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Physics in Sport Education: Insights from a decade of bibliometric analysis

Nur Habib Muhammad Iqbal[1], Nuzulira Janeusse Fratiwi[2], Reza Ruhbani Amarulloh[3*], Tian Kurniawan[4]

1,2 Department of Physics Education, Universitas Pendidikan Indonesia, Indonesia
3 Department of Physics Education, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Indonesia
4 Department of Sport Science, Universitas Pendidikan Indonesia, Indonesia

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Correspondence
Reza Ruhbani Amarulloh
E-mail:
rezaruhbaniamarulloh@uinjkt.ac.id

Abstract

This study aims to analyze trends in scientific publications related to the application of physics in sports education over the past decade using a bibliometric approach. Data were obtained from the Scopus database using the keywords "TITLE-ABS-KEY(Physics AND Sport AND Education)" within the publication range of 2015 to 2024, resulting in 83 relevant documents. The data were exported in CSV and RIS formats and analyzed using VOSviewer 1.6.20 and Microsoft Excel 365 to perform co-authorship and co-occurrence analyses. The findings reveal that research in this domain predominantly centers on biomechanics, coaching strategies, and the integration of technology in sports learning and training. Notably, there has been a significant rise in studies involving digital monitoring systems, indicating a growing emphasis on data-driven performance analysis. The bibliometric mapping also highlights limited collaboration among authors across different institutions and countries, suggesting opportunities for broader academic partnerships. Overall, the study concludes that the application of physics in sports education continues to develop in alignment with technological innovations. However, gaps remain in translating these advancements into effective teaching and coaching practices. Future research is encouraged to adopt a multidisciplinary framework that bridges physics, education, and sports science to optimize the implementation of physics-based technologies in educational and athletic settings.

Keywords: bibliometric analysis, physics, sport science, sport education.

Introduction

In the last decade, sports education has developed rapidly with increasing research highlighting the application of physics in the learning process. Physics plays a fundamental role in understanding various aspects of sports, such as biomechanics of motion, force, momentum, energy, and the interaction between the athlete's body and its environment (Chaeroni et al., 2024; Fratiwi et al., 2020). A deeper understanding of these principles allows sports education students to develop more effective learning strategies, improve movement efficiency, and understand the factors that influence athlete performance in various sports (Farrow & Robertson, 2017; Hastie & Wallhead, 2016; Wang & Wang, 2024). In addition, technological advances have encouraged the use of various physics-based devices, such as motion capture, force plates, and biomechanical sensors in the analysis of athlete performance. These tools not only help in understanding sports techniques but also support a more objective and data-driven science-based learning approach (Feng et al., 2020; Saura et al., 2023).

The application of physics in sports education has made significant contributions in various sports. In athletics and swimming, an understanding of aerodynamics and hydrodynamics allows for the optimization of movements to reduce air and water resistance, leading to increased athlete efficiency (Manshahia et al., 2016; Takagi et al., 2016; Zamparo et al., 2020). Meanwhile, in sports that require accuracy, such as archery and basketball, the concept of projectile trajectory and ball rotation dynamics can be utilized to improve shot accuracy (Adesida et al., 2019; Soltani & Morice, 2020). In other sports, such as soccer and tennis, aspects of friction and angular momentum also play a role in improving game strategies, such as optimizing the spin effect on the ball or controlling player movement (Liu et al., 2023; Naik et al., 2022). Not only in technical aspects, physics also plays a role in the development of sports equipment. The design of shoes with special soles, rackets with optimal balance, and aerodynamic clothing are real examples of how the use of physics principles can improve athlete performance and reduce the risk of injury (Harifi & Montazer, 2017). Therefore, understanding the concept of physics in sports education is crucial in supporting the development of sports science more broadly.

Several studies have explored the application of physics in various aspects of sports education, showing how the principles of mechanics, thermodynamics, and waves are used to enhance students' understanding of sports learning (Kirya et al., 2021; Kranjc Horvat et al., 2022; Parisoto & Pinheiro, 2016). More specific studies, such as those by Barbosa et al. (2023), highlight the role of biomechanical analysis in sports technique learning, while Hernández-Mustieles et al (2024) examine the use of biomechanical sensors to support technology-based learning processes. However, most studies are more oriented towards athlete performance and direct sports technique analysis, while studies that specifically examine how sports education students understand and apply physics concepts in learning are still limited. In fact, in the context of education, a deep understanding of physics principles can help students develop more effective science-based learning strategies, both in terms of theory, practice, and performance evaluation (Berie et al., 2022; Herodotou et al., 2019).

The rapid expansion of scholarly literature in this field underscores the critical need for a systematic review to synthesize existing knowledge, track evolving research trends, and map the intellectual structure of the discipline. Such an analysis not only identifies dominant themes and frequently debated topics but also illuminates the contributions of key researchers, institutions, and collaborative networks that have driven the field's progress. Among the methodologies available for analyzing research trends, bibliometric analysis has emerged as a powerful quantitative tool. By employing statistical techniques and data visualization, this approach enables large-scale evaluation of scientific publications, revealing patterns in citations, authorship dynamics, and thematic evolution (Skute et al., 2019). Beyond quantifying academic output, bibliometrics provides a holistic perspective on the field's development, highlighting research gaps and emerging frontiers. These insights are invaluable for designing future studies, particularly in underexplored or rapidly advancing areas. Against this backdrop, the present study utilizes bibliometric methods to examine publication trends over the past decade (2013–2023) in the application of physics to sports education.

Therefore, this study aims to analyze the trend of scientific publications related to the application of physics in sports education over the past decade using the bibliometric method. By exploring various publications over this period, this study is expected to provide broader insights into scientific developments in this field, identify emerging research directions, and provide perspectives for academics and practitioners in designing a more optimal physics-based sports education curriculum.

Methods

Design and Methods

This study employs bibliometric analysis to explore the trend of scientific publications related to the application of physics in sports education over the past decade. Bibliometric analysis was chosen because it provides a systematic approach to measuring and mapping research trends, identifying influential authors, institutions, and research themes in a particular field (Klarin, 2024). This method allows for a comprehensive assessment of the evolution of research topics and the structure of academic collaboration.

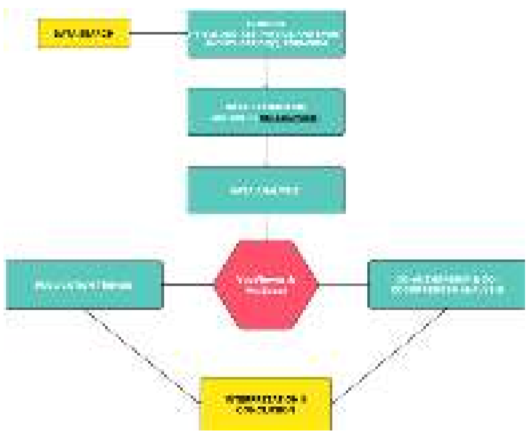
Data for this study were obtained from the Scopus database, one of the largest and most widely used academic databases for bibliometric analysis. Scopus was selected as the primary source because it covers a broad range of peer-reviewed literature across various disciplines and provides structured metadata for bibliometric studies (Donthu et al., 2021). The literature search was conducted using the query "TITLE-ABS-KEY (Physics AND Sport AND Education)" within the title, abstract, and keywords fields. The search covered the publication years 2015–2024 to capture the latest trends in this research area. The inclusion criteria were restricted to peer-reviewed journal articles, conference proceedings, review papers, book chapters, and other scholarly documents to ensure a comprehensive representation of research developments. Publications that were not relevant to the study, such as those focusing solely on general physics or unrelated sports sciences, were excluded through manual screening based on title and abstract analysis.

The selection of the 2015–2024 timeframe is justified by several factors. Over the past decade, there has been a significant increase in the integration of technology and physics-based approaches in sports education (Baca et al., 2022). This period has also seen rapid advancements in sports biomechanics, motion analysis, and physics-based training methodologies, particularly with the rise of data-driven sports science (Feng et al., 2020; Saura et al., 2023). Additionally, analyzing this specific period allows the study to identify emerging research trends and potential gaps to guide future studies (Skute et al., 2019).

After the initial search, a total of 83 documents were extracted, consisting of 42 journal articles, 26 conference papers, 5 errata, 4 review papers, 3 book chapters, 2 conference reviews, and 1 note. All data were exported in CSV and RIS formats and subsequently analyzed using VOSviewer version 1.6.20 and Microsoft Excel 365. VOSviewer was utilized to generate bibliometric maps that visualize co-authorship networks, keyword co-occurrences, and research clusters, while Microsoft Excel was used for statistical analysis of publication trends, including distributions by year, country, and institution. The selection process involved automatic filtering based on search criteria, manual screening of titles and abstracts to ensure relevance, and the removal of duplicate records or publications outside the intended scope of research.

Several bibliometric techniques were applied in this study. Co-authorship analysis was used to identify leading authors, institutions, and collaborative networks in the field of physics in sports education, allowing the mapping of research collaboration structures and highlighting key contributors. Co-occurrence analysis was conducted to examine the relationships between frequently appearing keywords, helping to identify major research themes and emerging trends in the field (Klarin, 2024). In addition, publication trend analysis was

Figure 1
Research workflow



carried out using Microsoft Excel to track annual publication distributions, subject areas, and country-wise contributions, providing insight into the global research landscape. By integrating these bibliometric techniques, this study aims to offer a comprehensive overview of the development of physics applications in sports education, identify gaps in existing research, and provide insights for future investigations. The workflow of this research is illustrated in Figure 1.

Result

Recent Research Trends

The number of publications on a particular research topic serves as an indicator of research development and direction (Donthu et al., 2021). As shown in Figure 2, the research trend on Physics in Sports Education has fluctuated over the past decade, reflecting varying levels of academic interest in this field. In 2015, only five studies were published, followed by a slight increase to seven in 2016. A significant rise occurred in 2017, with the number of studies reaching 11. However, this momentum did not continue, as 2018 saw a sharp decline to just four publications. The trend rebounded in 2019 with eight studies and continued upward in 2020, returning to 11—the same peak as in 2017. The highest number of publications was recorded in 2021, with 13 studies, marking the peak of research activity in this field. However, this was followed by another decline in 2022, where only six studies were published. In contrast, 2023 and 2024 showed stabilization, with nine studies each year. This fluctuation suggests that while interest in the topic remains present, it has yet to establish a consistent growth trajectory.

From a geographical perspective, as shown in Figure 3, the United States (US) leads in publication output, contributing 21 studies, making it the most active country in this research field. China follows with 12 publications, while Indonesia ranks third with 10 studies. Other countries such as Japan and Russia each contributed six studies, whereas nations like the United Kingdom (UK), Canada, Italy, and Australia had a relatively lower number of publications, ranging between three and four. These differences in publication numbers may indicate regional variations in research priorities, funding availability, and institutional focus on the intersection of physics and sports education.

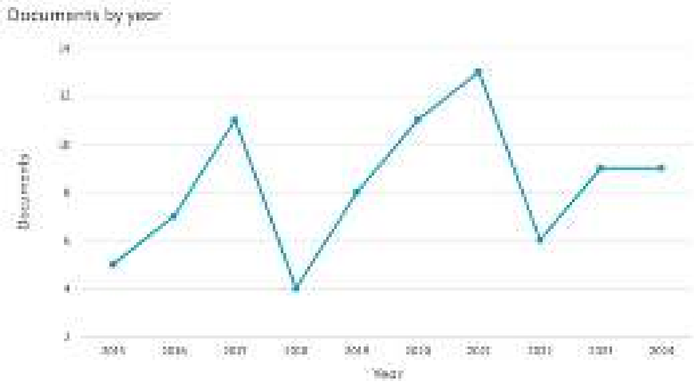
Co-Authorship Analysis

Collaboration among researchers plays a crucial role in shaping the development of a research field. In this study, Table 1 presents the co-authorship network based on Total Link Strength (TLS), which measures the intensity of an author's collaborative connections. A higher TLS value suggests a strong and well-established research network. The number of links represents direct collaborations between authors, while the number of documents reflects individual productivity in scientific contributions. The co-authorship network visualization, presented in Figure 3, reveals several research clusters that represent distinct approaches within the field. Among the most prominent clusters is Gabdrakhmanov et al. (2016) (TLS = 4), which explores pedagogical strategies for integrating physics concepts into sports curricula. Another key cluster is led by Suzuki et al. (2020) (TLS = 10), which focuses on the application of technology and simulation in physics-based sports training. Meanwhile, Sari et al. (2021, 2022) (TLS = 4) examines experimental methods for introducing physics concepts through sports activities, while Tang et al. (2021) (TLS = 4) specializes in biomechanics and motor skills development. The most influential contributions come from Fadly et al. (2017) and Zulfaris et al. (2017) (TLS = 18), whose research significantly advances the understanding of environmental factors, sports physiology, and the complex interplay between physics, health, and athletic performance.

Co-Occurrence Analysis

Figure 2

Publication trends by year



To gain a deeper understanding of the dominant research themes, a co-occurrence analysis was conducted, as summarized in Table 2. This analysis utilized two key metrics: occurrence, which represents the frequency of a keyword in the dataset and indicates its relevance to the field, and Total Link Strength (TLS), which measures the strength of a keyword's connection with other terms, highlighting its interdisciplinary significance. Initially, 778 keywords were extracted from publication titles and abstracts. To refine the analysis, a minimum occurrence threshold of two was applied, narrowing the selection to 104 relevant keywords for further examination.

The results reveal that the most frequently occurring keyword is "Sports," appearing 22 times with a Total Link Strength (TLS) of 30, indicating that the majority of research focuses on the application of physics in sports settings. Similarly, the keyword "Students" appears 20 times with a TLS of 46, highlighting the pedagogical emphasis on how learners grasp physics concepts within sports education.

This pedagogical relevance is further reinforced by the presence of "education" (13 occurrences, TLS = 22) and "physical education" (13 occurrences, TLS = 27), confirming the strong connection between this field and instructional strategies as well as curriculum development.

Beyond the educational focus, the analysis also points to an increasing integration of technology in sports physics education. Keywords such as "augmented reality," "interactive graphics," "tangible interaction," and "visualization" exhibit relatively high TLS values (ranging from 32 to 34), suggesting a growing reliance on digital tools for immersive learning experiences. This trend aligns with the co-authorship network, where Suzuki et al. (2020) emerged as a leading contributor to research on artificial intelligence, digital modeling, and simulation-based training.

In addition to technology, biomechanics and physiology have also emerged as significant research directions. Keywords such as "Biomechanics" (5 occurrences, TLS = 15), "Dynamics" (3 occurrences, TLS = 35), and "Physiology" (4 occurrences, TLS = 17) indicate that studies in this domain extend beyond education, emphasizing the role of physics principles in optimizing athlete performance and training methodologies. This focus is consistent with the Tang et al. (2021) cluster, which explores biomechanics and physical performance in sports.

Discussion

The findings from the bibliometric analysis provide valuable insights into research trends, collaboration patterns, and thematic connections within the field of Physics in Sports Education. The fluctuations in publication trends over the past decade, as observed in Figure 2, may be attributed to various factors, such as shifts in researcher interest, funding availability, and technological advancements that influence the direction of research. The increases in 2017, 2020, and 2021 may indicate the impact of innovations or new discoveries in applying physics principles to sports training, whereas the declines in 2018 and 2022 might reflect reduced interest or challenges in conducting research during those periods.

The global distribution of research publications suggests that Physics in Sports Education has

Table 1

Co-Authorsip Analysis

No	Authors	Documents count	Total Link Strength	Cluster
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	5
	[illegible]	[illegible]	[illegible]	2
	[illegible]	[illegible]	[illegible]	2
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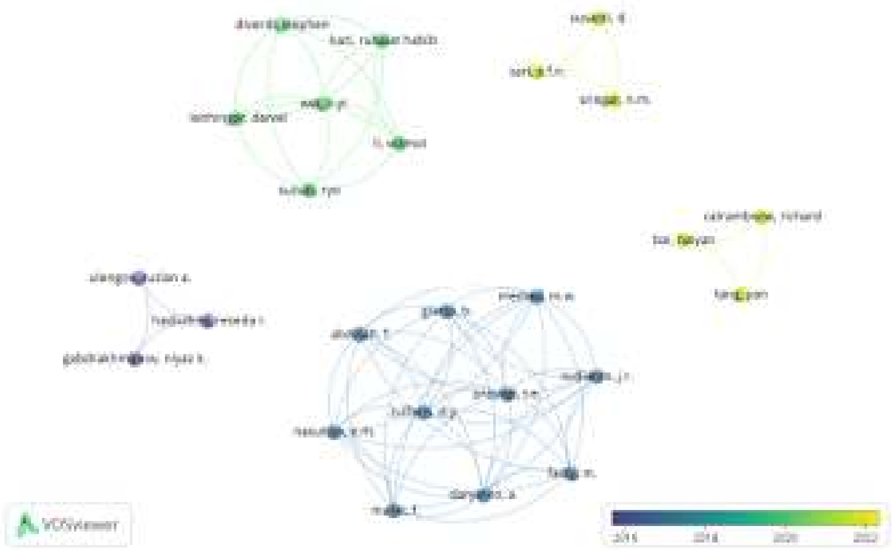
	[illegible]	[illegible]	[illegible]	3
	[illegible]	[illegible]	[illegible]	3
	[illegible]	[illegible]	[illegible]	4
	[illegible]	[illegible]	[illegible]	4
	[illegible]	[illegible]	[illegible]	4

Figure 3

Bibliometric Mapping



gained significant attention in specific regions. The high number of publications from the United States indicates the presence of a strong research ecosystem, substantial funding support, and an emphasis on integrating technology into education and sports. China's notable contribution aligns with its national policies aimed at advancing science, technology, and sports education. Indonesia's position as the third-largest contributor highlights its growing efforts to enhance physics education and sports science development. Meanwhile, Japan and Russia, with moderate publication numbers, may reflect their respective emphases on technology-driven education and sports science traditions. The lower publication numbers from the UK, Canada, Italy, and Australia suggest that while research in this domain exists, academic focus in these countries may be directed toward other aspects of science or sports education.

Beyond publication trends, the analysis of co-authorship patterns reveals important insights into the nature of collaboration in this field. Bibliometric mapping using VOSviewer identified several research clusters that reflect different approaches to understanding and applying physics concepts in sports education. The prominent cluster is the Gabdrakhmanov et al. (2016) cluster, which has a TLS of 4. Research in this cluster focuses on pedagogical approaches to integrating physics concepts into sports curricula. Many studies in this cluster explore concept-based learning strategies, the effectiveness of teaching methods, and their impact on students' understanding in connecting physics theories with everyday sports phenomena.

On the other hand, the Suzuki et al. (2020) cluster shows a dominance of research that links technology and simulation in physics learning and sports training. With a TLS of 10, research in this group focuses more on the use of augmented reality (AR), artificial intelligence (AI), and digital modeling to analyze athlete movements and improve training effectiveness. This cluster provides an important perspective in the development of technology-based learning aids, which can help students understand physics principles more deeply and interactively. Then, the Experimental and Laboratory-based Approach is seen in the Sari et al. (2021, 2022) clusters, with a TLS of 4. Studies in this cluster discuss experimental methods that can be applied to introduce physics concepts such as force, energy, and momentum in sports activities. This approach is a strategy that can strengthen students' critical thinking skills, especially in analyzing sports events using scientific principles. Meanwhile, the Tang et al. (2021) clusters are more oriented towards biomechanics and motor skills, with a TLS of 4. The main focus of research in this cluster is how the laws of physics can be used to improve athlete performance in various sports. This study highlights how a deep understanding of physics can help in modifying training techniques and optimizing body posture and balance, which are not only relevant to athletes but can also be applied in movement-based learning in the classroom.

Finally, the Fadly et al. (2017) and Zulfaris et al. (2017) clusters reflects research with a broader scope, covering various aspects such as the environment, sports physiology, and the relationship between physics, health, and athlete performance. This cluster has the highest TLS, which is 18, indicating a wider collaboration network than other clusters. External factors such

Table 2
Co-Occurence Analysis

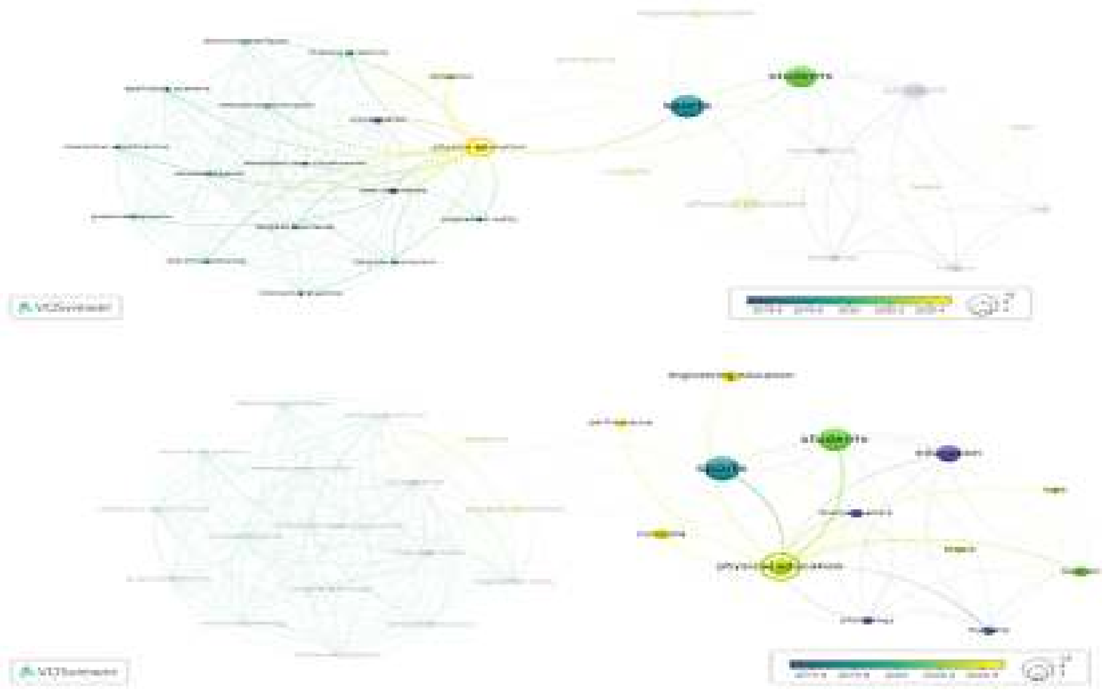
No	Keywords	Occurrences	Total Link Strength
	Students	20	46
	Dynamics	3	35
	physics education	6	35
	user interfaces	3	34
	Visualization	3	34
	application scenario	2	32
	augmented reality	2	32
	drawing (graphics)	2	32
	embedded data visualization	2	32
	graphical elements	2	32
	interaction techniques	2	32
	interactive graphics	2	32
	interactive visualizations	2	32
	physical objects	2	32
	real-time authoring	2	32
	sketching interfaces	2	32
	tangible interaction	2	32
	tangible interfaces	2	32
	Sports	22	30
	physical education	13	27
	Human	7	24
	Education	13	22
	Humans	5	21
	Curricula	7	19
	Physiology	4	17
	Biomechanics	5	15
	engineering education	7	14
	Female	3	13
	Male	3	13
	Performance	4	11

as temperature, humidity, and air quality are the main concerns in this study, indicating that physics learning in the context of sports is not only limited to mechanical aspects, but also involves interaction with environmental conditions. From the results of the co-authorship analysis, it can be seen that although research on physics in sports education is developing in various directions, there are still challenges in building connections between clusters. Most research is still fragmented, with limited collaboration within a particular discipline. In fact, strengthening connections between these fields is very important to encourage interdisciplinary research, which can lead to a more comprehensive approach to teaching physics to students. This finding is in line with the bibliometric study conducted by Liu et al. (2023), who found that research in this field still tends to be separated into different clusters, thus hampering innovation in learning methodology and application of technology in the field of sports.

In the context of this study, the bibliometric analysis conducted aims to understand how a systematic approach to problem solving can play a role in improving students' analytical skills, especially in filtering and evaluating information in the digital era. This is reinforced by the research of Deák et al. (2021), which highlights that science-based learning that integrates an interdisciplinary approach can significantly improve students' critical thinking skills. With the increasing trend of research in this field, there is a great opportunity to develop a science-based learning model that not only teaches physics concepts theoretically, but also trains critical and systematic thinking patterns in dealing with information circulating in society. Research by Naylor et al. (2015) highlights that a science-based approach in sports education has the potential to strengthen students' critical thinking skills, especially in evaluating athlete performance data objectively.

These findings provide perspectives for academics and practitioners to strengthen integration between fields, encouraging interdisciplinary research, and optimizing science-based curriculum in sports education. With closer cooperation, it is hoped that studies on the application of physics in sports education can continue to develop and provide a more significant impact on strengthening scientific literacy and critical thinking skills of students. Despite the diversity of research directions, the co-authorship analysis also reveals a challenge: the fragmentation of research clusters. Most collaborations remain confined within specific disciplines, limiting interdisciplinary connections. Strengthening linkages between these research areas is crucial for fostering a more integrated approach to teaching physics in sports education. This aligns with the findings of Liu et al. (2023), who noted that research in this field remains divided into distinct clusters, hindering broader methodological innovation. Encouraging cross-disciplinary research can bridge these gaps, facilitating a more holistic application of physics concepts in sports education.

Figure 4
Visualization from VOSviewer



The keyword co-occurrence analysis further reinforces these findings. The results of the co-occurrence analysis show that the most dominant keywords in this study are sports with 22 occurrences and a total link strength of 30, and students which appeared 20 times with a total link strength of 46. The dominance of these two words indicates that most studies in this field focus on how physics concepts are applied in the world of sports and how students understand and apply them in the context of learning. In addition, the presence of the keyword's education and physical education, each with 13 occurrences and a total link strength of 22 and 27, further emphasizes that this study has a strong pedagogical orientation, both in the context of teaching physics and physical education. In addition to the pedagogical aspect, this analysis also reveals trends in the use of technology to support physics learning in sports. Keywords such as augmented reality, interactive graphics, tangible interaction, and visualization have a fairly high total link strength, ranging from 32 to 34, which shows that interactive visualization and augmented reality-based technology are increasingly used in learning. This finding is in line with the results of the co-authorship analysis, where one of the main clusters consisting of Suzuki et al. (2020) focus on the development of technologies such as artificial intelligence, digital modeling, and simulation for athlete motion analysis and improving training effectiveness.

On the other hand, research related to biomechanics and physiology aspects in sports also shows considerable significance in this research network. Keywords such as biomechanics with 5 occurrences and a total link strength of 15, dynamics with 3 occurrences and a total link strength of 35, and physiology with 4 occurrences and a total link strength of 17, illustrate that this field does not only focus on learning aspects, but also on how the laws of physics can be applied to improve athlete performance and develop more effective training techniques. This finding is in line with the Tang et al. (2021) cluster in the co-authorship analysis, which shows that research in this field is often closely related to physical performance and biomechanics aspects in sports.

Visualization from VOSviewer in Figure 4 further clarifies the pattern of keyword associations in this study. Physics education has a fairly strong relationship with various concepts of data visualization and interaction, such as interactive visualizations, augmented reality, and user interfaces, indicating that technological approaches are increasingly being used to enhance physics learning in the context of sports. In addition, sports are closely related to students, education, and biomechanics, while physical education is often associated with sports, curriculum, and performance, which confirms that there is a lot of research on how physics is applied in physical education, both in the curriculum and in improving athletic performance. In terms of research trends based on publication year, there are differences in color in the visualization that reflect the development of this field. More yellow colors indicate that topics such as performance and engineering education are newer areas (2020 and later), while bluish green colors indicate that areas such as students and sports have been widely researched since around 2019. The focus on interactive visualization and augmented reality in physics education emerged earlier but remains an important area. In addition, the close relationship between physics education and various visualization methods on the left side of the graph, such as interactive visualizations, embedded data visualization, and augmented reality, further confirms that this technology-based approach is an important part of teaching physics in the context of sports.

Although research in this area continues to grow, the analysis also reveals limitations in the interrelationships between the fields. The visualization results show that research in the field of Physics in Sports Education is still fragmented, with collaborations tending to be limited to a specific disciplinary scope. In fact, strengthening the connections between physics, technology, biomechanics, and pedagogy can produce a more holistic approach in science and sports education. This is supported by the findings of Abrahamson & Mechsner (2022), who highlighted the importance of synergy between physics and sports science in developing more effective learning methods. In addition, Cossich et al. (2023) emphasized that the integration of data-driven technology in sports education not only improves students' scientific literacy but also helps them develop stronger analytical skills. As this research trend continues to grow, further attention is needed to how the various approaches in this field can be integrated to create more comprehensive learning and research models.

Future Implication

The findings of this study provide deeper insights into the development of physics in sports education, revealing established research patterns over the past decades. Through bibliometric analysis, it was identified that studies in this field extend beyond understanding theoretical physics concepts. They encompass applications in biomechanics, athlete training technologies, and curriculum development for students and prospective coaches. This aligns with Ji et al. (2022), who emphasized the crucial role of physics-based biomechanics in optimizing athletic techniques and designing more effective training strategies.

Moving forward, this study highlights opportunities to further integrate science-based approaches into sports education. The co-occurrence analysis suggests a growing trend in the use of technologies such as augmented reality, interactive visualization, and tangible interfaces in learning, indicating a shift toward more simulation-based and interactive training methods. Supporting this, Li et al. (2024) found that virtual reality-based simulations significantly enhance athletes' comprehension of motion mechanics, while Cossich et al. (2023) demonstrated that artificial intelligence-based performance analysis provides more accurate feedback for athletic improvement.

Moreover, the study underscores the importance of stronger interdisciplinary collaboration between physics, biomechanics, education, and technology to develop more effective and applicable teaching methods. Integrating sports physics research with coaching curricula can foster evidence-based training methods that align with technological and scientific advancements.

A systematic approach to curriculum design is needed. Fundamental physics concepts—such as mechanics, dynamics, and thermodynamics—should not only be taught theoretically but also applied in real sports practice. The increasing use of digital simulations in training presents an opportunity to develop learning modules that combine laboratory-based experiments with virtual technology, enabling students to better understand the direct relationship between physics principles and athletic performance. Clyne & Billiar (2016) found that integrating biomechanics laboratories with digital simulations significantly enhances students' learning experiences, reinforcing the potential benefits of such an approach.

Furthermore, this study provides insights for educational institutions in optimizing physics-based coaching curricula. By recognizing the strong link between physics and various aspects of sports, future coaches can be equipped with scientific insights to analyze athlete movements, design more effective training strategies, and leverage emerging technologies for performance optimization. This transition toward research-based learning could establish a scientific foundation for coaching methodologies, fostering a more analytical approach to athlete development.

Recent trends indicate a shift in sports education from merely understanding physics concepts to applying them in performance optimization and data-driven coaching strategies. This aligns with advancements in training systems engineering and the increasing use of digital simulations, artificial intelligence, and biomechanical modeling. Future research could focus on leveraging these technologies to personalize training programs and enhance coaching efficiency. Rana & Mittal (2021) demonstrated that machine learning-based analysis in sports biomechanics allows real-time adjustments to training programs based on data collected from motion sensors, highlighting the growing role of artificial intelligence in sports science.

While these developments offer promising prospects, several challenges must be addressed. The integration of physics-based training methodologies may face barriers such as limited access to advanced technologies in developing countries, resistance from traditional coaching systems, and the need for interdisciplinary expertise among educators and coaches. Strengthening institutional support and fostering collaboration among physics educators, sports scientists, and technology developers will be essential in overcoming these obstacles.

Given these findings, research in physics and sports education still has vast potential for expansion. The integration of physics, technology, and pedagogy will be crucial in developing more effective teaching and coaching methods while enhancing scientific literacy among students and sports practitioners. Strengthening interdisciplinary collaboration and embracing cutting-edge technology will accelerate progress in this field, ensuring that physics education in sports remains relevant to contemporary needs and continues to provide meaningful contributions to both academia and the sports industry.

The results of the study show that the study of physics in sports education has grown significantly in the last decade, with a wider focus including biomechanics, coaching strategies, and optimizing athlete performance. Bibliometric analysis reveals that the integration of physics concepts in the education of prospective coaches is not only theoretical, but also applied, with the use of technology in motion simulation and athlete performance analysis. In addition, the mapping of academic collaborations shows that research in this field increasingly involves various institutions and disciplines, especially in developing evidence-based approaches to improve the effectiveness of learning and coaching. These findings confirm that understanding physics in the context of sports has an important role in improving the quality of learning and coaching practice, thus requiring a more structured and innovation-based approach.

In line with these developments, further exploration is needed regarding the integration of technology such as augmented reality and interactive visualization in physics learning for prospective sports coaches to improve conceptual and applied understanding. In addition, cross-disciplinary collaboration between physics, education, and sport science must be strengthened to develop a more innovative curriculum based on the needs of the sports industry. Strengthening academic networks and practice-based research is also a strategic step in ensuring that the developed approach is not only theoretical, but also able to provide concrete solutions for the world of coaching. Thus, scientific literacy in sports can be increasingly relevant and contribute significantly to improving athlete performance and the effectiveness of coaching methods in the future.

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