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A Bibliometric Trend Analysis of Sports Biomechanics Research in the Era of Industry 4.0

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Abstract

The purpose of this study is to conduct a comprehensive bibliometric analysis of sports biomechanics research during the Industry 4.0 period focusing on identifying patterns in publications, technological innovations, research hotbeds, and collaborations for the time span of 2020 to 2025. Using VOSViewer and Microsoft Excel, citation patterns, keyword co-occurrences, and global research networks in 1,619 publications tracked by Scopus were analyzed, revealing the rapid integration of technology in tracking and improving injury prevention and rehabilitation. Studies of elite athletes and mainstream sports remain predominant, while amateur athletes and non- mainstream sports receive considerably less research attention. Collaboration on a global scale is dominated by primaries such as the US, UK, and Australian economies and scholars. Of particular interest are the significant advancements and applications of AI in data processing, real-time systems, and predictive biomechanical systems. However, challenges continue to exist which include lack of accessibility and inclusion of multidisciplinary approaches to the practical application in diverse sport populations. This study, in its entirety, illustrates the need for a collection of well-coordinated and integrated approaches to technology in sports biomechanics. It also offers a clear pathway for contemporary data and a well-defined research agenda. The contributions and outcomes of the study will enhance systems available for athletes, promote alignment within policies, and contribute to the field of contemporary sports science..

Keywords: biomechanics, bibliometric, research trends, sports.

Introduction

Over the past 5 years, the field of biomechanical engineering has garnered interest from both academics and practitioners. The use of new technology has transformed the studies involving gait and performance analysis (Roggio et al., 2021). The use of advanced analytics and the real-time monitoring of wearable devices has made biomechanical parameter tracking and performance optimization in various sports, especially movement-dominating sports, easily accessible (Alzahrani & Ullah, 2024).

Artificial Intelligence (AI) and machine learning allow us to easily analyze complex datasets to provide real-time feedback to improve training, avoid injuries, and inform rehabilitation plans (Souaifi et al., 2025).

Wearable technology enables us to monitor our body's physical and mechanical components in real time. People can learn new things and get ready for mental challenges by employing immersive virtual reality (VR) and augmented reality (AR) environments that look like real world but are controlled (Alzahrani & Ullah, 2024). These modifications could help professional athletes, normal individuals, and even amateur athletes perform better, stay healthy, and get around more easily (Ali et al., 2025).

Technology has advanced significantly, however critical research deficiencies persist. Schumann and Doherty (2024) assert that a lot of studies look at elite athletes, which doesn't include a lot of people or less popular sports. Second, even if wearable technology may correctly collect biomechanical data, it is currently unable to evaluate the data in real time and give coaches and athletes relevant feedback based on the results (Alzahrani & Ullah, 2024). Third, current biomechanical technologies are still hard to get to and use, especially in places with few resources (McDevitt et al., 2022). It could even lead to better training and rehabilitation systems by combining ideas from biomechanics, physiology, psychology, and data science (Padulo, 2025). Integration across disciplines is still not good enough. We need to close these gaps so that more athletes can benefit from advances in biomechanics, sports science research can be more complete, and coaches and politicians can make decisions based on facts.

We desire a bibliometric framework to comprehensively evaluate the progression of sports biomechanics research as we go towards Industry 4.0. Bibliometric analysis enables the quantitative mapping of publishing trends, subject development, and research networks, so offering a holistic view of the knowledge framework and identifying domains necessitating further inquiry (Donthu et al., 2021).

A lot of bibliometric studies have looked at general trends in sports science or exercise physiology. However, there aren't many that focus specifically on sports biomechanics in the context of Industry 4.0, which encompasses AI, IoT, and data-driven analytics. The aim of this work is to rectify that shortcoming by providing a focused bibliometric synthesis of the most recent developments in this field.

This study does a thorough bibliometric analysis of sports biomechanics literature from 2020 to 2025. The analysis. encompasses trends in publications, modifications in keywords, citation networks, and the contributions of prominent authors, institutions, and countries to identify established themes and areas necessitating further research. This study combines patterns to create a framework for future research and practical ways to use new technologies in sports biomechanics to boost performance, avoid injuries, and help people recover.

This project aims to address the subsequent research questions:

1. What are the principal themes and trends in. the publication of sports biomechanics research from 2020 to 2025?
2. Which prominent writers and nations have significantly. contributed to the development of this field?
3. What new topics and areas of study need to be looked into more within the Industry 4.0 framework?

Methods

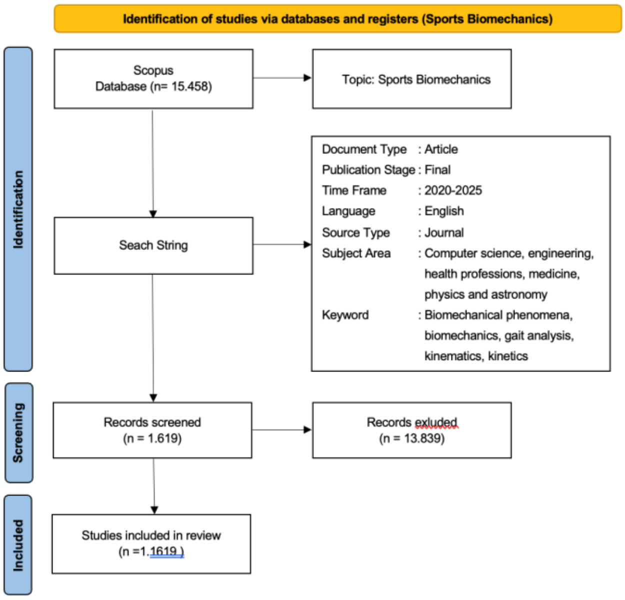
The research method is systematically organized to provide a clear picture of the approach, flow, and steps taken by researchers in answering the research questions (Fàbregues & Guetterman, 2025). The method is presented in a sequential manner so that the research can be understood, reviewed, and replicated by other researchers with the same level of reliability. Therefore, the description of the methods in this study is presented through five main components, namely: research design, participants and data sources, research instruments, research procedures, and data analysis techniques.

Research Design

This study employed a bibliometric design with a Citation Network Analysis (CNA) approach. This design allows for the tracing of specific research activities within the overall prism of internationalisation, dissemination, and networking in the field as structured by the citations. This study used Citation Network Analysis (CNA) as its bibliometric design. This design allows for the tracing of specific research activities within the

Figure 1

PRISMA Flowchart of Search and Screening Strategy



overall prism of internationalisation, dissemination and networking in the field, as structured by the citations. It allows for a complete evaluation of the state of the research in sports biomechanics. Bibliometric analysis can help assess the multiplicity of different types of scholarly output. Similar to a systematic review (Inoue et al., 2020), it aims to ensure a high degree of accuracy and reliability in the retrieved data and outcomes.

In this particular study, the analytical methodologies, and impact of the researched field(s) of study, and Citation Analysis (CNA) have underscored the novelty of this study. CNA employs network visualization with clustering to establish the most impactful authors, publications, and publications to assist in determining the thematic areas of focus. This technique outlines the links between said entities via citations and displays the organizations within the field as thematic clusters. Analyzing these clusters sheds light on the potential cited relationships and links in the particular field(s) of study. In this study, it allows:

1. recognize patterns in publications an thematic development across different time periods;
2. ascertain significant contributors and their collaboration networks; and
3. analyze scholarly domains that are currently insufficiently explored, or novel research fields that present future potential and relevance in an industrial context. Version 4.0.

This analytical approach guarantees the systematic alignment of the bibliometric data with the objectives of the study.

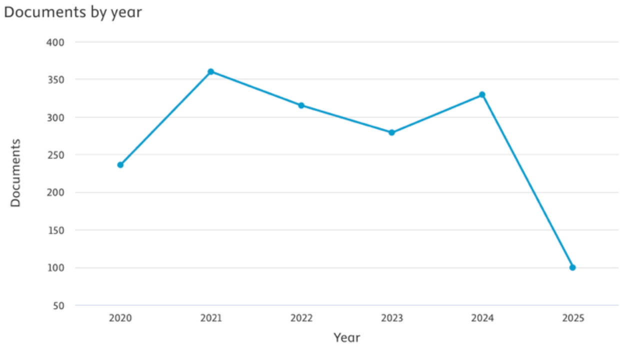
Data Sources

The bibliographical information regarding the research study was obtained from the Scopus (Elseviewer) database. Scopus was selected due to the database having the most comprehensive collection of information regarding peer-reviewed journals, proceedings of conferences, and book chapters across 1,000 subject areas. Scopus offers the best research collection to obtain a comprehensive perspective of research conducted across the globe. Scopus also exercises a stringent mechanism of quality control and indexing. For example, journals are required to self-assess the ethical standards of their publication process, citation metrics, and editorial policies. For the studies, Scopus was the most appropriate database to obtain the bibliometric and citation network analysis due to Scopus providing lower levels of duplicated data and higher levels of information.

We retained publications ranging from 2020 to 2025. There were 1,619 remaining from the original 15,458. To ensure dataset relevance to sports biomechanics, additional subfield specific filtering was performed at Scopus.com. This filtering process was based on the following index terms: sports biomechanics, motion analysis, kinematics, sports technology, and biomechanical performance.

Figure 2

Dokumen Published on Scopus Database



The design of the analysis is shown in Figure 1 which describes the steps of data harvesting, filtering and analysis.

Instrument

The main instruments used in this study are:

1. VOSviewer 1.6.20 was used to make maps of citation and co-occurrence networks, look at how topics are related, and show the intellectual structure of sports biomechanics research in the context of Industry 4.0. The software used the association strength normalization method, which makes sure that co-occurrence links between items are given the right amount of weight. To find a balance between network density and thematic interpretability, the clustering resolution was set to 1.0, which is the default value and the value that is most commonly used in bibliometric studies. Also, a minimum of five occurrences of a keyword and twenty citations of a document were set to make sure that only the most important and relevant items were included in the analysis.
2. Microsoft Excel is used to clean up data, combine terms, and prepare bibliometric metadata for display in VOSviewer.
3. Unlike other databases, Scopus (Elsevier) has more than 1000 subject categories and even had very good quality control, which is why we took to Scopus. Some of the keyword searches we used included kinematics, kinetics, biomechanical phenomena, biomechanics as well as gait analysis.

Procedure

In order to ensure reliability, accuracy, and replicability of the bibliometric analysis, this research process was divided into several (Donthu et al., 2021). This consisted of four main steps which included data collection, data processing, data analysis, and then the visualization and interpretation.

1. Data Collection

Metadata from the Scopus. database was gathered using keywords. related to sports biomechanics. The following query and filtering parameters were used to conduct the search. On

Figure 3

Influential Author generated using VOSviewer

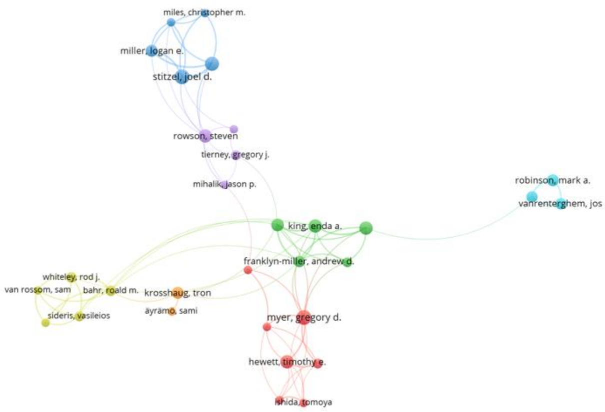


Table 1
Top Authors by Number of Publications in Sports Biomechanics (2020–2025)

Rank	Author by Document	Document
1	Gu, Yaodong	15
2	Myer, Gregory D.	14
3	Stitzel, Joel D.	14
4	Urban, Jillian E.	13
5	King, Enda A.	12
6	Hewett, Timothy E.	12
7	King, Mark A.	12
8	Daniels, Katherine A. J.	11
9	Rowson, Steven	11
10	Caparkapa, Ditrimije	11

The prevalence of writers like Gu and Myer indicates the existence of important research teams that continuously improve sports biomechanics.

TITLE-ABS KEY (sports AND biomechanics) AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "PHYS")) AND (LIMIT-TO (EXACTKEYWORD , "Biomechanics") OR LIMIT-TO (EXACTKEYWORD , "Biomechanical Phenomena") OR LIMIT-TO (EXACTKEYWORD , "Gait Analysis") OR LIMIT-TO (EXACTKEYWORD , "Kinematics") OR LIMIT-TO (EXACTKEYWORD , "Kinetics")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all")).

We collected information about. the article's title, authors, source journal, year of publication, number. of citations, abstract, keywords, and the authors' countries. To make sur. the data was correct and consistent before. analysis, Microsoft Excel. was used to find and fix. duplicate entries, incomplete records, and.differences.in author and keyword data.

2. Data Processing

We put the cleaned and checked metadata into Microsoft Excel so we could work with it. This step included:

1. Consolidating similar terms (e.g., “sports biomechanics” and “biomechanics in sports”);
2. Fixing differences in the names of authors and institutions;
3. Removing redundant entries and irrelevant records.

The most recent dataset was then imported to VOSViewer version 1.6.20 and used to conduct network analysis.

3. Data Analysis

The analysis of the dataset focused on the following bibliometric measures:

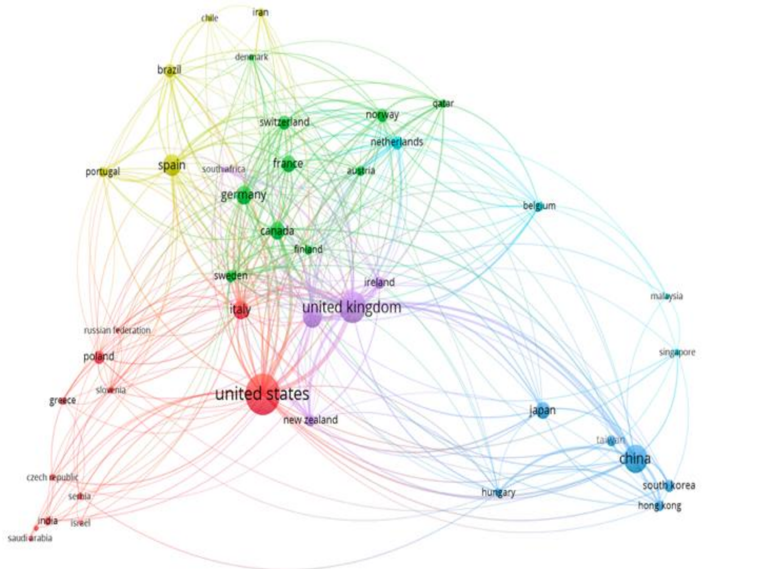
Table 2
Top Authors by Number of Citations in Sports Biomechanics (2020–2025)

Rank	Author by Citations	Citations
1	Bahr, Roald M.	364
2	Whiteley, Rod J.	337
3	Sideris, Vasileios	337
4	Myer, Gregory D.	321
5	Stitzel, Joel D.	298
6	Jonkers, Ilse	286
7	Van Rossom, Sam	286
8	King, Enda A.	280
9	Robinson, Mark A.	267
10	Dos’Santos, Thomas	230

The substantial citation impact of authors like Bahr, Whiteley, and Myer is indicative of their pivotal role in shaping international sports biomechanics research trends.

Figure 4

Citation network analysis that determines the nation of origin of authors



1. The trend of publication over time — The number of articles published from 2020 to 2025 was tracked and displayed by year.
2. The analysis of co-authorship — the recognition of collaboration of research at the level of authors, organizations, and countries.
3. The analysis of co-occurring keywords — the identification of primary themes of research and the relationships between topics.

The strength of the relationships between the different keywords was measured using the association strength method and clique identification parameters set at 1.0. The minimum number of occurrences for a keyword was set at five and 20 for the number of times the document was cited to improve the quality of the analysis and the visibility of the themes.

4. Visualization and Interpretation

Network maps of authors, keywords, and cited documents were created and displayed using VOSViewer (Arifin et al., 2025). The pictures showed how problems got worse and how sports biomechanics research was organized.

The overall publication trend (2020–2025), shown in Figure 2, indicates a fluctuating growth pattern. Publications increased sharply from 236 documents in 2020 to 360 in 2021 (the highest within five years), followed by declines in 2022 (315) and 2023 (279). The trend rose again in 2024 (329) before dropping in 2025 (100), suggesting a possible data lag for the current publication year.

Table 3

Top 10 Nations by Sports Biomechanics Publications (2020–2025)

Rank	Country by Dokument	Document
1	United States	446
2	United Kingdom	256
3	China	201
4	Australia	136
5	Spain	127
6	Italy	95
7	Germany	93
8	Canada	88
9	Japan	79
10	France	76

The majority of publications are produced in the United States and the United Kingdom, which is indicative of their dominance in the field of sports biomechanics and their vast research infrastructure.

Table 4

Top 10 Countries by Number of Citations in Sports Biomechanics (2020–2025)

Rank	Country by Citations	Citations
1	United States	4720
2	United Kingdom	3245
3	Australia	1810
4	China	1344
5	Italy	1211
6	Spain	1036
7	Germany	1036
8	Canada	994
9	Norway	735
10	Switzerland	691

The dominance of the United States and the United Kingdom in both publication and citation metrics indicates their strong academic centrality and international collaboration in biomechanics research.

Results

Author's Analysis

Based on the results of bibliometric analysis of a total of 1,619 documents, a list of authors with the highest publication and citation contributions in the field of sports biomechanics was obtained (Figure 3). In the publication count category (Table 1), author Gu, Yaodong ranked first with 15 documents, followed by Myer, Gregory D. and Stiezel, Joel D., each with 14 documents. Next, Urban, Jillian E. is listed with 13 documents, as well as several other authors such as Kida, Einda A., Hewett, Timothy E., and King, Mark A. with 12 documents. Meanwhile, Daniels, Katherine A., Rowson, Steven, and Gaparbag, Dimitrije each produced 11 documents.

Meanwhile, in the citation count category (Table 2), the author with the highest number of citations was Bahr, Roald M. with a total of 364 citations, followed by Whiteley, Rod J. with 337 citations, and Sideris, Vasilios with 337 citations. Author Myer, Gregory D. also shows significant influence with 321 citations, while Stiezel, Joel D. is recorded as having 298 citations. Other important authors are Jonkers, Ilse, and Van Rossom, Sam, who each have 286 citations; King, Einda A., who has 280 citations; Robinson, Mark A., who has 257 citations; and Dos Santos, Thomas, who has 230 citations

Country Analysis

These results show the consistency of certain authors' contributions in terms of both the quantity of publications and the quality of their academic

Figure 5

Citation network analysis that identifies occurrences based on keywords

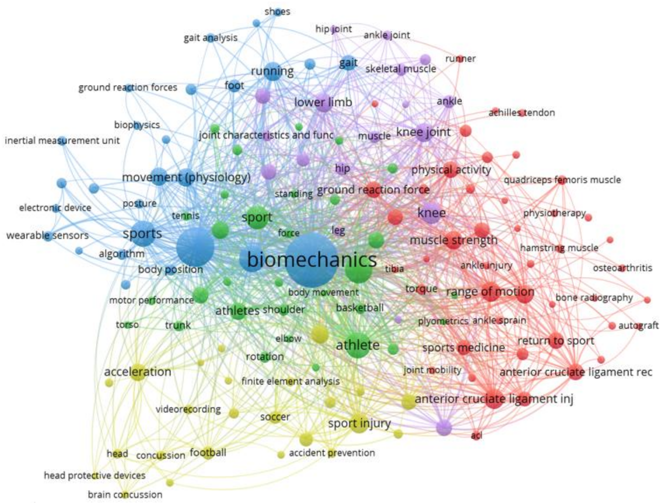


Table 5

Major Research Keyword Clusters Identified in Sports Biomechanics Publications (2020–2025)

Cluster	Item	Colour	Precentage	Total
1	Achilles tendon, acl, ankle injury, anckle sprain, anterior cruciate ligament, anterior cruciate ligament injury, anterior cruciate ligament reconstruction, autograft, body mass, bone radiography, electromyography, exercise, gastrocnemius muscle, grip strength, ground reaction force, hamstring muscle, joint mobility, knee function, knee injury, knee instability, knee meniscus rupture, knee osteoarthritis, muscle contraction, muscle isometric contraction, muscle strength, neuromuscular function, observational study, osteoarthritis, pain, patellofemoral joint, physical activity, physiotherapy, quadriceps femoris muscle, range of motion, rehabilitation, resistance training, return to sport, runner, shoulder injury, sports medicine, tendon graft, tibia, torque, treadmill exercise, weight bearing	Red	31%	45
2	anthropometry, athlete, athletes, athletic performance, baseball, basketball, basketball player, body height, body movement, body weight, controlled study, elbow, elite athlete, exercise test, fatigue, force, jumping, motor performance, pelvis, performance assessment, plyometrics, rotation, shoulder, sport, standing, tennis, torso, training, trunk, upper limb, velocity	Green	21%	31
3	algorithm, algorithms, biomechanical phenomena, biomechanics, biophysics, body position, electronic device, foot, gait, gait analysis, ground reaction forces, inertial measurement unit, joints (anatomy), kinematics, machine learning, motion capture, movement, movement (physiology), posture, running, shoe, shoes, skiing, sports, walking, wearable electronic devices, wearable sensors	Blue	19%	27
4	acceleration, accident prevention, athletic injuries, biological model, brain concussion, computer simulation, concussion, finite element analysis, football, football player, head, head injury, head protective devices, injury, injury prevention, risk assessment, risk factor, risk factors, simulation, soccer, soccer player, sport injury, sports equipment, videorecording	Yellow	17%	24
5	abduction, ankle, ankle joint, anterior cruciate ligament injuries, hip, hip joint, joint characteristics and functions, kinetics, knee, knee joint, leg, lower extremity, lower limb, muscle, muscle, skeletal, musculoskeletal system	Purple	12%	18

	parameters, range of motion, articular, skeletal muscle			
6	Achilles tendon, acl, ankle injury, anckle sprain, anterior cruciate ligament, anterior cruciate ligament injury, anterior cruciate ligament reconstruction, autograft, body mass, bone radiography, electromyography, exercise, gastrocnemius muscle, grip strength, ground reaction force, hamstring muscle, joint mobility, knee function, knee injury, knee instability, knee meniscus rupture, knee osteoarthritis, muscle contraction, muscle isometric contraction, muscle strength, neuromuscular function, observational study, osteoarthritis, pain, patellofemoral joint, physical activity, physiotherapy, quadriceps femoris muscle, range of motion, rehabilitation, resistance training, return to sport, runner, shoulder injury, sports medicine, tendon graft, tibia, torque, treadmill exercise, weight bearing	Red	31%	45
7	anthropometry, athlete, athletes, athletic performance, baseball, basketball, basketball player, body height, body movement, body weight, controlled study, elbow, elite athlete, exercise test, fatigue, force, jumping, motor performance, pelvis, performance assessment, plyometrics, rotation, shoulder, sport, standing, tennis, torso, training, trunk, upper limb, velocity	Green	21%	31
8	algorithm, algorithms, biomechanical phenomena, biomechanics, biophysics, body position, electronic device, foot, gait, gait analysis, ground reaction forces, inertial measurement unit, joints (anatomy), kinematics, machine learning, motion capture, movement, movement (physiology), posture, running, shoe, shoes, skiing, sports, walking, wearable electronic devices, wearable sensors	Blue	19%	27
9	acceleration, accident prevention, athletic injuries, biological model, brain concussion, computer simulation, concussion, finite element analysis, football, football player, head, head injury, head protective devices, injury, injury prevention, risk assessment, risk factor, risk factors, simulation, soccer, soccer player, sport injury, sports equipment, videorecording	Yellow	17%	24
10	abduction, ankle, ankle joint, anterior cruciate ligament injuries, hip, hip joint, joint characteristics and functions, kinetics, knee, knee joint, leg, lower extremity, lower limb, muscle, muscle, skeletal, musculoskeletal system parameters, range of motion, articular, skeletal muscle	Purple	12%	18

influence, as reflected in the citations they have received.

Table 3 shows the ten countries that have written the most papers. The US has 446 papers. With 256, the UK has the second most, and with 201, China has the third most. After the US, there are Canada (88 papers), Japan (79 papers), France (76 papers), Italy (95 papers), Germany (93 papers), Australia (136 papers), and Spain (127 papers).

The ten countries that get the most citations are shown in Table 4. The United States has the most citations (4720), followed by the United Kingdom (3245) and Australia (1810). The list also includes Canada (994 citations), Norway (735 citations), Switzerland (691 citations), Italy (1211 citations), Spain (1036 citations), Germany (1036 citations), and China (1344 citations). Figure 4 shows how networks of people who work together are getting bigger. The US is the most central, then the UK and Australia. Based on the centrality criteria, these states show strong international cooperation and strong academic involvement.

Analysis of co-occurrence of keywords

Table 6

Sports Biomechanics' Top 10 Most Cited Articles, 2020–2025

No	Title	Author	Year	Total Citation
1	Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes	(Kotsifaki, Van Rossom, et al., 2022)	2022	136
2	Sport biomechanics applications using inertial, force, and EMG Sensors: A literature overview	(Taborri et al., 2020)	2020	117
3	Prediction of lower limb kinetics and kinematics during walking by a single IMU on the lower back using machine learning	(Lim et al., 2020)	2020	117
4	A motion capturing and energy harvesting hybridized lower-limb system for rehabilitation and sports applications	(Gao et al., 2021)	2021	110
5	Real-time feedback by wearables in running: Current approaches, challenges and suggestions for improvements	(Van Hooren et al., 2020)	2020	102
6	Shear-stress sensing by PIEZO1 regulates tendon stiffness in rodents and influences jumping performance in humans	(Passini et al., 2021)	2021	97
7	(Kotsifaki, Whiteley, et al., 2022) 2022 93			
8	Test-retest reliability of a commercial linear position transducer (gymaware powertool) to measure velocity and power in the back squat and bench press	(Orange et al., 2020)	2020	93
9	Recent improvements in marathon run times are likely technological, not physiological	(Muniz-Pardos et al., 2021)	2021	83
10	Multidimensional ground reaction forces and moments from wearable sensor accelerations via deep learning	(Johnson et al., 2021)	2021	81

Table 7

Top 10 Most Cited Articles and Their Research Focus (2020–2025)

No	Title	Type of Study / Main Focus	Year	Total Citation
1	Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes	Cross-sectional biomechanical study / Knee deficits post-ACLR	2022	136
2	Sport biomechanics applications using inertial, force, and EMG Sensors: A literature overview	Literature review / Applications of sports biomechanics sensors	2020	117
3	Prediction of lower limb kinetics and kinematics during walking by a single IMU on the lower back using machine learning	Experimental study with machine learning / IMU-based Biomechanics Prediction	2020	117
4	A motion capturing and energy harvesting hybridized lower-limb system for rehabilitation and sports applications	Experimental system development / Hybrid Lower-Limb Motion Capture & Energy Harvesting	2021	110
5	Real-time feedback by wearables in running: Current approaches, challenges and suggestions for improvements	Review study on wearable feedback in running	2020	102
6	Shear-stress sensing by PIEZO1 regulates tendon stiffness in rodents and influences jumping performance in humans	Experimental mechanistic study on PIEZO1 and tendon stiffness	2021	97
7	Single leg hop for distance symmetry masks lower limb biomechanics: Time to discuss hop distance as decision criterion for return to sport after ACL reconstruction?	Experimental biomechanics study on ACLR hop symmetry	2022	93
8	Test-retest reliability of a commercial linear position transducer (gymaware powertool) to measure velocity and power in the back squat and bench press	Reliability study on GymAware measurements	2020	93
9	Recent improvements in marathon run times are likely technological, not physiological	Narrative review / Impact of shoe technology on running performance	2021	83
10	Multidimensional ground reaction forces and moments from wearable sensor accelerations via deep learning	Experimental study / Prediction of GRF/M from wearables	2021	81

The most frequently cited works highlight a paradigm shift toward data-driven and technologically enhanced sports science research by integrating biomechanics with digital technologies, especially sensors, artificial intelligence, and machine learning.

Researchers mapped the main factors contributing to publications, including authors, country of origin, and keywords. Keyword analysis was used to trace the direction of publication development and identify dominant themes. The size of the item labels in the visualization represents the frequency of publication, while the color differences represent specific fields of knowledge formed through software clustering techniques (Delmoral & João, 2024) . The citation relationship between documents is an important foundation in bibliometric studies, so the accuracy of citation data is a key requirement for the quality of the analysis (Wang et al., 2024).

In this study, keyword mapping was performed using VOSviewer software with a fractional counting approach. A minimum occurrence limit of 50 keywords was set, with author keywords selected as the unit of analysis. The clustering results are visualized in Figure 5 and then presented in Table 5 through cluster analysis.

Top 10 Most Cited Articles and Their Research Focus

According to bibliometric study using VOSviewer, wearable technology, data analysis, and smart sensors are used to evaluate athlete performance in the top ten sports biomechanics papers (Table 6). The most cited study is that of Kotsifaki et al. (2022) who used one-leg vertical jump performance to assess knee function impairments in male athletes following ACL surgery (136). These results show how important it is to use modern biomechanical methodologies and cutting-edge technology in clinical decision-making and data-based sports training.

In the top 10 articles, the most prevalent research types are cross-sectional biomechanical studies employing IMU sensors, EMG, force plates, and machine learning, experimental investigations, and literature reviews (Table 7). To forecast lower limb kinetics and kinematics, Lim et al. (2020) employed a single IMU and machine learning methods, whereas Taborri et al. (2020) Investigated the use of sensors in sports biomechanics. This trend shows how research on sports biomechanics is adopting digital technology and advanced data analysis, which are characteristics of the Industry 4.0 era.

A focus on improving athlete performance and rehabilitation effectiveness using wearable sensors, real-time input, and AI-based biomechanical predictions is shown by further study. While Samuel et al. (2020) evaluate the accuracy of speed and power measuring instruments, Passini et al. (2021) investigate the processes of shear stress on tendons. These results imply that in order to promote athlete development and evidence-based sports intervention, the research trend in sports biomechanics in the Industry 4.0 age will continue to include cutting-edge technology, smart sensors, and predictive assessment techniques.

Discussion

A bibliometric review focusing on the literature with respect to sports biomechanics between 2020 and 2025 indicates that there has been a steady development within the field owing to the increased use of augmented reality (AR), virtual reality (VR), Artificial Intelligence (AI), and portable devices. The rapid use of digital tracking technologies and the increase in publications within the field in 2021 indicates that there may have been a growing need on the part of coaches and researchers to more accurately and precisely assess an athlete's performance during the pandemic (Yu et al., 2020). The pattern shows that a significant number of people engage with the research contrary to the uneven distribution of ef fort which suggests that there are a number of barriers to the research such as a lack of proper research infrasturcture, inequity in available funding and acces to up to date technologies. These barriers are more pronounced in low and middle income countries (Godfrey et al., 2023).

According to the author's level analysis, it appears that there exists a very small and yet extremely productive and impactful group of academics, specifically Gu, Yaodong (volume of publication) and Bahr, Roald M. (impact of citation). This illustrates that a "scientific elite" is coming into existence, shaping the theory, methodology, and the research agenda in global biomechanics (Liu et al., 2022).

The concentration of output in the USA, UK, and Australia also illustrates long-standing disparities in scientific captivation which may narrow the variety of explored methodologies on a global scale. This trend shows that poor countries need to get more money, labs, and foreign partnerships in order to build research ecosystems.

The keyword and topic cluster analysis (Ciptaningrum et al., 2023) shows that smart sensors, real-time feedback, kinematic–kinetic integration, and AI-supported evaluation are all very important. Other studies have shown that force plates, EMG systems, IMUs, and machine learning algorithms are more useful for objectively measuring performance (Kotsifaki et al., 2022; Lim et al., 2020; Taborri et al., 2020). However, the majority of existing research continues to concentrate on elite athletes. Prior research corroborates this structural bias, indicating that amateur and youthful demographics are underrepresented due to the concentration of advanced biomechanical assessment equipment in high-performance training facilities (Galy et al., 2024). This difference makes us wonder about ecological validity and limits the usefulness of the current results to athletes at the community or school level.

The ten most cited articles that support this change in technology are Lim et al. (2020) on IMU-based prediction, Gao et al. (2021) on hybrid motion-capture systems, Van Hooren et al. (2020) on wearable-assisted feedback, and Passini et al. (2021) on tendon mechanobiology assessments. It seems that the research performed in biomechanics has shifted to more of a predictive and personalized focus as seen in the predominance of experimental and cross-sectional studies utilizing AI and sensor integration. This focus aligns with the justification for the injury prevention and return-to-sport frameworks and evaluations that aim to utilize evidence-based decision-making (Orange et al., 2020).

There are still a number of changes that still need to occur. One is that the demands of the amateur athletes, recreational exercisers, and para-athletes are unmet, and the elite focus makes it difficult to translate to the other groups. Another is that the differences in access to technology, especially in low-income countries, makes it so that advanced biomechanical methods are inaccessible to large portions of the population. A final one is the integration (especially with the disciplines of physiology, psychology, and data science) which, while pertinent to the construction of comprehensive performance and rehabilitation systems, still seems to be lacking (Zentgraf et al., 2024). These are the issues that we need to address in order to make biomechanical research more accessible and incorporate a greater degree of cultural sensitivity.

This research has several limitations. The study only used the Scopus database, which might not have included important papers that are indexed in Web of Science, PubMed, or regional databases. This could have led to selection bias. Also, contributions from countries where English is not spoken may not have been fully represented because only English-language texts were looked at. To encompass a broader spectrum of research impact, forthcoming studies should enhance database coverage, incorporate multilingual sources, and employ altmetric analysis. In addition, future bibliometric studies should look at subfields like youth biomechanics, adaptive sports, and low-cost sensor innovation to promote research development that is more inclusive and relevant to people all over the world.

Conclusions

This bibliometric study looks closely at sports biomechanics research from 2020 to 2025. It does this because technology is moving so quickly because of the use of wearable technologies, virtual and augmented environments, and AI-driven analytics. Mapping of publications, citation patterns, and network linkages shows that most scientific research is still done by a small number of authors, institutions, and countries. This is due to the significant disparities in research capability globally.

The results show that most of the current biomechanics research is focused on assessment and predictive evaluation models that use technology. However, the fact that amateur athletes, young people, and sports that aren't as well known are only included in a few studies shows that there is a big gap in the evidence that is available to everyone. Biomechanics could have a bigger effect on training, injury prevention, and rehabilitation if advanced tools were more evenly distributed and there were more interdisciplinary perspectives.

In theory, this study helps us better understand how the use of technology affects the growth of biomechanics research. The findings point to the need for more approachable techniques that can be applied in a variety of performance scenarios. The inclusion of people from different backgrounds, the affordability and accessibility of technological advancements, and the promotion of interdisciplinary professional collaboration should all be given top priority in future research.

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