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Review

Women's sports injuries: A bibliometric study of research trends and future perspectives

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ABSTRACT

Women's participation in sports has grown significantly, but concerns about sports-related injuries among female athletes persist. This study conducts a bibliometric analysis of women's sports injuries literature using data from 910 research articles retrieved from the Scopus database (1962 to July 2024). Employing Biblioshiny and VOSviewer, this study analyses performance and science mapping techniques to landscape the research overview. These findings delineate influential authors, impactful journals, and important articles. Also, identify the major areas of interest and suggest trending and future potential areas of research investigation in women's sports injuries. The study's implications support researchers, coaches, trainers, policymakers, and funding institutions in enhancing collaboration and prioritizing research on women's sports injuries. Recommendations include expanding this study to explore emerging research directions.

Introduction

Sports and games are not only an entertainment but also a highly competitive and professional field[1] in developed and developing countries. Sports activities provide better cultural and social understanding, opportunities for global recognition, and contribute to the better health and overall development of the country.[2] As the two sides of a coin, sports also has both negative and positive sides. While sports helps in psychosocial and personal development of an individual, the risk of injury and fear of failure which leads to poor mental health remain as some of the serious problems[–6].

In sports industry, to maintain high-level status, both growing and established athletes had to go through stress and pressure. These athletes train hardly to achieve maximum output, with maximum intensity and volume in their practice time[3] . This overload and lack of rest can lead to major injuries[4] . The athlete's poor physiological and physical conditions pave way to injury like lack of flexibility, strength and coordination in muscles and tendons. The physical conditions such as players' environment factors like practicing level, nature of the sports and position of the player in the game also matters.[5–7] So the major hazard in sports is injury which will lead to poor performance in the field of sports and poor metal health.[3,6,8]

In recent decades, studies show a significant growth in the participation of women in sports.[9] The increased visibility and success of female athletes globally have contributed to a more inclusive sports culture, although disparities in treatment still exist.[10,11] If comparing college level and high school level players, 2 to 10 fold females have a high risk of chances in injury.[12] Overuse injury types are highly evident in the adolescent females.[13] The locations of injuries that happen in the human body are knee, ankle, and thigh and the common types of injuries are sprains or strains, contusions, and fractures.[14,15] The anterior cruciate ligament and patellofemoral injuries are the major women's lower body injuries, cartilage and muscle injuries, fractures are less common were tendonitis and inflammation.[16–19]

Simultaneously, a unique set of injury risks, including higher rates of Anterior Crucial Ligament (ACL) injuries and stress fractures, compared to men, often due to anatomical and hormonal differences.[20] Moreover, in the case of women, most injuries occur during practice sections or during the competitions.[17] The games were mainly injuries happen are soccer, gymnastics, ice hockey, and basketball.[6,18] Several bio-psychosocial factors lead to the chance of injury.[6] When the disturbance and imbalance of knee neuromechanics, strength, flexibility.[13] Unbalanced loading and rest time lead to fatigue in the player and this causes injury.[4]

Addressing these gender-specific risks through tailored training and prevention programs is crucial for enhancing the safety and longevity of

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female athletes' careers.[21] Additionally, the academic community has explored this issue by conducting both clinical and theoretical studies to gain a deeper understanding of its dynamics. Various scientific methods have been employed to address research questions regarding injuries sustained by women in sports. The researcher's initial search for articles on women's injuries in sports produced numerous results and highlighted a significant rise in publications since 2015. Despite the extensive number of recent publications, none of the research efforts has been undertaken to explore how women's sports injury research has been studied. This observation has sparked an inquiry into the academic exploration of this topic, examining the breadth of this research domain, important contributors, and emerging themes. To address this research gap, we conduct a bibliometric analysis (BA) using Scopus data on women's sports injuries. We develop and implement key bibliometric analysis questions specifically tailored to the research domain of women's sports injuries. The research questions are as follows:

- How has the scholarly output on women's sports injuries evolved over the past years?
- Which authors and research teams have contributed the most to women's sports injuries research?
- What central research themes and areas have dominated the study of women's sports injuries?
- Which major publications have been most influential in the evolution of women's sports injuries research?
- What advancements in sports medicine are anticipated to significantly impact the prevention and management of women's sports injuries?
- What are the future potential areas of research in the women's sports injury research domain?

BA seeks to elucidate the expansion and evolution of a specific area of the research field, identify key leading authors, best sources, most contributing institutions, and sponsoring agencies, pinpoint thematic concentration, identify recent trends, and suggest potential keywords of recent and future areas of scope.[22,23] The current state of literature includes multiple bibliometric studies on sports injuries focusing on particular sports, such as football,[24] Ice and Snow Sports,[25] Karate Practitioner,[26] American Football,[27] and Cricket.[28] The current body of literature does not include a BA in women's sports-related injuries. This article follows the methodology adopted by Cherappurath et al. (2024) ,[29] in their recent BA of Women's football research. The present study diverges from previous bibliometric sports injury studies in four key ways. Firstly, concentrate specifically on women, making this the inaugural effort in this particular area. Secondly, Scopus, a widely used database in BA, has been used. Thirdly, data covers the period from 1962 to July 2024, and since 2015, there has been a substantial development in this area of study. Lastly, the bibliometric toolbox leverage of the Biblioshiny and VOSviewer was utilized to understand Science Mapping Analysis (SMA) and to obtain in-depth details.

The study finds that, in 2021, the highest number of articles on women's sports injuries was produced, a total of 102 publications. The United States (US) emerged as the foremost country in production, with the Norges Idrettshøgskole (Norwegian School of Sport Sciences, Oslo, Norway) identified as the top contributing institute. The National Institute of Arthritis and Musculoskeletal and Skin Diseases, US, sponsored the most studies in this domain, and the American Journal of Sports Medicine was the primary journal for publications. Hägglund has been identified as the leading author in the field based on fractionalized articles. Major thematic areas identified in the literature include head injuries, lower limb sports injuries, descriptive epidemiology, and traumatic brain injury (TBI). ACL Injuries, ACL Injury Prevention, Knee Biomechanics, Injury Risk Factors, Neuromuscular Training, and Sports Injury Epidemiology.

Further bibliometric coupling analysis highlighted concentrated areas of interest, indicating robust research activity in the field of women's sports injury. The major clusters include epidemiological research approach, knee-related injuries, ACL Injuries, injuries in women's soccer, comparison studies of male and female footballers, and injury prevention. From the multiple keyword analysis, topics such as sports medicine, rehabilitation, TBI, sports injury epidemiology, injury surveillance, ACL injury, return to sport, motion analysis, concussion, machine learning, fatigue, and team sports were identified as recent trends and future focuses in the field. These areas underscore the importance of advanced medical care, injury rehabilitation, and enhanced injury prevention strategies, particularly in contact sports. Integration of machine learning and motion analysis promises to deepen our understanding of injury mechanisms and optimize rehabilitation protocols, and thereby improving athlete safety and performance.

Data and methods

BA, introduced by Pritchard in 1969,[30] helps scholars identify significant contributors, landscaping research evolution, and suggesting potential future direction in a particular area domain,[22] using bibliometric data from academic literature.[31,32] This BA adheres to the workflow recommended by Zupic and Čater (2015)[33] and adopts analysis techniques followed by Cherappurath et al. (2024) .[29] The workflow starts with fixing objectives and identifying keywords to retrieve relevant academic literature targeted. The objective of this research on women's sports injuries and classify major keyword heads such as women, sports, and injuries. The second stage is to select an authentic source of bibliometric data. This article opted for the Scopus database due to its wide coverage and rich citation data,[34,35] and it is widely accepted as a leading source for bibliometric studies.[22,36,37] Data was retrieved using three-fold search queries: woman, sports, and injury. This study prefers article titles[38–40] for the document search over other search fields except in sports, where 'title' OR 'keywords' gave preferences. Additionally, the queries were refined by limiting the document type and language to articles and English, respectively. Data inclusion criteria are illustrated in Fig. 1, and the detailed research query is provided in the appendix (Table A1). The final dataset for analysis comprises 910 articles published in English.

The third stage is to conduct BA and visualization. The numerous BA techniques are classified into performance analysis (PA) and SMA. Performance indicators involve a descriptive evaluation of contributions from research parties, while SMA focuses on finding relationships between research themes.[37,41,42] The SMA techniques help to identify the focus areas, evolution, trends, and future of a particular research constituent.[22] This research utilizes possible publication and citation-related metrics such as total publications, number of citations, and fractionalized articles to find the top contributors to women's sports injury research. Further, expand to citation analysis, co-citation analysis, bibliometric coupling, and co-word analysis from the science mapping toolbox. Additionally, use visualization techniques recommended by Aria & Cuccurullo,[23] Cobo et al.,[37] and Donthu et al..[22] Also, we prefer authors' keywords as the unit for all the SMA. This article uses Tableau, R-programmed Biblioshiny,[23] and Java Powered[43] for visualization analysis and presentation. The following section delves into the analysis and visualization process, emphasizing the interpretation and insights derived from the analyses.

The competence report from Biblioshiny on the bibliometric dataset indicates a range of quality across different metadata categories. The abstract (AB), document type (DT), journal (SO), language (LA), publication year (PY), title (TI), and total citations (TC) are all rated as having 'excellent' status, reflecting high-quality and reliable data. In addition, the author (AU), affiliation (C1), cited references (CR), and DOI (DI) are classified as having 'good' status, indicating that they are generally reliable but may benefit from some enhancements. Conversely, the keywords (DE) and corresponding author (RP) are marked as 'acceptable,' suggesting a need for improvement in specificity and relevance. Lastly, Keyword Plus (ID) and Science Category (WC) are rated as 'poor,'

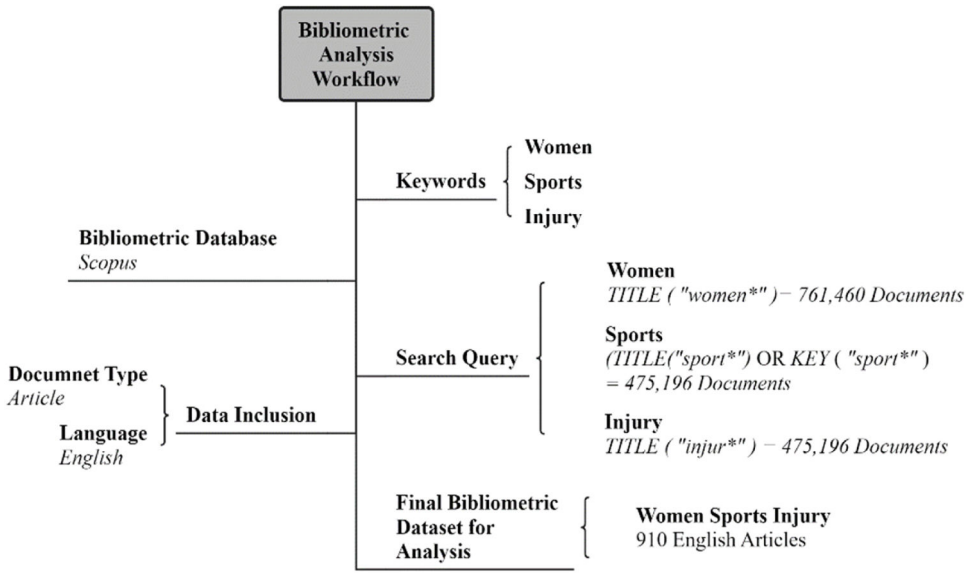

Fig. 1. Bibliometric analysis data inclusion criteria
*For the detailed search query, refer to Appendix Table A1.

highlighting significant gaps in data quality that require attention to strengthen the overall dataset's integrity. Despite these weaknesses, the overall assessment shows that the dataset is largely good to go for bibliometric analysis, particularly given the strong ratings in critical areas.

Results

The results section divided into two-part, PA and SMA. The PA covers annual scientific output, leading sources, most cited articles, and the most prolific authors. Additionally, this study examines publications by countries, institutions, and funding agencies worldwide in women's sports injury research. The SMA segment explores thematic concentration, thematic evolution, and potential future research areas in women's sports injuries.

Performance Analysis (PA)

The performance analysis section comprises four primary assessments of this paper on women's injuries in sports: the annual scientific production (Fig. 2), the leading sources of research articles (Table 1) depending on the number of publications, the most significant works (Table 2) measured by total citations and the most impactful authors (Table 3) in the area of women's sports injury.

Annual scientific production

Fig reveals the growth in research publications on women's sports injuries from 1962 to July 2024, with 910 research articles published during this period and an annual growth rate of 6.91 %. The scholarly output on women's sports injuries progressed slowly in the early years but has experienced significant growth since 2015. The highest article

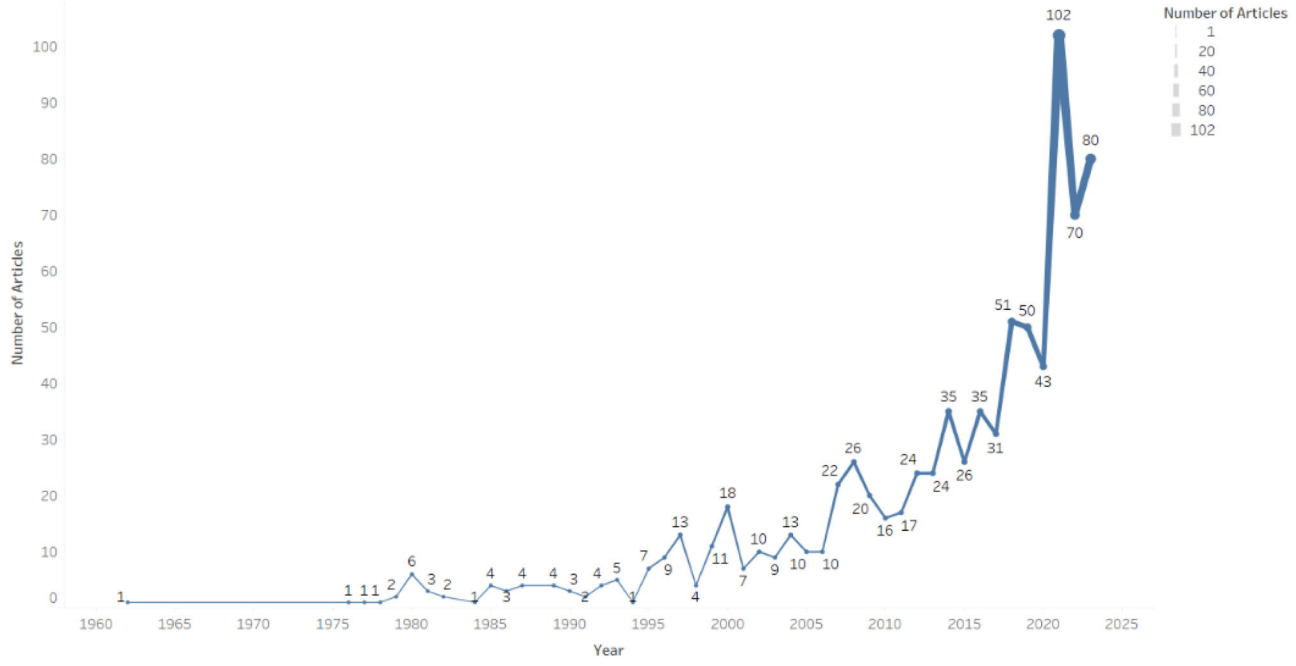

Fig. 2. Annual scientific production 1962–2024.

Table 1
Top sources.

Rank	Source Title	N	Publisher	SCY	CS	SNIP
1	American Journal of Sports Medicine	86	SAGE	from 1973*	9.3	1.945
2	British Journal of Sports Medicine	62	BMJ Publishing Group	1964, from 1974*	27.1	4.917
3	Journal of Athletic Training	38	National Athletic Trainers' Association Inc.	from 1996*	5.3	1.254
4	Scandinavian Journal of Medicine and Science in Sports	34	Wiley-Blackwell	from 1991*	7.9	1.542
5	Physical Therapy in Sport	28	Elsevier	from 2000*	4.5	1.042
6	Clinical Journal of Sport Medicine	25	Wolters Kluwer Health	from 1993*	4.9	1.259
7	Journal of Science and Medicine in Sport	25	Elsevier	from 1998*	7.4	1.289
8	Orthopaedic Journal of Sports Medicine	23	SAGE	from 2013*	4.3	1.222
9	Physician and Sportsmedicine	22	Taylor & Francis	from 1978-2005, from 2008*	4.9	1.259
10	Medicine and Science in Sports and Exercise	17	Wolters Kluwer Health	from 1969	7.7	1.388

Source: Scopus;N: Number of articles; SCY: Scopus Coverage Year; CS: Cite Score 2023; SNIP: Source Normalized Impact per Paper, 2023; *: to present date; Details are as of 05.08.2024.

Table 2
Top most cited articles.

Rank	Title	TC	TCPY	NTC
1	Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study[44]	2512	125.80	5.92
2	Knee Injury Patterns Among Men and Women in Collegiate Basketball and Soccer: NCAA Data and Review of Literature[45]	1333	44.43	5.06
3	The Effect of Neuromuscular Training on the Incidence of Knee Injury in Female Athletes[46]	1217	46.81	4.92
4	High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury[47]	1147	54.71	6.04
5	Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing Anterior Cruciate Ligament Injuries in Female Athletes: 2-Year Follow-up[48]	892	44.60	2.10
6	Prevention of Anterior Cruciate Ligament Injuries in Female Team Handball Players: A Prospective Intervention Study Over Three Seasons[49]	688	31.32	4.75
7	Mechanisms for Noncontact Anterior Cruciate Ligament Injuries: Knee Joint Kinematics in 10 Injury Situations from Female Team Handball and Basketball[50]	646	43.20	7.55
8	Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial[51]	600	35.29	5.07
9	Anterior Cruciate Ligament Injury Patterns among Collegiate Men and Women	496	19.08	2.01
10	Intrinsic risk factors for exercise-related injuries among male and female army trainees[52]	459	14.34	3.57

Source: Scopus; TC: Total Citations; TCPY: Total Citations per Year; NTC: Normalized TC; Details are as of 05.08.2024.

Table 3
Significant contributors.

Rank	Author	Articles	Rank	Author	Articles Fractionalized
1	Hägglund, M.	27	1	Hägglund, M.	6.38
2	Bahr, R.	24	2	Hewett, T.E.	4.92
3	Hewett, T.E.	23	3	Bahr, R.	4.69
4	Myer, G.D.	19	4	Myer, G.D.	4.11
5	Kerr, Z.Y.	18	5	Ford, K.R.	3.06
6	Dompier, T. P.	17	6	Waldén, M.	3.03
7	Ford, K.R.	16	7	Theberge, N.	3.00
8	Steffen, K.	15	8	Steffen, K.	2.81
9	Collins, C.L.	14	9	Finch, C.F.	2.81
10	Waldén, M.	14	10	Kerr, Z.Y.	2.55

Source: Scopus; Details are as of 05.08.2024.

102, was published in 2021, followed by 80 articles in 2023, 70 in 2022, and 51 in 2018. Forty-five percent of the publications have been produced in the last five years, and 64 % in the last decade. This result underscores the growing interest of scholars in women's sports injury research.

Figs. 3 and Fig. 4 display the collaboration networks among countries and institutions, respectively. The US heads with 41 research articles, trailed by Australia with 76, the United Kingdom with 76, Sweden with 60, and Canada with 49. The Norwegian School of Sport Sciences (Norges idrettshøgskole), Norway, is on the highest list with 36 research documents, followed by Linköping University, Linköping, Sweden, with 34 and Harvard Medical School, US, with 25. The major research funding sponsors for women's sports injury research are the National Institute of Arthritis and Musculoskeletal and Skin Diseases in the US, with 30 articles, the National Institutes of Health in the US with 28, and the National Collegiate Athletic Association in the US with 25 articles.

Source

Table 1 presents the top ten journal sources publishing research articles on women's sports injuries. This study identifies the leading journals are the first one is American Journal of Sports Medicine with 86 articles the second one is the British Journal of Sports Medicine with 62, the Journal of Athletic Training with 38, the Scandinavian Journal of Medicine and Science in Sports with 33, and Physical Therapy in Sport with 27 articles. Regarding the Cite Score for 2023, the British Journal of Sports Medicine achieved the top score of 27.1, trailed by the American Journal of Sports Medicine with 9.3, and the next one is the Scandinavian Journal of Medicine and Science in Sports with 7.9.

Documents

Table 2 highlights the top 10 most impactful articles based on global citation counts. The article by Hewett et al. (2005)[44] leads with the highest citation count (2512) and examines predictors of ACL injury risk among female athletes in high-risk sports like soccer, basketball, and volleyball, focusing on neuromuscular control and joint loading during jump-landing tasks. The second-most cited paper (1331) by Arendt & Dick (1995)[45] explores the incidence of ACL injuries in both men's and women's collegiate soccer and basketball players' programs over a 5-year span using data from the National College Athletic Association Injury Surveillance System. It aims to identify factors contributing to the higher ACL injury rates compared to female and male athletes' counterparts. The third-most cited study (1214) by Hewett et al. (1999)[46] investigates the impact of neuromuscular training, specifically a plyometric training program, on the knee injury frequency of female high school athletes who participate in soccer, volleyball, and basketball, comparing them to untrained female athletes and male athletes. Despite

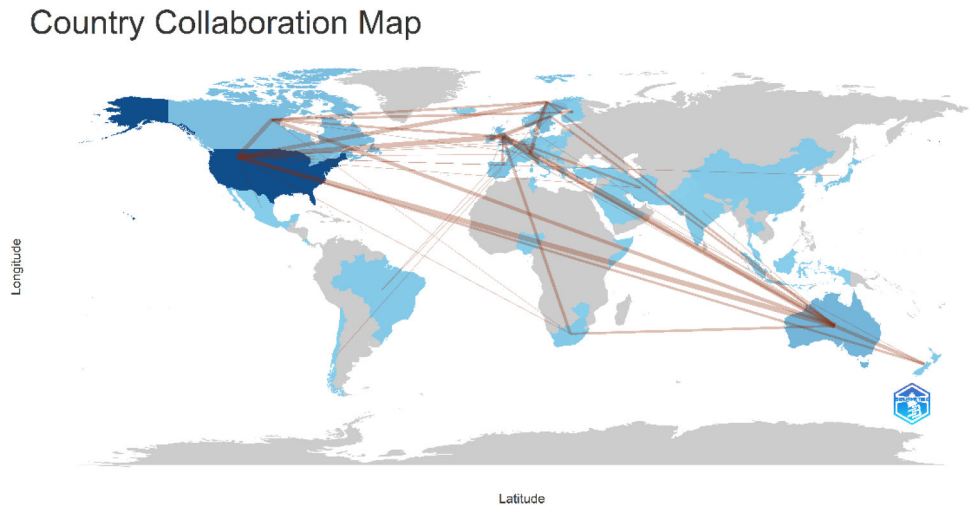

Fig. 3. World collaboration map.

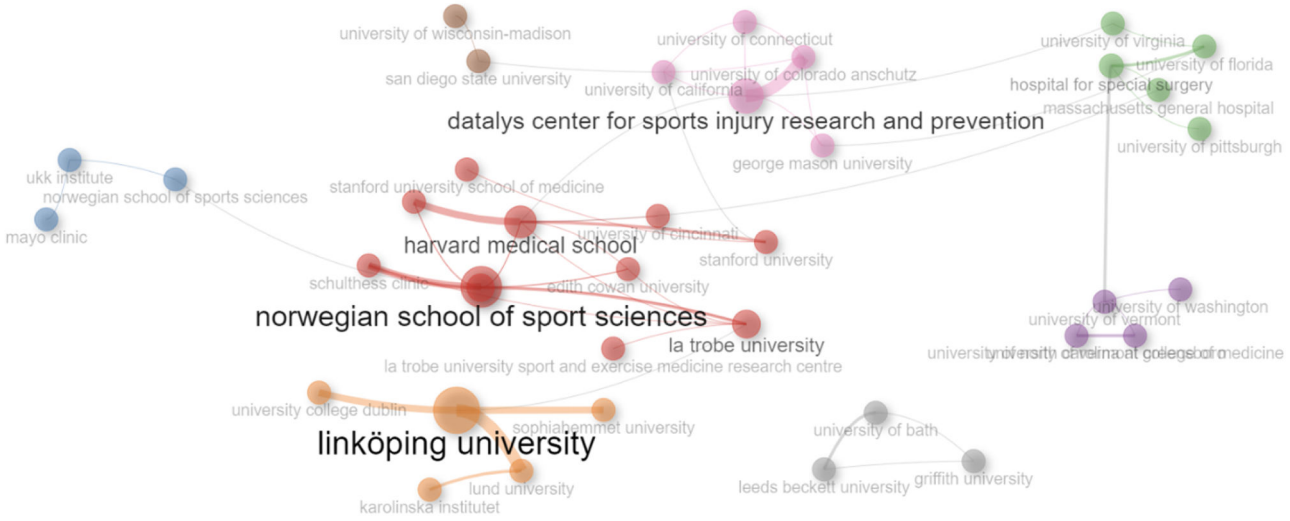

Fig. 4. Institution collaboration network
Layout: Automatic layout; Clustering Algorithm: Walktrap; Normalization: association Number of Nodes: 50; Minimum Number of Edges: 1.

their varying research questions, methods, and findings, all these studies focus on understanding knee-related injuries in female athletes, reflecting the interdisciplinary nature of this research field.

Author

The prime objective of this analysis is to find scholars who made pivotal contributions to the research domain. Table 3 ranks significant scholars based on article fractionalized values and the total number of publications. This article prioritize fractionalized counting, considered more potent than total numbers.[53] The results rank Hägglund, M list the top publishing author with a fractionalized count of 6.38, followed by Hewett, T.E (4.92), Bahr, R (4.69), Myer, G.D (3.92) and Ford, K.R (3.06).

Science mapping

This study explores a wide range of women's sports injury research, assessing the field's current status, and identifying new areas of research interest. In this research employ multiple science mapping techniques from the BA toolkit to do this. Therefore, the science mapping section divide into two parts: First, thematic concentration to understand the current status and focused areas using the co-occurrence map (Fig. 7), thematic map (Fig. 8), and Bibliometric Coupling (Fig. 9). Second, to recommend future research directions and areas in women's sports injuries research, use the thematic evolution map (Fig. 10), trending topics (Fig. 11), and keyword overlay visualization (Fig. 12) maps.

Thematic concentration

Before beginning the thematic concentration analyses, the study presents Figs. 5 and 6, where Word TreeMap and Word Cloud are derived from the authors' keywords (DE) through Biblioshiny, highlighting the most frequently cited keywords in the documents. The occurrence of keywords is represented by the size and color of the elements on the map: bigger box and text sizes represent a higher frequency of keyword occurrence. The most occurred keywords include females (139, 10 %), injuries (121, 8 %), football (108, 8 %), epidemiology (96, 7 %), ACL (87, 6 %), female athlete (64, 4 %), injury prevention (61, 4 %) and sports injury epidemiology (56, 4 %). Other keywords include sports, ACL injury, knee injuries, prevention, athletes, knee, risk factors, athletic injury, biomechanics, injury surveillance, young adult, basketball, concussions, gymnastics, injury risk, and sports medicine.

The co-occurrence map (Fig. 7) based on the authors' keywords produces four major-colored clusters. The major cluster colored in violet comprises females, injuries, sports injury epidemiology, athletes,

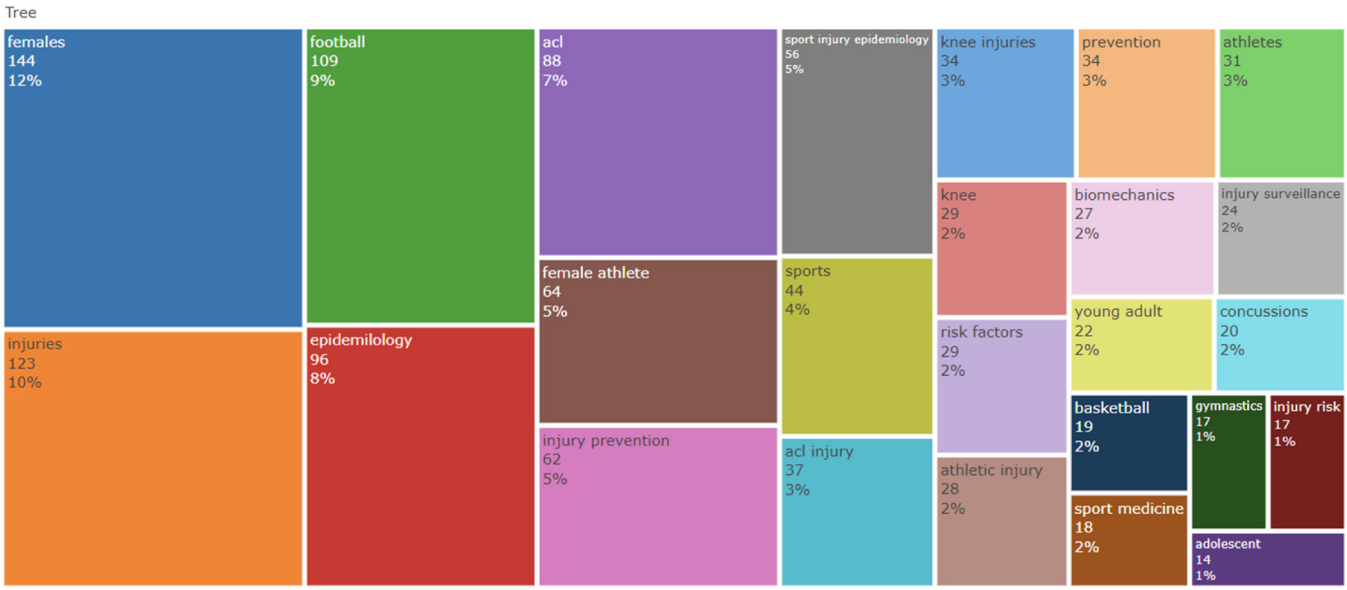

Fig. 5. Word TreeMap.

Fig. 6. Word cloud.

athletic injury, young adult, concussions, sports medicine, gymnastics, adolescent, gender, training, team sports, wounds and injuries, ice hockey, exercise, and NCAA. The green-colored cluster includes keywords such as football, female athlete, knee injuries, prevention, knee, risk factors, basketball, valgus knee, screen, incidence patterns, volleyball, ankle, implementation research, and performance. In the third blue-colored cluster, keywords include ACL, ACL injury, biomechanics, kinematics movement, neuromuscular training, fatigue, landing, dancers, and return to sport. The small orange-colored cluster includes keywords like epidemiology, injury prevention, sports, lacrosse, and rehabilitation.

Thematic maps aid in recognizing and displaying the concentration of the research efforts, patterns, and trends. Fig. 8 displays the thematic map produced using Biblioshiny. The basic themes encompass female athletes, football, epidemiology, sports injury epidemiology, knee injuries, prevention strategies, stress fractures, overuse injuries, injury surveillance, concussions, lacrosse, sex differences in injuries, injury rates, exercise-related injuries, and fractures. The motor themes include ACL injuries, ACL injury prevention, knee biomechanics, basketball injuries, injury risk factors, kinematics of movement, and neuromuscular training. Niche themes identified are single-leg hop tests, head injuries, and lower limb sports injuries while emerging themes include descriptive epidemiology, TBI, and running-related injuries.

The bibliometric coupling (Fig) produces seven major clusters colored red, green, yellow, blue, black, violet, and orange. The red cluster encompasses three predominant categories of studies. First, the epidemiological research approach[54]; second, studies focused on women in Gymnastics[55]; and finally, the epidemiological study of injuries among women gymnasts.[56,57] The Green cluster consists of a report from the National Collegiate Athletic Association (NCAA) on the epidemiology of injuries between both males and females,[58,59] specifically epidemiology of injuries in girls' lacrosse and National Collegiate Athletic Association women's lacrosse.[60] The Yellow cluster consists of research investigations on knee-related injuries among women[61] and ACL Injuries among female soccer players[62] and athletes.[63]

The blue cluster deals with injuries in women soccer players.[64,65] This cluster consists of major comparison studies on injuries between male and female footballers,[66,67] specifically on hamstring injury rates[68] and injuries sustained on turf versus grass surfaces.[69,70] The black color cluster shares the theme of injury prevention. Studies in this circle include prevention awareness,[71] knee,[72,73] and neuromuscular[74] injury prevention programs among football players. Studies by Myklebust et al. (2013)[75] and Steffen, Meeuwisse, et al. (2013)[76] evaluate the strategies and impact of different injury prevention programs. The violet-colored cluster shares the common theme of studies on injuries faced by female athletes. Major studies in this cluster are based on Anterior Cruciate Ligament injuries, discussing multiple dimensions such as relationship,[77] identification,[78] prediction,[79] prevention[80,81] and reduction[82] of ACL injuries. The orange-colored cluster predominantly addresses the Anterior Cruciate Ligament injuries sustained by female skiers.[83]

Thematic evolution and future

To identify the thematic evolution and recommend potential areas of future research, use a thematic evolution map, tend topics, and co-occurrence overlay analysis and visualizations. The thematic evolution map (Fig. 10), based on the Authors' Keywords to visualize and track the development and transformation of research themes over time, enabling a deeper understanding of how scientific knowledge progresses and interconnects. The analysis results showed that ACL, ACL injury, knee, biomechanics, return to sport, screen, landing, reinjuries, kinematics movement, motion analysis, body mass index, dancers, fatigue, ankle, women soccer, rehabilitation, video analysis, trauma, team sports, concussions, sports injuries, lacrosse, female football, female athlete, injury prevention, knee injuries, risk factors, basketball, injury risk,

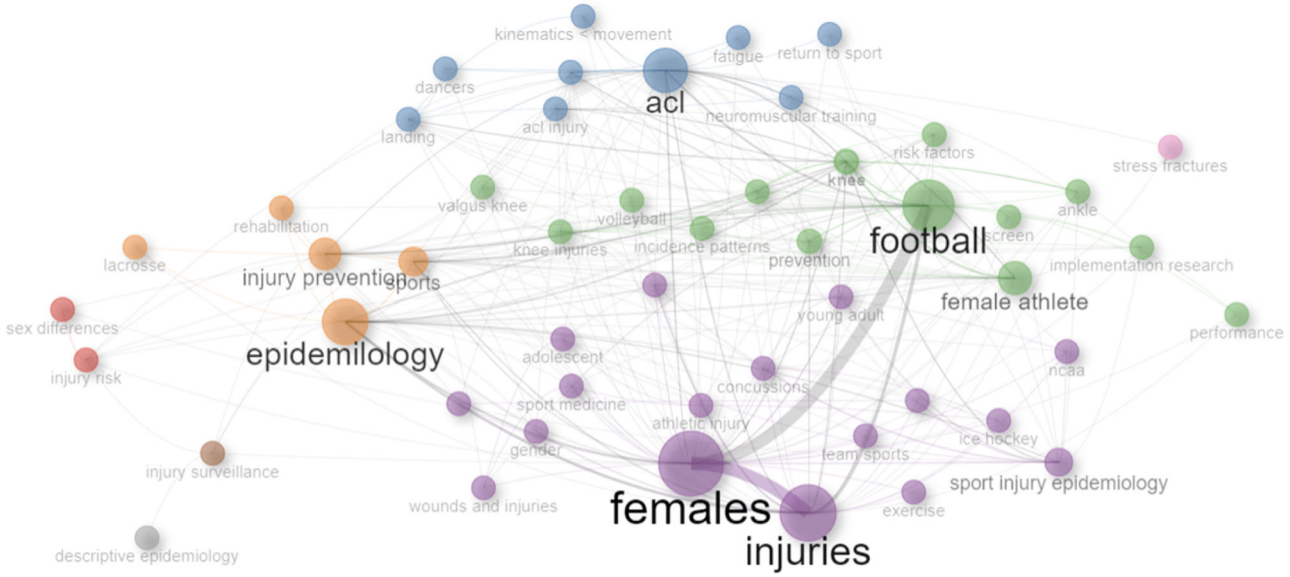

Fig. 7. Cooccurrence map
Network Layout: Automatic layout; Clustering Algorithm: Walktrap; Normalization: association; Minimum Number of Edges: 2.

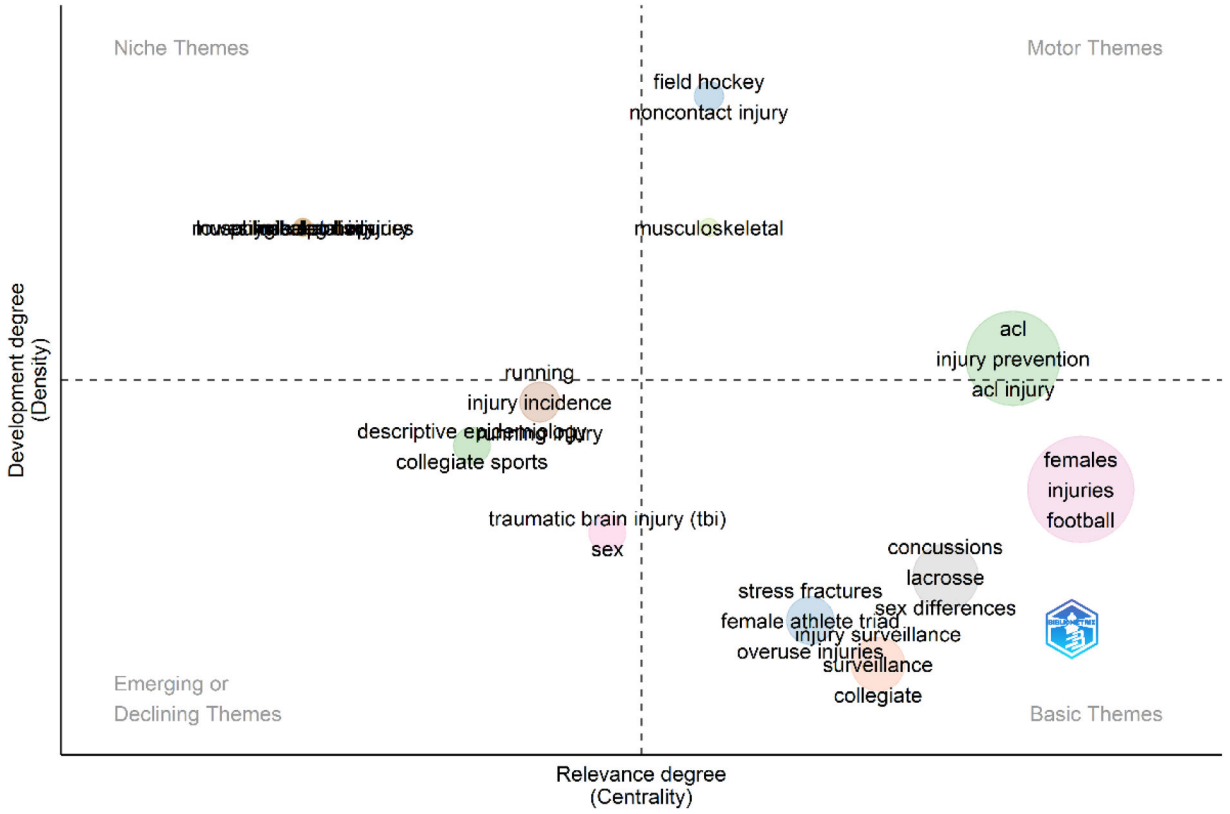

Fig. 8. Thematic map
Note: Field: Authors' Keywords, Minimum Cluster Frequency (per thousand documents): 5, Number of Labels: 1, Clustering Algorithm: Walktrap.

handball, lower extremity injury, females, injuries, football, epidemiology, sports injury epidemiology, sports, athletes, young adult, prevention, athletic injury, adolescent, sports medicine, wounds and injuries, gymnastics, rugby union, Australian football, burden, muscle injuries, gender, implementation research, running injury, overuse, overuse injuries, valgus knee, ice hockey, injury surveillance, volleyball, kinetics, lower limb sports injury, TBI, sex differences, stress fractures, female athlete triad, running, training landing major latest keywords. Furthermore, the trend topics (Fig. 11) identify keywords such as Australian football, biomechanics, gymnastics, sports medicine, kinematics movement, muscle injuries, TBI, young adult, females, injuries, epidemiology, female athlete, neuromuscular, knee injuries, risk factors, training, injury prevention, knee, ACL, injury surveillance, ACL injury are in trending during 2020 to 2024. Finally, Fig presented

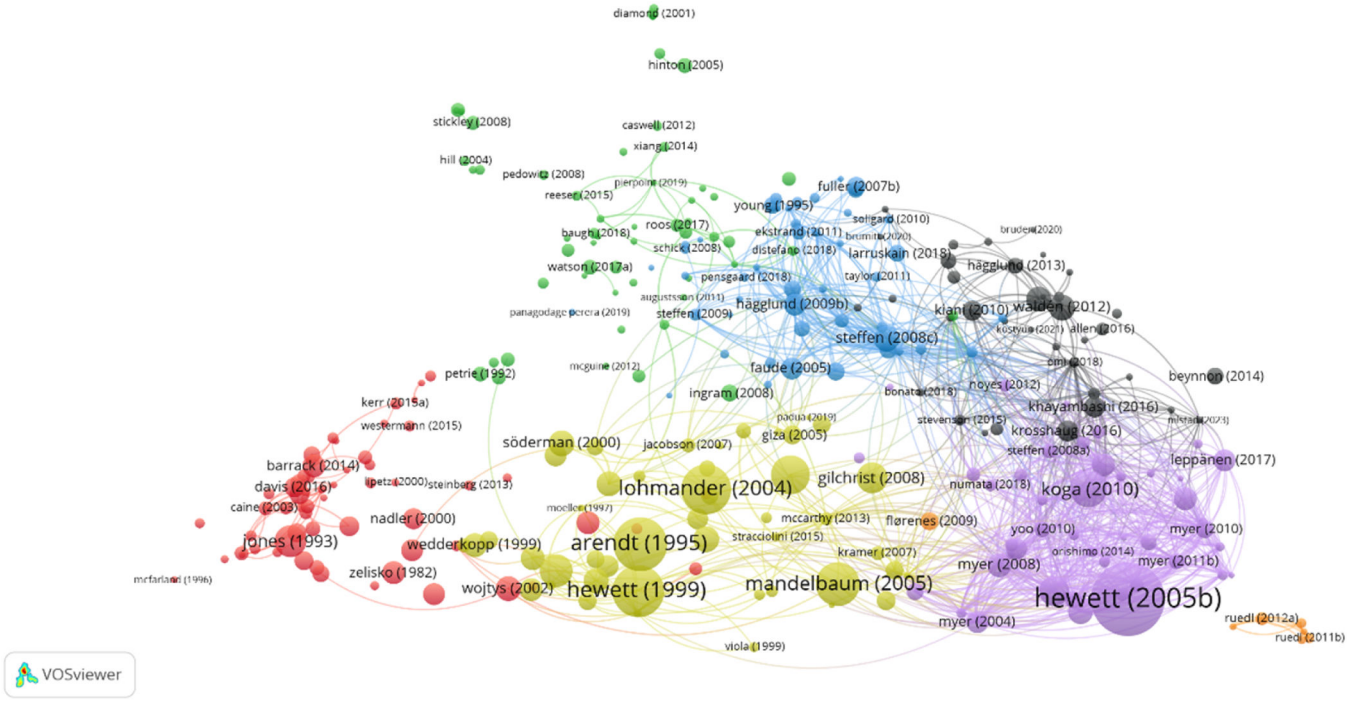

Fig. 9. Bibliometric coupling of documents.

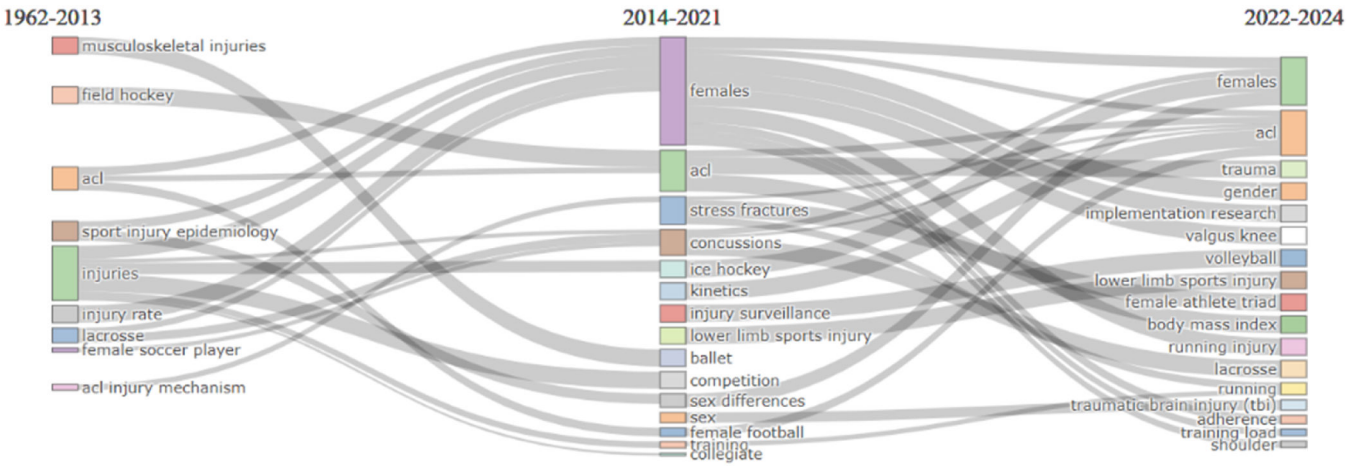

Fig. 10. Thematic evolution map
Parameters: Number of Words: 250; Minimum Cluster Frequency (per thousand documents): 5; Weight Index: Inclusion Index weighted by Word Occurrences; Minimum Weight Index: 0.1; Label Size: 0.3; Number of Labels (per cluster): 3; Clustering Algorithm: Walktrap; Time Slices: Number of Cutting Points: 2 (2013 & 2021).

cooccurrence, keyword Overlay Visualization, using a threshold of four minimum occurrences. Out of 1303 keywords, 128 meet this threshold. Our analysis identifies the following keywords as having significant potential for future research: sleep, machine learning, motion analysis, mental health, sleep, reinjury, return to sport, sports medicine, team sports, return to play, women in sports, rugby union, concussion, descriptive epidemiology, college sports, ACL reconstruction, menstrual cycle, pre-season, screening, and fatigue.

Discussion

BA provides a detailed overview of research within a specific area, offering valuable insights for researchers. It identifies leading contributors, prominent affiliations, funding agencies, key publications, and emerging trends, effectively mapping the intellectual landscape of the field. This research aims to support scholars focusing on women's sports injuries by highlighting significant research, current focal areas, and potential future directions. Performance metrics indicate that the Norwegian School of Sport Sciences in Oslo, Norway, is the leading contributing institute in women's sports injury research. Their highest cited (688) work is based on the evaluation of neuromuscular training to improve impacts on the occurrence of ACL injuries among female team handball athletes.[49] Their early research examined how a neuromuscular training program affects ACL injuries in female handball players[84] and the risk of injury on artificial turf versus natural grass in young female football players.[85] The latest studies from this institution are on the prevalence, incidence, and burden of groin injuries in the Norwegian women's premier footballers,[86] athletes returning to sports after an ACL injury have a high risk of injuring their ACL again,[87] and a coherent two seasons (2020–2021), study focuses on describing the characteristics,

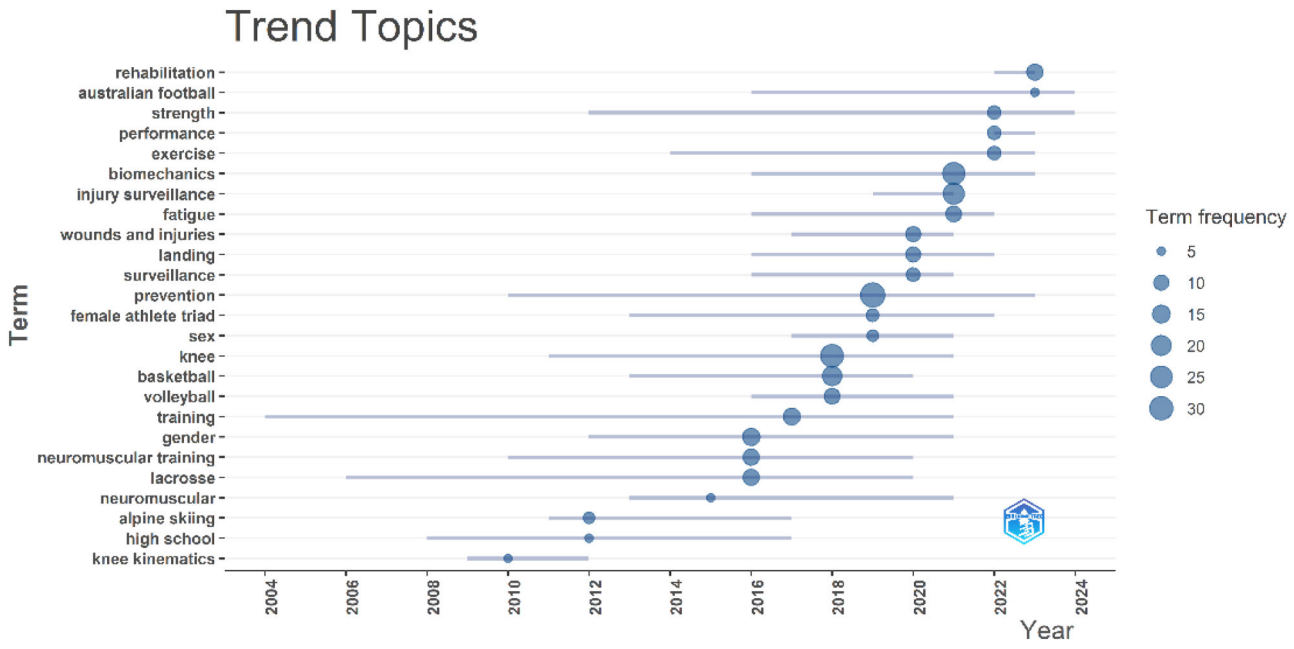

Fig. 11. Trend topics
Parameters: Field: Author's keywords; Word Mini. Frequency: 5; Number of Words per Year: 3.

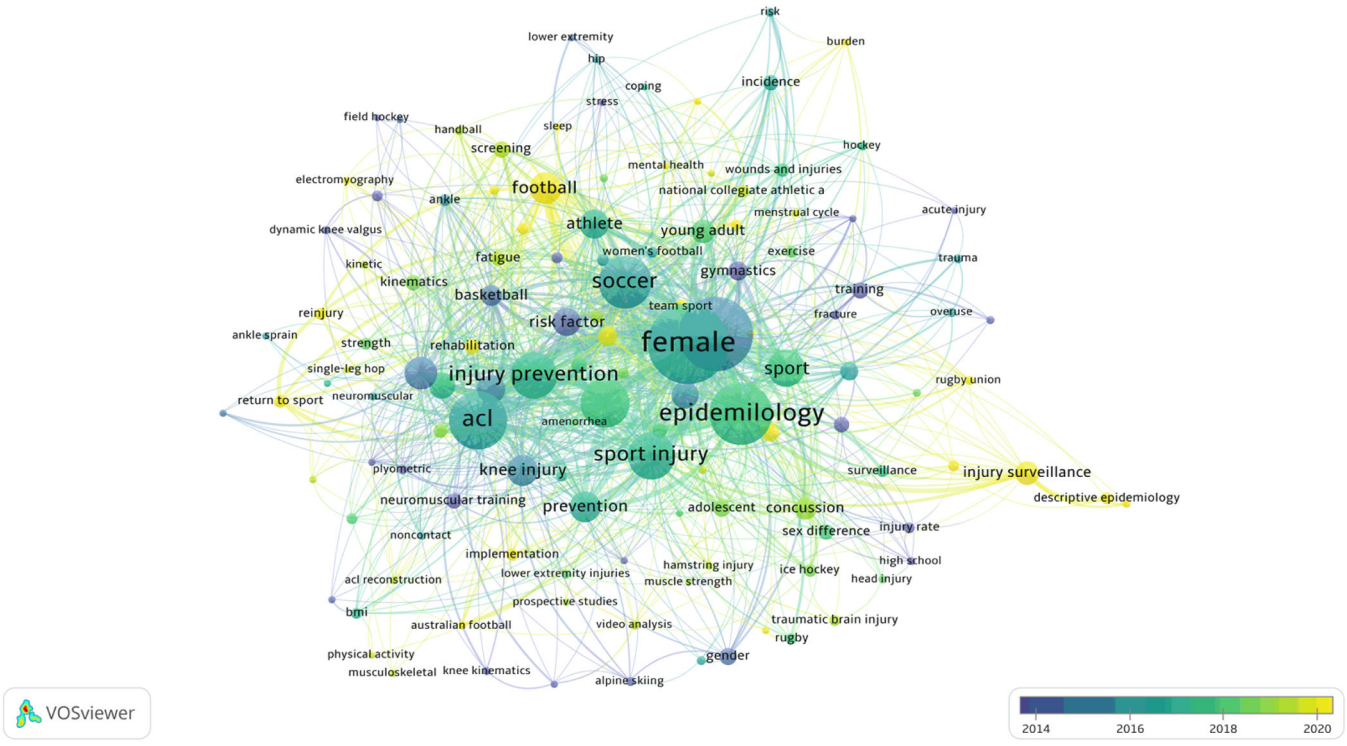

Fig. 12. Keyword overlay visualization
Parameter: minimum occurrences: 4; Out of 1303 keywords, 128 met the threshold.

clinical findings, and MRI results of hamstring injuries in the Norwegian women's premier league.[88]

The National Institute of Arthritis and Musculoskeletal and Skin Diseases, US, has sponsored notable research in this research constituent. Their most impactful work, cited 2512 times, is by Hewett et al., 2005[44]. This study investigates how neuromuscular control and joint loading dynamics during jump-landing tasks forecast the risk of ACL injury in female athletes participating in high-risk sports like soccer, basketball, and volleyball. Early studies sponsored by the agency found that knee motion and loading during landing predict ACL injury risk in female athletes. Those with more dynamic valgus and high abduction loads have a higher risk of ACL injury.[89] And review the overall landscape of ACL injury among female athletes.[90] The recent sponsored works assess how effective a neuromuscular training program is in reducing the incidence of lower-extremity musculoskeletal (LE MSK) injuries in female adolescent athletes who have a history of sport-related

concussions (SRC) .[91] Another study assesses the psychological factors related to kinesiophobia, confidence, and psychological readiness in athletes who sustain a second ACL injury within 2 years of ACL reconstruction (ACLR) compared to those who do not experience a second ACL injury.[92] Recent works also discuss the simpler methods using clinical-grade MRIs that can identify the same knee anatomy factors contributing to ACL injury risk as found with advanced research-grade imaging.[93]

The American Journal of Sports Medicine is a leading source of articles in studies related to women's sports injuries. The top-cited work (2512) published by the journal is by T. E. Hewett et al. (2005) ,[44] which is the top-cited article in this research area. The next highly cited (1338) work by Arendt & Dick[94] evaluates the rates and mechanisms of anterior cruciate ligament injuries in collegiate men's and women's soccer and basketball, specifically to assess the higher susceptibility of female athletes to these injuries and explore potential extrinsic and intrinsic factors contributing to this increased risk. The third most cited (1224) work evaluates the effect of neuromuscular training on the incidence of knee injury in female athletes and finds that collegiate female athletes have significantly higher rates of anterior cruciate ligament injuries than males, primarily due to non-contact mechanisms and various extrinsic and intrinsic factors.[95] The early publications from this journal were related to Injuries in women's gymnastics,[96] epidemiology of women's gymnastics injuries,[97] exercise-related injuries and performance-limiting conditions,[98] and an overview of injury experiences among collegiate women athletes.[99] Their recent publication investigates knee biomechanics during side-step cutting in female elite athletes with and without a history of ACL injury and their link to future ACL injuries[87]; evaluates multiple machine learning methods for predicting ACL injury risk factors[100]; and reviews research investigations on injuries in basketball.[101]

Hägglund, M. has significantly contributed 27 research articles to this research domain. His most cited (318 citations) study[73] evaluates the effectiveness of neuromuscular training programs in lowering the incidence of acute knee injuries. The early research includes assessing a warm-up program's effectiveness in preventing acute knee injuries in adolescent female football players[102] and comparing injury incidence and patterns between male and female players in the Swedish premier league, focusing on exposure, injury severity, and common injury sites to inform preventive measures.[103] The author has recently published articles on Prep-to-Play PRO, an injury prevention program for women's[104]; investigate the time-loss injury epidemiology and characteristics among women's elite football players[105]; assess whether hop performance tests can predict safe football participation and the risk of ACL injury or reinjury[106]; explore the knowledge, attitudes, and behaviors of players, head coaches, and medical personnel in the Irish Women's National League (WNL) to injury prevention and injury management[107]; investigate how different follow-up times and statistical methods (CART analysis and Cox regression) affect the association between various risk factors and ACL injury in female football players after ACL reconstruction[108]; explore factors affecting injury prevention and management[109]; measure changes in self-reported knee function, activity level, and satisfaction in female football players with or without ACL reconstruction[110]; and describe the injury prevalence, patterns, and potential baseline risk factors among male and female football players.[111]

Through a comprehensive inspection of science mapping performances, this study reveals that despite the trending feature of basic themes in women's sports injuries, there are still significant gaps and opportunities for further research. In addition to keywords associated with basic themes such as ACL injuries,[87] injury prevention,[112] and injury risk factors, major clusters of future research keywords were identified. First, injury types like TBI,[113,114] Lower extremity injury,[115] Overuse injuries,[116] and Concussions.[117] Second, Epidemiology and Descriptive Studies, epidemiology,[118] and descriptive epidemiology.[119] Furthermore, specific conditions include Sleep,[120] Stress,[121] Female athlete triad,[116] menstrual cycle,[122,123] and injury surveillance.[124,125] In addition, studies related to specific sports, such as gymnastics,[126] lacrosse,[119] Rugby,[127] and Australian Football.[128] Finally, others include the application of machine learning,[100,129] return to sport,[130,131] and rehabilitation,[132–134] which are also trending and have scope for future investigation. The aforementioned research works incorporate various combinations of these recommended keywords.

Conclusion

Women's participation in sports has grown significantly, paralleled by increased concerns about sports-related injuries among female athletes. This study investigated a detailed BA of women's sports injuries literature to elucidate the research landscape and identify future research directions. A total of 910 research articles were retrieved from the Scopus database from 1962 to July 2024 using advanced search strategies. This analysis, facilitated by Biblioshiny and VOSviewer, mapped performance metrics and scientific contributions, revealing trends, key contributors, and emerging themes. Our study can benefit academic stakeholders, trainers, and coaches. First, it gives a clear picture of the current research on women's sports injuries. Second, our findings highlight current challenges in the field, supporting policymakers in promoting athlete safety and developing effective injury prevention strategies. Finally, our analysis identifies key contributors and collaborations among researchers, funding agencies, and institutions, which can enhance cooperation and lead to more impactful policy outcomes. However, our study is limited to data from the Scopus database, which may result in missing relevant studies from other sources. Additionally, the accuracy of bibliometric studies can be influenced by the quality and appropriateness of authors' keywords, potentially affecting the identification of research clusters and emerging themes. Future research could benefit from including other sports-related injuries and exploring additional databases to provide a broader perspective on women's sports injury research.

Conflicts of interest

None

Appendix

Table A1
Search keywords.

Keywords	Result	
Women	women* OR female* OR girl*	761,460[a]
Sports	Sport* OR Athlet* OR Player* OR "Acrobatic Gymnastic*" OR "Alpine Skiing*" OR Archery* OR "Artistic Gymnastic*" OR "Artistic Swimming*" OR Athletic* OR Badminton* OR Baseball* OR Softball* OR Basketball* OR "Beach Handball*" OR "Beach Volleyball*" OR Biathlon* OR Bobsleigh* OR Boxing* OR	800623[b]

(continued on next page)

Table A1 (*continued*)

Keywords	Result	
	"Canoe Slalom*" OR "Canoe Sprint*" OR Cricket* OR "Cross-Country Skiing*" OR Curling* OR "Cycling BMX Freestyle*" OR "Cycling BMX Racing*" OR "Cycling Mountain Bike*" OR "Cycling Road*" OR "Cycling Track*" OR Diving* OR Equestrian* OR Fencing* OR "Fig Skating*" OR Football* OR "Freestyle Skiing*" OR Futsal* OR Golf* OR Handball* OR Hockey* OR "Ice Hockey*" OR Judo* OR Karate* OR "Lacrosse*" OR Luge* OR "Marathon Swimming*" OR "Modern Pentathlon*" OR "Nordic Combined*" OR "Rhythmic Gymnastic*" OR "Roller Speed Skating*" OR Rowing* OR "Rugby Sevens*" OR Sailing* OR Shooting* OR "Short Track Speed Skating*" OR "Skateboarding*" OR "Ski Jumping*" OR "Ski Mountaineering*" OR Snowboard* OR "Speed Skating*" OR "Sport Climbing*" OR Squash* OR Surfing* OR Swimming* OR Taekwondo* OR Tennis* OR Trampoline* OR Triathlon* OR Volleyball* OR "Water Polo*" OR Weightlifting* OR Wrestling* OR "skeleton bobsled" OR "Track and field" OR running* OR sprint* OR walking OR Walking OR jumping OR throwing OR racewalking OR "cross country" OR "cross-country" OR hurdles OR "steeplechase" OR Marathon OR "Half-marathon" OR "Half marathon" OR "Pole vault" OR jump* OR "High jump" OR "Long jump" OR "Triple jump" OR "Discuss throw" OR "Hammer throw" OR "Javelin throw" OR "Pentathlon" OR "Heptathlon" OR "Decathlon"	
Injury	Injur*	475,196[a]

*Superscript a: indicates search on Article title; Superscript b indicates only article title or Keywords; Search Date: 05.08.2024

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