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Advancing Athlete Health and Performance: A Bibliometric Study of Injury Prevention and Rehabilitation Techniques

Jalal kanan fahmi dababse^{1*}, Maksimenko Igor Georgievich¹,

Mahmoud Alatrash²

¹PH.D in physical culture and sport, Belgorod State National Research University, Belgorod, Russia. jalal.dababse1@gmail.com , maksimenko_76@mail.ru

²Department of Physical Education, Faculty of Educational Sciences and Teachers' Training, An-Najah National University, Nablus, State of Palestine. malatrash@najah.edu

Abstract:

This paper conducts a bibliometric analysis of injury prevention and rehabilitation techniques in athletic performance, mapping research trends and identifying future directions. Analyzing 338 studies from the Web of Science database, it applies performance analysis and science mapping tools like VOSviewer and R-Bibliometrix to assess publication trends, collaboration networks, and thematic clusters. Key contributors include Myer GD and Grooms DR, with the United States leading in output and citation impact. Four major author collaboration groups and five international cooperation networks were identified, revealing strong regional engagement but limited global coordination. Thematic mapping classified eight core research themes into four strategic quadrants, highlighting established areas such as “neuromuscular training” and emerging topics like “mental health in recovery.” Five research clusters based on keyword co-occurrence underscore the field's interdisciplinary nature. The study identifies gaps in theoretical and methodological diversity, offering insights into advancing evidence-based tools like wearable monitoring systems and standardized frameworks for global applications.

Keywords: Injury Prevention, Athletic Performance, Bibliometric Analysis, Neuromuscular Training, Mental Health Recovery.

*Corresponding author [/jalal.dababse1@gmail.com](mailto:jalal.dababse1@gmail.com)



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1. INTRODUCTION

Ineffective traceability and transparency in the health and performance of athletes have become global fears, especially in ensuring compliance with proven procedures in preventing injuries and meeting the expectations of athletes and coaches (Fredianto et al., 2024). In addition to these challenges, there is a growing concern for the credibility of rehabilitation techniques and the overall integrity of sports medicine in the athletic community (Penichet-Tomas, 2024). To solve these problems, Fredianto et al. (2024) emphasizes the importance of approaches based on evidence to strengthen transparency, streamline logistics, and promote effective rehabilitation protocols in athlete management. In addition, Alghurabi & Kumar (2025) emphasize that scientific methods are increasingly accepted in various areas such as sports training, rehabilitation, and athletic health care, suggesting a shift towards data strategies aimed at improving sports results.

In addition, by December 2025, many institutions have introduced advanced biomechanical analysis and wearable technologies to ensure the authenticity and efficiency of injury prevention programs (Al-Farouni & Kumar, 2025; Swafford et al., 2025). As a result, this increasing interest underlines the need for a more profound understanding of how these innovations integrate into contemporary practices (Kovoor et al., 2024). In accordance with this, academic interest has increased significantly, as the search made in April 2025 using the keyword "Prevention and rehabilitation techniques in sport" revealed more than 100 related contributions in the Web of Science database (Myer et al., 2011; Cools et al., 2021). Penichet-Tomas (2024) highlights that using detailed bibliometric analysis is important for understanding the main ideas and spotting new trends in the field.

In addition, advanced techniques such as mapping motives and analysis of thematic evolution are insufficiently used to understand the progression of research topics in the prevention and rehabilitation of sports injuries (Augustsson et al., 1998; Cordova et al., 2000). On the other hand, contemporary bibliometric studies in this area are primarily

limited to performance analysis (Shields, 2002; Mayo et al., 1999). For example, the efforts to map science often focus only on identifying topics or patterns of cooperation (Lee et al., 2003; Cupal & Brewer, 2001). As a result, there are complex analyses that combine performance indicators, bibliometric relations,

thematic mapping, and the development of the topic, still rare (Filipa et al., 2010; Paulos & Andrews, 2012).

Regarding these findings, this study aims to fill this gap by performing robust bibliometric analysis of prevention and rehabilitation techniques of sports injuries, focusing on wearable technologies, neuromuscular training, biomechanical analysis, and emerging development in sports medicine (Kovoor et al., 2024; Hassan & Kumar, 2025). In addition, research integrates performance mapping with scientific analysis and uses advanced methodologies, including motives mapping and thematic evolution analysis (Qi et al., 2024; Alzahrani & Ullah, 2024).

The study therefore addresses the following research questions:

Q1. What are the trends in the number of articles and citations related to prevention and rehabilitation techniques in sports?

Q2. What is the analysis of the performance of authors, countries, and publications in this area?

Q3. What are the results of the science mapping analysis in terms of cooperation in the magazine, cooperation in the country, bibliometric coexistence, thematic mapping, and thematic development?

Q4. What are the future research directions in receiving prevention and rehabilitation techniques for athletes?

At the same time, this study is engaged in gaps in our understanding and sets a scale for future research by explaining the intellectual environment surrounding the prevention and rehabilitation techniques of sports injuries (Fredianto et al., 2024). Unlike previous studies, our approach integrates performance analysis with techniques of advanced science mapping and offers a comprehensive understanding of the topic (e.g., Grooms et al., 2017; Ekstrom et al., 2007). In addition, our goal is to use the analysis of thematic mapping and thematic evolution to reveal shifts and trends in the research environment that could be overlooked in previous studies (e.g., Benjamins et al., 2015; Tenforde et al., 2011).

As a result, this study is one of the first to focus exclusively on prevention and rehabilitation techniques of injury in sport and ensures its uniqueness in a wider context of sports medicine and athletic performance. By providing comprehensive research trends, this study recalls scientists, government, and organization of knowledge needed for informed decision-making.

2. Rehabilitation Techniques

Rehabilitation techniques are becoming more important for helping people recover better, improving muscle control, and getting the best results in both

medical and sports settings (Fredianto et al., 2024). These strategies are particularly important in sports medicine, where the restoration of biomechanical efficacy and minimizing the risk of re-injury play a decisive role in long-term athletic performance and injury prevention (Alghurabi & Kumar, 2025).

In addition, to be successful in rehabilitation programs, it is necessary to implement strong clinical frameworks that support consistency, standardization, and measurable progress during the recovery journey (Myer et al., 2011). In this context, multidisciplinary cooperation plays a key role in reducing inefficiency in harmonizing complex therapeutic goals and rehabilitation standards (COOLS et al., 2021). As a result, the integration of these proven procedures into everyday routines ensures that adherence to the principles of rehabilitation becomes an integral part of the healing process (Mayo et al., 1999).



Fig.1. Cycle Rehabilitation techniques

Source: <https://www.cdc.ca.gov/rehabilitation>

Many modern rehabilitation systems use improvement models like the planned-do-check-act cycle (PDCA), which helps in regularly assessing and enhancing therapy methods (Ekstrom et al., 2007). It visually illustrates Figure 1: This model can be shown in a simple diagram that describes the steps in rehabilitation for athletes, which include immediate care (01), strength training (02), functional movement (03), neuromuscular retraining (04), recovery (05), and getting back to sports (06). In addition, such frameworks emphasize the integration of standardized evaluation—such as the Star Excursion Balance test and walking

analysis—to ensure quality, safety, and individualized care during the rehabilitation continuum (Filipa et al., 2010).

Looking back at the development of rehabilitation science since the beginning of 2000, the field has expanded significantly and has gained recognition not only in recovery after injury but also to increase performance among athletes (Sherry & Best, 2004). Initially, rehabilitation efforts were largely concentrated around basic strengthening exercises; however, recent advances now include neuromuscular training and the use of wearable sensors that have revolutionized monitoring and real-time feedback (Grooms et al., 2017). As a result, these innovations increase transparency in the recovery timelines, improve therapy efficiency, and increase monitoring of compliance with the rehabilitation of musculoskeletal (Lee et al., 2003). In addition, the integration of rehabilitation supported by technology has brought transformative changes, including the standardization of basic protocols and procedure indicators to ensure consistency and efficiency across different patient populations (di Stasi et al., 2013).

Especially Sabella, S. A. (2017) emphasizes the importance of clinical leadership in conducting advanced rehabilitation strategies (Paulos & Andrews, 2012). Similarly, Aldanyowi & AlOraini, (2024) claim that the corresponding rehabilitation potential with individual needs becomes a powerful tool for clinics to optimize medical plans for athletes and after surgery (Benjaminse et al., 2015). Similarly, Bickenbach et al. (2023) claims that when properly performed, rehabilitation can offer benefits to all participating parties, including patients, therapists, and carers (Tenforde et al., 2011).

Finally, the following part will provide a detailed explanation of the research methodology and outline the frames of scientific mapping, and the analysis tools used.

3. Methodology Overview

In this study, bibliometric analysis was used to explore progress in the health and performance of athletes, with a special focus on prevention and rehabilitation techniques of injuries. Research integrates both science mapping and performance analysis to provide a comprehensive field overview. As shown in Liu et al. (2018), performance analysis includes descriptive metrics, such as frequency of publications, authors' contributions, and numbers of citations. On the other hand, the analysis of science mapping examines the relationships between parameters such as authors' cooperation, thematic clusters, and keywords. In the data analysis,

a detailed description of the performance indicators and scientific mapping techniques used in this study is provided (Barbosa et al., 2024).

3.1. Screening process and data inclusion

The performing bibliometric analysis is to choose a suitable academic database. For this study, the Web of Science database was selected as a primary data source. This decision was based on several factors. First, the Web of Science offers extensive coverage of a magazine across several disciplines, including sports medicine, kinesiology, physical therapy, and exercise science (Pamboris et al., 2024). Secondly, it provides advanced search and analytical tools such as "refine results," "analyze results," and "view tools" that facilitate effective data surveys (Pamboris et al., 2024).

3.2. Data Collection and Pre-Execution

Data collection and cleaning were performed using Prisma Frame. Figure 2 illustrates a multi-stage process followed by this study. During the identification phase, a systematic search was performed using a complex set of keywords related to athletes, increasing performance, prevention of injury, and rehabilitation technology. The latest search string used to question the Web of Science database was:

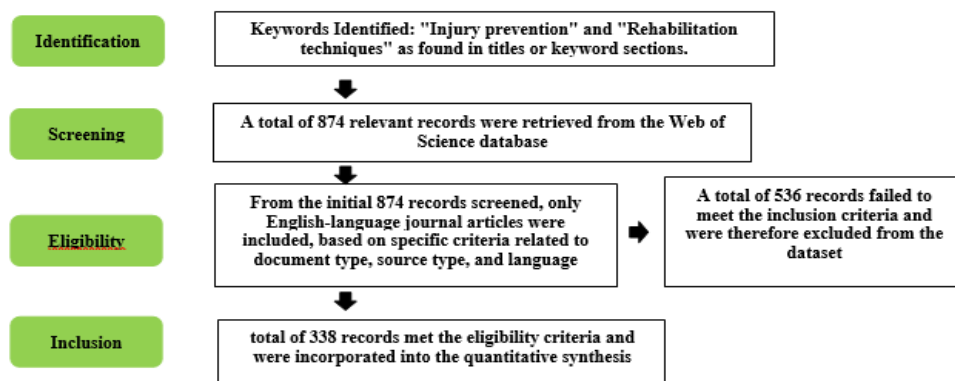


Fig.2. Stages of Document Filtering and Improvement

Source: Developed through authors' analysis

All = ("athlete health" OR "sports performance" OR "injury prevention" OR "rehabilitation techniques" OR "sports medicine" OR "athletic training" OR "physical therapy" OR "sports science" OR "exercise physiology" OR "biomechanics") AND ("performance enhancement" OR "injury recovery" OR

"rehabilitation strategies" OR "prevention methods" OR "health optimization" OR "sports injury" OR "musculoskeletal health" OR "recovery protocols" OR "training adaptation").

Keywords were required to appear in the title, abstract, or keywords of publications indexed in the Web of Science database. This approach ensured that the collected literature was directly relevant to the focus of the study on the prevention of injuries and rehabilitation in sport. In April 2025, the search yielded a total of 874 publications.

3.3. Access to statistical and analytical procedures

Bibliometric analysis included both performance analysis and science mapping to offer a holistic view of the research landscape. The performance analysis focused on monitoring the publication trends over time and evaluating the contributions of authors, countries, and individual documents. According to Becerra-Patiño et al. (2025), the main indicators used in this analysis included the number of publications and the total number of citations received.

For the mapping of science, the study examined bibliographic connections, international cooperation, and co-author patterns. In addition, the thematic evolutionary analysis and mapping of the keywords were used to identify newly emerging trends and shifts in the research focus over time. These methods have enabled the detection of key topics and development trajectories in the field of athletes' health and performance. Advanced tools such as Vosviewer and R-Bibliometrix (Barbosa et al., 2024; Hu et al., 2023; Mojgani et al., 2022) were used to effectively visualize and interpret complex bibliometric data.

4. Analysis and Discussion of Findings

A total of 338 articles were analyzed, as stated in the methodology, with key findings summarized in Table 1. Research on the prevention and rehabilitation of athletic injury from 2025 reflects long-term and growing interest in this area. The contributions were distributed to 54 specific sources, including magazines and various academic publications, indicating a wide disciplinary connection. A total of 964 keywords and 1,196 keywords plus (ID) were identified, emphasized by thematic wealth and developing literature.

The authorship included 1,497 individuals with an average of 5.2 authors per document, indicating a strong emphasis on research of cooperation. However, no international co-authorship has been recorded that pointed to a lack of cross-border cooperation. With an annual growth rate of 11.09% and an average of 22.46 citations on the document, Table 1 illustrates the expansion influence and relevance



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of this area, underlining the need for global cooperation to further increase the impact of research.

The data file includes a total of 12,592 links, showing the depth of scientific foundations supporting studies in the field of health and performance of athletes. In terms of publication types, the data file includes 327 reviewed articles from journals, 8 timely access articles, and 3 conference proceedings. Despite the high level of domestic cooperation, the absence of international partnership emphasizes the key area for future development in this rapidly growing area.

The following sections will be more detailed to examine key topics, authorial trends, and themes.

Table 1. General Overview of Injury Prevention and Rehabilitation in Athletic Performance

Category	Details
Timeframe	1997 to 2025
Publication Sources (Journals, Books, etc.)	54
Total Documents	338
Annual Growth Rate	11.09%
Average Age of Documents	7.39 years
Average Citations per Document	22.46
Total References	12,592
Document Contents	
Keywords Plus (ID)	1,196
Author's Keywords (DE)	964
Authors	
Total Authors	1,497
Single-Authored Documents	9
COLLABORATION AMONG AUTHORS	
Average Co-authors per Document	5.2

Percentage of International Co-authorships	0%
Types of Documents	
Articles	327
Articles (Early Access)	8
Articles (Proceedings Paper)	3

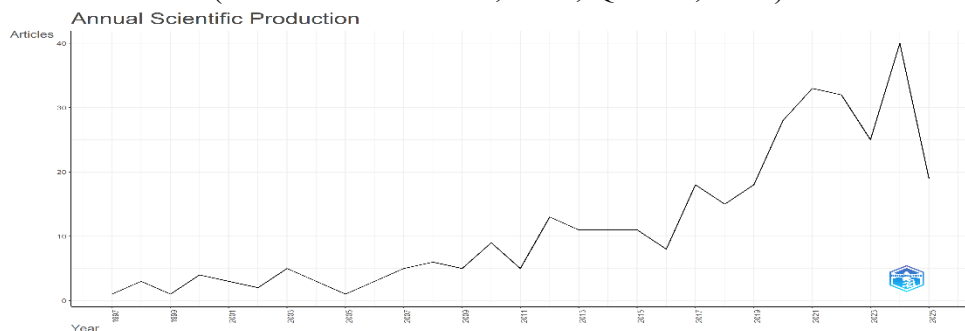
Source: Authors' analysis using the R-Bibliometrix package

4.1. Performance Review

4.1.1. Analysis of Citation and Publication Trends

Research on injuries and rehabilitation techniques in athletic performance has gained considerable attention from 1997 to 2025 (Figure 3). The number of publications increased in this period, with the peak observed in 2024, when 40 articles were published, compared to only 1 article in 1997. This growth reflects a growing interest in the development of innovative strategies for the prevention of sports injuries and improved athlete recovery through advanced methodologies such as biomechanics and wearable technologies (2025).

However, citation trends reveal the contrast formula (Figure 4). Despite the increase in publications, the average quotation of the article has decreased sharply over time. For example, the documents published in 1997 received an average of 41 citations, while the documents published in 2025 received an average of 0.11 citations. This decline indicates that newer studies on prevention and rehabilitation tend to rely more on outside information rather than building on earlier research in the field (Cord et al., 2000; Swafford et al., 2025). This trend underlines the interdisciplinary nature of a field that integrates concepts from sports science, physical therapy, and new technologies such as IoT and AI (Al-Farouni & Kumar, 2025; Qi et al., 2024).



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Fig.3. Publication Trends in Injury Prevention and Rehabilitation Techniques for Athletes

Source: Authors' analysis using the R-Bibliometrix package

The first study in this area focused on basic implementations, such as biomechanical assessments and protocols of timely intervention, but they lack extensive recognition in newer literature (Myer et al., 2011; Hiller et al., 2006). The growing number of publications signals field maturation and emphasizes its potential for future progress. These trends emphasize the importance of interdisciplinary cooperation and innovation in developing the health and performance of athletes through increased prevention and rehabilitation strategies.

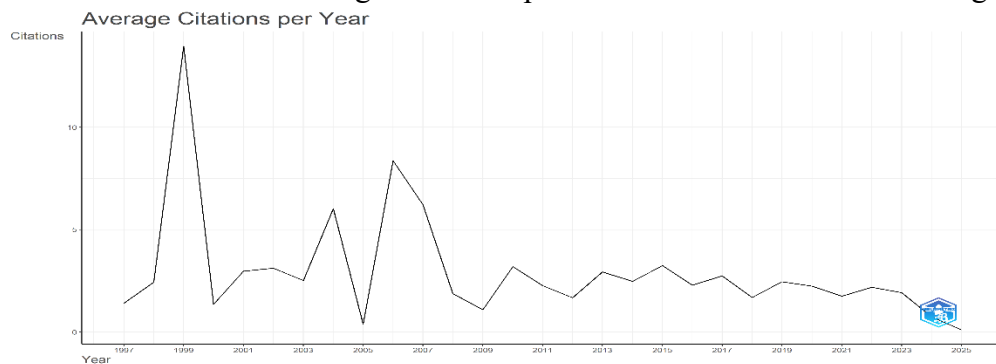


Fig.4. Citation Trend of Research on Injury Prevention and Rehabilitation in Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

4.1.2. Key Influential Authors

This part emphasizes the most influential authors who contribute to the area of prevention and rehabilitation of athletic injury. Figure 5 represents the first ten contributors based on H-Index, G-Index, and total citations. Among them, Myer GD appears as a leading author with an H-index of 14, 23 publications, and 847 total quotations since 2010.

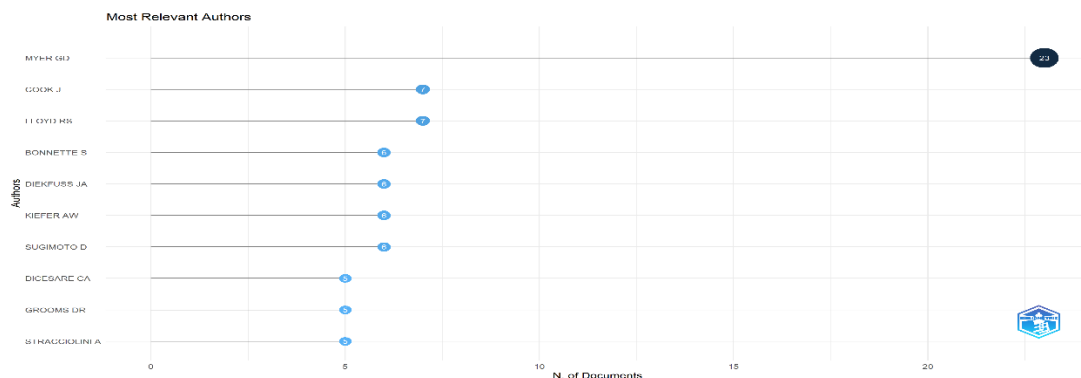


Fig.5. Top Ten Authors in Injury Prevention and Rehabilitation Research for Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

Figure 6 illustrates the trends of publication over time and reveals different formulas among the best contributors. Myer GD maintained stable production from 2010 to 2024, peaking in 2020 with five articles and a citation rate of 17.5 per year. Bonnette S. recently gained importance and, in 2020, published three posts, which collectively gained 74 citations, indicating early but strong field impact. Dice is a cat. They also showed consistent contributions within several years, especially between 2014 and 2023, focusing on core stability and prevention of lower limb injuries (DiCesare et al., 2014; DiCesare et al., 2018).

Kiefer he contributed from 2014 to 2023 and examined biomechanical risk factors and nerve adaptations after injury, especially in youth athletes (Kiefer et al., 2014; Kiefer et al., 2015). Lloyd Rs. He appeared as a key contributor since 2018, with increasing frequency of publications and growing influence by 2023 (Lloyd et al., 2014). His work focuses on long-term protocols for the development of athletes and training resistance.

Together, these authors have developed a framework, and procedures based on evidence to improve screening methods, intervention programs, and return processes. Their contributions are covered by clinical and applied environments, which emphasize the importance of the integration of biomechanical, physiological, and psychological aspects in the prevention and rehabilitation of injuries (Filipa et al., 2010; Benjaminse et al., 2015; di Stasi et al., 2013).

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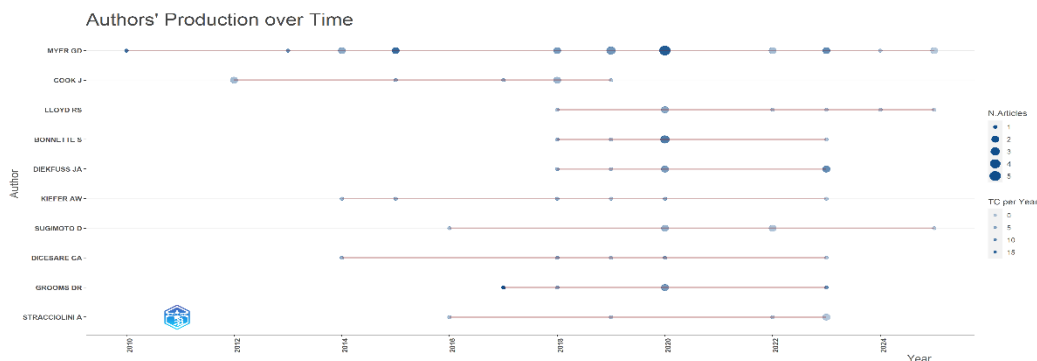


Fig.6. Top Ten Authors' Publication Output Over Time on Injury Prevention and Rehabilitation in Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

4.1.3. Top Publishing Country

A total of 39 countries actively contributed to the research of prevention and rehabilitation techniques in athletic performance. Table 2 emphasizes the top ten contributing nations and illustrates their academic engagement and efforts to cooperate. The United States leads a field with 101 publications, reflecting a strong and permanent obligation to develop the health and performance of athletes for several decades. The US also showed the number and frequency of the publication of the highest country (SCP), indicating both domestic focus and international cooperation.

Australia ranks second with 33 articles that show consistent contributions, especially in areas such as neuromuscular training, ankle instability, and return protocols (Hiller et al., 2006; Copal et al., 2001). The United Kingdom and Canada contribute 22 and 21 publications, focusing on biomechanics, motor learning, and neuroplasticity after sports injuries (Grooms et al., 2017; di Stasi et al., 2013).

Other remarkable contributors include Brazil (17), China (16), Sweden (11), Ireland (9), Spain (9), and Japan (8), which shows increasing interest in evidence-based approaches to prevent and rehabilitate sports injuries. These countries cover different levels of economic development and sports cultures and emphasize the global relevance and interdisciplinary nature of this research area.

The growing number of publications reflects the growing recognition of the importance of the integration of scientific methods into athletic training and rehabilitation procedures to increase performance and reduce injury risks (Myer et

al., 2011; Benjaminse et al., 2015). This trend underlines the need for standardized frames and cross-border cooperation in the development of proven procedures that can be adapted to different athletic populations.

Another analysis looks at how thematic development shapes these national contributions and influences new research paths that aim to improve athletes' health and performance.

Table 2. Top Ten Countries in Injury Prevention and Rehabilitation Research for Athletic Performance

Country	Articles	SCP	Freq
USA	101	101	0.299
Australia	33	33	0.098
United Kingdom	22	22	0.065
Canada	21	21	0.062
Brazil	17	17	0.05
China	16	16	0.047
Sweden	11	11	0.033
Ireland	9	9	0.027
Spain	9	9	0.027
Japan	8	8	0.024

Source: Authors' analysis using the R-Bibliometrix package

4.1.4. Leading Publication

This part emphasizes the most cited articles that significantly formed research in the prevention and rehabilitation of injuries for athletic performance, sorted according to the overall citations and the level of citation annually. As shown in Figure 7, Hiller et al. (2006) have the highest number of citations at 473 and a TCPY of 23.65, which is a tool that can be misleading for ankle instability in Cumberland, but it became an important way to assess sports rehabilitation (Hiller et al., 2006). Ekstrom et al. (2007) closely follow 397 citations and TCPY 20,89, offering basic insight into basic muscle activation during rehabilitation exercises (Ekstrom et al., 2007). Mayo et al. (1999), with 377 citations, provides a model of disabilities relevant to the framework of restoration used in the rehabilitation of the athlete (Mayo et al., 1999). Sherry and Best (2004) compare the rehabilitation programs of hamstrings, accept 267 citations, and emphasize eccentric training to prevent re-damage (Sherry & Best, 2004). Lee et al. (2003) examine patellofemoral mechanics with 233 citations and inform biomechanical approaches to knee injuries

(Lee et al., 2003). Filip et al. (2010) show how neuromuscular training improves balance in young athletes, with 229 citations and TCPY 14.31 (Filipa et al., 2010). Grooms et al. (2017) study how the brain changes after ACL surgery, receive 177 citations, and highlight how nerves adapt during recovery (Grooms et al., 2017). Copal and Brewer (2001) contribute to psychological knowledge with 173 citations, showing how controlled images strengthen post-surgical rehabilitation (Copal & Brewer, 2001). Leal et al. (2010) examine laser therapy at a low level in muscle recovery with 151 citations, supporting its use in evidence-based practice (Leal et al., 2010). Finally, di Stasi et al. (2013) solve neuromuscular deficits associated with secondary ACL injuries, with 127 citations and TCPY 9.77, leading targeted preventive strategies (di Stasi et al., 2013). In summary, these key works are the theoretical and practical basis of modern approaches to the health of athletes, forming clinical instructions, rehabilitation protocols, and interdisciplinary research in sports science.

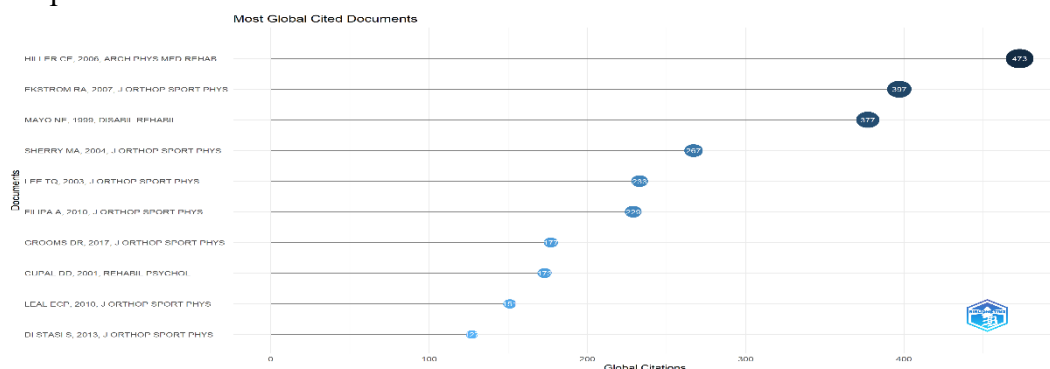


Fig.7. Top Ten Citations on Injury Prevention and Rehabilitation in Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

5. Mapping the Scientific Landscape

5.1. International Collaboration Framework

An analysis of co-authorship in the country was carried out to investigate international cooperation in the prevention of injuries and research on athletic performance. Figure 9 illustrates the four main clusters of cooperation, with the size of the node reflecting the publication output of each country. The main contributors include the United States (125 documents, 3739 citations), Australia (54 documents, 1415 citations), England (33 documents, 552 citations), Canada (30

documents, 964 citations), and Sweden (18 documents, 326 citations), et al. These countries form the core of a network of global cooperation, especially in North America, Europe, and Oceania. On the other hand, interregional cooperation between developed and developing nations remains limited, emphasizing the need for stronger international partnerships for the development of practices based on evidence across various athletic populations.

The United States leads not only in volume but also in influence, with the highest total connection strength (7867), indicating robust involvement with global scientists. Australia and Sweden contribute significantly to clinical evaluation tools, neuromuscular training, and return strategies (Hiller et al., 2006; Groom et al., 2017). Canada and England are key players in the development of biomechanics, and youth are developing extensive models of long-term training and risk factors for injuries (di Stasi et al., 2013; Lloyd et al., 2015).

Other remarkable contributors include Brazil (17 documents, 339 citations), which focus on methods of rehabilitation specific to sports, and catarrh (7 documents, 176 citations), emphasizing the elite recovery of athletes and monitoring performance. South Africa (6 documents, 22 citations) and Turkey (3 documents, 13 citations) also show a growing interest, especially in lower harm to harm and techniques of motor learning (Riley et al., 2021).

Despite regional progress, the lack of extensive global cooperation limits the development of standardized, interculturably usable rehabilitation frames. This emphasizes the importance of supporting multinational research partnerships to improve knowledge exchange, improve the health results of athletes, and develop generally effective injury prevention programs. The analysis then examines another perspective on these trends.

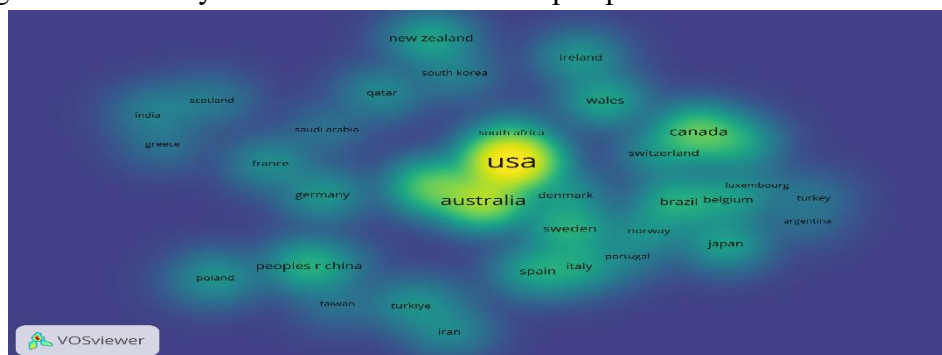


Fig.9. Visualization of Country Co-Authorship Networks in Injury Prevention and Rehabilitation Research for Athletic Performance



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Source: Analysis by the authors using VosViewer

5.2. Map of Research Themes

This subsection examines the main topics of research in the prevention and rehabilitation techniques of athletic performance based on thematic mapping analysis. After the COBO et al. (2015), the common occurrence of keywords was analyzed using two criteria: centrality (measuring how connected the topic is with others) and density (indicating internal development and maturity). The topics are categorized in four groups: motor themes (central and well developed), specialized topics (specialized but peripheral), appearing/declining topics (low capitality and density), and basic topics (important but insufficiently developed).

"Biomechanics" and "sports injuries" are key topics that connect well with other research areas and receive a lot of scientific focus, particularly in figuring out how injuries happen (Ekstrom et al., 2007; Myer et al., 2011). In contrast, topics like "concussion" and "muscle strength" are somewhat important but not as well-developed, indicating that they still need more research. On the other hand, topics such as "concussion" and "muscle strength" show mild centrality but lower density, suggesting that they are important but still develop areas that require further survey.

"Football" and "Resistance Training" appear as specialized topics with specialized focus and relatively limited cross-interaction, although both remain relevant in the context of rehabilitation and the context of the fortress (Dicesar et al., 2020). Developing topics include "mental health" and "walking analysis" that show a growing interest but are currently weakly developed in literature.

"Back pain," "tendinopathy," and "stroke" are identified as basic topics, which means their importance in clinical applications, but it emphasizes the need for more focused research in athletic populations. In addition, terms such as "exercise" and "epidemiology" reflect wide use but lack a cohesive thematic depth and point to opportunities for future specialization.

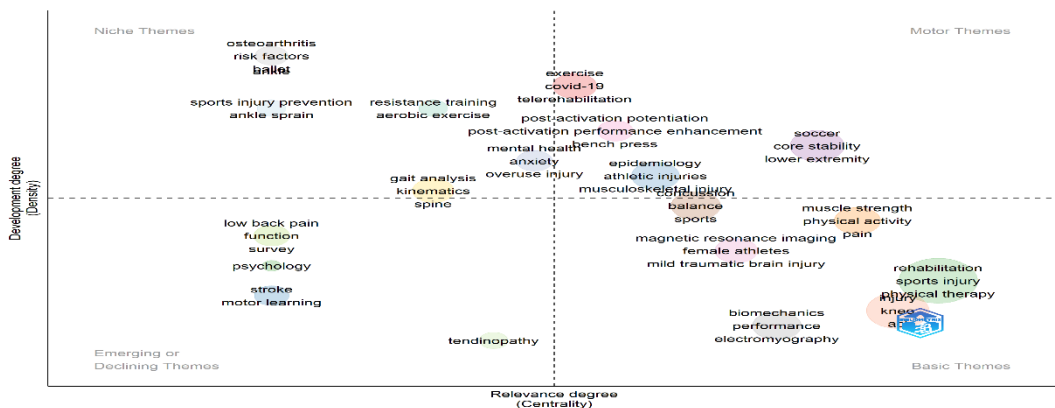


Fig.10. Thematic Map of Injury Prevention and Rehabilitation in Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

5.3. Development of Research Themes

This subsection delves into the thematic evolution of research techniques related to athlete prevention and rehabilitation in athletic performance over time. Figure 11 illustrates the development of key topics and emphasizes shifts in the focus and emerging trends in three different periods: 1997–2010, 2011–2020, and 2021–2025.

In the early phase (1997–2010), basic research focused on biomechanics, injuries, knee injuries, sports injuries, and physical therapy, suggesting a strong clinical and physiological orientation. During this period, the study primarily focused on understanding mechanisms of injury and the development of basic rehabilitation protocols (Ekstrom et al., 2007; Hiller et al., 2006). The stability index shows that concepts such as "injuries" and "rehabilitation" remained central, reflecting their lasting significance.

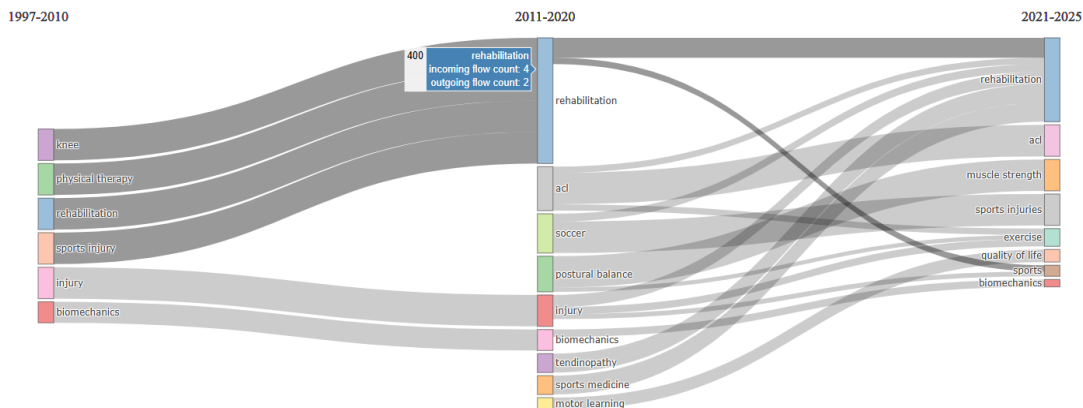


Fig.11. Thematic Evolution of Research on Injury Prevention and Rehabilitation in Athletic Performance

Source: Authors' analysis using the R-Bibliometrix package

5.4. Analysis of Co-Occurrences

The integration of prevention and rehabilitation techniques has proven to be a transformative approach that deals with critical challenges, such as neuromuscular deficits, the risk of re-damage, and the long-term development of athletes. Four different groups of research have been found based on keyword analysis (Figure 12), showing the main topics in the field: rehabilitation and physical therapy, biomechanics and neuromuscular control, neuromuscular training and exercise intervention, mental health, brain control, and neurological recovery. Together, these clusters offer insight into established practices and new trends that form contemporary sports medicine and rehabilitation science.

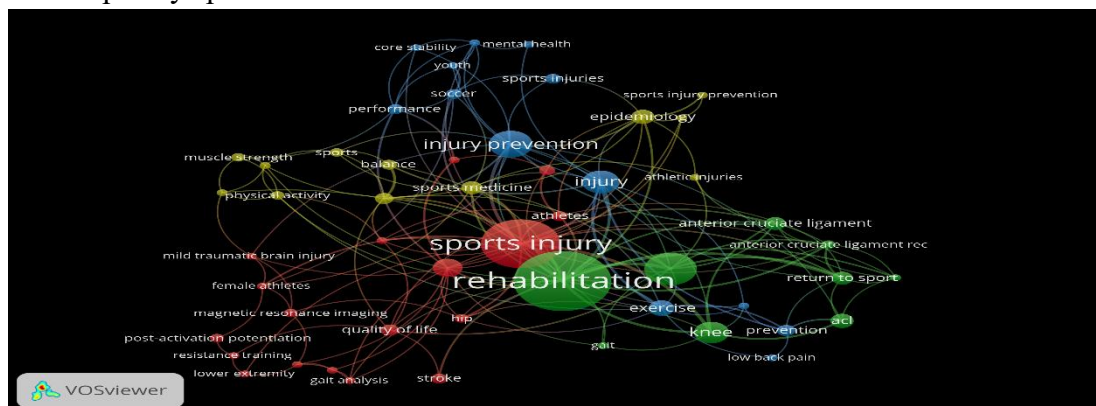


Fig.12. Co-Occurrence Analysis of Studies on Injury Prevention and Rehabilitation in Athletic Performance

Source: Analysis by the authors using VosViewer

The first cluster is concentrated around "rehabilitation," the most common keyword (44 occurrences) with the highest total connection strength (58), indicating its basic role in literature (Ekstrom et al., 2007; Grooms et al., 2017). Related terms include "physical therapies" (22 occurrences), "sports injuries" (35 occurrences), and "prevention of injury" (18 occurrences), which together underline the importance of structured programs based on evidence in the management of musculoskeletal injuries. The importance of "return to sport" (8 occurrences) further emphasizes the growing emphasis on functional recovery and decision-making protocols after injury (di Stasi et al., 2013).

Despite the expanded recognition of proven procedures, variability remains obvious, especially in the youth and amateur environment, where access to specialized care can be limited (Dicesar et al., 2014). Studies emphasized the need for standardized frames of return to the game, which include both biomechanical and psychological indicators of readiness (Arderm et al., 2013; Hewett et al., 2015). Additionally, the inclusion of "implementation" (4 occurrences) underscores the significance of translating research into practical applications, particularly in community sports, where adherence to evidence-based instructions is crucial (West et al., 2021; Sugimoto et al., 2016).

The second group looks at how our bodies move and how our muscles work, shown by terms like "ACL" (9 times), "knees" (14 times), "reconstruction of the anterior crossed ligament" (5 times), and "GAIT analysis" (4 times). These topics reflect the growing interest in the quality of movement, joint stability, and assessing the risk of injury. Research in this area often examines how biomechanical inefficiency contributes to patterns of injuries and how targeted interventions can improve dynamic balance and reduce the recurrence rate (Hiller et al., 2006; Riley et al., 2021).

For example, Lee et al. (2003) investigated the effect of tibial and femoral rotation on the patellofemoral contact area and pressure and contributed to our understanding of the knee mechanics during athletic movements. Similarly, Filip et al. (2010) have shown that neuromuscular training significantly improves dynamic balance in young athletes and emphasizes the preventive potential for ACL injury. Despite the strong theoretical foundations, however, the practical translation remains



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inconsistent, especially in sports in the community, where there is access to the technology of movement analysis or limited professional supervision (Stracciolini et al., 2014; Waldén et al., 2012). The mention of "kinematics" (4 times) highlights how important it is to analyze movements objectively to find at-risk individuals and guide tailored interventions (Kiefer et al., 2014; Riley et al., 2021).

The final cluster emphasizes mental health, shock control, and neurological recovery with keywords such as "concussion" (7 occurrences), "traumatic brain injury" (4 occurrences), "slight traumatic brain injuries" (4 occurrences), and "mental health" (4 occurrences). This area reflects growing awareness of psychological and cognitive aspects of injuries and recovery. The emerging research examines how mental health reflections affect the decision to return to the game and how neuroplasticity plays a role in rehabilitation after the reconstruction of ACL and other injuries (Grooms et al., 2017; Kiefer et al., 2014).

For example, Sherry & Best (2004) compared two hamstring rehabilitation programs and emphasized the importance of integrating psychological readiness along with physical recovery. In addition, Cupal & Brewer (2001) have found that controlled images and relaxation techniques can increase knee strength and reduce anxiety reconstruction after ACL, strengthening the biopsychosocial rehabilitation model.

In addition, while many studies focus on elite athletes, there is a clear opportunity to expand research into insufficiently represented groups, such as athletes with disabilities, youth populations, and disputes involved in non-profit sports such as football (6 occurrences), gymnastics, and ballet (Armstrong, R., & Relph, N. (2021; Emery et al., 2019). In addition, "screening" (4 occurrences) and "risk factors" (3 occurrences) underline the importance of early identification and targeted intervention for endangered athletes.

6. In-Depth Discussion of Major Findings

Science mapping has given rise to several important research issues, particularly in the application of advanced methodologies in injury prevention and rehabilitation techniques. The field is widely formed by two main perspectives: theoretical foundations and applied practices that are decisive for progress in the health and performance of athletes.

6.1. Applied Research: Development of tools and interventions

The first current consists of applied studies aimed at designing and implementing tools based on evidence, frames, and intervention models that facilitate effective prevention and rehabilitation of injuries. These include biomechanical evaluation (e.g., Ekstrom et al., 2007), neuromuscular training programs (e.g., Myer et al., 2010; Benjaminse et al., 2015), resistance protocols and wearable technologies (Kovoor et al., 2024; Hassan & Kumar, 2025).

Thematic analysis shows that these topics are well developed and often studied, supported by strong cooperation between scientists across sports medicine, physical therapy, and kinesiology. For example, Filip et al. (2010) examined how structured neuromuscular training improves dynamic balance in youth athletes, while Grooms et al. (2017) examined the neuroplasticity after the reconstruction of the anterior cruciate ligament (ACL), which significantly contributed to the decision-making framework of return. DICESAR et al. (2018) emphasized the role of training basic stability in reducing the risks of damage to the lower limbs in higher education athletes.

6.2. Theoretical research: understanding mechanisms and influences

The second stream focuses on theoretical research that seeks to understand mechanisms, risk factors, and wider impacts of injury and rehabilitation on the athletic population. Schools examine variables affecting injuries (Caine, 2022), anxiety of re-damage (Copal & Brewer, 2001), and long-term health results (Mayo et al., 1999).

Despite their importance, theoretical contributions remain less cohesive compared to applied research, with limited authorial cooperation and the interconnection of the quotation. Strengthening this current requires the integration of wider theoretical models, like the theory of motor management, biopsychosocial frameworks, or the principles of training specific to the task, to provide deeper insight into behavior, neurological and systemic effects on injuries, and recovery (van Dieën et al. 2019).

6.3. Interdisciplinary cooperation and integration

The complexity of athletes and performance management requires interdisciplinary cooperation. However, current research often lacks full integration across areas such as biomechanics, psychology, and technology. While studies like Ayala et al. (2024) began to integrate machine learning to detect early injury and Qi et al. (2024) explored digital tools in performance, many developing regions still face challenges related to resource availability and infrastructure limitations.



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Geographically, the United States leads in publication and impact, followed by Australia, Canada, and Sweden (Table 2). These countries have significantly contributed to areas such as neuromuscular training, shock management, and long-term development of athletes (Lloyd et al., 2015; di Stasi et al., 2013). On the other hand, nations with lower incomes show fewer contributions and emphasize the differences in research capacity and access to advanced technologies (Augustsson et al., 1998; Kaplinsky & Kraemer-Mbula, 2022).

7. Practical Implications and Directions for Future Research

Research in the health and performance of athletes includes a wide range of academic disciplines and professional areas, which contributes to a more profound understanding of prevention and rehabilitation techniques. By integrating performance analysis and science mapping, this study provides valuable knowledge that combines theoretical foundations with practical applications. For academic scientists, bibliometric analysis opens more paths for future surveys. It emphasizes key conceptual areas surrounding the development and implementation of innovative rehabilitation strategies and encourages scientists to delve deeper into these frames. There is also a strong need for further exploration of insufficiently represented regions and populations, where contextual and cultural factors can affect the efficacy and acceptance of injury prevention programs.

From a methodological perspective, this research emphasizes the importance of transition over conventional statistical instruments towards advanced analytical approaches. Traditional regression models are increasingly being replaced by complex techniques of data visualization and network analysis that better capture dynamic interactions in sports injury research. These methods enable a more nuanced understanding of developing trends and support both theoretical expansion and practical adaptation in various athletic environments.

8. Concluding Thoughts

Bibliometric analysis reveals a clear ascension trend in the number of articles discussing prevention techniques and rehabilitation of injury in athletic performance. However, citation patterns seem to decrease over time, suggesting that while research production is growing, scientific involvement remains uneven. The United States appears as a leading contributor to this set of literature, followed by Australia, Canada, and Sweden, reflecting strong academic activities and international influence in sports medicine and physical therapy.

Among the individual scientists, Myer GD stands out as the most influential author with the highest number of publications and citations, especially in the field of neuromuscular training and ACL prevention. Groom Dr. and Kiefer AW also frequently make significant contributions to the understanding of neuroplasticity and motor learning after injury. These scholars played a key role in the formation of current procedures based on evidence used in youth environments and elite sports.

Thematic analysis identifies three dominant research currents: "neuromuscular training," "biomechanical evaluation," and "rehabilitation programs," all of which are well developed and supported by extensive cooperation between scientists and practices. These topics form the core of current injury management strategies and are often associated with interventions aimed at reducing the risk of re-damage and increasing the resistance of the athlete.

On the other hand, other critical areas such as "mental health and psychological readiness to return to sport," "healthy athletes," and "long-term wellness results" remain insufficiently developed and require further investigation. These topics, although increasingly recognized as important, lack the same level of scientific attention and structured theoretical development.

The study emphasizes three key directions for future research: the expansion of theoretical frames beyond the description of descriptions, growing research efforts in low-income and developing countries, and receiving more advanced analytical methods beyond the basic regression models. Incorporating machine learning, network analysis, and longitudinal modeling could offer a deeper insight into complex interactions between biomechanics, physiology, and behavior factors affecting recovery and athletes' performance.

Notwithstanding these noteworthy discoveries, it is important to acknowledge several limitations. First, due to language restrictions, the analysis was limited to articles published in English, which potentially excluded valuable contributions in other languages, especially those from the bears of the Western academic communities. To achieve a more comprehensive understanding, future research should consider incorporating non-English publications.

Secondly, cross-border cooperation between institutions and countries remains limited, especially among nations with high and low incomes. Strengthening global partnerships can improve knowledge sharing, improve methodological consistency, and promote the development of culturally adaptable prevention programs and rehabilitation of injuries.



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Third, many relevant articles can be published in magazines or databases that are not indexed by the Web of Science, the primary source of this study. Although the Web of Science is widely considered to be a reliable database for bibliometric analysis, future studies could benefit from including Scopus, PubMed, and regional repositories to ensure a wider and more representative data file.

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