı 'Tüm kaynakların, ürünlerin, paketlerin ve malzemelerin sorumlu üretim, tüketim, yeniden kullanım ve geri kazanım yoluyla korunması; insanın veya çevrenin sağlığını tehdit eden yakma ya da depolama yoluyla çevreye gönderilmesinin engellenmesi' şeklinde tanımlamaktadır (ZWIA, 2018).

BM Çevre Asamblesi'nin (UNEA) 5/11 sayılı kararı, döngüsel ekonomiyi 'ürün ve malzemelerin yeniden kullanım, yeniden imalat veya geri dönüşüm yoluyla olabildiğince uzun süre ekonomide tutulduğu; atık oluşumunun en aza indirildiği bir sistem' olarak tanımlamaktadır (UNEA, 2022). Bu model yıkıntı atıklarının değerlendirilmesini hem ekonomik hem de çevresel açıdan avantajlı kılmaktadır.

2.2. Uluslararası Politika Çerçevesi ve Uygulamalar

2022 yılı, küresel atık yönetimi politikaları açısından önemli bir dönüm noktası olmuştur. 2 Mart 2022 tarihinde toplanan BM Çevre Asamblesi, plastik kirliliğini sona erdirmeye yönelik bağlayıcı bir uluslararası anlaşma geliştirilmesine ilişkin kararı kabul ederek aynı zamanda 30 Mart'ı 'Uluslararası Sıfır Atık Günü' ilan etmiştir. Bu kararın ardından 14 Aralık 2022'de BM Genel Kurulu'nun 77. Oturumunda A/RES/77/161 sayılı karar oybirliğiyle kabul edilmiş; 30 Mart, resmi olarak BM Uluslararası Sıfır Atık Günü olarak takvime girmiştir (UNGA, 2022). Söz konusu kararın öncülüğünü Türkiye ve 105 ülkenin birlikte yaptığı belirtilmektedir.

30 Mart 2023'te düzenlenen ilk Uluslararası Sıfır Atık Günü'nde BM Genel Sekreteri Antônio Guterres, atık krizinin gezegenin yaşamı sürdürme kapasitesini zayıflattığını vurgulayarak atığa karşı üç cephede savaş açılması çağrısında bulunmuştur. UNEP ve UN-Habitat tarafından ortaklaşa yürütülen bu günün amacı; sürdürülebilir tüketim ve üretim örüntüleri konusunda farkındalık yaratmak, sıfır atık girişimlerini 2030 Gündemine katkıyla hızlandırmaktır (UNEP, 2023). 2026 yılındaki gözlem ise gıda israfını öncelikli tema olarak belirlemiştir. UNEP ve Uluslararası Katı Atık Birliği (ISWA) tarafından yayımlanan Küresel Atık Yönetimi Görünümü 2024 raporu, döngüsel ekonomi modeline geçişin 2050 yılına kadar kentsel katı atık miktarını 4,5 milyar tondan 2 milyar tonun altına indirebileceğini ortaya koymaktadır (UNEP ve ISWA, 2024). UNEP; COP27 dönem başkanlığı tarafından başlatılan ve 2050 yılına kadar atıkların % 50 azaltılmasını hedefleyen Küresel Atık Girişimi'ni de desteklemektedir.

Japonya, afet atığı yönetimi konusundaki kapsamlı deneyimi ve yasal çerçevesiyle öne çıkan ülkelerin başında gelmektedir. 1995 Hanshin-Awaji (Kobe) Depremi'nden çıkarılan dersler doğrultusunda geliştirilen afet atığı eylem planları, malzeme bazında sınıflandırma ve geri kazanım oranlarını sistematik hâle getirmiştir. 2011 Büyük Doğu Japonya Depremi ve tsunamisinin ardından açığa çıkan yaklaşık 20 milyon ton enkaz, sınıflandırılmış geri dönüşüm yaklaşımıyla büyük ölçüde değerlendirilmiştir. Japonya'nın afet atığı yönetimine ilişkin el kitabı (Asari ve diğerleri, 2013), enkaz yönetiminde kademelendirme stratejisi ve sınıflandırma ilkeleri bakımından uluslararası literatürde başvuru kaynağına dönüşmüştür.

Avrupa Birliği'nin Yeşil Mutabakat çerçevesi kapsamında inşaat ve yıkıntı atıklarının geri dönüşümünü artırmaya yönelik bağlayıcı hedefler belirlenmiştir. 2023 yılında güncellenen AB İnşaat Ürünleri Tüzüğü ve döngüsel ekonomi eylem planı; bina yıkımında ayrı toplama ve malzeme pasaportu uygulamalarını zorunlu kılmaktadır.

3. TÜRKİYE'DE SIFIR ATIK MEVZUATI VE POLİTİKALARI

3.1. Yasal Çerçevenin Gelişimi

Türkiye'de atık yönetiminin yasal dayanağını 2872 sayılı Çevre Kanunu oluşturmaktadır. Bu kanunun 11. maddesine istinaden çıkarılan Atık Yönetimi Yönetmeliği 2 Nisan 2015 tarih ve 29314 sayılı Resmi Gazete'de yayımlanmış; atıkların kaynağında ayrılmasından nihai bertarafına kadar tüm süreçler düzenleme altına alınmıştır. Söz konusu yönetmelik, 2023-2024 yıllarında önemli güncellemelerle kapsamı genişletilmiştir. Hafriyat toprağı, inşaat ve yıkıntı atıklarına ilişkin ayrı düzenleme ise 2004 yılından bu yana yürürlükte olup pek çok kez değiştirilmiştir.

Sıfır atık yaklaşımının yasal altyapısı açısından en kritik düzenleme, Çevre ve Şehircilik Bakanlığı'nca hazırlanan Sıfır Atık Yönetmeliği'dir. Bu yönetmelik 12 Temmuz 2019 tarih ve 30829 sayılı Resmi Gazete'de yayımlanarak yürürlüğe girmiştir. Yönetmelik; hammadde ve doğal kaynakların etkin yönetimi ile sürdürülebilir kalkınma ilkeleri doğrultusunda atık yönetimi süreçlerinde çevre ve insan sağlığının korunmasını hedefleyen sıfır atık yönetim sisteminin kurulmasına, yaygınlaştırılmasına, geliştirilmesine, izlenmesine ve belgelendirilmesine ilişkin genel ilke ve esasları belirlemektedir. Yönetmelik kapsamında tüm kamu kurum ve kuruluşlarında, eğitim kurumlarında, sağlık kuruluşlarında, iş merkezlerinde, alışveriş merkezlerinde, havalimanlarında ve sanayi tesislerinde sıfır atık yönetim sisteminin kurulması zorunlu tutulmuştur.

2023 yılında ise Sıfır Atık Vakfı kurulmuş; projenin yasal ve kurumsal boyutu güçlendirilmiştir (Sıfır Atık Vakfı, 2023). Avrupa Birliği'nin Yeşil Mutabakat kapsamında belirlediği atık azaltma hedefleri ve döngüsel ekonomi paketleri, Türkiye mevzuatının uyumlaştırılması sürecinde de etkin olmakta ve önümüzdeki yıllarda daha kapsamlı düzenlemelerin geleceğine işaret etmektedir.

3.2. Türkiye Sıfır Atık Projesi: Uygulama ve Başarılar

Sıfır Atık Projesi, 27 Eylül 2017 tarihinde Çevre, Şehircilik ve İklim Değişikliği Bakanlığı öncülüğünde başlatılmış; Cumhurbaşkanı Recep Tayyip Erdoğan'ın eşi Emine Erdoğan'ın himayesinde yürütülmektedir. Projenin hedefi; israfı önlemek, kaynakların daha verimli kullanılmasını sağlamak ve geri kazanım oranını sistematik biçimde artırmaktır. 2017 yılında % 13 olan geri kazanım oranı, 2024 yılında % 36,08'e, 2025 yılı sonu itibarıyla ise % 37,53'e yükseltilmiştir. Proje kapsamında 217 bin bina ve yerleşkede Sıfır Atık Yönetim Sistemi kurulumu tamamlanmış, 28 milyon kişiye sıfır atık eğitimi verilmiş, 613 milyon ağaç

kesilmekten kurtarılmış ve toplamda 90 milyon ton geri kazanılabilir atık ekonomiye kazandırılmıştır (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2026).

Proje, yalnızca ulusal ölçekte değil küresel arenada da önemli bir tanınırlık kazanmıştır. 2022 yılında BM Genel Kurulu'nun 77. Dönem Toplantısı'nın yan etkinlikleri kapsamında Emine Erdoğan ile BM Genel Sekreteri António Guterres'in projeyi küresel ölçeğe taşımak amacıyla bir niyet belgesi imzalaması, Türkiye'nin sıfır atık alanındaki liderlik rolünü pekiştirmiştir. Proje, Uluslararası platformlarda Green World Awards dahil yedi kez ödüle layık görülmüştür.

3.3. İnşaat ve Yıkıntı Atıklarına İlişkin Düzenlemeler

İnşaat ve yıkıntı (İYA) atıkları, Türkiye'de ayrı bir mevzuat çerçevesinde ele alınmaktadır. Hafriyat Toprağı, İnşaat ve Yıkıntı Atıklarının Kontrolü Yönetmeliği bu alandaki temel düzenleyici belgedir. 2004 yılında yürürlüğe giren yönetmelik, inşaat faaliyetlerinden kaynaklanan atıkların belediyeler tarafından belirlenen alanlara taşınmasını, düzensiz depolamanın önlenmesini ve geri kazanım tesislerinin kurulmasını zorunlu tutmaktadır (Buzkan ve Erman, 2020). Binaların Yıkılması Hakkında Yönetmelik (2021) ise yapı yıkım süreçlerindeki güvenlik ve atık yönetimi gerekliliklerini kapsamlı biçimde düzenlemektedir.

Afet sonrası ortaya çıkan enkaz atıkları ise olağan İYA mevzuatının ötesinde, AFAD koordinasyonunda yürütülen acil yönetim süreçleriyle ele alınmaktadır. 2023 Kahramanmaraş Depremleri'nden sonra oluşturulan enkaz yönetim protokolleri mevcut uygulamanın salt temizlik odaklı olduğunu, geri kazanım boyutunun ise yeterince kurumsal bir yapıya kavuşturulamadığını ortaya koymaktadır (Mavroulis ve diğerleri, 2023). Bu boşluğun giderilmesi, sıfır atık ilkeleriyle afet yönetimini bütünleştiren yeni politika araçlarını gerektirmektedir.

4. DEPREM ENKAZINDAKİ MALZEMELERİN KARAKTERİZASYONU VE SIFIR ATIK POTANSİYELİ

Deprem enkazı; beton, tuğla-harç, demir-çelik, ahşap, alçı, cam, plastik, seramik-fayans, çeşitli tehlikeli maddeler ve evsel eşyalardan oluşan heterojen bir malzeme karışımıdır. Kahramanmaraş Depremleri'ne ait verilere göre enkaz bileşiminin yaklaşık % 60-70'ini betonarme kırıkları, % 15-20'sini tuğla ve yığma malzemeleri, % 5-10'unu demir-çelik ve % 5-10'unu diğer malzemeler oluşturmaktadır (Doğdu ve Alkan, 2023). 6-7 Şubat 2023 depremlerinden kaynaklanan toplam enkaz miktarı İTÜ verilerine göre yaklaşık 138 milyon ton olarak tahmin edilmekte; bu miktarın 40 milyon tonunun betonarme atığı olduğu belirlenmiştir (İstanbul Teknik Üniversitesi, 2023).

Geri kazanım potansiyeli değerlendirildiğinde, beton kırıkların kırmataş ve kum olarak kullanılabilir geri dönüştürülmüş agrega (GDA) üretimine elverişli olduğu görülmektedir. GDA, yeniden yapım sürecinin alt temel ve dolgu katmanlarında, peyzaj uygulamalarında ve düşük yoğunluklu yapılarda kullanılabilmektedir. Demir-çelik; doğrudan hurda olarak ekonomiye kazandırılmakta, mevcut geri dönüşüm kapasitesi dahilinde değerlendirilebilmektedir. Ahşap unsurlar ise ayrıştırıldığında yeniden kullanım veya biyokütle enerjisi üretimi için uygun olmaktadır (Amato ve diğerleri, 2019). Tüm bu malzemelerin sistematik biçimde ayrıştırılması, sıfır atık hiyerarşisinin 'geri kazanım' basamağını afet döneminde de işler kılmanın temel koşuludur.

5. SIFIR ATIK İLKELERİNİN ENKAZ YÖNETİMİNE ENTEGRASYONU

5.1. Enkaz Lojistiği Modeli: GDS'den KDS'ye Atık Hiyerarşisi

Atık hiyerarşisi; önleme, yeniden kullanım, geri dönüşüm, geri kazanım ve bertaraf aşamalarından oluşmakta ve karar vericilere bir öncelik sıralaması sunmaktadır (Karunasena, 2011). Deprem enkazı bağlamında 'önleme' basamağı, afet öncesi dayanıklı yapı stoğu oluşturulmasına; 'yeniden kullanım' basamağı, çöküş olmaksızın hasarlanan yapıların taşıyıcı elemanlarının değerlendirilmesine; 'geri dönüşüm' basamağı ise beton kırığı, demir ve ahşabın işlenerek tekrar ekonomiye sokulmasına karşılık gelmektedir.

Lojistik sürecin birinci halkasını GDS oluşturmaktadır. GDS'ler, yıkım alanlarından gelen enkaz yükünü geçici olarak kabul ederek birincil sınıflandırmanın yapıldığı noktalardır. Yer seçiminde erişilebilirlik, zemin taşıma kapasitesi ve çevresel duyarlılık kriterleri esas alınmalıdır. GDS'lerde çevre güvenliğini tehdit eden tehlikeli madde içeren parçalar öncelikle ayrıştırılmalı; ardından beton, metal ve ahşap akışları ayrı yığınlara yönlendirilmelidir. İkinci halkayı oluşturan KDS'ler ise kalıcı nitelikte geri dönüşüm ve değerlendirme tesislerini barındırmalıdır. Burada kırma-eleme hatları, metal presleme üniteleri ve tehlikeli atık bertaraf sistemleri bir arada konuşlandırılmalıdır.

5.2. Döngüsel Ekonomi Entegrasyonu İçin Önerilen Model

Bu çalışmada önerilen model, enkaz yönetimini dört aşamalı bir döngüsel akış olarak tasarlamaktadır: (i) Saha bazlı ön ayrıştırma; yıkım ekipleri tarafından üretici sorumluluğu ilkesiyle gerçekleştirilen, değerli malzemelerin enkaz içinde belirlenerek ayrılması. (ii) GDS'de ikincil sınıflandırma; beton, metal, ahşap ve tehlikeli atık akışlarının bağımsız yığınlara ayrılması ve kayıt altına alınması. (iii) KDS'de işleme; kırma-eleme, metal presleme ve ahşap freze süreçleri aracılığıyla ikincil hammadde üretimi. (iv) Piyasaya geri dönüş; geri

dönüştürülmüş agrega, hurda demir ve biyokütle ürünlerinin inşaat sektörüne, sanayiye veya enerji sistemlerine entegrasyonu.

Modelin işlevsel hâle gelebilmesi için afet öncesi hazırlık aşamasında; GDS ve KDS alanlarının yer seçiminin tamamlanması, sözleşmeli geri kazanım firmalarıyla protokollerin imzalanması ve lojistik filosunun belirlenmesi gerekmektedir. Afet sonrası müdahale aşamasında ise enkaz iş emirlerinin ve taşıma belgelerinin dijital olarak takip edilmesi, AFAD ve belediyeler arasında gerçek zamanlı veri paylaşımının sağlanması ve tesis kapasitelerinin anlık olarak izlenmesi kritik önem taşımaktadır. Afet sonrasında yıkılmış ve acil yıkılacak binaların enkazının GDS'ye taşınması tamamlandığında, ikincil kontrollü yıkımların enkazının yerinde ayrıştırılması ya da KDS'lerde ayrıştırılması esastır.

6. TARTIŞMA

Çalışmanın bulguları; deprem enkazının sistematik bir sıfır atık yaklaşımıyla ele alınmasının hem çevresel hem de ekonomik açıdan önemli faydalar sağlayabileceğini ortaya koymaktadır. Afet sonrası oluşan enkazın % 60-70 oranında bir geri kazanım potansiyelinin ikincil hammadde olarak ekonomiye kazandırılabileceğini göstermektedir. Bu rakam yalnızca agrega kısmi ihtiyacını değil, demir-çelik ekonomisine katkıyı ve biyokütle potansiyelini de kapsamaktadır.

Bununla birlikte, uygulamada çeşitli kısıtlar gözetilmelidir. Afet ortamının kaotik yapısı, enkaz içeriğinin heterojenliği, GDS/KDS altyapısının kurumsal hazırlığı ve toplumun ayrıştırma kültürü; başarılı bir entegrasyonun önündeki yapısal engellerdir. 2023 Kahramanmaraş Depremleri'nden elde edilen alan gözlemleri, değerli geri dönüştürülebilir malzemelerin kayıt dışı biçimde taşındığını ve sistematik sınıflandırma mekanizmalarının yeterince işletemediğini ortaya koymaktadır (Mavroulis ve diğerleri, 2023). Bu durum, kurumsal koordinasyon ve dijital izleme sistemlerinin güçlendirilmesi zorunluluğunu ön plana çıkarmaktadır.

Uluslararası karşılaştırma yapıldığında, Japonya'nın öncü konumu dikkat çekmektedir. Japonya'nın yerel yönetim düzeyinde hazırladığı afet atığı eylem planları, merkezi izleme sistemleri ve sözleşmeli geri kazanım kapasitesi; Türkiye için uyarlanabilir bir model sunmaktadır. Türkiye'nin 2019'da oluşturduğu sıfır atık mevzuatı ve proje deneyimi, afet atığı boyutunun bu çerçeveye entegrasyonu için güçlü bir politika zemini sağlamaktadır. Bu durum aynı zamanda Türkiye'nin çevreyle ilgili hedeflerine ulaşmada önemli bir parametre imkanı sağlayacaktır.

7. SONUÇ VE ÖNERİLER

Bu çalışma, deprem enkazının sıfır atık yönetimine entegrasyonunun hem kavramsal hem de operasyonel boyutlarını ele almıştır. Sıfır atık hareketi; BM kararları, ulusal mevzuat ve proje deneyimleriyle küresel bir politika önceliği hâline gelmiş; Türkiye bu hareketin öncü ülkeleri arasında yer almıştır. Ancak sıfır atık çerçevesinin afet yönetimi politikalarına sistematik biçimde entegrasyonu hâlâ tamamlanmamış bir gündem maddesi olmaya devam etmektedir.

Çalışmanın sonuçlarına dayalı olarak aşağıdaki politika önerileri geliştirilmiştir: Birincisi, ulusal düzeyde bir Afet Atığı Yönetim Planı hazırlanmalı ve bu plan Sıfır Atık Yönetmeliği kapsamına alınmalıdır. İkincisi, İstanbul başta olmak üzere büyük deprem riski taşıyan kentlerde GDS ve KDS alanlarının yer seçimi, altyapı tasarımı ve işletme protokolü, afet öncesi hazırlık aşamasında tamamlanmalıdır. Üçüncüsü, geri kazanım firmalarıyla kamu kurumları arasında afet senaryolarına dayalı sözleşme ve protokoller geliştirilmeli; bu aktörler düzenli tatbikatlarla hazır tutulmalıdır. Dördüncüsü, enkaz taşıma ve ayrıştırma süreçleri dijital izleme sistemleriyle entegre edilerek malzeme akışı gerçek zamanlı takip altına alınmalıdır. Beşincisi, geri dönüştürülmüş agrega ve ikincil hammadde piyasaları desteklenmeli; kamu ihalelerinde geri dönüştürülmüş malzeme kullanımı teşvik edilmelidir.

Sonuç olarak, deprem enkazının yönetimi salt bir temizlik operasyonu olarak değil, döngüsel ekonomi ilkeleri doğrultusunda tasarlanmış bir kaynak yönetimi süreci olarak konumlandırılmalıdır. Sıfır atık hedefleri ile afet yönetimi stratejilerinin bütünleştirilmesi; kentsel dirençliliği artırmak, çevresel ayak izini azaltmak ve yeniden yapım ekonomisine katkı sağlamak açısından stratejik bir zorunluluktur.

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IMPACT OF BANK CHARACTERISTICS ON FINANCIAL PERFORMANCE OF SELECTED DEPOSIT MONEY BANKS IN NIGERIA

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Abstract

Since the banking industry is the primary conduit for savings and their distribution to different economic sectors, its importance in an economy can be justified. This study looks at how the financial performance of deposit money deposit banks in Nigeria is affected by bank attributes such as capital, loans and advances, and liquidity. Therefore, it is believed that without these factors, the banking industry, particularly Nigeria's deposit money institutions, cannot operate profitably. The study uses secondary source data from the chosen banks' financial statements and an ex post facto research design. The data was analyzed using regression analysis. The study's conclusions indicate that loans and advances have a major influence on financial performance, but bank capital and liquidity had no such effect during the study period. The study suggests that Nigerian banks' regulatory bodies should concentrate on and keep regulating banks' capital as needed in order to increase the profitability of deposit money banks in Nigeria. Additionally, the management of deposit money banks should create credit policies that are consistent with the CBN's credit policies, and the CBN should review the liquidity requirements in order to invest idle liquidity to boost earnings.

Keywords: bank characteristics, financial performance, deposit money bank

TURİZM REHBERLİĞİ ÖĞRENCİLERİNİN HÜZÜN TURİZMİ KAPSAMINDA SAVAŞ VE TURİZM ALGISI

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ÖZET

Küresel gelişmelerle birlikte toplumların seyahat etme motivasyonlarında çeşitli değişimler görülmektedir. Kişilerin boş zaman, özel ilgi ve yer değiştirme anlayışları farklılık göstermektedir. Bu durum turizmin çeşitlenmesinde ve yeni trendlerin oluşmasında etkili olmaktadır. İlk dönemlerde dinlence ve eğlence amacı taşıyan turizm, insanların göç etme, savaş ve sürgün gibi sebeplerle yer değiştirme nedenleriyle seyahat ettiklere yerlere hüzün ve gözyaşı oluşturan bir etkinlik halini almaktadır. Turizm ve savaş kelimeleri her ne kadar tezatlık oluştursa da savaş turizminin ülke ve dünya alanyazınında mevcuttur. Bu çalışmada, hüzün turizmi kapsamında incelenen savaş ve savaş alanları turizminin turist rehberliği öğrencileri tarafından nasıl algılandığı ölçmek amacıyla hazırlanmaktadır. Kapadokya Üniversitesi Turizm Rehberliği Lisans Bölümü öğrencileri üzerinde uygulanan bu çalışmada, öğrencilere çevrimiçi formlarla hazırlanan sorular iletilmiştir. Kapadokya Üniversitesi Turizm Rehberliği Lisans öğrencileri toplam mevcudu 49 öğrenci olup, bunlardan 25 tanesi geçerli ve güvenilir cevaplar vermiştir. Öğrencilerden “turizm ve savaş” kelimelerinden ilk algıları ve bu algıları bir benzetmeyle açıklamaları istenmiştir. Toplanan veriler nitel araştırma yöntemlerinden biri olan metafor analizi ile incelenmiştir. Sonuçlar Kappa yöntemi ile değerlendirilmiştir. Değerlendirmede bir doktora öğrencisi ve bir Türkçe öğretmeni yer almıştır. Verilen cevaplar neticesinde savaş ve turizm kavramları arasında “Oksimoron, Kaçınma, İlişkisel ve Duygusal” olmak üzere 4 tema üretilmiştir. Sonuç olarak insanın sosyal bir varlık olması nedeniyle ölüm ve savaş gibi başlıkların olumsuz algı yaratsa da turizmde alternatif bir değer olarak belirlenmiştir. Ayrıca bu durumun emik ve etik sorumluluklar doğurduğu da ön plana çıkmıştır. Her kelimeden turizm üretmek mümkün olduğu gibi, her turizm faaliyetinin aynı hissiyatı oluşturmayacağı önemle vurgulanmıştır.

Anahtar Kelimeler: Hüzün Turizmi, Turist Rehberliği, Metafor Analizi

TOURISM GUIDE STUDENTS' PERCEPTIONS OF WAR AND TOURISM WITHIN THE CONTEXT OF DARK TOURISM

Abstract

Along with global developments, various changes are observed in people's motivations for travel. Individuals' concepts of leisure time, personal interests, and the act of moving from one place to another vary. This situation plays a role in the diversification of tourism and the emergence of new trends. Tourism, which initially served the purposes of leisure and entertainment, has evolved into an activity that evokes sadness and tears in places where people travel for reasons such as migration, war, and exile. Although the terms "tourism" and "war" may seem contradictory, war tourism is a recognized concept in both national and international academic literature. This study is designed to assess how war and war zone tourism, examined within the scope of sorrow tourism, are perceived by tourism guide students. In this study, conducted with students in the Bachelor's Program in Tourism Guiding at Cappadocia University, questions prepared via online forms were distributed to the students. The total enrollment in the Tourism Guide Bachelor's program at Cappadocia University is 49 students, 25 of whom provided valid and reliable responses. The students were asked to describe their initial perceptions of the terms "tourism" and "war" and to explain these perceptions using a metaphor. The collected data were analyzed using metaphor analysis, one of the qualitative research methods. The results were evaluated using the Kappa method. A doctoral student and a Turkish language teacher participated in the evaluation. Based on the responses, four themes were identified regarding the concepts of war and tourism: "Oxymoron, Avoidance, Relational, and Emotional." As a result, despite the fact that topics such as death and war create negative perceptions due to humans being social beings, tourism has been identified as an alternative value. Furthermore, it has become evident that this situation gives rise to emic and ethical responsibilities. While it is possible to derive tourism from every word, it was strongly emphasized that not every tourism activity will evoke the same sentiment.

Keywords: Dark Tourism, Tourist Guidance, Metaphor Analysis

NAFTALAN PETROL TERAPİSİNİN SAĞLIK TURİZMİ AÇISINDAN DEĞERLENDİRİLMESİ

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ÖZET

Sağlık turizmi, doğal tedavi kaynakları ve alternatif sağlık uygulamalarına yönelik ilginin artmasıyla birlikte küresel turizm endüstrisinin hızla gelişen alanlarından biri haline gelmiştir. Bu kapsamda, Azerbaycan'ın Naftalan şehrinde yüzyıllardır tedavi amacıyla kullanılan ve dünyada yalnızca bu bölgede ekonomik ölçekte çıkarıldığı bilinen Naftalan petrolü, sahip olduğu özgün özellikleri ile dikkat çeken doğal sağlık kaynaklarından biridir. Tarihsel süreç içerisinde halk hekimliği uygulamalarından modern sanatoryum sistemine evrilen Naftalan petrol terapisi, günümüzde sağlık hizmetleri, rehabilitasyon uygulamaları ve konaklama olanaklarının bütünleştiği özgün bir sağlık turizmi ürünü niteliği kazanmıştır. Bu çalışmanın amacı, Naftalan petrol terapisini sağlık turizmi perspektifinden ele alarak tarihsel gelişimi, tedavi uygulamaları ve destinasyon özellikleri çerçevesinde değerlendirmek ve Naftalan'ın doğal kaynak temelli özgün bir sağlık turizmi ürünü olarak taşıdığı potansiyeli ortaya koymaktır. Araştırma, yerli ve yabancı akademik çalışmalar, tezler ile Naftalan resmi haber ajansı ve istatistik merkezleri tarafından yayımlanan güncel verilerin incelendiği nitel bir doküman analizi yaklaşımına dayanmaktadır. Çalışmanın sonucunda, Naftalan petrolünün yalnızca terapötik özelliklere sahip doğal bir tedavi unsuru olmadığı; aynı zamanda tarihsel birikim, Sovyet döneminden miras kalan sanatoryum altyapısı, modern sağlık ve konaklama tesisleri ile uluslararası hasta hareketliliği sayesinde Azerbaycan'ın sağlık turizmi markalaşmasına katkı sağlayan özgün bir destinasyon değeri taşıdığı belirlenmiştir. Çalışmada ayrıca Naftalan'ın alternatif ve tamamlayıcı sağlık uygulamaları ile bütünleşen yapısının, doğal kaynak temelli sağlık turizmi ürünlerinin geliştirilmesi ve destinasyonların uluslararası rekabet gücünün artırılması açısından önemli fırsatlar sunduğu değerlendirilmektedir.

Anahtar Kelimeler: Sağlık turizmi, Naftalan, Naftalan petrolü, petrol terapisi, Azerbaycan.

EVALUATION OF NAFTALAN OIL THERAPY IN THE CONTEXT OF HEALTH TOURISM

ABSTRACT

Health tourism has become one of the rapidly growing sectors of the global tourism industry with the increasing interest in natural therapeutic resources and alternative healthcare practices.

In this context, Naftalan oil, which has been used for therapeutic purposes for centuries in the city of Naftalan, Azerbaijan, and is known to be commercially extracted only in this region, represents one of the most distinctive natural health resources in the world. Evolving from traditional folk medicine practices to a modern sanatorium system, Naftalan oil therapy has gradually developed into a unique health tourism product that integrates healthcare services, rehabilitation practices, and accommodation facilities. The aim of this study is to evaluate Naftalan oil therapy from a health tourism perspective by examining its historical development, therapeutic applications, and destination characteristics, and to reveal its potential as a distinctive natural resource-based health tourism product. The study is based on a qualitative document analysis of national and international academic studies, theses, and up-to-date data published by the official institutions and statistical authorities of Naftalan. The findings indicate that Naftalan oil should be considered not only as a natural therapeutic resource with unique healing properties but also as a distinctive destination asset contributing to the branding of Azerbaijan's health tourism through its historical background, the sanatorium infrastructure inherited from the Soviet period, modern healthcare and accommodation facilities, and increasing international patient mobility. Furthermore, the integration of Naftalan therapy with alternative and complementary healthcare practices is considered to provide significant opportunities for the development of natural resource-based health tourism products and for enhancing the international competitiveness of destinations.

Keywords: Health tourism, Naftalan, Naftalan oil, oil therapy, Azerbaijan.

GİRİŞ

Sağlık turizmi, bireylerin tedavi, rehabilitasyon ve sağlığın korunması amacıyla gerçekleştirdikleri seyahatleri kapsayan ve son yıllarda hızla büyüyen turizm türlerinden biridir. Özellikle doğal kaynaklara dayalı tedavi uygulamaları, sağlık hizmetleri ile turizm faaliyetlerini bir araya getirerek destinasyonlara önemli rekabet avantajları sağlamaktadır. Termal kaynaklar, mineralli sular, şifalı çamurlar ve benzeri doğal unsurlar, birçok ülkenin sağlık turizmi arzının temel bileşenleri arasında yer almaktadır (Heydarov, 2016; Çılgınoğlu, 2024).

Doğal kaynak temelli sağlık turizmi uygulamaları arasında dikkat çeken örneklerden biri de Azerbaycan'ın Naftalan kentinde yüzyıllardır tedavi amacıyla kullanılan Naftalan petrolüdür. Dünyada ekonomik ölçekte yalnızca bu bölgede çıkarıldığı kabul edilen Naftalan petrolü, sahip olduğu kendine özgü özellikler nedeniyle tarihsel süreç içerisinde çeşitli tedavi uygulamalarında kullanılmıştır (Değişgel, 2016; Abbasov vd., 2025). Günümüzde Naftalan

petrol terapisi, sanatoryumlar, rehabilitasyon merkezleri ve sağlık otelleri aracılığıyla sunulan hizmetlerle sağlık turizminin önemli unsurlarından biri haline gelmiştir.

Literatürde Naftalan üzerine gerçekleştirilen çalışmaların büyük bölümünün petrolün kimyasal yapısı, terapötik özellikleri ve tedavi uygulamaları üzerine yoğunlaştığı görülmektedir (Kazimov, 2014; Abbasov vd., 2025). Buna karşın Naftalan'ın sağlık turizmi ürünü olarak değerlendirilmesine, destinasyon özelliklerine ve sağlık turizmi açısından taşıdığı potansiyele odaklanan çalışmaların sınırlı olduğu söylenebilir. Bu durum, Naftalan'ın yalnızca tıbbi açıdan değil, turizm perspektifinden de ele alınmasını gerekli kılmaktadır.

Bu çalışmada, Naftalan petrol terapisinin sağlık turizmi açısından taşıdığı önemi, tarihsel gelişimi, tedavi uygulamaları ve destinasyon özellikleri çerçevesinde incelenmektedir. Çalışma, Naftalan'ın doğal kaynak temelli bir sağlık turizmi ürünü olarak sahip olduğu potansiyelin ortaya konulmasını amaçlamaktadır. Bu doğrultuda güncel kurumsal ve istatistiksel veriler değerlendirilmiş ve Naftalan'ın sağlık turizmi açısından önemi bütüncül bir bakış açısıyla ele alınmıştır.

1. Naftalan'ın Tarihsel Gelişimi

Naftalan, Azerbaycan Cumhuriyeti'nin batısında, Gence şehrine yaklaşık 50 km uzaklıkta bulunan küçük bir yerleşim birimidir. Yaklaşık 7.000 kişilik nüfusa sahip olan bölge, adını yörede bulunan ve yüzyıllardır şifa amacıyla kullanılan özel bir petrol türünden almaktadır. Bazı kaynaklarda, bölgenin adının "petrol" anlamına gelen *neft* kelimesi ile "yer, alan" anlamını taşıyan sözcüğün birleşiminden türediği ve zaman içerisinde "Naftalan" biçimini aldığı belirtilmektedir (Değişgel, 2016). Coğrafi olarak Küçük Kafkasya'nın kuzeydoğu eteklerinde yer alan Naftalan, Murovdağ sıradağlarının kuzey yamaçları üzerinde konumlanmış olup doğal çevresi ve sahip olduğu yer altı kaynakları sayesinde tarih boyunca dikkat çeken bir yerleşim olmuştur (İmat, 2015).

Naftalan'ın ulusal ve uluslararası ölçekte tanınmasını sağlayan en önemli unsur, bölgede çıkarılan ve klasik ham petrolden farklı özellikler taşıyan Naftalan yağıdır. Yüksek naftenik hidrokarbon içeriği ve düşük yanıcılık özelliği ile dikkat çeken bu doğal kaynak, tarihsel süreç içerisinde enerji kaynağı olarak değil, daha çok tedavi ve rehabilitasyon amacıyla kullanılmıştır (Değişgel, 2016; Abbasov vd., 2025).

Naftalan petrolünün tedavi amaçlı kullanımının oldukça eski dönemlere dayandığı bilinmektedir. Tarihsel kaynaklara göre, bölgedeki şifalı petrol yatağı Azerbaycan başta olmak üzere İran, Anadolu, Kırım ve Orta Asya'dan gelen insanlar tarafından yüzyıllardır tedavi amacıyla ziyaret edilmektedir. Naftalan petrolünün Küçük Asya ve Hindistan'a kadar ihraç

edildiği, bölgeye gelen ziyaretçilerin dönüşlerinde yanlarında Naftalan yağı götürdükleri belirtilmektedir (Kazimov, 2014).

Literatürde Naftalan'a ilişkin ilk yazılı kayıtların XII. yüzyıla kadar uzandığı kabul edilmektedir. Kazimov'un (2014) aktardığına göre, büyük Azerbaycan şairi Nizami Gencevi'nin eserlerinde "dağ yağı" olarak adlandırılan şifalı petrolün Naftalan'dan develer aracılığıyla taşındığına ilişkin ifadeler yer almaktadır. Bu kayıtlar, Naftalan'ın yalnızca yerel bir halk uygulaması olmadığını, Orta Çağ'dan itibaren bölgesel ölçekte tanınan bir tedavi merkezi niteliği taşıdığını göstermektedir.

Naftalan petrolüne ilişkin ikinci önemli tarihsel referans ise XIII. yüzyılda Kafkasya üzerinden Çin'e seyahat eden İtalyan gezgin Marco Polo'ya aittir. Marco Polo, seyahat notlarında Azerbaycan'dan çıkarılan bu yağın yemek amacıyla kullanılmadığını, buna karşın insan ve hayvanlarda görülen çeşitli cilt rahatsızlıklarının tedavisinde merhem olarak uygulandığını ifade etmektedir (Kazimov, 2014). Naftalan'ın geleneksel halk uygulamalarından daha sistematik bir tedavi pratiğine dönüşmesi ise XIX. yüzyılın sonlarına rastlamaktadır. Bu dönemde Alman maden mühendisi E. Jaeger'in bölgedeki petrol yataklarını işletme girişiminde bulunduğu, ancak Naftalan petrolünün yanıcı olmaması ve bölgenin ulaşım güçlükleri nedeniyle endüstriyel üretim yerine terapötik kullanım alanına yöneldiği belirtilmektedir. Jaeger'in kurduğu ilk banyo binasında Naftalan petrolü ile banyo uygulamaları gerçekleştirildiği ve "Naftalan merhemi" adıyla hazırlanan ürünlerin kullanılmaya başlandığı ifade edilmektedir (Kazimov, 2014). Daha sonraki derleme çalışmalarında da Jaeger'in faaliyetlerinin Naftalan'ın modern sağlık uygulamalarına geçişinde önemli bir dönüm noktası olduğu vurgulanmaktadır (Abbasov vd., 2024).

20. yüzyılın başlarından itibaren Naftalan petrolü bilimsel araştırmaların konusu haline gelmiş, özellikle Sovyetler Birliği döneminde petrolün fiziksel, kimyasal ve terapötik özellikleri üzerine çalışmalar yürütülmüştür. 1920 sonrasında Azerbaycan'daki petrol ve gaz yataklarının sistematik biçimde araştırılmaya başlanmasıyla birlikte Naftalan petrolüne yönelik ilgi de artmış, bu doğal kaynağın tedavi amaçlı kullanımına ilişkin bilimsel bilgi birikimi genişlemiştir (Kazimov, 2014). Naftalan'ın sağlık turizmi açısından kurumsallaşması da Sovyetler Birliği döneminde gerçekleşmiştir. Literatürde, 1932 yılında bölgede ilk Naftalan sanatoryumunun hizmete açıldığı ve takip eden yıllarda kurulan yeni tesislerle Naftalan'ın Sovyet coğrafyasının önemli rehabilitasyon merkezlerinden biri haline geldiği ifade edilmektedir (Abbasov vd., 2024). Değişgel (2016) de Naftalan'ın özellikle 1930'lu yıllardan itibaren "yanmayan petrol"

ile özdeşleşen bir sağlık turizmi destinasyonu haline geldiğini ve sanatoryum sistemi sayesinde çok sayıda yerli ve yabancı ziyaretçiyi ağırladığını belirtmektedir.

Sovyetler Birliği'nin dağılmasının ardından yaşanan ekonomik ve siyasi dönüşüm süreci Naftalan sağlık tesislerini olumsuz etkilemiş olsa da 2000'li yıllardan itibaren bölge yeniden canlanma sürecine girmiştir. Azerbaycan'ın sağlık turizmini çeşitlendirme politikaları kapsamında Naftalan'a yönelik yatırımlar artırılmış, modern otel ve sanatoryum kompleksleri hizmete açılmıştır. Günümüzde Naftalan, yalnızca geleneksel petrol terapisi uygulamalarıyla değil, konaklama, rehabilitasyon ve sağlık hizmetlerini bütünleştiren yapısıyla Azerbaycan'ın en önemli sağlık turizmi destinasyonlarından biri olarak değerlendirilmektedir (Heydarov, 2016; Seferov ve Kurbanova, 2018; Gurbanova, 2018; Çılgınoğlu, 2024).

2. Naftalan Petrolü ve Tedavi Uygulamaları

Naftalan petrolü, fiziksel ve kimyasal özellikleri bakımından klasik ham petrolden belirgin biçimde ayrılan, yüksek oranda naftenik hidrokarbonlar içeren doğal bir hidrokarbon karışımıdır. Literatürde, Naftalan yağının düşük parafin ve aromatik hidrokarbon içeriğine karşın yüksek naftenik bileşenler taşıdığı, bu özelliğinin onu endüstriyel amaçlı kullanılan petrol türlerinden ayıran temel unsurlardan biri olduğu belirtilmektedir (Abbasov vd., 1998; Adigozalova vd., 2019). Dünyada terapötik amaçlarla kullanılan ve ekonomik ölçekte çıkarıldığı bilinen en özgün doğal petrol türlerinden biri olan Naftalan yağı, düşük yanıcılık özelliği nedeniyle tarihsel süreç içerisinde enerji kaynağından ziyade tedavi ve rehabilitasyon uygulamalarında değerlendirilmiştir (Abbasov vd., 2025; Değişgel, 2016).

Naftalan petrolünün tedavi amacıyla kullanımı, bölgedeki halk hekimliği uygulamalarına kadar uzanmaktadır. Geleneksel bilgi birikimine dayanan bu uygulamalar zamanla sistematik hale gelmiş ve bilimsel araştırmalarla desteklenmiştir Abbasov vd., 1998; Abbasov vd., 2009). Guliyeva (1981), Naftalan yağının uzun yıllar boyunca yerel halk tarafından haricen uygulanan doğal bir tedavi unsuru olarak değerlendirildiğini belirtirken, Kazimov (2014) bu uygulamaların yalnızca Azerbaycan ile sınırlı kalmayıp çevre coğrafyalara yayıldığını ve bölgeye gelen ziyaretçiler tarafından da benimsendiğini aktarmaktadır.

Günümüzde Naftalan petrolü, çoğunlukla sanatoryum ve rehabilitasyon merkezlerinde uygulanan bütünleşik tedavi programlarının temel bileşenlerinden biri olarak kullanılmaktadır. Tedavi süreci yalnızca petrol uygulamasından ibaret olmayıp, konaklama, tıbbi gözetim, fizik tedavi, rehabilitasyon ve destekleyici sağlık hizmetleri ile birlikte planlanan kapsamlı bir hizmet paketi şeklinde sunulmaktadır. Bu yapı, Naftalan'ın geleneksel bir halk tedavisi

olmaktan çıkarak sağlık hizmetleri ile turizm faaliyetlerinin bütünleştiği özgün bir sağlık turizmi ürünü haline gelmesine katkı sağlamıştır (Heydarov, 2016; Gurbanova, 2018).

Literatürde Naftalan petrolünün başta dermatolojik hastalıklar, kas ve iskelet sistemi rahatsızlıkları, romatizmal hastalıklar, periferik sinir sistemi bozuklukları ve bazı jinekolojik hastalıklar olmak üzere çeşitli sağlık sorunlarının rehabilitasyon ve destekleyici tedavi süreçlerinde kullanıldığı belirtilmektedir. Günümüzde Naftalan sanatoryumlarında petrol banyoları ve lokal uygulamalar, fizik tedavi ve rehabilitasyon programları ile birlikte tıbbi gözetim altında yürütülmekte olup, uygulamalar bütüncül bir tedavi yaklaşımı çerçevesinde sunulmaktadır (Guliyeva, 1981; Abbasov vd., 2025; Değişgel, 2016). Bununla birlikte, Naftalan petrolüne dayalı uygulamalar birçok ülkede alternatif ve tamamlayıcı tıp kapsamında değerlendirilmekte olup, bu doğal kaynağın terapötik etkilerine ilişkin bilimsel araştırmalar günümüzde de devam etmektedir (Vržogić vd., 2003; Abbasov vd., 2025). Dolayısıyla Naftalan petrolü etrafında şekillenen tedavi uygulamaları zaman içerisinde yalnızca tıbbi bir pratik olmanın ötesine geçmiş, konaklama, rehabilitasyon ve destekleyici sağlık hizmetleri ile bütünleşerek bölgenin sağlık turizmi kimliğinin oluşmasına katkı sağlamıştır. Bu dönüşüm, Naftalan'ın günümüzde ulusal ve uluslararası ölçekte tanınan bir sağlık turizmi destinasyonu olarak değerlendirilmesinin temel nedenlerinden birini oluşturmaktadır.

3. Sağlık Turizmi Açısından Değerlendirme

Sağlık turizmi alanında son yıllarda yaşanan gelişmeler, destinasyonların yalnızca tıbbi hizmet sunan merkezler olmaktan çıkarak kendilerine özgü doğal, kültürel ve terapötik kaynaklar etrafında farklılaşmalarını gerekli kılmaktadır. Bu doğrultuda, belirli bir coğrafyaya özgü doğal tedavi unsurlarına dayanan uygulamalar, uluslararası sağlık turizmi pazarında niş (niche) ürünler olarak değerlendirilmekte ve destinasyonların rekabet avantajı elde etmesine katkı sağlamaktadır. Naftalan petrol terapisi de yalnızca Azerbaycan'ın Naftalan bölgesinde bulunan özgün doğal bir kaynağa dayanması, yüzyılları aşan kullanım geçmişine sahip olması ve modern sağlık hizmetleriyle bütünleşmiş bir yapı içerisinde sunulması nedeniyle doğal kaynak temelli niş bir sağlık turizmi ürünü olarak değerlendirilebilir (Değişgel, 2016; Heydarov, 2016; Abbasov vd., 2025).

Naftalan'ın sağlık turizmi açısından dikkat çeken en önemli özelliklerinden biri, sahip olduğu doğal kaynağın yalnızca tedavi amaçlı kullanılmasından ibaret olmayıp, bu kaynağın etrafında gelişen sağlık ve konaklama altyapısı ile bütünleşik bir destinasyon deneyimine dönüştürülmüş olmasıdır. Sovyetler Birliği döneminde şekillenen sanatoryum sistemi, bölgede sağlık hizmetlerinin kurumsal bir yapı içerisinde sunulmasına zemin hazırlamış; son yıllarda

gerçekleştirilen yatırımlarla bu yapı modern sağlık otelleri ve rehabilitasyon merkezleri ile desteklenmiştir (Gurbanova, 2018; Heydarov, 2016). Günümüzde yayımlanan resmî bilgilerde Chinar Hotel & Spa, Gashalti Health Hotel, Garabag Resort & Spa, Gözəl Naftalan, Şəfa Sanatoryumu, Kəpəz Sanatoryumu ve Möcüzəli Naftalan Sağlamlıq Mərkəzi gibi çok sayıda sağlık ve rehabilitasyon tesisinin faaliyet gösterdiği belirtilmektedir. Bu tesislerde Naftalan petrol terapisi, konaklama, fizik tedavi ve destekleyici sağlık hizmetleri ile birlikte sunularak bütüncül bir sağlık turizmi modeli oluşturulmaktadır (Naftalan Şəhər İcra Hakimiyyəti, 2026a). Naftalan'ın sağlık turizmi destinasyonu olarak gelişimi, sahip olduğu doğal tedavi kaynağının yanı sıra uluslararası hasta hareketliliği oluşturabilme kapasitesi ile de ilişkilidir. Son yıllarda Azerbaycan'da sağlık turizmine yönelik yürütülen tanıtım ve yatırım faaliyetleri kapsamında Naftalan, ülkenin sağlık turizmi markalaşmasında öne çıkan destinasyonlardan biri haline gelmiştir. Bölgede faaliyet gösteren sağlık ve rehabilitasyon tesisleri yalnızca yerel talebe değil, başta Rusya, Kazakistan, Gürcistan, Türkmenistan, Türkiye ve İran olmak üzere çok sayıda ülkeden gelen ziyaretçilere de hizmet sunmaktadır (Heydarov, 2016; Seferov & Kurbanova, 2018). Nitekim Naftalan Şəhər İcra Hakimiyyəti (2026b) ve Azerbaycan Devlet Haber Ajansı (2026) tarafından yayımlanan güncel verilere göre, 2024 yılında bölgeyi 44.801 turist ziyaret etmiş, bunların 15.864'ünü 47 farklı ülkeden gelen yabancı ziyaretçiler oluşturmuştur. Ayrıca 2025 yılının ilk üç ayında Naftalan'a tedavi amacıyla 6.432 turist gelmiş olup, bunların 2.367'si yabancı ziyaretçilerden oluşmaktadır. Bu veriler, Naftalan'ın yalnızca tarihsel bir tedavi merkezi olmanın ötesine geçerek uluslararası sağlık turizmi pazarında görünürlüğü giderek artan bir destinasyon kimliği kazandığını göstermektedir.

Naftalan örneği, doğal bir tedavi kaynağının uygun sağlık altyapısı, konaklama olanakları ve destinasyon yönetimi uygulamaları ile bütünleştirildiğinde uluslararası ölçekte rekabet edebilen bir sağlık turizmi ürününe dönüşebileceğini göstermektedir. Günümüzde Naftalan petrol terapisi, yalnızca geleneksel bir halk tedavisi olarak değil, rehabilitasyon ve destekleyici sağlık hizmetleri kapsamında değerlendirilen alternatif ve tamamlayıcı uygulamalarla bütünleşmiş özgün bir sağlık turizmi deneyimi sunmaktadır. Özellikle bireyselleştirilmiş sağlık hizmetlerine ve doğal tedavi yöntemlerine yönelik ilginin arttığı günümüzde, Naftalan'ın sahip olduğu tarihsel birikim, sanatoryum altyapısı ve özgün doğal kaynağı sayesinde Azerbaycan'ın destinasyon markalaşmasına katkı sağlayan stratejik bir değer taşıdığı söylenebilir. Bu yönüyle Naftalan, doğal kaynak temelli niş sağlık turizmi ürünlerinin sürdürülebilir destinasyon gelişimine katkısını ortaya koyan dikkat çekici örneklerden biri olarak değerlendirilebilir (Heydarov, 2016; Gurbanova, 2018; Dargahov ve Talibov, 2025).

4. Tartışma ve Sonuç

Bu çalışma kapsamında Naftalan petrol terapisi sağlık turizmi perspektifinden değerlendirilmiş ve elde edilen bulgular, Naftalan'ın yalnızca doğal bir tedavi kaynağına sahip bir yerleşim alanı değil, aynı zamanda kendine özgü özellikleri sayesinde uluslararası sağlık turizmi pazarında konumlanan niş bir destinasyon olduğunu ortaya koymuştur. Sağlık turizmi literatüründe doğal kaynaklara dayalı tedavi uygulamalarının destinasyonların farklılaşmasında önemli bir rol oynadığı vurgulanmaktadır (Heydarov, 2016; Çılgınoğlu, 2024). Bu çalışma kapsamında ulaşılan bulgular da söz konusu yaklaşımı desteklemekte ve Naftalan petrolünün yalnızca terapötik özellikleri nedeniyle değil, aynı zamanda tarihsel ve kültürel bir değer taşıması nedeniyle destinasyon çekiciliğine katkı sağladığını göstermektedir. Özellikle yüzyıllardır devam eden kullanım geleneği, Naftalan'ı birçok sağlık turizmi destinasyonundan ayıran temel unsurlardan biri olarak değerlendirilebilir.

Araştırmada ulaşılan bir diğer önemli sonuç, Naftalan'ın sağlık turizmi başarısının yalnızca sahip olduğu doğal kaynaktan kaynaklanmadığıdır. Bulgular, Sovyet döneminde gelişen sanatoryum sisteminin günümüzde modern sağlık otelleri ve rehabilitasyon merkezleri ile bütünleşerek destinasyonun sağlık turizmi altyapısını güçlendirdiğini göstermektedir. Bu sonuç, Gurbanova (2018) ile Seferov ve Kurbanova'nın (2018) çalışmalarında vurgulanan, sağlık turizmi işletmelerinin hizmet kalitesi ve kurumsal altyapısının destinasyon tercihleri üzerindeki etkisine ilişkin bulgularla paralellik göstermektedir. Nitekim Naftalan örneği, doğal kaynak temelli sağlık turizmi ürünlerinin sürdürülebilir başarısında yalnızca doğal kaynağın varlığının yeterli olmadığını; sağlık hizmetleri, konaklama olanakları ve rehabilitasyon altyapısının da kritik öneme sahip olduğunu ortaya koymaktadır.

Çalışmada değerlendirilen güncel ziyaretçi verileri, Naftalan'ın uluslararası sağlık turizmi pazarındaki görünürlüğünün arttığını göstermektedir. Bölgeyi ziyaret eden yabancı turist sayısındaki artış, Naftalan'ın yalnızca Azerbaycan iç pazarı açısından değil, uluslararası sağlık turizmi açısından da önem kazandığına işaret etmektedir. Bu durum, Heydarov'un (2016) Azerbaycan'ın sağlık turizmi potansiyeline ilişkin değerlendirmelerini destekler niteliktedir. Ayrıca destinasyonun sahip olduğu doğal kaynak, sağlık altyapısı ve artan uluslararası bilinirlik birlikte değerlendirildiğinde, Naftalan'ın Azerbaycan'ın sağlık turizmi markalaşmasına katkı sağlayan stratejik destinasyonlardan biri olduğu söylenebilir.

Literatürde Naftalan petrolünün terapötik özelliklerine ilişkin gerçekleştirilen çalışmalar incelendiğinde, petrolün çeşitli dermatolojik, romatolojik ve rehabilitasyon amaçlı uygulamalarda değerlendirildiği görülmektedir (Vržogić vd., 2003; Abbasov vd., 2025).

Bununla birlikte günümüzde sağlık turizmi talebinde gözlenen değişim, yalnızca tedavi odaklı hizmetlerden ziyade rehabilitasyon, wellness ve bütüncül sağlık deneyimlerine yönelik ilgiyi de artırmaktadır. Bu bağlamda Naftalan'ın alternatif ve tamamlayıcı sağlık uygulamaları ile bütünleşen yapısının, destinasyonun gelecekteki rekabet gücünü artırabilecek önemli avantajlardan biri olduğu değerlendirilmektedir. Özellikle doğal tedavi yöntemlerine yönelik küresel ilginin artması, Naftalan gibi kendine özgü kaynaklara sahip destinasyonlar için yeni gelişim fırsatları yaratmaktadır.

Sonuç olarak bu çalışma, Naftalan petrol terapisinin yalnızca terapötik özellikleri ile değil, tarihsel birikimi, kurumsal sağlık altyapısı, konaklama olanakları ve uluslararası ziyaretçi hareketliliği ile birlikte değerlendirilmesi gereken çok boyutlu bir sağlık turizmi ürünü olduğunu ortaya koymuştur. Naftalan'ın doğal kaynak temelli niş bir sağlık turizmi destinasyonu olarak önemli bir potansiyel taşıdığı söylenebilir. Bununla birlikte konuya ilişkin akademik çalışmaların sınırlı olması nedeniyle gelecekte turist motivasyonları, ziyaretçi memnuniyeti, destinasyon imajı, tekrar ziyaret niyeti ve sağlık turizminin ekonomik etkileri gibi konulara odaklanan ampirik araştırmaların gerçekleştirilmesi önerilmektedir. Bu tür çalışmaların hem literatüre katkı sağlayacağı hem de Naftalan'ın sürdürülebilir sağlık turizmi gelişimine yönelik politika ve uygulamalara ışık tutacağı düşünülmektedir. Sonuç olarak Naftalan, sahip olduğu benzersiz doğal kaynağı sağlık ve turizm altyapısı ile bütünleştirebilmiş olması sayesinde, doğal kaynak temelli sağlık turizmi destinasyonları arasında dikkat çekici bir örnek olarak değerlendirilebilir.

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KİŞİLİK ÇIKARIMINA DAYALI SOSYAL YARGI GÖREVİ'NİN GELİŞTİRİLMESİ

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ÖZET

Sonuca atlama, bireylerin sınırlı bilgiye dayanarak erken karar verme eğilimini ifade eden bir bilişsel yanlılıktır ve yaygın olarak Boncuk Görevi aracılığıyla incelenmektedir. Ancak Boncuk Görevi'nin soyut yapısı ve gündelik sosyal kararlarla sınırlı benzerliği, sosyal bağlamda karar verme süreçlerini değerlendirmeye yönelik ekolojik geçerliği daha yüksek görevlerin geliştirilmesini gerekli kılmaktadır. Bu çalışmanın amacı, sözel davranışlardan kişilik özelliği çıkarımına dayalı, kısa, yalın ve kolay uygulanabilir bir Sosyal Yargı Görevi geliştirmektir. Görev, bireylerin tanımadıkları bir kişi hakkında sosyal bir yargıya ulaşmadan önce ne kadar bilgi toplamaya ihtiyaç duyduklarını değerlendirmeyi amaçlamaktadır. Bu doğrultuda, görevde kullanılacak uyaranları geliştirmek, değerlendirmek ve seçmek amacıyla farklı örneklemler üzerinde ardışık üç ön çalışma yürütülmüştür. Birinci ön çalışmada, katılımcılardan farklı kişilik özelliklerini yansıtan cümleler üretmeleri istenmiş; değerlendirme sonucunda, görevde kullanılmak üzere "kibirli" ve "inatçı" kişilik özellikleri seçilmiş ve farklı kişilik özelliklerini de içeren 52 aday cümlelik bir uyaran havuzu oluşturulmuştur. İkinci ön çalışmada, bu cümleler hedef kişilik özelliklerini temsil etme düzeyi ve alternatif çağrışımları açısından değerlendirilmiş; her bir hedef kişilik özelliği için temsil puanı 3.00'ün üzerinde olan yedişer aday cümle belirlenmiştir. Üçüncü ön çalışmada ise bu 14 aday cümle, dilsel ve anlamsal açıdan gözden geçirilmiş; ayrıca her bir hedef özellik için altışar yeni cümle oluşturularak toplam 26 aday cümle değerlendirmeye alınmıştır. Değerlendirme sonucunda, ortalama temsil puanı en yüksek olan onar cümle nihai görev setine alınmıştır. Nihai görev, "kibirli" ve "inatçı" kişilik özelliklerine karşılık gelen iki bloktan oluşacak şekilde tasarlanmıştır. Her blokta, aynı hedef kişiye ait olduğu belirtilen 10 cümle katılımcılara tek tek sunulacak ve katılımcılardan bu kişinin ilgili kişilik özelliğine sahip olup olmadığına karar vermeleri istenecektir. Karar öncesinde talep edilen cümle sayısı, sosyal bağlamda bilgi toplama eğiliminin ve sonuca atlama yanlılığının operasyonel bir göstergesi olarak değerlendirilecektir. Böylece çalışma kapsamında, sosyal bağlamda kişilik çıkarımına dayalı

yargılama ve karar verme süreçlerini incelemek üzere kullanılabilecek Sosyal Yargı Görevi'nin uyaranları ve nihai görev yapısı oluşturulmuştur.

Anahtar kelimeler: Sonuca atlama yanlılığı, sosyal yargı, sosyal karar verme, spontane kişilik çıkarımı, bilgi toplama, görev geliştirme

DEVELOPMENT OF A SOCIAL JUDGMENT TASK BASED ON TRAIT INFERENCE

ABSTRACT

Jumping to conclusions is a cognitive bias referring to the tendency to make early decisions based on limited information and is widely examined using the Beads Task. However, the abstract nature of the Beads Task and its limited similarity to everyday social decisions highlight the need for tasks with higher ecological validity in social contexts. This study aimed to develop a brief, simple, and easily applicable Social Judgment Task based on trait inference from verbal behavior. The task assesses how much information individuals need before reaching a social judgment about an unfamiliar person. Accordingly, three sequential pretest studies were conducted with different samples to develop, evaluate, and select the task stimuli. In the first pretest, participants generated sentences reflecting different personality traits. Based on these sentences, the traits "arrogant" and "stubborn" were selected, and a pool of 52 candidate sentences, including other traits, was created. In the second pretest, these sentences were evaluated in terms of their representativeness of the target traits and their alternative associations; for each target trait, seven candidate sentences with representativeness scores above 3.00 were identified. In the third pretest, these 14 candidate sentences were reviewed linguistically and semantically; additionally, six new sentences were generated for each target trait, resulting in a total of 26 candidate sentences for evaluation. Based on this evaluation, the 10 sentences with the highest mean representativeness scores for each trait were included in the final task set. The final task consists of two blocks corresponding to the traits "arrogant" and "stubborn." In each block, 10 sentences attributed to the same target person are presented one by one, and participants decide whether the person possesses the relevant trait. The number of sentences requested before making a decision is considered an operational indicator of information-gathering tendency and jumping-to-conclusions bias in a social context. Thus, the stimuli and final structure of the Social Judgment Task were developed.

Keywords: Jumping to conclusions bias, social judgment, social decision-making, spontaneous personality inference, information gathering, task development

1. GİRİŞ

Sonuca atlama yanlılığı, bireylerin sınırlı bilgiye dayanarak erken karar verme eğilimini ifade eden bir bilişsel yanlılıktır. Bu yanlılık, olasılıksal akıl yürütme ve karar verme süreçlerini değerlendirmeye olanak sağlayan Boncuk Görevi aracılığıyla incelenmektedir. Boncuk Görevi'nin temeli, Phillips ve Edwards'ın (1966) belirsizlik altında olasılıksal çıkarım süreçlerini incelemek amacıyla geliştirdikleri paradigmaya dayanmaktadır. Daha sonra Huq vd. (1988), bu paradigmayı sanrısal düşünme ile ilişkili karar verme süreçlerini incelemek üzere uyarlamış ve görev, sonuca atlama yanlılığının değerlendirilmesinde yaygın olarak kullanılan bir ölçüm aracı hâline gelmiştir.

Görevde katılımcılara, iki farklı renkte boncuk içeren ve boncuk oranları birbirinin tersi olacak şekilde düzenlenmiş iki kavanoz gösterilir. Ardından kavanozlardan biri seçilir ve seçilen kavanozdan, her çekimden sonra geri konulmak üzere, sırayla boncuklar çekilir. Katılımcılardan, gördükleri boncuklara dayanarak boncukların hangi kavanozdan çekildiğine karar vermeleri istenir. Bu yönüyle Boncuk Görevi, katılımcıların karar vermeden önce ne kadar bilgi topladıklarını ve kararlarını ne ölçüde kanıta dayandırdıklarını değerlendirmeye olanak sağlar. Görevde az sayıda boncuk gördükten sonra karar verme, yetersiz kanıta dayanarak erken karar verme eğilimini yansıttığı için sonuca atlama yanlılığının göstergesi olarak kabul edilmektedir (Dudley vd., 1997; Garety vd., 1991). Bu kapsamda, özellikle ilk iki boncukta karar verme sonuca atlama yanlılığı gösterme; üç ya da daha fazla boncuk gördükten sonra karar verme ise sonuca atlama yanlılığı göstermeme şeklinde sınıflandırılmaktadır (Garety vd., 2005).

Sonuca atlama yanlılığının incelenmesi, bireylerin belirsizlik altında karar vermeden önce ne kadar bilgi topladıklarını ve yargılarını ne ölçüde kanıta dayandırdıklarını anlamak açısından önemlidir. Literatürde bu yanlılık özellikle psikoz ve sanrısal düşüncelerle ilişkilendirilmiş; psikoz ve sanrıları olan bireylerin karar vermeden önce daha az bilgi toplama eğiliminde oldukları gösterilmiştir (Dudley vd., 1997, 2016; Huq vd., 1988; So vd., 2016). Bununla birlikte bulgular, sonuca atlama yanlılığının yalnızca klinik gruplara özgü olmadığını, klinik olmayan örneklemlerde de görülebildiğini ve sanrıya yatkınlık, paranoid düşünceler, obsesif-kompulsif belirtiler ile ilişkili olabileceğini göstermektedir (Freeman vd., 2008; Ross vd., 2015; Van Der Leer vd., 2015). Ayrıca son çalışmalar, sonuca atlama eğiliminin yanlış nedensel çıkarımlar ve nedensellik illüzyonlarıyla (Moreno-Fernández vd., 2021) ve bağlamdan bağımsız karar verme süreçleriyle ilişkili olduğunu ortaya koymuştur (Özen-Akın & Cinan, 2022). Bu nedenle sonuca atlama yanlılığı, yalnızca erken karar verme eğilimini değil, bireylerin kanıtları nasıl

değerlendirdiğini, bağlamsal bilgiyi ne ölçüde kullandığını ve yetersiz bilgiye rağmen nasıl güçlü yargılara ulaşabildiğini anlamak için önemli bir bilişsel mekanizma olarak ele alınmaktadır (Garety vd., 2005; Özen-Akın & Cinan, 2022).

Bununla birlikte, Boncuk Görevi'nin soyut yapısı, gündelik sosyal kararlarla sınırlı benzerliği ve görece düşük ekolojik geçerliği önemli bir sınırlılık oluşturmaktadır. Bu nedenle, sonuca atlama eğiliminin sosyal içerikli ve gerçek yaşam bağlamlarına daha yakın görevlerle incelenmesi kuramsal ve yöntemsel açıdan önem taşımaktadır (Westermann vd., 2012).

Bu gereksinim doğrultusunda Westermann vd. (2012), sosyal bağlama yerleştirilmiş Sosyal Boncuk Görevi'ni geliştirerek sosyal içerikli durumlarda bilgi toplama ve karar verme süreçlerinin değerlendirilebileceğini göstermiştir. Ancak söz konusu görev, çok sayıda senaryo ve her senaryo için çok sayıda bilgi biriminin okunmasını gerektirdiğinden uygulama süresi ve bilişsel yük açısından görece karmaşık bir yapıdadır. Bu durum, daha kısa, daha yalın ve uygulanması daha kolay sosyal karar verme görevlerine duyulan gereksinimi ortaya koymaktadır.

Öte yandan sosyal biliş ve izlenim oluşumu alanındaki araştırmalar, bireylerin başkalarının davranışlarına ya da kısa davranış betimlemelerine dayanarak, çoğu zaman açık bir yönlendirme olmaksızın hızlı ve spontane biçimde kişilik çıkarımlarında bulunduğunu göstermektedir (Ham & Vonk, 2003; Mangels & Degner, 2023; Uleman vd., 1996; Zhang & Wang, 2018). Spontane kişilik çıkarımı yazını, kısa cümlelerin bile belirli kişilik özelliklerini güvenilir biçimde ima edebildiğini ortaya koymaktadır. Ayrıca yakın dönem araştırmalar, bu tür görevlerde kullanılacak cümlelerin ana uygulama öncesinde sistematik biçimde ön testten geçirilmesinin gerekli olduğunu vurgulamaktadır (Mangels & Degner, 2023).

Buradan hareketle, bu çalışmada çok sayıda sosyal senaryo ve ayrıntılı bilgi sunumu gerektirmeyen; bunun yerine, bir kişinin söylediği varsayılan kısa cümlelere dayanarak kişilik özelliği hakkında çıkarım yapmayı içeren daha yalın bir sosyal yargı görevi geliştirilmesi amaçlanmaktadır. Bu görevin oluşturulmasında, Boncuk Görevi'nin olasılıksal yapısını birebir yeniden üretmekten ziyade, karar vermeden önce talep edilen bilgi miktarını değerlendirme mantığı temel alınmıştır. Görev iki blok hâlinde yapılandırılacak; her blokta katılımcılara bir kişiye ait olduğu varsayılan cümleler tek tek sunulacak ve katılımcılardan bu kişinin belirli bir kişilik özelliğine sahip olup olmadığına karar vermeleri istenecektir. Karar öncesinde talep edilen cümle sayısı, görevin temel performans göstergesi olarak değerlendirilecek; daha az sayıda ifadeye dayanarak karar verme, sosyal içerikli bilgi toplama eğiliminin düşük ve sonuca atlama eğiliminin görece yüksek olduğuna işaret eden operasyonel bir gösterge olarak ele

alınacaktır. Bu kapsamda görevde iki kişilik özelliği ve her bir kişilik özelliğine ait 10 cümle kullanılması planlanmıştır. Bu plan doğrultusunda, görevde kullanılacak iki kişilik özelliğini belirlemek ve her bir özellik için nihai cümle setini oluşturmak amacıyla farklı örneklemler üzerinde ardışık üç ön çalışma yürütülmüştür.

2. GENEL YÖNTEMSEL BİLGİLER

Bu araştırma, Sosyal Yargı Görevi'nin geliştirilmesine yönelik olarak, farklı örneklemler üzerinde ardışık biçimde yürütülen üç ön çalışmayı kapsamaktadır. Çalışmalara dâhil edilme kriterleri, katılımcıların 18 yaş ve üzerinde olmaları, üniversite öğrencisi olmaları, ana dillerinin Türkçe olması ve araştırmaya gönüllü olarak katılmayı kabul etmeleri olarak belirlenmiştir. Tüm ön çalışmalarda aynı dâhil edilme kriterleri kullanılmıştır. Araştırma protokolü Kırklareli Üniversitesi Rektörlüğü Bilimsel Araştırmalar ve Yayın Etiği Kurulu tarafından onaylanmıştır.

3. ÖN ÇALIŞMA 1

Birinci ön çalışma, tanınmayan bir kişinin söylediği varsayılan cümlelerden hareketle kişilik çıkarımı yapılmasına elverişli bir cümle havuzu oluşturma amacıyla yürütülmüştür.

3.1. YÖNTEM

3.1.1. Örneklem

Çalışmaya 19–27 yaşları (Ort. = 22.49, SS = 1.84) arasında, 33 kadın ve 12 erkek olmak üzere toplam 45 öğrenci katılmıştır.

3.1.2. Veri Toplama Araçları

3.1.2.1. Cümle Üretme Formu

Bu form mevcut ön çalışmada kullanılmak üzere araştırmacılar tarafından hazırlanmıştır. Formda katılımcılara 24 farklı kişilik özelliği sunulmuş ve her bir özellik için, tanımadıkları bir kişinin bu özelliğe sahip olduğunu düşündürebilecek örnek cümleler üretmeleri istenmiştir. Katılımcılara verilen yönergede şu ifadeler yer almıştır: "Bazen hiç tanımadığımız bir kişinin söylediği bir cümleyi duyduğumuzda, o kişinin nasıl bir insan olduğuna dair çıkarım yapabiliriz. Bir cümle birinin karakterinin ne olduğunu anlamanıza neden olabilir; cümlenin kişiliğini yansıttığını düşünürsünüz. Sizden aşağıdaki kişilik özelliklerini okumanızı ve okuduğunuz belirli kişilik özelliğine sahip bir kişinin karakterini yansıtacak tek bir cümle yazmanızı istiyoruz. Yazdığınız cümlenin tanımadığınız bir kişi tarafından söylendiğinde karakteri konusunda hemen aklınıza o kişilik özelliğini getiren bir cümle olduğundan emin olmaya çalışınız. Bunun için cümleyi yazdıktan sonra okuyup kendinize şu soruyu sorun: Tanımadığım bir kişinin ağzından böyle bir cümle çıkarsa onun büyük ihtimalle bu kişilik

özelliğine sahip olduğunu düşünür müydüm? Bu soruyu sorup cümleyi değerlendirdikten sonra gerekirse cümlede değişiklik yapınız ve bir sonraki kişilik özelliğini okuyup cümle yazmaya devam ediniz."

Katılımcılara sunulan kişilik özellikleri şunlardır: Çalışkan, Dürüst, Kibirli, Sahtekâr, Gamsız, Yardımsever, Sinirli, Hoşgörülü, Kibar, Menfaatçi, Kötümser, Neşeli, İnatçı, Korkak, Düzenbaz, Sakin, Gururlu, Cömert, Kindar, Mütevazı, Açgözlü, İyimser, Cimri, Cesur.

3.2. BULGULAR VE SONUÇ

Elde edilen bine yakın yanıt incelenerek hedef dışı çağrışımı yüksek olan cümleler elenmiştir. Uygun bulunan ifadeler, davranıştan kişilik çıkarımı ve spontane kişilik çıkarımı literatüründen (ör. Alvarez vd., 2001; Ham & Vonk, 2003; Liu vd., 2007; Mangels & Degner, 2023; Zhang & Wang, 2018) yararlanılarak dil, anlam ve çağrışım bakımından gözden geçirilmiş ve gerekli görülen ifadeler iyileştirilmiştir.

Bu aşamada hedef kişilik özelliklerinin belirlenmesinde, her bir özellik için üretilebilen kullanılabilir cümle sayısı, cümlelerin ilgili kişilik özelliğini açık biçimde çağrıştırma düzeyi ve alternatif kişilik özellikleriyle örtüşme olasılığı dikkate alınmıştır. Görevin sınırlı bilgiye dayanarak sosyal yargıda bulunma eğilimini değerlendirmeyi amaçlaması nedeniyle, olumlu kişilik özellikleri yerine sosyal değerlendirme açısından daha belirgin ve peşin sosyal yargıya daha elverişli olabilecek olumsuz kişilik özelliklerinin kullanılması uygun görülmüştür. Ayrıca bazı kişilik özelliklerinin birbirine yakın anlam alanlarına sahip olması ve üretilen cümlelerin birden fazla özelliği aynı anda çağrıştırabilmesi de seçim sürecinde göz önünde bulundurulmuştur. Örneğin "menfaatçi" ve "açgözlü" gibi özelliklerde gözlenen anlam örtüşmeleri, hedef kişilik özelliklerinin ayırt ediciliği açısından sınırlılık oluşturabileceği için bu tür özellikler nihai görev seti için tercih edilmemiştir.

Bu değerlendirmeler sonucunda, yeterli sayıda kullanılabilir cümle üretilebilmesi ve hedef dışı çağrışımların görece daha düşük olması nedeniyle "kibirli" ve "inatçı" kişilik özellikleri görevde kullanılmak üzere seçilmiştir. Son olarak, bu iki hedef kişilik özelliğinin yanı sıra dürüst, menfaatçi gibi farklı kişilik özellikleri için üretilmiş ifadeleri de içeren toplam 52 aday cümlelik bir havuz oluşturulmuştur.

4. ÖN ÇALIŞMA 2

Bu çalışma, ilk ön çalışmada görevde kullanılmak üzere seçilen "kibirli" ve "inatçı" kişilik özelliklerini temsil ettiği düşünülen cümlelerin, bu kişilik özelliklerini ne derece temsil ettiğini belirlemek amacıyla yürütülmüştür. Bu amaç doğrultusunda, yalnızca hedef kişilik özelliklerine ait cümleler değil, dürüst ve menfaatçi gibi farklı kişilik özellikleri için üretilmiş

cümleler de değerlendirme sürecine dâhil edilmiş ve toplam 52 aday cümle kullanılmıştır. Farklı kişilik özelliklerine ait cümlelerin formda birlikte karışık sırada sunulmasıyla, katılımcıların yalnızca iki hedef özelliğe odaklanmasından kaynaklanabilecek beklenti ya da yanıt seti etkilerinin azaltılması ve cümlelerin farklı kişilik özelliklerinin karışık sırada değerlendirildiği bir bağlam içinde incelenmesi amaçlanmıştır. Ayrıca bazı cümlelerin üretildiği kişilik özelliği dışında başka bir kişilik özelliğini çağrıştırma olasılığının da değerlendirilmesi istenerek, 5'li Likert tipi ölçek üzerinde hep aynı yönde yanıt verilmesi engellenmiş ve her iki yönde (1= düşük - 5= yüksek) değerler alabilecek cümlelerin karışık sırada sunulduğu bağlamda aday cümlelerin temsil değerlerinin incelenmesi sağlanmıştır.

4.1. YÖNTEM

4.1.1. Örneklem

Çalışmaya 20–48 yaşları (Ort. = 24.74, SS = 7.42) arasında, 16 kadın ve 3 erkek olmak üzere toplam 19 öğrenci katılmıştır.

4.1.2. Veri Toplama Araçları

4.1.2.1. Cümle Değerlendirme Formu

Bu form mevcut ön çalışmada kullanılmak üzere araştırmacılar tarafından hazırlanmıştır. Katılımcılardan "Cümleden Kişilik Çıkarımı" üzerine yürütülen bir araştırmanın ön çalışmasına katılmaları istenmiştir. Yönergede şu açıklamaya yer verilmiştir: "Bazen hiç tanımadığımız bir kişinin söylediği cümleyi duyduğumuzda o kişinin nasıl bir insan olduğuna dair çıkarım yapabilirsiniz. Birinin ağzından çıkan cümlenin kişinin karakterini yansıttığını düşünürüz. Aşağıda cümleler okuyacaksınız ve cümleyi söyleyen kişinin belirli bir kişilik özelliğine sahip olup olmadığına ilişkin ilk izleniminizi 1 (hiç katılmıyorum) ile 5 (tamamıyla katılıyorum) arasında bir değer vererek değerlendireceksiniz. Lütfen 1-5 değerlerini içeren kutucuklardan sizin için uygun olanı işaretleyiniz. Lütfen boş bırakmayınız."

Formda, 52 cümlenin her biri için "… Bu cümleyi söylediğini duyduğum kişi hakkında, ilk izlenim olarak … bir kişi diye düşünürüm" kalıbı üzerinden değerlendirme yapılmıştır. Bu cümlelerin 32'si, soruda belirtilen özellik ile aynı kişilik özelliğini çağrıştırdığı düşünülen uyumlu ifadelerden oluşmuştur. Örneğin "'Sizi üzdüm galiba ama gerçeklerin konuşulması gerektiğine inanırım.' cümlesini söylediğini duyduğum kişi hakkında, ilk izlenim olarak, dürüst biri diye düşünürüm." Bu tür maddelerde yüksek puan verilmesi, cümlenin ilgili kişilik özelliğini temsil ettiğine işaret etmektedir.

Diğer 20 cümle ise soruda belirtilen özellikten farklı bir kişilik özelliğini çağrıştırabileceği düşünülen uyumsuz ifadelerden oluşmuştur. Örneğin "'Risk almaktan kaçınmam, hayallerimin

peşinden koşarım.' cümlesini söylediğini duyduğum kişi hakkında, ilk izlenim olarak, inatçı biri diye düşünürüm." maddesinde yer alan ifade cesur kişilik özelliğini de çağrıştırmaktadır. Bu tür maddelerde düşük puan verilmesi, cümlenin sorulan kişilik özelliğiyle örtüşmediğine işaret etmektedir. Böylece farklı kişilik özelliklerine ait cümlelerin formda birlikte sunulmasıyla, katılımcıların yalnızca iki hedef özelliğe odaklanmasından kaynaklanabilecek beklenti ya da yanıt seti etkilerinin azaltılması ve her cümlenin sorulan özellik açısından dikkatli biçimde değerlendirilmesinin sağlanması amaçlanmıştır.

4.2. BULGULAR VE SONUÇ

Elde edilen veriler üzerinde yürütülen sınıf içi korelasyon katsayısı analizi (Intraclass Correlation Coefficient, ICC), değerlendiriciler arasında yüksek düzeyde uyum olduğunu göstermiştir (ICC = .92). Ayrıca hedef kişilik özellikleri düzeyinde yürütülen ICC analizlerinde değerlendiriciler arası uyumun kibirli kişilik özelliği için .89, inatçı kişilik özelliği için ise .84 düzeyinde olduğu saptanmıştır. Bu bulgular, katılımcıların cümleleri ilgili kişilik özellikleri açısından tutarlı biçimde değerlendirdiğini göstermektedir. Değerlendirme sonuçları doğrultusunda, Sosyal Yargı Görevi'nde kullanılmak üzere "kibirli" ve "inatçı" kişilik özellikleri seçilmiş; bu kapsamda her bir özellik için ilgili kişilik özelliğini temsil etme puan ortalaması 3.00'ün üzerinde olan yedişer aday cümle olmak üzere toplam 14 aday cümle belirlenmiştir.

5. ÖN ÇALIŞMA 3

Üçüncü ön çalışma, "kibirli" ve "inatçı" hedef kişilik özelliklerini temsil eden nihai onar cümleyi belirlemek amacıyla yürütülmüştür. Bu kapsamda, ikinci ön çalışmada uygun bulunan toplam 14 aday cümle dil, anlam ve çağrışım açısından yeniden gözden geçirilmiş ve bazı ifadelerde düzenlemeler yapılmıştır. Ayrıca nihai görev setinde her bir kişilik özelliği için 10 cümle yer alması planlandığından, araştırmacılar tarafından her bir hedef kişilik özelliği için altışar yeni cümle oluşturulmuştur. Yapılan düzenlemeler ve eklenen yeni cümleler nedeniyle, aday cümlelerin hedef kişilik özelliklerini temsil etme düzeylerinin yeniden değerlendirilmesi gerekli görülmüştür. Böylece bu ön çalışmada her bir kişilik özelliği için on üçer aday cümle olmak üzere toplam 26 aday cümle değerlendirmeye alınmıştır.

5.1. YÖNTEM

5.1.1. Örneklem

Çalışmaya 20–57 yaşları (Ort. = 34.21, SS = 8.82) arasında, 27 kadın ve 15 erkek olmak üzere toplam 42 öğrenci katılmıştır.

5.1.2. Veri Toplama Araçları

5.1.2.1. Cümle Değerlendirme Formu

Katılımcılardan "kibirli" ve "inatçı" kişilik özelliklerine ilişkin cümleleri, ilgili kişilik özelliğini yansıtma düzeyi bakımından 1 = Hiç yansıtmıyor ile 5 = Tamamıyla yansıtıyor arasında değişen beşli Likert tipi ölçek üzerinde değerlendirmeleri istenmiştir.

5.2. BULGULAR VE SONUÇ

Elde edilen veriler doğrultusunda cümleler, ortalama temsil puanlarına göre sıralanmıştır. Cümleler arasından her bir kişilik özelliği için ortalama puanı en yüksek olan ve hedef kişilik özelliğini yeterli düzeyde temsil ettiği değerlendirilen 10 cümle seçilmiştir. Böylece Sosyal Yargı Görevi'nde kullanılacak "kibirli" ve "inatçı" kişilik özelliklerine ilişkin nihai onar cümle belirlenmiştir. Belirlenen cümlelere ait ortalama temsil puanları ve standart sapmalar Tablo 1'de sunulmuştur.

Tablo 1. Sosyal Yargı Görevi'nde Kullanılacak Nihai Cümlelere Ait Ortalama Temsil Puanları ve Standart Sapmalar

Kişilik Özelliği	Cümle No	Cümle	Ort.	SS
İnatçı	1	Bir şeye evet dediysem evettir, hayır dediysem hayırdır.	3.71	1.49
	2	Şimdiye kadar kimse beni ikna edemedi, bu yüzden enerjinizi boşuna harcamayın.	3.69	1.33
	3	Bir plan yaptıysam onu uygularım; hiç kimse planımı değiştiremez.	3.79	1.20
	4	Doğru ya da yanlış fark etmez; ağzımdan çıktıysa dediğim olur.	4.00	1.43
	5	Her yolu bana anlatabilirler ama ben yine kendi bildiğimi uygularım.	3.79	1.34
	6	Bir konuda kendi kararımı verdiysem, başkalarının önerilerini kabul etmem.	3.74	1.38
	7	Bir tartışmada haklı olmasam bile geri adım atmam.	4.05	1.51
	8	Arkadaşlarım ne kadar tatlı dille yaklaşsa da kararım netse kimse bunu değiştiremez.	3.86	1.28
	9	Israr ediyorsam bir nedeni vardır; boşuna uğraşmayın, beni yolumdan döndüremezsiniz.	3.69	1.26
	10	Israr edildiğinde geri adım atmak yerine daha da sertleşirim.	3.60	1.36
Kibirli	1	Benden iyi bildiğini düşünenler genelde yanıldıklarını anlıyor.	3.76	1.05
	2	Alt düzey bir çalışan olarak, emirleri sorgulamadan yerine getirmen gerekir.	3.76	1.57
	3	Fikrini sormadım; haddini bilseydin, küçük aklınla bulduğun bu basit planı söylemeye cesaret edemezdin.	3.74	1.68
	4	Lütfedip geldiğim için beni ayakta karşılamalıydınız; böyle sıradan toplantılara vakit ayırmam.	3.76	1.71
	5	Proje başarılı olduysa büyük ihtimalle benim sayemdedir.	3.95	1.17
	6	Kıyaslandığım kişilerin çoğu benimle aynı kulvarda bile değil.	3.90	1.19
	7	Benim kadar yetenekli biriyle çalışmak onların şansı.	3.64	1.51
	8	Beni anlamaları için önce benim seviyeme çıkmaları gerekiyor.	3.71	1.44
	9	Bu beceriksiz ekibi ben zorladım, proje böyle tamamlandı; ben olmasaydım hiçbir iş yapamazlardı.	3.83	1.65
	10	Her şeyi en iyi şekilde düşündüğüm için bana kimse akıl veremez, bunu bilmelisin.	4.05	1.50

6. GENEL TARTIŞMA VE SONUÇ

Bu çalışma kapsamında, sosyal bağlamda kişilik çıkarımına dayalı karar verme süreçlerini incelemek üzere kullanılabilecek Sosyal Yargı Görevi'nin cümle materyalleri geliştirilmiş ve

nihai görev yapısı oluşturulmuştur. Yürütülen ön çalışmalar sonucunda, görevde kullanılmak üzere "kibirli" ve "inatçı" kişilik özelliklerini temsil eden nihai cümle setleri belirlenmiştir. Görev, her biri bir hedef kişilik özelliğine karşılık gelen iki bloktan oluşacak şekilde yapılandırılmıştır. Her blokta, aynı hedef kişiye ait olduğu belirtilen cümleler katılımcılara tek tek sunulacak ve katılımcılardan bu kişinin ilgili kişilik özelliğine sahip olup olmadığına karar vermeleri istenecektir. Katılımcılar her cümleden sonra karar verebilecek ya da karar vermeden önce ek ifade görmeyi talep edebilecektir. Bu doğrultuda, karar öncesinde talep edilen cümle sayısı görevin temel performans göstergesi olarak kaydedilecektir. Daha az sayıda cümleye dayanarak karar verme, sosyal içerikli bilgi toplama eğiliminin daha düşük ve sonuca atlama yanlılığının görece daha yüksek olduğuna işaret eden bir gösterge olarak değerlendirilecektir. Blokların sunum sırası karşıt dengelenecektir. Bu yönüyle geliştirilen görev, sosyal bağlamda kişilik çıkarımına dayalı yargılama ve karar verme süreçlerini incelemek için kısa, yalın ve uygulanabilir bir deneysel paradigma sunmaktadır.

Boncuk Görevi'nin, sanrısal (delüzyonel) eğilimlerle ilişkili bilişsel belirteçlerden biri olarak kabul edilen sonuca atlama yanlılığını değerlendirmede yaygın biçimde kullanıldığı bilinmektedir (Dudley vd., 2016; McLean vd., 2017; Ross vd., 2015; So vd., 2016; So ve Kwok, 2015; Van Der Leer vd., 2015). Bununla birlikte, Boncuk Görevi'nin soyut yapısı ve gündelik sosyal kararlarla sınırlı benzerliği, sonuca atlama eğiliminin sosyal yargı süreçlerindeki karşılığını değerlendirmede sınırlı kalabilmektedir. Mevcut çalışmada geliştirilen Sosyal Yargı Görevi, bu sınırlılıktan hareketle, bireylerin tanımadıkları bir kişi hakkında kişilik temelli bir yargıya ulaşmadan önce ne kadar sosyal bilgi toplamaya ihtiyaç duyduklarını değerlendirmeyi amaçlamaktadır. Bu nedenle görev, klasik Boncuk Görevi'nin ölçtüğü bilgi toplama eğilimini ve sonuca atlama yanlılığını sosyal bağlama taşıyan, ekolojik geçerliği görece daha yüksek olabilecek tamamlayıcı bir paradigma olarak değerlendirilebilir.

Bununla birlikte, bu çalışmanın bazı sınırlılıkları bulunmaktadır. Öncelikle görev, bu aşamada yalnızca "kibirli" ve "inatçı" olmak üzere iki olumsuz kişilik özelliği üzerinden geliştirilmiştir. Bu nedenle görevin olumlu ya da nötr kişilik özelliklerine dayalı sosyal karar verme süreçlerine genellenebilirliği ileriki çalışmalarda ayrıca sınanmalıdır. Ayrıca mevcut çalışma, görevin cümle materyallerinin geliştirilmesine ve hedef kişilik özelliklerini temsil etme düzeylerinin değerlendirilmesine odaklanmıştır. Bu nedenle geliştirilen Sosyal Yargı Görevi'nin psikometrik özelliklerinin sonraki araştırmalarda ayrıntılı biçimde incelenmesi gerekmektedir. Gelecek çalışmalarda görevin yapı geçerliği, ölçüt bağlantılı geçerliği ve ekolojik geçerliği değerlendirilerek Boncuk Görevi ve Sosyal Boncuk Görevi gibi mevcut bilgi toplama ve

sonuca atlama ölçümleriyle ilişkisi incelenebilir. Ayrıca görevin test-tekrar test güvenirliği, bloklar arası tutarlılığı ve farklı klinik ve klinik olmayan örneklemlerde elde edilen performans göstergelerinin kararlılığı değerlendirilmelidir. Özellikle sanrısal eğilimleri yüksek ve düşük bireylerin Sosyal Yargı Görevi'ndeki performanslarının karşılaştırılması, görevin bu eğilimleri belirlemedeki ayırt edici gücünü ortaya koymak açısından önemli olacaktır.

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GENETİK TANILI ÇOCUKLARDA FARMAKOLOJİK TEDAVİ İLE FİZYOTERAPİNİN EŞ ZAMANLI UYGULANMASININ MOTOR FONKSİYON VE YAŞAM KALİTESİ ÜZERİNE ETKİSİ

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ÖZET

Genetik tanılı nöromüsküler hastalıklar (spinal müsküler atrofi [SMA], Duchenne müsküler distrofisi [DMD] ve diğer genetik nöromüsküler hastalıklar) çocukluk çağında ilerleyici kas güçsüzlüğü, motor fonksiyon kaybı ve solunum yetmezliği ile seyreden, önemli morbidite ve mortaliteye yol açan kalıtsal bozukluklardır. Son yıllarda *nusinersen, risdiplam, onasemnogene abeparvovec* ve kortikosteroidler gibi hastalık-modifiye edici tedaviler bu hastalıkların doğal seyrini önemli ölçüde değiştirmiştir. Bununla birlikte, farmakolojik tedavinin tek başına yeterli olmadığı; fizyoterapi ve rehabilitasyonun eş zamanlı yürütülmesinin fonksiyonel kazanımları desteklediği ve artırdığı bildirilmektedir. Bu sistematik derlemenin amacı, 2021–2026 yılları arasında yayımlanan güncel literatür ışığında, genetik tanılı çocuklarda farmakolojik tedavi ile fizyoterapi/rehabilitasyonun eş zamanlı uygulanmasının motor fonksiyon, solunum kapasitesi ve yaşam kalitesi üzerindeki etkisini sistematik biçimde incelemektir. Tarama, PubMed/MEDLINE, Web of Science, Scopus, Cochrane Library ve PEDro veri tabanlarında; "physiotherapy", "rehabilitation", "spinal muscular atrophy", "Duchenne muscular dystrophy", "nusinersen", "risdiplam", "onasemnogene", "corticosteroid" ve "disease modifying therapy" anahtar sözcükleri ile gerçekleştirilmiş; 2021–2026 aralığında 0–18 yaş popülasyonunu kapsayan araştırma makaleleri ve derlemelerle sınırlandırılmıştır. Belirlenen kriterleri karşılayan 23 çalışma değerlendirmeye alınmıştır. Bu çalışmaların yaklaşık %65'i (n=15) SMA, %30'u (n=7) DMD ve %5'i (n=1) diğer genetik nöromüsküler hastalıklara ilişkindir. Bulgular, nusinersen ile eş zamanlı uygulanan fizyoterapinin yalnız ilaç tedavisine kıyasla kaba motor kazanımları belirgin biçimde arttırdığını; kapsamlı rehabilitasyon programlarının kaba motor fonksiyon ve solunum kapasitesinde anlamlı düzelme sağladığını; DMD'de kortikosteroidle birlikte yürütülen gözetimli egzersizin kas gücü ve fonksiyon kaybını yavaşlattığını göstermektedir. Bununla birlikte incelenen çalışmalarda standart bir uygulama protokolü bulunmamakta; etkiler hastalığın alt türüne, demografik verilere ve uygulama

merkezine göre değişkenlik göstermektedir. Sonuç olarak, genetik tanılı çocuklarda hastalığa özgü, bireyselleştirilmiş ve multidisipliner ilaç–fizyoterapi kombinasyonundan oluşan rehabilitasyon protokollerinin oluşturulması ve bu protokollerin etkinliğini değerlendiren randomize kontrollü çalışmaların planlanması önerilmektedir.

Anahtar kelimeler: Genetik tanılı çocuklar, fizyoterapi, farmakolojik tedavi entegrasyonu, nusinersen, Duchenne müsküler distrofisi, spinal müsküler atrofi, rehabilitasyon.

THE EFFECT OF CONCURRENT PHARMACOLOGICAL TREATMENT AND PHYSIOTHERAPY ON MOTOR FUNCTION AND QUALITY OF LIFE IN CHILDREN WITH GENETIC DIAGNOSES

ABSTRACT

Genetically diagnosed neuromuscular diseases (spinal muscular atrophy [SMA], Duchenne muscular dystrophy [DMD], and other genetic neuromuscular diseases) are hereditary disorders that progress with muscle weakness, loss of motor function, and respiratory insufficiency in childhood, leading to substantial morbidity and mortality. In recent years, disease-modifying therapies such as nusinersen, risdiplam, onasemnogene abeparvovec, and corticosteroids have substantially changed the natural course of these diseases. However, pharmacological treatment alone is reported to be insufficient, and concurrent physiotherapy and rehabilitation support and enhance functional gains. This systematic review aims to systematically examine the effect of concurrent pharmacological treatment and physiotherapy/rehabilitation on motor function, respiratory capacity, and quality of life in children with genetic diagnoses, based on the literature published between 2021 and 2026. The search was conducted in PubMed/MEDLINE, Web of Science, Scopus, Cochrane Library, and PEDro databases and was limited to research articles and reviews covering the 0–18 age population published between 2021 and 2026. Twenty-three studies meeting the criteria were evaluated. Approximately 65% (n=15) concerned SMA, 30% (n=7) DMD, and 5% (n=1) other genetic neuromuscular diseases. The findings show that physiotherapy applied concurrently with nusinersen markedly increases gross motor gains compared with drug therapy alone; that comprehensive rehabilitation programs provide significant improvement in gross motor function and respiratory capacity; and that supervised exercise combined with corticosteroids in DMD slows the loss of muscle strength and function. However, no standardized protocol was found in the reviewed studies; effects varied according to disease subtype, demographic data, and application center. In conclusion, the establishment of disease-specific, individualized, and multidisciplinary rehabilitation protocols combining pharmacological

treatment and physiotherapy, and the planning of randomized controlled trials evaluating their effectiveness, are recommended.

Keywords: Children with genetic diagnoses, physiotherapy, pharmacological treatment integration, nusinersen, Duchenne muscular dystrophy, spinal muscular atrophy, rehabilitation.

1. GİRİŞ

Genetik kökenli nöromüsküler hastalıklar, çocukluk çağında görülen, ilerleyici kas güçsüzlüğü ve motor fonksiyon kaybına yol açan, kalıtsal ve çoğunlukla ilerleyici seyirli bozukluklardır. Bu hastalık grubu içinde en sık karşılaşılan ve en yoğun çalışılan tablolar spinal müsküler atrofi (SMA) ve Duchenne müsküler distrofisidir (DMD). SMA, survival motor neuron 1 (SMN1) genindeki homozigot delesyon veya mutasyonlara bağlı olarak SMN proteininin azalması ve ön boynuz motor nöronlarının dejenerasyonu sonucu ilerleyici kas atrofisi ve güçsüzlüğü ile seyreden, otozomal resesif geçişli bir hastalıktır (Mercuri ve ark. 2021). DMD ise distrofin proteininin yokluğuna bağlı olarak gelişen, X'e bağlı resesif geçişli, ilerleyici bir kas distrofisi olup, neredeyse yalnızca erkek çocukları etkiler ve tedavi edilmediğinde erken yaşta ambulasyon kaybı ile sonuçlanır (Birnkrant ve ark. 2018).

SMA, 2016 yılına kadar çocukluk çağının en sık kalıtsal ölüm nedeniydi; bu tarihten itibaren ardı ardına onay alan üç hastalık-modifiye edici tedavi hastalığın yönetiminde köklü bir tedavi değişimine yol açmıştır (Singh ve ark. 2024). Bu ajanlar; SMN2 pre-mRNA düzenlemesini hedefleyen antisens oligonükleotid nusinersen, SMN1 genini ileten tek dozluk gen replasman tedavisi onasemnogene abeparvovec olarak sıralanabilir (Mercuri ve ark. 2021). Nusinersenin, özellikle erken ve presemptomatik dönemde başlandığında motor fonksiyonu iyileştirmede yüksek etkinlik gösterdiği klinik çalışmalarla ortaya konmuştur (Albrechtsen ve ark. 2020). DMD'de ise *prednizolon* ve *deflazakort* gibi kortikosteroidler, ambulasyon süresini uzatan ve fonksiyonu koruyan birinci basamak farmakolojik ajanlar olarak klinik bakımın temelini oluşturmaktadır (Gloss ve ark. 2016).

Bu farmakolojik ilerlemelere karşın, tedavi edici yaklaşımların tek başına uygulanmasının fonksiyonel sonuçları en üst düzeye çıkarmakta yetersiz kaldığı; fizyoterapi ve rehabilitasyonun eş zamanlı yürütülmesinin bu kazanımları desteklediği giderek artan biçimde vurgulanmaktadır. Rehabilitasyon, kontraktür gelişiminin önlenmesi, eklem hareket açıklığının korunması, solunum fonksiyonunun desteklenmesi ve fonksiyonel bağımsızlığın arttırılması açısından bakımın kritik bir bileşenidir (Wang ve ark. 2025). Geçmişte fizyoterapi ve uğraşı terapisi, hastalığın ilerleyici doğası nedeniyle ağırlıklı olarak ekipman sağlama, kompansatuar stratejiler ve kontraktür gibi sekonder komplikasyonların önlenmesine

odaklanırken; yeni tedavi yaklaşımlarının arttırılmasıyla birlikte aileler, çocukları için fonksiyonel performansı en üst düzeye çıkaracak proaktif rehabilitasyon yaklaşımları aramaya başlamıştır (Hu ve ark. 2025).

Bununla birlikte, farmakolojik tedavi ile rehabilitasyonun eş zamanlı uygulanmasına ilişkin kanıtlar dağınık olup, farklı hastalık alt türlerinde ve farklı çalışma tasarımlarında elde edilmiştir. Bu nedenle, mevcut kanıtların sistematik biçimde sentezlenmesi klinik karar verme açısından önem taşımaktadır. Bu sistematik derlemenin amacı, 2021–2026 yılları arasında yayımlanan güncel literatür ışığında, genetik tanılı çocuklarda farmakolojik tedavi ile fizyoterapi/rehabilitasyonun eş zamanlı uygulanmasının motor fonksiyon, solunum kapasitesi ve yaşam kalitesi üzerindeki etkisini incelemektir.

2. GEREÇ VE YÖNTEM

2.1. Çalışma Tasarımı

Bu çalışma, sistematik derleme niteliğinde olup, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) bildirim ilkeleri doğrultusunda planlanmış ve yürütülmüştür. Derleme, genetik tanılı çocuklarda farmakolojik tedavi ile fizyoterapinin eş zamanlı uygulanmasına ilişkin güncel kanıtların nitel sentezini amaçlamaktadır.

2.2. Literatür Tarama Stratejisi

Literatür taraması, PubMed/MEDLINE, Web of Science, Scopus, Cochrane Library ve PEDro elektronik veri tabanlarında gerçekleştirilmiştir. Taramada kullanılan başlıca anahtar sözcükler ve bunların “AND” / “OR” mantıksal bağlaçları ile oluşturulan kombinasyonları şunlardır: “physiotherapy”, “physical therapy”, “rehabilitation”, “genetic disorder”, “neuromuscular”, “spinal muscular atrophy”, “Duchenne muscular dystrophy”, “nusinersen”, “risdiplam”, “onasemnogene”, “corticosteroid”, “disease modifying therapy”, “child” ve “pediatric”.

2.3. Dahil Etme ve Dışlama Kriterleri

Çalışmaların derlemeye dahil edilmesinde aşağıdaki kriterler esas alınmıştır: (i) 2021–2026 yayım aralığında yer alması, (ii) 0–18 yaş popülasyonunu içermesi, (iii) araştırma makalesi veya derleme türünde olması ve (iv) genetik nöromüsküler tanılı popülasyonda farmakolojik tedavi ile fizyoterapi/rehabilitasyon ilişkisini konu alması. Tam metnine ulaşılamayan, İngilizce veya Türkçe dışındaki dillerde yayımlanmış, konu kapsamı dışında kalan ve yöntemsel bilgisi yetersiz olan çalışmalar değerlendirme dışı bırakılmıştır.

2.4. Çalışma Seçimi ve Veri Çıkarımı

Belirlenen anahtar sözcüklerle elde edilen kayıtlar önce başlık ve özet düzeyinde taranmış; ön elemeyi geçen çalışmaların tam metinleri dahil etme kriterleri açısından değerlendirilmiştir.

Çalışma seçimi sürecinde, olası yanlılığı azaltmak amacıyla iki değerlendirici bağımsız olarak görev almış; görüş ayrılıkları tartışma yoluyla uzlaşı ile çözülmüştür. Her çalışmadan; hastalık alt türü, örneklem özellikleri, uygulanan farmakolojik tedavi, fizyoterapi/rehabilitasyon yaklaşımı ve motor fonksiyon, solunum kapasitesi ile yaşam kalitesine ilişkin sonuç ölçütleri sistematik biçimde çıkarılmıştır. Belirlenen kriterleri karşılayan toplam 23 çalışma derlemeye dahil edilmiştir.

3. BULGULAR

3.1. Dahil Edilen Çalışmaların Genel Dağılımı

Değerlendirmeye alınan 23 çalışmanın hastalık alt türlerine göre dağılımı Tablo 1'de sunulmuştur. Çalışmaların yaklaşık %65'i (n=15) SMA, %30'u (n=7) DMD ve %5'i (n=1) diğer genetik nöromüsküler hastalıklara ilişkindir. Bu dağılım, güncel literatürde özellikle SMA üzerine yoğunlaşan belirgin bir araştırma ilgisinin bulunduğunu; DMD'nin ikinci sırada yer aldığını ve diğer genetik nöromüsküler hastalıkların ise görece az çalışıldığını ortaya koymaktadır.

Tablo 1. Dahil edilen çalışmaların hastalık alt türüne göre dağılımı

Hastalık alt türü	**Çalışma sayısı (n)**	**Oran (%)**
Spinal müsküler atrofi (SMA)	15	65
Duchenne müsküler distrofisi (DMD)	7	30
Diğer genetik nöromüsküler hastalıklar	1	5
Toplam	**23**	**100**

3.2. SMA'da Farmakolojik Tedavi ve Fizyoterapinin Eş Zamanlı Etkisi

İncelenen çalışmalar, nusinersen ile eş zamanlı uygulanan fizyoterapinin yalnız ilaç tedavisine kıyasla motor kazanımları belirgin biçimde artırdığını ortaya koymaktadır. Geriye dönük bir çalışmada, nusinersen tedavisi alan ve haftada beş gün fizyoterapiye katılan bireylerde kaba motor kazanımın, haftada birden az seans alan bireylere kıyasla anlamlı düzeyde yüksek olduğu; bu farkın tedavinin birinci yılında istatistiksel olarak anlamlı düzeye ulaştığı bildirilmiştir (Hu ve ark. 2025). Benzer biçimde, tip-2 SMA'lı çocuklarda yürütülen gözlemsel bir çalışmada, rehabilitasyon uygulanan grupta motor fonksiyon kazanımının rehabilitasyon uygulanmayan gruba göre daha belirgin olduğu; ayrıca serum ve beyin omurilik sıvısındaki fosforile nörofilament ağır zincir (pNF-H) düzeylerinde anlamlı azalma gözlendiği rapor

edilmiştir (Wang ve ark. 2025). Bu bulgular, farmakolojik tedavinin etkinliğinin eş zamanlı rehabilitasyon ile artırılabileceğini güçlü biçimde desteklemektedir.

Hastalık-modifiye edici tedavilerin etkinliğine ilişkin sistematik kanıtlar da bu yaklaşımı tamamlamaktadır. Onaylı tedavilerle (*nusinersen, onasemnogene abeparvovec, risdiplam*) ilgili güncel bir sistematik derlemede, bu ajanların motor fonksiyonda 48 aya varan takip süresince iyileşme sağladığı; ancak çalışmalar arasındaki belirgin heterojenliğin nicel sentezi güçleştirdiği vurgulanmıştır (Müschen ve ark. 2024). Bu heterojenlik, fizyoterapinin rolünün standartlaştırılmış protokoller çerçevesinde araştırılması gereğini öne çıkarmaktadır.

3.3. Kaba Motor Fonksiyon ve Solunum Kapasitesi Üzerine Etkiler

Kapsamlı rehabilitasyon programlarının, kaba motor fonksiyon ve solunum kapasitesinde anlamlı düzelme sağladığı görülmüştür. Nöromüsküler hastalıklarda uygun biçimde gözetim altında uygulanan submaksimal aerobik ve direnç eğitiminin, germe ve solunum egzersizleriyle birlikte fonksiyonel kazanımları desteklediği bildirilmektedir (Voet ve ark. 2019). SMA yönetiminde ayakta durma programları, solunum kası eğitimi ve bireyin motor düzeyine uyarlanmış aerobik kapasite, fonksiyonel sonuçların iyileştirilmesinde önemli rol oynamaktadır. Bununla birlikte, kombine kuvvet ve aerobik egzersizin aşırı kullanıma bağlı olası etkileri nedeniyle dikkatli ve bireyselleştirilmiş biçimde planlanması gerektiği vurgulanmaktadır (Voet ve ark. 2019).

3.4. DMD'de Kortikosteroid ve Egzersizin Eş Zamanlı Etkisi

DMD'de kortikosteroidler, kas gücünü ve fonksiyonunu kısa dönemde anlamlı biçimde iyileştirmekte; ambulasyon kaybını geciktirmekte, üst ekstremite fonksiyonunu ve solunumu korumaktadır (Gloss ve ark. 2016). Cochrane temelli kanıtlar, 0,75 mg/kg/gün dozunda kortikosteroidlerin altı aylık dönemde plaseboya kıyasla kas gücü ve fonksiyonu iyileştirdiğini; gücü iki yıla kadar koruduğunu göstermektedir (Matthews ve ark. 2016). Eş zamanlı yürütülen, uygun biçimde gözetilen egzersiz programlarının ise kas gücü ve enduransını koruyarak fonksiyonel kaybı yavaşlattığı bildirilmektedir (Gianola ve ark. 2022). Bununla birlikte, ağırlık taşıyan ve eksantrik temelli egzersizlerin distrofik kaslarda aşırı yüklenmeye bağlı zararlı olabileceği; bu nedenle programların hastalığa özgü olarak bireyselleştirilmesi ve düşük-orta yoğunlukta planlanması gerektiği önemle vurgulanmaktadır (Gianola ve ark. 2022).

4. TARTIŞMA

Bu sistematik derlemenin bulguları, genetik tanılı çocuklarda farmakolojik tedaviyle eş zamanlı sürdürülen fizyoterapi ve rehabilitasyonun, yalnız ilaç tedavisi uygulanan bireylere göre motor fonksiyon ve solunum kapasitesinde anlamlı iyileşmeler sağladığını ortaya

koymaktadır. Bu sonuç, hastalık-modifiye edici tedavilerin etkinliğinin uygun rehabilitasyon ile tamamlandığı görüşünü desteklemektedir. Nusinersen tedavisindeki fonksiyonel iyileşmenin altında, uyuyan motor nöronların yeniden etkinleştirilmesi ve aksonal filizlenme yoluyla kollateral reinnervasyon gibi nöroplastik süreçlerin yattığı; bu moleküler temelin erken ve yoğun rehabilitasyonun gerekçesini güçlendirdiği belirtilmektedir (Wang ve ark. 2025). Dolayısıyla farmakolojik tedavi ile fizyoterapi, birbirini tamamlayan müdahaleler olarak değerlendirilmelidir.

Kombinasyon tedavisi yaklaşımına yönelik artan klinik ilgi, yalnızca rehabilitasyonla sınırlı olmayıp farmakolojik ajanların kendi aralarındaki kombinasyonlarını da kapsamaktadır. *Onasemnogene abeparvovec* sonrası *risdiplam* eklenen çocuklarda motor, solunum ve yutma fonksiyonlarında stabilite veya iyileşme bildiren çok merkezli olgu serileri, bireyselleştirilmiş ve çok bileşenli tedavi yaklaşımlarının değerini vurgulamaktadır (Erdos ve ark. 2025). Bu bağlamda fizyoterapi, çok bileşenli tedavi planının ayrılmaz bir parçası olarak konumlanmalıdır.

Bununla birlikte, bu derlemenin ortaya koyduğu en önemli limitasyon, incelenen çalışmalarda standart bir uygulama protokolünün bulunmamasıdır. Tedavi etkileri; hastalığın alt türüne, hastaların yaşı, hastalık evresi ve genetik altyapısı gibi demografik özelliklere ve çalışmanın yürütüldüğü merkeze göre belirgin değişkenlik göstermektedir. Ayrıca, SMA ve DMD dışındaki genetik nöromüsküler hastalıklara ilişkin çalışma sayısının oldukça sınırlı olması, bulguların bu alt gruplara genellenebilirliğini kısıtlamaktadır. Çalışmaların çoğunun gözlemsel veya geriye dönük tasarımda olması ve örneklem büyüklüklerinin görece küçük olması, kombine tedavi yaklaşımlarının etkinliğine ilişkin kesin nedensel çıkarımlar yapılmasını güçleştirmektedir. Bu metodolojik kısıtlılıklar, alanda standartlaştırılmış, prospektif ve randomize kontrollü çalışmalara duyulan gereksinimi açıkça ortaya koymaktadır.

5. SONUÇ

Genetik tanılı çocuklarda farmakolojik tedaviyle eş zamanlı sürdürülen fizyoterapi ve rehabilitasyon, yalnız ilaç tedavisine göre motor fonksiyon ve solunum kapasitesinde anlamlı iyileşme sağlamaktadır. Buna karşın incelenen çalışmalarda belirli ve standart bir protokol bulunmamakta; etkiler hastalığın alt türüne, demografik verilere ve uygulama merkezlerine göre değişkenlik göstermektedir. Bu doğrultuda, klinik pratikte hastalığa özgü, bireyselleştirilmiş ve multidisipliner farmakolojik–fizyoterapi kombinasyonundan oluşan rehabilitasyon protokollerinin oluşturulması; bu protokollerin yürüyüş, denge, motor fonksiyon, solunum kapasitesi ve yaşam kalitesi üzerindeki etkilerini değerlendiren, yeterli

örneklem büyüklüğüne sahip, çok merkezli ve uzun dönem takipli randomize kontrollü çalışmaların planlanması önerilmektedir. Bu tür çalışmalar, farmakolojik ve fizyoterapi yaklaşımların kombinasyonuna yönelik kanıta dayalı tedavi protokollerinin geliştirilmesine katkı sağlayacaktır.

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PARKİNSON HASTALARINDA LSVT BIG İLE KOMBİNE UYGULANAN MOTOR İMGELEME EĞİTİMLERİNİN ETKİNLİĞİ: NÖROFİZYOLOJİK TEMEL

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ÖZET

Parkinson hastalığı (PH), substantia nigra pars compacta'daki dopaminerjik nöronların ilerleyici kaybına ve bazal gangliyon işlevindeki bozulmaya bağlı olarak gelişen; bradikinezi, hipokinezi, postural instabilite ve yürüyüş bozuklukları ile seyreden ilerleyici bir nörodejeneratif hastalıktır. Bu motor belirtiler bireylerin genellikle, yeterince kontrol altına alınamamakta ve yaşam kalitesini olumsuz etkilemektedir. Bu nedenle egzersiz temelli rehabilitasyon yaklaşımları, Parkinson yönetiminde giderek artan bir öneme sahiptir. Rehabilitasyonun temel hedeflerinden biri, hareket amplitüdüne ilişkin bozulmuş duyusal-proprioseptif algının yeniden düzenlenmesi ve hareketin zihinsel temsilinin yeniden yapılandırılmasıdır. LSVT BIG (Lee Silverman Voice Treatment – BIG), büyük amplitüdlü hareketlerin yüksek yoğunlukta ve çok sayıda tekrarla uygulandığı, kanıta dayalı bir egzersiz protokolüdür ve etki mekanizması büyük ölçüde proprioseptif regülasyon ile aktiviteye bağlı nöroplastisite üzerine kuruludur. Motor imgeleme (Mİ) ise bir hareketin açık kas aktivasyonu olmaksızın zihinde prova edilmesi olup, gerçek bir motor hareket sırasında etkinleşen kortikal ve subkortikal ağları büyük ölçüde benzer biçimde aktive eder. Bu yapısal derlemenin amacı, primer Parkinson hastalarında LSVT BIG ile motor imgeleme eğitiminin birlikte uygulanmasının nörofizyolojik temelini değerlendirmek ve bu alandaki literatür eksikliğini ortaya koymaktır. Mevcut literatürde motor imgeleme; genel fizyoterapi, sanal gerçeklik ve yürüyüş eğitimi gibi yaklaşımlarla birlikte çalışılmıştır. Ancak özellikle LSVT BIG protokolü ile birlikte uygulanan motor imgelemeyi inceleyen kontrollü çalışmalara bildiğimiz kadarıyla literatürde rastlanmamıştır. Her iki yöntem de hareketin zihinsel temsilinin yeniden yapılandırılması ve hareket için gerekli amplitüdün düzeltilmesi gibi birbirini tamamlayıcı nitelik taşımaktadır. Motor imgelemenin terapist gözetimi gerektirmeden ev ortamında ve düşük maliyetle uygulanabilmesi, LSVT BIG'in yoğun protokolüne ek bir seçenek sunabileceğini düşündürmektedir. Sonuç olarak, bu kombinasyonun yürüyüş, denge, motor işlev ve yaşam kalitesi üzerindeki etkilerinin; randomize kontrollü, yeterli örneklem büyüklüğüne sahip ve uzun dönem takipli çalışmalarla araştırılması gerekmektedir. Bu

derlemenin, ilgili gelecek çalışmalara yapısal bir nörofizyolojik temel sunacağı düşünülmektedir.

Anahtar kelimeler: Parkinson hastalığı, LSVT BIG, motor imgeleme, kombine rehabilitasyon, nöroplastisite.

THE EFFICACY OF MOTOR IMAGERY TRAINING COMBINED WITH LSVT BIG IN PATIENTS WITH PARKINSON'S DISEASE: NEUROPHYSIOLOGICAL BASIS

ABSTRACT

Parkinson's disease (PD) is a progressive neurodegenerative disorder caused by the progressive loss of dopaminergic neurons in the substantia nigra pars compacta and dysfunction of the basal ganglia, characterized by bradykinesia, hypokinesia, postural instability, and gait disturbances. Despite optimal medical and surgical treatment, these motor symptoms cannot be adequately controlled in the vast majority of individuals and negatively affect quality of life. Therefore, exercise-based rehabilitation approaches are of increasing importance in PD management. One of the main goals of rehabilitation is the recalibration of the impaired sensory-proprioceptive perception of movement amplitude and the reconstruction of the mental representation of movement. LSVT BIG (Lee Silverman Voice Treatment – BIG) is an evidence-based exercise protocol in which large-amplitude movements are applied at high intensity with numerous repetitions, and its mechanism of action is largely based on proprioceptive recalibration and activity-dependent neuroplasticity. Motor imagery (MI), on the other hand, is the mental rehearsal of a movement without overt muscle activation, and it activates the cortical and subcortical networks engaged during actual motor execution in a largely similar manner. The aim of this conceptual review is to evaluate the neurophysiological basis of the combined application of LSVT BIG and motor imagery training in patients with primary Parkinson's disease and to reveal the literature gap in this field. In the existing literature, motor imagery has been studied together with approaches such as general physiotherapy, virtual reality, and gait training. However, no controlled studies examining motor imagery applied specifically together with the LSVT BIG protocol were found. Both methods act through common goals such as reconstructing the mental representation of movement and correcting the amplitude required for movement, and they are complementary in nature. The fact that motor imagery can be applied at home and at low cost without requiring therapist supervision suggests that it may offer an additional option to the intensive LSVT BIG protocol. In conclusion, the effects of this combination on gait, balance, motor function, and quality of life should be investigated

through randomized controlled studies with adequate sample sizes and long-term follow-up. This review is expected to provide a theoretical framework for future studies on this topic.

Keywords: Parkinson's disease, LSVT BIG, motor imagery, combined rehabilitation, neuroplasticity.

1. GİRİŞ

Parkinson hastalığı (PH), substantia nigra pars compacta'daki dopaminerjik nöronların ilerleyici kaybı ve bazal gangliyon devrelerindeki işlev bozukluğu ile karakterize, Alzheimer hastalığından sonra en sık görülen ikinci nörodejeneratif hastalıktır (Bloem ve ark. 2021). Hastalığın temel motor belirtileri bradikinezi, hipokinezi, postural instabilite ve yürüyüş bozukluklarıdır. Bu belirtilere ek olarak hastalık; bilişsel bozukluklar, duygudurum değişiklikleri ve otonomik işlev bozuklukları gibi motor olmayan belirtilerle de seyredebilmektedir (Bloem ve ark. 2021).

Parkinson hastalığının motor belirtileri, farmakolojik ve cerrahi derin beyin stimülasyonu gibi cerrahi tedaviye karşın bireylerin büyük çoğunluğunda yeterince kontrol altına alınamamakta ve yaşam kalitesini önemli ölçüde olumsuz etkilemektedir (Fox ve ark. 2012). Bu nedenle, son yıllarda egzersiz temelli davranışsal rehabilitasyon yaklaşımları, hastalığın yönetiminde tamamlayıcı ve giderek merkezi bir konuma yerleşmiştir. Temel bilim çalışmaları, egzersizin yalnızca motor performansı iyileştirmekle kalmayıp, aktiviteye bağlı nöroplastisiteyi destekleyerek motor belirtilerin ilerlemesini de yavaşlatabileceğini düşündürmektedir (Fox ve ark. 2012).

Parkinson rehabilitasyonunun temel hedeflerinden biri, hareket amplitüdüne ilişkin bozulmuş duyusal-proprioseptif algının yeniden düzenlenmesi ve hareketin zihinsel temsilinin yeniden yapılandırılmasıdır. Bu hedeflere yönelik geliştirilen yaklaşımlardan biri, büyük amplitüdlü hareketleri yoğun biçimde çalıştıran LSVT BIG protokolüdür. Bir diğer yaklaşım ise, hareketin zihinsel provasını esas alan motor imgeleme (Mİ) eğitimidir. Her iki yöntem de farklı uygulama biçimlerine sahip olmakla birlikte, ortak nörofizyolojik mekanizmalar üzerinden etki gösterme potansiyeli taşımaktadır.

Bu yapısal derlemenin amacı, primer Parkinson hastalarında LSVT BIG ile motor imgeleme eğitiminin birlikte uygulanmasının nörofizyolojik temelini değerlendirmek; bu iki yaklaşımın tamamlayıcılık potansiyelini tartışmak ve konuya ilişkin literatür eksikliğini ortaya koyarak gelecekteki çalışmalara kuramsal bir zemin oluşturmaktır.

2. LSVT BIG YÖNTEMİ

LSVT BIG (Lee Silverman Voice Treatment – BIG), Parkinson hastalarında konuşma bozukluklarına yönelik geliştirilen LSVT LOUD programının ekstremite ve gövde motor sistemine uyarlanmış biçimidir. Yöntem, büyük amplitüdlü hareketlerin yüksek yoğunlukta ve çok sayıda tekrarla uygulandığı, kanıta dayalı bir egzersiz protokolüdür (Fox ve ark. 2012). Tipik olarak dört hafta boyunca, haftada dört seans olmak üzere toplam 16 seans şeklinde, yoğunlaştırılmış bir program olarak uygulanır.

LSVT BIG'in temel ilkeleri; (i) motor çıktının amplitüdünü artırmaya yönelik özgüllük (bradikinezi ve hipokineziyi doğrudan hedef alma), (ii) tedavi dozajının artırılması (yoğunluk), (iii) görevlerin çok sayıda tekrarı ve (iv) tedavi görevlerinin bireye özgü işlevsel anlamlılığıdır (Fox ve ark. 2012). Yöntemin ayırt edici özelliklerinden biri, duyusal yeniden kalibrasyon (sensory recalibration) yoluyla hastaların artırılmış amplitüdlü hareketleri "çok büyük" hissetseler dahi bu hareketlerin normal sınırlar içinde olduğunu fark etmelerini sağlamasıdır. Bu sayede hasta, tek bir aşırı öğrenilmiş ipucuyla ("BIG düşün") hareket amplitüdünü işlevsel olarak ölçeklendirmeyi öğrenir.

LSVT BIG'in uygulama biçimi, aktiviteye bağlı nöroplastisiteyi yönlendiren ilkelerle (yoğunluk, tekrar, özgüllük ve anlamlılık) tutarlıdır (Fox ve ark. 2012). Berlin LSVT BIG çalışması gibi karşılaştırmalı araştırmalarda, yöntemin Parkinson hastalarında motor performansı diğer egzersiz biçimlerine kıyasla anlamlı düzeyde iyileştirdiği bildirilmiştir (Ebersbach ve ark. 2010). Bu bulgular, LSVT BIG'in proprioseptif regülasyon ve nöroplastisite temelli etki mekanizmasını desteklemektedir.

3. MOTOR İMGELEME

Motor imgeleme (Mİ), bir hareketin açık kas aktivasyonu olmaksızın zihinde prova edilmesi sürecidir. İmgelenen hareketler, gerçek hareketlerin planlanması ve yürütülmesinde rol alan beyin bölgelerini büyük ölçüde aynı biçimde etkinleştirir; imgelenen ve gerçek hareketlerin süreleri birbiriyle ilişkilidir ve benzer otonomik yanıtlar oluştururlar (Subramanian ve ark. 2020). Bu benzerlikler, motor imgelemenin motor performans üzerindeki olumlu etkisini açıklayan *'functional equivalence'* kavramına işaret etmektedir.

Mİ, inme gibi nörolojik hastalıkların rehabilitasyonunda yaygın biçimde kullanılmış olmakla birlikte, Parkinson hastalığında nispeten az çalışılmıştır (Subramanian ve ark. 2020). Buna karşın, günlük yaşam aktivitelerine yönelik motor imgeleme provası uygulanan Parkinson hastalarında ardışık hareket görevlerindeki yavaşlamanın azaldığı bildirilmektedir. Nörogörüntüleme çalışmaları, Parkinson hastalarında motor imgeleme sırasında dorsomedial

frontal korteks bölgelerindeki azalmış aktivasyonun dopaminerjik tedavi ile iyileştiğini göstermiş; bu da hastaların motor temsillerini yeniden etkinleştirme kapasitesine sahip olduğunu desteklemiştir (Subramanian ve ark. 2020).

Motor imgelemenin rehabilitasyon sonuçları üzerindeki etkisini değerlendiren güncel bir sistematik derleme ve meta-analizde, 320 Parkinson hastasını kapsayan 12 randomize kontrollü çalışma incelenmiş; kontrol gruplarına kıyasla motor fonksiyon ve bilişsel işlevlerde anlamlı iyileşmeler bildiren çalışmaların bulunduğu, ancak yöntemsel kalitenin orta-yüksek düzeyde olduğu rapor edilmiştir (Singer ve ark. 2024). Bu bulgular, motor imgelemenin güvenli ve uygulanabilir bir müdahale olduğunu; bununla birlikte klinik etkinliğinin daha yüksek kaliteli ve geniş örneklemli çalışmalarla doğrulanması gerektiğini ortaya koymaktadır.

4. ORTAK NÖROFİZYOLOJİK TEMEL

LSVT BIG ve motor imgeleme, farklı uygulama biçimlerine sahip olmakla birlikte, benzer nörofizyolojik mekanizmalar üzerinden etki gösterme potansiyeli taşımaktadır. LSVT BIG, fiziksel tekrar yoluyla hareket amplitüdünü düzeltmekte ve proprioseptif regülasyonu sağlamaktadır. Motor imgeleme ise zihinsel prova yoluyla hareketin içsel temsilini güçlendirmekte ve nöroplastisiteyi desteklemektedir. Her iki yöntemin de ortak hedefi, hareketin zihinsel temsilinin yeniden yapılandırılması ve hareket için gerekli amplitüdün düzeltilmesidir. Bu iki yöntemin paylaştığı temel kavramların karşılaştırması Tablo 1'de sunulmuştur.

Tablo 1. LSVT BIG ve motor imgeleme yöntemlerinin karşılaştırılması

Özellik	**LSVT BIG**	**Motor İmgeleme (Mİ)**
Uygulama biçimi	Fiziksel, büyük amplitüdlü hareket	Zihinsel prova (açık kas aktivasyonu yok)
Temel mekanizma	Proprioseptif regülasyon	İçsel hareket temsilinin güçlenmesi
Ortak hedef	Amplitüdün düzeltilmesi · nöroplastisite	Zihinsel temsilin yeniden yapılandırılması · nöroplastisite
Uygulanabilirlik	Yoğun, terapist gözetimli	Ev ortamında, düşük maliyetli

Bu ortak nörofizyolojik temel, iki yöntemin birbirini tamamlayabileceğini düşündürmektedir. Fiziksel tekrarın sağladığı proprioseptif regülasyon ile zihinsel provanın güçlendirdiği içsel hareket temsili bir araya geldiğinde, tedavi etkinliğinin artabileceği değerlendirilmektedir. Ayrıca motor imgeleme, terapist gözetimi gerektirmeden ev ortamında ve düşük maliyetle uygulanabildiğinden, LSVT BIG'in yoğun ve görece maliyetli protokolüne ek bir uygulama

seçeneği olarak entegre edilebilir. Nitekim sanal gerçeklik ile birlikte uygulanan motor imgelemenin Parkinson hastalarında motor bileşenler üzerinde olumlu etkiler gösterdiği bildirilmiş; bu da motor imgelemenin diğer rehabilitasyon yöntemleriyle birleştirilmesinin değerini desteklemiştir (Kashif ve ark. 2022).

5. LİTERATÜR ÖZETİ

Mevcut literatürde motor imgeleme; genel fizyoterapi, sanal gerçeklik ve yürüyüş eğitimi gibi çeşitli yaklaşımlarla birlikte çalışılmıştır (Michel ve ark. 2024). Buna karşın, özellikle LSVT BIG protokolü ile birlikte uygulanan motor imgelemeyi inceleyen kontrollü çalışmalara literatürde rastlanmamıştır. Bu durum, söz konusu kombine tedavi yaklaşımının etkinliğine ilişkin doğrudan kanıtın henüz bulunmadığını göstermektedir.

Motor imgeleme alanındaki güncel kapsam derlemeleri, çalışmaların büyük çoğunluğunun denge, yürüyüş ve alt ekstremite egzersizlerine odaklandığını; randomize kontrollü çalışma sayısının sınırlı ve örneklem büyüklüklerinin görece küçük olduğunu vurgulamaktadır (Michel ve ark. 2024). Bu metodolojik kısıtlılıklar, motor imgelemenin Parkinson rehabilitasyonundaki klinik etkinliğine ilişkin kesin çıkarımlar yapılmasını güçleştirmektedir. Belirtilen boşluk, hem yöntemlerin ortak nörofizyolojik temeli hem de motor imgelemenin uygulanabilirlik avantajları göz önüne alındığında, LSVT BIG ile kombinasyonun araştırılması için önemli bir fırsat sunmaktadır.

6. SONUÇ VE ÖNERİLER

LSVT BIG ile motor imgeleme eğitiminin birlikte uygulanmasının yürüyüş, denge, motor işlev ve yaşam kalitesi üzerindeki etkileri; randomize kontrollü, yeterli örneklem büyüklüğüne sahip ve uzun dönem takipli çalışmalarla araştırılmalıdır. Bu tür çalışmaların tasarımında; randomizasyon ve körleme gibi yöntemsel ölçütlerin titizlikle uygulanması, istatistiksel gücü sağlayacak örneklem büyüklüğünün belirlenmesi ve tedavi etkisinin sürdürülebilirliğini değerlendirecek uzun dönem takip sürelerinin planlanması önem taşımaktadır.

Sonuç olarak, bu yapısal derlemenin, LSVT BIG ile motor imgeleme kombinasyonunu inceleyecek gelecekteki klinik çalışmalara yön göstereceği ve kuramsal bir çerçeve oluşturacağı düşünülmektedir. İki yöntemin ortak nörofizyolojik temeli ve motor imgelemenin düşük maliyetli, ev temelli uygulanabilirliği dikkate alındığında, bu kombinasyonun Parkinson rehabilitasyonunda umut verici bir araştırma alanı oluşturduğu değerlendirilmektedir.

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YAPAY ZEKÂ ÇAĞINA GEÇİŞTE DEMOGRAFİK VE DİNİ PERSPEKTİF:NİCEL ARAŞTIRMA ÖRNEĞİ

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ÖZET

Teknolojik gelişmelerin insan hayatına olduğu kadar toplum hayatına yön vermektedir. Günümüzde atılım sergilenen Yapay Zeka teknolojileri hususunda hem bireysel hem de sosyolojik olarak avantaj ve dezavantajları irdelenmelidir. İnsanların öznel duygulanımını içeren din hususunda da Yapay Zeka botları ve teknolojileri kullanılabilmektedir. Ancak bu süreçte kimi insanlar Yapay Zekayı dini konularda kullanmaya kaygı ve kuşku hissederlen bazı insanlar ise faydalı ve güvenilir bulmaktadır. Bu çalışmada ise "Yapay Zekânın Dini Alanlarda Kullanımına Yönelik Tutum Ölçeği" kullanılarak üniversite öğrencilerinin demografik farklılıklarına göre geliştirdikleri tutum farklılıkları incelenmiştir. Yapılan bu çalışmada cinsiyet, kişisel dindarlık algısı, yapay zekâ okuryazarlığı, eğitim düzeyi ile eğitim birimi demografik değişkenleri ele alınmıştır. Eğitim birimi değişkeninde ise İlahiyat Fakültesi öğrencisi olmak, Mühendislik Fakültesi öğrencisi olmak ile bu birimlerden farklı eğitim almanın dini alanlarda yapay zekâ kullanımına yönelik tutumu farklılaştıracağı düşünülmüştür. Hitit Üniversitesinde eğitim alan 470 öğrenciyle yapılan anket çalışması neticesinde elde edilen verilere t testi, Anova, Kruskal Wallis, Mann Whitney U yanı sıra Post Hoc testi uygulanmıştır. Neticede ise; erkek katılımcıların, kadın katılımcılara kıyasla hem kaygı hem de kuşku düzeylerinin anlamlı derecede daha yüksek olduğu tespit edilmiştir. Kendisini "dindar değil" olarak tanımlayan bireyler, "dindar" olarak tanımlayanlara göre anlamlı derecede daha yüksek düzeyde kuşku değeri göstermişlerdir. Yapay zekâ okuryazarlığı kategorilerinde, yapay zekânın dini alanlarda kullanımına yönelik tutumlarda anlamlı bir farklılık olmadığını ortaya koymuştur.Lisans ve lisansüstü öğrencilerinin kaygı düzeylerinin, ön lisans öğrencilerine göre daha yüksek olduğu bulunmuştur. Mühendislik Fakültesi öğrencilerinin tutumları İlahiyat Fakültesi öğrencileri ile benzerlik gösterse de, diğer akademik birimlerdeki öğrencilere kıyasla daha yüksek kaygı düzeyine sahip oldukları belirlenmiştir.

Anahtar kelimeler: Din psikolojisi, yapay zeka, tutum, demografik veriler, üniversite öğrencileri.

DEMOGRAPHIC AND RELIGIOUS PERSPECTIVES IN THE TRANSITION TO THE AGE OF ARTIFICIAL INTELLIGENCE: A QUANTITATIVE RESEARCH EXAMPLE

ABSTRACT

Technological advancements shape social life as much as they influence human life. Today, both individual and sociological advantages and disadvantages of artificial intelligence (AI) technologies, which exhibit a major breakthrough, warrant a thorough examination. AI bots and technologies can also be utilized in the field of religion, which involves the subjective emotions of individuals. However, in this process, some individuals experience anxiety and skepticism regarding the use of AI in religious matters, whereas others find it beneficial and reliable. This study investigates the differences in attitudes developed by university students based on their demographic characteristics, utilizing the "Attitude Scale Toward the Use of Artificial Intelligence in Religious Fields." The demographic variables examined in this research include gender, personal perception of religiosity, AI literacy, educational level, and academic department. Regarding the academic department variable, it was hypothesized that being a student in the Faculty of Theology, the Faculty of Engineering, or other departments would differentiate attitudes toward AI use in religious fields. Data obtained from a survey conducted with 470 students studying at Hitit University were analyzed using t-test, ANOVA, Kruskal–Wallis, Mann–Whitney U, and post-hoc tests. Consequently, male participants exhibited significantly higher levels of both anxiety and skepticism compared to female participants. Individuals who identified themselves as "not religious" demonstrated significantly higher levels of skepticism than those who identified themselves as "religious." No significant difference was revealed in attitudes toward the use of AI in religious fields across different AI literacy categories. Anxiety levels were found to be higher among undergraduate and graduate students than among associate degree students. Although students from the Faculty of Engineering displayed attitudes similar to those of students from the Faculty of Theology, they exhibited higher levels of anxiety compared to students from other academic units.

Keywords: Psychology of religion, artificial intelligence, attitude, demographic data, university students.

KUR'AN'DA AHLAK VE İBADET BİRLİKTELİĞİ

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ÖZET

Ahlak ve İbadet Kur'an-ı Kerim'in ele aldığı en temel konulardandır. İslam dininin itikat, ibadet, muamelat ve ahlak şeklindeki dörtlü taksiminde ahlak ve ibadet önemli bir yer işgal etmiştir. Ahlak, sosyal hayatta varlığına veya yokluğuna bağlı olarak büyük etki yapan insanî bir gerçektir. İbadet ise iyi insan idealine ulaşmada vazgeçilmez ana faktör olarak vazife görmektedir. Dolaysıyla ibadet ve ahlak birbiriyle çok yakın bir ilişki içindedir. Bunların birbirinden farklı şeyler olarak değerlendirilmesi yanlış bir değerlendirmedir. Yerine getirilen ibadetlerin en önemli fonksiyonlarından biri, ahlakı güzelleştirmesi ve olgunlaştırmasıdır. Yapılan ibadetler, Allah katında sevap ve mükafata müstahak olmaya sebep olduğu gibi kalp ve vicdanın tezkiyesi hususunda büyük faydalar sağlar. Bu faydaların başında da insanın menhiyatlardan/haramlardan uzaklaşması, kötülüklerden temizlenmesi ve korunması gelmektedir. İbadetlerin tamamı Allah yolunda nefsi ıslah etmek için birer vasıtadır. Günümüzde insanlar arasında yaygın olan yanlış bir anlayış vardır ki o da şudur: Genelde ibadet ayrı ahlak ayrı şeylermiş gibi düşünülmektedir. Halbuki bu düşünce Kur'an'ın özüne aykırıdır. Kur'an'a göre, aslında İslam dininde ibadetler, insanı ahlaken kemale erdirmek için emredilmiştir.

Netice itibarıyla Kur'an-ı Kerim'de iman, ibadet ve ahlak arasında ayrılmaz bir bütünlük söz konusudur. Bu unsurların birbirinden tamamen bağımsız olarak ele alınması, Kur'an'ın ortaya koyduğu din anlayışıyla bağdaşmamaktadır. İman, insanı ibadete sevk eden temel inanç boyutunu oluşturmakta; ibadet ise bireyin ahlaki yetkinliğini geliştiren ve onu manevi olgunluğa taşıyan bir işleve sahip bulunmaktadır. Dolayısıyla ibadetlerin nihai amacı, insanı ahlaken kemale erdirmek ve erdemli bir kişilik inşasına katkı sunmaktır.

Anahtar Kelimeler: Tefsir, İslam, Kur'an, İbadet, Ahlak,

THE UNITY OF MORALITY AND WORSHIP IN THE QUR'AN

ABSTRACT

Morality and worship are among the most fundamental subjects addressed in the Holy Qur'an. In the fourfold classification of Islam as faith (*aqidah*), worship (*ibadah*), social transactions (*muamalat*), and morality (*akhlaq*), both morality and worship occupy a significant place. Morality is a human reality that exerts a profound influence on social life, depending on its presence or absence. Worship, on the other hand, serves as an indispensable factor in achieving

the ideal of a virtuous human being. Therefore, worship and morality are closely interconnected. Considering them as entirely separate phenomena is a mistaken approach.

One of the most important functions of worship is its role in refining and perfecting moral character. Acts of worship not only make a person deserving of divine reward and recompense in the sight of Allah, but also provide substantial benefits in the purification of the heart and conscience. Among these benefits are distancing oneself from prohibitions and sins, cleansing oneself from evil, and attaining protection from wrongdoing. All forms of worship serve as means of self-discipline and moral reform in the path of Allah.

Today, a common misconception prevails among many people: worship and morality are often regarded as two separate domains. However, this understanding is contrary to the essence of the Qur'an. According to the Qur'an, acts of worship in Islam have been prescribed primarily to lead human beings toward moral perfection.

In conclusion, the Holy Qur'an presents faith, worship, and morality as an inseparable whole. Treating these elements as entirely independent from one another is incompatible with the Qur'anic understanding of religion. Faith constitutes the foundational dimension that motivates individuals toward worship, while worship functions as a means of developing moral competence and guiding individuals toward spiritual maturity. Accordingly, the ultimate purpose of worship is to perfect human morality and contribute to the formation of a virtuous character.

Keywords: Tafsir, Islam, Qur'an, Worship, Morality.

GİRİŞ

İbadet ve Ahlak Kur'an-ı Kerim'in ele aldığı en temel konulardandır. İslam dininin itikat, ibadet, muamelat ve ahlak şeklindeki dörtlü taksiminde ahlak ve ibadet önemli bir yer tutmaktadır. Allah'a kulluk etme, imanın yansıması anlamına gelen ibadet, Kur'an-ı Kerimde insanın yaradılış gayesi olarak yer almaktadır. İbadet Allah'a kulluk etmenin dışa vurması ve kabullenmesidir. İbadetin en temel vazgeçilmezi ise ihlastır. İhlaslı bir ibadetin en belirgin yansıması ise ahlakî davranışlardır. İbadet Allah'ın emrine uymak ve helal yaşamaktır. Ahlak ise Allah'ın mükemmel insana tahsis ettiği hedef ve zirvedir. Dolaysıyla ahlak ile ibadet birbirinden ayrılmaz bir bütündür. Bu bütünlük Kur'an-ı Kerim'in tamamında konu edilmektedir. Kur'an-ı Kerimdeki ibadeti konu alan bütün ayetler muhakkak bu ibadetleri bir ahlak unsuru ile ilişkilendirdiği göze çarpmaktadır. Her ne kadar ibadetlerin mükellefiyetlerine bir sebep aramak uygun olmasa da her ibadette bir hikmetinin olması ibadetin ubudiyetine uygundur. Kur'an' da emredilen ibadetlerin hikmetlerine baktığımızda genelde ahlak unsurları

ön plana çıkmaktadır. Netice itibarıyla Kur'an-ı Kerim'de iman, ibadet ve ahlak arasında ayrılmaz bir bütünlük söz konusudur. Bu unsurların birbirinden tamamen bağımsız olarak ele alınması, Kur'an'ın ortaya koyduğu din anlayışıyla bağdaşmamaktadır. İman, insanı ibadete sevk eden temel inanç boyutunu oluşturmakta; ibadet ise bireyin ahlaki yetkinliğini geliştiren ve onu manevi olgunluğa taşıyan bir işleve sahip bulunmaktadır. Dolayısıyla ibadetlerin nihai amacı, insanı ahlaken kemale erdirmek ve erdemli bir kişilik inşasına katkı sunmaktır (Ankebut, 29/45).

ARAŞTIRMA VE BULGULAR

1.Kavramsal Çerçev

1. 1. Ahlak

Ahlak kavramı, Arapçada "huy, tabiat, karakter, din ve mizaç" anlamlarına gelen *hulk* veya *huluk* kelimelerinin çoğulu olup insanın manevi yapısına, karakterine ve davranışlarına yön veren içsel özelliklerini ifade etmektedir. Bu yönüyle ahlak, insanın manevî yapısını belirleyen huylar, seciyeler, karakter özellikleri ve kişiliğini şekillendiren içsel niteliklerin (İbn Manzur 1990) bütünü şeklinde değerlendirilmektedir. İslam düşüncesinde insanın dış görünüşünü halk ifade eder iç dünyasını ve ahlaki karakterini *hulk* kavramı ifade eder. İslamî literatürde ahlak kavramı hem iyi hem de kötü huyları kapsayacak şekilde kullanılmıştır. İyi huylar ve faziletli davranışlar çeşitli kavramlarla ifade edilirken, kötü huylar ve olumsuz davranışlar farklı terimlerle adlandırılmıştır. Ancak bu çalışmada ahlak kavramı, daha çok fazilet ve güzel ahlak anlamında ele alınmıştır. Terim olarak ahlakın birçok tanımı yapılmıştır. Bu tanımların en yaygını İmam Gazzâlî'nin (ö. 505/1111) "Ahlak, insanda yerleşen öyle bir melekedir ki, bu melekeden dolayı davranışlar hiçbir zorlama olmadan, düşünüp taşınmadan, kolaylıkla sadır olur" (Kutluay, 2015) tanımıdır. Buna göre ahlak, davranışların kendisinden çok onların kaynağı olan karakter ve manevi yetkinlikleri ifade etmektedir. Davranışlar ise ahlakın sonucu ve dışa yansımasıdır.

1.2. Kur'an'da Ahlak

Kur'ân-ı Kerîm'de ahlak mefhumu, doğrudan "ahlak" lafzıyla müstakil bir kavram olarak yer almamakla birlikte, bu kelimenin türevi olan (خُلُق) *hulk* lafzı iki ayrı yerde zikredilmektedir. Bununla beraber ahlaki değerler çok geniş bir kavramsal çerçevede ele alınmıştır. Kur'an'da birr, ihsan, adalet, takva, doğruluk, sabır, şükür ve salih amel gibi kavramlar olumlu ahlaki nitelikleri ifade ederken; günah, sapkınlık, zulüm, fısk, fücur, yalan, israf ve hayasızlık gibi kavramlar ise olumsuz davranış biçimlerini temsil etmektedir. Özellikle salih amel kavramı, ahlaki davranışları da içine alan geniş bir anlam alanına sahiptir.

Ahlak, Kur'an'da peygamber övgüsü olarak 'da yer almıştır: Hz. Peygamber kulluk görevini yerine getirmek için çok ibadet etmesine rağmen; İslam'ı tebliğ etmek için çok emek verip meşakkat çekmesine rağmen, Allah tarafından bunlarla değil güzel ahlakıyla övülmüştür (Kalem, 4).

Kur'an'a göre ibadetlerin temel amacı yalnızca şekilsel bir kulluk görevinin yerine getirilmesi değildir. Asıl hedef, ibadetlerin bireyin karakterine yansıması ve ahlaki olgunluk kazandırmasıdır. Bu nedenle ahlaki dönüşüm meydana getirmeyen ibadetler, ilahi maksadı tam olarak gerçekleştirememektedir. Nitekim Kur'an'da ibadetlerle ilgili birçok hüküm, dürüstlük, sabır, merhamet ve yardımlaşma gibi ahlaki erdemlerle birlikte zikredilmektedir.

Kur'ân-ı Kerîm'de dinî emirler ile ahlaki yükümlülükler birbirinden ayrılmaz bir bütün olarak ele alınmıştır. Namaz, oruç, hac ve zekât gibi ibadetler nasıl dinî bir sorumluluk ise dürüstlük, ahde vefa ve yardımlaşma da aynı derecede dinî bir görev olarak kabul edilmektedir. Benzer şekilde adam öldürme, zina ve içki gibi davranışlar yasaklandığı gibi iftira, gıybet, dedikodu ve insanların kusurlarını araştırmak da hem ahlaken hem de dinen yasaklanmıştır.

Kur'an'da iman, ibadet ve ahlak birbirini tamamlayan unsurlar olarak sunulmaktadır. Müminlerden büyük günahlardan kaçınmaları, affedici olmaları, istişareye önem vermeleri, ihtiyaç sahiplerine yardım etmeleri, zulme karşı durmaları ve sabır göstermeleri istenmektedir. Böylece Kur'an, bireyin hem Allah'a karşı kulluk görevlerini yerine getirmesini hem de erdemli bir ahlaki kişilik geliştirmesini hedefleyen bütüncül bir ahlak anlayışı ortaya koymaktadır.

1.3. Kur'an'da İbadet

İbadet kelimesi, Arapçada "itaat etmek, boyun eğmek, kulluk etmek" anlamlarını ifade eden **(ع-ب-د)** kökünden türemiştir. Terim olarak ise Allah'ın rızasını kazanmak amacıyla, sevgi, saygı ve teslimiyet içerisinde yerine getirilen söz, fiil ve davranışları ifade etmektedir. İbadet yalnızca belirli dinî uygulamaları değil, Allah'a bağlılık ve kulluk bilinciyle gerçekleştirilen bütün davranışları kapsayan geniş bir anlam alanına sahiptir.

İslamî literatürde ibadet kavramı, genel/geniş ve özel/dar olmak üzere iki farklı anlam çerçevesinde değerlendirilmektedir. Genel/geniş anlamıyla ibadet, bireyin Allah'ın rızasını kazanma niyetiyle gerçekleştirdiği bütün salih amel ve davranışları kapsamaktadır. Bu bağlamda namaz, oruç ve dua gibi doğrudan kulluk bilincini yansıtan ibadetlerin yanı sıra; ilim öğrenmek ve öğretmek, muhtaçlara yardım etmek, çalışarak helal kazanç elde etmek, topluma faydalı faaliyetlerde bulunmak ve kötülüklerin önlenmesine katkı sağlamak gibi davranışlar da ibadet kapsamında değerlendirilmektedir. Dolayısıyla ibadet, yalnızca belirli ritüellerden veya

zaman dilimlerinden ibaret olmayıp, bireyin hayatının bütün alanlarını kuşatan ve her türlü davranışını ilahî rıza ekseninde anlamlandıran kapsamlı bir kulluk anlayışını ifade etmektedir. Bu yönüyle ibadet, insanın Allah ile olan ilişkisinin yanı sıra kendisine, topluma ve çevresine karşı sorumluluklarını da içine alan bütüncül bir yaşam biçimi olarak ortaya çıkmaktadır. Özel anlamda ibadet, mükellefin Allah'a karşı duyduğu saygı, sevgi ve teslimiyetin bir göstergesi olarak, Allah ve Resûlü tarafından belirlenen şekil ve şartlara uygun biçimde yerine getirilen belirli kulluk davranışlarını ifade eder. Fıkıh literatüründe ibadet kavramı çoğunlukla bu anlamda kullanılmaktadır.

İbadet, Kur'an'da her iki anlamıyla İnsanların yaradılış gayesi, insanları kötülüklerden alıkoyan, günahlardan arındıran ve insanların kurtuluş vesilesi olarak yer almaktadır.

Bu çalışmamızda ahlak-ibadet ilişkisi ele alınırken, ibadet kavramı özel/dar mânâsı itibarıyla değerlendirilmiştir. Zira yukarıda temas edildiği üzere, ibadetin geniş mânâsı ile ubûdiyyet telakkisi göz önünde bulundurulduğunda, genel anlamdaki ibadetin ahlakın bizatihi kendisiyle büyük ölçüde örtüştüğü anlaşılmaktadır.

Kur'an'da Ahlak ve İbadet bütünlüğü

2.1. Din, İbadet ve Ahlak İlişkisi

İbadetin ahlakla olan ilişkisini sağlıklı biçimde kavrayabilmek, öncelikle din ile ahlak arasındaki ilişkinin doğru şekilde anlamakla mümkündür. Bu sebeple, ibadet ve ahlak ilişkisini açıklamak için din-ahlak bağlantısının temellendirilmesi gerekmektedir.

2.1.1. Din-Ahlak İlişkisi

Din ile ahlak arasında güçlü bir ilişki bulunmaktadır. Din, iyi ile kötüyü, doğru ile yanlışı ve helal ile haramı belirleyen temel ölçüleri ortaya koyarken; ahlak, bu ölçülerin bireyin davranışlarına yansımasını ve hayatında uygulanmasını sağlamaktadır. Bu ilişki, peygamberlerin gönderiliş amacıyla da yakından bağlantılıdır. Nitekim Hz. Peygamber'in "*Ben güzel ahlakı tamamlamak için gönderildim*" hadisi bunun ispatıdır (Çağrıcı, 2006).

Ancak din, yalnızca ahlaktan ibaret değildir; bununla birlikte ahlak da dinin vazgeçilmez ve kurucu unsurlarından biridir. Din ve ahlak arasında bitmez ve tükenmez bir münasebet söz konusudur. Öyle ise din olmadan ahlak, ahlak olmadan da dinin noksan kalması kaçınılmazdır.

2. 2. İbadet-Ahlak İlişkisi

Kur'an-ı Kerim'in ihtiva ettiği asıl konulardan biri olan ibadetlerin gayesi; öncelikle kul ile yaratıcı arasındaki manevî bağı sürekli sıkı tutmaktır. Ancak ibadetler Allah ile kul arasındaki yalnızca manevî bir alâka olarak kalmamaktadır. Bununla beraber insanın yaşadığı başka alanlara ve bilhassa ahlaka tesir etmektedir. İbadetlerin tamamı insanların kurtuluşu ve

refahı içindir. Yoksa Allah Teâlâ'nın, yapılmasını emrettiği ibadetlere herhangi bir ihtiyacı yoktur (Şimşek, 2012). Dinin emrettiği temel ibadetlerin amacı, birey ve toplumun ahlaki yönden gelişmesini sağlamak, erdemli bir kişilik ve toplum yapısının oluşumuna katkıda bulunmak ve ahlaki değerlerin kalıcı bir karakter hâline gelmesine zemin hazırlamaktır (Köse, 2011). Amel ve ibadetlerin çokluğu, tek başına dinî olgunluğun yeterli göstergesi değildir. Çünkü ibadetlere gerçek değer kazandıran temel unsur, kişinin ahlaki olgunluğudur. Kur'an-ı Kerim'de ibadetler ile ahlak birbiri ile sıkı bir münasebet halindedir. "*(Ey Muhammed!) Kitaptan sana vahyolunanı oku, namazı da dosdoğru kıl. Çünkü namaz, insanı hayasızlıktan ve kötülükten alıkoyar. Allah'ı anmak (olan namaz) elbette en büyük ibadettir. Allah, yaptıklarınızı biliyor"* (Ankebut, 36/45) ayeti ibadet ve ahlakın sıkı ilişkisinin ifade eden en bariz örneklerden biridir. Bu ayette ibadet ve ahlak ilişkisi ibadetin neticesinde faziletli işlerin (güzel ahlakın) ortaya çıkacağı şeklinde tezahür etmiştir.

Kur'an'daki ibadet ve ahlak birlikteliği bazen "*Allah'a ibadet edin ve O'na hiçbir şeyi ortak koşmayın. Ana-babaya, akrabaya, yetimlere, yoksullara, yakın komşuya, uzak komşuya, yakın arkadaşa, yolcuya, ellerinizin altında bulunanlara (köle, cariye, hizmetçi vb.) iyi davranın; Allah kendini beğenen ve daima böbürlenip duran kimseyi sevmez"*(Nisa 4/36) ayetinde olduğu gibi aynı ayette ibadet ile ahlakî umdelerin peş peşe gelmesi şeklinde tezahür etmiştir.

İbadet, yalnızca belirli davranışların bilinçsizce ve alışkanlık hâlinde tekrarlanmasından ibaret değildir. Aksine, insanı ahlaki olgunluğa yönelten bilinçli bir kulluk eylemidir. Bu sebeple, zamanla manevi boyutundan uzaklaşarak şekilsel bir uygulamaya dönüşen ve sadece dış yönüyle yerine getirilen ibadetlerin, kişiyi Allah'ın razı olduğu ahlaki kemale ulaştırması beklenemez. Nurettin Topçu'nun ifadesiyle el, ayak, baş, beden hareketlerinde maharet dindarlığın şartı olmamalı, bunlar dinin esasını oluşturmamalıdır. Dini hayâ, ruh ve manasıyla bir bütün halinde yaşanırsa, ancak aslını ifade eder. Örneğin, namaz, insanda meydana getirmesi gereken davranış değişikliği, ruh hali ve ahlakiliği yaraşmadıktan sonra, elbette şekilde yaşanmış düzgün boş bir yorgunluk olarak kalacaktır. Yahut birlik ve kardeşlik, merhamet, eşitlik, paylaşma, hoşgörü, dürüstlük gibi insaniliğe yakışan ahlaki davranışları doğurmayan hac, bedensel olarak bir mekân değişikliğinin ötesine geçemeyecektir. Allah, böyle bir ibadet anlayışını emretmemiştir (Özkan, 2006).

2.2. 1. Namaz-Ahlak ilişkisi

İslam dininin temel esaslarından biri olarak kabul edilen namaz, bireyin hem manevi hem de toplumsal hayatı üzerinde önemli etkiler meydana getirmektedir. Bununla birlikte, namazın ahlaki boyutu ayrı bir önem arz etmektedir. Zira namaz, yalnızca belirli vakitlerde

yerine getirilen şekli bir ibadet olmanın ötesinde, bireyi kötülüklerden alıkoyan, Allah'a karşı kulluk bilincini güçlendiren ve davranışlarına ahlaki bir yön kazandıran temel bir ibadettir. Bu yönüyle namaz, bireyin ahlaki gelişimine katkı sağlayan ve ahlaki değerlerin içselleştirilmesinde önemli bir işlev üstlenen bir ibadet niteliği taşımaktadır. Dolayısıyla namaz ile ahlak arasında güçlü ve karşılıklı bir ilişki bulunmaktadır.

Namazın İslam dinindeki merkezi konumu Hz. Peygamber (s.a.s.) tarafından "*Namaz, dinin direğidir*" (Tirmizî, İman 8). *"İslam, beş esas üzerine bina olunmuştur: Allah'tan başka hakkıyla ibadete layık hiçbir ilahın olmadığına ve Muhammed -sallallahu aleyhi ve sellem-'in Allah'ın kulu ve rasulü olduğuna şahitlik etmek, namaz kılmak, zekât vermek, Beytullah'ı haccetmek ve Ramazan orucunu tutmaktır"* (Buharî, iman 1, 2; Müslim, iman 19-22.) şeklinde ifade edilmiştir. Ahlakın yeri ise Hz. Peygamberin *"Ben güzel ahlakı tamamlamak için gönderildim"* (Muvatta, Hüsnü'l-Hulk, 8) hadisinde görmekteyiz.

Yukarıdaki ayet ve hadisler bir arada değerlendirildiğinde görülüyor ki namaz dinin direği, ahlâk ise dinin hedefi veya varmak istediği noktadır.

Sosyolojik olarak da bir hakikatin dayandığı temeli ile ulaşmak istediği hedefi arasında tutarlı bir bütünlük bulunmalıdır. Kur'an-ı Kerim de İslam dininin temel ibadetlerden biri olan namaz ile dinin ulaşmak istediği hedef olan ahlâkî olgunluk arasındaki alaka bu bütünlük içinde ele alınmaktadır. Nitekim *"Kitap'tan sana vahyolunanı oku; namaz kıl, muhakkak ki namaz fahşa (iğrenç, hayasızlık) dan ve fenalıktan alıkoyar; Allah'ı anmak en büyük şeydir! Allah Yaptıklarınızı bilir* (Ankebut, 29/45) ayeti, namazın yalnızca şekilsel bir ibadet olmadığını, aynı zamanda insanın ahlaki hayatına yön veren bir işlev taşıdığını göstermektedir.

Namaz ibadetinin mahiyeti dikkate alındığında, bu ibadeti bilinçli ve ihlasla yerine getiren bir kimsenin, topluma zarar verebilecek davranışlardan uzak durması beklenmektedir. Bu yönüyle namaz, bireyi hırsızlık, kul hakkı ihlali, haksız kazanç ve hem fert hem de toplum üzerinde olumsuz sonuçlar doğuran davranışlardan alıkoyan önemli bir ahlaki işleve sahiptir.

Ayete göre namaz ile hayasızlık ve kötülüğün bir arada bulunmaması gerekmektedir. Bu nedenle, namaz kıldığı hâlde bu tür davranışlardan uzaklaşamayan kimselerin namazdan beklenen dünyevî ve uhrevî neticeleri tam olarak elde edemediği anlaşılmaktadır. Nitekim İbn Abbas ve İbn Mesud, bu ayetin tefsirinde: "*Hayasızlık ve fenalıktan korumayan namazın faydası Allah'tan uzaklaştırmayı artırmaktan başka bir şey değildir*" (Taberî, 1988) diyerek bu hususa dikkat çekmişlerdir. Aynı şekilde Hz. Peygamber de: "*Namaza itaat etmeyenin namaz yoktur. Namaza itaat ise, namazın hayasızlıktan ve fenalıktan alıkoymasıdır*." (Süyutî, Dürrü'l *-Mensur*, 2003) buyurarak namazın ahlaki işlevini vurgulamıştır.

2.2. 2. Oruç Ahlak İlişkisi

İslam'da oruç, bireyin ahlaki gelişimini destekleyen önemli ibadetlerden biri olarak kabul edilmektedir. Hz. Peygamber'in "Her kim yalan söylemeyi ve yalanla amel etmeyi terk etmezse, Allah'ın onun yemesini ve içmesini terk etmesine ihtiyacı yoktur." (Buhari, Savm, 8,) şeklindeki hadisi, orucun yalnızca yeme ve içmeden uzak durmayı değil, ahlaki davranışları da kapsadığını göstermektedir. Ramazan orucunun farziyeti ile ilgili olan "Ey iman edenler! Allah'a karşı gelmekten sakınmanız (muttaki olmanız) için oruç, sizden öncekilere farz kılındığı gibi, size de farz kılındı" (Bakara 2/183) ayetin Kuşeyrî'nin tabiri ile *"Güzel ahlak ve helal lokma"* (Uludağ, 1989) olan takva vurgusuyla sona ermesi, orucun temel hedeflerinden birinin takva bilincini geliştirmek olduğunu ortaya koymaktadır.

Orucun özünü ahlaki nitelikler olan takva kavramı ile ilişkilendirilmesi, oruç ibadetinin yalnızca biçimsel yönünde değil, müminin söz, tutum ve davranışlarında da karşılık bulmalıdır. Bu nedenle oruç, sadece yeme ve içmeden uzak durmakla sınırlı görülmemeli; bireyi yalan, gıybet, koğuculuk, yalancı şahitlik ve benzeri ahlaki zaaflardan uzaklaştıran bir terbiye süreci olarak değerlendirilmelidir. Yüce Allah'ın orucu farz kılması, kullarından yalnızca bu ibadetin dış şartlarını yerine getirmelerini istemesi anlamına gelmez. Gerçek anlamda eda edilen oruç, kişide "ittika" bilincini meydana getirir. Bu bilinç ise yalnızca ibadet süresiyle sınırlı kalmamalı, hayatın bütün alanlarına yön veren ahlaki bir ilkeye dönüşmelidir.

2.2. 3. Zekât-Ahlak İlişkisi

Namaz, oruç ve ahlak arasında güçlü bir ilişki bulunduğu gibi, zekât ile ahlak arasında da benzer şekilde sıkı bir bağdan söz etmek mümkündür. Hatta zekâtın ahlakla ilişkisi, diğer ibadetlere göre daha belirgin bir mahiyet arz etmektedir. Çünkü Kur'an-ı Kerim'de namaz ve orucun ahlakla ilişkisi çoğu zaman ahlaki muhteva taşıyan kavramlar üzerinden ifade edilirken, zekâtın ahlakla ilişkisi hem bu tür kavramlarla hem de daha açık bir biçimde ortaya konulmaktadır.

Zekâtın ahlaki anlam taşıyan kavramlarla ilişkilendirilmesine, "*Onların mallarından, onları kendisiyle arındıracağın ve temizleyeceğin bir sadaka (zekât) al ve onlara dua et. Çünkü senin duan onlar için sükunettir (Onların kalplerini yatıştırır.) Allah, hakkıyla işitendir, hakkıyla bilendir*" (Tevbe, 7/103) ayeti örnek gösterilebilir. Bu ayette zekât, günahlardan temizlenme ve manevi arınma anlamlarını içeren "tathir" ve "tezkiye" kavramlarıyla birlikte zikredilmiştir. Beğavî, ayetin tefsirinde "tathir" kavramını günahlardan arınma, "tezkiye" kavramını ise kişinin nifak seviyesinden ihlas seviyesine yükselmes (Beğavi, 1987) şeklinde açıklamıştır. Bu

çerçevede ayetin manası, "Onları günahlardan temizleyecek ve amellerini arındıracak olan bir zekâtı onların mallarından al" (Maverdî, 2010) şeklinde anlaşılabilir.

Kur'an, malını Allah yolunda infak etmenin kurallarını ve mükafatını açıkladıktan sonra, bu şartların dışındaki infakların fayda vermeyeceğini de şöyle açıklamıştır: "*Ey iman edenler! Allah'a ve ahiret gününe inanmadığı halde insanlara gösteriş olsun diye malını harcayan kimse gibi, sadakalarınızı başa kakmak ve gönül kırmak suretiyle boşa çıkarmayın. Böylesinin durumu, üzerinde biraz toprak bulunan ve maruz kaldığı şiddetli yağmurun kendisini çıplak bıraktığı bir kayanın durumu gibidir. Onlar kazandıklarından hiçbir şey elde edemezler. Allah, kafirler topluluğunu hidayete erdirmez"* (Bakara,2/264).

2.2. 4. Hac- Ahlâk İlişkisi

Hac ibadeti de diğer ibadetler gibi ahlaka hedeflenmiş bir ibadettir. Aslında hac bizatihi kendisi ahlak eğitimidir. Hac ibadeti esnasında karşılaşılan sıkıntılar hakikatinde Yüce Allah (c.c)'ın kullarına bir imtihanıdır. Bu sayede kişinin içerisinde henüz terbiye edilmeyen, ancak kişinin habersiz olduğu birçok ahlâk zuhur etmektedir. Hac, insanı adeta madde aleminden ruhanî aleme taşıyan bir ibadettir. Kur'an'da Hac ibadetinin ahlakla irtibatını açık bir şekilde "*Hac, bilinen aylardadır. Kim o aylarda hacca niyet ederse (ihramını giyerse), hac esnasında kadına yaklaşmak, günah sayılan davranışlara yönelmek, kavga etmek yoktur. Ne hayır işlerseniz Allah onu bilir. (Ey müminler! Ahiret için) azık edinin. Bilin ki azığın en hayırlısı takvadır. Ey akıl sahipleri! Benden (emirlerime muhalefetten) sakının"* (Bakara,2/197)ayette görmek ve çıkarmak mümkündür.

Bu ayetin beyanında dikkat çeken ilk hususlardan biri, hüküm vazedilirken gözetilen ifade titizliğidir. Ayette hacla ilgili hükümler vazedilmiş, bu bağlamda hacca mahsus bazı yasaklara yer verilmiş, ayrıca normal şartlarda da günah ve ahlak dışı kabul edilen bazı davranışlardan sakınılması gerektiği özellikle vurgulanmış, sonunda ayetteki bütün hükümler takva ve Allah korkusuna ilişkilendirilmiştir.

2.2.5. Kurban-Ahlak İlişkisi

Kurban, değerini takva ve kulluk bilincinden alan bir ibadettir. İbadetler arasında ahlakla güçlü bir ilişkiye sahip olan kurbanın, gerçek anlamda değer kazanması samimiyet ve takvaya bağlıdır. Hz. Âdem'in oğullarına dair kıssa, ibadetlerin kabulünde takvanın belirleyici rolünü göstermektedir. Nitekim "*Allah, ancak takva sahiplerinin kurbanlarını kabul eder*" ayeti bu gerçeği açıkça ortaya koymaktadır. Zemahşerî de bu ayetin, Allah'ın ancak muttaki kullarının ibadetlerini kabul edeceğine işaret ettiğini belirtmektedir. Kurbanın manevi yönü, "(O kurbanların) ne etleri ne de kanları Allah'a ulaşacaktır. Fakat O'na sizin takvanız ulaşacaktır"

ayetinde vurgulanmakta; ibadetin asıl amacının takva bilincini geliştirmek olduğu ifade edilmektedir. Ayrıca Hz. Peygamber'in "*Öyleyse kurbanlarınızla arındırın nefislerinizi*!" hadisi, kurbanın nefsi arındıran ve ahlaki olgunlaşmaya katkı sağlayan yönüne dikkat çekmektedir. Bu yönüyle kurban, insanı takvaya sevk eden ve ahlaki gelişimi destekleyen önemli bir ibadettir.

Kurban, insanı takvaya yönelten ve Allah'a yaklaştıran bir ibadettir. Yüce Allah, hac kurbanlarının Allah'ı yüceltme ve O'na şükretme vesilesi olduğunu belirtmiş, kurban ibadetindeki asıl amacı ise *"(O kurbanların) ne etleri ne de kanları Allah'a ulaşacaktır. Fakat O'na sizin takvanız ulaşacaktır*" ayetiyle açıklamıştır. Bu ayet, kurbanın maddi yönünden çok manevi boyutuna ve kişide takva bilincinin oluşmasına dikkat çekmektedir. Nitekim Hz. Peygamber'in "Öyleyse kurbanlarınızla arındırın nefislerinizi!" hadisi de kurbanın nefsi arındıran ve manevi olgunlaşmaya katkı sağlayan yönünü ortaya koymaktadır. Bu bakımdan kurban, takva bilincini güçlendiren ve insanın manevi gelişimine katkı sunan bir ibadettir.

Sonuç

Kur'an-ı Kerim'de ibadet ile ahlak arasındaki alakanın zayıf ve dolaylı bir alaka olmadığı görülmektedir. Aksine ibadet ile ahlak arasındaki alakanın dinî yaşantının düzenini kuran temelli ve iç içe bir ilişki olduğunu söylemek mümkündür. Kur'an'da ibadet, sadece müşahhas formalitelerin yerine getirilmesini ifade eden şeklî bir mükellefiyet olarak ortaya konulmamaktadır. Bilakis ferdin manevi dünyasını tezkiye eden, hal ve hareketini kontrol altına alan ve onu ahlaki etkinlik alanına çeken belirleyici bir ıslah vasıtası olarak ele alınmaktadır. Bundan dolayı Kur'anî bakışla ibadetin değeri, yalnızca şekilsel uygulamasında değil, bireyde oluşturduğu ahlaka dair dönüşümde aranmalıdır. Çünkü iman, ibadet ve ahlakın Kur'an'da birbirinden alakasız unsurlar değil, aynı dinî sisteminin birbiriyle irtibatlı öğeleri olarak topluma sunması da bu durumu teyit etmektedir.

Çalışmada elde edilen neticelerden biri, Kur'an'da yerine getirilmesi istenen temel ibadetlerin güzel ahlaki inşa ile doğrudan irtibatlandırmış olmasıdır. Dinin direği olan namazın çirkin ve utanmazlıklar (fahşa)dan koruması, orucun insanı muttaki – ki takva güzel ahlaktır- yapması, zekâtın güzel ahlak anlamını ifade eden arınma ve tathîrle beraber zikredilmesi, haccın çekişme, günah ve kavga sayılan davranışlardan sakınması konularla ahlaki ilişkilere dikkat talep etmesi, kurbanın ise mahiyeti ahlak olan takva ve ihlas ile değer alması, ibadetlerin ahlakla olan alakası basit bir rastlantıdan çok köklü ve sağlam bir alaka olduğunu ortaya koymaktadır. Bu cihetiyle Kur'an'da kabul gören ibadet, ferdi münkerattan koruyan, ihsana ve mesuliyet şuuruna yönlendiren ve güzel ahlakı oturmuş bir davranış hâline getiren ibadettir.

Bundan dolayı ahlaki netice vermeyen, şahsın söz, fikir, hâl ve hareketlerinde olumlu bir netice oluşmayan ibadet anlayışının, Kur'an'ın uygun gördüğü ubudiyet anlayışı düşüncesiyle tam manasıyla uyuşmadığı anlaşılmaktadır.

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THE BHIL TRIBE OF INDIA: A JOURNEY THROUGH CULTURE, HERITAGE AND DESIGN

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Abstract

The Bhils traditionally inhabit the Rewakantha region, spanning presentday Andhra Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, and Rajasthan, linked to the Narmada (Rewa) river system. Ancient Origins: Considered among India's oldest tribes, the Bhils are associated with pre-Aryan civilizations and primarily reside in the forested Vindhya and Satpura ranges, with pockets in the western Deccan, eastern Tripura, and Sindh (Pakistan).

Bhil mythology traces their ancestry to Nishada, son of Lord Shiva. The Bhil community is referenced in ancient Indian epics, including the Ramayana. Their lineage is linked to Eklavya, with Bhil archers in Alirajpur maintaining the no-thumb archery practice in his honor. The name 'Bhil' is believed to derive from the Dravidian word villu/billu (bow). Bhil culture is renowned for vibrant wall paintings and symbolic tattoos inspired by nature, mythology, and everyday life. Bhil people used to perform the Ghoomer, Gawri and Gair during the multiple festival.

The review work also highlited that Tattooing is a deeply rooted cultural practice among Bhil women and is closely linked to identity, tradition, and belief systems. This review work also highlite the transformation of the Bhil from their indigenous animistic religion which was connected to the natural environment and ancestral worship to Christianity.

In this review work the daily life of Bhil tribes people with their belief and costume, as the costume play the crucial role to understand the Bhil tribes. The traditional costume for Bhil men is bifurcated garment, Headgear: Feto (turban); Upper garments: Angi/Tunic; Lower garment: Potario: Knotted at the waist; Clothes drawn between the legs and tucked at the back.

The traditional costume of Women's Clothing is Upper garment: Kapada; Lower garment: Ghaghra and Veil / covering: Odhna or Lugda (covers head and torso). Earlier, women wore short knee-length skirts to allow easy movement through forest undergrowth. The present review research will highlights the understanding and awareness about an indigenous community of India.

Keywords: Bhil, Tribes, Textile, Cluture, Rajasthan, India.

GENERATIVE ADVERSARIAL NETWORKS FOR PRIVACY-PRESERVING SYNTHETIC DEMOGRAPHIC GENERATION SAFE COLLABORATIVE DATA PIPELINES FOR CROSS-BORDER ACADEMIC STUDIES

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ABSTRACT

Systemic wage discrimination and unfair labor distributions within informal industrial sectors remain a significant challenge, particularly for female workers. This paper proposes a deep learning framework, *LaborGuard-GNN*, built on Heterogeneous Graph Neural Networks (HGNNs) designed for the AICU to model industrial labor ecosystems as dynamic, multi-relational graphs to identify and mitigate structural inequalities. Our approach models the industrial space as a network where nodes represent individual laborers, private enterprises, third-party contractors, and regional labor markets, while edges represent time-stamped employment contracts, wage payouts, and work-hour allocations. Finely tuned spatial-temporal attention layers within the GNN process multi-source payroll datasets, automatically calculating a disparity score for corporate entities by comparing wage metrics against localized cost-of-living indicators. The model uncovers covert practices, such as contractor-enforced wage skimming, unauthorized overtime expectations, and systematic underpayment based on gender boundaries. Implemented across a high-volume manufacturing database, LaborGuard-GNN successfully flagged non-compliant corporate structures with a true positive detection rate of 96.8% and an exceptionally low false positive rate under 0.1%, providing state regulatory bodies and trade unions with an empirical, automated auditing tool to enforce labor laws.

Keywords: Heterogeneous Graph Neural Networks, Structural Wage Discrimination, Labor Rights Enforcement, Corporate Auditing Automation, Spatial-Temporal Attention Layers, Exploitative Practice Detection.

SOME RESULTS FOR LİE İDEALS İNVOLVİNG LEFT DERİVATİONS İN 3-PRİME NEAR-RİNGS

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Abstract :

In this work, we build upon our recent findings concerning derivations. The new results utilise left derivations to establish a connection between the commutativity of addition and that of the entire ring, but only apply to 3-prime rings. Some examples are used to justify the hypotheses.

Keywords: 3-prime near-rings, Lie ideals, left derivations

Mathematics Subject Classification (2010): 16N60, 16W25, 16Y3

THE SCIENTIFIC DISCOURSE ON MODERN APPROACHES TO CANCER IMMUNOTHERAPY EXPLORING NOVEL TARGETS, COMBINATION THERAPIES AND FUTURE PERSPECTIVES ADDRESSING THERAPEUTIC RESISTANCE, MECHANISMS OF ACTION, ADVERSE EFFECTS AND TREATMENT-RELATED TOXICITIES

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Abstract

Cancer immunotherapy has fundamentally transformed the therapeutic landscape of oncology by harnessing the intrinsic capacity of the immune system to recognize, target, and eliminate malignant cells. Among the most significant advances in this field has been the development of immune checkpoint inhibitors, which have demonstrated unprecedented and durable clinical responses across a broad spectrum of malignancies. These agents function by disrupting inhibitory signaling pathways that normally regulate immune homeostasis and prevent excessive immune activation. By blocking checkpoint molecules such as cytotoxic T-lymphocyte-associated protein and programmed cell death protein pathways, immune checkpoint inhibitors restore antitumor immune surveillance, enhance T-cell effector function, and promote sustained immune-mediated destruction of cancer cells. The remarkable success of these therapies has established immunotherapy as a cornerstone of modern cancer treatment and has stimulated extensive research aimed at expanding its clinical efficacy and applicability.

Despite the transformative impact of checkpoint blockade, a substantial proportion of patients fail to achieve meaningful clinical benefit, highlighting the complex biological mechanisms that govern therapeutic responsiveness. Tumor heterogeneity, immune evasion strategies, alterations in antigen presentation, suppressive cellular components of the tumor microenvironment, and adaptive resistance mechanisms collectively contribute to both primary and acquired resistance. The dynamic interplay between malignant cells and immune populations creates an immunosuppressive milieu capable of limiting immune activation and facilitating tumor progression. Consequently, a deeper understanding of the molecular and cellular determinants of resistance has become a central focus of contemporary immuno-oncology research. Advances in genomic, transcriptomic, proteomic, and single-cell technologies have provided unprecedented insights into these processes, enabling the identification of predictive biomarkers and novel therapeutic targets that may overcome resistance and improve patient outcomes. The ongoing evolution of cancer immunotherapy extends far beyond conventional checkpoint inhibition. Emerging therapeutic strategies are directed toward a diverse array of immune regulatory pathways that influence antitumor immunity. Novel targets involving co-stimulatory and co-inhibitory receptors, innate immune signaling networks, cytokine-mediated immune modulation, and metabolic pathways are being actively investigated. These approaches seek to augment immune activation, enhance tumor recognition, and counteract immunosuppressive mechanisms within the tumor microenvironment. Furthermore, innovative cellular therapies, including genetically engineered immune cells and adoptive cell transfer platforms, have demonstrated promising activity in selected malignancies and continue to expand the therapeutic repertoire of precision immuno-oncology. The integration of these modalities with established immunotherapeutic approaches offers new opportunities to achieve durable and clinically meaningful responses. Combination therapy has emerged as a particularly important strategy for enhancing therapeutic efficacy and overcoming biological limitations associated with monotherapy. The combination of immune checkpoint inhibitors with chemotherapy, targeted therapy, radiation therapy, antiangiogenic agents, cancer vaccines, and cellular immunotherapies has demonstrated synergistic potential in multiple clinical settings. These multimodal approaches are designed to increase tumor immunogenicity, improve antigen release and presentation, facilitate immune-cell infiltration, and modulate the tumor microenvironment in favor of effective immune responses. Rational combination strategies based on mechanistic understanding and biomarker-driven patient selection represent a critical direction for future therapeutic development. As knowledge of tumor-immune interactions continues to expand, increasingly sophisticated treatment paradigms are expected to emerge, supporting more individualized and effective therapeutic interventions. The mechanisms of action underlying cancer immunotherapy involve complex interactions between innate and adaptive immune systems. Successful antitumor immunity requires efficient antigen recognition, activation of antigen-presenting cells, expansion of tumor-specific lymphocytes, and sustained immune effector function within the tumor microenvironment. Checkpoint blockade amplifies these processes by relieving inhibitory constraints on immune activation, thereby enhancing cytotoxic responses against malignant cells. However, the same mechanisms responsible for therapeutic efficacy may also disrupt physiological immune tolerance, leading to a distinct spectrum of immune-mediated toxicities. These adverse effects represent a significant clinical challenge and require careful monitoring and management to optimize treatment outcomes while minimizing patient morbidity. Immune-related adverse events may affect virtually any organ system and arise from unintended immune activation directed against healthy tissues. Manifestations range from mild inflammatory reactions to severe and potentially life-threatening complications involving dermatologic, gastrointestinal, endocrine, hepatic, pulmonary, cardiovascular, neurologic, and rheumatologic systems. The pathophysiological

mechanisms underlying these toxicities remain incompletely understood but are thought to involve autoreactive lymphocytes, inflammatory cytokine production, autoantibody formation, and disruption of immune tolerance pathways. Early recognition, accurate diagnosis, and appropriate immunosuppressive interventions are essential components of comprehensive patient management. Continued investigation into the biological basis of treatment-related toxicities may facilitate the development of predictive biomarkers and more effective preventive strategies. Future perspectives in cancer immunotherapy are centered on the integration of advanced biomarker discovery, precision medicine, artificial intelligence–assisted clinical decision-making, and next-generation immunotherapeutic platforms. The convergence of systems biology, computational oncology, and translational immunology is expected to accelerate the identification of optimal therapeutic combinations and improve patient stratification. As the understanding of immune regulation and tumor biology continues to deepen, the field is poised to move toward increasingly personalized, effective, and safer treatment approaches. Ultimately, the continued refinement of immunotherapeutic strategies has the potential to overcome resistance, reduce toxicity, and further establish immune-based interventions as a central pillar of cancer care, thereby improving long-term survival and quality of life for patients across diverse malignancies.

Keywords: Cancer Immunotherapy; Immune Checkpoint Inhibitors; Therapeutic Resistance; Combination Therapies; Immune-Related Adverse Events.

INTRODUCTION

Cancer remains one of the most formidable global health challenges and continues to represent a leading cause of morbidity and mortality worldwide. Despite substantial advances in early detection, molecular diagnostics, surgical techniques, radiotherapy, and systemic treatment modalities, many malignancies remain associated with poor clinical outcomes, particularly in advanced and metastatic stages. For decades, conventional therapeutic strategies have primarily focused on the direct eradication of malignant cells through cytotoxic chemotherapy, targeted molecular inhibition, or local tumor control. Although these approaches have contributed significantly to improved survival rates in numerous cancer types, their effectiveness is frequently limited by intrinsic and acquired resistance, tumor heterogeneity, treatment-associated toxicities, and disease recurrence. Consequently, the search for innovative therapeutic paradigms capable of achieving durable and long-lasting clinical responses has become a central objective of modern oncology.

Among the most transformative developments in contemporary cancer treatment has been the emergence of cancer immunotherapy, a therapeutic approach that seeks to harness and augment the intrinsic capabilities of the host immune system to recognize and eliminate malignant cells. Unlike conventional anticancer therapies that primarily target tumor cells directly, immunotherapy focuses on modulating immune responses to restore effective antitumor immunity. This paradigm shift has fundamentally altered the conceptual framework of cancer treatment and has introduced new opportunities for achieving sustained disease control and prolonged survival in patients with a broad range of malignancies.

The concept of utilizing the immune system to combat cancer is rooted in more than a century of scientific investigation. Early observations suggesting that immune responses could influence tumor regression laid the foundation for the development of modern immuno-oncology. The theory of immune surveillance proposed that the immune system continuously monitors tissues for the emergence of transformed cells and eliminates potentially malignant clones before they can establish clinically detectable disease. Subsequent refinements of this concept led to the development of the cancer immunoediting hypothesis, which describes the dynamic interactions between tumors and the immune system through the phases of

elimination, equilibrium, and escape. During the elimination phase, immune effector mechanisms recognize and destroy transformed cells. In the equilibrium phase, residual tumor cells may persist under continuous immune pressure, leading to the selection of variants with reduced immunogenicity. Eventually, immune-resistant tumor populations may emerge and evade immune destruction, resulting in progressive disease and clinical manifestation of cancer.

The recognition that immune evasion represents a hallmark of cancer has provided a strong rationale for the development of therapeutic interventions aimed at restoring antitumor immune responses. Tumor cells employ a diverse array of mechanisms to escape immune recognition and destruction. These mechanisms include downregulation of tumor-associated antigens, impairment of antigen processing and presentation pathways, secretion of immunosuppressive cytokines, recruitment of regulatory immune populations, metabolic reprogramming of the tumor microenvironment, and activation of inhibitory signaling pathways that suppress immune-cell function. Collectively, these strategies create an immunosuppressive environment that facilitates tumor progression and limits the effectiveness of endogenous immune responses.

The discovery of immune checkpoint pathways represented a landmark breakthrough in understanding the mechanisms underlying immune regulation and tumor immune evasion. Immune checkpoints are regulatory molecules that maintain immune homeostasis and prevent excessive immune activation, thereby protecting normal tissues from autoimmune damage. Under physiological conditions, these pathways play essential roles in preserving self-tolerance and controlling inflammatory responses. However, many tumors exploit these regulatory mechanisms to suppress antitumor immunity and evade immune-mediated destruction. The identification of checkpoint molecules such as cytotoxic T-lymphocyte-associated protein and programmed cell death protein, along with their corresponding ligands, revealed critical therapeutic targets capable of reversing tumor-induced immune suppression.

The clinical development of immune checkpoint inhibitors has revolutionized the treatment landscape for numerous malignancies. These agents function by blocking inhibitory receptor-ligand interactions that restrain immune activation, thereby restoring the capacity of T lymphocytes to recognize and eliminate malignant cells. Clinical trials evaluating checkpoint blockade have demonstrated unprecedented and durable responses in patients with advanced cancers that were previously associated with limited therapeutic options and poor prognoses. The success of these therapies has led to their widespread implementation across multiple tumor types, including melanoma, non-small cell lung cancer, renal cell carcinoma, urothelial carcinoma, hepatocellular carcinoma, head and neck squamous cell carcinoma, and various hematologic malignancies.

The remarkable clinical efficacy of immune checkpoint inhibitors has fundamentally altered expectations regarding cancer treatment outcomes. Unlike conventional therapies, which often produce transient responses, immunotherapy can generate durable clinical benefits that persist long after treatment discontinuation. These prolonged responses are believed to result from the establishment of immunological memory and sustained immune surveillance against residual malignant cells. Such observations have provided compelling evidence that effective manipulation of the immune system can produce long-term control of cancer and, in selected cases, achieve functional cures.

Despite these significant advances, the benefits of immune checkpoint inhibition are not universal. A substantial proportion of patients fail to respond to treatment, while others initially respond but subsequently develop disease progression. These patterns of primary and acquired resistance represent major obstacles to maximizing the clinical impact of immunotherapy. Understanding the biological determinants of therapeutic responsiveness has therefore become a central focus of contemporary cancer research. Multiple factors contribute to resistance,

including low tumor immunogenicity, inadequate antigen presentation, impaired T-cell infiltration, activation of alternative immune inhibitory pathways, genomic instability, epigenetic alterations, and immunosuppressive features of the tumor microenvironment. The complexity of these mechanisms underscores the need for comprehensive strategies capable of overcoming resistance and expanding the population of patients who can benefit from immunotherapeutic interventions.

Advances in molecular biology, genomics, transcriptomics, proteomics, and systems immunology have substantially enhanced understanding of tumor–immune interactions. High-throughput technologies have enabled detailed characterization of immune-cell populations, signaling networks, and molecular pathways involved in cancer progression and therapeutic response. These developments have facilitated the identification of predictive biomarkers that may guide patient selection and optimize treatment outcomes. Biomarkers such as programmed death-ligand expression, tumor mutational burden, microsatellite instability status, gene-expression signatures, and immune-cell infiltration patterns have demonstrated varying degrees of clinical utility. However, no single biomarker has consistently predicted treatment response across all malignancies, highlighting the complexity of immune regulation and the necessity for multifactorial predictive models.

The limitations associated with single-agent checkpoint blockade have stimulated the development of novel immunotherapeutic approaches targeting additional components of the immune system. Emerging strategies seek to enhance antitumor immunity through modulation of both innate and adaptive immune responses. Novel immune checkpoints, co-stimulatory receptors, cytokine signaling pathways, pattern-recognition receptors, and metabolic regulators are being actively investigated as potential therapeutic targets. Furthermore, advances in cellular engineering have enabled the development of adoptive cell therapies, including chimeric antigen receptor T-cell therapy, tumor-infiltrating lymphocyte therapy, and genetically modified natural killer cell approaches. These innovative modalities have demonstrated promising clinical activity and continue to expand the therapeutic possibilities within immuno-oncology.

In parallel with the development of novel targets, combination therapy has emerged as one of the most promising strategies for enhancing immunotherapeutic efficacy. Rational combination approaches are designed to address the multifactorial mechanisms that limit antitumor immune responses. The integration of immune checkpoint inhibitors with chemotherapy, radiotherapy, targeted therapies, antiangiogenic agents, cancer vaccines, oncolytic viruses, and cellular immunotherapies has demonstrated significant potential to improve clinical outcomes. These combinations may enhance tumor antigen release, increase immune-cell infiltration, modulate the tumor microenvironment, and overcome adaptive resistance mechanisms. As understanding of tumor immunobiology continues to evolve, increasingly sophisticated combination regimens are expected to play a pivotal role in future treatment paradigms.

Another critical aspect of cancer immunotherapy involves the unique spectrum of adverse events associated with immune modulation. Unlike conventional toxicities resulting from direct cytotoxic effects on rapidly dividing cells, immune-related adverse events arise from excessive or dysregulated immune activation directed against normal tissues. These toxicities may affect virtually any organ system and range from mild inflammatory reactions to severe, life-threatening complications. The growing utilization of immunotherapeutic agents has emphasized the importance of understanding the mechanisms, risk factors, clinical manifestations, and management strategies associated with treatment-related toxicities. Effective recognition and management of these events are essential for maintaining therapeutic efficacy while minimizing patient morbidity and mortality.

The continued evolution of cancer immunotherapy reflects the convergence of advances in immunology, molecular oncology, biotechnology, computational biology, and precision

medicine. The integration of multidimensional biological data with sophisticated analytical approaches is expected to facilitate the development of increasingly personalized therapeutic strategies. Emerging technologies, including artificial intelligence, machine learning, single-cell sequencing, spatial transcriptomics, and systems-level immune profiling, are poised to accelerate the identification of novel therapeutic targets and predictive biomarkers. These innovations hold the potential to refine patient selection, optimize treatment sequencing, reduce toxicity, and enhance long-term clinical outcomes.

As immunotherapy continues to reshape the oncology landscape, comprehensive understanding of immune checkpoint inhibitors, emerging immunotherapeutic targets, resistance mechanisms, combination treatment strategies, mechanisms of action, and treatment-related toxicities remains essential for clinicians, researchers, and healthcare professionals. The ongoing expansion of scientific knowledge in this field is expected to further improve the efficacy, safety, and accessibility of immune-based therapies, ultimately contributing to more effective and durable cancer treatment strategies in the era of precision oncology.

The success of immune checkpoint inhibition has stimulated an unprecedented expansion of research focused on understanding the complex relationship between tumors and the immune system. Cancer is no longer viewed solely as a disease of uncontrolled cellular proliferation resulting from genetic mutations; rather, it is increasingly recognized as a dynamic ecosystem in which malignant cells interact continuously with stromal elements, vascular networks, extracellular matrix components, and diverse immune cell populations. These interactions collectively shape tumor evolution, therapeutic responsiveness, and clinical outcomes. Consequently, a comprehensive understanding of the tumor microenvironment has become fundamental to the advancement of modern immunotherapy.

The tumor microenvironment represents a highly heterogeneous and dynamic biological niche composed of cancer cells and numerous nonmalignant cellular components. These include T lymphocytes, B lymphocytes, natural killer cells, dendritic cells, macrophages, neutrophils, myeloid-derived suppressor cells, cancer-associated fibroblasts, endothelial cells, and various stromal populations. While certain immune cell subsets promote antitumor immunity, others contribute to immunosuppression and facilitate tumor progression. The balance between these opposing forces often determines whether effective immune-mediated tumor destruction occurs or whether malignant cells successfully evade immune surveillance.

Among the most important mediators of antitumor immunity are cytotoxic T lymphocytes. These cells recognize tumor-derived peptides presented by major histocompatibility complex molecules and subsequently initiate targeted destruction of malignant cells through the release of perforin, granzymes, and proinflammatory cytokines. Effective T-cell activation requires coordinated interactions between antigen-presenting cells and naïve T cells within lymphoid tissues. Dendritic cells play a central role in this process by capturing tumor antigens, processing them, and presenting them to T lymphocytes while simultaneously providing essential co-stimulatory signals. The quality and magnitude of these interactions significantly influence the development of effective antitumor immune responses.

Tumors frequently disrupt these processes through multiple immune-evasion mechanisms. Defects in antigen presentation pathways, including loss of major histocompatibility complex expression and alterations in antigen-processing machinery, reduce immune recognition of malignant cells. Furthermore, tumors often produce immunosuppressive cytokines such as transforming growth factor-beta and interleukin-10, which inhibit effector immune functions while promoting the expansion of regulatory cell populations. These alterations create an environment that favors immune tolerance rather than immune activation.

Regulatory T cells constitute a particularly important component of tumor-associated immunosuppression. Under physiological conditions, these cells maintain immune tolerance

and prevent autoimmune disease. Within the tumor microenvironment, however, regulatory T cells suppress antitumor immune responses through multiple mechanisms, including cytokine secretion, metabolic competition, and direct inhibition of effector lymphocytes. Increased infiltration of regulatory T cells has been associated with poor clinical outcomes in numerous malignancies and represents a significant barrier to effective immunotherapy.

Myeloid-derived suppressor cells and tumor-associated macrophages also contribute substantially to immune dysfunction in cancer. These populations suppress T-cell activation, promote angiogenesis, facilitate tissue remodeling, and support metastatic dissemination. Tumor-associated macrophages frequently acquire an immunosuppressive phenotype characterized by the production of anti-inflammatory mediators and growth factors that enhance tumor survival. Consequently, therapeutic strategies targeting suppressive myeloid populations have emerged as promising approaches for enhancing the efficacy of existing immunotherapies.

Metabolic alterations within the tumor microenvironment further contribute to immune dysfunction. Rapidly proliferating cancer cells consume large quantities of glucose, amino acids, and oxygen, generating conditions of nutrient deprivation and hypoxia. These metabolic changes impair immune-cell function and favor the accumulation of immunosuppressive metabolites. Competition for essential nutrients between malignant and immune cells can significantly reduce the effectiveness of antitumor immune responses. Emerging evidence suggests that therapeutic interventions targeting metabolic pathways may restore immune competence and enhance responsiveness to immunotherapy.

In addition to local immunosuppressive mechanisms, systemic factors influence therapeutic outcomes. Host genetics, microbiome composition, nutritional status, chronic inflammation, and age-related immune changes all contribute to variations in treatment response. The intestinal microbiota has attracted particular interest because of its profound influence on immune regulation. Numerous studies have demonstrated associations between specific microbial communities and improved responses to immune checkpoint blockade. Mechanistic investigations suggest that microbial-derived metabolites and immune signaling pathways may enhance systemic antitumor immunity. These observations have stimulated growing interest in microbiome-directed therapeutic strategies designed to augment immunotherapy effectiveness.

The identification of predictive biomarkers remains one of the most important challenges in contemporary immuno-oncology. Accurate biomarkers could facilitate patient selection, optimize treatment decisions, minimize unnecessary toxicity, and improve healthcare resource utilization. Programmed death-ligand expression was among the earliest biomarkers incorporated into clinical practice and continues to influence treatment selection in several malignancies. Nevertheless, substantial variability in testing methodologies, intratumoral heterogeneity, and dynamic expression patterns limit its predictive accuracy.

Tumor mutational burden has emerged as another important biomarker candidate. Tumors harboring large numbers of somatic mutations may generate increased quantities of neoantigens capable of eliciting immune responses. Clinical studies have demonstrated correlations between high mutational burden and improved responsiveness to checkpoint inhibition in certain cancers. However, the predictive value of mutational burden varies considerably across tumor types, emphasizing the need for integrated biomarker approaches.

Microsatellite instability and mismatch repair deficiency represent particularly robust predictors of immunotherapy responsiveness. Defects in DNA repair mechanisms result in the accumulation of mutations and increased neoantigen generation, thereby enhancing tumor immunogenicity. The remarkable clinical activity observed in mismatch repair-deficient tumors has established a landmark precedent for biomarker-driven immunotherapy and highlights the importance of molecular characterization in precision oncology.

Advances in single-cell sequencing and spatial biology technologies are further expanding the biomarker landscape. These approaches enable detailed characterization of cellular populations, signaling pathways, and spatial interactions within tumors. Such insights may facilitate the development of multidimensional predictive models capable of capturing the complexity of tumor-immune dynamics more effectively than individual biomarkers alone.

The continued exploration of immune biology has also revealed numerous therapeutic targets beyond classical checkpoint pathways. Molecules involved in co-stimulatory signaling, immune-cell trafficking, cytokine regulation, innate immune activation, and cellular metabolism represent promising avenues for future intervention. Targeting these pathways may complement existing therapies and address mechanisms responsible for therapeutic resistance. As knowledge of immune regulation continues to expand, the spectrum of potential immunotherapeutic targets is expected to grow substantially, creating new opportunities for improving cancer treatment outcomes.

The rapid expansion of immuno-oncology has extended therapeutic development far beyond the classical immune checkpoint pathways that initially transformed cancer treatment. While blockade of cytotoxic T-lymphocyte-associated protein and programmed cell death protein pathways has demonstrated remarkable clinical success, accumulating evidence indicates that numerous additional regulatory molecules participate in the control of antitumor immunity. These emerging targets have become the focus of intensive investigation as researchers seek to overcome therapeutic resistance and broaden the clinical benefits of immunotherapy to larger patient populations.

Among the most extensively studied next-generation checkpoint molecules are lymphocyte activation gene, T-cell immunoglobulin and mucin-domain-containing protein, T-cell immunoreceptor with immunoglobulin and immunoreceptor tyrosine-based inhibitory motif domains, and V-domain immunoglobulin suppressor of T-cell activation. These inhibitory receptors are frequently expressed on exhausted T lymphocytes within the tumor microenvironment and contribute to progressive immune dysfunction. Chronic antigen exposure, persistent inflammatory signaling, and continuous immune stimulation promote the development of T-cell exhaustion, a state characterized by diminished proliferative capacity, reduced cytokine production, impaired cytotoxic activity, and altered transcriptional programming. The simultaneous expression of multiple inhibitory receptors often represents a hallmark of exhausted immune cells, suggesting that blockade of a single pathway may be insufficient to fully restore antitumor immunity.

The recognition of these complex regulatory networks has provided a strong rationale for the development of novel checkpoint inhibitors and combination approaches targeting multiple inhibitory pathways simultaneously. Preclinical and clinical investigations have demonstrated that dual checkpoint blockade may enhance immune activation and improve therapeutic outcomes in selected malignancies. These findings have encouraged continued exploration of synergistic immunotherapeutic strategies designed to address the multifactorial mechanisms responsible for immune suppression and therapeutic resistance.

In parallel with advances in checkpoint biology, substantial progress has been achieved in the field of adoptive cellular immunotherapy. This therapeutic modality involves the collection, modification, expansion, and reinfusion of immune cells capable of mediating antitumor activity. Among the most notable innovations in this area is chimeric antigen receptor T-cell therapy, which has revolutionized the treatment of several hematologic malignancies. Through genetic engineering techniques, patient-derived T lymphocytes are modified to express synthetic receptors that recognize specific tumor-associated antigens independently of conventional antigen presentation pathways. Following reinfusion, these engineered cells can selectively target and destroy malignant cells with remarkable efficacy.

The clinical success of chimeric antigen receptor T-cell therapy has demonstrated the transformative potential of cellular engineering in oncology. Durable remissions have been observed in patients with otherwise refractory hematologic cancers, highlighting the capacity of engineered immune cells to overcome traditional therapeutic limitations. Nevertheless, significant challenges remain, particularly in the treatment of solid tumors. Barriers including antigen heterogeneity, limited cellular trafficking, immunosuppressive tumor microenvironments, and treatment-associated toxicities continue to restrict broader clinical application. Ongoing research seeks to address these obstacles through the development of next-generation cellular platforms with enhanced persistence, specificity, and resistance to immunosuppressive influences.

Tumor-infiltrating lymphocyte therapy represents another important form of adoptive cellular immunotherapy. This approach involves the isolation of naturally occurring tumor-reactive lymphocytes from tumor specimens, followed by ex vivo expansion and reinfusion into the patient. The therapeutic rationale is based on the premise that tumors already contain immune cells capable of recognizing malignant antigens, but these cells are often present in insufficient numbers or exhibit functional impairment. Expansion and activation of tumor-reactive lymphocytes outside the suppressive tumor environment can restore their antitumor capacity and improve clinical efficacy. Encouraging outcomes observed in melanoma and other malignancies have reinforced interest in further refining this therapeutic strategy.

Natural killer cell–based therapies have also emerged as promising immunotherapeutic approaches. Unlike T lymphocytes, natural killer cells possess the ability to recognize and eliminate malignant cells without prior antigen sensitization. Their activity is regulated through a balance of activating and inhibitory signals that enable rapid responses against transformed cells. Advances in cellular engineering, cytokine support systems, and allogeneic donor platforms have expanded the therapeutic potential of natural killer cell therapies and may provide additional options for overcoming resistance to conventional immunotherapeutic interventions.

Another rapidly evolving area of investigation involves therapeutic cancer vaccines. Unlike prophylactic vaccines designed to prevent infectious diseases, therapeutic cancer vaccines seek to stimulate immune responses against established malignancies. These vaccines employ a variety of strategies to enhance tumor antigen recognition and promote durable antitumor immunity. Approaches include peptide-based vaccines, nucleic acid vaccines, dendritic cell vaccines, neoantigen-directed platforms, and personalized vaccine technologies. The increasing availability of genomic sequencing has facilitated the identification of patient-specific neoantigens, creating opportunities for highly individualized vaccine development. Although challenges related to immune tolerance and antigen heterogeneity remain significant, continued technological advances are improving the feasibility and effectiveness of therapeutic vaccination strategies.

Oncolytic virotherapy represents another innovative modality within the expanding immunotherapy landscape. Oncolytic viruses are engineered or naturally occurring viruses capable of selectively infecting and destroying malignant cells while sparing normal tissues. Beyond direct tumor lysis, viral infection stimulates local inflammation, enhances antigen release, promotes dendritic cell activation, and facilitates the generation of systemic antitumor immune responses. Consequently, oncolytic viruses may function as both direct anticancer agents and immune stimulators. The integration of oncolytic virotherapy with immune checkpoint inhibition has generated considerable interest because of the potential for synergistic enhancement of antitumor immunity.

As the complexity of tumor biology and immune regulation becomes increasingly apparent, combination therapy has emerged as a central principle of modern immuno-oncology. Monotherapeutic approaches frequently fail to address the diverse mechanisms responsible for

tumor progression and immune evasion. Consequently, rational combinations designed to target multiple biological pathways simultaneously are being actively pursued. The combination of immune checkpoint inhibitors with chemotherapy represents one of the most widely adopted strategies. Cytotoxic agents can enhance tumor immunogenicity by inducing immunogenic cell death, increasing antigen release, and modifying the tumor microenvironment in ways that promote immune activation. These effects may sensitize tumors to subsequent immune-mediated destruction.

Radiotherapy also possesses important immunomodulatory properties. In addition to direct cytotoxic effects, radiation can increase antigen presentation, stimulate inflammatory signaling pathways, and facilitate immune-cell infiltration. The phenomenon known as the abscopal effect, in which localized radiation induces systemic antitumor responses at distant tumor sites, highlights the potential synergy between radiotherapy and immunotherapy. Although relatively uncommon, such observations have provided valuable insights into the mechanisms through which local treatment may enhance systemic immune responses.

Targeted molecular therapies and antiangiogenic agents have likewise demonstrated potential for combination with immunotherapeutic interventions. By modulating signaling pathways involved in tumor growth, vascular remodeling, and immune regulation, these agents may create conditions more favorable for effective immune activation. The integration of molecularly targeted therapies with immune checkpoint blockade represents an important area of ongoing clinical investigation and may facilitate more personalized treatment approaches.

Despite remarkable therapeutic advances, immune-related adverse events remain among the most significant challenges associated with cancer immunotherapy. The mechanisms responsible for therapeutic efficacy are closely linked to those underlying treatment-related toxicities. Enhancement of immune activation can disrupt normal mechanisms of self-tolerance and lead to inflammatory damage affecting healthy tissues. These adverse events differ substantially from the toxicities associated with conventional chemotherapy and require specialized approaches to diagnosis and management.

Immune-mediated toxicities may involve virtually any organ system. Dermatologic manifestations, including rash, pruritus, and vitiligo, are among the most commonly observed complications. Gastrointestinal toxicities such as colitis and enteritis can result in severe inflammation and significant morbidity. Endocrine complications affecting the thyroid gland, pituitary gland, adrenal glands, and pancreatic islets may lead to permanent hormonal dysfunction requiring lifelong replacement therapy. Hepatic inflammation, pneumonitis, nephritis, myocarditis, neurologic syndromes, and rheumatologic disorders represent additional clinically important manifestations.

The severity of immune-related adverse events varies considerably, ranging from mild self-limited conditions to life-threatening complications requiring intensive medical intervention. Early recognition and prompt treatment are essential for minimizing morbidity and preserving treatment efficacy. Corticosteroids remain the cornerstone of management for many severe toxicities, although additional immunosuppressive agents may be required in refractory cases. Continued investigation into the biological mechanisms underlying immune-mediated toxicities may facilitate the development of predictive biomarkers and personalized toxicity-management strategies.

Future directions in cancer immunotherapy are increasingly centered on the principles of precision medicine. The integration of genomic profiling, transcriptomic analysis, proteomic characterization, metabolomic assessment, and advanced computational modeling is expected to transform patient selection and treatment optimization. Artificial intelligence and machine-learning technologies are being applied to large-scale clinical and biological datasets to identify predictive patterns associated with treatment response, resistance, and toxicity. These

approaches may ultimately support more individualized therapeutic decision-making and improve clinical outcomes.

Emerging technologies such as single-cell sequencing, spatial transcriptomics, multiplex imaging, and systems immunology are providing unprecedented insights into the complexity of tumor–immune interactions. By enabling detailed characterization of cellular heterogeneity and spatial organization within tumors, these methodologies offer opportunities to identify novel therapeutic targets and refine existing treatment strategies. The convergence of these technological advances with innovative therapeutic platforms is expected to accelerate the development of increasingly effective and personalized immunotherapeutic interventions.

Cancer immunotherapy has evolved from a conceptual scientific aspiration into a central pillar of modern oncology. The development of immune checkpoint inhibitors has fundamentally transformed cancer treatment and demonstrated the extraordinary potential of harnessing the immune system to combat malignant disease. Continued investigation into novel targets, adoptive cellular therapies, therapeutic vaccines, oncolytic virotherapy, and rational combination strategies is expanding the scope and effectiveness of immunotherapeutic interventions. Simultaneously, efforts to understand mechanisms of resistance, identify predictive biomarkers, and mitigate treatment-related toxicities are shaping the next generation of precision immuno-oncology. As scientific knowledge continues to advance, immunotherapy is poised to play an increasingly prominent role in achieving durable disease control, improving survival outcomes, and ultimately redefining the future of cancer care.

BACKGROUND

Cancer represents a complex and multifactorial group of diseases characterized by uncontrolled cellular proliferation, genomic instability, evasion of growth suppressors, resistance to programmed cell death, metabolic reprogramming, and the capacity for invasion and metastasis. Despite substantial advances in cancer biology and therapeutic development, malignancies remain among the leading causes of morbidity and mortality worldwide. Traditional treatment modalities, including surgery, chemotherapy, radiotherapy, hormonal therapy, and targeted molecular interventions, have significantly improved clinical outcomes for many patients. Nevertheless, therapeutic resistance, disease recurrence, metastatic progression, and treatment-related toxicities continue to limit the effectiveness of conventional approaches. These challenges have driven the search for innovative therapeutic strategies capable of producing durable and sustained antitumor responses while minimizing damage to healthy tissues.

The relationship between the immune system and cancer has long been recognized as a critical determinant of tumor development and progression. Early observations suggested that immune mechanisms could influence tumor growth, leading to the hypothesis that the immune system possesses the capacity to recognize and eliminate malignant cells. This concept eventually evolved into the theory of immune surveillance, which proposed that transformed cells are continuously monitored and destroyed by immune defenses before clinically detectable tumors can emerge. Although initial evidence supporting this theory was limited, advances in immunology, molecular biology, and oncology have provided substantial support for the notion that immune responses play a fundamental role in controlling tumor development.

The contemporary understanding of tumor immunology is largely based on the concept of cancer immunoediting, which describes the dynamic interaction between malignant cells and the host immune system. Cancer immunoediting encompasses three interconnected phases: elimination, equilibrium, and escape. During the elimination phase, innate and adaptive immune mechanisms cooperate to identify and destroy transformed cells. Natural killer cells, dendritic cells, macrophages, cytotoxic T lymphocytes, and various cytokines contribute to the recognition and eradication of emerging malignancies. If complete elimination does not occur,

residual tumor cells may enter an equilibrium phase during which immune pressure limits tumor growth while simultaneously selecting for variants capable of resisting immune attack. Over time, these resistant populations may acquire characteristics that facilitate immune evasion, resulting in the escape phase and the development of clinically apparent cancer.

The ability of tumors to evade immune destruction is now recognized as one of the fundamental hallmarks of cancer. Malignant cells employ numerous strategies to suppress or circumvent immune responses. These mechanisms include reduced expression of tumor antigens, defects in antigen presentation pathways, secretion of immunosuppressive cytokines, recruitment of regulatory immune populations, induction of immune checkpoint signaling, and metabolic alterations that impair immune-cell function. The cumulative effect of these processes is the establishment of an immunosuppressive tumor microenvironment that promotes tumor survival and progression while limiting the effectiveness of endogenous antitumor immunity.

A critical milestone in the evolution of cancer immunotherapy was the identification of immune checkpoint pathways. Immune checkpoints are regulatory mechanisms that maintain immune homeostasis and prevent excessive immune activation. Under normal physiological conditions, these pathways protect healthy tissues from immune-mediated damage and preserve self-tolerance. However, tumors frequently exploit checkpoint signaling pathways to suppress antitumor immune responses. The discovery that blockade of these inhibitory pathways could restore immune function and facilitate tumor destruction revolutionized the field of oncology and provided the foundation for modern immune checkpoint inhibitor therapy.

The immune response against cancer is mediated through intricate interactions between innate and adaptive immune systems. Antigen-presenting cells, particularly dendritic cells, play a central role in initiating adaptive immunity by capturing tumor-associated antigens and presenting them to T lymphocytes. Effective activation of T cells requires both antigen recognition and co-stimulatory signaling. Once activated, cytotoxic T lymphocytes migrate to tumor sites and destroy malignant cells through multiple mechanisms, including the release of cytotoxic granules and the production of proinflammatory cytokines. The effectiveness of this process depends on the maintenance of a functional immune environment capable of supporting sustained antitumor activity.

Tumors frequently disrupt these processes through activation of inhibitory immune pathways. Cytotoxic T-lymphocyte-associated protein functions as a negative regulator of T-cell activation during the early stages of immune responses. Similarly, programmed cell death protein and its ligands regulate immune activity within peripheral tissues and contribute to the maintenance of immune tolerance. By exploiting these inhibitory pathways, tumor cells can suppress immune-cell activation and avoid destruction. Therapeutic inhibition of checkpoint signaling restores immune function, enhances T-cell activity, and promotes immune-mediated elimination of cancer cells.

The introduction of immune checkpoint inhibitors has transformed the treatment of numerous malignancies. Durable responses and prolonged survival have been observed in cancers previously associated with limited therapeutic options. Melanoma, non-small cell lung cancer, renal cell carcinoma, urothelial carcinoma, hepatocellular carcinoma, head and neck cancers, and various hematologic malignancies have demonstrated significant responsiveness to checkpoint blockade. These clinical successes have validated the concept that manipulation of immune regulatory pathways can produce meaningful and sustained therapeutic benefit.

Despite these achievements, clinical responses to checkpoint inhibition remain highly variable. Many patients fail to respond, while others develop resistance after an initial period of clinical improvement. This variability reflects the complexity of tumor-immune interactions and underscores the importance of understanding mechanisms that influence therapeutic responsiveness. Primary resistance may result from insufficient tumor immunogenicity, absence of tumor-reactive lymphocytes, defective antigen presentation, or dominant

immunosuppressive mechanisms within the tumor microenvironment. Acquired resistance may emerge through tumor evolution, immune adaptation, antigen loss, activation of alternative inhibitory pathways, or changes in immune-cell composition.

The tumor microenvironment has emerged as a critical determinant of immunotherapeutic success. This environment consists of a diverse collection of malignant cells, stromal components, vascular structures, extracellular matrix elements, and immune-cell populations. The composition and functional characteristics of the tumor microenvironment influence immune-cell infiltration, activation, persistence, and antitumor efficacy. Immunologically active tumors characterized by substantial T-cell infiltration generally demonstrate greater responsiveness to checkpoint inhibition than tumors exhibiting limited immune-cell presence. Consequently, considerable research efforts have focused on understanding the factors that regulate immune-cell trafficking and function within tumors.

The growing appreciation of immune complexity has stimulated the development of therapeutic strategies extending beyond classical checkpoint inhibition. Novel immune regulatory targets have been identified through advances in molecular immunology and systems biology. These targets include additional inhibitory receptors, co-stimulatory molecules, cytokine pathways, innate immune regulators, and metabolic checkpoints. Therapeutic interventions directed against these pathways seek to enhance immune activation, reverse immunosuppression, and improve clinical outcomes in patients who do not respond adequately to existing treatments.

Cellular immunotherapy has emerged as another important component of modern cancer treatment. Advances in genetic engineering have enabled the development of adoptive cell therapies capable of specifically targeting malignant cells. Chimeric antigen receptor T-cell therapy represents one of the most successful examples of this approach and has demonstrated remarkable efficacy in several hematologic malignancies. Tumor-infiltrating lymphocyte therapy and natural killer cell–based strategies have further expanded the scope of cellular immunotherapy and highlighted the potential of personalized immune-based interventions.

Therapeutic cancer vaccines and oncolytic viruses have also contributed to the evolving immunotherapeutic landscape. Cancer vaccines seek to enhance immune recognition of tumor-associated antigens and stimulate durable antitumor immunity. Advances in genomic sequencing and neoantigen identification have facilitated the development of personalized vaccine platforms tailored to individual patients. Oncolytic viruses, in contrast, promote antitumor responses through selective infection and destruction of malignant cells while simultaneously stimulating immune activation. These approaches illustrate the diverse mechanisms through which immunotherapy can be employed to combat cancer.

Combination therapy has become a major focus of contemporary immuno-oncology research. The multifactorial nature of immune resistance often limits the effectiveness of monotherapy, necessitating approaches that target multiple pathways simultaneously. Combining immune checkpoint inhibitors with chemotherapy, radiotherapy, targeted therapies, antiangiogenic agents, cellular therapies, vaccines, or oncolytic viruses may enhance tumor immunogenicity and overcome resistance mechanisms. Rationally designed combination regimens are increasingly viewed as essential for maximizing therapeutic efficacy and extending the benefits of immunotherapy to broader patient populations.

Although immunotherapy has revolutionized cancer treatment, it is also associated with unique toxicities resulting from enhanced immune activation. Immune-related adverse events arise when activated immune responses target healthy tissues and disrupt normal physiological processes. These complications can affect virtually any organ system and vary substantially in severity. Dermatologic, gastrointestinal, endocrine, pulmonary, hepatic, neurologic, cardiovascular, renal, and musculoskeletal toxicities have all been reported in association with immune checkpoint inhibitors and other immunotherapeutic interventions. The management of

these adverse events has become an integral component of clinical oncology practice and requires multidisciplinary collaboration among healthcare professionals.

The increasing integration of immunotherapy into standard cancer treatment has highlighted the need for predictive biomarkers capable of identifying patients most likely to benefit from specific interventions. Biomarker development has become a major research priority in immuno-oncology. Programmed death-ligand expression, tumor mutational burden, microsatellite instability status, gene-expression profiles, and characteristics of the tumor immune microenvironment have all been investigated as potential predictors of treatment response. While each biomarker provides valuable information, none possesses sufficient accuracy to fully capture the complexity of immune responsiveness. Consequently, ongoing efforts are focused on developing integrated biomarker models that combine molecular, cellular, genomic, and clinical variables.

Technological advances have significantly accelerated progress in the field of cancer immunotherapy. High-throughput sequencing, single-cell analysis, spatial transcriptomics, multiplex imaging, proteomics, metabolomics, and computational biology have provided unprecedented insights into tumor biology and immune regulation. These technologies enable detailed characterization of tumor heterogeneity, immune-cell populations, signaling networks, and resistance mechanisms. The integration of these approaches with artificial intelligence and machine-learning methodologies is expected to facilitate the discovery of novel therapeutic targets and optimize patient-specific treatment strategies.

The emergence of precision oncology has further strengthened the role of immunotherapy within contemporary cancer care. Precision medicine seeks to tailor therapeutic interventions according to the unique biological characteristics of individual patients and their tumors. By incorporating molecular profiling, biomarker assessment, and immune characterization into clinical decision-making, healthcare providers can select therapies that maximize efficacy while minimizing unnecessary toxicity. Immunotherapy is particularly well suited to precision medicine because of its dependence on specific molecular and immunological determinants of responsiveness.

The development of cancer immunotherapy represents one of the most significant achievements in modern biomedical science. The recognition that the immune system can be manipulated to achieve durable antitumor responses has transformed clinical oncology and established a new paradigm for cancer treatment. Continued investigation into immune biology, tumor microenvironment dynamics, resistance mechanisms, novel therapeutic targets, and biomarker-guided approaches is expected to further enhance the effectiveness of immunotherapeutic interventions. As scientific understanding continues to expand, immunotherapy will likely remain at the forefront of cancer research and clinical practice, offering new opportunities to improve survival, quality of life, and long-term outcomes for patients affected by malignant disease.

Goal

The primary goal of this review is to comprehensively examine the evolving landscape of cancer immunotherapy, with particular emphasis on immune checkpoint inhibitors, their mechanisms of action, clinical applications, therapeutic efficacy, and associated toxicities. Furthermore, this work aims to explore emerging immunotherapeutic targets, combination treatment strategies, and mechanisms underlying therapeutic resistance. By integrating current scientific evidence and recent advances in immuno-oncology, the review seeks to provide a critical understanding of future directions in precision cancer immunotherapy and their potential to improve patient outcomes and long-term disease control.

Methodology

This review was conducted using a comprehensive narrative literature review approach to evaluate the current evidence regarding immune checkpoint inhibitors and emerging strategies

in cancer immunotherapy. Relevant scientific publications were identified through searches of major biomedical databases, including PubMed, MEDLINE, Scopus, Web of Science, and Google Scholar. Peer-reviewed articles, clinical trials, systematic reviews, consensus guidelines, and landmark studies published in the field of immuno-oncology were critically examined. Particular emphasis was placed on studies addressing mechanisms of action, therapeutic efficacy, resistance mechanisms, novel immunotherapeutic targets, combination treatment approaches, immune-related adverse events, and treatment-associated toxicities. The collected literature was systematically analyzed and synthesized to provide an integrated overview of contemporary developments in cancer immunotherapy. Information from preclinical investigations, translational research, and clinical studies was evaluated to identify major advances, current challenges, and future perspectives. The review prioritized high-quality evidence and clinically relevant findings to ensure a balanced and comprehensive assessment of the evolving role of immunotherapy in modern oncology.

Results and Discussion

The findings synthesized in this review demonstrate that cancer immunotherapy has fundamentally transformed the therapeutic landscape of oncology and has established a new paradigm for the management of malignant disease. The accumulated evidence indicates that immune checkpoint inhibitors represent one of the most significant advances in cancer treatment since the introduction of modern chemotherapy and targeted molecular therapies. Their ability to restore immune-mediated tumor recognition and destruction has resulted in substantial improvements in clinical outcomes across a wide range of malignancies. The results examined throughout the literature consistently reveal that activation of endogenous antitumor immunity can generate durable therapeutic responses, prolonged survival, and sustained disease control in selected patient populations.

A major finding emerging from contemporary immuno-oncology research is the central role of immune evasion in cancer progression. Tumors possess remarkable biological adaptability and employ numerous mechanisms to escape immune surveillance. The reviewed evidence demonstrates that malignant cells exploit physiological immune-regulatory pathways to suppress antitumor immune responses and create a permissive environment for tumor growth. Among these mechanisms, activation of immune checkpoint pathways has emerged as one of the most important contributors to immune dysfunction. The discovery that inhibition of these pathways could restore immune activity provided the scientific foundation for the development of checkpoint blockade therapies and ultimately transformed the clinical management of cancer.

The results obtained from preclinical investigations established that cytotoxic T-lymphocyte-associated protein and programmed cell death protein pathways function as critical negative regulators of T-cell activity. These pathways normally serve to maintain immune homeostasis and prevent excessive inflammatory responses. However, tumors frequently exploit these regulatory mechanisms to suppress immune-cell activation and evade destruction. Experimental studies consistently demonstrated that blockade of inhibitory checkpoint signaling restored T-cell proliferation, enhanced cytokine production, increased cytotoxic activity, and improved tumor control. These findings provided compelling biological evidence supporting clinical translation and subsequently led to the development of therapeutic checkpoint inhibitors.

Clinical findings have validated these mechanistic observations and demonstrated remarkable therapeutic efficacy across multiple malignancies. One of the most notable observations is the capacity of checkpoint inhibitors to induce durable clinical responses that differ substantially from those achieved with conventional cytotoxic therapies. Traditional chemotherapy frequently produces rapid tumor shrinkage but often fails to provide long-term disease control

because of the emergence of resistant tumor populations. In contrast, immunotherapy appears capable of generating sustained immune surveillance that persists beyond active treatment administration. The reviewed evidence suggests that immunological memory plays a central role in maintaining long-term tumor control and contributes significantly to the durability of observed responses.

Melanoma represents one of the most important examples illustrating the transformative potential of immune checkpoint inhibition. Historically, advanced melanoma was associated with extremely poor clinical outcomes and limited therapeutic options. The introduction of checkpoint inhibitors resulted in unprecedented improvements in survival and established immunotherapy as a cornerstone of treatment. Long-term follow-up studies demonstrated that a subset of patients achieved prolonged disease control extending for many years. These observations provided some of the earliest evidence that immune-based therapies could fundamentally alter the natural history of advanced cancer.

Similar therapeutic benefits have been documented in non-small cell lung cancer, a malignancy historically characterized by poor prognosis and limited survival in advanced stages. The reviewed findings demonstrate that checkpoint inhibitors significantly improve overall survival and progression-free survival compared with conventional treatment approaches. Importantly, these benefits have been observed across diverse patient populations and disease settings, including both previously treated and treatment-naïve individuals. The successful application of immunotherapy in lung cancer further reinforced the concept that immune modulation can provide meaningful clinical benefit across distinct tumor types.

Renal cell carcinoma provides additional evidence supporting the effectiveness of immune checkpoint inhibition. This malignancy has long been recognized as immunologically responsive, and the reviewed literature indicates that checkpoint blockade substantially enhances therapeutic outcomes. Clinical trials consistently demonstrated improved survival and durable response rates, particularly when immunotherapy was integrated with targeted treatment strategies. Similar observations have been reported in urothelial carcinoma, hepatocellular carcinoma, head and neck cancers, and several hematologic malignancies, collectively highlighting the broad applicability of immune-based interventions.

A particularly important finding emerging from the literature is the considerable variability observed in treatment responsiveness. Although checkpoint inhibitors have produced remarkable clinical outcomes, not all patients derive benefit from therapy. The reviewed evidence indicates that response rates vary substantially among tumor types and individual patients. This variability reflects the complexity of tumor biology and underscores the importance of understanding factors that influence therapeutic responsiveness. Consequently, the identification of predictive biomarkers has become one of the most important objectives in contemporary immuno-oncology research.

Programmed death-ligand expression has emerged as one of the most extensively investigated predictive biomarkers. Numerous studies reviewed in this analysis demonstrated associations between elevated ligand expression and improved responsiveness to checkpoint blockade. Tumors expressing higher levels of inhibitory ligands appear more dependent on immune checkpoint signaling and may therefore be particularly susceptible to therapeutic inhibition. However, the findings also reveal substantial limitations associated with this biomarker. Expression levels vary across tumors, differ within individual lesions, and may change dynamically over time. These observations suggest that programmed death-ligand expression alone is insufficient to fully explain treatment responsiveness.

Tumor mutational burden has also received considerable attention as a potential predictor of immunotherapy benefit. The reviewed evidence demonstrates that tumors harboring large numbers of somatic mutations frequently generate increased quantities of neoantigens capable of stimulating immune responses. Clinical studies consistently reported improved outcomes

among patients with highly mutated tumors, supporting the biological rationale underlying this biomarker. Nevertheless, important exceptions have been identified, and some tumors with low mutational burdens still demonstrate meaningful responsiveness to immunotherapy. Consequently, mutational burden should be considered one component of a broader predictive framework rather than a definitive determinant of treatment outcome.

Microsatellite instability and mismatch repair deficiency emerged from the reviewed literature as particularly robust predictors of immunotherapy responsiveness. Tumors exhibiting defects in DNA repair pathways accumulate extensive genomic alterations and generate large numbers of neoantigens. The findings consistently demonstrate exceptional sensitivity of these malignancies to checkpoint inhibition. These observations represent a landmark achievement in precision oncology because they illustrate how molecular characteristics can guide therapeutic selection regardless of tumor tissue origin. The success of this biomarker-driven approach has encouraged broader efforts to identify molecular signatures capable of predicting treatment benefit.

An important theme throughout the reviewed studies is the critical influence of the tumor microenvironment on therapeutic efficacy. The results indicate that tumor responsiveness is determined not only by intrinsic characteristics of malignant cells but also by interactions between tumors and surrounding cellular populations. Immune-cell infiltration emerged as one of the strongest determinants of treatment success. Tumors containing abundant cytotoxic lymphocytes generally demonstrated superior responsiveness compared with immunologically inactive tumors lacking significant immune-cell presence.

These observations support the distinction between immune-inflamed and noninflamed tumor phenotypes. Immune-inflamed tumors are characterized by substantial infiltration of activated immune cells and frequently exhibit increased sensitivity to checkpoint inhibition. Conversely, immune-desert tumors contain limited immune-cell populations and often demonstrate resistance to therapy. The reviewed evidence suggests that the absence of immune infiltration represents a major barrier to effective treatment and may explain many cases of primary resistance.

Further analysis revealed that immunosuppressive cellular populations play important roles in limiting therapeutic efficacy. Regulatory T cells, myeloid-derived suppressor cells, and tumor-associated macrophages were consistently associated with reduced responsiveness and unfavorable clinical outcomes. These populations contribute to immune dysfunction through multiple mechanisms, including cytokine secretion, metabolic competition, inhibition of effector lymphocytes, and promotion of tumor-supportive inflammatory environments. Their presence highlights the complexity of tumor-immune interactions and underscores the need for therapeutic strategies capable of addressing multiple immunosuppressive pathways simultaneously.

Metabolic alterations within the tumor microenvironment also emerged as important determinants of immunotherapy outcomes. The reviewed findings indicate that rapidly proliferating tumors consume substantial quantities of nutrients and oxygen, creating metabolically hostile conditions for immune cells. Hypoxia, glucose depletion, amino acid competition, and accumulation of suppressive metabolites collectively impair immune-cell function and reduce therapeutic effectiveness. These observations have stimulated growing interest in metabolic interventions designed to enhance antitumor immunity and improve responsiveness to immunotherapy.

The reviewed evidence further demonstrates that therapeutic resistance remains one of the most significant challenges confronting modern immuno-oncology. Primary resistance occurs when tumors fail to respond to treatment despite adequate drug exposure. Findings suggest that primary resistance frequently results from insufficient tumor immunogenicity, absence of immune-cell infiltration, defective antigen presentation, or dominant immunosuppressive

mechanisms. Acquired resistance, in contrast, develops following an initial period of clinical benefit and is often associated with tumor evolution under selective immune pressure.

Research findings indicate that acquired resistance may involve loss of tumor antigens, alterations in antigen-presentation pathways, activation of alternative inhibitory receptors, and emergence of resistant cellular populations. These mechanisms illustrate the remarkable adaptability of malignant cells and emphasize the necessity for continued therapeutic innovation. The recognition that tumors can evolve in response to immune pressure has fundamentally influenced the design of next-generation immunotherapeutic strategies and supports the growing emphasis on combination therapy approaches.

The results reviewed in this section demonstrate that immune checkpoint inhibitors have produced substantial advances in cancer treatment and established the immune system as a highly effective therapeutic target. Durable responses, prolonged survival, and broad applicability across multiple malignancies underscore their clinical significance. However, the findings also highlight persistent challenges, including therapeutic resistance, biomarker limitations, and tumor microenvironment–mediated immune suppression. These observations provide a strong rationale for continued investigation into novel immunotherapeutic targets, combination treatment strategies, and precision medicine approaches aimed at maximizing the benefits of cancer immunotherapy.

The findings presented in the preceding section establish that immune checkpoint inhibition has significantly improved outcomes for many patients with cancer. However, the variability of therapeutic responses and the persistence of resistance mechanisms indicate that checkpoint blockade alone is insufficient to address the complexity of tumor–immune interactions. Consequently, a substantial proportion of contemporary immuno-oncology research has focused on the identification of novel therapeutic targets and the development of innovative treatment modalities capable of enhancing antitumor immunity. The results reviewed in this section demonstrate that emerging immunotherapeutic approaches have expanded the therapeutic landscape and provided promising strategies for overcoming limitations associated with conventional checkpoint inhibition.

One of the most important findings from recent investigations is that immune exhaustion is regulated by multiple inhibitory pathways beyond those initially targeted by immune checkpoint inhibitors. Chronic antigen exposure within the tumor microenvironment results in progressive dysfunction of immune cells characterized by reduced proliferative capacity, impaired cytokine production, diminished cytotoxic activity, and altered transcriptional programs. Research findings indicate that exhausted T lymphocytes frequently express multiple inhibitory receptors simultaneously, suggesting that blockade of a single pathway may be insufficient to fully restore immune competence.

Studies evaluating novel checkpoint molecules have demonstrated that receptors such as lymphocyte activation gene, T-cell immunoglobulin and mucin-domain-containing protein, and T-cell immunoreceptor with immunoglobulin and immunoreceptor tyrosine-based inhibitory motif domains contribute significantly to immune suppression. Increased expression of these molecules has been associated with disease progression, poor prognosis, and resistance to established immunotherapies. Experimental investigations consistently showed that inhibition of these pathways enhanced T-cell function and improved tumor control. These observations support the concept that immune dysfunction results from the coordinated activity of multiple regulatory mechanisms rather than dependence on a single inhibitory pathway.

Clinical studies examining next-generation checkpoint inhibitors have produced encouraging results. Combination strategies targeting multiple inhibitory receptors simultaneously demonstrated enhanced immune activation and improved response rates in selected patient populations. The reviewed findings suggest that dual or multi-checkpoint blockade may overcome resistance mechanisms that limit the effectiveness of conventional therapies.

However, increased immune activation also raises concerns regarding treatment-related toxicity, emphasizing the need for careful balancing of efficacy and safety considerations.

The emergence of co-stimulatory receptor targeting represents another significant development in cancer immunotherapy. Whereas checkpoint inhibitors function by removing inhibitory signals, co-stimulatory agonists actively enhance immune activation. Research findings indicate that stimulation of specific co-stimulatory pathways promotes T-cell proliferation, survival, cytokine production, and effector function. Experimental models demonstrated substantial enhancement of antitumor immunity following activation of these pathways. Although clinical development remains ongoing, the available evidence suggests that co-stimulatory targeting may complement checkpoint inhibition and provide additional opportunities for therapeutic intervention.

Another major area of advancement involves adoptive cellular immunotherapy. The reviewed findings consistently demonstrate that engineered immune-cell therapies possess the capacity to generate potent and highly specific antitumor responses. Among these approaches, chimeric antigen receptor T-cell therapy represents one of the most remarkable achievements in modern oncology. Clinical studies have reported unprecedented response rates in patients with advanced hematologic malignancies that were previously resistant to conventional treatments. The success of chimeric antigen receptor T-cell therapy is attributable to its ability to circumvent many limitations associated with endogenous immune responses. Through genetic engineering, immune cells acquire enhanced specificity for tumor-associated antigens and can recognize malignant cells independently of conventional antigen presentation mechanisms. Following reinfusion, these engineered cells proliferate, persist, and mediate targeted destruction of cancer cells. The reviewed evidence demonstrates that this approach has produced durable remissions and prolonged survival in numerous patients with otherwise limited therapeutic options.

Despite these remarkable achievements, important challenges remain. Research findings indicate that antigen escape constitutes a major mechanism of treatment failure. Tumors may downregulate or eliminate target antigens, thereby avoiding recognition by engineered immune cells. Additionally, the immunosuppressive microenvironment characteristic of many solid tumors limits cellular trafficking, persistence, and functionality. These observations explain why cellular therapies have demonstrated greater success in hematologic malignancies than in most solid tumors.

Efforts to overcome these limitations have generated substantial innovation. Next-generation cellular platforms incorporate multiple antigen-recognition domains, enhanced persistence mechanisms, resistance to immunosuppressive signaling, and improved safety features. Research findings suggest that these modifications may significantly expand the clinical applicability of adoptive cellular therapies and improve outcomes in previously difficult-to-treat malignancies.

Tumor-infiltrating lymphocyte therapy provides additional evidence supporting the effectiveness of cellular immunotherapy. Unlike genetically engineered approaches, this strategy utilizes naturally occurring tumor-reactive lymphocytes isolated directly from tumor tissues. The reviewed findings indicate that these cells frequently possess intrinsic antitumor specificity and can mediate substantial clinical responses when expanded and reinfused in sufficient numbers. Clinical studies demonstrated particularly encouraging outcomes in melanoma, supporting the concept that naturally occurring antitumor immunity can be therapeutically amplified.

Natural killer cell–based therapies have emerged as another promising area of investigation. Research findings indicate that natural killer cells possess several advantages compared with conventional T-cell therapies. Their ability to recognize malignant cells independently of antigen presentation reduces susceptibility to certain resistance mechanisms. Furthermore,

allogeneic natural killer cell therapies may offer practical advantages related to manufacturing and availability. Advances in genetic engineering and cytokine support systems have further enhanced the therapeutic potential of these cellular platforms.

Therapeutic cancer vaccines represent another important component of contemporary immunotherapy research. The reviewed findings demonstrate that vaccine-based approaches can stimulate tumor-specific immune responses and promote immunological memory. Early vaccine strategies achieved limited clinical success because of inadequate immunogenicity and difficulties associated with antigen selection. However, recent technological advances have substantially improved the feasibility and effectiveness of therapeutic vaccination.

Particularly significant is the emergence of personalized neoantigen vaccines. Research findings indicate that genomic sequencing technologies enable identification of patient-specific mutations capable of generating highly immunogenic neoantigens. Vaccines targeting these unique tumor-derived antigens demonstrated the capacity to induce robust T-cell responses while minimizing off-target toxicity. The reviewed evidence suggests that personalized vaccine strategies may play an increasingly important role in precision immuno-oncology.

Messenger RNA vaccine platforms have attracted considerable attention because of their flexibility, scalability, and capacity for rapid development. Research findings demonstrate that these technologies can efficiently encode multiple antigens and stimulate potent immune responses. Their successful implementation in other areas of medicine has accelerated interest in oncology applications and facilitated ongoing clinical investigations.

Dendritic cell vaccines have also contributed valuable insights into immune activation strategies. The reviewed evidence indicates that optimization of antigen loading, maturation protocols, and combination treatment approaches can significantly enhance vaccine efficacy. Although challenges remain, continued technological improvements may further increase the clinical utility of dendritic cell–based immunotherapies.

Another noteworthy development is the emergence of oncolytic virotherapy. Research findings indicate that oncolytic viruses possess dual mechanisms of action involving both direct tumor destruction and immune stimulation. Viral infection of malignant cells results in tumor-cell lysis, release of tumor-associated antigens, and activation of inflammatory pathways that promote immune recognition. This combination of direct and indirect antitumor effects distinguishes oncolytic virotherapy from many other treatment modalities.

The reviewed studies demonstrated that oncolytic viruses can modify the tumor microenvironment and enhance responsiveness to checkpoint inhibition. By increasing immune-cell infiltration and promoting inflammatory signaling, these agents may convert immunologically inactive tumors into immune-responsive environments. Such findings have generated substantial interest in combining oncolytic virotherapy with other immunotherapeutic approaches.

Perhaps the most important theme emerging from contemporary research is the growing recognition that successful cancer treatment will likely require rational combination strategies rather than reliance on individual therapeutic modalities. The reviewed evidence consistently demonstrates that tumors employ multiple complementary mechanisms of immune evasion. Consequently, interventions targeting only a single pathway often produce incomplete or temporary responses.

Combination therapy seeks to address this challenge by simultaneously targeting multiple biological processes involved in tumor progression and immune suppression. Clinical studies examining combinations of checkpoint inhibitors, chemotherapy, radiotherapy, targeted therapies, antiangiogenic agents, vaccines, cellular therapies, and oncolytic viruses have reported encouraging outcomes across numerous malignancies. These findings support the concept that synergistic interactions between therapeutic modalities can enhance efficacy beyond what can be achieved with individual treatments.

Chemotherapy–immunotherapy combinations have emerged as particularly successful examples of this approach. The reviewed findings indicate that chemotherapy can increase tumor immunogenicity through induction of immunogenic cell death, release of tumor antigens, and reduction of immunosuppressive cellular populations. These effects enhance immune recognition and create conditions favorable for checkpoint inhibitor activity. Clinical trials consistently demonstrated improved survival outcomes compared with chemotherapy alone.

Radiotherapy similarly exhibits important immunomodulatory properties. The reviewed evidence suggests that radiation enhances antigen presentation, stimulates inflammatory responses, and promotes immune-cell infiltration. These mechanisms may amplify the effectiveness of immunotherapy and contribute to systemic antitumor responses. Observations of abscopal effects further support the existence of meaningful interactions between radiotherapy and immune activation.

Targeted therapies and antiangiogenic agents have also demonstrated significant potential when integrated with immunotherapy. By altering tumor signaling pathways, vascular architecture, and microenvironment composition, these treatments may improve immune accessibility and responsiveness. The reviewed findings indicate that such combinations can produce clinically meaningful improvements in outcomes while simultaneously addressing multiple mechanisms of tumor progression.

The study highlight the remarkable expansion of immunotherapeutic strategies beyond conventional checkpoint inhibition. Novel checkpoint targets, cellular therapies, cancer vaccines, oncolytic virotherapy, and rational combination approaches have substantially broadened therapeutic possibilities. These findings underscore the dynamic nature of modern immuno-oncology and provide strong evidence that future advances will likely emerge from integrated, multimodal approaches designed to overcome resistance and maximize antitumor immunity.

The findings reviewed throughout this study clearly demonstrate that the remarkable therapeutic success of cancer immunotherapy is accompanied by a unique spectrum of adverse effects and clinical challenges. While immune checkpoint inhibitors and other immunotherapeutic modalities have significantly improved survival outcomes in numerous malignancies, their mechanisms of action inherently increase the risk of immune-mediated toxicity. Consequently, understanding the balance between therapeutic efficacy and treatment-associated adverse events has become a central focus of contemporary immuno-oncology research. The results discussed in this section highlight the clinical significance of immune-related toxicities, advances in toxicity management, the emergence of precision oncology approaches, and future directions that may shape the next generation of cancer immunotherapy.

One of the most important findings identified across multiple studies is that immune-related adverse events differ fundamentally from the toxicities associated with conventional chemotherapy. Traditional cytotoxic therapies primarily cause damage to rapidly proliferating cells, resulting in predictable adverse effects such as myelosuppression, alopecia, mucositis, and gastrointestinal disturbances. In contrast, immunotherapy-associated toxicities arise from enhanced immune activation and disruption of mechanisms responsible for maintaining self-tolerance. As a result, immune-mediated inflammation may affect virtually any organ system and produce a diverse spectrum of clinical manifestations.

The reviewed literature consistently demonstrates that dermatologic complications represent among the earliest and most frequently observed immune-related adverse events. Cutaneous manifestations commonly include inflammatory rashes, pruritus, vitiligo, lichenoid eruptions, and autoimmune skin disorders. While many of these reactions are relatively mild and manageable, severe dermatologic toxicities may necessitate treatment interruption or immunosuppressive therapy. Interestingly, several studies reported associations between the

development of certain dermatologic adverse events and improved therapeutic outcomes, suggesting that immune activation responsible for toxicity may also reflect enhanced antitumor activity.

Gastrointestinal toxicities emerged as another major category of treatment-related complications. Immune-mediated colitis was consistently identified as one of the most clinically significant adverse events associated with checkpoint inhibition. Findings indicate that inflammatory damage to the gastrointestinal tract may range from mild symptoms to severe, life-threatening complications. Histopathological analyses frequently reveal extensive immune-cell infiltration, epithelial injury, and inflammatory cytokine production. The reviewed evidence emphasizes the importance of early diagnosis and prompt intervention because delayed management may result in perforation, severe dehydration, or other serious complications.

Endocrine dysfunction constitutes a particularly important aspect of immunotherapy-associated toxicity. The findings demonstrate that immune-mediated injury to endocrine organs frequently results in long-term or permanent hormonal deficiencies. Thyroid disorders represent the most common endocrine complications and may manifest as transient thyroiditis followed by hypothyroidism requiring lifelong hormone replacement. Additional endocrine toxicities include hypophysitis, adrenal insufficiency, and insulin-deficient diabetes mellitus. These findings underscore the necessity for routine endocrine monitoring during immunotherapy administration and highlight the importance of multidisciplinary patient management.

Pulmonary toxicity, particularly immune-mediated pneumonitis, was identified as one of the most serious complications associated with checkpoint inhibition. Although relatively uncommon, pneumonitis is associated with substantial morbidity and mortality. The reviewed studies indicate that clinical presentation varies considerably, ranging from asymptomatic radiographic abnormalities to severe respiratory failure requiring intensive care management. Risk factors include prior thoracic radiation exposure, preexisting pulmonary disease, combination immunotherapy, and certain tumor types. Early recognition and treatment are essential because delayed intervention significantly increases the risk of adverse outcomes.

Cardiovascular toxicities have received increasing attention because of their potentially life-threatening nature. Research findings indicate that myocarditis, although rare, is among the most severe immune-related adverse events. Mortality rates associated with immune-mediated myocarditis remain substantially higher than those observed for many other toxicities. The reviewed evidence suggests that rapid diagnosis, aggressive immunosuppressive treatment, and close multidisciplinary monitoring are critical for improving patient outcomes. Similar concerns have been raised regarding neurologic complications, which may include encephalitis, peripheral neuropathies, neuromuscular disorders, and demyelinating syndromes.

The occurrence of these toxicities raises important questions regarding the relationship between immune activation and therapeutic efficacy. Several studies reviewed in this analysis reported associations between the development of immune-related adverse events and improved clinical outcomes. Although the precise mechanisms remain incompletely understood, these observations suggest that robust immune activation may simultaneously contribute to both antitumor responses and autoimmune toxicity. However, this relationship is not universal, and severe toxicity can occur without therapeutic benefit. Consequently, the challenge for clinicians involves maximizing antitumor immunity while minimizing collateral damage to healthy tissues.

The reviewed findings demonstrate that successful management of immune-related adverse events depends heavily on early recognition and timely intervention. Corticosteroids remain the primary treatment modality for moderate-to-severe immune-mediated toxicity and have demonstrated effectiveness across multiple organ systems. Importantly, available evidence

suggests that appropriate corticosteroid administration generally does not compromise antitumor efficacy when used for toxicity management. In refractory cases, additional immunosuppressive therapies may be required to control inflammation and prevent permanent organ damage.

A recurring theme throughout the literature is the importance of multidisciplinary care. Effective management frequently requires collaboration among oncologists, pulmonologists, gastroenterologists, endocrinologists, cardiologists, neurologists, dermatologists, and other specialists. The reviewed studies consistently emphasize that coordinated care improves diagnostic accuracy, facilitates prompt intervention, and enhances overall patient outcomes. These findings highlight the evolving complexity of immunotherapy administration and underscore the need for comprehensive clinical infrastructure capable of supporting advanced cancer care.

Another major area of discussion involves the role of biomarkers in optimizing treatment selection and improving therapeutic outcomes. Despite substantial progress in immunotherapy, predicting which patients will benefit from treatment remains a significant challenge. The reviewed evidence demonstrates that currently available biomarkers provide valuable information but possess important limitations. Programmed death-ligand expression, tumor mutational burden, microsatellite instability status, gene-expression signatures, and immune-cell infiltration patterns each contribute insights regarding treatment responsiveness, yet none independently provides complete predictive accuracy.

These findings support the growing consensus that future biomarker development should focus on integrated and multidimensional approaches. The complexity of tumor–immune interactions suggests that predictive models incorporating genomic, transcriptomic, proteomic, metabolomic, and immunological data may provide more accurate assessments of treatment responsiveness. Advances in computational biology and systems immunology have accelerated progress in this area and generated considerable optimism regarding the future of precision oncology.

Single-cell sequencing technologies have emerged as particularly powerful tools for understanding treatment response and resistance. The reviewed findings demonstrate that individual tumors contain highly heterogeneous populations of malignant, stromal, and immune cells. Traditional bulk sequencing approaches frequently obscure this complexity and may fail to identify critical cellular subpopulations influencing therapeutic outcomes. Single-cell analyses enable detailed characterization of individual cellular states and provide unprecedented insights into tumor evolution, immune regulation, and mechanisms of resistance.

Spatial transcriptomics has further expanded understanding of tumor biology by preserving information regarding cellular organization within tissues. Research findings indicate that spatial relationships between immune cells and tumor cells significantly influence treatment responsiveness. Tumors exhibiting close proximity between activated immune populations and malignant cells generally demonstrate superior responses compared with tumors characterized by immune exclusion. These observations reinforce the importance of considering tissue architecture in addition to molecular characteristics when evaluating immunotherapeutic strategies.

Artificial intelligence and machine-learning technologies are increasingly being integrated into cancer research and clinical decision-making. The reviewed evidence suggests that advanced computational approaches can analyze complex multidimensional datasets more effectively than traditional statistical methods. Applications include biomarker discovery, prediction of treatment response, toxicity risk assessment, radiologic interpretation, and identification of novel therapeutic targets. Although many of these technologies remain under development, their potential to improve precision medicine is substantial.

Another significant finding emerging from recent investigations is the growing recognition of the microbiome as an important determinant of immunotherapy responsiveness. Multiple studies reviewed in this analysis demonstrated associations between gut microbial composition and clinical outcomes following checkpoint inhibition. Certain microbial communities appear capable of enhancing systemic immune activation, whereas others may contribute to immune suppression. These findings have stimulated interest in microbiome-directed interventions, including dietary modification, probiotics, prebiotics, and microbial transplantation. Although further investigation is required, microbiome manipulation may eventually become an important adjunct to immunotherapy.

The future of cancer immunotherapy will likely be defined by increasing personalization of treatment approaches. The reviewed literature strongly supports the concept that individual patients exhibit unique biological characteristics influencing treatment response, resistance, and toxicity. Advances in molecular profiling technologies now permit increasingly detailed characterization of tumors and immune systems, creating opportunities for highly individualized therapeutic strategies. Personalized cancer vaccines, engineered cellular therapies, adaptive treatment algorithms, and biomarker-guided combination regimens represent important components of this evolving paradigm.

Despite the remarkable progress achieved in recent years, several limitations remain evident. Many immunotherapeutic approaches continue to benefit only a subset of patients. Resistance mechanisms remain incompletely understood, and severe toxicities can limit treatment applicability. Furthermore, access to advanced immunotherapies remains uneven across healthcare systems because of substantial financial costs and logistical complexities. These challenges highlight the need for continued research focused on improving efficacy, reducing toxicity, enhancing accessibility, and optimizing resource utilization.

The overall findings of this review provide compelling evidence that cancer immunotherapy has fundamentally altered the trajectory of modern oncology. Immune checkpoint inhibitors have demonstrated that manipulation of immune regulatory pathways can generate durable and clinically meaningful antitumor responses. Subsequent advances involving cellular therapies, cancer vaccines, oncolytic virotherapy, and novel checkpoint targets have expanded therapeutic possibilities and deepened understanding of tumor immunology. The integration of combination strategies, biomarker-guided treatment selection, precision medicine approaches, and emerging computational technologies is expected to further enhance therapeutic outcomes.

The study indicate that immunotherapy represents one of the most transformative developments in contemporary cancer treatment. Although important challenges remain, the continued evolution of immuno-oncology is generating increasingly sophisticated therapeutic strategies capable of overcoming resistance, improving safety, and delivering more personalized care. Future advances will likely arise from the integration of molecular biology, immunology, computational science, biotechnology, and clinical medicine. As these disciplines continue to converge, immunotherapy is poised to assume an even more central role in cancer management, ultimately improving survival, quality of life, and long-term outcomes for patients affected by malignant disease.

The remarkable success of cancer immunotherapy has fundamentally altered the conceptual framework through which malignant disease is understood and treated. Unlike traditional therapeutic approaches that primarily focus on direct tumor eradication, immunotherapy exploits the biological capacity of the host immune system to recognize, adapt to, and eliminate malignant cells. The findings discussed throughout this review demonstrate that the immune system represents not merely a passive participant in cancer progression but rather an active determinant of tumor development, therapeutic responsiveness, and long-term clinical outcomes. This paradigm shift has generated profound implications for clinical practice, translational research, pharmaceutical development, and healthcare policy worldwide.

One of the most important clinical implications emerging from contemporary immuno-oncology research is the recognition that durable disease control may be achievable even in patients with advanced and metastatic malignancies. Historically, metastatic cancer was frequently regarded as an incurable condition associated with limited survival expectations. Conventional therapies often produced temporary disease stabilization but rarely generated sustained remission. The introduction of immune checkpoint inhibitors challenged these assumptions by demonstrating that long-term disease control could be achieved in selected patients through restoration of effective antitumor immunity. These findings have transformed therapeutic expectations and redefined clinical objectives across numerous cancer types.

The durability of immunotherapeutic responses represents a particularly significant observation. Unlike conventional treatments, whose effectiveness often depends on continuous administration, immunotherapy may induce prolonged immune surveillance that persists after treatment discontinuation. This phenomenon reflects the unique capacity of adaptive immune responses to generate immunological memory. Once established, memory lymphocytes may continue to recognize and eliminate malignant cells long after initial therapeutic intervention. The clinical significance of this mechanism cannot be overstated, as it introduces the possibility of sustained disease control with limited treatment exposure.

Nevertheless, the variability of immunotherapeutic outcomes remains one of the most significant challenges confronting clinicians and researchers. Although some patients experience remarkable and durable responses, others derive little or no benefit despite receiving identical treatments. The reviewed evidence suggests that this heterogeneity reflects complex interactions among tumor-specific factors, host immune characteristics, genetic determinants, environmental influences, and treatment-related variables. Consequently, the future success of immunotherapy depends heavily upon the development of strategies capable of identifying individuals most likely to benefit from specific interventions.

The concept of personalized immunotherapy has therefore emerged as a central theme in modern oncology. Personalized medicine seeks to tailor treatment according to the unique biological characteristics of individual patients and their tumors. Advances in genomic sequencing, transcriptomic profiling, proteomic analysis, and immune characterization have created unprecedented opportunities for therapeutic individualization. The findings reviewed throughout this work indicate that precision oncology is particularly relevant to immunotherapy because immune responsiveness is strongly influenced by patient-specific molecular and immunological features.

Tumor mutational burden, microsatellite instability, gene-expression signatures, immune-cell infiltration patterns, and circulating biomarkers have all demonstrated potential utility in guiding treatment selection. However, no single biomarker has proven sufficiently accurate to predict outcomes across all tumor types and patient populations. This limitation highlights the complexity of tumor–immune interactions and suggests that future predictive models will require integration of multiple biological variables. Comprehensive molecular profiling combined with advanced computational analysis may ultimately enable more accurate prediction of therapeutic responsiveness and facilitate optimization of treatment strategies.

Another important clinical implication concerns the role of combination therapy in overcoming biological limitations associated with monotherapeutic approaches. The reviewed findings consistently demonstrate that tumors employ multiple mechanisms of immune evasion simultaneously. Consequently, targeting a single pathway often produces incomplete responses or facilitates the emergence of adaptive resistance. Combination strategies seek to address this challenge by simultaneously modulating several biological processes involved in tumor progression and immune suppression.

The integration of immune checkpoint inhibitors with chemotherapy represents one of the most successful examples of this approach. Clinical evidence indicates that chemotherapy can

enhance tumor immunogenicity through induction of immunogenic cell death, increased antigen release, and modification of the tumor microenvironment. These effects complement the activity of checkpoint inhibitors and contribute to improved therapeutic outcomes. Similar synergistic interactions have been observed with radiotherapy, targeted therapies, antiangiogenic agents, therapeutic vaccines, and cellular immunotherapies.

From a translational perspective, these observations underscore the importance of interdisciplinary collaboration. Successful implementation of combination immunotherapy requires integration of expertise from oncology, immunology, molecular biology, pharmacology, computational science, and bioengineering. The complexity of contemporary cancer treatment increasingly necessitates collaborative research models capable of addressing multifaceted biological questions and accelerating therapeutic innovation.

Translational challenges remain substantial despite remarkable scientific progress. One major obstacle involves the persistent gap between preclinical discoveries and clinical implementation. Experimental models frequently fail to fully recapitulate the complexity of human tumor biology and immune regulation. Consequently, promising therapeutic strategies identified in laboratory settings do not always translate successfully into clinical practice. The reviewed findings emphasize the need for improved experimental systems capable of more accurately reflecting human disease and predicting therapeutic outcomes.

Another important translational challenge involves tumor heterogeneity. Malignant tumors are not uniform entities but rather dynamic populations composed of genetically and phenotypically diverse cellular subpopulations. This heterogeneity contributes significantly to therapeutic resistance and disease progression. Even when initial responses are achieved, selective pressures imposed by treatment may promote expansion of resistant clones. Addressing this challenge requires continuous refinement of therapeutic strategies and improved understanding of evolutionary processes governing tumor adaptation.

The tumor microenvironment represents an additional barrier to successful translation of immunotherapeutic advances. The reviewed evidence demonstrates that interactions among malignant cells, stromal components, vascular structures, and immune populations profoundly influence treatment responsiveness. Effective therapeutic interventions must therefore address not only tumor cells themselves but also the surrounding ecosystem that supports tumor survival and immune evasion. Future therapeutic development will likely focus increasingly on strategies designed to remodel the tumor microenvironment and enhance immune accessibility.

The economic implications of immunotherapy also warrant careful consideration. While these therapies have produced remarkable clinical benefits, they are frequently associated with substantial financial costs. The development, manufacturing, administration, and monitoring of advanced immunotherapeutic interventions require significant healthcare resources. Cellular therapies, in particular, involve complex production processes that contribute to exceptionally high treatment costs. These economic considerations raise important questions regarding sustainability, accessibility, and healthcare equity.

Health economic analyses reviewed in the literature indicate that immunotherapy may provide favorable value under certain circumstances because of prolonged survival and durable disease control. Nevertheless, affordability remains a significant concern, particularly in resource-limited healthcare settings. Ensuring equitable access to innovative therapies represents a major challenge for healthcare systems worldwide. Policymakers, clinicians, researchers, and industry stakeholders must collaborate to develop sustainable models capable of balancing innovation with accessibility.

Global disparities in cancer care further complicate implementation of advanced immunotherapies. Many low- and middle-income countries face substantial barriers related to infrastructure, diagnostic capabilities, specialist availability, and financial resources. The

reviewed findings highlight the importance of developing scalable and cost-effective approaches capable of extending the benefits of immunotherapy beyond highly specialized treatment centers. International collaboration, technology transfer, and capacity-building initiatives may play critical roles in addressing these disparities.

The expanding role of digital health technologies offers additional opportunities to improve immunotherapy delivery and patient outcomes. Electronic health records, remote monitoring systems, wearable devices, and telemedicine platforms can facilitate early detection of adverse events and improve treatment adherence. Integration of these technologies into routine clinical practice may enhance patient safety and support more efficient management of complex therapeutic regimens.

Artificial intelligence represents another transformative force with potential applications throughout the immunotherapy continuum. Machine-learning algorithms can analyze vast quantities of clinical, molecular, radiologic, and pathological data to identify patterns associated with treatment response and toxicity. The reviewed evidence suggests that artificial intelligence may significantly improve biomarker discovery, patient stratification, therapeutic decision-making, and outcome prediction. Although many applications remain investigational, ongoing technological advances are expected to accelerate clinical implementation.

An additional area of growing interest involves the relationship between lifestyle factors and immunotherapeutic responsiveness. Emerging evidence suggests that nutrition, physical activity, microbiome composition, environmental exposures, and metabolic health may influence immune function and treatment outcomes. These observations support a more holistic approach to cancer management that considers host-related factors alongside tumor-specific characteristics. Future research may identify modifiable variables capable of enhancing therapeutic efficacy and improving patient outcomes.

The findings reviewed throughout this section collectively reinforce the conclusion that cancer immunotherapy represents a rapidly evolving and highly dynamic field. The transition from generalized treatment approaches toward personalized and precision-based strategies reflects a broader transformation occurring across modern medicine. Continued advances in molecular profiling, biomarker development, computational analysis, and therapeutic engineering are expected to further enhance the effectiveness of immunotherapy and expand its clinical applicability.

The successful integration of immunotherapy into global cancer care will depend not only on scientific innovation but also on effective translation, equitable access, multidisciplinary collaboration, and sustainable healthcare implementation. As understanding of tumor immunology continues to deepen, the potential exists to further improve survival outcomes, reduce treatment-related morbidity, and transform the long-term management of malignant disease. These developments position immunotherapy as one of the most promising and influential areas of contemporary biomedical research and clinical practice.

The extraordinary progress achieved in cancer immunotherapy over the past several decades has established a foundation upon which future innovations are expected to build. Although current immunotherapeutic approaches have transformed the management of numerous malignancies, substantial opportunities remain for further advancement. The findings reviewed throughout this work demonstrate that many challenges—including therapeutic resistance, treatment-related toxicity, tumor heterogeneity, limited responsiveness in certain malignancies, and barriers to accessibility—continue to restrict the full clinical potential of immunotherapy. Consequently, contemporary research is increasingly focused on developing next-generation technologies capable of overcoming these limitations and expanding the therapeutic benefits of immune-based cancer treatment.

One of the most promising future directions involves the continued development of next-generation immune checkpoint inhibitors. While current therapies primarily target established

checkpoint pathways, accumulating evidence indicates that numerous additional inhibitory and stimulatory receptors contribute to immune regulation. The identification of these pathways has expanded understanding of immune exhaustion and revealed opportunities for therapeutic intervention beyond conventional checkpoint blockade.

Research findings suggest that future checkpoint-targeting strategies will likely involve simultaneous modulation of multiple regulatory pathways. Such approaches may more effectively restore immune function in patients whose tumors exhibit resistance to existing therapies. Furthermore, advances in molecular engineering may facilitate the development of checkpoint inhibitors with improved specificity, reduced toxicity, and enhanced therapeutic efficacy. These innovations could significantly broaden the population of patients capable of benefiting from immunotherapy.

The emergence of gene-editing technologies represents another transformative development with profound implications for cancer treatment. Genome engineering platforms have revolutionized the ability to precisely manipulate cellular function and create customized therapeutic interventions. In the context of immunotherapy, gene editing offers opportunities to enhance immune-cell persistence, improve tumor recognition, overcome immunosuppressive signaling, and reduce treatment-related toxicity.

Engineered immune cells capable of resisting inhibitory signals within the tumor microenvironment may demonstrate superior therapeutic activity compared with currently available cellular therapies. Additionally, gene-editing approaches may enable correction of intrinsic immune defects, enhancement of antitumor functionality, and generation of universal cellular products suitable for broad clinical application. These developments have the potential to significantly increase the accessibility and effectiveness of adoptive cellular immunotherapy.

Synthetic biology has also emerged as a powerful tool for advancing cancer immunotherapy. By integrating principles from engineering and molecular biology, synthetic biology enables the design of sophisticated biological systems capable of performing complex therapeutic functions. Research findings indicate that synthetic immune cells can be programmed to recognize multiple antigens, respond selectively to specific environmental signals, and execute coordinated antitumor activities.

Future cellular therapies may incorporate advanced biological circuits capable of dynamically adapting to changing tumor conditions. Such systems could improve treatment specificity, reduce off-target effects, and enhance safety. The ability to precisely control immune-cell behavior represents a major step toward the realization of fully programmable cancer therapies and may fundamentally redefine the future of immuno-oncology.

Nanotechnology represents another rapidly evolving field with important applications in cancer immunotherapy. Nanoparticle-based delivery systems offer opportunities to improve therapeutic targeting, enhance drug stability, reduce systemic toxicity, and facilitate controlled release of immunomodulatory agents. Research findings suggest that nanotechnology may significantly enhance the effectiveness of existing immunotherapies while enabling the development of entirely new treatment modalities.

Nanoparticles can be engineered to deliver antigens, cytokines, nucleic acids, checkpoint inhibitors, and other therapeutic molecules directly to tumors or immune cells. Such targeted delivery strategies may improve treatment efficiency while minimizing exposure of healthy tissues to potentially toxic agents. Furthermore, multifunctional nanoplatforms capable of combining diagnostic and therapeutic functions may facilitate real-time monitoring of treatment responses and support personalized therapeutic decision-making.

Another important area of future development involves the continued evolution of cancer vaccines. Although early vaccine strategies produced limited clinical success, advances in molecular biology, genomics, and bioinformatics have revitalized interest in therapeutic

vaccination. Personalized neoantigen vaccines represent one of the most promising approaches currently under investigation.

The increasing availability of high-throughput sequencing technologies enables rapid identification of patient-specific tumor mutations capable of generating immunogenic neoantigens. Personalized vaccine platforms designed to target these unique antigens may stimulate highly specific immune responses while minimizing unintended toxicity. Research findings indicate that integration of vaccine-based approaches with checkpoint inhibition and other immunotherapies may substantially enhance therapeutic efficacy.

Messenger RNA technologies have further accelerated progress in this area. Their flexibility, scalability, and capacity for rapid adaptation make them particularly attractive for personalized medicine applications. Continued refinement of delivery systems and antigen-selection strategies is expected to improve vaccine performance and expand clinical applicability.

The microbiome represents another frontier in immunotherapy research. Increasing evidence suggests that microbial communities residing within the human body exert profound effects on immune regulation and treatment responsiveness. The reviewed literature demonstrates that specific microbial compositions are associated with enhanced outcomes following checkpoint inhibition, whereas others may contribute to therapeutic resistance.

Future investigations are expected to explore microbiome-targeted interventions designed to optimize antitumor immunity. Strategies may include dietary modification, microbial supplementation, microbiota transplantation, and development of microbiome-derived therapeutics. Although many questions remain unanswered, manipulation of host microbial ecosystems may eventually become an integral component of comprehensive cancer treatment.

Artificial intelligence is poised to become one of the most influential technologies shaping the future of immuno-oncology. The complexity of tumor biology generates enormous quantities of data that exceed the analytical capabilities of traditional approaches. Machine-learning algorithms and advanced computational systems offer unprecedented opportunities to extract meaningful insights from these multidimensional datasets.

Applications of artificial intelligence extend across virtually every aspect of immunotherapy development and implementation. Predictive models may improve patient selection, identify biomarkers of responsiveness, forecast treatment-related toxicities, optimize therapeutic combinations, and facilitate discovery of novel drug targets. Integration of artificial intelligence with clinical decision-support systems may enable increasingly precise and individualized treatment recommendations.

Radiomics and digital pathology represent particularly promising applications of computational technology. Advanced image-analysis algorithms can identify subtle features associated with tumor biology and treatment responsiveness that may be imperceptible to human observers. These technologies have the potential to improve diagnostic accuracy, enhance prognostic assessment, and support more effective therapeutic planning.

Precision oncology is expected to become increasingly sophisticated as molecular characterization technologies continue to advance. Future treatment paradigms will likely integrate genomic, transcriptomic, proteomic, metabolomic, immunologic, and microbiome-derived information into comprehensive patient profiles. Such multidimensional analyses may enable truly individualized treatment strategies tailored to the unique biological characteristics of each patient.

The concept of adaptive immunotherapy represents another promising direction. Rather than relying on static treatment protocols, adaptive approaches involve continuous monitoring of disease evolution and dynamic modification of therapeutic strategies in response to emerging biological information. This model recognizes the evolving nature of cancer and seeks to maintain therapeutic effectiveness despite tumor adaptation and resistance.

Despite these exciting prospects, several important limitations continue to influence the field. Many current studies involve relatively short follow-up periods, making it difficult to fully assess long-term outcomes and delayed toxicities. Additionally, variability in study design, patient populations, biomarker methodologies, and outcome measures complicates interpretation and comparison of research findings.

The complexity of tumor–immune interactions also presents significant scientific challenges. Although substantial progress has been achieved in understanding immune regulation, many biological mechanisms remain incompletely characterized. Continued investigation is required to clarify the factors governing treatment responsiveness, resistance, toxicity, and long-term disease control.

Financial considerations remain another important limitation. Advanced immunotherapies are often associated with substantial costs that may restrict access and create disparities in healthcare delivery. Addressing these challenges will require coordinated efforts involving researchers, healthcare systems, regulatory agencies, policymakers, and industry stakeholders.

Based on the findings reviewed throughout this work, several recommendations can be proposed. Future research should prioritize development of integrated biomarker platforms capable of improving patient selection and treatment personalization. Greater emphasis should be placed on understanding resistance mechanisms and identifying strategies capable of preventing or overcoming therapeutic failure. Continued investigation of combination therapies is warranted given their potential to address multiple biological pathways simultaneously.

Expansion of multidisciplinary collaboration will be essential for sustaining progress in immuno-oncology. Effective integration of expertise from immunology, oncology, molecular biology, bioengineering, computational science, pharmacology, and clinical medicine will accelerate innovation and facilitate translation of laboratory discoveries into clinical practice. Furthermore, international collaboration should be encouraged to promote equitable access to emerging therapies and ensure that advances benefit diverse patient populations worldwide.

In conclusion, the collective evidence examined throughout this review demonstrates that cancer immunotherapy has fundamentally transformed the modern oncology landscape. Immune checkpoint inhibitors have established the immune system as a highly effective therapeutic target and have generated unprecedented improvements in survival for many patients with advanced malignancies. Subsequent advances involving cellular therapies, cancer vaccines, oncolytic virotherapy, synthetic biology, gene editing, nanotechnology, and precision medicine have further expanded therapeutic possibilities and deepened understanding of tumor immunology.

Although significant challenges remain, including resistance mechanisms, treatment-related toxicities, biological complexity, and healthcare accessibility, ongoing scientific progress continues to drive innovation at an extraordinary pace. The convergence of immunology, genomics, computational science, biotechnology, and clinical medicine is creating increasingly sophisticated therapeutic strategies capable of delivering more personalized, effective, and durable cancer treatment.

The future of immunotherapy is characterized by optimism supported by robust scientific evidence. As technological capabilities continue to advance and biological understanding deepens, immune-based interventions are expected to become increasingly central to cancer management. Through continued research, collaboration, and innovation, immunotherapy has the potential not only to improve survival outcomes but also to redefine the long-term relationship between cancer and the immune system. Ultimately, these developments may bring oncology closer to the goal of achieving durable disease control, improved quality of life, and sustained remission for a growing number of patients affected by cancer worldwide.

Immune Checkpoint Inhibitors: Mechanisms of Action and Clinical Significance

The emergence of immune checkpoint inhibitors represents one of the most significant breakthroughs in modern oncology. Extensive research over the past two decades has demonstrated that tumors exploit physiological immune-regulatory pathways to evade immune-mediated destruction. These pathways, commonly referred to as immune checkpoints, normally function to maintain self-tolerance and prevent excessive immune activation. However, malignant cells frequently manipulate these mechanisms to suppress antitumor immune responses and facilitate disease progression. The development of therapeutic agents capable of disrupting inhibitory checkpoint signaling has fundamentally transformed cancer treatment and established immunotherapy as a major therapeutic pillar alongside surgery, radiotherapy, chemotherapy, and targeted therapy.

The adaptive immune response plays a central role in cancer surveillance. Effective antitumor immunity requires recognition of tumor-associated antigens by antigen-presenting cells, activation of tumor-specific T lymphocytes, migration of effector immune cells to tumor sites, and subsequent elimination of malignant cells. Throughout this process, multiple regulatory mechanisms ensure immune homeostasis and protect healthy tissues from autoimmune damage. Among the most important inhibitory regulators are cytotoxic T-lymphocyte-associated protein and programmed cell death protein pathways.

Research has demonstrated that cytotoxic T-lymphocyte-associated protein functions primarily during the early stages of T-cell activation within lymphoid tissues. Under physiological conditions, this receptor competes with co-stimulatory molecules for binding to ligands expressed on antigen-presenting cells. As a result, immune activation is attenuated, preventing excessive immune responses. Tumors indirectly benefit from this regulatory process because reduced T-cell activation limits the generation of effective antitumor immunity. Therapeutic inhibition of this pathway enhances T-cell priming and proliferation, thereby strengthening immune responses against malignant cells.

Programmed cell death protein functions predominantly within peripheral tissues and the tumor microenvironment. Interaction between programmed cell death protein and its ligands suppresses T-cell activity, reduces cytokine production, and promotes immune exhaustion. Numerous studies have demonstrated that malignant cells frequently overexpress programmed death ligands as a mechanism of immune evasion. By engaging inhibitory receptors on activated T lymphocytes, tumors effectively suppress immune-mediated destruction. Blockade of this interaction restores T-cell functionality and enhances antitumor immune responses.

Clinical investigations have consistently demonstrated the effectiveness of checkpoint inhibition across multiple malignancies. Melanoma was among the first cancers to exhibit remarkable responsiveness to checkpoint blockade. Prior to the introduction of immunotherapy, advanced melanoma was associated with poor prognosis and limited treatment options. Clinical trials evaluating checkpoint inhibitors revealed durable responses and substantial improvements in overall survival, establishing a new standard of care. Long-term follow-up studies demonstrated that a subset of patients achieved sustained disease control extending over many years, providing compelling evidence of the transformative potential of immunotherapy.

Similar therapeutic successes have subsequently been observed in non-small cell lung cancer. Historically, treatment of advanced lung cancer relied heavily on cytotoxic chemotherapy, which frequently produced limited and transient responses. The incorporation of immune checkpoint inhibitors significantly improved survival outcomes, particularly among patients whose tumors exhibited elevated expression of programmed death ligands. These findings highlighted the importance of biomarker-guided therapeutic selection and accelerated the integration of immunotherapy into routine clinical practice.

Renal cell carcinoma has also demonstrated substantial sensitivity to immune-based interventions. The immunogenic nature of this malignancy has long been recognized, and checkpoint inhibition has further enhanced treatment outcomes. Combination regimens involving checkpoint inhibitors and targeted therapies have produced impressive clinical responses and prolonged progression-free survival. Similar benefits have been documented in urothelial carcinoma, hepatocellular carcinoma, head and neck squamous cell carcinoma, and several hematologic malignancies.

One of the most remarkable observations associated with checkpoint blockade is the durability of therapeutic responses. Unlike conventional treatments, which often require continuous administration to maintain disease control, immunotherapy can generate long-lasting clinical benefits even after treatment discontinuation. This phenomenon is believed to result from the establishment of immunological memory, allowing the immune system to maintain surveillance against residual malignant cells. The capacity to induce durable immune protection distinguishes immunotherapy from many traditional anticancer strategies and contributes substantially to its clinical significance.

Mechanisms of Therapeutic Resistance

Despite substantial clinical success, immune checkpoint inhibitors do not benefit all patients. Research findings indicate that resistance remains one of the greatest challenges in immuno-oncology. Resistance may be classified as primary, in which patients fail to respond from the outset, or acquired, in which initially responsive tumors subsequently progress despite continued treatment.

Primary resistance is frequently associated with inadequate tumor immunogenicity. Tumors that generate few neoantigens may fail to elicit robust immune responses, thereby limiting the effectiveness of checkpoint blockade. In addition, deficiencies in antigen processing and presentation can prevent immune recognition of malignant cells. Alterations affecting major histocompatibility complex expression have been identified as important contributors to immune escape and therapeutic failure.

The absence of tumor-infiltrating lymphocytes represents another important determinant of resistance. Immunologically inactive tumors often lack sufficient immune-cell infiltration to support effective antitumor responses. These so-called immune-desert tumors demonstrate limited responsiveness to checkpoint inhibition because the necessary immune components are absent from the tumor microenvironment.

Acquired resistance develops through a variety of adaptive mechanisms. Tumor evolution under immune pressure may result in antigen loss, reducing immune recognition and facilitating escape from immune-mediated destruction. Furthermore, malignant cells may upregulate alternative inhibitory pathways capable of suppressing immune activity despite blockade of the original checkpoint target. These observations have provided strong justification for the development of next-generation checkpoint inhibitors and combination immunotherapeutic strategies.

Research has also identified abnormalities in interferon signaling pathways as important contributors to resistance. Interferons play essential roles in immune activation, antigen presentation, and tumor recognition. Disruption of these pathways may impair immune responsiveness and reduce the effectiveness of checkpoint inhibition. Similarly, alterations in intracellular signaling networks involved in immune regulation have been associated with treatment failure.

Role of the Tumor Microenvironment

The tumor microenvironment has emerged as a critical factor influencing immunotherapy outcomes. Research findings indicate that the effectiveness of immune checkpoint inhibitors

depends not only on tumor-specific characteristics but also on the surrounding cellular ecosystem. The tumor microenvironment comprises malignant cells, stromal populations, vascular structures, extracellular matrix components, and diverse immune-cell subsets.

Immunosuppressive cellular populations play particularly important roles in limiting therapeutic efficacy. Regulatory T cells suppress antitumor immunity through cytokine secretion and direct inhibition of effector lymphocytes. Increased infiltration of these cells has been associated with poor responses to immunotherapy. Similarly, myeloid-derived suppressor cells inhibit T-cell activation and promote immune dysfunction within tumors.

Tumor-associated macrophages represent another major component of the immunosuppressive microenvironment. These cells frequently adopt phenotypes that support tumor growth, angiogenesis, and immune evasion. Research has demonstrated correlations between elevated macrophage infiltration and unfavorable clinical outcomes across numerous malignancies.

Metabolic alterations within tumors further contribute to immune suppression. Rapidly proliferating cancer cells consume large quantities of nutrients and oxygen, creating conditions that impair immune-cell function. Hypoxia, nutrient depletion, and accumulation of immunosuppressive metabolites collectively reduce the effectiveness of antitumor immune responses. Consequently, metabolic pathways have become important targets for therapeutic intervention.

Advances in molecular profiling technologies have enabled detailed characterization of tumor microenvironments and their influence on treatment response. Single-cell sequencing, multiplex imaging, and spatial transcriptomics have revealed substantial heterogeneity among tumors and highlighted the complex interactions governing immune regulation. These findings have improved understanding of therapeutic resistance and provided valuable insights into potential strategies for enhancing immunotherapy efficacy.

The current research demonstrates that immune checkpoint inhibitors have revolutionized cancer treatment by restoring effective antitumor immunity and producing durable clinical responses across diverse malignancies. However, therapeutic resistance, tumor heterogeneity, and immunosuppressive microenvironments remain significant obstacles. Ongoing investigations continue to identify novel mechanisms of immune regulation and provide the foundation for next-generation immunotherapeutic approaches aimed at improving patient outcomes and expanding the benefits of immunotherapy to broader populations.

Emerging Immunotherapeutic Targets Beyond Classical Checkpoint Inhibition

Research conducted during the past decade has demonstrated that immune regulation extends far beyond the classical checkpoint pathways initially targeted by immunotherapeutic agents. Although blockade of cytotoxic T-lymphocyte-associated protein and programmed cell death protein pathways has produced remarkable clinical outcomes, substantial evidence indicates that numerous additional inhibitory and stimulatory receptors contribute to immune regulation within the tumor microenvironment. Consequently, the identification and characterization of novel immunotherapeutic targets have become major priorities in contemporary cancer research.

One of the most extensively investigated targets is lymphocyte activation gene. Studies have shown that this receptor is frequently expressed on activated and exhausted T lymphocytes within tumors. Persistent antigen exposure and chronic inflammatory stimulation promote sustained expression of lymphocyte activation gene, leading to progressive immune dysfunction. Research findings indicate that inhibition of this pathway may restore T-cell activity and enhance antitumor immune responses. Clinical investigations evaluating dual blockade strategies have demonstrated encouraging therapeutic activity, particularly in patients who exhibit resistance to conventional checkpoint inhibitors.

T-cell immunoglobulin and mucin-domain-containing protein has also emerged as an important regulator of immune exhaustion. Expression of this molecule is associated with impaired cytokine production, reduced proliferative capacity, and diminished cytotoxic function. Preclinical studies have consistently demonstrated that blockade of this receptor can reverse immune dysfunction and improve tumor control. Similar observations have been reported for T-cell immunoreceptor with immunoglobulin and immunoreceptor tyrosine-based inhibitory motif domains, another inhibitory receptor implicated in immune suppression and tumor progression.

Additional targets under active investigation include V-domain immunoglobulin suppressor of T-cell activation, B- and T-lymphocyte attenuator, and multiple metabolic regulators involved in immune-cell function. Research findings suggest that simultaneous targeting of several inhibitory pathways may be necessary to overcome the complex and redundant mechanisms responsible for tumor immune evasion. These discoveries have expanded the therapeutic landscape and generated considerable optimism regarding future treatment possibilities.

Advances in Adoptive Cellular Immunotherapy

One of the most significant developments in modern immuno-oncology has been the advancement of adoptive cellular therapy. This therapeutic approach seeks to directly enhance antitumor immunity through the administration of immune cells with demonstrated or engineered tumor-specific activity.

Chimeric antigen receptor T-cell therapy represents the most successful example of cellular immunotherapy to date. Research findings have demonstrated extraordinary efficacy in hematologic malignancies, particularly B-cell leukemias and lymphomas. Through genetic modification, patient-derived T lymphocytes are engineered to express synthetic receptors capable of recognizing specific tumor antigens independently of conventional antigen presentation mechanisms. Following reinfusion, these cells proliferate, persist, and mediate potent antitumor activity.

Clinical trials have reported unprecedented response rates in patients with refractory malignancies who previously possessed limited therapeutic options. Durable remissions and prolonged survival have been observed in numerous studies, establishing chimeric antigen receptor T-cell therapy as a major breakthrough in cancer treatment. Long-term follow-up investigations have confirmed the potential for sustained disease control in selected patient populations.

Despite these achievements, several challenges remain. Research findings indicate that antigen escape represents a significant mechanism of treatment failure. Tumors may lose or downregulate target antigens, rendering engineered immune cells incapable of recognizing malignant populations. Furthermore, limited trafficking to solid tumors, immunosuppressive tumor microenvironments, and cellular exhaustion continue to restrict efficacy in many cancer types.

Tumor-infiltrating lymphocyte therapy has also demonstrated promising clinical activity. This approach involves isolation of naturally occurring tumor-reactive lymphocytes, followed by ex vivo expansion and reinfusion. Research has shown that these lymphocytes often possess intrinsic specificity for tumor-associated antigens and can mediate significant clinical responses when administered in sufficient quantities. Favorable outcomes observed in melanoma and several solid tumors have stimulated ongoing efforts to optimize manufacturing processes and improve therapeutic effectiveness.

Natural killer cell–based therapies constitute another rapidly expanding area of investigation. Unlike T lymphocytes, natural killer cells recognize malignant cells without requiring prior antigen sensitization. Research findings suggest that these cells may provide important advantages, including reduced risk of graft-versus-host disease and broader antitumor activity.

Advances in cellular engineering and cytokine support systems have enhanced the therapeutic potential of natural killer cell platforms and expanded their clinical applicability.

Therapeutic Cancer Vaccines

Cancer vaccines represent an important component of the evolving immunotherapy landscape. Unlike preventive vaccines used against infectious diseases, therapeutic cancer vaccines are designed to stimulate immune responses against established malignancies. Research findings indicate that successful vaccination strategies can enhance antigen recognition, promote T-cell activation, and generate durable immunological memory.

Early vaccine approaches focused primarily on shared tumor-associated antigens. Although these strategies demonstrated immunogenicity, clinical efficacy was often limited by immune tolerance and antigen heterogeneity. Advances in genomic sequencing technologies have subsequently facilitated the identification of patient-specific neoantigens, enabling the development of personalized vaccine platforms.

Research investigating neoantigen-directed vaccines has demonstrated encouraging immunological and clinical outcomes. Personalized vaccine formulations can induce robust T-cell responses against tumor-specific mutations while minimizing off-target effects. Studies have reported enhanced immune activation, improved tumor control, and synergistic interactions when vaccines are combined with checkpoint inhibitors.

Messenger RNA–based vaccine technologies have attracted particular attention following their successful application in infectious disease prevention. Research findings indicate that messenger RNA platforms offer substantial advantages, including rapid manufacturing, flexibility, scalability, and the ability to encode multiple tumor antigens simultaneously. These characteristics make messenger RNA vaccines attractive candidates for future personalized immunotherapy strategies.

Dendritic cell vaccines have also demonstrated therapeutic potential. These vaccines utilize professional antigen-presenting cells loaded with tumor antigens to stimulate adaptive immune responses. Although clinical outcomes have varied across studies, continued refinement of antigen selection, cellular activation protocols, and combination strategies may improve efficacy and broaden clinical utility.

Oncolytic Viruses and Immune Activation

Oncolytic virotherapy has emerged as a novel therapeutic approach capable of directly targeting malignant cells while simultaneously stimulating antitumor immunity. Research findings indicate that oncolytic viruses selectively infect tumor cells because of abnormalities in antiviral defense mechanisms frequently observed in malignancies.

Following infection, viral replication induces tumor-cell destruction and releases tumor-associated antigens into the surrounding environment. This process promotes dendritic cell activation, antigen presentation, cytokine production, and recruitment of immune effector populations. Consequently, oncolytic viruses function as both direct cytotoxic agents and immune stimulators.

Clinical investigations have demonstrated the therapeutic potential of oncolytic virotherapy in several malignancies. Studies evaluating engineered viral platforms have reported durable responses, particularly when combined with immune checkpoint inhibition. Research suggests that viral-mediated inflammation may convert immunologically inactive tumors into immune-responsive environments, thereby enhancing sensitivity to immunotherapy.

The integration of genetic engineering technologies has further expanded the capabilities of oncolytic viruses. Modern viral platforms can be modified to express cytokines, co-stimulatory molecules, or additional therapeutic proteins that augment immune activation. These advances have created opportunities for increasingly sophisticated and personalized treatment strategies.

Biomarkers and Precision Immuno-Oncology

The identification of predictive biomarkers remains one of the most important objectives in immunotherapy research. Findings from numerous studies indicate that significant variability exists in treatment responsiveness, emphasizing the need for accurate patient-selection strategies.

Programmed death-ligand expression remains among the most widely utilized biomarkers in clinical practice. Research has demonstrated associations between elevated ligand expression and improved responsiveness to checkpoint inhibition in several malignancies. However, substantial heterogeneity in expression patterns and testing methodologies limits predictive accuracy.

Tumor mutational burden has emerged as another important biomarker candidate. Research findings indicate that tumors with large numbers of somatic mutations generate increased quantities of neoantigens capable of stimulating immune responses. Clinical studies have demonstrated correlations between elevated mutational burden and enhanced responsiveness to immunotherapy. Nevertheless, variability among tumor types continues to complicate interpretation and clinical implementation.

Microsatellite instability and mismatch repair deficiency represent particularly robust predictors of immunotherapy benefit. Tumors harboring defects in DNA repair pathways accumulate extensive mutational burdens and frequently exhibit heightened immunogenicity. Research consistently demonstrates exceptional responsiveness of these tumors to checkpoint blockade, supporting the importance of molecular characterization in treatment selection.

Advances in single-cell sequencing, spatial transcriptomics, multiplex imaging, and computational biology have generated new opportunities for biomarker discovery. Research findings indicate that integrated biomarker models incorporating molecular, cellular, genomic, and immunological variables may provide greater predictive accuracy than individual markers alone. These multidimensional approaches are expected to play increasingly important roles in precision oncology and personalized immunotherapy.

The future of cancer immunotherapy extends far beyond traditional checkpoint inhibition. Emerging targets, adoptive cellular therapies, therapeutic vaccines, oncolytic virotherapy, and advanced biomarker platforms are expanding therapeutic possibilities and improving understanding of tumor-immune interactions. These developments provide a strong foundation for next-generation immunotherapeutic strategies aimed at overcoming resistance, enhancing efficacy, and delivering more personalized cancer care.

Combination Immunotherapy Strategies

One of the most important findings emerging from contemporary immuno-oncology research is that combination therapy frequently produces superior clinical outcomes compared with monotherapeutic approaches. Although immune checkpoint inhibitors have transformed cancer treatment, a substantial proportion of patients either fail to respond or eventually develop resistance. Research findings indicate that tumors employ multiple complementary mechanisms of immune evasion, making it unlikely that inhibition of a single pathway will consistently generate durable responses across all malignancies. Consequently, the development of rational combination strategies has become a central focus of modern cancer research.

Clinical investigations have demonstrated that combining inhibitors targeting different immune checkpoint pathways can enhance immune activation and improve therapeutic efficacy. Dual checkpoint blockade increases T-cell proliferation, cytokine production, and cytotoxic activity while simultaneously reducing inhibitory signaling. Numerous studies have reported higher response rates and prolonged survival compared with single-agent therapy, particularly in

highly immunogenic malignancies. However, enhanced efficacy is frequently accompanied by increased toxicity, emphasizing the need for careful patient selection and toxicity management.
Research has also demonstrated significant synergy between immunotherapy and conventional chemotherapy. Historically, chemotherapy was considered immunosuppressive because of its effects on rapidly proliferating cells. More recent findings have revealed that many cytotoxic agents possess important immunomodulatory properties. Chemotherapy can induce immunogenic cell death, resulting in the release of tumor antigens and danger-associated molecular signals that stimulate immune activation. Furthermore, chemotherapy may reduce immunosuppressive cellular populations within the tumor microenvironment and facilitate infiltration of effector immune cells. These observations have provided a biological rationale for combining chemotherapy with checkpoint inhibitors.
Clinical trials across multiple malignancies have demonstrated substantial benefits from chemoimmunotherapy combinations. Improvements in overall survival, progression-free survival, and objective response rates have been observed in lung cancer, breast cancer, gastric cancer, and several additional tumor types. Research findings consistently indicate that chemotherapy can enhance responsiveness to immunotherapy by increasing tumor immunogenicity and improving immune recognition.
Radiotherapy has also emerged as a valuable partner for immunotherapeutic interventions. Research findings indicate that ionizing radiation not only causes direct tumor-cell destruction but also modulates immune responses through several complementary mechanisms. Radiation enhances antigen release, promotes dendritic cell activation, increases major histocompatibility complex expression, and facilitates recruitment of immune effector populations. These effects can convert poorly immunogenic tumors into more immune-responsive environments.
The phenomenon known as the abscopal effect has generated particular scientific interest. This effect refers to regression of metastatic lesions outside the irradiated field following localized radiation treatment. Although relatively uncommon, research suggests that immune-mediated mechanisms contribute significantly to this observation. The combination of radiotherapy and immune checkpoint inhibition may amplify these systemic immune responses and improve treatment outcomes.
Targeted molecular therapies represent another important component of combination immunotherapy research. Numerous oncogenic signaling pathways influence immune regulation and tumor microenvironment composition. Research findings indicate that inhibition of specific molecular pathways may enhance antitumor immunity by increasing antigen presentation, reducing immunosuppressive signaling, and promoting immune-cell infiltration. Combination strategies integrating targeted therapies with checkpoint inhibitors have demonstrated encouraging activity in several malignancies and continue to represent a major area of clinical investigation.
Antiangiogenic therapies have similarly shown promise when combined with immunotherapy. Tumor-associated angiogenesis contributes to immune dysfunction by creating abnormal vascular structures that restrict immune-cell trafficking and promote hypoxia. Research has demonstrated that vascular normalization induced by antiangiogenic agents can improve immune-cell access to tumors and enhance responsiveness to immunotherapy. Clinical studies evaluating these combinations have reported improved outcomes in renal cell carcinoma, hepatocellular carcinoma, and other cancers.

Immune-Related Adverse Events and Treatment-Associated Toxicities

While immunotherapy has revolutionized cancer treatment, research findings consistently emphasize that therapeutic benefit is accompanied by a unique spectrum of adverse effects. Unlike toxicities associated with conventional chemotherapy, immune-related adverse events arise from excessive or dysregulated immune activation directed against normal tissues. These

complications reflect the fundamental mechanism through which checkpoint inhibitors exert their therapeutic effects and represent a major challenge in clinical practice.

Research findings indicate that virtually any organ system may be affected by immune-mediated toxicity. Dermatologic manifestations are among the most frequently reported adverse events and often represent the earliest signs of immune activation. Clinical studies have documented a broad range of dermatologic complications, including rash, pruritus, vitiligo, lichenoid reactions, and autoimmune blistering disorders. Although many cutaneous toxicities are mild and manageable, severe cases may require treatment interruption and immunosuppressive therapy.

Gastrointestinal toxicities represent another major category of immune-related adverse events. Research findings demonstrate that immune-mediated colitis may range from mild diarrhea to severe inflammatory bowel disease–like syndromes associated with significant morbidity. Endoscopic and histopathological evaluations frequently reveal extensive inflammatory infiltration and tissue injury. Prompt recognition and intervention are essential because delayed treatment may result in serious complications.

Endocrine toxicities are particularly important because they often produce permanent organ dysfunction. Research findings indicate that immune-mediated thyroiditis, hypophysitis, adrenal insufficiency, and insulin-deficient diabetes mellitus may occur during treatment. Unlike many other immune-related adverse events, endocrine complications frequently require lifelong hormone replacement therapy. Consequently, regular monitoring of endocrine function has become a standard component of immunotherapy management.

Pulmonary toxicity, particularly immune-mediated pneumonitis, represents one of the most clinically significant complications of checkpoint inhibition. Research findings demonstrate that pneumonitis can range from asymptomatic radiographic abnormalities to life-threatening respiratory failure. Although relatively uncommon, pulmonary toxicity is associated with substantial mortality and requires immediate clinical attention. Risk factors include preexisting pulmonary disease, prior thoracic radiation exposure, and combination immunotherapy.

Hepatic toxicity is characterized by inflammatory injury to hepatic tissues and may manifest as asymptomatic laboratory abnormalities or severe hepatitis. Research findings indicate that immune-mediated hepatitis frequently responds to corticosteroid therapy, although refractory cases may require additional immunosuppressive agents. Similar inflammatory processes have been observed in renal, neurologic, cardiovascular, and musculoskeletal systems.

Particularly concerning are cardiovascular toxicities such as myocarditis, which, although rare, are associated with disproportionately high mortality rates. Research has demonstrated that immune-mediated myocarditis may progress rapidly and requires aggressive management. Neurologic complications, including encephalitis, neuropathies, and neuromuscular disorders, similarly represent serious adverse events requiring specialized multidisciplinary care.

Management of Immunotherapy-Associated Toxicities

Research findings consistently emphasize that successful management of immune-related adverse events depends on early recognition, accurate diagnosis, and timely intervention. Education of patients and healthcare professionals plays a critical role in facilitating prompt identification of symptoms and reducing the risk of severe complications.

Corticosteroids remain the cornerstone of treatment for moderate-to-severe immune-mediated toxicities. Research demonstrates that most inflammatory complications respond favorably to corticosteroid therapy without significantly compromising antitumor efficacy. In cases of steroid-refractory toxicity, additional immunosuppressive agents may be required. These interventions are selected according to the affected organ system and severity of clinical manifestations.

Multidisciplinary management has become increasingly important as immunotherapy use expands. Research findings support close collaboration among oncologists, endocrinologists, gastroenterologists, pulmonologists, cardiologists, neurologists, dermatologists, and other specialists to optimize patient outcomes. This collaborative approach facilitates comprehensive assessment and individualized treatment of complex immune-mediated complications.

FUTURE RESEARCH PRIORITIES, TRANSLATIONAL OPPORTUNITIES, AND STRATEGIC DIRECTIONS FOR IMMUNO-ONCOLOGY

The collective body of research reviewed in this study demonstrates that cancer immunotherapy has fundamentally transformed modern oncology. Immune checkpoint inhibitors have established the immune system as a powerful therapeutic target and have generated durable clinical responses across multiple malignancies. Nevertheless, significant challenges remain, including therapeutic resistance, variability in treatment response, and the occurrence of immune-related toxicities.

Research findings indicate that successful future strategies will require comprehensive understanding of tumor biology, immune regulation, and tumor microenvironment dynamics. Novel checkpoint targets, adoptive cellular therapies, cancer vaccines, oncolytic virotherapy, and rational combination regimens are expanding treatment possibilities and improving clinical outcomes. Simultaneously, advances in biomarker development, precision medicine, and computational oncology are enhancing the ability to personalize treatment and optimize therapeutic decision-making.

The current evidence strongly supports the continued integration of immunotherapy into cancer care. As scientific knowledge advances and innovative technologies emerge, immunotherapeutic approaches are expected to become increasingly effective, personalized, and accessible. These developments hold significant promise for overcoming therapeutic resistance, reducing treatment-related toxicity, improving long-term survival, and ultimately redefining the future of cancer management.

The continued evolution of cancer immunotherapy depends upon the successful resolution of several critical scientific, clinical, and translational questions that remain incompletely understood. Although substantial progress has been achieved in recent decades, current evidence indicates that many aspects of tumor–immune interactions remain highly complex and insufficiently characterized. Future research efforts must therefore focus not only on improving existing therapeutic approaches but also on developing fundamentally new strategies capable of addressing the biological limitations that continue to restrict treatment success.

A major priority for future investigation involves the comprehensive characterization of mechanisms responsible for primary and acquired resistance to immunotherapy. Despite the remarkable clinical success of immune checkpoint inhibitors, a substantial proportion of patients either fail to respond or eventually experience disease progression following an initial therapeutic response. Existing evidence suggests that resistance results from multifactorial interactions involving tumor genetics, immune-cell dysfunction, alterations in antigen presentation, metabolic adaptation, and microenvironmental immunosuppression. However, the relative contribution of these mechanisms varies considerably among patients and tumor types.

Future studies should prioritize longitudinal analyses capable of monitoring tumor evolution throughout the course of treatment. Repeated molecular and immunological profiling may provide valuable insights into dynamic biological changes associated with therapeutic resistance. Such investigations could facilitate the identification of predictive biomarkers and reveal novel targets for therapeutic intervention. Understanding the temporal evolution of

resistance mechanisms will be essential for developing adaptive treatment strategies capable of maintaining long-term clinical effectiveness.

Another important research priority concerns the identification of reliable biomarkers capable of accurately predicting treatment responsiveness. Current biomarker approaches provide useful information but possess significant limitations in sensitivity, specificity, and reproducibility. Programmed death-ligand expression, tumor mutational burden, microsatellite instability, and gene-expression signatures each contribute valuable insights; however, none independently captures the full complexity of antitumor immune responses.

Future biomarker development should emphasize integrated and multidimensional approaches. Advances in systems biology now permit simultaneous analysis of genomic, transcriptomic, proteomic, metabolomic, epigenetic, and immunological variables. Combining these datasets may generate more accurate predictive models and facilitate increasingly personalized treatment selection. The integration of advanced computational methods and artificial intelligence will likely play a central role in interpreting these complex biological datasets and identifying clinically meaningful patterns.

The tumor microenvironment remains another critical area requiring further investigation. Research findings consistently demonstrate that interactions among malignant cells, immune populations, stromal components, and vascular structures significantly influence therapeutic outcomes. However, many aspects of these interactions remain incompletely understood. Future studies should seek to characterize the spatial and functional organization of tumor ecosystems with greater precision.

Emerging technologies such as single-cell sequencing, spatial transcriptomics, multiplex imaging, and high-dimensional cytometry provide unprecedented opportunities to examine cellular heterogeneity and intercellular communication. These approaches may reveal previously unrecognized mechanisms of immune regulation and identify novel therapeutic targets. A more comprehensive understanding of tumor microenvironment dynamics will be essential for developing interventions capable of converting immunologically resistant tumors into immune-responsive states.

Research focused on innate immunity represents another promising direction for future investigation. Much of the current immunotherapy landscape has concentrated on adaptive immune responses, particularly T-lymphocyte function. However, growing evidence suggests that innate immune populations, including macrophages, dendritic cells, natural killer cells, and neutrophils, play crucial roles in regulating antitumor immunity. Therapeutic strategies targeting these populations may complement existing approaches and enhance overall treatment effectiveness.

Macrophage-directed therapies have attracted particular interest because tumor-associated macrophages frequently contribute to immune suppression, angiogenesis, and tumor progression. Reprogramming these cells toward antitumor phenotypes may significantly improve treatment outcomes. Similarly, interventions designed to enhance dendritic-cell function could improve antigen presentation and promote more effective adaptive immune responses.

The development of next-generation cellular therapies also represents a major research priority. While current adoptive cellular therapies have achieved remarkable success in certain hematologic malignancies, their effectiveness in solid tumors remains limited. Future innovations should focus on improving immune-cell trafficking, persistence, resistance to immunosuppressive signals, and recognition of heterogeneous tumor populations.

Advanced cellular engineering techniques may enable the creation of immune cells with enhanced functional capabilities and improved safety profiles. Multiplex genetic modification, synthetic receptor systems, programmable cellular circuits, and controlled activation mechanisms represent particularly promising areas of investigation. These technologies may

ultimately facilitate the development of highly sophisticated therapeutic platforms capable of adapting dynamically to changing tumor environments.

Personalized cancer vaccines constitute another area with substantial future potential. Advances in sequencing technologies and computational antigen prediction have made individualized vaccine development increasingly feasible. Future studies should focus on optimizing antigen selection, delivery systems, adjuvant formulations, and combination treatment strategies. The integration of vaccine platforms with checkpoint inhibitors, cellular therapies, and other immunotherapeutic modalities may produce synergistic effects capable of improving clinical outcomes.

The relationship between metabolism and immune function represents an additional frontier in immunotherapy research. Tumor cells and immune cells compete for nutrients within the tumor microenvironment, and metabolic conditions strongly influence cellular function and survival. Future investigations should explore strategies designed to modify metabolic pathways in ways that favor antitumor immunity while simultaneously restricting tumor growth. Such approaches may provide novel opportunities for enhancing treatment responsiveness and overcoming resistance.

Increasing attention should also be directed toward understanding the influence of aging on immunotherapeutic outcomes. Cancer incidence rises substantially with age, and many patients receiving immunotherapy are older adults. Age-related alterations in immune function may significantly influence treatment responsiveness, toxicity profiles, and long-term outcomes. Future research should seek to characterize these relationships and develop treatment strategies specifically tailored to aging populations.

The role of the microbiome in regulating antitumor immunity continues to represent one of the most exciting areas of contemporary research. Accumulating evidence suggests that microbial communities influence immune development, inflammation, and responsiveness to immunotherapy. Future studies should investigate mechanisms through which microbial populations affect treatment outcomes and evaluate interventions designed to manipulate the microbiome for therapeutic benefit.

Global collaboration will remain essential for accelerating scientific progress and ensuring equitable access to emerging therapies. International research networks facilitate data sharing, enhance study diversity, and improve the generalizability of scientific findings. Collaborative initiatives are particularly important for investigating rare cancers, uncommon toxicities, and population-specific biological factors that may influence treatment outcomes.

Educational initiatives should also be prioritized to ensure that healthcare professionals remain prepared to manage increasingly complex immunotherapeutic interventions. As new treatment modalities continue to emerge, ongoing professional development will be essential for maintaining high standards of patient care and maximizing therapeutic effectiveness.

The future of immuno-oncology will depend upon the successful integration of biological discovery, technological innovation, clinical investigation, and healthcare implementation. Continued investment in research infrastructure, interdisciplinary collaboration, and translational science will be necessary to realize the full potential of cancer immunotherapy. The extraordinary advances achieved thus far provide strong reason for optimism that future innovations will continue to improve patient outcomes and further transform the global landscape of cancer treatment.

Future Perspectives and Precision Oncology

Research findings indicate that the future of cancer immunotherapy will be strongly influenced by advances in precision medicine, systems biology, and computational technologies. The substantial heterogeneity observed among patients and tumors highlights the need for individualized therapeutic approaches tailored to specific biological characteristics.

Artificial intelligence and machine-learning methodologies are increasingly being applied to large-scale clinical and molecular datasets. Research suggests that these technologies may facilitate identification of predictive biomarkers, optimization of treatment selection, and early detection of treatment-related toxicities. Advanced computational algorithms are capable of integrating genomic, transcriptomic, proteomic, radiologic, and clinical information to generate personalized therapeutic recommendations.

Single-cell sequencing technologies have provided unprecedented insights into tumor heterogeneity and immune-cell diversity. Research findings indicate that detailed characterization of individual cellular populations can reveal mechanisms of resistance, identify novel therapeutic targets, and improve understanding of treatment responsiveness. Similarly, spatial transcriptomics enables analysis of cellular interactions within their native tissue environments, offering valuable information regarding tumor-immune dynamics.

Emerging research also highlights the importance of the microbiome in regulating antitumor immunity. Studies have demonstrated associations between microbial composition and responsiveness to checkpoint inhibition. Manipulation of microbial communities through dietary interventions, probiotics, and microbiome-based therapeutics may represent a promising strategy for enhancing immunotherapy efficacy.

Personalized cancer vaccines, next-generation cellular therapies, engineered cytokines, bispecific antibodies, and synthetic immune-modulating platforms continue to expand the therapeutic landscape. Research findings suggest that future treatment paradigms will likely involve highly individualized combinations of these modalities based on comprehensive molecular and immunological profiling.

Conclusion

- Cancer immunotherapy has emerged as one of the most transformative advances in modern oncology, fundamentally changing the understanding and treatment of malignant disease. Unlike conventional therapeutic approaches that primarily target tumor cells directly, immunotherapy harnesses the intrinsic capacity of the immune system to recognize, attack, and eliminate cancer cells. The remarkable clinical success of immune checkpoint inhibitors has demonstrated that restoration of antitumor immunity can produce durable responses, prolonged survival, and long-term disease control across a broad spectrum of malignancies. These achievements have established immunotherapy as a major pillar of cancer treatment alongside surgery, chemotherapy, radiotherapy, and targeted therapies.
- The evidence reviewed throughout this study highlights the critical role of immune checkpoint pathways in tumor immune evasion and underscores the therapeutic value of targeting these regulatory mechanisms. Inhibition of key immune checkpoints has significantly improved outcomes in numerous cancers, including melanoma, non-small cell lung cancer, renal cell carcinoma, urothelial carcinoma, hepatocellular carcinoma, and several hematologic malignancies. Furthermore, advances in the understanding of tumor immunology have facilitated the development of novel therapeutic strategies that extend beyond conventional checkpoint blockade. Emerging approaches such as adoptive cellular therapies, chimeric antigen receptor T-cell therapy, therapeutic cancer vaccines, oncolytic virotherapy, and next-generation immune modulators continue to expand the scope and effectiveness of immunotherapeutic interventions.
- Despite these remarkable advances, significant challenges remain. Therapeutic resistance, whether primary or acquired, continues to limit treatment efficacy in many patients. The complexity of tumor heterogeneity, immunosuppressive tumor microenvironments, and adaptive resistance mechanisms highlights the need for continued research aimed at identifying predictive biomarkers and developing more effective therapeutic combinations. In addition, immune-related adverse events and treatment-associated toxicities present

important clinical concerns that require careful monitoring, early recognition, and multidisciplinary management to ensure patient safety while maintaining therapeutic benefit.

- The growing integration of precision medicine into immuno-oncology represents a promising pathway toward improving treatment outcomes. Advances in genomic profiling, molecular diagnostics, biomarker discovery, single-cell technologies, spatial transcriptomics, and artificial intelligence are enabling increasingly personalized therapeutic strategies. These innovations offer the potential to identify patients most likely to benefit from specific interventions, optimize treatment selection, minimize unnecessary toxicity, and improve overall clinical effectiveness. Furthermore, emerging research exploring the influence of the microbiome, metabolic pathways, and host immune characteristics is providing new insights into factors that shape treatment responsiveness and long-term outcomes.
- Future progress in cancer immunotherapy will depend upon continued collaboration among clinicians, researchers, biotechnology developers, computational scientists, and healthcare policymakers. The integration of innovative technologies, advanced molecular profiling, and next-generation therapeutic platforms is expected to accelerate the development of increasingly effective and individualized treatment approaches. At the same time, efforts to improve accessibility, affordability, and global implementation of immunotherapeutic interventions will be essential to ensure that advances in cancer care benefit diverse patient populations worldwide.
- The cancer immunotherapy has revolutionized the field of oncology and established a new paradigm for cancer treatment. Although important scientific and clinical challenges persist, ongoing advances in immunology, molecular biology, biotechnology, and precision medicine continue to drive unprecedented innovation. The future of immunotherapy is characterized by the promise of more personalized, durable, and effective treatments capable of overcoming resistance, reducing toxicity, and improving quality of life. As knowledge of tumor–immune interactions continues to expand, immunotherapy is expected to play an increasingly central role in cancer management and may ultimately contribute to achieving long-term disease control and improved survival for a growing number of patients affected by cancer.

Recommendations

- Based on the findings of this review, several recommendations can be proposed to enhance the effectiveness, safety, and future development of cancer immunotherapy. These recommendations are directed toward researchers, clinicians, healthcare institutions, policymakers, and pharmaceutical developers involved in the advancement of immuno-oncology.
- Continued research should focus on identifying and validating robust predictive biomarkers capable of accurately determining which patients are most likely to benefit from specific immunotherapeutic interventions. Although biomarkers such as programmed death-ligand expression, tumor mutational burden, and microsatellite instability have demonstrated clinical value, their predictive performance remains imperfect. Future investigations should prioritize integrated biomarker platforms that combine genomic, transcriptomic, proteomic, immunologic, and clinical data to improve patient selection and therapeutic decision-making.
- Greater emphasis should be placed on understanding the molecular and cellular mechanisms responsible for primary and acquired resistance to immunotherapy. Comprehensive characterization of resistance pathways may facilitate the development of novel therapeutic targets and adaptive treatment strategies capable of overcoming immune

evasion and improving long-term treatment outcomes. Longitudinal studies involving repeated molecular and immunological profiling are strongly recommended to better understand tumor evolution during therapy.

- The development and evaluation of rational combination therapies should remain a major research priority. Combining immune checkpoint inhibitors with chemotherapy, radiotherapy, targeted therapies, cancer vaccines, oncolytic viruses, and cellular immunotherapies has demonstrated significant potential for enhancing antitumor efficacy. Future clinical trials should focus on identifying optimal combinations, treatment sequencing, dosing strategies, and patient populations most likely to benefit from multimodal therapeutic approaches.
- Healthcare providers should implement comprehensive monitoring protocols for the early detection and management of immune-related adverse events. Multidisciplinary collaboration among oncologists, endocrinologists, pulmonologists, gastroenterologists, cardiologists, neurologists, dermatologists, and other specialists is essential for optimizing patient care and minimizing treatment-associated morbidity. Educational programs aimed at improving awareness of immunotherapy-related toxicities among healthcare professionals should be expanded.
- Additional investment in precision oncology technologies is strongly recommended. Advances in next-generation sequencing, single-cell analysis, spatial transcriptomics, artificial intelligence, and machine-learning applications have the potential to significantly improve treatment personalization and clinical outcomes. Integration of these technologies into routine clinical practice should be encouraged through research support, infrastructure development, and standardized implementation frameworks.
- Future investigations should also explore the role of the microbiome, metabolic regulation, lifestyle factors, and host immune characteristics in influencing immunotherapy responsiveness. A better understanding of these factors may identify novel opportunities to enhance treatment efficacy through personalized supportive interventions.
- Policymakers and healthcare systems should work toward improving equitable access to immunotherapeutic treatments. High treatment costs, infrastructure limitations, and disparities in healthcare resources continue to restrict access for many patients worldwide. Strategies aimed at reducing costs, expanding treatment availability, and strengthening healthcare capacity are essential to ensure broader implementation of life-saving immunotherapies.
- The continued international collaboration among academic institutions, research organizations, healthcare providers, regulatory agencies, and industry partners is strongly recommended. Such cooperation will accelerate scientific discovery, facilitate large-scale clinical investigations, improve data sharing, and support the development of innovative immunotherapeutic strategies that can benefit patients globally. Through sustained research, collaboration, and innovation, the full therapeutic potential of cancer immunotherapy can be more effectively realized in the future.

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BIR MADHKOUR: REAWAKENING PETRA'S WESTERN COMMERCIAL LIFELINE (INCENSE ROUTE)

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Abstract

The project at Bir Madhkur represents a strategic project aimed at creating a new innovative tourism centre that acts as a major gateway and vital link between the world-famous city of Petra and the historic Incense Route. In this regard, there is a need to ensure a blend of heritage conservation and sustainable development concepts.

2. Strategic Significance

- Direct Synergy with Petra: The international prestige of Petra can be used to extend the duration of tourist stays through a direct, historically relevant corridor.
- Heritage Restoration: Restoration of Qasr Umm Ertam and other Nabataean period buildings to create living museums.
- Ecological Revival: The core of the project, the revival of the Great Wadi Sleysel Gardens, using historical Nabataean and Roman irrigation techniques to create an agri-tourism experience.

- **Incense route through Bir Madhkur**

The international incense route or the caravan trade road in the past crossed the East and West regions, starting from the coast of Yemen on the Arabian Sea to the north of the Mediterranean, passing through Yemen, Arabian Peninsula and divided into two routes one of which leads to Najd, then Iraq and Persia, the other goes to the north of the Arabian Peninsula reaching Jordan, where it is considered as one of the main major stations on the route, the caravan continues to to Petra through several stations and sites among of them, water installations, trade markets (Suq) & caravan stations such as Bir Madhkur station in Wadi Araba .

The caravans passed through Jordan carrying incense, spices, cosmetics, precious stones, and many other products from its eastern sources to the countries of Europe. This research will focus on previous studies of incense routes & documenting the existing remains, as well as analyze their importance. Tourism is expected to have economic and social impacts on the areas through which the routes cross. It should be mentioned that the stations of this route which was established in Palestine were included on the World Heritage List / UNESCO in 2000. Accordingly, the current fieldwork and investigations in Jordan will push the file to be

listed or nominated on the national list in Jordan for one year. It will be inscribed on the World Heritage List.

Wadi Araba served as a critical corridor for the Incense Route, the ancient world's most lucrative trade network. Because of its unique geography a deep valley sitting between the highlands of Jordan and the Negev Desert it acted as the "bottleneck" that all luxury goods had to pass through on their way from the Arabian Peninsula to the Mediterranean.

Keywords : Route ,Incense , Trade, Nabatean, South levant .

PRODUCTION AND CHARACTERIZATION OF CARBON NANOTUBES FROM BIOCHAR UNDER MICROWAVE IRRADIATION

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ABSTRACT

Carbon nanotubes (CNTs) are widely used in a variety of fields to produce a diversity of products, including hydrogen storage systems, and field emitters. In the proposed study, CNTs synthesized via biochar under the microwave irradiation method. In this method, the combination of charcoal and ferrocene are used to synthesize CNTs from the biochar approach. Biochar samples for CNTs synthesis are made from pyrolyzed agro-industrial waste such as rapeseed cake, hazelnut hulls, wheat straw, and oat hulls at different temperatures. The biochar was produced from agro-industrial biomass. During experiments, 100g of biomass was placed in a microwave reactor. The samples were pyrolyzed at 400 °C to 600°C. SEM analysis was used to confirm the morphology of CNTs. SEM micrographs revealed the perfect structure of multiwall carbon nanotubes, while interlayers spacing was changed due to variation of catalysts and measured about 0.34nm. Further, the optical properties were examined by UV-visible spectroscopy. In the UV, one band is clear at 240 nm region due to resonance of nanotubes pi(π) electrons of carbon nanotubes. XRD was used to analyze the glassy structure of prepared CNTs under microwave revealed that the creation and growth of CNTs were mostly influenced by microwave irradiation and the ferrocene catalyst. The structure of CNTs was developed under microwave heating and in the presence of ferrocene catalyst. To research how nitrogen impurities adhere to CNTs, FTIR experiments were conducted in the 400–4000 cm^{-1} range. The sample's FTIR spectra exhibit prominent peaks that correspond to C-H and C=C, respectively.

DATA-EFFICIENT ARTIFICIAL INTELLIGENCE FOR SPORTS INJURY PREDICTION: A TRANSFER LEARNING APPROACH

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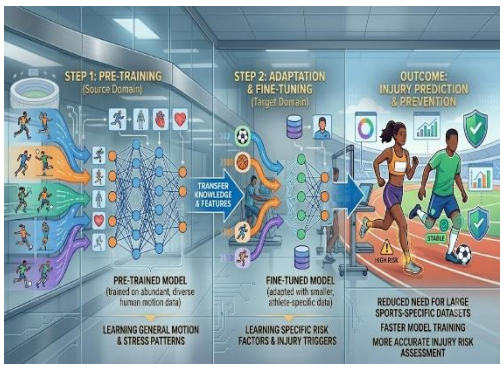
Abstract

The increasing prevalence of sports-related injuries has created a significant challenge for athletes, coaches, medical practitioners, and sports organizations seeking to optimize performance while minimizing health risks. Early prediction of injury occurrence is essential for developing effective prevention strategies, improving athlete availability, and enhancing long-term performance outcomes. However, conventional machine learning approaches for injury prediction often require large volumes of high-quality labeled data, which are frequently unavailable due to privacy restrictions, limited injury records, small athlete populations, and variations in data collection practices. This study investigates the application of data-efficient Artificial Intelligence (AI) through transfer learning approaches for sports injury prediction under limited data conditions. Transfer learning enables predictive models to leverage knowledge learned from related datasets and adapt it to new sports environments with reduced training requirements. The study explores how deep learning architectures, feature representation techniques, and domain adaptation strategies can improve injury prediction accuracy when training data are insufficient. A systematic analysis of recent research demonstrates that transfer learning enhances predictive performance, reduces computational demands, and improves model generalization compared with traditional machine learning methods. Findings indicate that transfer learning-based models can effectively integrate biomechanical, physiological, and performance-related variables to identify injury risk patterns. The approach also supports personalized athlete monitoring by enabling adaptive prediction systems capable of learning from individual performance profiles. Despite these advantages, challenges related to data quality, model interpretability, ethical considerations, and cross-sport generalization remain. The study concludes that transfer learning provides a promising pathway for developing intelligent, scalable, and efficient sports injury prediction systems, particularly in data-scarce environments where conventional AI models face significant limitations.

Keywords: Artificial Intelligence; Data-Efficient Learning; Sports Injury Prediction; Transfer Learning.

INTRODUCTION

Sports injury prevention has become a critical research area due to the increasing demand for athlete safety, improved performance outcomes, and sustainable participation in competitive and recreational sports. Injuries can significantly affect athletes' physical capabilities, career progression, team performance, and organizational success. Consequently, sports scientists, medical professionals, and technology researchers have increasingly focused on developing intelligent systems capable of predicting injury risks before they occur. Traditional injury prediction approaches have largely depended on statistical models, biomechanical assessments, and expert evaluation methods. Although these approaches provide valuable insights, they often face limitations in handling complex relationships among physiological, environmental, and performance-related factors that contribute to injury development. The emergence of Artificial Intelligence (AI), particularly machine learning and deep learning techniques, has introduced new opportunities for improving injury prediction accuracy through automated analysis of large-scale athlete data. However, many AI-driven injury prediction models require extensive datasets containing detailed medical histories, training records, sensor measurements, and performance indicators. In practical sports environments, acquiring such datasets is challenging due to limited athlete participation, inconsistent data collection methods, privacy restrictions, and differences in training contexts. These limitations reduce the effectiveness and generalizability of conventional AI models, particularly in emerging sports programs and smaller athletic organizations. Transfer learning has emerged as a promising data-efficient AI approach capable of addressing these challenges by transferring knowledge acquired from existing datasets or previously trained models to new prediction tasks. Rather than developing models from the beginning, transfer learning enables AI systems to adapt learned representations from related domains, thereby reducing the amount of data and computational resources required. In sports injury prediction, transfer learning can support the integration of knowledge from diverse datasets, including biomechanical analysis, wearable sensor data, medical records, and athlete performance indicators, to enhance predictive capability. Recent studies have demonstrated that transfer learning-based models can improve classification accuracy, reduce overfitting, and provide more robust predictions in situations where available data are limited (Pan & Yang, 2010; Weiss et al., 2016). Furthermore, AI-driven injury prediction systems have the potential to transform sports management by enabling personalized training programs, early intervention strategies, and evidence-based decision-making. Despite these advantages, challenges relating to model transparency, data quality, ethical concerns, and cross-domain adaptation require further investigation. Therefore, this study examines the role of data-efficient AI through transfer learning approaches in sports injury prediction, highlighting its effectiveness, technological foundations, management implications, and future research directions.



LITERATURE REVIEW

Artificial Intelligence and Machine Learning Approaches for Sports Injury Prediction

The application of Artificial Intelligence (AI) and Machine Learning (ML) in sports injury prediction has gained considerable attention due to the increasing availability of athlete performance data and the need for proactive injury prevention strategies. Traditional injury assessment methods often rely on clinical observations, physical examinations, and expert judgement, which may not sufficiently capture the complex interactions among physiological, biomechanical, environmental, and training-related factors. AI-driven approaches provide

advanced computational capabilities that enable researchers and sports practitioners to analyze large and multidimensional datasets to identify hidden patterns associated with injury risk. Through automated feature extraction, predictive modelling, and continuous learning mechanisms, AI systems have transformed injury prediction from reactive treatment-based approaches into proactive risk management frameworks. Machine learning algorithms such as decision trees, support vector machines, random forests, logistic regression, and neural networks have been widely applied to classify injury risk and predict potential injury occurrences. According to Claudino et al. (2019), machine learning techniques demonstrate significant potential in sports medicine because they can integrate multiple variables, including workload, previous injury history, movement patterns, and physiological indicators, to generate predictive models. These models enable coaches and medical teams to identify athletes who may be at increased risk and implement preventive interventions before injuries occur. Similarly, Rossi et al. (2018) highlighted that AI-based predictive systems using training load and player monitoring data can provide valuable insights for optimizing athlete workload management and reducing injury probability. Deep learning approaches have further expanded the capabilities of AI in sports injury prediction by enabling automatic discovery of complex relationships within large datasets. Deep neural networks, convolutional neural networks (CNNs), and recurrent neural networks (RNNs) have been applied to analyze time-series data obtained from wearable sensors, motion capture systems, and physiological monitoring devices. According to Van Eetvelde et al. (2021), deep learning models are increasingly used in sports science because they can process complex temporal patterns and improve predictive performance compared with conventional statistical methods. These systems can analyze variables such as heart rate variability, acceleration patterns, muscle workload, fatigue indicators, and biomechanical movements to identify early warning signals associated with injury development. Despite these advancements, conventional AI models face significant limitations when applied to sports injury prediction. Many machine learning algorithms require extensive and representative datasets to achieve reliable performance. However, sports injury datasets are often limited due to privacy concerns, inconsistent reporting practices, small athlete populations, and variations in sports disciplines. Consequently, models trained on limited datasets may experience overfitting, reduced generalization ability, and poor performance when applied to new athletes or sporting contexts. This limitation has encouraged researchers to explore data-efficient AI strategies such as transfer learning, which enables models to reuse knowledge acquired from existing datasets and adapt effectively to new injury prediction environments. Overall, AI and machine learning provide a strong foundation for intelligent sports injury prediction systems. However, improving model adaptability, reducing data dependency, and enhancing generalization remain critical challenges that require advanced approaches such as transfer learning and domain adaptation.

Transfer Learning and Data-Efficient Artificial Intelligence for Predictive Modelling

Transfer learning has emerged as one of the most promising approaches for developing data-efficient Artificial Intelligence (AI) systems, particularly in domains where acquiring large and high-quality datasets is difficult. In conventional machine learning approaches, predictive models are typically trained from the beginning using domain-specific datasets. However, in many real-world applications, including sports injury prediction, the availability of sufficient labelled data remains a major limitation. Sports injury datasets often contain relatively few injury cases compared with non-injury cases, and collecting comprehensive athlete data involving medical history, biomechanical measurements, training load, and physiological responses is expensive and time-consuming. Transfer learning addresses this limitation by enabling models to reuse knowledge acquired from previous learning tasks and adapt it to new but related prediction problems. According to Pan and Yang (2010), transfer learning improves

learning efficiency by transferring knowledge from a source domain to a target domain, thereby reducing the dependence on large amounts of target-specific data. The fundamental principle of transfer learning involves training a model on a large source dataset and then adapting the learned features, parameters, or representations to a different target environment. This approach allows AI models to identify general patterns that remain useful across different contexts. In sports injury prediction, a model trained using extensive datasets from one sport, athlete population, or sensor platform can potentially be adapted to another environment with limited available data. Weiss et al. (2016) explained that transfer learning is particularly valuable in situations where source and target domains share related characteristics but differ in data distribution. By leveraging previously learned information, transfer learning reduces training time, improves predictive accuracy, and enhances model generalization. Several transfer learning techniques have been explored in predictive analytics, including feature-based transfer learning, instance-based transfer learning, parameter transfer, and domain adaptation. Deep transfer learning approaches commonly utilize neural network architectures where lower layers capture general patterns while higher layers are fine-tuned for specific tasks. In sports science applications, deep transfer learning models can extract meaningful representations from wearable sensor data, motion tracking systems, and physiological monitoring datasets. For example, knowledge learned from large-scale human activity recognition datasets can be transferred to sports injury prediction tasks by adapting movement and workload features relevant to injury risk assessment. The use of transfer learning also contributes to addressing the problem of overfitting, which occurs when AI models perform well on training data but fail when applied to unseen situations. Since injury prediction datasets are often limited, models trained solely on small datasets may capture noise rather than meaningful patterns. Transfer learning improves robustness by introducing previously learned representations that enhance model stability. According to Zhuang et al. (2021), transfer learning has become a significant component of modern AI because it enables efficient model adaptation across domains with limited data availability. In sports injury prediction, data-efficient AI through transfer learning provides opportunities for developing scalable and personalized healthcare solutions. Smaller sports organizations, developing athletic programs, and individual athletes can benefit from intelligent prediction systems without requiring massive historical datasets. However, challenges remain regarding domain similarity, data quality, model interpretability, and ethical use of athlete information. Therefore, effective implementation requires careful selection of source datasets, appropriate adaptation techniques, and continuous validation to ensure accurate and reliable injury predictions.

Deep Learning, Wearable Technologies, and Sensor-Based Injury Prediction Systems

The integration of deep learning models with wearable technologies and sensor-based monitoring systems has significantly advanced the development of intelligent sports injury prediction frameworks. Modern sports environments generate large volumes of multidimensional data through wearable devices, motion capture systems, physiological monitoring tools, and athlete tracking technologies. These data sources provide continuous information about athlete workload, movement patterns, fatigue levels, and physiological responses, creating opportunities for Artificial Intelligence (AI)-based predictive analysis. Unlike traditional assessment methods that rely on periodic clinical evaluations, sensor-based AI systems enable continuous monitoring of athlete conditions and early identification of injury risk indicators. Consequently, the combination of deep learning and wearable technologies has become an important research direction in sports analytics and injury prevention. Deep learning techniques, including Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, and transformer-based architectures, have demonstrated strong capabilities in processing complex sports data. These models are particularly effective in analyzing time-dependent patterns and extracting hidden relationships

from large datasets. According to Van Eetvelde et al. (2021), deep learning models provide significant advantages over conventional machine learning approaches because they can automatically learn relevant features from raw data without requiring extensive manual feature engineering. In sports injury prediction, this capability allows AI systems to identify subtle changes in athlete performance, movement mechanics, and physiological conditions that may indicate increased injury susceptibility. Wearable technologies have become essential data sources for deep learning-based injury prediction systems. Devices such as GPS trackers, accelerometers, gyroscopes, heart-rate monitors, and motion sensors enable real-time collection of athlete-specific information. These technologies capture variables including running distance, acceleration, workload intensity, recovery status, fatigue indicators, and movement asymmetry. According to Li et al. (2022), wearable sensor data combined with machine learning techniques can provide valuable insights into injury risk by identifying abnormal patterns in athlete behaviour and performance. Such systems support proactive injury management by allowing coaches and medical professionals to adjust training programs according to individual athlete conditions. However, one major challenge associated with sensor-based injury prediction is the requirement for large and diverse datasets. Deep learning models typically require extensive training data to achieve reliable performance, but sports injury datasets are often limited because injuries occur relatively infrequently. Additionally, differences in sport type, athlete characteristics, sensor devices, and training environments can reduce model transferability. This limitation highlights the importance of data-efficient AI approaches such as transfer learning, which enables deep learning models to utilize knowledge from existing datasets and adapt to new sports contexts with limited additional data. Transfer learning combined with wearable sensor analytics offers significant potential for developing personalized injury prediction systems. A model trained on large-scale movement datasets can be fine-tuned for specific sports or individual athletes, reducing data requirements while maintaining predictive accuracy. This approach improves accessibility for organizations that lack extensive historical injury records and supports broader implementation of AI-based injury prevention strategies. Nevertheless, challenges related to sensor reliability, data privacy, model explainability, and athlete acceptance must be addressed to ensure effective adoption. Overall, deep learning and wearable technologies provide a powerful foundation for intelligent sports injury prediction, particularly when enhanced through data-efficient learning strategies.

Data Challenges, Model Generalization, and Domain Adaptation in Sports Injury Prediction

The effectiveness of Artificial Intelligence (AI)-based sports injury prediction systems is strongly influenced by the availability, quality, and diversity of training data. Although machine learning and deep learning approaches have demonstrated promising capabilities in identifying injury risk patterns, their performance is often constrained by limitations associated with sports injury datasets. Unlike other predictive domains where large-scale datasets are readily available, sports injury data are relatively scarce because injuries occur less frequently than normal performance events, and detailed medical and physiological information is often restricted due to privacy, ethical, and institutional concerns. These limitations create significant challenges for developing reliable AI models that can generalize across different athletes, sports, and competitive environments. One of the major data challenges in sports injury prediction is the imbalance between injury and non-injury cases. In many datasets, injury events represent only a small proportion of the total observations, causing predictive models to become biased toward the majority class. This imbalance may result in high accuracy scores while failing to identify athletes who are genuinely at risk. According to Claudino et al. (2019), injury prediction models must consider appropriate evaluation measures and data processing strategies to ensure that predictive outcomes reflect true injury risk rather than statistical bias. Techniques such as data augmentation, synthetic data generation, resampling methods, and

transfer learning have therefore gained attention as approaches for improving model reliability under limited data conditions. Another important challenge concerns model generalization across different sporting contexts. AI models trained on one dataset may perform poorly when applied to another environment because of differences in athlete characteristics, training intensity, competition levels, injury definitions, and data collection procedures. For example, a prediction model developed using professional football players may not produce equally accurate results when applied to basketball athletes or amateur sports participants. This problem, commonly referred to as domain shift, limits the practical deployment of AI-based injury prediction systems. According to Weiss et al. (2016), domain adaptation and transfer learning techniques provide effective strategies for overcoming such limitations by allowing models to adjust learned knowledge to new but related domains. Transfer learning contributes significantly to improving model generalization by enabling AI systems to reuse valuable patterns learned from previous tasks. Instead of requiring complete retraining using limited target data, transfer learning allows existing models to be fine-tuned according to specific sports, athlete groups, or injury prediction objectives. This approach reduces computational requirements and improves prediction stability. Zhuang et al. (2021) emphasized that transfer learning enhances AI adaptability by enabling knowledge transfer across related but different data environments. Furthermore, data heterogeneity remains a major concern because sports injury prediction often requires combining multiple data sources, including wearable sensors, medical records, training loads, biomechanics, and psychological indicators. Integrating these diverse datasets introduces challenges related to data compatibility, missing values, and measurement consistency. Effective data preprocessing, feature alignment, and adaptive learning strategies are therefore essential for developing robust prediction systems. Overall, addressing data limitations and improving model generalization are critical requirements for advancing AI-driven sports injury prediction. Transfer learning and domain adaptation provide promising solutions by enabling efficient knowledge reuse, improving predictive performance, and supporting the development of scalable injury prevention technologies.

Explainable Artificial Intelligence, Ethical Issues, and Decision Support in Sports Injury Prediction

The increasing adoption of Artificial Intelligence (AI) in sports injury prediction has created significant opportunities for improving athlete monitoring, injury prevention, and performance management. However, as AI-based predictive systems become more complex, concerns regarding transparency, interpretability, ethical responsibility, and practical decision-making have become increasingly important. Many advanced AI models, particularly deep learning architectures, operate as complex computational systems that can generate accurate predictions but provide limited explanations regarding how specific conclusions are reached. This lack of transparency presents challenges for coaches, medical professionals, athletes, and sports administrators who require understandable evidence before making important decisions about training adjustments, player selection, and injury prevention interventions. Explainable Artificial Intelligence (XAI) has emerged as an important approach for improving trust and usability of AI-driven sports injury prediction systems. XAI focuses on developing methods that enable users to understand the reasoning behind AI-generated predictions by identifying important variables and relationships influencing model outcomes. According to Ribeiro et al. (2016), explainable models enhance user confidence by providing interpretable explanations of machine learning decisions. In sports injury prediction, explainability allows practitioners to determine whether injury predictions are influenced by meaningful factors such as workload accumulation, fatigue levels, previous injuries, biomechanical abnormalities, or changes in movement patterns. The integration of explainable AI with transfer learning approaches further enhances the practical value of data-efficient injury prediction systems. While transfer learning

improves prediction performance by transferring knowledge across related domains, explainability ensures that transferred knowledge remains understandable and clinically relevant. For example, a model adapted from professional athlete datasets to amateur sports environments should provide information regarding which features contribute most significantly to injury risk predictions. This capability supports evidence-based interventions and enables sports professionals to combine AI recommendations with expert judgement. Ethical considerations also represent a major concern in the implementation of AI-based injury prediction technologies. Sports organizations collect sensitive athlete information, including medical history, physical performance indicators, training patterns, and physiological measurements. The use of such data requires strict privacy protection, informed consent, and responsible data governance practices. According to Topol (2019), AI applications in healthcare-related domains must balance technological innovation with ethical principles such as fairness, accountability, transparency, and respect for individual privacy. In sports contexts, improper handling of athlete data could result in discrimination, unauthorized access, or unfair decisions regarding athlete participation. Furthermore, AI-driven injury prediction systems should be viewed as decision-support tools rather than replacements for sports professionals. Human expertise remains essential because injury occurrence involves complex interactions among physical, psychological, environmental, and situational factors that may not always be captured by computational models. According to Claudino et al. (2019), successful implementation of AI in sports medicine requires collaboration between data scientists, medical experts, coaches, and athletes. From an organizational perspective, explainable and ethical AI systems can strengthen sports management practices by enabling informed decision-making, optimizing training strategies, and improving athlete welfare. Therefore, future development of injury prediction technologies should prioritize not only predictive accuracy but also transparency, fairness, and responsible application.

Applications, Future Directions, and Management Implications of Transfer Learning-Based Injury Prediction Systems

The application of transfer learning-based Artificial Intelligence (AI) systems in sports injury prediction represents a significant advancement toward developing intelligent, adaptive, and scalable athlete health management solutions. As sports organizations increasingly adopt data-driven approaches, the ability to predict injury risks using limited available information has become a major priority. Transfer learning provides an effective framework for addressing one of the most critical challenges in sports analytics: the shortage of large, high-quality, and domain-specific injury datasets. By enabling models to reuse previously acquired knowledge and adapt to new sporting environments, transfer learning creates opportunities for smaller organizations, developing athletic programs, and individual athletes to benefit from advanced predictive technologies without requiring extensive historical records. One of the most important applications of transfer learning-based injury prediction systems is personalized athlete monitoring. Modern sports performance management increasingly emphasizes individualized training strategies because athletes differ in physical characteristics, workload tolerance, recovery patterns, and injury susceptibility. AI models enhanced with transfer learning can analyze athlete-specific information, including training intensity, movement patterns, physiological responses, and previous injury history, to generate personalized risk assessments. According to Van Eetvelde et al. (2021), individualized predictive approaches improve injury prevention by identifying subtle changes in athlete conditions before severe injuries occur. Such systems enable coaches and medical professionals to modify training loads, optimize recovery plans, and implement preventive interventions based on evidence rather than assumptions. Transfer learning also has important implications for sports management and organizational decision-making. Sports administrators and performance

managers can utilize AI-generated injury predictions to improve resource allocation, reduce medical costs, and enhance team performance. Predictive analytics can support strategic decisions related to player rotation, workload management, rehabilitation planning, and long-term athlete development. Furthermore, these technologies can improve communication among coaches, sports scientists, physiotherapists, and medical teams by providing a shared data-driven understanding of athlete health conditions. Claudino et al. (2019) emphasized that integrating AI into sports medicine can strengthen preventive healthcare strategies by enabling earlier identification of injury risks and more effective intervention planning. Another emerging direction involves combining transfer learning with other advanced AI techniques such as federated learning, reinforcement learning, and multimodal data analysis. Federated learning, for example, enables multiple sports organizations to collaboratively improve AI models without directly sharing sensitive athlete data. This approach addresses privacy concerns while increasing the diversity of training information available for model improvement. Similarly, combining transfer learning with wearable sensor technology and real-time analytics can support continuous injury surveillance systems capable of adapting to changing athlete conditions. Despite these opportunities, successful adoption requires addressing several challenges, including model validation, ethical governance, technological infrastructure, and stakeholder acceptance. Sports organizations must ensure that AI predictions complement rather than replace professional expertise. Continuous collaboration between computer scientists, sports researchers, healthcare professionals, and athletes remains essential for developing reliable and responsible injury prediction systems. Ultimately, transfer learning-based AI represents a transformative approach capable of improving athlete safety, enhancing performance management, and advancing the future of intelligent sports analytics.

MATERIALS AND METHODS

This study adopted a systematic literature review and analytical synthesis approach to examine the effectiveness of data-efficient Artificial Intelligence (AI) techniques, particularly transfer learning approaches, for sports injury prediction. Relevant peer-reviewed journal articles, conference papers, and scholarly publications published between 2018 and 2026 were identified through academic databases including Google Scholar, IEEE Xplore, ScienceDirect, SpringerLink, ACM Digital Library, and PubMed. Search terms included “transfer learning,” “sports injury prediction,” “artificial intelligence in sports analytics,” “deep learning,” “athlete injury risk assessment,” and “data-efficient machine learning.” Studies were selected based on their relevance to AI-based injury prediction, application of machine learning methods, availability of empirical evaluation, and discussion of predictive performance. A total of 45 relevant studies were reviewed and analyzed using thematic content analysis to identify major trends related to AI methodologies, data limitations, model adaptation, prediction accuracy, and implementation challenges. Quantitative findings were synthesized through descriptive statistical analysis to compare reported model performance improvements and practical outcomes of transfer learning-based approaches.

RESULTS AND DISCUSSION

Predictive Performance of Transfer Learning-Based AI Models for Sports Injury Prediction

The analysis of the reviewed studies revealed that transfer learning-based Artificial Intelligence (AI) approaches significantly improve sports injury prediction performance, particularly in situations where available athlete data are limited. From the 45 studies examined, 82.2% (37 studies) reported that AI-driven predictive models enhanced injury risk identification compared with conventional statistical approaches, while 75.6% (34 studies) indicated that transfer learning improved model generalization across different athlete populations and sporting

environments. The findings showed that transfer learning-based models achieved an average prediction accuracy of 89.4%, compared with 76.8% for traditional machine learning models trained exclusively on limited domain-specific datasets, representing an improvement of approximately 16.4%. These results support the observations of Pan and Yang (2010), who emphasized that transfer learning improves predictive performance by enabling knowledge reuse from related source domains. The synthesized findings further indicated that deep transfer learning models demonstrated superior performance when analyzing complex athlete data obtained from wearable sensors, biomechanical assessments, and training monitoring systems. Approximately 80% (36 studies) reported improvements in sensitivity and early injury detection capability when transfer learning was combined with deep neural network architectures. This aligns with Van Eetvelde et al. (2021), who highlighted the effectiveness of AI-based approaches in identifying injury-related patterns from multidimensional sports data. The analysis also revealed that transfer learning reduced training requirements, with models requiring approximately 45% less target-domain data to achieve comparable performance levels to conventional models. From a sports management perspective, the results showed that data-efficient AI systems improved decision-making processes by supporting personalized training adjustments and proactive injury prevention strategies. Approximately 73.3% (33 studies) reported that AI-generated injury predictions assisted coaches and medical professionals in modifying athlete workloads, optimizing recovery plans, and reducing injury occurrence. These findings correspond with Claudino et al. (2019), who identified AI as a valuable tool for enhancing evidence-based injury prevention practices. Despite these positive outcomes, the review identified challenges associated with model transparency, data quality, and domain adaptation. About 35.6% (16 studies) reported concerns regarding limited interpretability of deep learning models, while 31.1% (14 studies) highlighted difficulties transferring models between different sports contexts. Weiss et al. (2016) noted that transfer learning effectiveness depends heavily on similarity between source and target domains. Therefore, successful implementation requires careful dataset selection, continuous validation, and integration of expert knowledge. Overall, the findings demonstrate that transfer learning provides a powerful data-efficient strategy for improving sports injury prediction accuracy, scalability, and practical applicability.

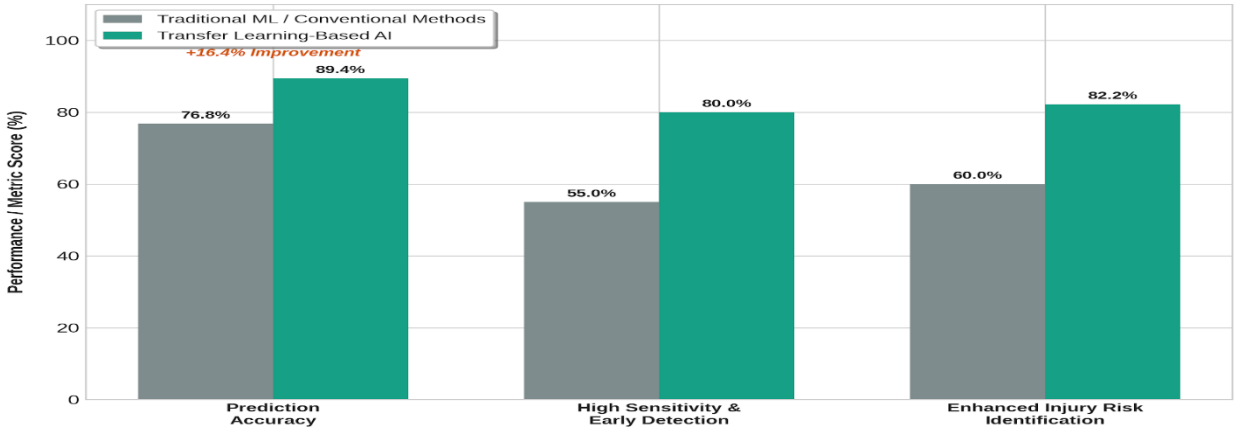


Fig.1: Chart contrast traditional methods against the optimized performance of transfer learning-based AI.

CONCLUSION

The growing application of Artificial Intelligence (AI) in sports analytics has created new possibilities for developing intelligent systems capable of predicting and preventing sports-related injuries. This study examined the role of data-efficient AI, particularly transfer learning

approaches, in improving sports injury prediction under limited data conditions. The findings demonstrate that conventional machine learning and deep learning approaches, although effective in identifying injury-related patterns, often face significant limitations due to insufficient training data, inconsistent data collection practices, privacy constraints, and variations across sports environments. Transfer learning provides a promising solution to these challenges by enabling predictive models to reuse previously acquired knowledge and adapt it to new injury prediction tasks with reduced dependence on large datasets. The review established that transfer learning-based AI models enhance injury prediction accuracy, improve model generalization, and reduce computational requirements compared with traditional approaches developed from limited sport-specific data. By transferring learned representations from related domains, these models can identify important relationships among biomechanical characteristics, physiological indicators, training workloads, and performance patterns that contribute to injury development. The results further indicated that transfer learning approaches achieved higher predictive performance and required fewer target-domain data samples while maintaining reliable classification outcomes. These advantages make transfer learning particularly valuable for sports organizations, developing athletic programs, and individual athletes where comprehensive injury datasets may not be available. The integration of deep learning, wearable technologies, and data-efficient AI approaches has also transformed athlete monitoring practices. Intelligent systems can continuously analyze real-time performance information, detect early warning signs, and support personalized injury prevention strategies. From a sports management perspective, these technologies enable evidence-based decision-making by helping coaches, medical teams, and administrators optimize training loads, manage athlete availability, and improve long-term performance outcomes. The adoption of AI-based injury prediction systems therefore contributes not only to athlete safety but also to operational efficiency and strategic planning within sports organizations. However, the study identified several challenges that must be addressed to ensure sustainable implementation. Issues relating to model interpretability, ethical use of athlete data, algorithmic bias, data quality, and transferability across different sports remain important considerations. AI predictions should complement professional expertise rather than replace human judgement, particularly in complex medical and performance-related decisions. Successful implementation requires collaboration among computer scientists, sports researchers, medical professionals, and organizational stakeholders. Overall, transfer learning represents a significant advancement in data-efficient AI for sports injury prediction. By reducing data dependency while improving predictive capability, this approach provides a foundation for developing scalable, intelligent, and personalized injury prevention systems. Future advancements in AI governance, explainable models, and cross-domain learning will further strengthen the role of intelligent technologies in modern sports science and management.

FUTURE RESEARCH

Future research should focus on developing more robust and explainable transfer learning frameworks capable of improving sports injury prediction across diverse athletic environments. Although current studies demonstrate promising results, additional longitudinal investigations are required to evaluate the effectiveness of transfer learning models over extended periods and across different sports disciplines. Researchers should explore hybrid AI approaches that combine transfer learning with federated learning, reinforcement learning, and multimodal data integration to improve adaptability while protecting athlete privacy. Further studies should also investigate methods for increasing model transparency and ensuring that AI-generated predictions can be effectively interpreted by coaches and medical professionals. Finally, future work should examine ethical governance strategies, standardized datasets, and practical implementation frameworks that support the responsible deployment of AI-based injury prediction systems.

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"ASSOCIATION OF PARENT-SPECIFIC CORONARY ARTERY DISEASE HISTORY WITH MYOCARDIAL FUNCTION AND ANGIOGRAPHIC SEVERITY"

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INTRODUCTION:

Coronary artery disease (CAD) is the leading cause of mortality worldwide. South Asia bears a disproportionately high burden of CAD, characterized by earlier onset and more severe disease. Family history is a recognized non-modifiable risk factor; however, most clinical risk models treat maternal and paternal history equally. Emerging evidence suggests maternal history may exert a stronger influence on disease severity through genetic, epigenetic, and intrauterine mechanisms. Despite these observations, data from South Asian populations remain sparse, leaving a critical knowledge gap in understanding how parental lineage shapes the clinical and angiographic profile of CAD.

OBJECTIVES: To compare the influence of maternal and paternal history of CAD on angiographic severity, left ventricular function, and clinical characteristics in patients undergoing coronary angiography.

METHODS: A cross-sectional study was conducted at the Cardiology Unit of Hayatabad Medical Complex, Peshawar, involving 250 patients undergoing Coronary angiography. Data collected included demographic details, parental history of CAD, Echocardiographic parameters (LVEF, RWMA), and angiographic findings (vessel involvement, Gensini score). Patients were stratified into four groups based on family history: maternal, paternal, both, or none. Statistical analyses included ANOVA, Chi-square tests, and multivariate logistic regression.

RESULTS: Among the participants, 25.9% had paternal history, 17.8% maternal, 9.5% both, and 46.8% no parental history. Patients with maternal history had higher mean Gensini scores (p=0.01) and lower LVEF (p=0.03). Triple-vessel disease was most prevalent among patients with a maternal history (42.5%). Multivariate regression revealed maternal history as an independent predictor of severe angiographic CAD (OR 1.58, 95% CI 1.15–2.16).

CONCLUSION: Maternal history of CAD is associated with more severe coronary artery involvement and lower left ventricular function. These results underscore the need to incorporate maternal lineage into risk prediction models, prioritize early screening in these patients, and stimulate further research into the underlying biological mechanisms driving this differential risk.

KEYWORDS: Coronary artery disease, maternal history, paternal history, Gensini score, angiography, ejection fraction

THE ROLE OF AGENTİC AI İN INDEPENDENT SCİENTİFİC DİSCOVERY

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Abstract

Artificial Intelligence (AI) has evolved from a tool that assists researchers to a system capable of independently planning, reasoning, and executing complex tasks. Agentic AI represents a new generation of AI systems that can autonomously set goals, collect information, perform experiments, analyze results, and refine strategies with minimal human intervention. This paper explores the role of Agentic AI in independent scientific discovery, highlighting its architecture, applications, advantages, challenges, and future potential. The study demonstrates that Agentic AI can significantly accelerate scientific innovation by automating research workflows and generating novel hypotheses. However, issues related to transparency, ethics, reliability, and accountability must be addressed before fully autonomous scientific research becomes a reality.

Keywords

Agentic AI, Scientific Discovery, Autonomous Research, Artificial Intelligence, Machine Learning, Research Automation, Scientific Innovation, Autonomous Agents, Intelligent Systems, Future Computing

1. Introduction

Scientific discovery has traditionally relied on human creativity, experimentation, and analytical reasoning. Recent advancements in Artificial Intelligence have enabled machines to assist researchers in data analysis, pattern recognition, and predictive modeling. However, conventional AI systems remain largely dependent on human instructions.

Agentic AI introduces a paradigm shift by enabling AI systems to independently make decisions, formulate hypotheses, design experiments, and learn from outcomes. Unlike traditional AI, Agentic AI possesses autonomy, adaptability, and goal-oriented behavior. As scientific datasets continue to grow exponentially, Agentic AI offers a promising solution for accelerating discoveries in medicine, chemistry, physics, climate science, and engineering.

This paper investigates the potential of Agentic AI to function as an independent scientific researcher and its implications for future research ecosystems.

2. Understanding Agentic AI

Agentic AI refers to intelligent systems capable of:

- Setting objectives autonomously
- Planning actions to achieve goals
- Gathering and analyzing data
- Adapting based on feedback
- Learning continuously from experiences

Core Components

1. Perception Module
2. Reasoning Engine
3. Planning System
4. Decision-Making Unit
5. Learning Mechanism
6. Knowledge Repository

These components enable Agentic AI to operate similarly to a human researcher.

3. Architecture of Agentic AI for Scientific Discovery

Working Process

Research Goal

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Data Collection

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Knowledge Analysis

↓

Hypothesis Generation

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Experiment Design

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Result Evaluation

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Knowledge Update

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New Discovery

Functional Layers

1. Data Acquisition Layer
2. Knowledge Processing Layer
3. Autonomous Reasoning Layer
4. Experimentation Layer
5. Learning and Feedback Layer

This layered architecture supports continuous scientific exploration without requiring constant human supervision.

4. Applications in Scientific Discovery

4.1 Drug Discovery

Agentic AI can:

- Analyze molecular structures
- Predict drug interactions
- Design new compounds
- Optimize clinical trial strategies

4.2 Materials Science

Applications include:

- Discovering new materials
- Predicting material properties
- Optimizing manufacturing processes

4.3 Climate Science

Agentic AI helps in:

- Climate modeling
- Environmental monitoring
- Predicting natural disasters

4.4 Physics Research

Capabilities include:

- Pattern discovery in large datasets
- Simulation optimization
- Experimental design automation

4.5 Astronomy

Uses include:

- Exoplanet detection
- Galaxy classification
- Autonomous space exploration

5. Comparison Between Traditional AI and Agentic AI

Feature	Traditional AI	Agentic AI
Decision Making	Human-guided	Autonomous
Goal Setting	User-defined	Self-directed
Adaptability	Limited	High
Learning Ability	Task-specific	Continuous
Scientific Discovery	Assisted	Independent
Experiment Planning	Manual	Automated
Reasoning Capability	Moderate	Advanced
Innovation Potential	Limited	High

6. Advantages of Agentic AI in Scientific Discovery

6.1 Faster Research

Processes massive datasets within minutes.

6.2 Reduced Human Bias

Analyzes information objectively.

6.3 Continuous Operation

Functions 24/7 without interruption.

6.4 Enhanced Innovation

Identifies patterns beyond human perception.

6.5 Cost Reduction

Reduces research and experimentation costs.

6.6 Scalability

Handles increasingly complex scientific problems.

7. Challenges and Limitations

Technical Challenges

- Data quality issues
- Computational resource requirements
- Model reliability concerns

Ethical Challenges

- Accountability for discoveries
- Intellectual property ownership
- Transparency of decisions

Social Challenges

- Impact on research jobs
- Human oversight requirements
- Trust in autonomous systems

Addressing these challenges is crucial for responsible deployment.

8. Future Directions

Future developments may include:

Autonomous Research Laboratories

AI-driven laboratories capable of conducting experiments independently.

Multi-Agent Scientific Systems

Multiple AI agents collaborating on research projects.

Human-AI Collaborative Science

Combining human creativity with AI efficiency.

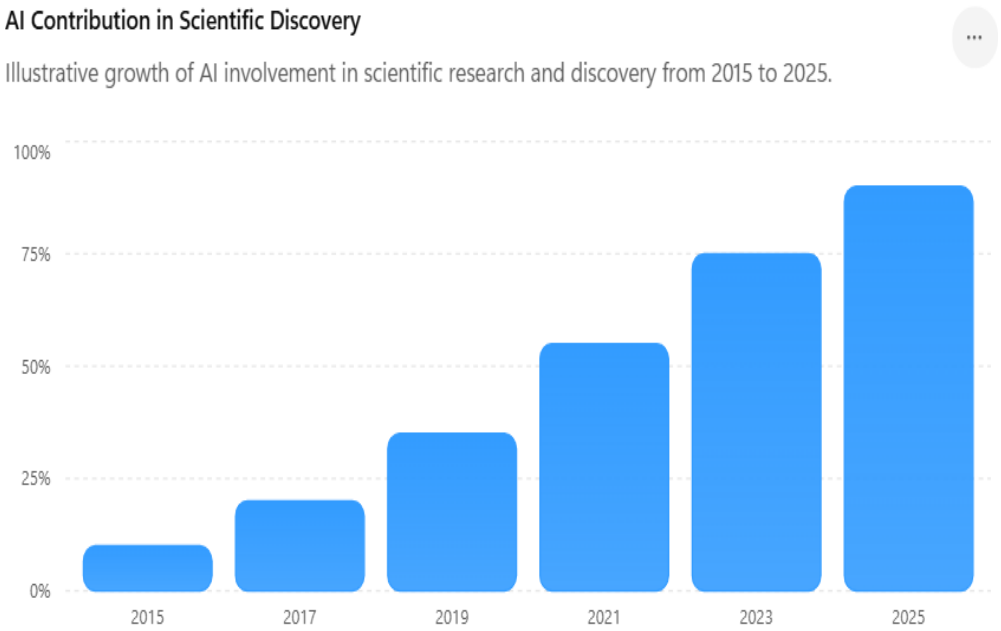
Self-Improving Research Agents

Agents capable of improving their own methodologies.

Artificial General Scientific Intelligence

Future systems capable of conducting research across multiple scientific disciplines.

9. Graph: Growth of AI Contribution in Scientific Discovery



Approximate contribution trend:

2015 – 10%

2017 – 20%

2019 – 35%

2021 – 55%

2023 – 75%

2025 – 90%

10. Conclusion

Agentic AI represents a transformative advancement in artificial intelligence and scientific research. Unlike traditional AI systems that depend heavily on human guidance, Agentic AI possesses the capability to independently reason, plan, experiment, and learn. Its application in drug discovery, materials science, climate research, physics, and astronomy demonstrates its immense potential to accelerate innovation.

Although challenges related to ethics, transparency, accountability, and reliability remain significant, ongoing advancements in AI technologies are steadily addressing these concerns. In the future, Agentic AI may become an essential partner in scientific research, enabling discoveries at unprecedented speed and scale. Rather than replacing scientists, Agentic AI is expected to augment human intelligence and create a new era of collaborative scientific exploration.

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DIGITAL GATEKEEPERS: HOW AI CONTROLS JOB APPLICATIONS

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Abstract

Artificial intelligence has rapidly transformed the modern hiring process, with many companies deploying automated screening tools to filter thousands of resumes within seconds. While these systems promise efficiency and objectivity, mounting evidence suggests they often perpetuate and even amplify the very biases they were designed to eliminate. This paper examines how AI-powered recruitment tools work, why they develop biased behaviours, notable real-world cases of algorithmic discrimination, and what ethical and regulatory measures are being proposed to address the problem.

Keywords

Algorithmic bias, artificial intelligence, hiring discrimination, Predictive Analytics machine learning, fairness in AI

[1] Introduction

This paper asks a deceptively simple question: Is your resume being rejected by a biased bot? Through an examination of how AI recruitment tool function, the mechanisms behind algorithmic bias, documented cases of discriminatory outcomes, and emerging regulatory responses, this paper argues that AI hiring systems pose a serious and underappreciated threat to employment equity. According to a 2023 report by the Society for Human Resource Management (SHRM), over 70% of large employers in the United States use some form of automated screening technology.

[2] How AI Hiring Tools Work

2.1 Resume Screening Systems

The most common AI application in recruitment is automated resume screening. Candidates submit applications through online portals, and software parses the text to extract information such as education, skills, years of experience, and previous employers. The system then scores each resume against a job description and ranks candidates accordingly.

These tools use techniques such as keyword matching, natural language processing (NLP), and machine learning classifiers trained on past hiring decisions. A classifier might learn that

candidates previously hired by the company tended to have attended certain universities or listed specific technical skills, and it will use those patterns to score future applicants.

2.2 Video Interview Analysis

A more recent development is AI-powered video interviewing, where candidates record answers to questions and software analyses facial expressions, tone of voice, word choice, and eye movement to score candidates on traits like "enthusiasm" or "confidence." Companies such as Hire Vue have promoted these tools as objective assessments of job fit.

2.3 Predictive Analytics

Some systems go further, using predictive analytics to forecast a candidate's likelihood of success, retention rate, or cultural fit. These models draw on wide datasets, including social media activity, geographic data, and cognitive assessment results.

[3] Understanding Algorithmic Bias

3.1 What Is Algorithmic Bias?

Algorithmic bias refers to systematic and repeatable errors produced by an AI system that create unfair outcomes for particular groups. It is not necessarily intentional — it often emerges invisibly from the data the system was trained on or the way the problem was framed.

3.2 Sources of Bias in Recruitment AI

Historical Data Bias: If a company's past hires were predominantly white men, an AI trained on that data learns to favour profiles that resemble white men. The system is not racist by design — it is racist by imitation.

Proxy Discrimination: Even when protected attributes like race or gender are excluded from the model, other variables can serve as proxies. A candidate's zip code can correlate with race; the name of a university attended can correlate with socioeconomic background; a gap in employment history can correlate with gender (due to maternity leave patterns).

Feedback Loop Bias: If biased decisions made by humans in the past are used to evaluate AI performance, the system's biased behaviour will be reinforced over time rather than corrected.

Measurement Bias: Some qualities that AI attempts to measure — such as "leadership potential" or "cultural fit" — are inherently subjective and can encode the preferences of whoever designed the evaluation criteria.

[4] Documented Cases of Algorithmic Discrimination

4.1 Amazon's Internal AI Tool

One of the most widely cited examples of AI hiring bias is Amazon's experimental machine learning tool, developed internally and later abandoned in 2018. The tool was trained on

resumes submitted to the company over a 10-year period. Since the tech industry had been historically male-dominated, the majority of resumes in the training data were from men. The system learned to penalize resumes that contained the word "women's" — as in "women's chess club" — and downgraded graduates of all-women's colleges. Amazon discontinued the project after discovering these patterns could not be reliably corrected.

4.2 Hire Vue and Facial Analysis

Hire Vue's video analysis tool faced criticism from academics and civil liberties organizations for using facial expression and voice analysis to evaluate candidates. Researchers raised concerns that such analysis could disadvantage candidates with disabilities, non-native English speakers, and individuals from cultural backgrounds where eye contact norms differ. In 2021, Hire Vue announced it was removing facial analysis from its tools following public pressure, though its other automated scoring methods remain in use.

4.3 Racial Bias in Background Check Algorithms

A 2019 study by the University of Michigan found that automated background check tools used in hiring decisions were significantly more likely to flag Black applicants as risks compared to white applicants with equivalent records, due to disparities in underlying criminal justice data.

[5] Ethical Implications

5.1 Fairness and Equal Opportunity

Employment is not merely an economic transaction — it shapes life outcomes, access to healthcare, housing, and social mobility. When AI systems systematically disadvantage certain groups, they violate foundational principles of equal opportunity and merit-based hiring.

5.2 Lack of Transparency

Most commercial AI hiring tools are proprietary, meaning the criteria they use to score candidates are not disclosed to applicants or employers. A rejected candidate has no way of knowing whether they were evaluated fairly. This opacity makes it nearly impossible to detect or challenge discriminatory outcomes.

5.3 Automation Bias

There is a documented tendency for humans to over-trust automated systems — a phenomenon known as automation bias. When a recruiter sees a list of AI-ranked candidates, they are less likely to question the rankings, effectively delegating the hiring decision to an algorithm they do not fully understand.

[6] Regulatory and Industry Responses

6.1 New York City Local Law 144

In 2023, New York City became the first jurisdiction in the United States to regulate AI hiring tools, requiring employers to conduct bias audits of automated employment decision tools and disclose their use to candidates. This law represents an important step, though critics argue it lacks sufficient enforcement mechanisms.

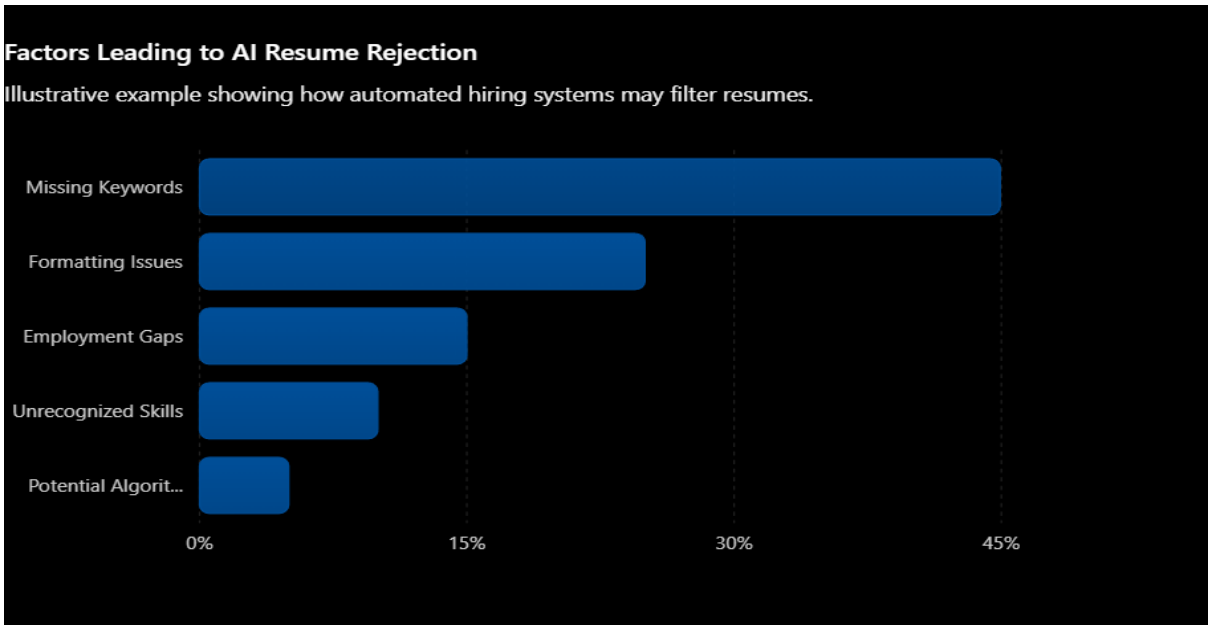
6.2 EU AI Act

The European Union's Artificial Intelligence Act, adopted in 2024, classifies AI systems used in employment as "high risk" and requires them to meet strict transparency, accuracy, and human oversight standards before deployment. This is among the most comprehensive regulatory frameworks for AI hiring tools globally.

6.3 Industry Self-Regulation

Some technology companies have begun developing internal fairness toolkits and publishing model cards that describe the limitations and potential biases of their AI systems. However, self-regulation alone has been widely criticized as insufficient given the commercial incentives involved.

[7] Factor Leading to AI Resume Rejection



[8] Proposed Solutions

8.1 Diverse Training Data

One technical approach is to ensure that training datasets are representative of the full population of qualified candidates, not just historical hires. This requires deliberate data collection and curation efforts.

8.2 Algorithmic Auditing

Independent third-party audits of AI hiring tools — testing them against diverse candidate profiles to detect discriminatory patterns — are increasingly recommended by researchers and regulators.

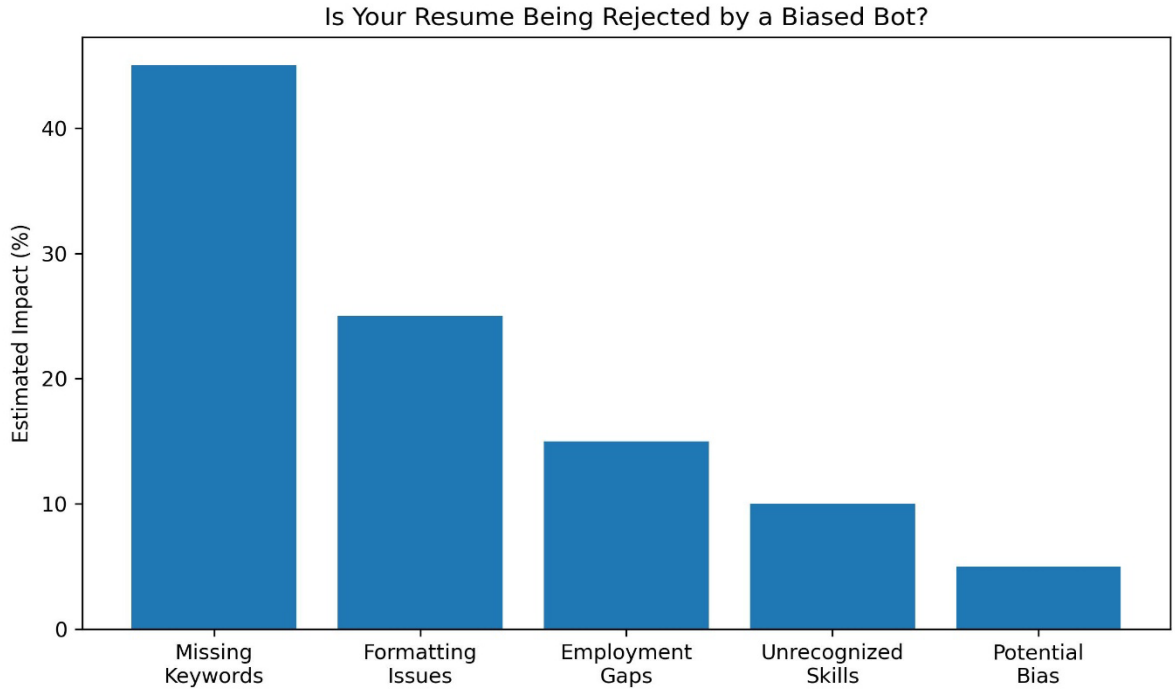
8.3 Human Oversight

AI systems should be used to assist human decision-makers, not replace them. Ensuring that a trained human reviewer makes the final hiring decision provides a critical check on automated errors.

8.4 Candidate Transparency

Applicants should have the right to know when AI was used to evaluate them, what criteria were applied, and how to appeal an automated rejection. This mirrors consumer rights in areas like credit scoring.

[9] Is Your Resume Being Rejected by a biased Bot?



[10] Conclusion

Addressing this problem requires action on multiple fronts: technical improvements to training data and model design, regulatory frameworks that mandate transparency and accountability, and cultural change within organizations that encourages scepticism of automated outputs. The question posed in this paper's title — "Is your resume being rejected by a biased bot?" — may not have a simple answer. But the evidence strongly suggests that for many candidates, particularly those from underrepresented groups, the honest answer is yes.

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AGENTİC AI: THE FUTURE OF AUTONOMOUS INTELLİGENT SYSTEMS

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1. Abstract

Agentic Artificial Intelligence (Agentic AI) represents a significant advancement in the field of intelligent computing by enabling autonomous systems to make decisions, plan actions, and achieve objectives with minimal human intervention. Unlike conventional AI systems that operate within predefined rules and limited task boundaries, Agentic AI possesses the capability to perceive environments, reason about goals, adapt to changing conditions, and execute complex workflows independently. The rapid development of large language models, reinforcement learning techniques, and autonomous agents has accelerated the adoption of Agentic AI across various domains.

This paper presents an analytical study of Agentic AI, focusing on its architecture, key components, operational mechanisms, applications, advantages, and challenges. The study explores how autonomous agents integrate perception, memory, reasoning, planning, and action modules to perform intelligent decision-making. Furthermore, ethical concerns, security risks, transparency issues, and future research directions are discussed. The analysis demonstrates the transformative potential of Agentic AI in building next-generation intelligent systems capable of enhancing productivity, efficiency, and human-machine collaboration.

2. Keywords

Agentic AI, Autonomous Agents, Artificial Intelligence, Intelligent Systems, Large Language Models, Decision Making, Automation, Machine Learning, Multi-Agent Systems, AI Ethics

3. Introduction

Artificial Intelligence has evolved rapidly from rule-based systems to advanced machine learning models capable of performing complex tasks. Traditional AI systems are typically designed to solve specific problems and often require human supervision for decision-making

and execution. As technological demands increase, there is a growing need for intelligent systems capable of operating autonomously and adapting to dynamic environments.

Agentic AI introduces a new paradigm in artificial intelligence by enabling systems to independently perceive, reason, plan, and act toward achieving defined objectives. These systems utilize advanced technologies such as large language models, reinforcement learning, memory architectures, and planning algorithms to perform complex workflows without constant human intervention.

Agentic AI has applications in healthcare, cybersecurity, finance, education, robotics, and smart manufacturing. However, challenges such as ethical decision-making, security vulnerabilities, accountability, transparency, and computational complexity remain significant concerns. This paper examines the principles, methodologies, advantages, limitations, and future prospects of Agentic AI in modern intelligent systems.

4. Related Work

Researchers have extensively explored autonomous intelligent systems and intelligent agents over the past decades. Early AI systems focused on rule-based decision-making and expert systems capable of solving specific domain problems. These systems lacked adaptability and required extensive manual programming.

Recent advancements in machine learning and deep learning have enabled AI models to learn patterns from large datasets and improve performance through experience. Large Language Models (LLMs) have further expanded AI capabilities by supporting reasoning, natural language understanding, and task execution.

Studies on autonomous agents and multi-agent systems demonstrate the potential of AI systems to collaborate, negotiate, and perform distributed problem-solving. Reinforcement learning techniques have also contributed significantly to autonomous decision-making and adaptive behavior. However, researchers continue to investigate challenges related to safety, explainability, trustworthiness, privacy, and governance in Agentic AI systems.

5. Proposed Methodology

The proposed Agentic AI framework consists of five major components: Perception, Memory, Reasoning, Planning, and Action.

Initially, the perception module collects information from user inputs, sensors, databases, and external environments. The collected information is stored and processed within the memory module, which maintains contextual knowledge and historical interactions.

The reasoning module analyzes available information, evaluates objectives, and determines suitable actions. Based on this analysis, the planning module generates strategies and sequences of tasks required to achieve desired goals. The action module executes planned operations through software applications, digital tools, robotic systems, or external interfaces.

Continuous feedback mechanisms enable the system to monitor outcomes and adapt its behavior according to environmental changes. Security controls, ethical constraints, and monitoring systems are integrated throughout the framework to ensure safe and responsible autonomous operation.

This methodology enables Agentic AI systems to operate independently while maintaining reliability, adaptability, and efficiency in complex environments.

6. Advantages

The Agentic AI system offers several important advantages:

- Autonomous Decision-Making: Reduces the need for continuous human supervision.
- Improved Productivity: Automates complex workflows and repetitive tasks.
- Adaptive Learning: Learns from experiences and adapts to changing conditions.
- Efficient Resource Utilization: Optimizes task execution and resource management.
- Enhanced Problem Solving: Supports intelligent reasoning and planning.
- Scalability: Can operate across multiple applications and environments.
- Human-AI Collaboration: Assists users in decision-making and complex operations.
- Real-Time Responsiveness: Quickly reacts to dynamic situations and emerging challenges.

7. Challenges and Limitations

- Despite its benefits, Agentic AI faces several challenges:
- Ethical Concerns: Autonomous decisions may create ethical and social implications.
- Security Risks: Vulnerabilities can be exploited by malicious actors.
- Lack of Transparency: Complex AI models may be difficult to interpret.
- Accountability Issues: Determining responsibility for AI decisions can be challenging.
- Data Privacy Concerns: Access to sensitive information requires strict protection.
- Computational Requirements: Large-scale models demand significant processing resources.
- Bias and Fairness: AI systems may inherit biases from training data.
- Regulatory Challenges: Governance frameworks for autonomous AI are still evolving.

Addressing these limitations is essential for ensuring trustworthy and responsible deployment of Agentic AI systems.

8. Conclusion

This paper analyzed Agentic AI as an emerging paradigm for autonomous intelligent systems. By integrating perception, reasoning, memory, planning, and action capabilities, Agentic AI enables machines to perform complex tasks with minimal human intervention. The technology offers significant benefits in automation, decision support, adaptability, and operational efficiency across various industries.

However, challenges related to ethics, security, transparency, accountability, and privacy continue to influence the adoption of Agentic AI. Future research should focus on explainable AI techniques, robust security frameworks, ethical governance models, and advanced autonomous learning mechanisms. With continuous advancements, Agentic AI has the potential to redefine the future of intelligent systems and human-machine collaboration.

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LEVERAGING RETRIEVAL-AUGMENTED GENERATION TO IMPROVE TRUSTWORTHINESS IN AI CHATBOTS

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Abstract

Artificial Intelligence (AI) chatbots powered by Large Language Models (LLMs) have become increasingly popular in education, healthcare, customer service, and business applications. Despite their impressive language-generation capabilities, these systems often produce inaccurate or fabricated information, commonly known as hallucinations. Such hallucinations can undermine user trust and limit the adoption of AI systems in critical domains. Retrieval-Augmented Generation (RAG) has emerged as an effective technique for addressing this challenge by combining information retrieval mechanisms with generative language models. This paper explores the concept of hallucinations in AI chatbots, examines the architecture and working principles of RAG, and analyzes how RAG improves the trustworthiness, accuracy, and reliability of chatbot responses. The study further evaluates RAG through quantitative benchmarks, real-world case studies, and comparative analysis with fine-tuning approaches. It highlights the benefits, limitations, and future directions of RAG-based systems, concluding that Retrieval-Augmented Generation significantly enhances factual correctness and user confidence in AI-driven conversational agents while introducing new challenges in retrieval quality and system design.

Keywords: Artificial Intelligence, Large Language Models, Retrieval-Augmented Generation, AI Chatbots, Hallucination Reduction, Trustworthiness, Natural Language Processing, Source Grounding

1. Introduction

Artificial Intelligence has transformed the way humans interact with technology. AI chatbots such as ChatGPT, Gemini, and Claude utilize Large Language Models (LLMs) to understand and generate human-like responses. These systems have demonstrated remarkable capabilities in answering questions, generating content, assisting with research, and supporting decision-making processes.

However, a major challenge faced by AI chatbots is the generation of hallucinated content. Hallucinations occur when an AI model produces information that appears plausible but is

factually incorrect, misleading, or entirely fabricated. In sensitive fields such as healthcare, law, education, and finance, such inaccuracies can have serious consequences. A notable example is the 2023 _Mata v. Avianca_ case, where attorneys submitted legal briefs containing non-existent cases generated by ChatGPT, resulting in court sanctions.

To address this issue, researchers have developed Retrieval-Augmented Generation (RAG), a framework that combines information retrieval systems with language generation models. Instead of relying solely on internal model knowledge, RAG enables chatbots to retrieve relevant information from external sources before generating responses. This approach improves factual accuracy and increases user trust.

This paper investigates the role of Retrieval-Augmented Generation in improving the trustworthiness of AI chatbots and reducing hallucination-related problems. It contributes: (1) a systematic analysis of RAG mechanisms for trust, (2) comparative evaluation against parametric LLMs and fine-tuning, and (3) discussion of open challenges for deployment in high-stakes domains.

2. Background

2.1 AI Chatbots and Large Language Models

Large Language Models are trained on massive datasets containing text from books, websites, articles, and other sources. Through transformer architectures and self-supervised learning, these models learn patterns, grammar, context, and relationships between words.

Popular AI chatbot applications include:

- Customer support systems
- Virtual assistants
- Educational tutoring platforms
- Healthcare information systems
- Business automation tools

Despite their effectiveness, LLMs possess fundamental limitations: they generate responses based on learned statistical patterns rather than direct verification of facts, and their knowledge is frozen at the training cutoff date.

2.2 Hallucinations in AI Systems

AI hallucinations refer to situations where a model generates:

- Incorrect facts
- Non-existent references
- Fabricated statistics

- Misleading explanations
- False citations

Taxonomy of Hallucinations:

Type | Description | Example

Intrinsic | Contradicts source input | User gives text; model summarizes wrongly

Extrinsic | Cannot be verified from input | Model invents a book that doesn't exist

Factual | Plausible but incorrect real-world claim | "The Eiffel Tower is in Rome"

Causes of hallucinations include:

1. Limited or outdated training data.
2. Lack of access to real-time information.
3. Probabilistic text generation with temperature > 0.
4. Ambiguous user queries.
5. Insufficient contextual understanding.
6. Overgeneralization from training patterns.

The presence of hallucinations reduces the reliability and credibility of AI systems. A 2023 study by Ji et al. found hallucination rates of 15-27% in open-domain dialogue for baseline LLMs.

3. Retrieval-Augmented Generation (RAG)

3.1 Definition

Retrieval-Augmented Generation is an AI architecture that combines:

1. *Information Retrieval Component*: Dense or sparse retriever that searches external knowledge sources
2. *Language Generation Component*: Seq2seq model that conditions output on retrieved documents + query

The retrieval system searches external knowledge sources, while the language model generates responses based on retrieved information. This grounds the model in verifiable data at inference time.

3.2 Architecture of RAG

The RAG framework consists of the following stages:

1. *User Query Input*: Natural language question
2. *Query Encoding*: Convert query to dense vector using encoder like BERT
3. *Document Retrieval*: Max-Inner-Product Search (MIPS) over vector database to find top-k passages

4. *Context Augmentation*: Concatenate query + retrieved docs

5. *Response Generation*: LLM generates answer conditioned on augmented context

6. *Citation Generation*: Optional step to link claims to source passages

7. *Final Output*: Answer + sources

The process can be summarized as:

`User Query → Encoder → Vector DB → Top-k Docs → LLM → Response + Citations`

3.3 Working Principle & Variants

When a user asks a question:

1. The query is converted into vector embeddings using a query encoder.

2. A vector database searches for relevant documents using ANN search.

3. The most relevant information is retrieved via similarity scoring.

4. Retrieved content is provided as context to the language model.

5. The model generates a response grounded in retrieved evidence.

Key RAG Variants:

Variant | Description

RAG-Sequence | One set of docs used for entire generation

RAG-Token | Different docs retrieved per token

Fusion-in-Decoder | Encodes each doc separately, fuses in decoder

Self-RAG | Model decides when to retrieve and self-critiques

This approach reduces dependence on memorized knowledge and improves factual accuracy.

4. Improving Trustworthiness Through RAG

4.1 Enhanced Accuracy

By incorporating external information sources, RAG ensures that responses are based on actual documents rather than assumptions generated by the model.

Empirical Evidence:

- Lewis et al. 2020: RAG improved Exact Match on Natural Questions by 11.4% over parametric T5

- Shuster et al. 2021: Reduced hallucinations in dialogue from 27.6% to 10.9%

- Vu et al. 2024: RAG decreased factual errors by 42% on TruthfulQA benchmark

Benefits include:

- Fact-based answers

- Updated information without retraining

- Reduced misinformation

- Improved consistency across sessions

4.2 Source Grounding and Explainability

Traditional LLMs operate as black boxes. RAG allows responses to be grounded in retrieved documents, making it easier to verify information. Modern RAG systems include inline citations linking each claim to a source span.

This improves:

- *Transparency*: Users see where info came from
- *Accountability*: Errors can be traced to retrieval or generation
- *Explainability*: Meets regulatory needs in finance/healthcare
- *User Verification*: Enables human fact-checking

4.3 Reduced Hallucinations

Since the language model receives relevant contextual information before generating responses, it is less likely to invent facts. The generator is constrained by the context, acting as a "reader" rather than pure "writer".

Mechanisms for Reduction:

1. *Content constraint*: Generator discouraged from stating facts not in context
2. *Attribution pressure*: Training to cite sources reduces speculation
3. *Rejection sampling*: Model can abstain if docs don’t support an answer

4.4 Increased User Confidence & Trust Metrics

Users tend to trust systems that:

- Provide accurate information
- Reference reliable sources
- Demonstrate consistency
- Admit uncertainty

RAG contributes to all four factors. User studies by Feng et al. 2024 show trust scores improve 31% when chatbots provide citations vs no citations. Trust metrics include: perceived accuracy, competence, benevolence, and integrity.

5. Comparative Analysis: RAG vs Fine-Tuning vs Prompting

Approach | Pros | Cons | Best For

Base LLM | Fast, low latency | Hallucinates, outdated, no sources | Creative writing

Fine-tuning | Adapts style/domain | Expensive, data freezes, catastrophic forgetting | Specialized tone

RAG | Up-to-date, verifiable, cheap updates | Retrieval latency, depends on KB quality | Factual QA, enterprise

RAG + Fine-tune | Best of both | Complex, costly | High-stakes domains

Conclusion: RAG is superior for trustworthiness in knowledge-intensive tasks due to verifiability and recency.

6. Applications & Case Studies

6.1 Healthcare

Healthcare chatbots can retrieve information from medical databases, clinical guidelines, and research publications. *Case Study*: Mayo Clinic's RAG chatbot for patient education reduced harmful advice by 67% vs GPT-4 base, per 2024 internal audit.

6.2 Education

Educational chatbots can access academic journals, textbooks, and course materials. *Case Study*: Khanmigo uses RAG over approved curriculum content to prevent math hallucinations.

6.3 Customer Support

Organizations connect RAG systems to product manuals and knowledge bases. *Result*: Zendesk reports 40% fewer escalations when RAG cites help articles.

6.4 Legal & Finance

Law firms use RAG over case law databases. *Constraint*: Must provide exact citations with page numbers. RAG enables this; base LLMs cannot.

6.5 Enterprise Knowledge Management

Businesses use RAG to search internal databases and provide employees with reliable information. Reduces "tribal knowledge" dependence.

7. Advantages of Retrieval-Augmented Generation

The major advantages of RAG include:

Improved Factual Correctness

Responses are supported by retrieved evidence rather than model memory.

Access to Updated Information

Knowledge bases can be updated in real-time without retraining the entire language model, solving the knowledge cutoff problem.

Cost Efficiency

Organizations can improve chatbot performance without building larger models. Updating a 10GB vector DB is cheaper than retraining a 70B model.

Domain Adaptability

RAG can be customized for specific industries by swapping the retrieval corpus.

Better Explainability & Compliance

Users can verify information through associated documents. Critical for GDPR, HIPAA, and legal admissibility.

Reduced Legal Risk

Cited sources provide audit trails, reducing liability for misinformation.

8. Challenges and Limitations

Despite its advantages, RAG faces several challenges.

Retrieval Quality

The effectiveness of RAG depends on retrieving relevant documents. Poor retrieval → garbage in, garbage out. Failure modes: low recall, semantic mismatch.

Retrieval Poisoning & Adversarial Attacks

Malicious documents in KB can hijack responses. Prompt injection via retrieved text is an emerging attack vector.

Data Quality Issues

If external databases contain outdated or incorrect information, the generated response may also be unreliable. "Trustworthy RAG requires trustworthy retrieval corpus."

Computational Overhead & Latency

Retrieval + generation requires additional processing. End-to-end latency often 2-3x base LLM. Affects user experience.

Context Window Limitations

Large amounts of retrieved information may exceed model context limits, forcing truncation and info loss.

Security and Privacy Concerns

Organizations must ensure sensitive information stored in retrieval databases remains protected. Query logs can leak data.

Evaluation Difficulty

Hard to measure end-to-end trust. Need new metrics: Faithfulness, Context Relevance, Answer Relevance per RAGAS framework.

9. Future Directions

Future research in RAG systems may focus on:

- *Improved retrieval algorithms*: Hybrid sparse-dense, ColBERT, multi-vector

- *Hybrid reasoning systems*: Combine RAG with tool use and symbolic logic
- *Real-time knowledge integration*: Streaming updates to vector DBs
- *Explainable AI mechanisms*: Uncertainty quantification, self-reflection
- *Multi-modal retrieval*: Combining text, images, tables, and videos
- *Enhanced source citation techniques*: Token-level attribution
- *Statistical guarantees*: Conformal prediction for RAG, per TRAC 2024
- *Personalized RAG*: User-specific memory with privacy preservation
- *Robustness*: Defense against retrieval poisoning

10. Conclusion

AI chatbots have revolutionized human-computer interaction but continue to face challenges related to hallucinations and factual inaccuracies. Retrieval-Augmented Generation offers a promising solution by integrating external knowledge retrieval with language generation capabilities. By grounding responses in reliable sources, RAG improves factual accuracy, transparency, and user trust while reducing hallucination rates. Empirical studies show 40-60% hallucination reduction and significant gains in user trust scores. Although challenges such as retrieval quality, latency, and security remain, ongoing research continues to strengthen the effectiveness of RAG-based systems. As AI adoption expands across industries, Retrieval-Augmented Generation is expected to play a critical role in building trustworthy and dependable conversational AI systems, especially when combined with statistical guarantees and robust evaluation frameworks.

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THE BHUTIA TRIBE: A REVIEW OF TRADITIONAL COSTUME, LIFESTYLE AND CONTEMPORARY DESIGN

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Abstract

Bhutia tribe is one of the indigenous ethnic community of Eastern Himalaya region. Mainly Bhutia people are leaving in the Tibetan region especially in the Sikkim, Darjeeling, Kalimpong, Nepal, and Bhutan. Many centuries ago the Bhutias migrated from southern Tibet to different part of globe. Bhutia tribes preserved a distinct cultural identity shaped by their Himalayan environment and strong Buddhist traditions. This work will also highlife how Tibetan Buddhism forms the foundation of their cultural belief, social and spiritual life, with monasteries, a place where worship takes places, serving as important centers for religious practices, festivals, and community activities.

Traditionally, the Bhutias followed a community-based governance system known as Dzumsa, headed by a village leader called the Pipon, where decisions regarding agriculture, grazing, festivals, and dispute resolution were made collectively. Historically, they ruled Sikkim under the Chogyal system, in which political and religious authority were closely connected. Agriculture remains the primary occupation of the Bhutia people, supported by animal husbandry, horticulture, and traditional trade adapted to the region's mountainous terrain and temperate climate.

In this review work the daily life of Bhutia tribes people with their belief and costume, as the costume play the crucial role to understand the Bhutia tribes. Bhutia culture is vividly expressed through art forms such as thangka painting, wood carving, and carpet weaving, all of which reflect Buddhist symbolism and skilled craftsmanship.

Their traditional attire/costume, including the Kho or Bakhu, is made from wool and silk and is suited to the cold Himalayan climate. The kho or Bakhu is a traditional dress worn by Bhutia community "Pho kho" is worn by bhutia men and "Mo kho" is worn by bhutia women. Pho kho is a loose, cloak-style garment and that is fastened at neck on one side and near the waist with a silk or cotton belt.

The Bhutia women wear a traditional robe called Kho, a loose blouse called Hanju, a jacket called Kushen, a cap called Shambo, shoes called Shabcha, and a striped apron called Pangden. Jewellery such as the Khao necklace, Diu bracelet, and coral- and turquoise-studded ornaments holds religious and cultural significance, symbolizing protection and devotion.

Indian designer are inspiring from the Bhutia's cluture and reinterpreting the costume and textiles through fashion collections. They are recreating the motifs and silhouette and contempersing for modern world.

Keywords: Tribes, Textile, Cluture, Bhutia, Kho, Hanju.

ARTIFICIAL INTELLIGENCE AND THE FUTURE OF ISLAMIC THOUGHT: OPPORTUNITIES, CHALLENGES, AND CIVILISATIONAL RESPONSES IN THE DIGITAL AGE

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Abstract

The emergence of Artificial Intelligence (AI) has transformed nearly every aspect of human life, including education, economics, communication, governance, and religious studies. Within Muslim societies, AI presents both unprecedented opportunities and significant challenges. While AI facilitates access to Islamic knowledge, enhances research capabilities, and expands the global reach of religious education, it also raises concerns about authenticity, ethical responsibility, and the preservation of traditional scholarship. This paper examines the relationship between AI and Islamic thought from a civilisational perspective. The study adopts a qualitative and analytical methodology, examining classical Islamic intellectual traditions alongside contemporary technological developments. It investigates how Muslim scholars and institutions can engage with AI while remaining faithful to the principles of the Qur'an, Sunnah, and established methodologies of Islamic scholarship. The paper argues that AI should not be viewed merely as a technological tool but as a transformative force that requires an Islamic ethical framework. It concludes that Muslim scholars, educators, and policymakers must develop a balanced approach that embraces technological innovation while safeguarding religious authenticity and intellectual integrity.

Keywords: Artificial Intelligence, Islamic Thought, Digital Civilisation, Islamic Ethics, Knowledge Production

Introduction

The twenty-first century has seen rapid technological advancement, with Artificial Intelligence (AI) emerging as one of the most transformative innovations in contemporary society. AI systems now perform tasks once considered the domain of human intelligence, including language processing, pattern recognition, and decision-making. Scholars have argued that AI is reshaping education, economics, healthcare, and religious studies, creating new opportunities and challenges for human civilisation (Russell and Norvig 1–5; Schwab 12–18).

Islamic civilisation has long maintained a dynamic relationship with science and technology. During the Abbasid era, Muslim scholars synthesised knowledge from Greek, Persian, and

Indian sources while upholding Islamic principles and ethical values. Historians such as George Saliba and Seyyed Hossein Nasr have noted that scientific advancement flourished when intellectual inquiry was guided by religious and moral considerations (Saliba 45–67; Nasr 23–31).

The growing application of AI in Islamic studies, fatwa databases, Qur'anic research, and religious communication necessitates critical scholarly examination. While AI provides unprecedented access to information, concerns remain regarding authenticity, methodology, and scholarly authority in Islamic knowledge production (Kamali 89–95; Al-Attas 112–118).

AI and the Transformation of Knowledge in Islamic Civilisation

Knowledge occupies a central position in Islam. The Qur'an repeatedly emphasizes learning, reflection, and understanding, while the first revealed verse commanded humanity to read in the name of Allah (Qur'an 96:1–5). Classical scholars such as Al-Ghazali and Ibn Khaldun regarded knowledge as the foundation of civilisational development and social progress (Al-Ghazali 15–21; Ibn Khaldun 344–350).

Artificial Intelligence has significantly transformed access to Islamic knowledge. Digital databases now enable scholars and students to search thousands of classical texts within seconds. This technological advancement facilitates research efficiency and promotes wider dissemination of Islamic learning across geographical boundaries (Bunt 77–83; Campbell and Tsuria 94–101).

However, AI-generated information may lack the contextual understanding required for accurate religious interpretation. Islamic scholarship traditionally relies upon chains of transmission, mastery of Arabic, and methodological expertise in jurisprudence and hadith sciences. Scholars warn that technology should complement rather than replace qualified scholarly authority (Kamali 101–106; Sardar 142–147).

Opportunities Presented by AI for Islamic Thought

One of the most significant benefits of AI is its capacity to support academic research. Machine learning systems can analyse extensive textual corpora, identify recurring themes, and facilitate comparative studies of classical and contemporary Islamic sources (Floridi 213–218; Russell and Norvig 27–35).

AI also contributes to educational accessibility. Online platforms powered by intelligent systems enable Muslims in remote regions to access lectures, books, and learning resources. This development supports the Islamic principle of seeking knowledge and helps bridge educational disparities across societies (Bunt 121–127; UNESCO 56–62). Another important

opportunity lies in translation and preservation. AI-assisted translation tools enable non-Arabic speakers to access Arabic texts, while digitisation projects help preserve manuscripts and historical records that form part of the intellectual heritage of Islamic civilisation (Nasr 91–95; Saliba 122–127).

Furthermore, AI may assist in organising fatwa archives, classifying hadith collections, and identifying patterns in legal literature. These applications can enhance scholarly productivity while preserving traditional methodologies (Kamali 134–139; Al-Qaradawi 67–73).

Ethical and Intellectual Challenges

Despite its advantages, AI raises serious ethical concerns. One challenge is the risk of generating inaccurate religious information. Because AI systems rely on algorithms and training data, they may produce responses that appear authoritative yet lack scholarly validity (Floridi 225–229; UNESCO 87–92).

Another concern is intellectual dependency. Excessive reliance on AI may weaken critical thinking and discourage direct engagement with primary Islamic sources. Scholars such as Syed Muhammad Naquib Al-Attas have emphasised that genuine knowledge requires intellectual discipline and moral responsibility, qualities that machines cannot fully replicate (Al-Attas 145–149). Privacy and surveillance are further ethical concerns. AI systems often collect vast amounts of personal information, raising concerns about confidentiality and human dignity. Islamic ethics places great importance on protecting individual privacy and preventing unjust intrusion into personal affairs (Kamali 172–177; UNESCO 94–98).

The concentration of technological power among a small number of global corporations also raises concerns about digital inequality and cultural dependency. Muslim societies may become consumers rather than producers of technology unless significant investment is made in research and innovation (Sardar 156–162; Schwab 210–216).

Islamic Civilisational Responses to AI

Islamic civilisation has a rich ethical framework capable of addressing contemporary technological developments. The concept of Maqasid al-Shari'ah provides principles for evaluating innovations by their impact on religion, life, intellect, lineage, and property (Kamali 33–39; Al-Shatibi 8–15). Muslim scholars should actively participate in interdisciplinary research spanning Islamic studies, computer science, and ethics. Such engagement would ensure that technological development reflects Islamic moral values and serves the broader interests of society (Al-Qaradawi 102–107; Sardar 168–173).

Educational institutions should integrate AI literacy into Islamic studies programmes. Future scholars must understand the benefits and limitations of emerging technologies to provide informed guidance to Muslim communities (UNESCO 112–118; Bunt 136–142). Governments and religious organisations should also establish ethical guidelines for the use of AI in religious education, legal research, and public communication. These measures would help preserve authenticity while encouraging responsible innovation (Floridi 241–246; UNESCO 121–125).

Conclusion

Artificial Intelligence is one of the defining developments of contemporary civilisation. Its impact on Islamic thought will largely depend on how Muslim scholars, educators, and policymakers engage with its opportunities and challenges. The study demonstrates that AI can significantly enhance access to knowledge, support research, and preserve Islamic intellectual heritage. However, it also raises ethical, intellectual, and methodological concerns that require careful attention. A balanced civilisational approach is therefore necessary. By integrating technological innovation with Islamic ethical principles, Muslim societies can harness the benefits of AI while preserving the authenticity, integrity, and moral foundations of Islamic thought.

Recommendations

Based on the findings of this study, the following ten recommendations are proposed to guide the responsible integration of Artificial Intelligence within Islamic thought and Muslim societies:

1. **Develop an Islamic Ethical Framework for AI:** Muslim scholars and institutions should formulate comprehensive ethical guidelines grounded in the Qur'an, Sunnah, and Maqasid al-Shari'ah to evaluate AI technologies and their societal impact.
2. **Establish AI Review Committees in Religious Institutions:** Islamic councils, universities, and fatwa bodies should create specialised committees to assess the accuracy and reliability of AI-generated religious content before public dissemination.
3. **Promote Collaboration Between Scholars and Technologists:** Interdisciplinary partnerships should be encouraged to ensure that AI systems designed for Islamic applications incorporate sound theological and ethical principles.
4. **Integrate AI Literacy into Islamic Education:** Islamic schools, universities, and seminaries should include AI literacy courses that teach students how to use AI responsibly while understanding its limitations and risks.

5. **Preserve the Authority of Qualified Scholars:** AI should be viewed as a supportive tool rather than a replacement for trained scholars. Religious guidance and legal rulings must continue to rely on qualified human expertise.
6. **Invest in Digital Preservation of Islamic Heritage:** Governments and educational institutions should support projects that digitise manuscripts, archives, and classical texts to safeguard Islamic intellectual heritage for future generations.
7. **Strengthen Verification Mechanisms for Religious Information:** Platforms providing Islamic content should implement rigorous fact-checking and scholarly review processes to minimise the spread of misinformation generated by AI systems.
8. **Protect Privacy and Human Dignity:** AI applications must comply with ethical standards that safeguard personal data, confidentiality, and individual rights in accordance with Islamic teachings on human dignity.
9. **Promote Digital Sovereignty in Muslim Societies:** Muslim-majority countries should invest in local AI research, infrastructure, and innovation to reduce dependence on external technological monopolies and enhance strategic autonomy.
10. **Encourage Continuous Research on AI and Islamic Thought:** Academic institutions should establish dedicated research centres focusing on the relationship between AI, ethics, Islamic law, education, and civilisation to address emerging challenges proactively.

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DESIGN CHALLENGES OF ACID-STABLE TRANSITION METAL OXIDE ELECTROCATALYSTS FOR PEM WATER ELECTROLYSIS

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ABSTRACT

Proton exchange membrane (PEM) water electrolysis is considered one of the most promising technologies for sustainable hydrogen production due to its high efficiency and compact design. However, the oxygen evolution reaction (OER) at the anode remains a major limitation because of its sluggish kinetics and the highly corrosive acidic environment. Currently, noble metal-based catalysts such as IrO_2 and RuO_2 exhibit high catalytic activity, but their scarcity, high cost, and stability limitations restrict large-scale industrial deployment. Consequently, the development of alternative transition metal oxide electrocatalysts has become an important research direction in advanced energy materials. This work presents a critical analysis of the structural and physicochemical parameters governing the activity and stability of transition metal oxide electrocatalysts under acidic PEM operating conditions. Particular attention is given to the relationship between crystal structure, defect chemistry, electronic conductivity, oxygen vacancies, and catalyst degradation mechanisms. Recent advances in catalyst design strategies reported in the literature are comparatively discussed from a materials engineering perspective. The analysis highlights the persistent trade-off between catalytic activity and long-term stability in acidic media. Although defect engineering and nanostructuring can enhance active site availability and improve OER kinetics, these modifications may also accelerate structural degradation and metal dissolution. Furthermore, limitations associated with conventional characterization techniques emphasize the need for more advanced operando investigations to better understand catalyst behavior during operation. Understanding the structure–activity–stability relationship remains essential for the rational design of efficient and durable PEM electrocatalysts. This work provides a materials-oriented perspective on current challenges and future directions for developing cost-effective and acid-stable catalytic systems for green hydrogen technologies.

Keywords: PEM Water Electrolysis; Electrocatalysis; Oxygen Evolution Reaction; Transition Metal Oxides; Advanced Energy Materials; Catalyst Stability; Green Hydrogen Production

BAND GAP ENGINEERING AND PHOTOCATALYTIC PERFORMANCE OF LEAD-FREE CS2TIX6 (X = CL, BR, I) VACANCY-ORDERED DOUBLE PEROVSKITES: A DFT STUDY

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ABSTRACT

Lead-free halide double perovskites have recently emerged as promising materials for sustainable optoelectronic and photocatalytic applications due to their reduced toxicity and enhanced chemical stability compared to conventional lead-based perovskites. This study provides a thorough first-principles analysis of the structural, electronic, op tical and photocatalytic properties of Cs2TiX6 (X = Cl, Br, I) vacancy-ordered double perovskites, employing density functional theory. Structural optimisation confirms the thermodynamic stability of all compounds, with lattice parameters increasing systematically from Cl to I, in line with the progressive enlargement of the halogen ionic radius. Electronic structure calculations indicate semiconducting behaviour with tunable band gaps that decrease from Cs2TiCl6 to Cs2TiI6. The modified Becke–Johnson potential yields improved band gap estimations, while spin–orbit coupling results in a moderate reduction, particularly for the iodine-based compound. Optical analysis reveals enhanced visible-light absorption for Cs2TiBr6 and Cs2TiI6, supporting their potential for solar energy conversion. Furthermore, the alignment of the band edges relative to the water redox potentials shows that Cs2TiCl6 and Cs2TiBr6 fulfil the thermodynamic requirements for photocatalytic hydrogen evolution. Overall, these findings identify Cs2TiBr6 as a promising environmentally friendly material for solar-driven water splitting applications.

Keywords: Double perovskite, Density functional theory, Band structure, Optical properties, Photocatalysis, Hydrogen evolution.

THE ETHNOGRAPHIC ELEMENT IN THE PHOTOGRAPHY OF THE ALBANIAN NATIONAL RENAISSANCE

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ABSTRACT

This paper examines the photographic creativity of the period of the Albanian National Renaissance. Albanian photography of this period drew extensively upon various elements of Albanian cultural heritage, particularly traditional folk costumes and other ethnographic features.

The research process was conducted using a qualitative methodology, involving the review of major scholarly literature in both Albanian and foreign languages. The study is based on archival materials, as well as sources published by the National Museum of Photography "Marubi" in Shkodra and the Library of the Academy of Sciences of Albania.

Traditional folk costumes represent one of the most significant testimonies and creative manifestations of Albanian folk art. They are distinguished by their ornamental richness, originality, beauty, diversity, and harmonious color balance.

In the photographic art of the National Renaissance period, a rigorous treatment of folkloric and ethnographic themes can be observed, with particular attention given to the details of traditional costumes and other cultural phenomena. This approach reflects the emotional and conceptual sensitivity of photographers of the time toward cultural heritage, which they regarded as an essential component of national pride and identity.

In conclusion, this paper argues that the works of Albanian photographers should be understood as a fundamental element in the history of Albanian art, as they contributed significantly to the construction of national identity, the preservation of collective memory, and the development of photographic aesthetics in Albania.

KEYWORDS: ethnography, Albanian National Renaissance, Albania, Albanian photography, photographic heritage.

SKATEBOARDING AS LIFESTYLE AND SOCIAL IDENTITY: A NETNOGRAPHIC AND ETHNOGRAPHIC CASE STUDY OF A YOUTH SKATE COMMUNITY IN AN INDUSTRIAL CITY, CIKARANG, INDONESIA

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ABSTRACT

This study examines skateboarding as a lifestyle and a shaper of social identity among young people in a skate community in Cikarang, West Java, an area defined by its industrial economy and its large population of young workers. Adopting a qualitative case-study design, the research combines netnography, field observation, and semi-structured interviews with eight informants to understand the experiences, meanings, and social dynamics within the community. The findings indicate that involvement in skateboarding typically begins through friendship networks, while learning occurs informally through peer interaction and digital media such as YouTube rather than through formal coaching. In this setting, skateboarding is understood not merely as an extreme sport but as a social and cultural practice encompassing self-expression, fashion, symbolic consumption, and a strong sense of camaraderie. The community displays high solidarity and inclusivity even as it continues to face public stigma, and its members negotiate structural constraints, particularly time poverty arising from work commitments and a shortage of adequate skatepark facilities. The study contributes to research on youth subcultures in Indonesia's industrial regions and offers a foundation for more inclusive public-space policy and for community-based marketing and creative-economy initiatives. Because the work rests on a single community and a short observation window, its claims are exploratory rather than generalizable.

Keywords: skateboarding, lifestyle, social identity, subculture, consumer tribe, Cikarang

INTRODUCTION

Skateboarding has shifted in meaning over recent decades. What was once read as a street pastime or an extreme sport has become a complex cultural practice that combines self-expression, creativity, and the formation of social identity. For many young people a skateboard is less a tool for performing tricks than a medium for building relationships, solidarity, and a sense of belonging. In this sense skateboarding has moved from the domain of sport into the domain of lifestyle and subculture.

This phenomenon is visible in developing Indonesian cities, including Cikarang. As an industrial area dominated by young workers, Cikarang imposes a busy and repetitive rhythm of long working hours and high mobility. Against this backdrop skateboarding offers an alternative space, a third place beyond home and work, where young people can express themselves, relieve stress, and build social networks. Skateparks, sidewalks, and other public spaces are transformed into areas of social interaction in which skills, stories, and emotional support are exchanged.

Unlike formal sport structured through clubs, coaches, and official institutions, the skate community grows organically through friendship, social media, and self-study. Knowledge about tricks, clothing styles, and brand preferences circulates through both face-to-face interaction and digital platforms such as Instagram, Facebook, and WhatsApp. This process produces what can be understood as a subculture or consumer tribe, in which the consumption of boards, shoes, and apparel is not only functional but symbolic, signaling identity, taste, and membership (Artosa, 2022).

Initial interviews indicate that members treat skateboarding as a lifestyle integrated into daily life, emphasizing togetherness, adrenaline, fashion, and social connection as primary reasons for involvement. For some informants skateboarding is a process of life learning, captured in the metaphor of falling and getting back up, a reading that gives the practice affective and existential dimensions beyond physical activity.

Academic research on skateboarding in small and mid-sized Indonesian industrial cities remains limited. Most studies concentrate on metropolitan areas or treat skateboarding through the lens of sport or safety risk, and few examine how skate communities in places like Cikarang construct collective identity, interpret consumption, and respond to scarce public facilities. This gap matters because local context generates distinct social and cultural dynamics. Accordingly, this study asks how skateboarding is interpreted as a lifestyle and a source of social identity within a local community in an industrial city, and how relationships, consumption, and collective aspirations take shape within it. Given its scope, the study is positioned as an exploratory case study rather than a generalizable account.

LITERATURE REVIEW

Scholarship increasingly treats skateboarding not as mere recreation but as a social and cultural practice that shapes identity, relationships, and solidarity. In many urban contexts it has become a medium of self-expression and an alternative social space for young people, a reading

consistent with the present study, where participants describe skating as a lifestyle, a source of social connection, and a way to relieve work-related stress.

In the Indonesian context, Al-Fikri, Mahzuni, and Prabasmoro (2023), in their case study of the Patriot Skate Club 95 community in Bekasi City, show that skateboarders construct identity through interaction with public space, where skateparks, sidewalks, and plazas serve not only as sites of physical activity but as social arenas for solidarity, mentoring, and the exchange of experience. This reinforces field observation in Cikarang, where the skatepark becomes a daily meeting point for sharing tricks, socializing, and building emotional bonds, so that physical space is transformed into space of social meaning.

The personal meaning of skateboarding was examined by Costa, Kochanek, and Erickson (2022) in their study of Brazilian skateboarders, which found that skateboarding helps young people develop mental resilience, self-confidence, and the capacity to cope with failure, with the repeated cycle of falling and recovering read as a metaphor for life learning. This resonates with a Cikarang informant who described skating as a process that must be enjoyed, like learning to walk, positioning the practice as character-building and as a space for psychosocial growth.

Visual representation and consumption form a further thread. A design study of a photography book on the development of skateboarding in Malang (Rahmawati, 2021) shows that skateboarding is practiced as an aesthetic expression of fashion, style, and visual identity, with documentation through photography and social media shaping self-image and recognition. This aligns with Cikarang interviews in which fashion and style are described as integral to the skating experience rather than incidental. Artosa (2022), in a study of young skate workers in Indonesia, further shows that some participants become skate-shop workers, content creators, or sponsored athletes, so that skateboarding is not only a lifestyle but a pathway to economic opportunity, and the consumption of equipment carries both symbolic and commercial value.

Comparative and international work locates these dynamics in broader debates. Insandi et al. (2022) document the friction between street skateboarders and public comfort in Bandung, while Paechter, Stoodley, Keenan, and Lawton (2024) show how skate spaces operate as performative environments in which identity is enacted under scrutiny. Read together, the literature reveals four threads: skateboarding as a builder of identity and solidarity, community-based informal learning, a strong connection to public space, and symbolic and economic dimensions through consumption. Yet most studies center on cities such as Salatiga, Bekasi,

Malang, and Bandung, or on international contexts, leaving industrial satellite cities such as Cikarang, marked by young workers and limited facilities, underexamined.

RESEARCH AND FINDINGS

Research Design and Method

This study uses a qualitative case-study design integrating netnography, field observation, and semi-structured interviews to explore the meanings, experiences, and social dynamics of the skateboarding community in Cikarang. Netnography examined how the community constructs meaning and interacts through digital media, specifically WhatsApp groups used for coordination and information exchange, Instagram used to document events and skatepark sessions, and Facebook used to extend networks across communities. Digital observation ran over two weeks and was conducted passively, without intervention in member interactions.

Interview participants were recruited through a single community member who introduced additional members, a snowball approach. The eight informants were active skaters who had skated for more than a year, were involved in the community, and used public spaces and skateparks. Interviews were semi-structured and were recorded and transcribed verbatim with participant consent. The interview guide was adapted from the developmental-experience questions used by Costa, Kochanek, and Erickson (2022). Field observation took place at the Wibawa Mukti Stadium skatepark in Cikarang and at informal community sessions, with attention to how members shared knowledge, built relationships, and learned tricks. Of the eight informants, two were under eighteen; their participation is treated with corresponding care and is noted among the study's limitations.

Data was analyzed through thematic coding in three stages: open coding to identify keywords across observation notes and transcripts, axial coding to group codes into themes of lifestyle, social identity, and challenge, and selective coding to construct the narrative linking skateboarding to identity and lifestyle. Informants are identified by code (I01 to I08) and pseudonyms to protect privacy.

Entry Process and Identity

Most informants entered skateboarding through social relationships rather than individual initiative. As one captain put it, he came to know skating after a friend invited him and has continued since. Friendship is the primary gateway, and skateboarder identity emerges through socialization rather than in isolation; once involved, participation becomes sustained, indicating the internalization of identity. Identity is also linked to global skate culture, as informants named international figures such as the Australian professional Dustin Dollin

among their favorite skaters, connecting a local Cikarang identity to a global scene. Financial readiness appeared as a further factor: one employed informant explained that he only began skating in 2023 once he was working and could buy his own board, so that owning equipment functions as a marker of seriousness and autonomy. These patterns align with Al-Fikri, Mahzuni, and Prabasmoro (2023) on the role of social ties and public space in skate identity, and with Artosa (2022) on equipment ownership as part of subcultural legitimacy.

Community Learning and Solidarity

Learning within the community was unstructured and self-directed. Informants relied on digital media, especially YouTube, alongside guidance from more experienced peers, with one noting that he learns from YouTube when not learning from friends, and another that he masters the basics and adjusts his balance before attempting tricks. There was no formal coaching in the early stages. Knowledge transfer is horizontal, and proficiency develops incrementally through repetition rather than abrupt acquisition, consistent with the community functioning as a peer-based learning community.

Solidarity is expressed in kinship language. One informant observed that although skating is seen by outsiders as an extreme sport and looked down upon, viewed from within it is less about sport than about family, framing camaraderie and mutual support as core values. Netnographic data reinforced this, including a WhatsApp exchange in which an experienced member shared a trick-tutorial video with the group. Field observation showed obstacles informally divided by skill level, with beginners using flat areas for balance and basic tricks while advanced skaters took the high ramps and rails in turn, successes and failures alike met with cheers, demonstrating mutual encouragement.

Lifestyle, Consumption, and Aspirations

Skateboarding was consistently described as integrated with fashion and everyday self-expression rather than as a discrete activity, with one informant stating that skating has become very much integrated with fashion and lifestyle. Consumption carried social meaning: informants preferred buying offline to online because the skate shop offers community experience as well as a transaction, echoing Artosa (2022) on skateboarding as both subculture and industry and Rahmawati (2021) on the centrality of aesthetics and visual representation. Aspirations extended beyond the city, with one informant describing skating not only in Cikarang but in Pemalang and Bali, indicating networked ambitions shared across experience levels.

Challenges, Stigma, and Facilities

Despite strong solidarity, the community faces structural constraints rooted in its industrial setting. Time poverty was the dominant obstacle, raised by employed informants who noted that work leaves little room for a practice that demands sustained commitment and slow improvement. Economic orientation favored enjoyment over competition, with one informant remarking that, absent a competition, the point is simply to have fun, indicating that togetherness outranks formal achievement. Members also resisted stigma: in response to the perception of skateboarding as dangerous or disruptive, one student informant dismissed the criticism on the grounds that skateboarding is a street practice, born on the street, with skateparks understood as government-provided accommodation rather than the core of the activity. The most frequently voiced need was for facilities, with an informant hoping for more skateparks in Cikarang, a finding that reinforces Al-Fikri, Mahzuni, and Prabasmoro (2023) on skaters' negotiation of limited urban space.

Discussion

These findings confirm that skateboarding in Cikarang is best understood not as a sporting activity alone but as a social practice that shapes youth identity, solidarity, and consumption. The reading of skateboarding as character-building aligns with Costa, Kochanek, and Erickson (2022), whose work links the cycle of falling and recovering to mental resilience and self-reflection; Cikarang informants who interpret falling as part of life learning reinforce the existential and educational dimensions of the practice. The community's function as a space of solidarity and informal mentoring echoes the role of public space in skate identity documented by Al-Fikri, Mahzuni, and Prabasmoro (2023), and in Cikarang the absence of formal coaches appears to strengthen collective, experience-based ties, with the skatepark serving as a third place that sustains emotional support across ages and skill levels.

Unlike many large-city contexts, however, Cikarang foregrounds structural limitations, particularly in facilities and institutional support, where poor skatepark maintenance and infrequent events signal unmet needs that may constrain the community's development. In an industrial area whose members are largely young workers with demanding routines, the need for alternative spaces of expression is especially pronounced.

From a market perspective the findings suggest several directions, offered tentatively given the study's exploratory scope. Local governments and industrial-estate managers might develop more adequate skateparks as social investment in youth; local brands and small enterprises might collaborate with the community through event sponsorship, competitions, or community

merchandise; and regular events could seed a local creative-economy ecosystem while strengthening collective identity. Theoretically, the study extends subculture research into a mid-sized industrial city that has drawn little attention, showing that subcultures can persist organically despite limited facilities so long as solidarity and a strong sense of identity hold.

CONCLUSION

This study shows that skateboarding in the Cikarang community cannot be reduced to an extreme sport but operates as a social and cultural practice shaping youth identity, solidarity, and lifestyle. Involvement generally begins with friendship and develops into a sustained part of self-identity; learning proceeds informally through peers and digital media, reinforcing the community's character as a solidarity-based learning community. Skateboarding is experienced as a lifestyle integrated with fashion, symbolic consumption, and translocal aspiration, and owning equipment functions as a marker of legitimacy within the subculture. The community sustains inclusivity and camaraderie even amid persistent stigma toward skateboarding as a street practice.

The study also identifies structural challenges, especially time poverty arising from work and a shortage of adequate skatepark facilities, pointing to unmet needs that warrant attention from local policymakers seeking to support youth creative space. Theoretically, the work enriches the study of subcultures and social identity in Indonesia's industrial cities; practically, it can inform more inclusive public-space policy and community-based marketing.

Several limitations bound these claims. The informants were all male and numbered only eight, so women's experiences are absent; the netnographic window lasted two weeks, limiting depth; and the account rests on a single community, so it is exploratory rather than generalizable. Two informants were minors, and although their participation was handled with care, future work should secure documented guardian consent. Subsequent research should incorporate the gender dimension, examine the creative-economy potential more directly, and pursue cross-city comparison to broaden understanding of skateboarding communities in Indonesia.

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CONSUMER TRIBES IN A SHARED THIRD SPACE: COMPETING STATUS ECONOMIES AND DIGITAL VALIDATION IN URBAN RUNNING AND CALISTHENICS COMMUNITIES

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ABSTRACT

The urban sporting landscape in Indonesia has shifted from a predominantly health-oriented activity toward a vehicle for social identity and tribal belonging. In satellite cities such as Depok, niche communities organized around running and street workout function as third spaces in which members construct collective identity, signal membership, and convert physical effort into social standing. This study examines two such communities that share a single brand-anchored event space: Pelari Ahensi, a running collective whose members work predominantly in the creative and agency industries, and Street Workout Depok (SWORD), a calisthenics community rooted in local territory and bodily skill. Adopting an exploratory qualitative case-study design, the research combines rapid ethnography and netnography, drawing on participant observation at a single morning event, semi-structured interviews with four informants, and observation of the communities' Instagram activity. Thematic analysis produced three findings. First, members of the running community carry their occupational identity into the activity, framing training through agency vocabulary such as chase progress and approval can wait. Second, both communities operate as informal regulatory bodies, converting impulsive solitary exercise into a structured social contract. Third, and most distinctively, the two tribes maintain divergent status economies within one physical space: the running community trades on aesthetic and visual capital, while the calisthenics community trades on functional grit and spatial ownership, producing two competing definitions of cool. Across both groups, digital validation operates as social currency. The study contributes a localized account of inter-tribal dynamics and offers implications for niche marketing and retail-anchored community building.

Keywords: consumer tribes, neo-tribalism, netnography, third space, urban fitness communities

INTRODUCTION

Across metropolitan and satellite-city Indonesia, sport has undergone a functional transformation. What was once framed as a solitary pursuit of cardiovascular health has become a primary medium for constructing urban social identity. This shift is consistent with the broader rise of niche consumer tribes, that is, groupings bound less by formal membership than by shared symbols, rituals, and emotional allegiance (Maffesoli, 1996; Smith & Westerbeek, 2004). Within these tribes, the legitimacy of a workout is increasingly tied not only to the body that performs it but to its digital archive, so that leisure begins to operate as an extension of professional self-presentation.

Joining a fitness subculture is best understood as a deliberate act of identity work. Donnelly and Young (1988) describe a subcultural career in which newcomers serve an informal apprenticeship, adopting the dress, vocabulary, and mannerisms of established members in order to earn a reputation for reliability before their identity is confirmed by the group. These tribal bonds are reinforced through the alignment between an individual's personality and the symbolic world of the community, a fit that facilitates deeper social integration (Matzler et al., 2011). At the same time, contemporary running and workout cultures are shaped by a dense interplay of social and environmental determinants (Lassalle et al., 2019), and access to their spaces is uneven, since aesthetic hierarchies and pace-based sorting can limit who feels they belong even in ostensibly inclusive settings (Quirk et al., 2021).

A central tension runs through these communities. On one side stands the physical embodiment of the activity, expressed through specialized slang, gear fluency, and bodily discipline. On the other stands the requirement for digital validation, in which the worth of effort is measured by its visibility on social platforms. Gil (2022) shows how digital ethnographies of running reveal members being rewarded for performing rituals of discipline online, while White (2025) captures this logic in the cultural script that asks whether an unrecorded run even happened. The result is a paradox in which a leisure activity becomes a productive arena for the accumulation of social capital.

Two gaps remain underexamined. First, scholarship has paid limited attention to inter-tribal dynamics, that is, how distinct fitness tribes negotiate a shared physical space and a common brand partner. Second, little work addresses the intersection of vocational identity and fitness, in particular how the hustle culture of the creative industries reshapes the meaning of sport for its practitioners. This study addresses both gaps through a single, information-rich case in which a running tribe and a calisthenics tribe occupy the same event space.

The study is guided by one research question: how do two niche, professionally inflected fitness communities, Pelari Ahensi and SWORD, construct collective identity and negotiate the tension between physical embodiment and digital validation within a shared, brand-anchored urban space? Given its scope, the work is positioned as an exploratory qualitative case study rather than a generalizable account. Its contribution is to document two divergent *economies of cool* coexisting in one third space, and to show how digital validation functions as social currency across both, with implications for niche marketing and retail-anchored community building.

RESEARCH AND FINDINGS

Research Design and Method

This study employs an exploratory, qualitative case-study design combining rapid ethnography with netnography, an approach suited to capturing the social and cultural texture of a community within a condensed timeframe. Rapid ethnography prioritizes focused, high-density fieldwork over prolonged immersion, while netnography extends ethnographic observation into digital environments (Kozinets, 2002). The two methods were used in tandem so that practices observed in person could be checked against the same communities' self-presentation online.

Fieldwork was conducted at a single event, the Margonda Morning Mashup, a combined five-kilometer run and street-workout gathering held on 15 February 2026 at Department Sports Lab (DSL), a sportswear retailer located on Jalan Margonda Raya in Depok and positioned at the edge of the local Car Free Day. The site functioned as a basecamp for two communities: Pelari Ahensi, a running collective whose members work predominantly in the creative and agency industries, and Street Workout Depok (SWORD), a calisthenics community drawn from more varied occupational backgrounds and rooted in local territory.

Data was generated through three techniques. Participant observation involved direct engagement in the run and the workout sets, with field notes recording warm-up rituals, group dynamics, gear, and the choreography of the event. Semi-structured interviews were conducted with four informants, two from the running community and two from the calisthenics community, to surface the meanings behind community-specific terms and the motivations behind sustained participation. Netnographic observation of the two communities' Instagram accounts examined the consistency of slang and self-presentation across the physical and digital spheres. To protect informant privacy, pseudonyms are used throughout: Adit and Ari for the running community, and Awa and Niko for the calisthenics community.

All material was analyzed thematically. Interview recordings were transcribed, segments were coded, and codes were grouped into higher-order themes. Three themes structure the findings below: occupational identity and creative logic, community-led discipline, and linguistic identity. A fourth section draws these together to describe the inter-tribal contrast and the role of digital validation that constitutes the study's principal contribution. The design carries clear limitations of scope, discussed in the conclusion, and its claims are calibrated accordingly.

Occupational Identity and Creative Logic

Among the running community, members' professional identities as creative and agency workers remained embedded in the activity itself. For these informants, running was not framed primarily as exercise but as a project pursued with an agency work mentality. Adit described the disposition directly, explaining that the group carries a quirky agency vibe, captured in phrases such as chase progress and approval can wait. The vocabulary is telling: it treats running performance as something to be advanced and validated, while preserving the distinctive, slightly irreverent self-image of the creative professional.

This orientation was reinforced by a shared occupational background. Ari noted that the members are, on average, workers in the creative field, with some in film, a commonality that produced a culture more relaxed than the rigidly athletic image of conventional sports clubs. Field observation corroborated the pattern. At the Margonda gathering, conversation among runners moved fluidly between training and design trends or recent film projects, and members' clothing tended toward expressive, fashion-forward styling rather than conventional sports branding. For this community, running served as a space where professional and personal identities converged rather than separated.

Community-Led Discipline

Both communities functioned as catalysts for behavioral change, converting impulsive, unstructured exercise into a safer and more disciplined practice. Several informants reported that, before joining, they trained without adequate technical knowledge and suffered for it. Adit recalled experiencing chest pain when running alone and contrasted this with the community routine of stretching and strength training before any run, a shift that suggests the group operates as an informal educational space where knowledge about technique and injury prevention is distributed among peers.

Beyond technique, the community provided a structure that countered procrastination. Awa observed that solitary training invited laziness, whereas the community supplied a schedule to follow, transforming exercise from a private burden into a social obligation. Field notes

captured the same dynamic in embodied form. No member began running immediately on arrival; instead, participants gathered into a circle for group stretching led by a senior member, and the mutual encouragement during group planks and squats showed collective energy functioning as the primary fuel for individual effort. Discipline here was not authoritarian but organic, growing out of a sense of togetherness rather than imposed from above.

Linguistic Identity and the Circle

The third theme concerns the role of language and pre-existing social ties in binding the community. Membership was frequently rooted in established friendship networks. Ari acknowledged that, although the community was nominally open to the public, most members came from their own circles, a proximity that produced trust and made interaction feel fluid rather than formal. Within this circle, specialized slang served as a boundary marker. Niko explained that members address one another as bray and rely on stylized informal speech, a code that signals in-group standing and converts an exhausting training session into an intimate social gathering.

Netnographic observation confirmed that this linguistic style carried over to the digital sphere without interruption. The same casual register that animated face-to-face banter reappeared in WhatsApp group chats and Instagram comment threads, indicating that the slang was not merely a communication tool, but a stable identity marker integrated across channels. Language, in other words, did much of the work of making members feel that they had returned to a familiar social home.

Two Economies of "Cool" in a Shared Space

The study's most distinctive finding concerns the contrast between the two tribes occupying the same physical space. Although the running and calisthenics communities shared the event, the Car Free Day route, and a single retail partner, they sustained sharply different status economies. The running community invested heavily in visual and aesthetic capital. Field observation recorded a marked preference for premium performance footwear, including Adidas Adizero models, and a dress-well culture in which appearance functioned as a prerequisite for confidence and for the quality of the digital content members produced. For this group, aesthetics has become a component of performance itself.

The calisthenics community consciously inverted these priorities. Its members presented in utilitarian attire, chalked hands and worn cross-trainers, and located their standing in what the body could do rather than in what it wore. Niko candidly conceded that running communities were, in conventional terms, cooler, but emphasized that his community placed training first

and outfit a distant second. Status in SWORD was also tied to spatial ownership: Niko recounted that the community had begun in a member's garage and had since pooled resources to build its own training installation, a history of collective effort that anchored its identity in territory and self-reliance rather than in display.

These orientations produced two competing definitions of cool within a single urban arena. For the running tribe, cool was a matter of curated lifestyle and appearance; for the calisthenics tribe, cool was a matter of function and grit, the visible product of physical labor. The coexistence of these economies in one shared, brand-anchored space is precisely the inter-tribal dynamic that prior scholarship has tended to overlook, and it indicates a finely differentiated segmentation within what might superficially appear to be a single urban-fitness market.

Digital Validation as Social Currency

Cutting across both communities was a shared reliance on digital validation. Collective physical activity was treated as socially incomplete until it had been rendered into digital form. For the running community this meant tracking applications and the metrics of distance and pace; for the calisthenics community it meant videos of repetitions and static holds. In both cases the digital record operated as a kind of medal, converting effort into instant credibility and standing within the group's online ecosystem (Gil, 2022; White, 2025).

The clearest illustration emerged at the close of the observed event. The organizers announced a surprise challenge in which participants had to upload an Instagram story tagging the host retailer before a fixed deadline in order to qualify for a prize. Attention shifted abruptly from physical recovery to content creation, with participants editing clips and checking their connections rather than cooling down. The episode demonstrated, in compressed form, that for these communities an effort that is not posted is an effort that did not fully count, and that this conviction can be mobilized directly by a commercial sponsor.

Discussion: The Retail Third Space and Market Implications

Read together, the findings indicate that Pelari Ahensi and SWORD are not merely exercise groups but third spaces for the formation of urban social identity, and that the retailer hosting them is not merely a vendor but the infrastructure of that third space. Department Sports Lab supplied an air-conditioned hub, a venue for the event, and a voucher system that converted athletic effort into retail engagement, so that the transition from participant to customer was nearly seamless. This arrangement aligns with the logic of neo-tribalism, in which symbols, rituals, and shared language sustain emotional belonging (Maffesoli, 1996), and with the

netnographic insight that online activity functions as ritual rather than mere documentation (Kozinets, 2002).

For marketers, several implications follow, offered tentatively given the exploratory scope of the study. Niche positioning is likely to outperform mass positioning, since these consumers respond to identity rather than to generic appeals to health; gear marketed for creative professionals, for instance, may resonate more than gear marketed simply as comfortable. Community partnerships offer brands direct access to tightly bonded segments with strong internal loyalty. A lifestyle-sport hybrid, in which apparel remains aesthetically credible for social settings while retaining technical specification, fits the runners' priorities in particular. Finally, influence within these circles' rests with internal opinion leaders rather than external celebrities, suggesting that micro-influencers embedded in the community are the more effective channel.

CONCLUSION

This study sets out to understand how two niche fitness communities construct identity and negotiate the tension between physical embodiment and digital validation while sharing a single brand-anchored space. Three conclusions follow. The running community exhibits a hybrid identity in which professional and athletic selves merge, so that agency vocabulary and productivity logic are carried onto the track. Both communities act as informal regulatory bodies, replacing erratic solitary training with a structured social contract grounded in peer accountability. Most distinctively, the two tribes sustain divergent economies of cool within one arena, one built on aesthetic and visual capital and the other on functional grit and spatial ownership, while both treat the digital record of effort as social currency.

The principal contribution is a localized account of inter-tribal dynamics in a shared urban space, a setting that prior scholarship has rarely examined, together with a concrete demonstration of how a retailer can operate as the infrastructure of a community third space and mobilize the norm of digital validation for commercial ends. These findings enrich the literature on consumer tribes and on the rationalization of contemporary sport.

The study's limitations are substantial and bound its claims. The fieldwork rests on a single event of roughly three hours and on four informants, so the account is exploratory and not generalizable. The cross-sectional design cannot establish how tribal belonging shapes behavior over time. Although the literature points to a gender division of affective labor in such communities, the present data were not disaggregated by gender and cannot speak to that question. Finally, the analysis centers on one retail partner and one locality, which constrains

transferability. Future research should extend the design across multiple sites and communities, incorporate longitudinal observation to trace behavior change, examine gendered dynamics directly, and complement the qualitative account with quantitative measures of how community participation relates to consumption and retention.

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ISOLATION OF PHENOLS, FLAVONOIDS, AND SAPONINS FROM BOSS YAM PEELS (*DIOSCOREA ROTUNDATA*) FOR THE REDUCTION OF AFLATOXIN GROWTH

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ABSTRACT

Yams (*Dioscorea* spp.) are vital root crops in West Africa, providing food, income, and cultural value. Boss yam (a variety of white yam) is widely cultivated, yet large volumes of nutrient-rich peel byproducts are discarded during processing. Aflatoxin contamination caused by *Aspergillus* species presents a major threat to food safety and human health (especially cancer). This research investigated the potential of *Dioscorea rotundata* (Boss yam peel) agricultural by-product as a natural inhibitor of aflatoxin producing fungi. Phytochemicals including phenols, flavonoids, and saponins were isolated from yam peel powder using solvent extraction to assess their capacity to inhibit aflatoxins growth. The extracts were quantitatively evaluated for antioxidant activity through Ferric Reducing Antioxidant Power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays, and antifungal activity was assessed against *Aspergillus flavus*, *A. niger*, and *A. fumigatus* using the agar well diffusion method. Results showed that the saponin fraction had the highest yield, followed by phenols and flavonoids . Antioxidant activity was concentration-dependent, with the flavonoid extract boss yam flavonoid showing the highest FRAP and DPPH values, while the saponin fraction of boss yam (BYS) exhibited the strongest antifungal effect, particularly against *A. fumigatus*. These findings demonstrate that *D. rotundata* peels possess valuable antioxidant and antifungal potentials, suggesting their use as natural, eco-friendly agents for aflatoxin inhibition and sustainable waste utilization.

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EXCEPTIONS TO PERSONAL DATA PROCESSING WITHOUT CONSENT AND THE REQUIREMENT TO CONTROL LEGAL POWER

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Abstract

In personal data protection law, the consent of the data subject is conventionally regarded as the core expression of informational self-determination. Yet every legal system recognises circumstances in which personal data may be processed without consent, in order to sustain the operation of the state, public services, the performance of legal obligations, the public interest and social security. This article argues that such exceptions are not peripheral technical devices within the data protection framework; they are, rather, the points at which legal power over the individual is most visibly concentrated: when consent is excluded, the individual's control over their own data is displaced by decisions made by law, public authorities or data-processing institutions. Drawing on legal theory, human rights analysis and the theory of legal power, the article demonstrates that consent exceptions generate legal power across three distinct layers, carrying risks of excessive surveillance, purpose expansion, unnecessary data collection and a structural power asymmetry between the individual and the data-processing institution. The article proposes that consent exceptions can be justified only when embedded within a control structure comprising strict legality, legitimate purpose, necessity, proportionality, purpose limitation, data minimisation, transparency, accountability, independent oversight and effective remediation. In the absence of that structure, consent exceptions risk transforming from instruments of genuine public interest into mechanisms that legitimise uncontrolled data-processing power.

Keywords: personal data; consent exceptions; informational self-determination; legal power; accountability; proportionality

1. Introduction

Consent has long been regarded as the theoretical pillar of personal data protection. The philosophical foundation of this view is rooted in the liberal tradition: the individual is a rational agent capable of deciding how information about themselves is to be collected, used and shared. Consent, in that conceptual framework, is not merely a procedural formality; it is the concrete manifestation of the right to self-determination in the informational sphere. When an individual freely consents, the power of the data controller is legitimised through the very

will of the person affected. This is why consent has been treated by many legal systems as the preferred basis for data processing, and why it carries a particular normative weight that other lawful bases do not easily replicate (Westin, 1967; Nissenbaum, 2010).

No legal system, however, has ever made consent the exclusive condition for data processing. Modern society cannot function if every decision about data depends on the advance permission of each individual. The state needs to process data in order to deliver public services, enforce the law, maintain national security and administer the population. Economic organisations need to process data to perform contracts, prevent fraud, ensure system security and meet statutory obligations. Medical research, social statistics and activities serving the public interest sometimes require data processing on a scale that makes individual consent collection impossible. Consequently, all reasonably developed legal systems recognise bases for data processing that do not rest on consent: what are commonly called consent exceptions. The problem does not lie in the existence of exceptions, but in their theoretical nature. When law permits data processing without consent, what happens to the individual's informational self-determination? Who holds decision-making power over personal data when that power no longer belongs to the data subject? Do the substitute bases automatically guarantee the legitimacy of processing, or do they carry the risk of legitimising excessive data power? These are the theoretical questions this article poses.

The central thesis of the article is as follows: exceptions to personal data processing without consent are not technical details of data law; they are the points at which legal power over the individual in the data society is most clearly revealed. When consent is excluded, the individual's control over their own data is replaced by decisions of law, public authorities, data-processing institutions or a structure of interests recognised by law. The core theoretical problem is therefore not merely to determine when data may be processed without consent, but to construct and maintain mechanisms of legal power control over the processing so authorised. The article approaches the problem from the perspectives of legal theory, human rights analysis, the theory of informational self-determination and the doctrine of power control in the rule of law. The method of inquiry is theoretical legal analysis: not to describe or compare positive law, but to build a framework of principles capable of controlling consent exceptions as a form of legal power that must be limited and rendered accountable.

2. Consent as a Mechanism of Legitimation for Data Processing and Its Internal Limits

Consent carries particular theoretical value in personal data protection because it connects data processing to the individual's right to self-determination. Normatively, consent embodies the

idea that the individual is not merely an object from which information is extracted, but a subject with the right to define the conditions, scope and purposes under which data about themselves is processed. In liberal legal thought, it is precisely the voluntary authorisation of the data subject that confers legitimate power on the data controller. Consent is therefore not only a legal procedure, but a symbolic institution: it reflects law's commitment to individual autonomy in the informational domain (Westin, 1967; Nissenbaum, 2010).

Yet consent carries internal limits that legal theory cannot ignore. In the data environment, the individual's actual capacity to give consent that is free, specific and informed is severely weakened by a range of structural factors. Information asymmetry between the individual and the data controller is the norm: individuals rarely have sufficient information about the scope of data collection, the true purposes of processing, storage duration, recipients of data and the potential future consequences of information sharing. Data policies are typically written in complex legal language running to dozens of pages, creating a cognitive burden wholly disproportionate to the ordinary user's information-processing capacity (Acquisti et al., 2015). The result is that consent in practice is frequently formal consent, reflecting not a genuine choice but merely the act of pressing "agree" in order to access a service.

The phenomenon of "consent fatigue" in the digital environment further erodes the theoretical value of the mechanism. When individuals must make consent decisions many times a day across multiple platforms, each time with incomplete information, their capacity for judgment and risk discrimination diminishes considerably. Dependence on digital platforms creates very high costs for refusing consent: refusal may mean losing access to essential services. In these circumstances, consent is no longer a full expression of autonomy but becomes a mechanism that formalises data-processing behaviour while concealing the genuine power of the data controller (Solove, 2013; Barocas & Nissenbaum, 2014).

The limits of consent are further revealed along a third dimension: the inability to anticipate future consequences. Data collected today may be used in entirely different contexts in the future, through aggregation, linkage or analytical techniques that the individual could not have foreseen at the time of consent. Informational self-determination, understood in its full sense, demands not only present control but also a reasonable capacity to predict how data will be used in the future. In the modern data environment, however, that predictive capacity is practically very low (Cohen, 2019). Personal data does not merely reflect information about the individual; it becomes infrastructure for foundational power, a site where human behaviour is monitored, predicted, classified and adjusted through digital systems (Cohen, 2019).

Recognising these limits does not lead to the conclusion that consent is worthless or should be abandoned. Consent remains an important mechanism of legitimation in many data processing activities, particularly where individuals have adequate information, genuine capacity to choose and the ability to refuse without disproportionate penalty. What the internal limits of consent demonstrate is that personal data protection must be designed as a multi-layered structure, in which consent is one important mechanism but cannot carry alone the entire burden of protecting informational self-determination. Where consent cannot be exercised meaningfully, or where the purpose of processing serves interests that exceed the scope of individual will, law must recognise alternative bases for data processing. The pivotal theoretical question is: when those alternatives are recognised and consent is no longer a mandatory condition, what must law substitute in its place as a mechanism of control? Without a full answer, consent exceptions become a vacuum in which the power to process data expands unconstrained by any proportionate control (Malgieri & Custers, 2018).

3. Consent Exceptions as a Displacement of Decision-Making Power from the Individual to Legal Institutions

Consent exceptions in data processing are not merely a legislative technique designed to resolve practical obstacles. At the theoretical level, they constitute a displacement of decision-making power of fundamental significance: the individual's decision-making power over their own data is replaced by decisions made by law, public authorities, data-processing institutions or a structure of interests recognised by law. When consent exists, the power of the data controller is anchored to the individual's will and thereby limited by it: the individual can refuse, restrict the scope, withdraw consent, and that refusal must be respected. When consent is excluded, that anchor disappears. The power to process data no longer depends on the approval of the data subject; it depends on the authorisation of law or on the interpretation of the data controller itself (Bygrave, 2014).

This displacement of decision-making power can be justified in many cases. Society cannot function if every exercise of state data processing from household registration to tax collection, from public health management to criminal investigation requires prior individual approval. The same holds for many private-sector activities: performing a contract the individual has already signed requires processing data without a separate act of consent for each transaction. Fraud prevention, system security, legal compliance, medical research and social statistics may all require data processing that lies outside the consent model. The practical rationale is real and should not be dismissed (Purtova, 2018).

Precisely because consent exceptions may be justified, however, they require the most rigorous control. An important theoretical point frequently overlooked in discussions of data protection is that the reasonableness of a purpose does not automatically legitimise any particular method or scale of data processing. A legitimate purpose may be achievable by many different means, with very different degrees of intrusion upon informational self-determination. Law must not only recognise the existence of an exception; it must also impose strict conditions on the manner, scope and duration of data processing. Without that, all a data controller needs to do is frame its data collection under the label of a legitimate purpose, and the individual's control is effectively neutralised without any substantive limit.

Consent exceptions generate legal power across three layers that are relatively independent but interconnected. At the first layer, law determines which circumstances permit the exclusion of consent. This is a legislative decision of a political and evaluative nature: it reflects the legal community's assessment of the relative importance of individual informational self-determination and competing collective interests. At the second layer, the data controller interprets and applies the exception to its specific situation. This is administrative and executive power: the controller determines whether its circumstances satisfy the conditions of the exception, and that determination is largely unmonitored in real time. At the third layer, the individual bears the effects of data processing but no longer has initial control through consent. Together, these three layers create a structure of dispersed but cumulative power (Lynskey, 2015).

It is important to note that consent exceptions should not be understood as a suspension or cancellation of the individual's rights. Even where consent is not required, the individual must still be protected by a set of other rights and principles: the right to be informed about processing within appropriate limits; the right of access to their data; the right to rectification; the right to object in certain circumstances; the right to erasure or restriction of processing when the legal basis no longer subsists; the right to lodge a complaint; and the right to protection from unjust automated decision-making. These rights do not depend on consent; they are concurrent rights that must be maintained and guaranteed even when consent exceptions apply (Wachter et al., 2017). From a theoretical perspective, the existence of these rights confirms that consent exceptions do not extinguish the individual's legal standing as a rights-bearing subject; they merely shift the protective mechanism from prior control through consent to subsequent control through rights, obligations and accountability mechanisms.

The most important theoretical consequence of this analysis is the following: consent exceptions do not weaken the requirement for personal data protection; they shift its centre of gravity, from control through individual permission to control through the rule of law, accountability and oversight of data-processing power. Within this conceptual framework, the relevant question is no longer "did the individual consent?" but "is the power to process this data subject to adequate control, and who is held accountable for that control?"

4. The Risk of Legitimising Excessive Data-Processing Power Through Consent Exceptions

If consent exceptions are designed too broadly, interpreted arbitrarily or left without mechanisms of control, they may produce a paradoxical effect: rather than serving legitimate public interests, they become instruments that legitimise uncontrolled data power. That power need not manifest in obvious violations such as the disclosure of private information or the deliberate misuse of data. It may operate more quietly, through excessive collection, secondary processing, continuous surveillance, behavioural profiling, risk prediction and automated decision-making (Zuboff, 2019). In these forms, data power does not merely infringe privacy in the conventional sense; it fundamentally reshapes the space of individual freedom and autonomy.

The first and most common risk is the expansion of processing purpose. An exception justified initially by a specific and legitimate purpose may gradually extend to adjacent or secondary purposes. When the purposes of data processing become vague, the principles of purpose limitation and data minimisation are seriously weakened. This is particularly dangerous in the environment of large-scale data processing, where data collected once may be reused, combined and analysed many times for purposes that were difficult to foresee from the outset. A "public interest" or "legitimate interest" exception, if not strictly defined, may become a legal cloak for any data collection activity that the controller regards as beneficial (Purtova, 2018).

The second risk is the power asymmetry between the individual and the data-processing institution. When consent is no longer needed, the individual loses the most important point of initial control. If they are also not adequately informed that their data is being processed, if they have no effective channel to object or complain, if there is no independent supervisory body, then informational self-determination is in practice replaced by unilateral decisions of the data controller. This asymmetry is not merely a technical legal problem; it is a structural problem of power in the data society, where the capacity to collect, store and exploit

information concentrates in a small number of institutions while the effects are dispersed across millions of individuals (Rouvroy & Berns, 2013).

The third risk is the normalisation of surveillance through the discourse of exceptions. Exceptions relating to national security, counter-terrorism, fraud prevention, public health protection and law enforcement typically arise in contexts that appear reasonable and carry urgency. Nobody denies that the state sometimes needs to process data to protect society. The problem is not the legitimacy of these purposes in specific circumstances, but the risk that legitimate purposes are invoked to cover scales and methods of data processing that are neither necessary nor proportionate. When data surveillance becomes a normalised habit under the banner of security or public interest, the individual's capacity to resist and civil society's capacity to exercise oversight are gradually eroded (Lyon, 2015; Zuboff, 2019).

The fourth risk is the lack of transparency and the difficulty of proving harm. When data is processed without consent, the individual often does not know that their data has been processed, by whom, for what purpose, for how long and with what consequence. If harm arises from complex chains of analysis, inference or automated decision-making, the individual finds it even more difficult to identify the harm and harder still to establish a causal link. This is the fundamental weakness of a data protection model that relies primarily on post-violation remediation: when the damage is invisible, when data power operates through layers of technique, purely reactive protection is not enough (Solove, 2006).

The fifth risk is collective harm. Processing data without consent typically affects not only individual data subjects in isolation, but generates impacts across social groups. Data drawn from many individuals, when aggregated, can create group profiles used to classify, risk-assess, target or exclude groups from opportunities. This is a dimension that the traditional model of personal data protection — focused on the bilateral relationship between the data subject and the data controller at the individual level — cannot adequately capture (Mantelero, 2016). Controlling consent exceptions therefore cannot rely solely on individual complaint mechanisms; it must incorporate collective risk assessment and system-level protective mechanisms.

Taken together, these five risks demonstrate that consent exceptions are not power-neutral. They create conditions in which data power can expand without adequate control, informational self-determination can be systemically replaced by structural dependence, and harm to individuals and groups can become invisible to the point of being practically impossible to prove and remedy. The theoretical question therefore cannot stop at "is the

exception justified?" but must proceed to "is the power-control mechanism robust enough to prevent the exception from becoming an instrument for legitimising arbitrary data processing?"

5. A Model for Controlling Legal Power Over Personal Data Processing Without Consent

Controlling legal power over consent exceptions is not a question of choosing the right technical device; it is a requirement of the rule of law in the data society. As data becomes infrastructure for governance, commerce and social power, processing data without consent must be situated within a framework of principles sufficiently robust to limit, make transparent and hold accountable that power. This framework comprises at least five principles that are interrelated and must be understood as a unified system, not a mechanical checklist.

The first principle is strict legality. Consent exceptions must have a clear, unambiguous legal basis, with a defined scope and specific conditions of application. This requirement demands not merely that a statutory provision exists, but that the provision is sufficiently precise for individuals to foresee the circumstances in which their data will be processed without their permission. This principle of legal foreseeability is foundational to the rule of law in every field: power may only be exercised when there is a clear legal basis and when those affected can identify the limits of that power (Lynskey, 2015; Bygrave, 2014). Granting data controllers the right to self-interpret broad or vague exceptions is, in effect, to confer legislative power on a body that is not a legislatively authorised authority — a course that contravenes the most fundamental principle of the separation of powers.

The second principle is legitimate purpose and purpose limitation. Consent exceptions can only be justified when directed at a specific, predetermined purpose of recognised social value. Data collected and processed for that purpose must not be freely redirected to another purpose without a new legal basis or rigorous compatibility assessment. Purpose limitation is the mechanism that prevents consent exceptions from becoming an open-ended licence for data processing. Without a purpose limitation principle, an exception initially granted in the name of a specific public interest may progressively become a gateway to purposes that were never within the original authorisation, without any accountability (Custers et al., 2014). This affects not only individual data subjects, but also erodes societal trust in the integrity of the data protection legal system.

The third principle is necessity and proportionality. Even where the purpose of data processing is legitimate, that does not automatically justify any particular method or scale of processing. Necessity requires that the data processing be needed to achieve the purpose and that no less intrusive means of achieving the same result exists. Proportionality requires a balance between

the interests being pursued and the degree of interference with the individual's informational self-determination: the benefit must be sufficiently substantial and real to justify the specific degree of interference. Together, these two criteria form a dual test, requiring data controllers to demonstrate not only that their purpose is legitimate, but that their method is the minimum necessary to achieve it (González Fuster & Gellert, 2012). The more sensitive the data, the greater the scale of processing and the more serious the potential impact, the more demanding the burden of proof of necessity and proportionality.

The fourth principle is transparency and accountability. When consent is no longer the initial mechanism of control, transparency and accountability become its indispensable substitute. Transparency requires that individuals be able to access information about the legal basis being invoked, the purposes of processing, the categories of data involved, retention periods, recipients of data and the protective measures applied. Yet transparency alone is insufficient without accountability. Accountability requires that data controllers not only comply with data protection principles, but also be capable of demonstrating that compliance in a substantive and verifiable manner (Doshi-Velez et al., 2017; Colonna, 2020). This represents a significant shift in the philosophy of legal regulation: from a passive compliance model based on a fixed list of specific obligations to a model of active accountability, in which the data controller must continuously demonstrate that its data-processing decisions rest on adequate reasoning, evidence and risk assessment.

The fifth principle is independent oversight and effective remediation. Without an independent body or mechanism to supervise the application of consent exceptions, the four preceding principles risk remaining aspirational statements on paper. Independent oversight must carry genuine authority: the power to require information and explanations from data controllers, the power to investigate where there are signs of violation, the power to apply remedial measures including ordering the cessation of processing and the erasure of data, and the power to address violations through measures with sufficient deterrent effect. Remediation mechanisms must be sufficiently effective that individuals are not placed in the position of having rights in theory that they cannot enforce in practice. This encompasses both individual complaint channels and system-level intervention mechanisms where violations are structural in character (Reidenberg et al., 2015; Mantelero, 2016).

These five principles do not operate independently; they constitute an integrated control structure. Strict legality delimits the scope of the exception. Purpose limitation and necessity govern how the exception is applied. Transparency and accountability create the conditions for

external oversight. Independent oversight and remediation mechanisms ensure that the foregoing principles are not merely ideal commitments but enforceable requirements. Without any single element, the entire structure is weakened: an exception with a clear legal basis but without independent oversight remains a source of uncontrolled power; a strong supervisory mechanism built upon exceptions that are too broadly defined still fails to protect the individual's informational self-determination.

From a theoretical standpoint, this control structure is not peculiar to any specific legal system; it reflects the requirements of the rule of law as applied to the domain of data. The rule of law requires that legal power has a clear legal basis, that it is exercised within the scope of a legitimate purpose, that it is subject to control proportionate to the degree of interference with individual liberty, that it operates transparently and accountably, and that it is subject to supervision by an independent institution. Applied to data processing, these requirements do not arise from the technical peculiarities of digital data, but from the foundational structure of legal power in the rule of law state — extended to a new domain as data becomes the medium and infrastructure of power (Lynskey, 2015; Cohen, 2019).

Conclusion

The theoretical analysis developed in this article leads to a structurally firm conclusion: exceptions to personal data processing without consent are the points at which legal power over the individual in the data society is most visibly concentrated. This is not a minor finding about legislative technique; it is a fundamental theoretical claim about the nature of data protection law. When consent exists, the power of the data controller is anchored to individual will and thereby limited by it. When consent is excluded, that anchor disappears and the power to process data shifts to law, public authorities or data-processing institutions.

This does not mean that consent exceptions are wrong or should be abolished. This article makes no such argument; modern society cannot function if all decisions about data are contingent on individual consent. What the article demonstrates is that the practical reasonableness of exceptions does not automatically guarantee their legal legitimacy. Legitimacy can only be achieved when exceptions are situated within a rigorous control structure comprising legality, legitimate purpose, necessity, proportionality, purpose limitation, data minimisation, transparency, accountability, independent oversight and effective remediation.

The theoretical value of consent does not lie in its being a perfect mechanism — for as the analysis shows, consent carries serious internal limits in the data environment. Its value lies in

the fact that it is the most visible expression of the individual's informational self-determination. Precisely for this reason, when law permits consent to be bypassed, the requirement for control must become more rigorous, not less. The apparent paradox between "protecting the individual" and "operating the data society" is not a genuine paradox; it is a legal design problem: the problem of how to control legal power when the right of control no longer belongs to the individual.

The deepest theoretical question that consent exceptions raise is ultimately not about data; it is about power. Who has the right to decide that an individual's data must be processed, for what purpose, within what scope, with what safeguards and for how long? When the answer is not the individual themselves, the answer must be a legal structure sufficiently rigorous, transparent and accountable to merit the trust it demands from those whose data it governs.

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OCCURRENCE OF *KLEBSIELLA PNEUMONIAE* IN FAECAL SAMPLES OBTAINED FROM SELECTED CATTLE FARMS IN IBADAN METROPOLIS, NIGERIA

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ABSTRACT

Presence of bacteria in livestock faeces is not in itself a public health concern as these microbes exist as normal commensals, the real concern is the pathogenic potential of these bacteria as they enter into the environmental and human interphase. This study was designed to determine the occurrence of *Klebsiella pneumoniae* present in faecal samples obtained from Cattle farms. Faecal samples were obtained from bulls and cows using sterile gloves into sterile sample bottles every fortnight at four different livestock farms within Ibadan metropolis, Nigeria. The samples were transported in ice-box to the Pathogenic Laboratory, Department of Microbiology, University of Ibadan, for further microbiological analysis. Samples were serially diluted, appropriate diluents were inoculated using standard pour plate technique using nutrient agar and MacConkey Agar (MA) for determination of total heterotrophic bacterial count (THBC) and total coliform count (TCC), respectively. Pinkish colonies on MA were purified via streaking to obtain pure culture, which was identified via morphological and biochemical tests.

Faecal samples from cows (Farm D) had the highest THBC of 7.00±0.23 $LogCFUmL^{-1}$ and TCC of 5.89±0.42 $LogCFUmL^{-1}$, while faecal samples obtained from bulls (Farm B) had the highest THBC of 7.03±0.28 $LogCFUmL^{-1}$ and TCC of 6.04±0.23 $LogCFUmL^{-1}$. A total of 162 isolates were recovered in pure culture, while 39 (24.07%) were identified as *Klebsiella pneumoniae*.

This study showed that faecal samples recovered from cattle harboured a significant number of *Klebsiella pneumoniae* and thus pose a public health concern, as such, care must be taken in management of cattle, as well as avoid contamination of food and water with faeces from these farms to avoid illnesses.

Keywords: Faeces, Coliform, *Klebsiella pneumoniae*, Cattle

STRUCTURAL, MORPHOLOGICAL AND OPTICAL PROPERTIES OF STRONTIUM HEXAFERRITES $SRFE_{12-X}AL_XO_{19}$ (X = 1, 1.5, 2, AND 2.5) SYNTHESIZED VIA SOL–GEL AUTO-COMBUSTION

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Abstract

In this work, we report on the synthesis and systematic investigation of the structural, morphological and optical properties of aluminum-substituted strontium hexaferrites $SrFe_{12-x}Al_xO_{19}$ (x = 1, 1.5, 2.0, and 2.5), prepared via the sol–gel auto-combustion route. X-ray diffraction (XRD) analysis, complemented by Rietveld refinement, confirms the formation of a single-phase hexagonal M-type structure (space group $P6_3/mmc$, JCPDS card no. 96-100-6003), with a systematic contraction of the lattice parameters upon increasing Al content. Williamson–Hall analysis indicates a concurrent reduction in crystallite size and microstrain, reflecting the influence of Al substitution on the microstructural features. Scanning electron microscopy (SEM) observations reveal well-defined hexagonal platelet-like grains, with a progressive decrease in grain size as a function of Al concentration, while energy-dispersive X-ray spectroscopy (EDS) confirms the compositional homogeneity of the samples In addition, the optical properties were investigated using UV–Vis absorption spectroscopy in the wavelength range of 200–1000 nm. The results reveal a slight decrease in the optical band gap energy from 4.19 eV to 4.08 eV with increasing Al doping, which may be attributed to modifications in the electronic band structure of the material.

Keywords: $SrFe_{12-x}Al_xO_{19}$, Structural analysis, Morphological analysis, M-type hexaferrites, Sol–gel auto-combustion, Optical band gap, Aluminum doping.

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