Review Article

Determining the DNA of Sport Sciences Research Through Advanced Bibliometric Topic Modeling

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This study aims to present a comprehensive bibliometric overview of the sport sciences category, focusing on analyzing the multidisciplinary nature of research. The analysis is based on advanced topic modeling developed by the Centre for Science and Technology Studies (CWTS), applied to scholarly outputs from 2001 to 2022 using Clarivate Analytics' Web of Science. Descriptive bibliometric indicators and topic modeling clustered global research into 4,159 topics, including 60,321 outputs specific to sport sciences. The results show significant expansion in sport sciences research, with increased international collaboration and a notable contribution to 1,279 global research topics. Research activity is concentrated, with 75% of output focused on Biomedical and Social Sciences themes.Noteworthy areas include injury prevention, performance optimization, psychological aspects of sports performance, and effective teaching methodologies, highlighting the multidisciplinary nature of the field. These findings provide valuable insights for guiding evidence-based decision-making, shaping science policy, and promoting research diversity and collaboration in sport sciences.

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1. Background

Bibliometrics, the discipline that quantifies the generation and consumption of scientific information, has been indispensable for interpreting scientific advancement since the 1970s[1]. Descriptive

bibliometrics offers a tool for determine the evolution, dispersion, and citation of scientific literature whereas evaluative bibliometrics offers to policy makers rigorous assessment frameworks to enhance allocation of research funds, refine specific disciplines, and increase research efficacy[2]. Both areas in bibliometrics involve a systematic analysis of a multitude of data that are captured from bibliographic databases like the *Web of Science* (WoS) or *Scopus*. Thus, through a multifaceted approach, bibliometrics could provide a comprehensive picture of scientific productivity and influence, enabling a more data-driven and objective assessments of scientific research[3]. Moreover, the proliferation of data has complicated obtaining a clear picture of research fronts, but science mapping has emerged as a powerful bibliometric tool for creating visual representations of research fields and their interrelationships[4]. For these reasons nowadays bibliometrics has been extensively utilized to analyze multiple research fields, and sport sciences has not remained on the sidelines.

Biomedicine has been the primary focus of bibliometric analyses in the field of sport sciences. Various research fronts have been studied, including anabolic steroid usage in sports and its prevalence as a substance of abuse[5] or determining the nexus between physical activity and health in children, adults and older adults[6]. The role of technology in sports and health promotion have been another area of significant bibliometric investigation, shedding light on the transformative effects of technological advancements in these domains[7]. Additionally, a comprehensive exploration of global research on sleep studies in athletes was undertaken, covering scholarly outputs from 1966 to 2019[8]. In expanding the scope of research, bibliometric analyses have been applied to studies concerning coffee/caffeine's relation to sport[9], as well as exploring the literature on the connection between exercise and neuropathic pain[10]. Sport biomechanics research has also been under the bibliometric microscope, focusing on citation metrics as indicators of research excellence[11]. This was supplemented by an investigation into the most-cited research in sports biomechanics[12]. The impact of outdoor air quality on environments used for exercise and sports practice was also examined[13]. Finally, research in mindfulness within sports has been also studied through a bibliometric lens[14]. Indeed, there have been numerous studies that have analyzed the intersection of biomedicine and sports.

In the same way, there are bibliometric studies in sport sciences related to social sciences, and mainly on topics within education and economics/management. There are articles that establish a link between sport management and education management[15], as well as those that assess the progression of scientific production and map the thematic scope of research in physical education[16]. Other studies

focus on crucial topics such as inclusion in physical education[17], and the impact of online education in the realm of sports from 2001 to 2022, particularly during the COVID-19 era[18]. Bibliometrics has also been employed in sport economics[19], sport policy[20], and sport management[21]. Within this specialty, other studies have discussed topics related to the management of sport organizations and events[22], or have aimed to identify the scientific production on sports sponsorship[23]. Innovation in sports is another topic that has been analyzed, providing a more contextual focus[24]. Likewise, other studies have discussed the most relevant journals that publish research work on sport management[25][26].

More peripheral areas such as the intersection of sport and psychology have focused on the intellectual foundation of the subjects[27]. Additionally, sport history journals have been evaluated using several metrics[28]. We must not overlook certain bibliometric studies that have centered on specific sports disciplines, including rugby[29], judo[30][31], futsal[32], taekwondo[33][34], combat sports[35], fitness[36], and women's football[37]. Taking a geographical perspective, there are studies that have conducted a comprehensive analysis of collaboration patterns among countries, revealing a notable increase in international partnerships[38]. Research efforts in South American countries have also been examined, covering a time span from 1970 to 2012[39]. Lastly, it is crucial to acknowledge studies distinguished by their methodological ambition. These papers conduct structural analyses of domains within sport sciences, deploying advanced mapping centered on citation analysis[40], co-word networks[41][42], or social network analysis[43].

Based on an analysis of the existing literature, three significant aspects become apparent. Firstly, the multidisciplinary nature of sport sciences is emphasized, as it intersects with both health and social sciences. Secondly, the bibliometric approach to sport sciences has been conducted in a fragmented manner impeding to obtain a comprehensive picture of global trends, actors, and significant topics. Thirdly, a limited number of bibliometric experts have exhibited interest in this field, resulting in articles focusing on descriptive bibliometrics and basic counts. Currently, bibliometrics is a field closely linked to big data and data science[3]. Therefore, it facilitates the implementation of more sophisticated techniques, such as advanced topic modeling, allowing for the exploration of complex research structures from millions of scholarly outputs simultaneously[44][45]. As bibliometricians, these maps are essential today for the detection of central and emerging topics that can assist in the organization of scientific agendas. Building on the identified gaps in the literature, this study is guided by the following research questions:

1. How has scientific production in sport sciences evolved over the past two decades?

2. To what extent is sport sciences a multidisciplinary field?
3. What are the major research topics within sport sciences, and how are they distributed across different scientific domains?

To address these questions, this study aims to provide a comprehensive and multidisciplinary bibliometric analysis of sport sciences. The main objective is to move beyond fragmented approaches and offer a broader view of the field's development, research structures, and thematic trends. The present article seeks to fill these knowledge gaps by pursuing the following objectives:

1. To provide a bibliometric contextualization of the global evolution within the sport sciences category in the *Web of Scien*ce from 2001 to 2022.
2. To analyze the overall research trends and the multidisciplinary nature of sport sciences using advanced topic modeling techniques.
3. To explore the main research topics within sport sciences and compare their distribution with global research trends.

2. Methods

The main source of information for this study is *Clarivate Analytics' Web of Science*. This bibliographic database has three main indexes: *Science Citation Index Expanded* (SCIE), *Social Science Citation Index* (SSCI), and *Arts and Humanities Citation Index* (AHCI), where the scientific production of national and international reference can be found[46]. This is why it is a leading tool for research evaluation and policy science. The database was accessed through *InCites*, the bibliometric suite that is part of the *Clarivate Analytics* ecosystem of tools and is focused on the evaluation of scientific production. It allows the generation of a range of bibliometric indicators based on data from the three main indexes of *Web of Science* (SCIE, SSCI, and AHCI) and *Emerging Sources Citation Index* (ESCI) at diverse levels (e.g., authors, research areas, countries, etc.). In this manner, we have generated an exhaustive dataset encompassing all scholarly outputs in the field of sport sciences, categorized by country, using *InCites* analysis by "Research areas" (*Web of Science* category level) and "Locations" (country level). This dataset includes all articles and reviews published between 2001 and 2022.

The bibliometric indicators provided by *InCites* and descriptive statistics were used for the analysis of sport sciences scholarly outputs. Furthermore, we have also explored the main research fronts of this research field using topic modeling, a technique that identifies thematic structures in large text datasets.

In this study, we apply the solution developed by the *Centre for Science and Technology Studies* (CWTS) for its *Leiden Ranking*[47]. This thematic classification is performed through a network-based clustering approach, conducted annually by CWTS, clustering the articles and reviews published from 2000 onwards, which are indexed in the three main indexes of *Web of Science* (SCIE, SSCI, and AHCI), based on the citations among them[48][49]. This method enables large-scale topic classification with very high granularity, distinguishing between macro, meso, and micro levels. The micro-level clusters, in particular, allow the identification of research fronts. Its relevance is further demonstrated by its subsequent integration not only into *Web of Science*, but also through its adaptation in other major databases such as *OpenAlex*. The clustering algorithm, optimized for large-scale bibliometric networks, results in 4,159 (micro-level fields of science), which are then overlapped with the 254 categories of *Web of Science* (excluding multidisciplinary). From there, one of the five main research areas (macro-level fields of science) of these categories is assigned to each research topic if at least 25% of the publications belong to it. The distribution of these 4,159 global categories or micro-topics is analyzed, and then the contribution of sport sciences to these topics within the context of worldwide science is examined. The result is a thematic map of science in which each node represents a research topic. The color of the node represents the main area, and the positions of the nodes on the map reflect the citation links. Using this thematic map as a basis, the production of sport sciences has been overlayed on it, allowing the identification of its main research topics.

The supplementary material (SM) includes a.*xls* file with these sections: global bibliometric indicators in the sport sciences (SM_Sheet1), main indicators at country for two different period (SM_Sheet2), list of 4,159 research topics for world science research (SM_Sheet3), a detailed description of main research topics in sport sciences (SM_Sheet4) and the number of journals included in the *Journal Citation Reports* (JCR) in the sport sciences category and the topic distribution according to the Gini Index are as follows (SM_Sheet5). The dataset is available at *Zenodo* (https://doi.org/10.5281/zenodo.8171511). To facilitate the comprehension of the clusters an interactive world map (corresponding to Figure 1 of this article) and another for sport sciences (Figure 2) have been shared (https://doi.org/10.5281/zenodo.7973574). Finally, the results section is organized as follows: Section 3.1 presents the indicators and identifies the principal contributors among countries. Section 3.2 provides a topic analysis, offering an overview of 4,159 research topics applied to global scholarly outputs as a comparative framework for subsequent specific research topics in sport sciences. The results culminate with a comprehensive delineation of main research topics.

3. Results

3.1. Bibliometric context

To better understand these trends, we first examine the bibliometric indicators that provide a broader perspective on the field's evolution. Table 1 and data included SM_Sheet1 (supplementary material) presents the bibliometric analyses of the sport sciences literature from 2001 to 2022, revealing several trends. The volume of scholarly outputs in the field has shown steady growth. For example, the number of documents increased from 4,814 in 2001 to 13,279 in 2022. A trend toward international collaboration is particularly evident, with the percentage of international collaborations escalating from 12.07% in 2001 to 30.48% in 2022, and the average number of authors per paper also showing progressive growth from 3.676 in 2001 to 5.525 in 2022. However, the percentage of documents in first quartile (Q1) journals, after 2001 (51.31%), has exhibited a downward trend with a trough of 30.72% in 2020, potentially reflecting shifts in publication practices and journal standards. These patterns highlight the increasing globalization of sport sciences research. They also suggest that publication dynamics are changing, which may influence how the relevance and impact of the field are perceived. Taken together, these findings illustrate the dynamic evolution of the sport sciences research landscape over the past two decades, characterized by a growing research output, heightened international and multi-author collaboration.

Period	*Scholarly outputs*	*Scholarly outputs in Q1 journals*		*Times cited*	*% International collaborations*	*Coauthorship average*
2001-2005	26.599	12,387		1,289,775	13.27	3.76
2018-2022	71,049	16,741		519,490	29.76	5.30
GLOBAL (2001-2022)	**207,032**	**72,771**		**514,8641**	**23.44**	**4.47**

Table 1. Main bibliometrics indicators in sport sciences between 2001 and 2022

Building on this, we now turn to the contributions of various countries, highlighting their evolving

impact on sport sciences research. Figure 1 and SM_Sheet2 shows the production and impact in sport sciences of several countries. In the period of 2001-2005, the leading countries in sport sciences research according to the number of scholarly outputs were the United States, the United Kingdom, Canada, Australia, and Germany. During 2018–2022, these countries remained predominant. However, new contributors also emerged, such as Spain, Brazil, and China. Throughout these periods, the United States maintained its leadership in terms of scholarly outputs volume but experienced a slight decrease in its Category Normalized Citation Impact (CNCI), from 1.108 to 1.151, and the proportion of documents in Q1 journals, from 50.5% to 34.99%. Conversely, the United Kingdom and Australia not only substantially increased their production, the United Kingdom from 2,825 to 9,046 and Australia from 1,803 to 7,254, but also improved their Category Normalized Citation Impact, the United Kingdom from 1.039 to 1.480, suggesting their growing influence in the field of sport sciences.

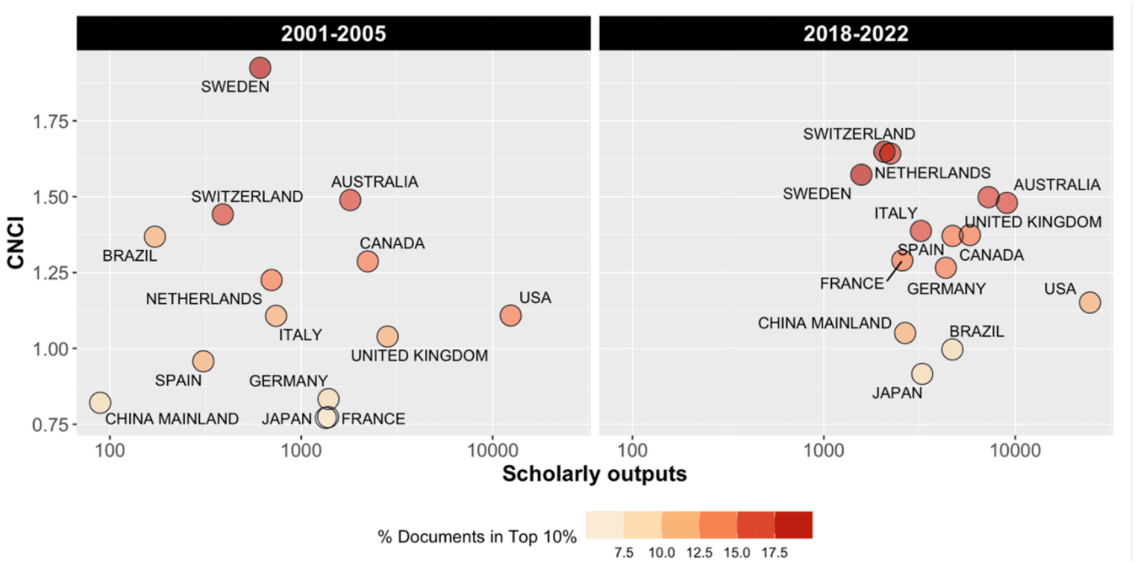

Figure 1. Production and impact of various countries in sport sciences. Indicators: Category Normalized Citation Impact (CNCI) is the actual citations divided by category expected citations.Scholarly outputs = nr of article and reviews. % Documents in Top10%: share of 10% citation-ranked scholarly outputs in all fields. Complete data available at SM_Sheet2

Beyond the leading contributors, other regions have also demonstrated notable advancements, further diversifying the global research landscape. The Scandinavian countries, namely Sweden, Norway, and Denmark, also demonstrated considerable progress. Sweden increased its scholarly outputs from 610 to 1,571 and maintained a high percentage of documents in Q1 journals, around 50%. Norway distinguished

itself with a high in category normalized citation impact 1.742 and a high percentage of documents in Q1 journals of 55.67%. Denmark also improved its scholarly outputs from 343 to 1264 and boasted a remarkable percentage of documents in Q1 journals of 57.56%. Spain, a new entrant in the list of leading producers in the second period, exhibited a substantial increase in international collaborations, from 30.84% to 55.11%, and a commendable Category Normalized Citation Impact of 1.370, despite a slight decrease in its proportion of documents in Q1 journals from 49,23% to 33.36%. Lastly, China, another newcomer in the second period, despite exhibiting a lower category normalized citation impact (1.051), sustained a percentage of documents in Q1 journals of 29.34%.

3.2. Advanced topic modeling: World map

Having established the global distribution of research outputs, we now explore how research topics are structured across different scientific domains. In Table 2 and Figure 2, we present an overview of the major research topics worldwide that have been identified, encompassing a vast collection of 11,305,631 documents distributed across 4,159 distinct research topics. These cluster topics are categorized into five broad areas. The distribution of research topics and scholarly outputs demonstrates a relatively homogeneous spread across the fields, although there are variations in their proportions. Biomedical and health sciences is during 2018-2022 the most prominent area, capturing a significant share of the topics at 31.88% and a substantial portion of the scholarly outputs at 34.46%. Social sciences and humanities exhibit the lowest number of topics, accounting for 11.13% of the topics and 9.28% of the scholarly outputs. This concentration in biomedical and health sciences aligns with the historical trajectory of sport sciences research, which has predominantly focused on physiological, medical, and performance-related aspects, while social and computational dimensions remain underdeveloped. The presented data is complemented by a two-dimensional distribution, visually representing the relationships and patterns between different topics. We recommended check supplementary material for a better understanding of the figures.

Map Color Fig. 2	*Area*	*Nr. Research topic clusters*	*% Research topic clusters*	*Nr. Scholarly outputs*	*Nr. Scholarly outputs*
	**Social sciences and humanities**	463	11.13%	1,049,567	9.28%
	**Biomedical and health sciences**	1,326	31.88%	3,896,255	34.46%
	**Physical sciences & engineering**	1,120	26.93%	3,117,566	27.58%
	**Life and earth sciences**	534	12.84%	1,553,939	13.74%
	**Mathematics and computer science**	716	17.22%	1,688,304	14.93%
TOTAL 2018-2022		**4,159**	**100%**	**11,305,631**	**100%**

Table 2. Overview of the worldwide research topics between 2018 and 2022

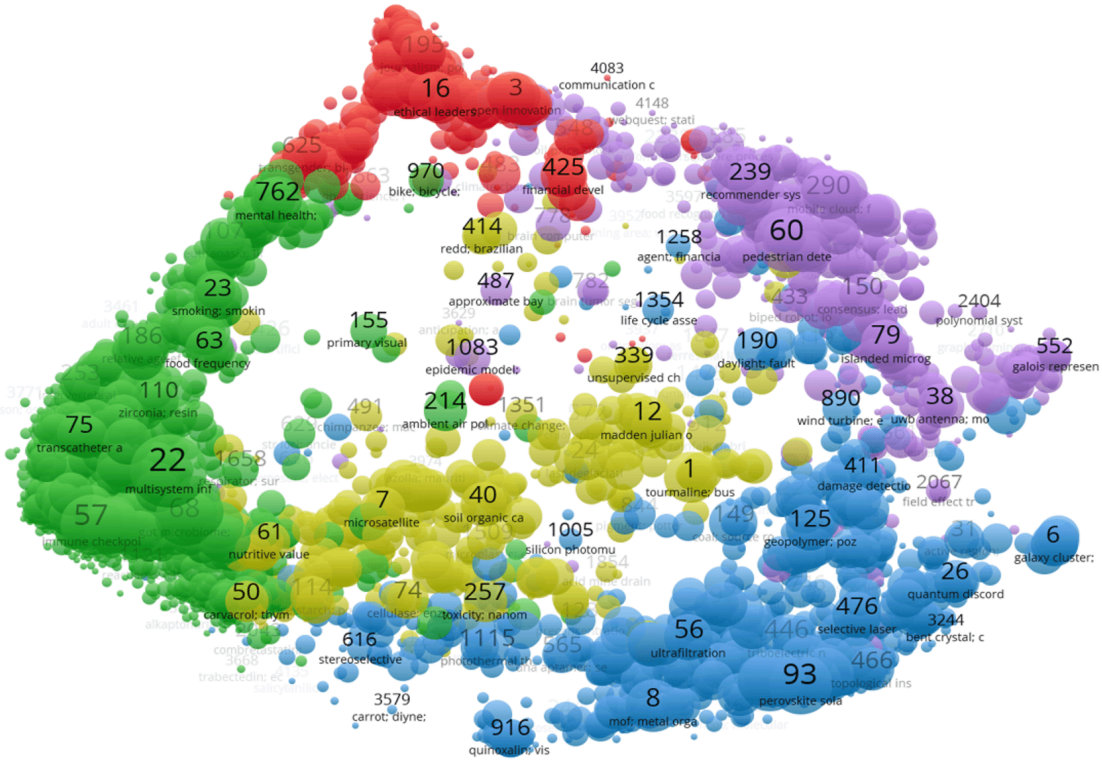

Figure 2. Worldwide research topic clusters between 2018 and 2022. Each cluster represents a research topic, the size reflects the number of scholarly outputs, and the color the area.

Interactive map → https://doi.org/10.5281/zenodo.8171511.

Clusters description → https://doi.org/10.5281/zenodo.7973574 (SM_Sheet3)

3.3. Advanced topic modeling: Sport sciences map

Narrowing our focus to sport sciences, we analyze its thematic distribution and how it aligns with global research trends. Table 3 and Figure 3 provides an overview of the distribution of 60,321 scholarly outputs clustered in the category of sport sciences. The analysis identifies 1,279 distinct research topics. Most of these are concentrated in biomedical and health sciences, which make up 61.45% of all topics. This area also accounts for 90.69% of the total publications. In contrast, social sciences and humanities account for a smaller proportion of topics, making up 14.54% of the total. Publications in this category represent 7.70% of the overall scholarly output. The remaining categories, namely physical sciences and engineering, life and earth sciences, and mathematics and computer science, each contribute approximately 8-9% of the total topics identified within the field of sport sciences. These figures reflect

where sport sciences research is positioned within the global academic structure, with its primary contributions aligned with biomedical disciplines and a secondary presence in social sciences. It is important to note, however, that these categories exhibit relatively lower scholarly outputs, amounting to less than 1%.

Map Color Fig. 3	*Area*	*Nr. Research topic clusters*	*% Research topic clusters*	*Nr. Scholarly outputs*	*Nr. Scholarly outputs*
	**Social sciences and humanities**	186	14.54%	4,644	7.70%
	**Biomedical and health sciences**	786	61.45%	54,705	90.69%
	**Physical sciences & engineering**	97	7.58%	332	0.55%
	**Life and earth sciences**	95	7.43%	290	0.48%
	**Mathematics and computer science**	115	8.99%	350	0.58%
TOTAL 2018-2022		1,279	100%	60,321	100%

Table 3. Overview of the research topics for **sport sciences between 2018 and 2022**

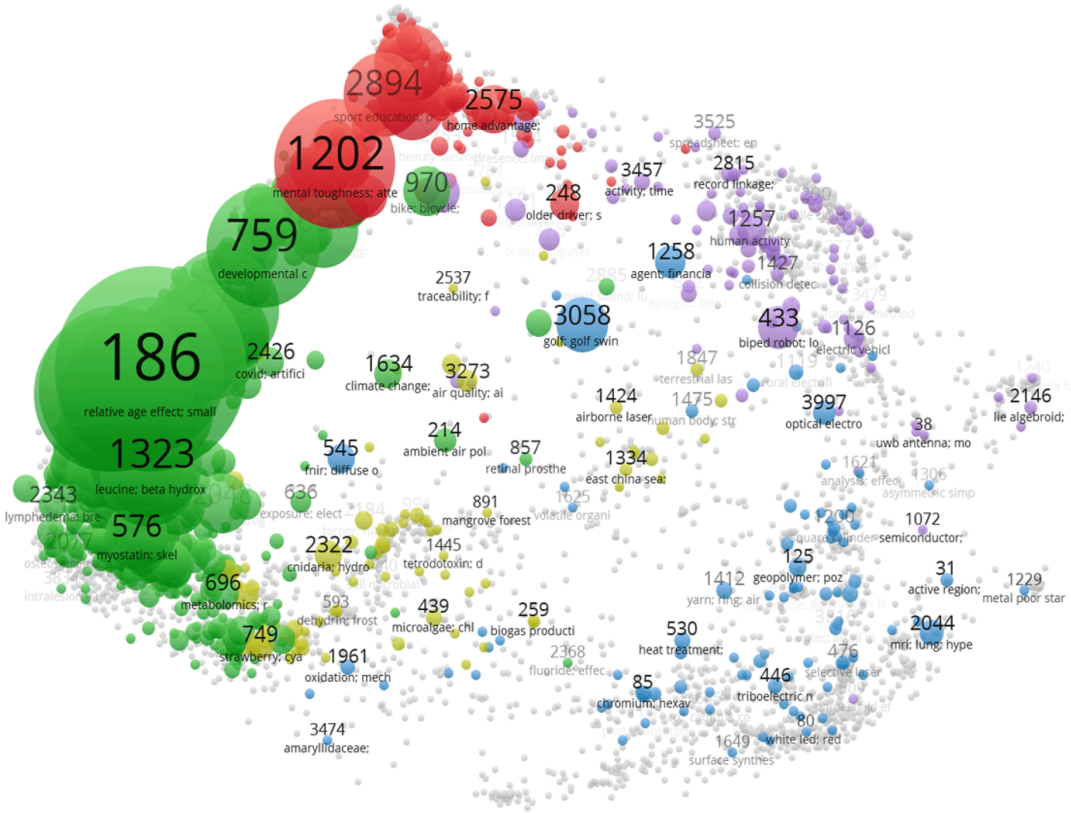

Figure 3. Research topic clusters for sport sciences between 2018 and 2022. Each cluster represents a research topic, the size reflects the number of scholarly outputs, and the color the area.

Interactive map → https://doi.org/10.5281/zenodo.8171511

Clusters description → https://doi.org/10.5281/zenodo.7973574 (SM_Sheet4)

3.4. Analysis of the evolution of research topics

Examining the temporal evolution, we see how the concentration of research topics has changed over time, revealing broader shifts in research focus. Figure 4A illustrates the increasing concentration of research topics over the past two decades, as evidenced by the rise in the Gini coefficient from 0.7657 in 2001 to a peak of 0.8431 in 2018. This upward trend shows growing inequality in how research efforts are distributed. Fewer topics now capture a larger share of the scientific output. The sharp increase in concentration from the mid-2000s to 2018 aligns with broader trends in research specialization, where established fields attract more funding and citations, reinforcing their dominance in the global scientific landscape. After reaching its highest point in 2018, the Gini coefficient stabilized and has fluctuated around 0.839 since 2020. This plateau started with the onset of the COVID-19 pandemic, which may have

disrupted normal research dynamics, funding, priorities, and publication patterns. The stagnation in topic concentration post-2020 suggests that the pandemic may have temporarily altered the trajectory of scientific specialization, potentially redistributing research efforts across a wider range of topics or slowing the pace of concentration due to shifting global research agendas.

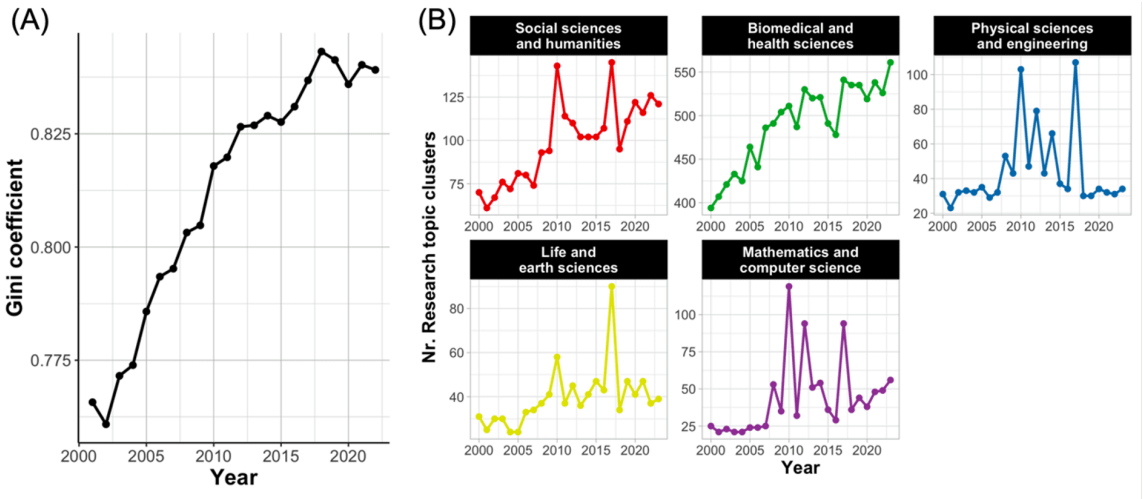

Figure 4. Evolution of research topic concentration and distribution in sport sciences (2001–2022): (A) Trend of the Gini coefficient in sport sciences; (B) Evolution of research topic clusters by main areas.

This evolving distribution underscores the dynamic nature of sport sciences research, with certain fields expanding while others remain stable. Figure 4B presents the evolution of research topics across different scientific domains, highlighting variations in thematic expansion and stability. Despite the overall trend toward concentration, some fields have continued to expand. For example, both social sciences and humanities, as well as biomedical and health sciences, have seen a continuous increase in the number of research clusters. The expansion in biomedical and health sciences is particularly notable, with the number of topic clusters growing from approximately 394 in 2001 to 526 in 2022, reflecting sustained diversification within this domain. Similarly, social sciences and humanities exhibit a long-term upward trend, albeit with fluctuations, indicating dynamic shifts in research priorities. In contrast, fields such as physical sciences and engineering and mathematics and computer science display less consistent growth patterns, with sharp increases followed by periods of decline.

doi.org/10.32388/LXCEUL

3.5. Detailed major research topics

With this foundation, we now delve into the specific major research topics that have emerged within sport sciences. Before we begin, it should be noted that the topics have been assigned to main areas. However, more interdisciplinary topics may belong to two areas simultaneously, as is the case with cluster *"Delving into prosthetics and EMG"*. It is assigned to *"Biomedical and health sciences"* and *"Mathematics and computer science"* (*SM_Sheet3, Column G).* For the purpose of analysis, it is included in the main areas with the higher contribution. Following a broad overview provided in Table 4, we present what could be considered the current major topics in sport sciences, specifically those that are most frequently published internationally. We have included only 39 most representative and the rest are available in the Supplementary Material (SM_Sheet4).

We have used the research topic keywords for a description with a title and the main lines of research. Three indicators are included: 1) number of scholarly outputs published on these topics; 2) a percentage that indicates how many of these outputs are published in the *Web of Science* category of sport sciences; 3) a percentage that reflects the contribution of sport sciences to the world. For example, the topic *"Understanding sports dynamics"* has globally 10,723 scholarly outputs, of which 7,402 (69%) are from sport sciences. This indicates topics that, regardless of the field, occupy a principal place in our research. Similar cases are *"Analyzing swimming performance"* (57%) or, in the case of social sciences, *"Investigating psychological aspects of sports performance"* (41%). This classification not only identifies the most prolific areas of research but also contextualizes their relevance within the broader scientific landscape, helping to define how sport sciences integrate into the global research ecosystem.

ID	3.1 Major Topics in Biomedical and Health Sciences (> 450 papers)	*World papers*	Sport sciences	
			Nr.	%
186	Understanding sports dynamics a comprehensive exploration of relative age effects, efficacy of small-sided games and the global popularity and implications of sports like soccer, basketball, and football.	10,723	7,402	69%
351	Advancing in knee injury treatments detailed examination of anterior cruciate ligament reconstruction strategies, double bundle and meniscal repair, and the functional relevance of anterolateral ligament.	7,175	4,018	56%
324	Shoulder repair interventions a deep dive into reverse shoulder arthroplasty, treatment of proximal humeral fractures, arthroscopic rotator cuff repair, and dealing with adhesive capsulitis.	7,100	3,274	46%
612	Performance Analysis of Sport The front crawl technique, critical power, oxygen uptake kinetics, maximal lactate steady state, and foot strike patterns.	5,432	3,104	57%
759	Understanding motor disorders Intensive study of developmental coordination disorder (DCD), related motor competence, motor skill acquisition, and promoting physical literacy.	6,358	1,367	22%
421	Enhancing knee surgery techniques: A deep dive into total knee arthroplasty (TKA), high tibial osteotomy, total knee, and unicompartmental knee surgeries.	7,442	1,362	18%
273	Occupational health and wellness A holistic approach to occupational physical activity, office worker health, prescription guidelines, affective responses, and workplace wellness.	8,784	1,341	15%
252	Focusing on falls prevention	8,255	1,336	16%

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ID	3.1 Major Topics in Biomedical and Health Sciences (> 450 papers)	*World papers*	Sport sciences	
			Nr.	%
	Highlighting the fear of falls among older adults, community engagement, and the importance of fall prevention strategies.			
303	Unraveling concussion complexities Study of sports-related concussions, chronic traumatic encephalopathy, and their impact in athletes.	8,814	1,312	15%
1435	Delving into hip pathologies Detailed review of femoroacetabular impingement, hip arthroscopy, capital femoral epiphysis, periacetabular osteotomy, and Legg-Calve-Perthes disease.	3,687	1,133	31%
1323	Nutrition and muscle synthesis Investigating leucine, beta-hydroxy-beta-methylbutyrate's roles, energy intake, and appetite control in muscle building.	3,189	1,009	32%
1846	Exploring elbow surgery techniques Comprehensive analysis of distal humerus, radial head, total elbow arthroplasty, distal bicep, and supracondylar fracture treatments.	2,549	963	38%
1831	Understanding ankle conditions Examination of chronic ankle instability, ankle fractures, kinesio taping, and Ottawa Ankle Rule application.	3,030	945	31%
1644	Cryotherapy and exercise Investigating the role of cryotherapy in reducing oxidative stress, lipid peroxidation, and interleukin release post-eccentric exercise.	2,432	854	35%
1112	Delving into tendon pathologies Comprehensive study of Achilles tendinopathy, patellar issues, and lateral epicondylitis.	3,845	844	22%
1364	Firefighter safety and wellness	3,251	781	24%

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ID	3.1 Major Topics in Biomedical and Health Sciences (> 450 papers)	*World papers*	Sport sciences	
			Nr.	%
	Examining hypothermia risks, heat acclimation strategies, heat stress management, and hydration in firefighters.			
2550	Knee disorder investigations In-depth exploration of patellofemoral pain syndrome, medial patellofemoral ligament reconstruction, patellar instability, recurrent dislocation, and trochlear dysplasia.	1,675	753	45%
438	Innovations in cartilage repair Research into talus conditions, cartilage tissue engineering, osteochondral defects, autologous chondrocyte implantation, and chondrogenic differentiation.	5,270	566	11%
1826	Exploring high altitude physiology Acute mountain sickness, hypoxia, high altitude pulmonary edema and the effects of hypobaric hypoxia.	2,227	550	25%
191	Investigating hand osteoarthritis in older adults The potential role of glucosamine, understanding Kashin-Beck disease, and ADAMTs.	9,421	543	6%
1124	Examining spinal cord injuries Autonomic dysreflexia, the effects of traumatic injuries leading to paraplegia and the mechanics of wheelchair.	3,796	524	14%
477	Delving into cardiovascular health Understanding heart rate variability, baroreflex sensitivity, the link to metabolic syndrome.	5,048	518	10%
2420	Examining physical health during pregnancy pelvic girdle pain, the role of abdominal muscles, and the impact on pregnant women.	1,752	493	28%
566	Investigating muscle health	8,619	484	6%

ID	3.1 Major Topics in Biomedical and Health Sciences (> 450 papers)	*World papers*	Sport sciences	
			Nr.	%
	sarcopenia and sarcopenic obesity, the use of dual-energy x-ray absorptiometry, and the obesity paradox.			
389	Exploring rehabilitation techniques for stroke patient the use of serious games, virtual reality, and kinect systems.	7,370	479	6%

Table 4. Major research topics in sport sciences between 2018 and 2022

ID	3.2. Major Topics in Social Sciences and Humanities (> 50 papers)	*World papers*	Sport sciences	
			Nr.	%
202	Investigating psychological aspects of sports performance The roles of mental toughness, attention, burnout, anxiety, and passion in athletes.	4,379	1,799	41%
2894	Studying the pedagogy of sport and physical education The training of physical education teachers, the role of games in teaching, and the influence of kinesiology in school physical education.	1,308	508	39%
1426	Impact of large-scale events An exploration of how large-scale leisure events, particularly in London, impact politics and women's experiences.	3,603	385	11%
308	Psychology of motivation and achievement Entered on motivational climate, drawing from self-determination theory and the need for autonomy support	7,909	270	3%
123	Exploring effective teaching methods Pedagogical content knowledge, the role of student teachers, the implementation of lesson study, etc	9,611	104	1%
848	Advancing psychometric research Item response theory, differential item functioning, investigating measurement invariance, the application of computerized adaptive testing, and the use of structural equation modeling in psychometrics.	5,289	101	2%
2575	Analyzing sports competition dynamics The concept of home advantage, the importance of competitive balance in sports leagues, prediction markets as indicators, and the market impact on Major League Baseball.	1,616	84	5%

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ID	3.2. Major Topics in Social Sciences and Humanities (> 50 papers)	*World papers*	Sport sciences	
			Nr.	%
1209	Exploring motor cognition processes Action observation, the role of motor imagery and imitation, the mirror neuron system, and the influence of semantic dementia on motor representations.	3,125	82	3%
821	Analyzing disability rights and empowerment The inclusion of disabled individuals, the concept of self-determination, the American perspective on disability, the specific focus on women with disabilities, and the impact of the Disabilities Act.	5,296	69	1%
1663	Advancing open science practices Promoting replication studies, assessing the significance through p-values, and emphasizing reproducibility in research.	4,441	62	1%

ID	3.3. Major Topics in Physical Sciences and Engineering (> 50 papers)	World papers	Sport sciences	
			Nr.	%
3058	Exploring the dynamics of golf The golf swing, its effects on ball trajectory, and the influence of smartphone technology in golf performance analysis.	867	126	15%

ID	3.4. Major Topics in Mathematics and Computer Science (> 50 papers)	World papers	Sport sciences	
			Nr.	%
433	Advancing robotics in human locomotion Exploring the design and functionality of biped robots, lower limb exoskeletons, and their applications in walking, navigating stairs, and traversing uneven terrain.	6,158	53	1%

These findings highlight key areas of emphasis, particularly in biomedical and health sciences, where injury prevention and rehabilitation remain dominant themes. Section 3.1 reflects significant trends in biomedical and health sciences research. One can identify a compelling focus on injury prevention and treatment methodologies, especially related to sports activities. The subjects "*Advancing in knee injury treatments*" (4,018 scholarly outputs) and "*Shoulder repair interventions*" (3,274), along with advancements in elbow and ankle surgery techniques, reflect a deep-rooted interest in optimizing the treatment of sports-related injuries. Elbow and ankle surgery techniques demonstrate an understanding that effective treatment and prevention must extend to all areas of the body. Additionally, there is a clear focus on integrating new technologies and strategies into these topics, as evidenced by the study of innovative treatments for knee injuries and advancements in surgery techniques. The table also underscores the ongoing quest to understand the human body's performance under various conditions signify a multifaceted approach to understand and enhance human physiological responses. Topics like "*Exploring high altitude physiology*" (550), "*Cryotherapy and exercise*" (854), and "*Nutrition and muscle synthesis*" (1,009) are indicative of a broader interest in understanding the body's responses and recovery to different physiological and environmental stimuli. Moreover, the inclusion of specific professional groups, such as "*Firefighter safety and wellness*" (781), and broader demographics like "*Occupational health and wellness*" (1,341) and older adults, hint at the integration lifestyle considerations within the biomedical and sport sciences fields.

Beyond biomedical research, sport sciences also engage with social sciences, particularly in education, psychology, and competition dynamics. Section 3.2 outlines the major research topics within the social sciences and humanities. A notable cluster within these subjects is centered around "*Psychological*" (Cluster id 202, 308, 84) with this area of focus containing research topics such as "*Investigating psychological aspects of sports performance*" (1,799 scholarly outputs) and "*Psychology of motivation and achievement*" (270). This grouping reflects a robust interest in understanding the psychological factors that impact athletes' performance and motivation, underscoring the importance of mental resilience, focus, and drive in sport sciences research. Education has a leading role, there are two main topics "*Studying the pedagogy of sport and physical education*" (508) and "*Exploring effective teaching methods*" (104) emphasizes the critical role of education and effective teaching methods in sports and physical activities. Similarly, the study of the "*Impact of large-scale events*" (385) signifies an understanding of the societal and political influences of sports events. Topics such as "*Analyzing sports competition dynamics*"

(84) delve into the intricate factors that shape competitive sports. We a much lower number of scholarly outputs in 3.3. and 3.4. show residual topics related to physical sciences and engineering as well as mathematics and computer science.

4. Discussion

4.1. Limitations

Despite these insights, it is important to acknowledge certain methodological limitations, particularly regarding data coverage and the use of *Web of Science*. Although it is an internationally recognized bibliographic database, it does not provide complete coverage of all scientific literature. This limitation is particularly evident for non-English literature and fields such as social sciences and humanities. Consequently, research outputs published in other languages or in non-indexed journals may be underrepresented, which could result in an overemphasis on trends and topics prevalent in English-speaking and biomedical contexts. This potential bias means that the global picture presented here may overlook relevant contributions from other regions and disciplines, and the thematic diversity of sport sciences could be underestimated. However, the use of *Web of Science* is indispensable in this study, as the topic modeling employed is exclusively based on publications indexed in this database.

Thus, while this analysis includes significant contributions, particularly those of international significance, others may have been overlooked. Furthermore, the maps generated in this study have two limitations. They are derived from their creation method, which involves processing hundreds of millions of citation relationships between scholarly outputs each year. As a result, the clusters depicted in the maps may vary over time, and different groupings could exist in previous or subsequent editions. Also, some scholarly outputs may not fit neatly into any specific research topic cluster due to the connections established through their citations.

4.2. Interpretation of outcomes

Even with these constraints, the analysis provides valuable insights into the structure and trajectory of sport sciences research. The bibliometric results indicate a rise in the contributions within the sport sciences category, a trend attributable to both the discipline's expansion and the indexing policies of the *Web of Science*. Notably, the number of journals in the sport sciences category has grown from 68 in 2001 to 93 in 2022 (SM_Sheet5). This increase signifies an annual growth rate of 5%, slightly surpassing the

overall growth rate of the *Web of Science* database at 4.7%. These figures suggest that the growth in sport sciences is proportional to the expansion of the database. Concerning the collaboration indicator, the percentage of collaborative documents has demonstrated a systematic rise since 2012. In that year, the collaboration percentage was 21% globally and specifically in the sport sciences category. By 2022, this percentage had escalated to between 26% and 30%, respectively. This observation is further supported by the increase in the average number of authors per article, rising from 3.7 in 2001 to 5.6 in 2022 (SM_Sheet5).

These findings align with previous research, indicating a more interconnected field with a significant rise in collaborative and team-based research practices. The study portrays sport sciences' contribution across a broad range of the 4,159 global topics detected. The results underscore sport sciences' clear multidisciplinary profile, primarily concentrating in two significant fields: biomedical and health science and social sciences. Comparing with global trends, the topics appear relatively evenly distributed, yielding a Gini concentration index of 0.65, while in sports sciences, it is 0.90. Paradoxically, while the number of research topics within sport sciences has increased over time, the actual distribution of publications has become progressively more concentrated in fewer topics. The figure included in SM_Sheet5 clearly exhibits the differences in high concentration on certain topics. Therefore, it can be stated that sport sciences is a discipline with highly concentrated multidisciplinarity in two fields that "occasionally" accumulate 75% of the topics and participate in other major fields sporadically (physical sciences & engineering, life and earth sciences, and mathematics and computer science). In this context, the results quantitatively confirm other partial analyses[50], indicating that sports science is beginning to undertake integrated research combining multiple sub-disciplines.

The increasing concentration of research in fewer topics has both positive and negative implications. On one hand, increased specialization may foster deeper expertise and drive advances within specific areas. On the other hand, this trend could limit the diversity of research topics and potentially reduce opportunities for innovation and multidisciplinary collaboration. As a consequence, there is a risk that research in sport sciences may become less likely to produce disruptive advances or open up entirely new directions, as has been observed in other scientific domains[51]. Therefore, while specialization can enhance progress in established fields, it is important to also encourage diversity to maintain a dynamic and innovative research environment.

4.3. Implications and conclusion

These findings could inform decision-making processes in science policy, potentially guiding funding bodies and policymakers in identifying key research areas deserving attention and financial support. Institutions, like universities and research centers, could use these insights to refine their research agendas, allocate resources more efficiently, and identify strategic opportunities for collaboration. By analyzing their contributions to major global themes and assessing their positioning within specialized topics, institutions can adapt their funding strategies and research priorities to align with rapidly evolving areas of knowledge. Additionally, these findings can help universities establish new research clusters in emerging fields that are gaining prominence, ensuring long-term competitiveness in the global research landscape. Offering a multidisciplinary perspective could help stakeholders gain a comprehensive understanding of the research landscape and evaluate the efforts devoted across various crucial areas. Ultimately, this inclusive perspective can aid researchers in positioning their work within the broader field, thereby fostering impactful and progressive sports sciences research. In conclusion, this study provides valuable insights into the intricate and applied aspects of sport sciences research, despite certain limitations. The findings presented can help shape science policy decisions, foster a more global and interconnected research field, and support the progression of impactful research in this field.

5. Conclusion

This study provides a comprehensive bibliometric analysis of sport sciences research over the past two decades, revealing a clear concentration of publications in biomedical and health sciences, alongside a smaller but consistent presence in social sciences. The field has experienced significant growth in international collaborations and co-authorship, reflecting an increasingly global and networked research environment. The evolution of research topics, characterized by a rise in thematic concentration over time, indicates a dynamic interplay between specialization and diversification. By employing advanced topic modeling, this study offers a structured classification of sport sciences research, providing valuable insights into the distribution of research efforts. While the dominance of biomedical topics aligns with the field's historical development, the minimal presence of sport sciences in other domains, such as physical sciences or engineering, reflects the natural disciplinary boundaries. Given these results, future bibliometric studies should pay closer attention to areas outside biomedicine, with particular focus on the social sciences and humanities, to capture a more complete and nuanced picture of the discipline. Ultimately, this study enhances the understanding of the structure and evolution of sport sciences, laying

the groundwork for future bibliometric studies that further explore emerging trends and disciplinary intersections.

Statements and Declarations

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Conflicts of Interest

The authors have no competing interest to declare.

Ethics Approval

Not applicable.

Consent to Participate

Not applicable.

Author Contribution

- DTS – Conceptualization; Formal Analysis; Funding acquisition; Investigation; Methodology; Resources; Software; Writing – original draft
- WAM – Data curation; Formal Analysis; Investigation; Methodology; Software; Visualization; Writing – review & editing
- AU – Formal Analysis; Project administration; Writing – review & editing
- JRR – Formal Analysis; Supervision; Validation; Writing – review & editing
- FBO – Formal Analysis; Supervision; Validation; Writing – review & editing
- RE – Conceptualization; Formal Analysis; Funding acquisition; Project administration; Resources; Writing – review & editing

Data Availability

The dataset with the bibliometric indicators and research topics is available at Zenodo (https://doi.org/10.5281/zenodo.8171511). Interactive world map (corresponding to Figure 1 of this article) and another for sport sciences (Figure 2) have been shared (https://doi.org/10.5281/zenodo.7973574).

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