Turkish Journal of Sport and Exercise /
Türk Spor ve Egzersiz Dergisi
http://dergipark.gov.tr/tsed
Year: 2025 - Volume: 27 – Issue 1 - Pages: 118-132
10.15314/tsed.1564899

Turkish Journal of Sport and Exercise
Türk Spor ve Egzersiz Dergisi
ISSN: 2147-5652
https://dergipark.org.tr/tr/pub/tsed

A Review of Artificial Intelligence Studies in Sports Sciences

İlhan GÖZEN [1A]

[1] *Gazi University, Ankara, Türkiye*
Address Correspondence to İlhan GÖZEN: gozen.edu@gmail.com

Ethical Statement: It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.

(Date Of Received): 10.10.2024 (Date of Acceptance): 24.03.2025 (Date of Publication): 30.04.2025

A: Orcid ID: 0000-0002-4682-967X

Abstract

This study conducts a bibliometric analysis of artificial intelligence studies in sports sciences from the (WoS) database, emphasize the importance of utilizing AI in sports sciences, provide data for future research, highlight the need for the application of AI across all areas of sports in line with global trends, and most importantly, offer a perspective on the use of AI in sports sciences in our country. Initially, 164 research articles were accessed from the WoS database, and the VOSviewer software package was used for data analysis. It was observed that the first publication related to artificial intelligence in sports sciences was published in 1995, with a significant increase in 2019, and the number of publications has shown an upward trend from 2023 to the present. The low number of publications in 2024 is due to only considering studies published up to July 2024. The most cited article, with 107 citations, is "Motor Unit Control and Force Fluctuation During Fatigue," while the author with the most publications, with six papers, is “Kunze, Kyle N.” The most cited authors are “De Luca and Carlo J.” with 171 citations. The journal with the most citations, (226), is "Knee Surgery, Sports Traumatology, Arthroscopy," and the institution with the most publications (8), is “Hosp Special Surg,” while the institution with the most citations, (171), is “Boston Univ.” The country with the most publications (23) and citations (613), is the USA. In the institutional collaboration network, among 11 institutions the highest collaboration was observed between the 8 institutions marked in red, while 3 institutions marked in green had fewer collaborations. In the co-keyword network, 12 keywords were identified, with the densest clusters being red (machine learning) and yellow (artificial intelligence). In the authors’ co-citation network, 12 authors were identified, with the most cited cluster containing 7 authors in red, while the green clusters, consisting of 5 authors, had fewer citations. In conclusion, there has been a significant increase in publications related to the use of artificial intelligence in sports sciences in recent years, indicating a growing interest in the subject.

Keywords: Bibliometric Analysis, Sports Sciences, Artificial Intelligence.

Spor Bilimlerinde Yapay Zekâ Çalışmalarına Genel Bir Bakış

Özet

Bu çalışmada Web of Science (Wos) veri tabanından spor bilimlerinde yapay zekâ çalışmalarının bibliyometrik analizlerinin incelemek, spor bilimlerinde yapay zeka kullanılmasının önemine vurgu yapmak, yapılacak çalışmalara veri sağlamak, küresel ölçekte trend olan yapay zekâ kullanımının sporun her alanına indirgemesi gerektiğini belirtmek ve en önemlisi ülkemizde spor bilimlerinde yapay zekâ kullanımına yönelik bir bakış açısı ortaya koymak amaçlanmıştır. İlk olarak Wos veri tabanından 164 araştırma makalesine ulaşılmış, verilerin analizinde VOSviewer

paket program kullanılmıştır. Yapılan analizler sonucunda, spor bilimlerinde yapay zekâ ile ilgili ilk yayının 1995 yılında yayımlandığı, 2019 yılında ise çok önemli bir artış olduğu, 2023 yılından günümüze kadar ise yayınların artış eğiliminde olduğu görülmüştür. 2024 yılındaki yayın sayısının az olması, 2024 Temmuz ayına kadar yayınlanan araştırmalar baz alınmasından kaynaklanmaktadır. 107 atıfla en fazla atıf alan makale "Motor Unit Control and Force Fluctuation During Fatigue", 6 yayınla en fazla yayın yapan yazar "Kunze, Kyle N.", 171 atıfla en fazla atıf alan yazarlar "De Luca ve Carlo J." olmuştur. 226 atıfla en fazla atıf alan dergi "Knee Surgery, Sports Traumatology, Arthroscopy", 8 yayınla en fazla yayın yapan kurum "Hosp Special Surg", 171 atıfla en fazla atıf alan kurum "Boston Univ" olmuş, 23 yayın ve 613 atıfla en fazla yayın yapan ve atıf alan ülke ABD olmuştur. Kurumlar arası iş birliği ağında 11 kurum arasında en fazla iş birliği kırmızı renkteki 8 kurum, daha az iş birliğine sahip kurumlar ise yeşil renkteki 3 kurum olduğu görülmüştür. Ortak anahtar kelime ağında 12 anahtar kelimeye ulaşılmış, en fazla yoğunluk kırmızı (Machine learning) ve sarı (Artificial intelligence) renkteki anahtar kümeler olduğu görülmüştür. Yazarların ortak atıf alma ağında toplam 12 yazara ulaşılmış, en fazla atıf alma ağı 7 yazarla kırmızı kümeler, 5 ortak atıf alma ağıyla yeşil renkteki kümeler ise daha az atıf alan kümeler olmuştur. Sonuç olarak son dönemlerde spor bilimlerinde yapay zekâ kullanımına yönelik oldukça fazla yayın yapıldığı ve konuya ilginin arttığı görülmüştür.

Anahtar Kelimeler: Bibliyometrik Analiz, Spor Bilimleri, Yapay Zekâ.

INTRODUCTION

In our changing and developing world, technological advances, social media platforms, and artificial intelligence development have brought about large-scale changes and transformations in education and sports. Artificial intelligence, which has developed a lot since its first appearance, has become very popular today and has started to be used in the private and public sectors. Artificial intelligence technologies, with their positive and negative effects, have paved the way for revising all systems operating with traditional methods. Artificial intelligence platforms, which provide services according to individual or corporate needs, have brought a different perspective to the ways and methods of learning. The active use of artificial intelligence in contemporary sports sciences and their operations has introduced an entirely new paradigm (10).

As can be seen, technological developments and the use of artificial intelligence in sports and their functioning have brought about many changes. Recently, especially in athlete performance measurements, smart stadiums, sports facilities integrated with the best technology, wearable technologies, and smart sports equipment have brought quality service in sports and their functioning. In this regard, they make it possible to obtain the best results in improving athlete performance. With artificial intelligence technologies, energy savings in sports facilities have reached the best level (32).

Nowadays, when technological developments have reached a very advanced level, new applications, technological products, and services in sports and their functioning have gained a different dimension, thanks to social media platforms, digital systems, and artificial intelligence technologies. Artificial intelligence technologies have provided significant gains for athletes in areas such as the type of training, performance development, strength gain and physical development, and psychological and mental strengthening. From the audience's perspective; it can be seen that technology and artificial intelligence technologies have brought about a great change and transformation in terms of offering a high-quality service for an enjoyable viewing experience, decision-making and fair evaluation, and making future sports predictions and analysis (23).

Artificial intelligence has also become highly functional through recently developed mobile applications aimed at treating athletes' injuries and enhancing their performance. In addition to offering programs that include preventive measures against potential injuries and risks in athletes, artificial intelligence also entails concerns regarding the protection of athletes' data (22).

As can be seen, athletic injuries result in financial, health-related, and psychological losses. Through analyses and evaluations conducted with the help of specific algorithmic programs, artificial intelligence technology minimizes these risks. Particularly in sports medicine, artificial intelligence—widely employed across various domains—significantly contributes through wearable technologies and sensor-equipped equipment by

maximizing sensory perception, minimizing anxiety and fear, and optimizing motivation and performance. Today, sports medicine greatly benefits from artificial intelligence technologies in these respects (24).

As observed in existing studies, artificial intelligence is widely used not only in mobile applications and sports medicine but also in athlete nutrition. Especially in recent times, with the increasing use of artificial intelligence, it is believed that AI can have a significant impact on analyzing the most appropriate nutritional programs for athletes aiming to improve performance, muscle mass, speed, explosive strength, endurance, and physical transformation. By analyzing athletes' genetic structures, physiological measurements, and performance data, artificial intelligence technologies can now calculate with high accuracy how, to what extent, and at what intervals nutritional values should be consumed to achieve maximum efficiency in the shortest possible time. Alongside all these positive developments, concerns also arise regarding the continuation of artificial intelligence development within systems that may violate data privacy and ethical principles (13).

By looking at the historical process of artificial intelligence technology and its understanding, artificial intelligence, which was first discussed by John McCarthy at the Dortmund conference in 1956, has undergone great changes and developments until today. Artificial intelligence, in terms of its operation, is continuously advancing in several areas. These include very early learning, making intelligent predictions, solving extremely difficult and time-consuming problems in a very short period, providing forecasts and predictions related to all kinds of climate, natural, and human events, and offering the most likely possibility by considering the conditions at hand. Additionally, it is capable of adopting different languages and cultural understandings, achieving rapid adaptation, developing programs in the fields of education and training according to the needs of the era, and producing efficient and effective solutions as well as outlining roadmaps. With each passing day, artificial intelligence is further enhancing itself in these areas (2).

As a result, it is predicted that artificial intelligence, which has many benefits in sports and its operations, will be integrated into all functions of sports day by day. In this study, it was aimed to examine the bibliometric analysis of research articles on the use of artificial intelligence in sports sciences, which is the subject of many academic studies, and it aimed to emphasize the importance and future of the use of artificial intelligence in sports sciences.

METHOD

Research Design

In this study, 164 studies related to artificial intelligence in sports sciences in the Web Of Science (WoS) database were examined using the bibliometric analysis method. Bibliometric analysis is the description of the findings obtained as a result of analyzing academic studies conducted in certain fields by making some field narrowing (3). Bibliometric studies were first started in 1917 by Cole and Eales. The examination of bibliometric studies in Türkiye shows that the first study was in the 1970s (14). When looking at bibliometric analysis from another perspective, it is seen that it examines the distribution of certain field-specific studies by years, the relationships in areas such as author, institution, journal, reference, common word network, common author network, and common citation, and reveals the conceptual, social and intellectual structure of the research (6). Bibliometric analysis is a very popular and effective research method that is frequently used in academic studies and aims to obtain and interpret quantitative and qualitative data from studies conducted in a certain field from the past to the present. Bibliometric analysis reveals the results of the studies in two ways, one of which is the equivalent and the impact of the studies in the academic world, and the other is the comparative mapping of the studies (8).

Data Collection

In the first stage of creating the data, some criteria were determined for the classification of the study. These criteria were keywords, period, document type, and research field. As the first criterion, the keyword, "sports sciences and artificial intelligence" was written. As the second criterion, only articles were selected for the document type. As the third criterion, while the starting year for the period is not determined, July 2, 2024, is determined as the ending date. As the fourth criterion, sports research areas were selected in the research category. Finally, the scanning was started by typing the keywords "sports sciences and artificial intelligence"

into the WoS database and selecting the "topic" research area. As a result of this process, 164 studies were reached. These studies were then downloaded to the computer in "Plain text file" format and the findings of the study were obtained.

Data Analysis

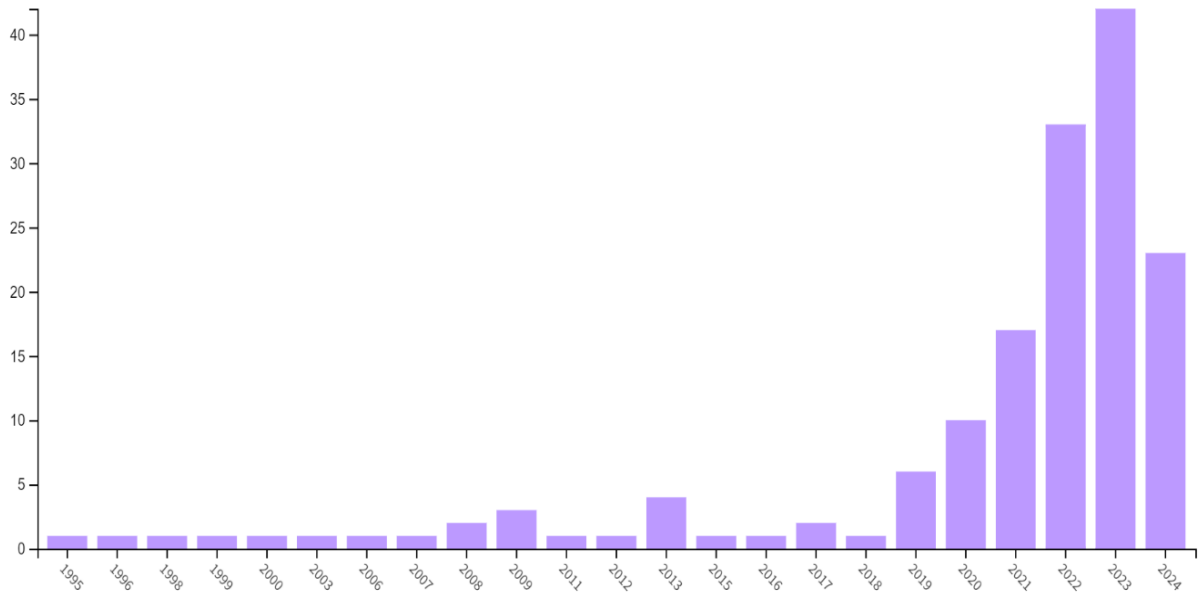
The databases that bibliometric method researchers mostly prefer in their studies are “Scopus”, “Google Scholar” and “Web of Science” (17). The data in the VOSviewer database can be classified and visualized using the bibliometric analysis method. In this way, relationships between data can be examined more easily. In our study, the data of the most cited articles, authors, journals, institutions, and countries on artificial intelligence in sports sciences were obtained with bibliometric analysis data, and within the scope of citation analysis, the authors, journals, institutions, and countries that published the most articles on artificial intelligence in sports sciences were revealed. As a co-author analysis, the authors who collaborate most in the field of artificial intelligence in sports sciences were examined, and within the scope of keyword analysis, the common keywords used by authors in sports sciences and finally common collaboration networks were revealed.

FINDINGS

In this study, a bibliometric analysis of studies on artificial intelligence in sports sciences was conducted among the journals in the WoS database.

Distribution of Articles Published on Artificial Intelligence by Years

The findings showing the distribution of studies on the use of artificial intelligence in sports sciences in the WoS database by years are shown in Graph 1 as follows.



Graph 1. Distribution of publications by years

When Graph 1 is examined, it is observed that the first publication on artificial intelligence in sports sciences in the WoS indexes was published in 1995, and until 2007, the number of publications was very low and the publication increases were parallel. There were small but parallel increases in 2008 and 2009, and again a small parallel decrease in 2011 and 2012 was observed, these parallel decreases reached the levels of 2007. There was a significant increase in 2013, parallel decreases were observed in 2015 and 2016, a small increase in the number of publications was observed in 2017, and a decrease was observed again in 2018. Gradual but substantial increases were seen from 2019 to 2023, and it was understood that the real peak in the graph was in 2023. Although there were decreases in 2024, it did not decrease more than in 2021.

Most Cited Articles on Artificial Intelligence in Sports Sciences

According to the data obtained from the WoS database, Table 1 shows information about the top 15 most cited articles on artificial intelligence in sports sciences as follows.

Table 1. Most cited articles

	Article name	Total citations	Citation average
1	"Contessa P, Adam A, De Luca CJ. Motor unit control and force fluctuation during fatigue. Journal of Applied Physiology, 2009; 107(1): 235-243."	107	6,69
2	"Dergaa I, Chamari K, Zmijewski P, Saad HB. From human writing to artificial intelligence generated text: Examining the prospects and potential threats of ChatGPT in academic writing. Biology of Sport, 2023; 40(2): 615-622."	81	40,5
3	"Savelberg HHCM, De Lange ALH. Assessment of the horizontal, fore-aft component of the ground reaction force from insole pressure patterns by using artificial neural networks. Clinical Biomechanics, 1999; 14(8): 585-592."	72	2,77
4	"Nawab SH, Wotiz RP, De Luca CJ. Decomposition of indwelling EMG signals. Journal of Applied Physiology, 2008; 105(2): 700-710."	64	3,76
5	"Novatchkov H, Baca A. Artificial intelligence in sports on the example of weight training. Journal of Sports Science and Medicine, 2013; 12(1): 27-37."	52	4,33
6	"Ramkumar PN, Kunze KN, Haeberle HS, Karnuta JM, Luu BC, Nwachukwu BU, Williams RJ. Clinical and research medical applications of artificial intelligence. Arthroscopy: The Journal of Arthroscopic and Related Surgery, 2021; 37(5): 1694-1697."	49	12,25
7	"Yi PH, Wei J, Kim TK, Sair HI, Hui F, Hager GD, Fritz J, Oni JK. Automated detection & classification of knee arthroplasty using deep learning. The Knee, 2020; 27(2): 535-542."	49	9,8
8	"Jo C, Ko S, Shin WC, Han HS, Lee MC, Ko T, Ro DH. Transfusion after total knee arthroplasty can be predicted using the machine learning algorithm. Knee Surgery, Sports Traumatology, Arthroscopy, 2020; 28(6): 1757-1764."	44	8,8
9	"Armand S, Watelain E, Roux E, Mercier M, Lepoutre FX. Linking clinical measurements and kinematic gait patterns of toe-walking using fuzzy decision trees. Gait & Posture, 2007; 25(3): 475-484."	44	2,44
10	"Bartlett R. Artificial intelligence in sports biomechanics: New dawn or false hope?. Journal of Sports Science and Medicine, 2006; *5*(4): 474-479."	40	2,11
11	"Karnuta JM, Churchill JL, Haeberle HS, Nwachukwu BU, Taylor SA, Ricchetti ET, Ramkumar PN. The value of artificial neural networks for predicting length of stay, discharge disposition, and inpatient costs after anatomic and reverse shoulder arthroplasty. Journal of Shoulder and Elbow Surgery, 2020; 29(11): 2385-2394."	34	6,8
12	"Pua YH, Kang H, Thumboo J, Clark RA, Chew ESX, Poon CLL, Chong HC, Yeo SJ. Machine learning methods are comparable to logistic regression techniques in predicting severe walking limitation following total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy, 2020; 28(10): 3207-3216."	33	6,6
13	"Ramkumar PN, Luu BC, Haeberle HS, Karnuta JM, Nwachukwu BU, Williams RJ. Sports medicine and artificial intelligence: A primer. The American Journal of Sports Medicine, 2022; 50(4): 1166-1174."	30	7,5
14	"Bongiovanni T, Trecroci A, Cavaggioni L, Rossi A, Perri E, Pasta G, Iaia FM, Alberti G. Importance of anthropometric features to predict physical performance in elite youth soccer: A machine learning approach. Research in Sports Medicine, 2021; 29(3): 213-224."	28	5,6
15	"Riganello F, Dolce G, Sannita, WG. Heart rate variability and the central autonomic network in severe disorder of Consciousness. Journal of Rehabilitation Medicine, 2012; 44(6): 495-501."	26	2

When Table 1 is examined, it is apparent that the most cited article with 107 citations is "Motor unit control and force fluctuation during fatigue" (Contessa P, Adam A, De Luca CJ). In that study, motor unit control and fluctuation during fatigue are mentioned. With an average of 40.5 citations, the study titled "From human writing to artificial intelligence generated text: Examining the prospects and potential threats of ChatGPT in academic writing" (Dergaa I, Chamari K, ... Saad HB) is observed to be the highest-performing

work in terms of average citation performance. In this study, the use of ChatGPT in academic writing is mentioned.

Researchers with the Most Publications and Citations on the Use of Artificial Intelligence in Sports Sciences

According to the results obtained from the WoS database, Table 2 shows the information of the top 15 researchers who published the most and received the most citations among studies on the use of artificial intelligence in sports sciences.

Table 2. Researchers with the most publications and citations

	Authors	Number of Publications	Citation Average		Authors	Number of Publications	Number of Citations
1	**Kunze, Kyle N.**	6	3.659	**1**	**De Luca, Carlo J.**	2	171
2	**Pareek, Ayoosh**	5	3.049	**2**	**Karnuta, Jaret M.**	5	139
3	**Ramkumar, Prem N.**	5	3.049	**3**	**Ramkumar, Prem N.**	5	139
4	**Nwachukwu, Benedict U.**	5	3.049	**4**	**Nwachukwu, Benedict U.**	5	133
5	**Karnuta, Jaret M.**	4	2.439	**5**	**Haeberle, Heather S.**	4	123
6	**Polce, Evan M.**	4	2.439	**6**	**Adam, Alexander**	1	107
7	**Dergaa, Ismail**	4	2.439	**7**	**Contessa, Paola**	1	107
8	**Klemt, Christian**	4	2.439	**8**	**Chamari, Karim**	1	81
9	**Kwon, Young-Min**	4	2.439	**9**	**Dergaa, Ismail**	1	81
10	**Haeberle, Heather**	4	2.439	**10**	**Kunze, Kyle N.**	4	81
11	**Persson, Andreas**	3	1.829	**11**	**Saad, Helmi Ben**	1	81
12	**Wolfson, Julian**	3	1.829	**12**	**Zmijewski, Piotr**	1	81
13	**Williams Iii, Riley J.**	3	1.829	**13**	**Luu, Bryan C.**	2	79
14	**Visnes, Havard**	3	1.829	**14**	**Williams, Riley J.**	2	79
15	**Solvejg Wastvedt**	3	1.829	**15**	**De Lange, Alh**	1	72

Upon examining Table 2, it is observed that the most productive researcher in the field of artificial intelligence in sports sciences is "Kunze, Kyle N." with 6 articles and an average of 3,659 citations. With 5 publications and an average of 3,049 citations, "Pareek, Ayoosh" stands out in second place, followed by "Ramkumar, Prem N." in third place, and "Nwachukwu, Benedict U." in fourth place. When we look at the number of publications of other researchers in the table, it is seen that they vary between 4 and 3. When looking at the researchers with the highest number of citations in the field of artificial intelligence in sports sciences, "De Luca, Carlo J." stands out in first place with 171 citations. "Karnuta, Jaret M." is in second place with 139 citations, followed closely by "Ramkumar, Prem N." in third place, also with 139 citations. It is noteworthy that in the number of citations, "Adam, Alexander" and "Contessa, Paola" stand out with 107 citations, even though they have a single article each.

Journals with the Most Publications and Citations on Artificial Intelligence in Sports Sciences

According to the data obtained from the WoS database, information about the 15 journals with the most publications and citations on artificial intelligence in sports sciences is shown in Table 3 as follows.

Table 3. Journals with the most publications and citations

	Journal name	Number of citations	Number of publications
1	**"Knee Surgery, Sports Traumatology, Arthroscopy"**	226	11
2	**"Journal of Applied Physiology"**	184	3
3	**"Clinical Biomechanics"**	104	3
4	**"Journal of Sports Science and Medicine"**	92	2
5	**"Arthroscopy- The Journal of Arthroscopic and Related Surgery"**	85	4
6	**"Biology of Sport"**	81	1
7	**"Gait & Posture"**	58	2
8	**"The American Journal of Sports Medicine"**	52	3
9	**"The Knee"**	49	1
10	**"Archives of Physical Medicine and Rehabilitation"**	43	2
11	**"Journal of Sports Sciences"**	37	2
12	**"Journal of Shoulder and Elbow Surgery"**	34	1
13	**"European Journal of Sport Science"**	29	2
14	**"Research in Sports Medicine"**	28	1
15	**"Journal of Rehabilitation Medicine"**	26	1

Upon examining Table 3, the journal with the highest number of publications, with 11 articles, is "Knee Surgery, Sports Traumatology, Arthroscopy." In second place, with 184 citations, is the "Journal of Applied Physiology," and in third place, with 104 citations, is "Clinical Biomechanics." Although "Biology of Sport" has only 1 publication, it stands out with 81 citations. When examining these journals in terms of publication and citation numbers, as well as their aims and scope, it can be said that they are the most productive and influential journals in the field of artificial intelligence in sports sciences.

Institutions with the Most Publications and Citations on Artificial Intelligence in Sports Sciences

According to the results obtained from the WoS database, information about the top 15 institutions with the most publications and citations on artificial intelligence in sports sciences is shown in Table 4 as follows.

Table 4. Institutions with the most publications and citations

	Institution name	Number of articles	Number of citations		Institution name	Number of citations	Number of articles
1	**Hosp Special Surg**	8	171	**1**	**Boston Univ**	171	2
2	**Cleveland Clin**	4	123	**2**	**Hosp Special Surg**	171	8
3	**Harvard Med Sch**	4	70	**3**	**Cleveland Clin**	123	4
4	**Brigham & Women Hosp**	3	95	**4**	**Univ Padua**	107	1
5	**Maastricht Univ**	3	96	**5**	**Maastricht Univ**	96	3
6	**Univ Wisconsin**	3	32	**6**	**Brigham & Women Hosp**	95	3
7	**Victoria Univ**	3	58	**7**	**Jozef Pilsudski Univ Phys Educ Warsaw**	81	1
8	**Baylor Coll Med**	2	79	**8**	**Natl Observ Sport**	81	1
9	**Boston Univ**	2	171	**9**	**Orthopaed & Sports Med Hosp**	81	1
10	**Rush Univ**	2	22	**10**	**Primary Health Care Corp Phcc**	81	1
11	**Univ Pisa**	2	52	**11**	**Univ Sfax**	81	1
12	**Univ Trento**	2	29	**12**	**Univ Sousse**	81	1
13	**Univ Verona**	2	29	**13**	**Baylor Coll Med**	79	2
14	**Aarhus Univ Hosp**	1	21	**14**	**Fontys Univ Profess Educ**	72	1
15	**Auckland Univ Technol**	1	16	**15**	**Univ Utrecht**	72	1

Upon examining Table 4, the most productive institution in terms of the number of publications is "Hosp Special Surg," ranked first with 8 articles. In second place is "Cleveland Clin" with 4 publications, followed by "Harvard Med Sch" in third place with 4 publications, and "Brigham & Women Hosp" in fourth place with 3 publications. In terms of citation rankings, "Boston Univ" holds the top spot with 171 citations, followed by "Hosp Special Surg" also with 171 citations, and "Cleveland Clin" in third place with 123 citations. Additionally, it is noteworthy that "Univ Padua" ranks fourth with 107 citations from a single publication.

Countries with the Most Publications and Citations on Artificial Intelligence in Sports Sciences

Considering the results obtained from the WoS database, information about the top 15 countries with the most publications and citations on artificial intelligence in sports sciences is shown in Table 5 as follows.

Table 5. Countries with the most publications and citations

	Country Name	Number of articles	Number of citations		Country Name	Number of citations	Number of articles
1	**ABD**	23	613	**1**	**ABD**	613	23
2	**Italy**	6	214	**2**	**Italy**	214	6
3	**Australia**	5	102	**3**	**Australia**	102	5
4	**Austria**	4	90	**4**	**Netherlands**	96	3
5	**New Zealand**	4	79	**5**	**Austria**	90	4
6	**Netherlands**	3	96	**6**	**Poland**	81	1
7	**Brazil**	2	27	**7**	**Qatar**	81	1
8	**Denmark**	2	32	**8**	**Tunisia**	81	1
9	**France**	2	57	**9**	**New Zealand**	79	4
10	**Germany**	2	31	**10**	**South Korea**	66	2
11	**Singapore**	2	47	**11**	**Switzerland**	60	2
12	**South Korea**	2	66	**12**	**France**	57	2
13	**Switzerland**	2	60	**13**	**Singapore**	47	2
14	**Croatia**	1	11	**14**	**Denmark**	32	2
15	**Egypt**	1	10	**15**	**Germany**	31	2

Looking at the results of the data in Table 5, the United States stands out as the most productive country with 23 publications. When examining the other most productive countries related to artificial intelligence, Italy ranks second with 6 publications, Australia ranks third with 5 publications, and Austria ranks fourth with 4 publications. In terms of citation rankings, the United States is again in first place with 613 citations, followed by Italy in second place with 214 citations, Australia in third place with 102 citations, and the Netherlands in fourth place with 96 citations. Despite having only one publication each, Poland, Qatar, and Tunisia are notable as effective countries in the citation rankings with 81 citations.

Collaboration Analyzes Between Institutions Publishing on Artificial Intelligence in Sports Sciences

When looking at the results obtained from the WoS database, a total of 123 institutions were reached. Based on the criterion of having at least one publication, the two institutions with the strongest collaboration are represented in two different colors, totaling 11 institutions. The inter-institutional collaboration network in the obtained findings is shown in Figure 1 as follows.

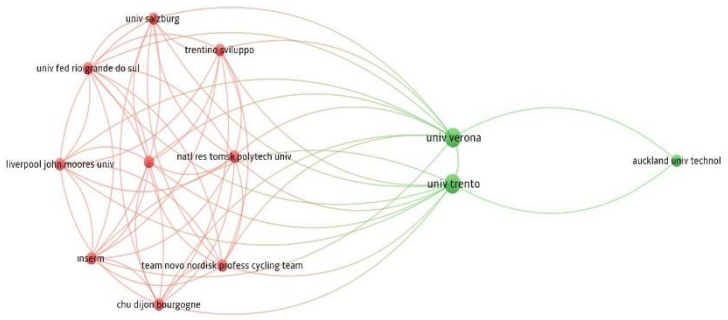


Figure 1. Inter-institutional collaboration network

Upon examining the results of Figure 1, it is observed that there are two clusters in different colors. This indicates that there is a stronger collaboration among institutions within the same color. In the inter-institutional collaboration network, a total of 11 institutions were identified, and the most intense collaboration is seen in the red clusters with 8 institutions. The institutions with the strongest collaboration network are observed to be "Natl Tomsk Polytech Univ," "Team Nova," "Trentino Svlippo," "Univ Salzburg," "Univ Fed Rio," "Liverpool John," "Insefm," and "Chu Dijon." On the other hand, the institutions with less collaboration are "Univ Verona," "Univ Trento," and "Auckland Univ," which are represented in green and consist of 3 institutions.

Common Keyword Analyzes of Authors Publishing on Artificial Intelligence in Sports Sciences

Upon examining the results of the WoS data, a total of 177 different author keywords used in the publications have been identified. As a result of using these keywords at least twice as a criterion, 16 different keywords have emerged. Common keyword analysis regarding artificial intelligence in sports sciences is shown in Figure 2 as follows.

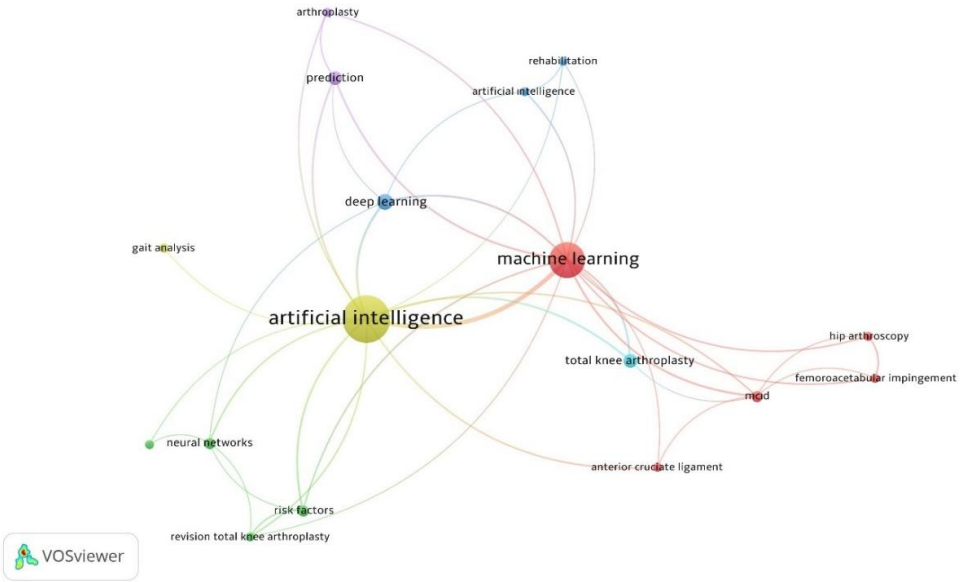


Figure 2. Common keyword network

According to the results of Figure 2, an examination of the findings regarding the keywords most frequently used by authors related to artificial intelligence in sports sciences reveals 16 clusters, with the densest clusters being the red (machine learning) and yellow (artificial intelligence) clusters. The keywords in the red clusters that stand out are "Mcid," "Femoroacetabular impingement," "hip arthroscopy," and "anterior cruciate ligament."

Co-Citation Analysis of Authors Publishing on Artificial Intelligence in Sports Sciences

Upon examining the results of the WoS data in the author co-citation analysis, a total of 1,538 cited authors have been identified. When the criterion of receiving more than 5 citations was established, 12 authors emerged. The co-citation networks of these authors are illustrated in Figure 3 as follows.

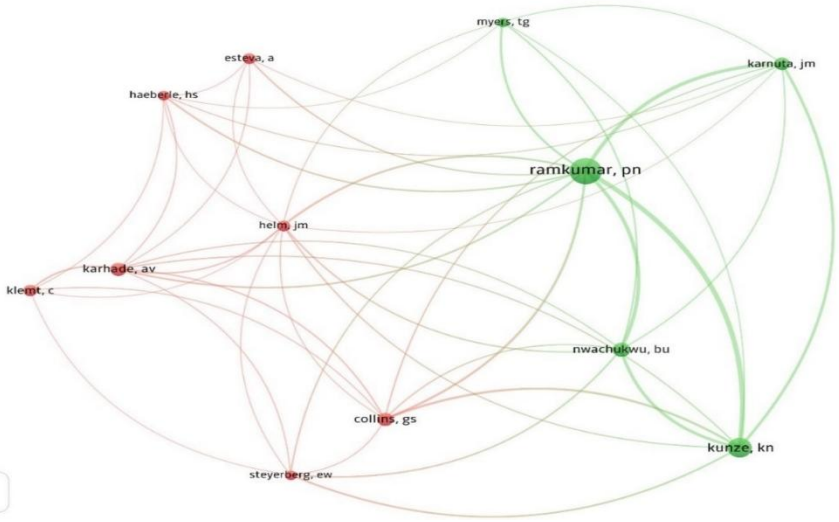


Figure 3. Authors' co-citation network

When analyzing the findings obtained from the results in Figure 3, networks related to the authors who received co-citations were identified. These networks consist of two clusters with different colors. In this two-colored cluster, a total of 12 authors were found in the co-citation network. The red cluster, with 7 authors, stands out as having the most co-citation connections. This situation is related to their close collaboration with other clusters. The authors in the dense red clusters are observed to be "Helm, J. M," "Collins, G. S," "Esteva, A," "Haberle, H. S," "Karhade, A. V," "Steyerberg, E. W," and "Klemt, C." In the green cluster, there are 5 authors: "Ramkumar, P. N," "Kunze, K. N," and "Nwachukwu, B. U," who are identified as the most cited authors.

DISCUSSION AND CONCLUSION

This study aims to examine the bibliometric analysis of artificial intelligence studies in sports sciences. When examining Graphic 1, it is observed that the first publication related to artificial intelligence in sports sciences indexed in WoS was published in 1995 and that the number of publications was very low until 2007. It has been noted that publication increases have shown parallel trends. There were small but parallel increases in the years 2008 and 2009, followed by slight parallel decreases in 2011 and 2012, bringing the numbers back to the level of 2007. A significant increase occurred in 2013, with parallel decreases observed in 2015 and 2016. In 2017, there was a slight increase in the number of publications, while another decrease was noted in 2018. From 2019 to 2023, there have been gradual but substantial increases, and it is understood that the peak occurred in 2023. Although there were decreases in 2024, they have not fallen below the levels of 2021 (Graphic 1). The recent increase in publication numbers is attributed to the growing interest in artificial intelligence and the prediction that artificial intelligence technologies will be integrated into many areas of life in the upcoming period.

In a study conducted by Şimşek (33) on artificial intelligence; it was reported that nowadays, research on artificial intelligence technologies has increased both in academic circles and in the business world. Similarly, Ceyhan and Çakır (7) stated that there has been an increased interest in the use of artificial intelligence in sports sciences recently, which supports the data of our study.

When examining the data in the first table related to artificial intelligence in sports sciences, it is observed that the studies support the thoughts mentioned above. Looking at the statistical counterpart of academic studies on the use of artificial intelligence in sports sciences in this study, the article with the highest number of citations, with 107 citations, is "Motor unit control and force fluctuation during fatigue" (Contessa P, Adam A, De Luca, CJ). This study discusses motor unit control and fluctuations during fatigue. With an average of 40.5 citations, the study titled "From human writing to artificial intelligence generated text: Examining the prospects and potential threats of ChatGPT in academic writing" (Dergaa I, Chamari K, ... Saad HB) is seen to have the highest average citation performance. This study discusses the use of ChatGPT in academic writing (Table 1).

Considering the content of the data obtained in the studies, it is thought that artificial intelligence will be a part of all social and community life in the future, and many institutions, sports, and operations will be integrated into artificial intelligence systems. In research, it is observed that some sources adopt the view that humanity will confront artificial intelligence and that artificial intelligence may bring about the end of humanity. However, it is also observed that some thinkers advocate the view that if artificial intelligence is given proper use and functionality in light of international norms and ethical values, it can complement humanity, contribute to peace, and promote social justice, thus offering a beneficial use in the service of humanity (27).

According to the data from the second table obtained from the WoS database, the most productive researcher in artificial intelligence in sports sciences is "Kunze, Kyle N." with 6 articles and an average of 3,659 citations. Following "Kunze, Kyle N.", with 5 publications and an average of 3,049 citations, "Pareek, Ayoosh" ranks second, "Ramkumar, Prem N." ranks third, and "Nwachukwu, Benedict U." ranks fourth. When looking at the number of publications by other researchers in the table, it is seen that the numbers vary between 4 and 3. Regarding the researchers with the most citations in artificial intelligence in sports sciences, "De Luca, Carlo J." stands out in first place with 171 citations. In second place is "Karnuta, Jaret M." with 139 citations, and in third place, "Ramkumar, Prem N." also stands out with 139 citations. Despite having only one article, "Adam, Alexander" and "Contessa, Paola" stand out with 107 citations, which is noteworthy (Table 2).

On the other hand, when examining the content of studies on artificial intelligence, it is seen that in addition to those who assess the opportunities provided by artificial intelligence technologies positively, there are also some opponents of artificial intelligence. Some thinkers argue that AI-powered machines, systems, and programs will not be able to think like humans and will not exhibit the emotions and consciousness that humans possess (25). Another group of thinkers predicts that in the coming years, robotic systems capable of performing all tasks and emotions that humans experience will be developed thanks to artificial intelligence technologies and that AI forms will provide great benefits to humanity (25).

According to the data from Table 3 obtained from the WoS database, when looking at the journals with the most citations and publications in artificial intelligence within sports sciences, the journal with the highest number of publications is "Knee Surgery, Sports Traumatology, Arthroscopy" with 11 publications. The journal "Journal of Applied Physiology" ranks second with 184 citations, and in third place is "Clinical Biomechanics" with 104 citations. Despite having only 1 publication, "Biology of Sport" stands out with 81 citations (Table 3). When these journals are examined in terms of the number of publications and citations, as well as their purpose and scope, it can be said that they are the most productive and influential journals in the field of artificial intelligence in sports sciences.

In our study on the use of artificial intelligence in sports sciences, it is believed that in the coming years, artificial intelligence technologies will be widely used in sports management and operations, exercise and physical transformations, viewing of sports competitions, athlete performance and talent identification, genetic measurements, and the techniques and capacities of coaches (10).

According to the data from Table 4 obtained from the WoS database, when looking at the institutions with the most publications and citations in artificial intelligence within sports sciences, “Hosp Special Surg” ranks first as the most productive institution with 8 publications. “Cleveland Clin” ranks second with 4 publications, followed by “Harvard Med Sch” in third place with 4 publications, and “Brigham & Women Hosp” in fourth place with 3 publications. In terms of citation rankings, “Boston Univ” ranks first with 171 citations, followed by “Hosp Special Surg” also with 171 citations, and “Cleveland Clin” in third place with 123 citations. Additionally, it is noteworthy that “Univ Padua” ranks fourth with 107 citations despite having only one publication (Table 4).

As seen, significant progress has been made in the development of artificial intelligence in recent years, making it the subject of many scientific studies, and numerous predictions regarding artificial intelligence have been put forward. In their study, Feijóo et al. (12) stated that artificial intelligence technology will exist in all forms of life and, while offering many advantages, it will also come with certain disadvantages. Additionally, they pointed out that the advancements in artificial intelligence will be integrated into new technologies and approaches that will emerge, and will simplify many aspects of societal life.

According to the data from Table 5 obtained from the WoS database, when looking at the countries with the most publications on artificial intelligence in sports sciences, the United States stands out as the most productive country with 23 publications, ranking first. Among other highly productive countries in artificial intelligence, Italy ranks second with 6 publications, Australia third with 5 publications, and Austria fourth with 4 publications. In terms of citation rankings, the United States again ranks first with 613 citations, followed by Italy in second place with 214 citations, Australia in third place with 102 citations, and the Netherlands in fourth place with 96 citations. Despite having only one publication, Poland, Qatar, and Tunisia stand out as impactful countries in the citation rankings with 81 citations (Table 5).

When examining the aforementioned studies on artificial intelligence, it becomes evident that humanity is preparing for a new era with the emergence of artificial intelligence. Particularly in developed countries, artificial intelligence technologies are being actively used in both the private and public sectors. Looking at the content of the research conducted on artificial intelligence, it is predicted that, with the development of AI systems in the future, artificial intelligence will dominate not only in social and societal areas but also in the field of sports. Preparations are recommended for the upcoming period in which robots and artificial intelligence will prevail. In this context, it has become a necessity to establish an international will to control and develop artificial intelligence, and to use it for the benefit of humanity (19).

Artificial intelligence development and usage areas are increasing day by day. As can be seen, developed countries are quite advanced in getting efficiency in artificial intelligence technologies. Artificial intelligence, which has become very popular in Türkiye, has gained a place in academic studies and has begun to be used in many fields. In addition to achieving sporting success, the use of artificial intelligence also demonstrates Türkiye’s capacity to revise itself by not being indifferent to new developments in the world and preventing foreign dependency. The increasing use of artificial intelligence, especially in the field of sports, informs us that new rules and regulations will come and some new applications will begin in the coming periods (32).

When the figure obtained from the WoS database is analyzed, it is observed that there are two different colored clusters. This situation indicates that there is stronger collaboration among institutions of the same color. In the inter-institutional collaboration network, a total of 11 institutions have been identified, with the most intense collaboration occurring in the red clusters, which consist of 8 institutions. The institutions with the strongest collaboration network are seen to be “Natl Tomsk Polytech Univ,” “Team Nova,” “Trentino Svlippo,” “Univ Salzburg,” “Univ Fed Rio,” “Liverpool John,” “Insefm,” and “Chu Dijion.” On the other hand, institutions with less collaboration include the green-colored “Univ Verona,” “Univ Trento,” and “Auckland Univ,” each with 3 institutions (Figure 1).

According to the data obtained from Figure 2 of the WoS database, a total of 177 different author keywords used in the publications included in the research have been identified. It has been established that these keywords should be used at least twice as a criterion. As a result of this process, 16 different keywords have emerged. When examining the keyword network created for the common keyword analysis related to artificial intelligence in sports sciences, it is observed that based on the results of Figure 2, 16 clusters have appeared concerning the most frequently used keywords by authors related to the topic of artificial intelligence in sports sciences, with the most prominent clusters being the red cluster (machine learning) and the yellow cluster (artificial intelligence). The keywords found in the red clusters include "Mcid", "Femoroacetabular impingement," "Hip arthroscopy," and "Anterior cruciate ligament" (Figure 2).

According to the results in Figure 3 obtained from the WoS database, there are 1,538 authors cited in the co-citation analysis. A criterion of receiving more than 5 citations was established, leading to a total of 12 authors. When examining the co-citation networks of these authors, networks related to the authors who were cited together have been reached. These networks consist of two clusters with different colors. In this two-colored co-citation network, a total of 12 authors have been identified. The red cluster with 7 authors stands out the most in the co-citation network. This situation is associated with their close collaboration with other clusters. The authors found in the densely populated red clusters are "Helm, J. M," "Collins, G. S," "Esteva, A," "Haberle, H. S," "Karhade, A. V," "Steyerberg, E. W," and "Klemt, C." In the green cluster, 5 authors, namely "Ramkumar, P. N," "Kunze, K. N," and "Nwachukwu, B. U," are noted as the most cited authors (Figure 3).

Considering the scope and content of the results obtained, it is understood that there are numerous studies on the use of artificial intelligence in sports sciences and other fields and that artificial intelligence technologies have become quite popular in the academic world. It is also anticipated that in the upcoming period, artificial intelligence technologies will be utilized in many areas. Particularly, when looking at the content of studies related to the use of artificial intelligence in sports management, it is clear that they have a global impact. Kayıkçı and Bozkurt (19) stated in their study that the new generation will not struggle to keep up with the evolving artificial intelligence and digital systems, whereas older generations will find it very challenging to adapt. They noted that this is because new generations start life with the internet and integrate technology and social media into all aspects of their lives.

When examining the research articles on the use of artificial intelligence in sports sciences, which is also the subject of our study, it can be seen that incredible results have been achieved in the performance increases of athletes in tests conducted with the support of artificial intelligence. Analyses and tests conducted using artificial intelligence technologies have also been the subject of many academic studies. At the same time, the analyses and tests carried out by artificial intelligence provide results that are close to zero error, helping coaches, athletes, and spectators to act and make decisions more accurately (16).

Artificial intelligence has emerged today as a technology utilized across all social and humanistic fields, integrated by many governments and societies around the world. Capable of performing highly intensive and complex tasks in a very short period of time, this technology has been incorporated into numerous aspects of sports. States that employ artificial intelligence technologies gain various advantages. Therefore, as in many other fields, a national policy should be established for the use of artificial intelligence in sports sciences; AI should be integrated into sports education; its significance should be emphasized in academic studies within sports science; it should be utilized in the production of scientific knowledge; and it should be employed to ensure more rational and impartial competitions, as well as to support the development of athletes.

In conclusion, in this study on the use of artificial intelligence in sports sciences, it is observed that artificial intelligence technologies are extensively used in sports and their operations. With the integration of artificial intelligence into every aspect of sports, it is anticipated that it will contribute to providing amateur athletes with higher quality and more effective sports life, enhancing the performance and physical structures of professional athletes, increasing the efficiency of sports public institutions, enabling the sports industry to produce goods and services with better technology, and making sports facilities more modern and accessible. Most importantly, the significant presence of artificial intelligence in academic studies related to sports sciences projects the significance of the subject, as well as the areas it will encompass and its effects in the future.

REFERENCES

1. Armand S, Watelain E, Roux E, Mercier M, Lepoutre FX. Linking clinical measurements and kinematic gait patterns of toe-walking using fuzzy decision trees. Gait & Posture, 2007; 25(3): 475-484.
2. Arslan K. Eğitimde yapay zekâ ve uygulamaları. Batı Anadolu Eğitim Bilimleri Dergisi, 2020; 11(1): 71-88.
3. Barca M, Hızıroğlu M. 2000'li yıllarda Türkiye'de stratejik yönetim alanının entellektüel yapısı. Eskişehir Osmangazi Üniversitesi İ.İ.B.F. Dergisi, 2009; 4(1): 113-148.
4. Bartlett R. Artificial intelligence in sports biomechanics: New dawn or false hope?. Journal of Sports Science and Medicine, 2006; *5*(4): 474-479.
5. Bongiovanni T, Trecroci A, Cavaggioni L, Rossi A, Perri E, Pasta G, Iaia FM, Alberti G. Importance of anthropometric features to predict physical performance in elite youth soccer: A machine learning approach. Research in Sports Medicine, 2021; 29(3): 213-224.
6. Boyack KW, Klavans R. Co-citation analysis, bibliographic coupling, and direct citation: Which citation approach represents the research front most accurately?. Journal of the American Society for Information Science and Technology, 2010; 61(12): 2389-2404.
7. Ceyhan MA, Çakir Z. Examination of fear of missing out (FOMO) states of students who study at the school of physical education and sports in terms of some variables. Education Quarterly Reviews, 2021; 4(4): 419-427. https://doi.org/10.31014/aior.1993.04.04.404
8. Cobo MJ, López-Herrera AG, Herrera-Viedma E, Herrera F. Science mapping software tools: Review, analysis, and cooperative study among tools. Journal of the American Society for information Science and Technology, 2011; 62(7): 1382-1402.
9. Contessa P, Adam A, De Luca CJ. Motor unit control and force fluctuation during fatigue. Journal of Applied Physiology, 2009; 107(1): 235-243.
10. Çakır Z, Ceyhan MA, Gönen M, Erbaş Ü. Yapay Zeka Teknolojilerindeki Gelişmeler ile Eğitim ve Spor Bilimlerinde Paradigma Değişimi. Dede Korkut Spor Bilimleri Dergisi, 2023; 1(2): 56-71.
11. Dergaa I, Chamari K, Zmijewski P, Saad HB. From human writing to artificial intelligence generated text: Examining the prospects and potential threats of ChatGPT in academic writing. Biology of Sport, 2023; 40(2): 615-622.
12. Feijóo C, Kwon Y, Bauer JM, Bohlin E, Howell B, Jain R, Potgieter P, Vu K, Whalley J, Xia J. Harnessing artificial intelligence (AI) to increase wellbeing for all: The case for a new technology diplomacy. Telecommunications Policy, 2020; 44(6): 1-14.
13. Gençoğlu C, Asan S. Dijital çağda sporcu beslenmesi ve yapay zeka. In: Kishalı NF, Özbay S, Ulupınar S, editors. Dijital çağda spor araştırmaları 1. Gaziantep: Özgür Yayınları; 2023. P. 1-91.
14. Hotamışlı M, Erem I. Muhasebe ve finansman dergisi'nde yayınlanan makalelerin bibliyometrik analizi. Muhasebe ve Finansman Dergisi, 2014; (63): 1-20.
15. Jo C, Ko S, Shin WC, Han HS, Lee MC, Ko T, Ro DH. Transfusion after total knee arthroplasty can be predicted using the machine learning algorithm. Knee Surgery, Sports Traumatology, Arthroscopy, 2020; 28(6): 1757-1764.
16. Karafil AY, Abd SYB, Çifci ÖÜA, Kirbaş İ. E-sporda performans ve strateji optimizasyonu için yapay zeka kullanimi. 4. Bilsel International World Science And Research Congress; 22-23 June 2024; İstanbul,Türkiye.
17. Karagoz B, Seref I. Yunus Emre ile ilgili araştırmaların bibliyometrik analizi. Akdeniz Eğitim Araştırmaları Dergisi, 2019; 13(27): 123-141.
18. Karnuta JM, Churchill JL, Haeberle HS, Nwachukwu BU, Taylor SA, Ricchetti ET, Ramkumar PN. The value of artificial neural networks for predicting length of stay, discharge disposition, and inpatient costs after anatomic and reverse shoulder arthroplasty. Journal of Shoulder and Elbow Surgery, 2020; 29(11): 2385-2394.
19. Kayıkçı M, Bozkurt A. Dijital çağda Z ve Alpha kuşağı, yapay zeka uygulamaları ve turizme yansımaları. Sosyal Bilimler Metinleri, 2018; (1): 54-64.
20. Nawab SH, Wotiz RP, De Luca CJ. Decomposition of indwelling EMG signals. Journal of Applied Physiology, 2008; 105(2): 700-710.
21. Novatchkov H, Baca A. Artificial intelligence in sports on the example of weight training. Journal of Sports Science and Medicine, 2013; 12(1): 27-37.
22. Öniz M, Göçer İ. Yapay zekâ destekli mobil uygulamaların spor sakatlanmalarının önlenmesinde etkisi. Egzersiz ve Spor Bilimleri Araştırmaları Dergisi, 2024; 4(2): 74-92.
23. Özsoy D, Özsoy Y, Karakuş O. Endüstri 5.0'da Spor. Fenerbahçe Üniversitesi Spor Bilimleri Dergisi, 2023; 3(2): 83-94.

24. Öztop B. Artificial intelligence applications in sports medicine. III. Uluslararasi Avrasya Sağlik Bilimleri Kongresi; 28-29 Ağustos 2024; Trabzon, Türkiye.
25. Pirim AGH. Yapay zeka. Yaşar Üniversitesi E-Dergisi, 2006; 1(1): 81-93.
26. Pua YH, Kang H, Thumboo J, Clark RA, Chew ESX, Poon CLL, Chong HC, Yeo SJ. Machine learning methods are comparable to logistic regression techniques in predicting severe walking limitation following total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy, 2020; 28(10): 3207-3216.
27. Puaschunder JM. Artificial diplomacy: A guide for public officials to conduct artificial intelligence. Journal of Applied Research in the Digital Economy, 2019; 1: 39-54.
28. Ramkumar PN, Kunze KN, Haeberle HS, Karnuta JM, Luu BC, Nwachukwu BU, Williams RJ. Clinical and research medical applications of artificial intelligence. Arthroscopy: The Journal of Arthroscopic and Related Surgery, 2021; 37(5): 1694-1697.
29. Ramkumar PN, Luu BC, Haeberle HS, Karnuta JM, Nwachukwu BU, Williams RJ. Sports medicine and artificial intelligence: A primer. The American Journal of Sports Medicine, 2022; 50(4): 1166-1174.
30. Riganello F, Dolce G, Sannita, WG. Heart rate variability and the central autonomic network in severe disorder of Consciousness. Journal of Rehabilitation Medicine, 2012; 44(6): 495-501.
31. Savelberg HHCM, De Lange ALH. Assessment of the horizontal, fore-aft component of the ground reaction force from insole pressure patterns by using artificial neural networks. Clinical Biomechanics, 1999; 14(8): 585-592.
32. Şentürk E, Özer M. Sporda teknolojik gelişmeler. Fenerbahçe Üniversitesi Spor Bilimleri Dergisi, 2022; 2(2): 49-63.
33. Şimşek ÖG. Endüstri 4.0 ve Yapay Zeka Çerçevesinde genç işgücü için aktif işgücü programlarının dönüşümü [Uzmanlık tezi]. Ankara: Türkiye İş Kurumu Genel Müdürlüğü; 2023.
34. Yi PH, Wei J, Kim TK, Sair HI, Hui F, Hager GD, Fritz J, Oni JK. Automated detection & classification of knee arthroplasty using deep learning. The Knee, 2020; 27(2): 535-542.