REVIEW ARTICLE

A bibliometric analysis of knowledge structure and research trends in swimmer's shoulder (2015-2025)

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ABSTRACT

Shoulder pain remains one of the most common and persistent problems in competitive swimming. Unlike acute traumatic injuries, swimmer's shoulder usually develops gradually through the combined effects of repetitive stroke motion, fluctuating training load, movement compensation, and insufficient recovery. Although an expanding body of research has examined this topic from the perspectives of biomechanics, training load, muscle function, and rehabilitation, the overall knowledge structure and developmental trajectory of the field remain insufficiently clarified. To address this gap, the present study conducted a bibliometric analysis of swimmer's shoulder research using the Web of Science Core Collection. A total of 195 publications published between 2015 and 2025 were included. Publication trends, core authors, leading journals, country-level contributions, relative growth rate, doubling time, field-normalised citation score, and keyword co-occurrence patterns were analysed with CiteSpace and VOSviewer. The results show a sustained increase in research output and the emergence of a relatively stable but heterogeneous academic network. Clear differences were observed between high-output and high-impact contributors, particularly at the journal and country levels. Keyword co-occurrence, clustering, and timeline analyses indicate a transition from symptom-oriented research toward mechanism-based and intervention-oriented approaches, with increasing attention to biomechanics, functional assessment, monitoring, prevention, and rehabilitation. The study proposes a three-level framework of symptom identification, mechanism explanation, and intervention-oriented management. This framework integrates fragmented findings and clarifies how swimmer's shoulder research has evolved from describing pain to explaining mechanisms and informing applied prevention and rehabilitation strategies.

Keywords: Swimmer's shoulder, Competitive swimming, Shoulder injury, Biomechanics, Injury prevention, Bibliometric analysis.

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INTRODUCTION

Shoulder-related problems have long been among the most frequently discussed and complex issues in competitive swimming. Although many studies appear to focus on shoulder pain, overuse injury, or swimmer's shoulder, the field addresses a broader set of questions concerning how training load is organised, how stroke technique develops, how physical function adapts, and how rehabilitation strategies are implemented. Swimmer's shoulder should therefore not be interpreted only as a local joint complaint, but as the outcome of interacting factors within the training system of competitive swimming (Hill et al., 2015; Struyf et al., 2017). Swimming involves highly repetitive upper-limb motion, and the shoulder repeatedly moves through large ranges while producing force over long periods of training. Among competitive swimmers, symptoms often do not follow a single identifiable injury event. Instead, they tend to emerge gradually through repeated exposure, accumulated workload, altered movement patterns, and insufficient recovery. Recent reviews have continued to associate shoulder pain with workload-related factors, musculoskeletal dysfunction, and other interacting risk factors in competitive swimmers (Feijen et al., 2020; McKenzie et al., 2023). Because this process is complex, research has expanded in several directions. Some studies emphasise training volume and workload progression, whereas others focus on stroke mechanics, scapular control, strength imbalance, functional assessment, exercise therapy, preventive training, and rehabilitation management. These lines of work provide valuable evidence, but together they also reveal a broad field whose internal structure is not yet fully synthesised (Struyf et al., 2017; Feijen et al., 2020; Yoma et al., 2022). This diversity is not necessarily a limitation. Rather, it suggests that swimmer's shoulder is no longer a narrowly defined clinical label but an interdisciplinary topic linking training practice, injury risk identification, biomechanical explanation, and rehabilitation management. The challenge is that, as the literature broadens, researchers may focus on isolated segments and overlook the connections among themes. Recent reviews have mainly synthesised evidence within specific subtopics, such as risk factors, workload, or exercise intervention, which further highlights the need for a broader perspective on the knowledge structure of the field (McKenzie et al., 2023; Feijen et al., 2020; Yoma et al., 2022). Bibliometric analysis provides a useful approach for examining this broader structure. Unlike traditional narrative reviews, bibliometric analysis can reveal publication trends, influential authors, core journals, country-level contributions, citation patterns, and keyword co-occurrence relationships, thereby clarifying how research themes are organised and how they evolve over time. The present study therefore uses the Web of Science Core Collection to analyse English-language literature published between January 1, 2015 and December 31, 2025. By mapping publication patterns, leading contributors, national differences, bibliometric indicators, and thematic networks, this study aims to reposition swimmer's shoulder from a single injury category to a structured research field within competitive swimming, sports medicine, and rehabilitation science.

Literature review

Mechanisms of training load, repetitive motion, and overuse

In competitive swimming, the training load is widely recognised as one of the primary factors associated with shoulder pain and overuse injuries. Swimming is characterised by highly repetitive upper limb motion, where athletes may perform thousands of stroke cycles within a single training session. Such repetitive exposure places continuous mechanical stress on the shoulder joint, particularly on the rotator cuff and surrounding soft tissues (McKenzie et al., 2023; Stella et al., 2024).

Prior studies have consistently associated excessive training volume, sudden workload increases, and insufficient rest with the onset of swimmer's shoulder. The association between training load and shoulder injury appears to be multifactorial rather than linear. Some swimmers may tolerate high training volumes without symptoms, whereas others may develop shoulder pain under comparable workloads. This

inconsistency indicates that training load interacts with various aspects, including technique, strength, and individual adaptability (McKenzie et al., 2023; Tavares et al., 2025).

Furthermore, contemporary research frequently depends on cross-sectional or short-term observations, which constrains the comprehension of cumulative load effects over time. Consequently, whereas training load is a critical element, it cannot solely account for the emergence of swimmer's shoulder (Takayama et al., 2024; McKenzie et al., 2023).

Biomechanics, stroke technique, and control of the scapula

Biomechanical analysis provides an important framework for understanding the mechanisms underlying swimmer's shoulder. A substantial body of research has examined stroke technique, joint kinematics, scapular movement patterns, and shoulder loading. Efficient stroke mechanics require coordinated motion between the glenohumeral joint and the scapulothoracic articulation. Disruption of this coordination may alter load distribution across the shoulder complex and increase injury risk (Kennedy et al., 2024; Stella et al., 2024).

Swimmers with shoulder pain often present altered movement patterns, including scapular dyskinesis, changes in stroke timing, and modified rotation angles. These findings suggest that shoulder symptoms may arise not only from excessive training volume but also from movement compensation, impaired neuromuscular control, and inefficient force transfer during repetitive swimming motion (Kennedy et al., 2024; Yoma et al., 2022).

Nevertheless, many biomechanical studies are conducted in laboratory settings, which may not fully reflect the complexity of daily training environments. The causal relationship between altered movement patterns and shoulder injury also remains uncertain. Field-based and longitudinal biomechanical research is therefore needed to clarify how stroke mechanics, fatigue, workload, and recovery interact over time (Kennedy et al., 2024).

Strength, balance of muscles, and functional

Muscle strength and functional capacity are essential for maintaining shoulder stability during repetitive swimming motion. The rotator cuff and scapular stabilisers help maintain joint alignment and support force transfer throughout the stroke cycle (McKenzie et al., 2023; Stella et al., 2024). Previous studies have associated shoulder pain with muscle weakness, neuromuscular deficits, strength imbalance, limited range of motion, and reduced dynamic stability. These factors may increase movement compensation and contribute to local overload (McKenzie et al., 2023; Tavares et al., 2025). However, there is still no consensus regarding optimal assessment methods or strength-training protocols. Many studies examine isolated variables, which limits the development of integrated functional models that could guide comprehensive screening, training, and rehabilitation strategies (Yoma et al., 2022; Kennedy et al., 2024).

Management of training, prevention, and rehabilitation

As prevention oriented thinking has developed, research has increasingly moved toward intervention and management strategies. Preventive programmes commonly include strength training, flexibility exercises, technique correction, workload monitoring, and recovery management. These strategies aim to reduce injury risk while preserving swimming performance. Rehabilitation studies have also focused on restoring function and supporting return to training. However, intervention protocols vary considerably across studies, which makes it difficult to formulate generalisable recommendations. In addition, many intervention studies are conducted under controlled conditions and may not fully represent the variability of real training environments,

athlete responses, and competition schedules. This limits the direct transferability of some findings to applied swimming practice.

From fragmented evidence to knowledge mapping: The need for bibliometric analysis
Overall, existing research on swimmer's shoulder covers multiple dimensions, including training load, biomechanics, muscle function, monitoring, prevention, and rehabilitation. These studies provide important insights, but they are often conducted within separate subfields, resulting in a fragmented understanding of the literature (McKenzie et al., 2023; Yoma et al., 2022). Most reviews focus on specific subtopics, such as risk factors or rehabilitation, and therefore provide limited information about the overall intellectual structure and thematic evolution of the field. Bibliometric analysis can integrate these diverse research themes by identifying publication patterns, influential contributors, keyword relationships, and emerging topics. It therefore offers a structured basis for clarifying the knowledge structure of swimmer's shoulder research and for identifying future research directions (Donthu et al., 2021; Öztürk et al., 2024).

DATA SOURCES AND METHODS

Data source and search strategy
This study adopted a bibliometric design to examine the knowledge structure, publication patterns, and thematic evolution of swimmer's shoulder research. Bibliometric analysis is suitable for mapping the development of a research field when the aim is to identify publication trends, influential contributors, major journals, country-level contributions, and conceptual relationships among research themes (Donthu et al., 2021). Recent methodological discussions have also emphasised that bibliometric studies should clearly report the search strategy, database selection, inclusion and exclusion criteria, data cleaning procedures, and analytical tools to ensure transparency and reproducibility (Öztürk et al., 2024).

The Web of Science Core Collection was selected as the primary data source for this study. This database was chosen because it provides standardised bibliographic records, citation information, subject classifications, and export formats that are widely used in bibliometric and scientometric studies. In addition, the Web of Science Core Collection is described by Clarivate as a publisher-independent global citation database, which makes it appropriate for tracing publication output and citation relationships across disciplines (Clarivate, 2024).

The literature search was conducted in the Web of Science Core Collection using the topic search field. The search period was limited to publications from January 1, 2015 to December 31, 2025. This time frame was selected to capture the most recent decade of swimmer's shoulder research and to examine how the field has developed from symptom-oriented studies toward mechanism-based, prevention-oriented, and rehabilitation-related research. The search was performed using the following search query:

TS = ("*swimmer's shoulder*" OR ("*swimming*" AND "*shoulder pain*") OR ("*competitive swimmers*" AND "*shoulder injury*") OR ("*swimmers*" AND "*shoulder*" AND "*risk factor*") OR ("*swimmers*" AND "*shoulder*" AND "*prevention*") OR ("*swimmers*" AND "*shoulder*" AND "*rehabilitation*")).

The search terms were designed to cover the major expressions used in swimmer's shoulder research, including the direct term "*swimmer's shoulder*" and related expressions referring to swimming-related shoulder pain, shoulder injury, risk factors, prevention, and rehabilitation. The use of Boolean operators was intended to balance sensitivity and specificity, ensuring that relevant studies were captured while limiting records that were only generally related to the shoulder or to swimming.

The initial search retrieved 269 records. A stepwise screening procedure was then applied to improve topical relevance and analytical reliability. First, Web of Science subject categories were used to retain records in sports science, sports medicine, rehabilitation, biomechanics, physical therapy, orthopaedics, health sciences, and closely related areas; records from unrelated categories were removed, leaving 201 records. Second, titles, abstracts, keywords, and Web of Science citation topic information were reviewed to determine whether each record addressed swimming-related shoulder pain, swimmer's shoulder, shoulder injury in swimmers, risk factors, biomechanics, prevention, or rehabilitation. Studies that mentioned swimming or shoulder terms only incidentally were excluded, leaving 198 records. Third, the sample was restricted to English-language articles and review articles because these document types provide complete bibliographic records, abstracts, keywords, and cited references suitable for bibliometric analysis. After this process, 195 valid publications were retained.

Eligibility criteria

To strengthen methodological transparency and improve the reproducibility of the bibliometric analysis, explicit inclusion and exclusion criteria were applied. In bibliometric research, the use of predefined filtering criteria is important because database searches may retrieve records that are outside the actual conceptual scope of the study. Therefore, researchers are expected to clarify how the final sample was identified and why certain records were excluded (Öztürk et al., 2024).

Publications were included if they met all of the following criteria:

1. The publication focused on swimmer's shoulder, swimming-related shoulder pain, shoulder injury, shoulder injury risk, prevention, rehabilitation, biomechanics, functional assessment, training load, or training-related shoulder problems in swimmers.
2. The research population or research context was directly related to swimmers, competitive swimmers, elite swimmers, or swimming training.
3. The publication was indexed in the Web of Science Core Collection.
4. The publication was written in English.
5. The document type was classified as an article or review article.
6. The publication year fell within the period from 2015 to 2025.

Publications were excluded if they met any of the following criteria:

1. The publication focused on general shoulder pain or general shoulder injury without a clear connection to swimming.
2. The study examined shoulder injuries in other sports or general athletic populations without providing direct relevance to swimming-related shoulder problems.
3. The publication was a conference abstract, editorial, letter, book chapter, correction, news item, or other non-research document type.
4. The publication was not written in English.
5. The bibliographic record was incomplete, duplicated, or lacked sufficient information for bibliometric analysis.
6. The publication contained broad terms such as "*shoulder*" or "*swimming*" but did not make a meaningful contribution to understanding swimmer's shoulder, swimming-related shoulder pain, risk factors, prevention, biomechanics, or rehabilitation.

These criteria were applied to ensure that the final dataset represented the core literature of swimmer's shoulder research rather than a broad and heterogeneous set of studies on shoulder problems or swimming in general.

Screening procedure

The screening procedure was conducted in four stages. In the first stage, the topic search identified 269 potentially relevant records. In the second stage, subject-category filtering excluded records outside sports science, sports medicine, rehabilitation, biomechanics, physical therapy, orthopaedics, health sciences, and related fields, reducing the dataset to 201 records. In the third stage, titles, abstracts, keywords, and citation topic information were reviewed for topical relevance. Records were retained only when the swimming context and shoulder-related problem were both explicit. Studies on general shoulder pain, other sports, non-athlete populations, or general swimming performance without a shoulder-injury focus were removed, leaving 198 records. In the final stage, language and document-type restrictions were applied. Only English-language articles and review articles were retained, resulting in the final dataset of 195 valid publications.

This screening procedure was designed to improve the reproducibility of the study and to reduce the risk of including irrelevant records. Similar to reporting principles used in systematic and bibliometric reviews, the screening process was presented in a transparent format so that readers can understand how the final analytical dataset was constructed (Page et al., 2021; Montazeri et al., 2023).

Table 1. Literature search, screening, and eligibility process

Screening stage	Criterion applied	Records retained	Records excluded	Main reason for exclusion
Initial search	Topic search in Web of Science Core Collection	269	—	Initial retrieval
Subject category filtering	Records related to sports science, sports medicine, rehabilitation, biomechanics, physical therapy, and related health sciences were retained	201	68	Irrelevant subject categories
Citation topic and relevance screening	Citation topic information, titles, and abstracts were checked for topical relevance	198	3	Weak relevance to swimmer's shoulder or swimming related shoulder problems
Language and document type filtering	English language articles and review articles were retained	195	3	Non eligible language or document type
Final dataset	Publications included in bibliometric analysis	195	—	Final valid publications

Data extraction, cleaning, and keyword normalisation

After screening, the full records and cited references of the 195 eligible publications were exported from the Web of Science Core Collection for bibliometric analysis. The exported information included titles, authors, journal names, publication years, countries or regions, institutional affiliations, abstracts, author keywords, Keywords Plus, citation counts, and cited references. These fields were used to examine publication output, research collaboration, citation influence, and thematic relationships within swimmer's shoulder research.

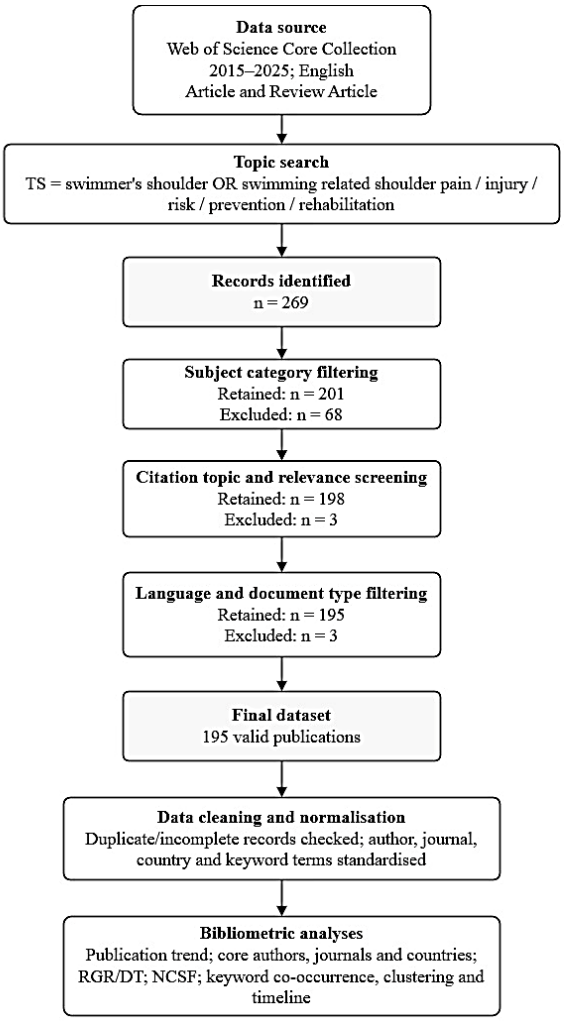
Before the bibliometric analysis, the dataset was cleaned to improve consistency and reduce errors. Data cleaning is a necessary step in bibliometric research because bibliographic databases may contain inconsistencies in author names, institutional names, journal titles, keywords, and cited references. Recent methodological work has stressed that insufficient preprocessing may lead to inaccurate network structures and misleading bibliometric interpretations (Lim et al., 2024; Nowakowska, 2025).

The cleaning process included checking for duplicate and incomplete records, standardising author and journal names where necessary, verifying publication years, and reviewing country and institutional

information. Keyword normalisation was also performed to reduce fragmentation caused by spelling differences, plural forms, hyphenation, abbreviations, and semantically equivalent terms. For example, closely related expressions such as "*risk factor*" and "*risk factors*" were unified, and terms referring to the same anatomical or functional concept were merged when appropriate. Ambiguous terms were retained only when their meaning could be confirmed from the title, abstract, or keyword context. This procedure ensured that the keyword network reflected the conceptual structure of swimmer's shoulder research rather than inconsistencies in terminology.

Bibliometric analysis and visualisation

This study used CiteSpace and VOSviewer to analyse and visualise the final dataset. CiteSpace was used to identify knowledge structures, keyword clusters, citation patterns, and thematic evolution. CiteSpace has been widely used to detect and visualise emerging trends and structural patterns in scientific literature (Chen, 2006). VOSviewer was used to construct and visualise bibliometric networks, including author collaboration and keyword co-occurrence networks. VOSviewer is particularly useful for constructing and displaying large bibliometric maps in an interpretable visual format (van Eck & Waltman, 2010).



Note. RGR = Relative Growth Rate; DT = Doubling Time; NCSF = Field-Normalised Citation Score.

Figure 1. Workflow of the bibliometric analysis and literature screening process for swimmer's shoulder research.

The analysis focused on the following dimensions: annual publication output, core authors, core journals, core countries, relative growth rate, doubling time, field-normalised citation score, high-frequency keywords, keyword co-occurrence networks, keyword clustering, and keyword timeline evolution. These indicators were selected not only to describe the publication characteristics of swimmer's shoulder research but also to clarify the intellectual and thematic development of the field.

In this study, performance analysis was used to identify publication output, influential authors, journals, and countries. Science mapping was used to examine relationships among keywords, clusters, and research themes. This combination of performance analysis and science mapping is consistent with established bibliometric approaches, which recommend integrating descriptive indicators with network-based visualisation to obtain a more complete understanding of a research field (Donthu et al., 2021; Öztürk et al., 2024).

The bibliometric results were further interpreted in relation to the conceptual development of swimmer's shoulder research. Specifically, keyword co-occurrence, clustering, and timeline analyses were used to examine whether the field has evolved from symptom identification toward mechanism explanation, functional assessment, prevention, and rehabilitation management. This interpretive step was included to avoid limiting the study to descriptive statistics and to strengthen the conceptual contribution of the bibliometric findings.

The overall workflow of literature retrieval, eligibility screening, data cleaning, keyword normalisation, and bibliometric analysis is presented in Figure 1. This workflow clarifies how the initial 269 records retrieved from the Web of Science Core Collection were processed into the final dataset of 195 valid publications. It also shows the subsequent analytical procedures, including data cleaning, bibliometric mapping, and thematic interpretation. By presenting both the screening process and the analytical pathway, the workflow strengthens the transparency and reproducibility of the study.

RESULTS

Descriptive statistics

This study collected a total of 195 publications. These papers were written by 826 authors from 423 institutions across 41 countries and were published in 64 journals. Together, these publications cited 4,708 references from 1,251 different journals.

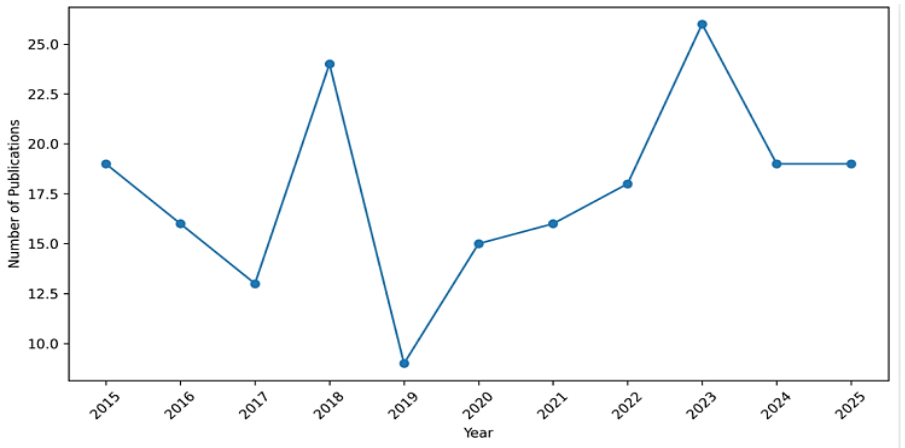


Figure 2. Annual number of publications from 2015 to 2025.

Core author analysis

Studying the writers of the literature can teach us about the main researchers and experts in this subject of study. The eminent researcher Price (1963) noted that within the same subject, fifty percent of the articles were authored by a cohort of exceptionally prolific writers, with the size of this group being roughly equivalent to the square root of the total number of authors. In his work, Egghe accurately determined the correlation between Price's Law and Lotka's Law, providing a mathematical demonstration of the law's applicability (Egghe, 2005). Nicholls objectively examined the validity of Price's square root law and investigated its correlation with Lotka's Law (Nicholls, 1988). That is:

$$\sum_{m+1}^{\mathrm{I}} n(x) = \sqrt{N}$$

In this study, the most productive author published 9 papers (NMAX = 9). According to Price's Law, the minimum number of papers required for a core author is m = 0.749 $\sqrt{N}$ max ≈ 2.247. Therefore, authors who have published three or more papers were classified as core authors in this field.

$$m = 0.794 \times N_{MAX} \approx 2.38$$

A total of 34 core authors published 144 papers, accounting for 73.8% of the total number of publications. This proportion exceeds the 50% threshold proposed by Price, indicating that a relatively stable core author group has emerged in swimmer's shoulder research.

Table 2. Bibliometric analysis of core authors in swimmer's shoulder research.

Rank	Author	Documents	Citations	Average citation/Publication
1	Tate, Angela	9	216	24
2	Kaneoka, Koji	7	76	10.9
3	Akuzawa,Hiroshi	6	76	12.7
4	Feijen, Stef	6	186	31
5	Kuppens, Kevin	6	186	31
6	Matsuura, Yuiko	6	68	11.3
7	Struyf, Filip	6	186	31
8	Ginn, Karen A.	5	99	19.8

Table 2 presents the most productive and influential authors in swimmer's shoulder research. Angela Tate ranked first, with 9 publications, 216 citations, and an average of 24 citations per publication, indicating both sustained productivity and substantial citation influence. Koji Kaneoka ranked second with 7 publications and 76 citations, showing an important contribution to publication output. Feijen, Stef; Kuppens, Kevin; and Struyf, Filip each published 6 papers and received 186 citations, with an average of 31 citations per publication, suggesting strong citation influence relative to output. Overall, the author-level findings indicate that a relatively stable core author group has emerged, while productivity and citation impact remain unevenly distributed across researchers.

Figure 3 presents the author collaboration network generated by VOSviewer. The size, colour, and connections of the nodes indicate the relative contribution of authors and the collaborative relationships among research groups. The overall network shows several connected clusters rather than a single dominant group, suggesting that swimmer's shoulder research has gradually moved from isolated studies toward a more organised but still heterogeneous collaborative structure. Angela Tate occupies a central position in the

network and is connected with several author groups, which is consistent with her high publication output and citation count. Kaneoka, Koji and Feijen, Stef also hold prominent positions. Kaneoka contributes strongly to research productivity, whereas Feijen shows high citation influence. These findings indicate that the field contains both productive contributors and influential authors whose work shapes the academic direction of swimmer's shoulder research.

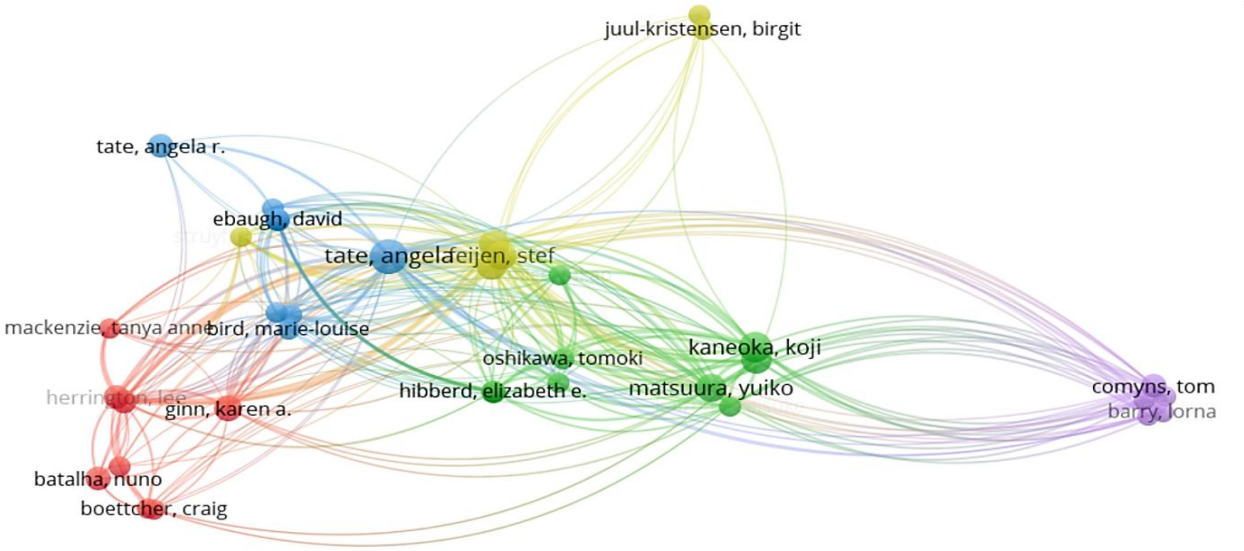


Figure 3. Author collaboration network in swimmer's shoulder research.

Several collaboration clusters can be identified in the network. One cluster includes Mackenzie, Tanya Ann; Herrington, Lee; Ginn, Karen A.; Batalha, Nuno; and Boettcher, Craig, indicating a relatively stable internal collaboration pattern. Another cluster, represented by Tate, Angela R.; Ebaugh, David; and Bird, Marie-Louise, is more centrally positioned and connects with multiple parts of the network. A third cluster includes Kaneoka, Koji; Matsuura, Yuiko; Oshikawa, Tomoki; and Hibberd, Elizabeth E., representing another important research pathway. The group represented by Feijen, Stef and Juul-Kristensen, Birgit appears smaller but may contribute to knowledge integration across related themes. These patterns suggest three complementary roles in the field: authors who sustain publication growth, authors whose studies receive high citation attention, and bridging authors who connect different research communities.

Core journal analysis

Table 3. Ranking of influential core journals in swimmer's shoulder research.

Rank	Source	Documents	Citations	Average citation/Publication
1	Physical Therapy in Sport	17	301	17.7
2	Journal of Athletic Training	13	171	13.1
3	International Journal of Sports Physical Therapy	12	95	7.9
4	Journal of Sport Rehabilitation	10	73	7.3
5	American Journal of Sports Medicine	7	394	56.3
6	Journal of Science and Medicine in Sport	7	112	16
7	Orthopaedic Journal of Sports Medicine	7	83	11.8
8	British Journal of Sports Medicine	6	1370	228.3
9	Sports Biomechanics	6	64	10.7
10	Sports Health: A Multidisciplinary Approach	6	77	12.8

The core journal analysis in Table 3 shows that swimmer's shoulder research is mainly published in journals related to sports rehabilitation, athletic training, sports medicine, physical therapy, and biomechanics. This distribution indicates that the topic is no longer limited to swimming technique alone but has developed into a broader research concern involving injury prevention, functional evaluation, training management, and rehabilitation intervention. Physical Therapy in Sport published the largest number of articles (17), received 301 citations, and achieved an average of 17.7 citations per article, suggesting that it is both a major publication venue and a stable source of applied research in this field. The Journal of Athletic Training, International Journal of Sports Physical Therapy, and Journal of Sport Rehabilitation also contributed substantially, reflecting the practical orientation of current swimmer's shoulder research.

Highly prolific journals and highly influential journals were not identical. Although Physical Therapy in Sport published the largest number of papers, the British Journal of Sports Medicine and the American Journal of Sports Medicine showed stronger citation impact. The British Journal of Sports Medicine published 6 articles but received 1,370 citations, with an average of 228.3 citations per article. The American Journal of Sports Medicine published 7 articles and received 394 citations, with an average of 56.3 citations per article. These findings suggest that some high-impact sports medicine journals publish fewer swimmer's shoulder studies, but those studies are more visible within broader debates on sports injury prevention, clinical assessment, and athlete health.

The Journal of Science and Medicine in Sport, the Orthopaedic Journal of Sports Medicine, Sports Biomechanics, and Sports Health: A Multidisciplinary Approach also ranked among the top ten journals. Their presence shows that swimmer's shoulder research is informed by sport science, orthopaedic sports medicine, biomechanics, and multidisciplinary athlete health management. The Journal of Science and Medicine in Sport published 7 papers and received 112 citations, with an average of 16 citations per article. The Orthopaedic Journal of Sports Medicine published 7 papers and received 83 citations, with an average of 11.8 citations per article. Sports Biomechanics published 6 articles and received 64 citations, with an average of 10.7 citations per article. Sports Health: A Multidisciplinary Approach published 6 papers and received 77 citations, with an average of 12.8 citations per article. These journals further demonstrate that contemporary swimmer's shoulder research has developed clear interdisciplinary characteristics through the integration of rehabilitation science, clinical medicine, biomechanics, and training science.

Overall, the journal distribution shows a clear dual structure. High-output publications are mainly concentrated in sports rehabilitation and athletic training journals, indicating that the field is strongly oriented toward functional recovery, preventive intervention, and practical application. By contrast, highly influential findings are often published in internationally recognised sports medicine journals, suggesting that swimmer's shoulder has gradually been incorporated into broader discussions of sports injury and clinical management. This pattern reflects the disciplinary characteristics of the publication platforms and indicates that future research is likely to develop through deeper integration between sports rehabilitation and sports medicine.

Core country analysis

The distribution of academic output and citation impact illustrates the contributions and influence of various countries within this research domain. By analysing the number of publications, total citations, and average citations per publication (CPP) of the top ten countries, a clearer picture of each country's research performance in this field can be obtained.

The data in Table 4 reveal a clear concentration in the national distribution of swimmer's shoulder research. The United States ranked first with 68 publications, 1,360 citations, and an average of 20 citations per

publication. This indicates a broad and sustained research base, likely supported by extensive sports medicine, athletic training, physical therapy, and university-based clinical research infrastructure. The high output of the United States suggests that swimmer's shoulder has been examined across multiple institutional and professional settings, including athlete health management, injury prevention, functional assessment, and rehabilitation intervention.

Table 4. Ranking of core countries by publication output and academic influence in swimmer's shoulder research.

Rank	Source	Documents	Citations	Average citation/Publication
1	USA	68	1360	20
2	Australia	27	1967	72.8
3	England	22	320	14.5
4	Brazil	15	219	14.6
5	Canada	13	238	18.3
6	Japan	13	106	8.2
7	Belgium	10	216	21.6
8	Portugal	10	189	18.9
9	Spain	9	149	16.6
10	Iran	8	83	10.4

Australia ranked second with 27 publications. Although its publication output was lower than that of the United States, its total citation count reached 1,967, the highest among all countries, and its average citation count per article was 72.8. This indicates a pattern of concentrated and highly visible research influence. The Australian contribution may be associated with strong traditions in competitive swimming, sports physiotherapy, athlete monitoring, and applied sport science. In bibliometric terms, Australia therefore represents a high-impact profile: fewer publications than the United States, but stronger normalised citation influence and international visibility.

England ranked third with 22 publications, 320 citations, and an average of 14.5 citations per publication. Brazil ranked fourth with 15 publications, 219 citations, and an average of 14.6 citations per publication. Canada and Japan each published 13 papers, but their citation influence differed. Canada received 238 citations, with an average of 18.3 citations per article, whereas Japan received 106 citations, with an average of 8.2 citations per article. These differences show that publication volume does not necessarily correspond to citation influence and that national contributions should be interpreted through both productivity and impact.

Belgium and Portugal each published 10 papers and ranked among the top eight countries. Belgium received 216 citations, with an average of 21.6 citations per article, while Portugal received 189 citations, with an average of 18.9 citations per article. Although their publication output was moderate, their average citation performance was relatively strong. This suggests that swimmer's shoulder research is not limited to a small number of dominant countries but also includes meaningful contributions from countries with established expertise in sports medicine, rehabilitation science, biomechanics, and training science.

There are two clear patterns in the national distribution in this field. First, most of the publications come from Europe, North America, and English-speaking countries, especially the US, Australia, England, and Canada. This suggests that the development of swimmer's shoulder research is closely related to the long-term accumulation of these countries in competitive swimming, sports medicine, and sports rehabilitation. Second, highly productive countries and highly influential countries are not exactly the same. The United States has an absolute advantage in publication scale, whereas Australia performs more prominently in both total

citations and average citations per article, indicating that its research outcomes are more representative and influential within the field. This difference suggests that publication quantity can only reflect research activity but cannot fully represent academic influence, and both dimensions should be considered together.

This outcome underscores the robust interdisciplinary nature of swimmer's shoulder research. This subject is intricately associated not only with competitive swimming but also with research domains such as sports injury prevention, clinical evaluation, functional recovery, and rehabilitation interventions. Consequently, nations with more robust foundations in sports medicine, rehabilitation science, and advanced athletic training systems are more likely to yield enduring and significant research findings in this area. In the future, as research methodologies evolve and international collaboration intensifies, the national distribution of swimmer's shoulder research may become increasingly varied. Nevertheless, European and North American countries are expected to retain a predominant position for an extended period, primarily due to their established research institutions, funding prospects, and access to elite athletes for study purposes.

RGR, DT and NCSF

The data on the relative growth rate (RGR) and doubling time (DT) reveal the growth trend and maturity of literature in a particular field. RGR reflects the growth speed of publications within a specific time interval, while DT indicates the time required for the number of publications to double (Mahapatra, 1994; Javed & Liu, 2018).

1.Relative Growth Rate (RGR)

The Relative Growth Rate (RGR) is used to measure the growth rate of publications, and its calculation formula is as follows:

$$\mathrm{RGR} = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{T2} - \mathrm{T1}}$$

Among them, W1 and W2 respectively represent the natural logarithms of the cumulative number of publications at time $\mathrm{T1}$ and $\mathrm{T2}$. $\mathrm{T1}$ and $\mathrm{T2}$ are adjacent years.

2.Doubling Time (DT)

The doubling time (DT) represents the time needed for the number of publications to double. The relationship between DT and RGR is as follows:

$$\mathrm{DT} = \frac{0.693}{\mathrm{RGR}}$$

Among them, ln(2)≈0.693 is the constant of the natural logarithm, and RGR is the relative growth rate.

3.Relative growth rate(RGR) and Doubling time(DT) of publications

As shown in Table 5, although the annual number of publications fluctuated across individual years, the cumulative number of publications showed a steady upward trend during the observation period. This indicates that swimmer's shoulder has remained a sustained research topic rather than a short-term or temporary academic concern. The publication output was relatively active in several years, particularly after 2020, suggesting that shoulder-related problems in swimmers have continued to attract attention in sports medicine, rehabilitation, biomechanics, and training science.

Table 5. Relative growth rate and doubling time of publications.

Years	Publications	Cumulative Sum	W1	W2	RGR	Mean (R)	DT (P)	Mean (DT)
2015	19	19	2.944	3.555	0.611		1.134	
2016	16	35	3.555	3.871	0.316		2.194	
2017	13	48	3.871	4.277	0.405		1.709	
2018	24	72	4.277	4.407	0.130		5.329	
2019	10	82	4.407	4.575	0.168		4.125	
2020	15	97	4.575	4.727	0.153	0.297	4.539	3.172
2021	16	113	4.727	4.875	0.148		4.688	
2022	18	131	4.875	5.056	0.181		3.828	
2023	26	157	5.056	5.170	0.114		6.066	
2024	19	176	5.170	5.273	0.103		6.760	
2025	19	195	5.273	—	—	0.136	—	5.336

The RGR results further reveal that the growth speed of swimmer's shoulder research gradually slowed over time. In the earlier stage, the mean RGR was higher, indicating a period of relatively rapid expansion in which the basic clinical problem, injury characteristics, and research boundaries of swimmer's shoulder were being established. In the later stage, the mean RGR decreased, while the mean DT increased. This pattern suggests that the field has moved from rapid growth toward a more stable and mature phase of development. A decline in RGR and an increase in DT should not be interpreted as a reduction in academic value. Rather, these indicators may reflect the gradual consolidation of the research field, in which the number of publications grows more slowly but the research questions become more focused and specialised.

This interpretation is consistent with the keyword timeline analysis. Earlier studies were mainly concerned with shoulder pain, injury occurrence, diagnosis, and epidemiological characteristics, whereas later studies increasingly addressed biomechanics, muscle strength, range of motion, scapular control, monitoring, prevention, and rehabilitation management. Therefore, the RGR and DT results do not only describe publication growth; they also reflect the intellectual development of the field. Swimmer's shoulder research appears to have shifted from problem recognition toward mechanism explanation and practical management, which indicates a more mature stage of knowledge development.

4. Field-Normalized Citation Score (NCSF)

The Field-Normalized Citation Score (NCSF) is used to measure the relative academic impact of different countries within a specific field. An NCSF value of 1.0 indicates that the number of citations of a country's or institution's publications is at the average level for that field. An NCSF greater than 1.0 means that the citations exceed the average for the field, indicating a higher level of impact; whereas an NCSF below 1.0 suggests lower-than-average citation levels within the field.

The NCSF (Field-Normalized Citation Score) is calculated using the following formula:

$$NCSF = \frac{CPP}{CI}$$

Where:

CPP represents the average number of citations per paper.

CI (Citation Impact) is the benchmark citation impact for the field. Here, CI = 4708 / 195 ≈ 24.14 is calculated from the WoS (Web of Science) data source, which reflects the average number of citations for all related publications in the field of swimmer's shoulder.

The CI value is used to normalize citation rates across different subfields, allowing for a comparison of the academic performance of different countries and journals in the field of swimmer's shoulder with this benchmark.

The top 10 journals ranked by NCSF are shown in Table 6:

Table 6. NCSF values of core journals in swimmer's shoulder research.

Nº	Journal	Documents	Citations	NCSF
1	British Journal of Sports Medicine	6	1370	9.46
2	American Journal of Sports Medicine	7	394	2.33
3	Physical Therapy in Sport	17	301	0.73
4	Journal of Science and Medicine in Sport	7	112	0.66
5	Journal of Athletic Training	13	171	0.54
6	Sports Health: A Multidisciplinary Approach	6	77	0.53
7	Orthopaedic Journal of Sports Medicine	7	83	0.49
8	Sports Biomechanics	6	64	0.44
9	International Journal of Sports Physical Therapy	12	95	0.33
10	Journal of Sport Rehabilitation	10	73	0.30

Table 6 shows that journal level NCSF values were not fully consistent with publication output. Some journals, such as Physical Therapy in Sport, Journal of Athletic Training, International Journal of Sports Physical Therapy, and Journal of Sport Rehabilitation, published a relatively large number of swimmer's shoulder studies. These journals represent important and continuous publication platforms for research on functional assessment, rehabilitation strategies, preventive training, and clinical management. Their contribution is therefore reflected mainly in sustaining the development and accumulation of applied research in this field.

However, journals with fewer publications, such as the British Journal of Sports Medicine and the American Journal of Sports Medicine, showed much higher normalised citation influence. This indicates that publication quantity and citation impact represent different dimensions of journal contribution. A journal may publish fewer studies but still exert stronger academic influence if those studies are widely cited and connected to broader debates in sports medicine, injury prevention, and clinical rehabilitation. Therefore, the journal distribution of swimmer's shoulder research should be interpreted from both output and influence perspectives.

The journal level NCSF results suggest that swimmer's shoulder research has developed through two complementary knowledge dissemination channels. One channel is represented by rehabilitation and physical therapy-oriented journals, which provide stable publication space for applied and clinically relevant studies. The other channel is represented by high-impact sports medicine journals, which disseminate influential findings to a wider academic community. This dual structure indicates that swimmer's shoulder research is both an applied rehabilitation topic and an issue of broader relevance within sports medicine and athlete health management.

The top 10 countries ranked by NCSF are shown in Table 7. As shown in this table, the country-level NCSF results also demonstrate that publication output and citation influence are not identical. The United States produced the largest number of publications, which suggests a broad and active research base in sports medicine, athletic training, physical therapy, and university-based rehabilitation research. This high output may reflect the strong institutional foundation and research capacity of the United States in athlete injury prevention and clinical sport science.

Table 7. NCSF data table ranked by country.

Nº	Country	Documents	Citations	NCSF
1	Australia	27	1967	3.02
2	Belgium	10	216	0.89
3	USA	68	1360	0.83
4	Portugal	10	189	0.78
5	Canada	13	238	0.76
6	Spain	9	149	0.69
7	Brazil	15	219	0.60
8	England	22	320	0.60
9	Iran	8	83	0.43
10	Japan	13	106	0.34

Australia, although producing fewer publications than the United States, showed stronger normalised citation influence. This pattern suggests that Australian research may have contributed more concentrated and highly visible findings in competitive swimming, sports physiotherapy, athlete monitoring, and clinically relevant injury prevention. In this sense, the United States and Australia represent two different forms of contribution to swimmer's shoulder research. The United States reflects research scale and institutional breadth, whereas Australia reflects citation concentration and international influence.

The NCSF results therefore help clarify the difference between productivity and impact. A country with a larger publication base may contribute to the breadth and continuity of the field, while a country with higher normalised citation influence may play a stronger role in shaping the conceptual, methodological, or practical direction of the research area. This distinction is important because evaluating national contribution only by publication counts may underestimate the influence of countries that produce fewer but more highly cited studies.

Taken together, RGR, DT, and NCSF provide evidence that swimmer's shoulder research is entering a more mature stage. The field is no longer defined only by increasing publication numbers. Instead, its development is reflected in the consolidation of research themes, the differentiation between output and impact, and the growing integration of symptom identification, biomechanical explanation, functional assessment, prevention, and rehabilitation. These findings strengthen the scientific value of the bibliometric analysis by connecting quantitative indicators with the intellectual evolution of the field.

Keyword analysis

Table 8 shows that swimmer's shoulder research is concentrated around several primary themes: swimming-specific context, shoulder symptoms, injury prevention, and functional management. The keyword "*swimming*" appeared 75 times, indicating that the literature is strongly grounded in swimming-specific settings. "*Shoulder pain*" appeared 64 times, followed by "*shoulder*" and "*pain*" with 55 and 53 occurrences, respectively. These findings confirm that shoulder symptoms remain the central problem domain of the field. At the same time, the presence of prevention, risk factors, strength, and competitive swimmers among the high-frequency keywords indicates that research has extended beyond symptom description toward risk identification and functional management.

From the perspective of injury and risk identification, both "*injuries*" and "*risk factors*" appeared 40 times, indicating that research in this field has moved beyond simply describing pain and has gradually extended to the investigation of injury mechanisms and contributing factors. In particular, the fact that "*risk factors*" ranked among the top ten keywords suggests that recent studies have increasingly recognised that swimmer's shoulder is not caused by a single factor but is more likely related to the combined influence of training load,

movement patterns, local stability, muscle strength, and recovery status. This indicates that the research perspective in this field is shifting from merely identifying pain to explaining why it occurs and how risks can be recognised at an early stage.

Table 8 High Frequency Keywords in Swimmer's Shoulder Research

Rank	Keyword	Occurrences
1	swimming	75
2	shoulder pain	64
3	shoulder	55
4	pain	53
5	injuries	40
6	risk-factors	40
7	strength	38
8	swimmers	36
9	competitive swimmers	34
10	impingement	31

The keyword "*strength*" ranked seventh with 38 occurrences, indicating that strength-related factors occupy an important position in swimmer's shoulder research. This finding reflects increasing attention to shoulder muscular strength, muscle balance, rotator cuff function, and functional support capacity in both prevention and rehabilitation. The prominence of strength-related terms suggests that the field is moving beyond pain description and toward a more functional understanding of shoulder health in swimmers.

In addition, "*swimmers*" and "*competitive swimmers*" appeared 36 and 34 times, respectively, further indicating that current studies are mainly focused on swimming athletes, especially competitive swimmers. This suggests that a swimmer's shoulder is not simply a general shoulder problem but rather a sports injury issue closely associated with specialised training. Because competitive swimmers perform high frequency and repetitive stroke movements over long periods, their shoulders are exposed to substantial demands in both range of motion and workload, making them a key population for related research. This finding also suggests that future studies should continue to examine the specific influence of training patterns, performance level, and training stage on shoulder problems in relation to the particular characteristics of competitive swimming.

The keyword "*impingement*" appeared 31 times and remained among the top ten keywords. This indicates that shoulder impingement and related clinical mechanisms continue to be important topics in swimmer's shoulder research. Its frequent occurrence suggests that the field is concerned not only with subjective pain or general injury description, but also with specific pathological mechanisms and clinical interpretation. This further confirms the interdisciplinary nature of swimmer's shoulder research, particularly the integration of sports rehabilitation, biomechanics, and clinical medicine.

Overall, the distribution of high-frequency keywords indicates that swimmer's shoulder research has developed a relatively clear thematic structure. It is grounded in the specific context of swimming, centred on shoulder pain and injury manifestations, and extended through important directions such as risk factor identification, muscle strength and functional analysis, and the exploration of impingement mechanisms. This suggests that the field has gradually evolved from simply describing shoulder symptoms to a more comprehensive stage that also addresses injury mechanisms, functional assessment, and preventive intervention. It can be expected that, with the continued development of training monitoring, functional screening, and rehabilitation management research, future hotspots in swimmer's shoulder research will increasingly focus on risk warning, precise intervention, and the integrated analysis of multiple factors.

Keyword co-occurrence analysis

Figure 4 shows that the keyword co-occurrence network generated with CiteSpace has a multicentre structure with dense connections among major terms. This indicates that swimmer's shoulder research is not organised around a single issue, but around an interconnected set of themes including shoulder pain, swimming, injuries, prevention, strength, biomechanics, and functional assessment. The network structure therefore supports the view that the field has developed from an isolated injury topic into a broader knowledge system linking symptoms, mechanisms, and applied management.

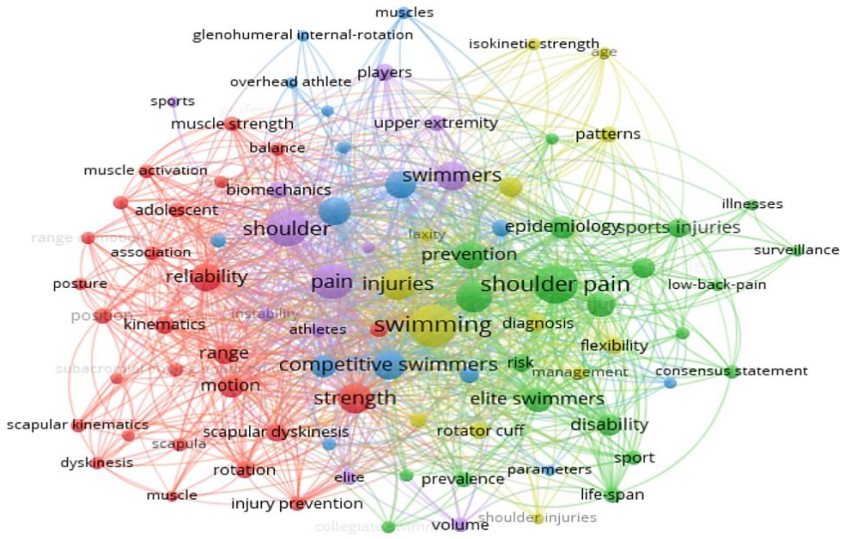


Figure 4. Keyword co-occurrence network of swimmer's shoulder research.

Table 9. Characteristics and academic significance of key keywords.

Thematic node	Node characteristics	Academic role
Shoulder pain	Keywords such as swimming, injuries, pain, epidemiology and diagnosis, and serves as one of the core nodes in the network	Closely connected with Forms the core problem domain of swimmer's shoulder research and provides the basis for shoulder problem identification, injury analysis, and rehabilitation research
Swimming	Widely co-occurs with swimmers, competitive swimmers, shoulder pain, prevention, and injuries, and is located in the central area of the network	Clarifies the sport specific nature of the field and shows that the research is consistently grounded in swimming training and competition contexts
Injuries/ epidemiology	Shows strong links with sports injuries, prevalence, risk, diagnosis, and surveillance	Helps reveal the occurrence patterns, epidemiological characteristics, and risk distribution of shoulder injuries and provides evidence for prevention strategies
Biomechanics	Frequently co-occurs with kinematics, motion, scapular dyskinesis, rotation, and muscle activation	Provides theoretical support for explaining the movement mechanisms and functional imbalance involved in swimmer's shoulder
Strength	Closely related to muscle strength, rotator cuff, isokinetic strength, muscles, and upper extremity	Highlights the importance of strength level and local functional support in injury prevention and rehabilitation
Prevention	Forms a clear cluster with risk, injury prevention, management, and elite swimmers	Promotes the shift of research from problem description to risk management and preventive intervention
Competitive swimmers	Closely associated with swimmers, elite swimmers, volume, risk, and shoulder pain	Emphasizes the specific nature of the study population and provides a basis for examining the relationship between training load and shoulder problems
Scapular dyskinesis	Strongly linked with scapular kinematics, rotation, and motion	Provides an important entry point for understanding movement compensation and functional imbalance in the development of shoulder pain
Rotator cuff	Closely connected with strength, prevention, and shoulder pain	Reflects the key role of rotator cuff function in local stability, preventive training, and rehabilitation management

The thematic nodes in swimmer's shoulder research are closely connected and jointly form a field centred on shoulder-related problems in swimming, while also addressing mechanical explanation and practical intervention. The terms "*shoulder pain*," "*swimming*," and "*injuries*" occupy central positions in the network, indicating that the main research concern remains shoulder symptoms and injury occurrence in competitive swimming. Strong links among nodes such as swimmers and competitive swimmers further confirm the sport-specific nature of the field. At the same time, connections among biomechanics, motion, rotation, scapular dyskinesis, and muscle activation suggest that current research has moved beyond pain description toward explanations based on movement mechanisms, functional imbalance, and scapular control.

In addition, the frequent appearance of nodes such as rotator cuff and upper extremity indicates that muscle strength and local stabilisation have received substantial attention in relation to injury prevention and rehabilitation. The clustering of prevention with risk, injury prevention, and management further suggests that the field is moving from problem identification toward risk management and preventive intervention. Overall, swimmer's shoulder research has developed a framework centred on shoulder pain and injury, explained through biomechanical and functional mechanisms, and extended toward prevention and rehabilitation.

Keyword clustering relationships

Figure 5 shows that the keyword clustering structure in swimmer's shoulder research is relatively clear, mainly forming thematic groups such as monitoring, athletes, muscle strength, range of motion, forward head posture, taekwondo, neck, lower limbs, and freestyle swimming. Overall, the links among these clusters are relatively close, indicating that research in this field is concerned not only with shoulder pain and injury itself but has also gradually expanded to related topics such as muscle strength, joint range of motion, postural characteristics, training monitoring, and sport-specific movement patterns. Among these clusters, monitoring, muscle strength, strength, and range of motion are particularly prominent, suggesting that current research places greater emphasis on functional assessment, risk monitoring, and preventive intervention. Overall, swimmer's shoulder research has shown a clear trend toward developing from a simple description of injury to a more balanced focus on functional mechanism analysis and comprehensive management.

To further clarify the thematic structure of swimmer's shoulder research, the major clusters identified in the keyword clustering map were summarized in terms of topic name, representative keywords, and research direction, as shown in Table 10.

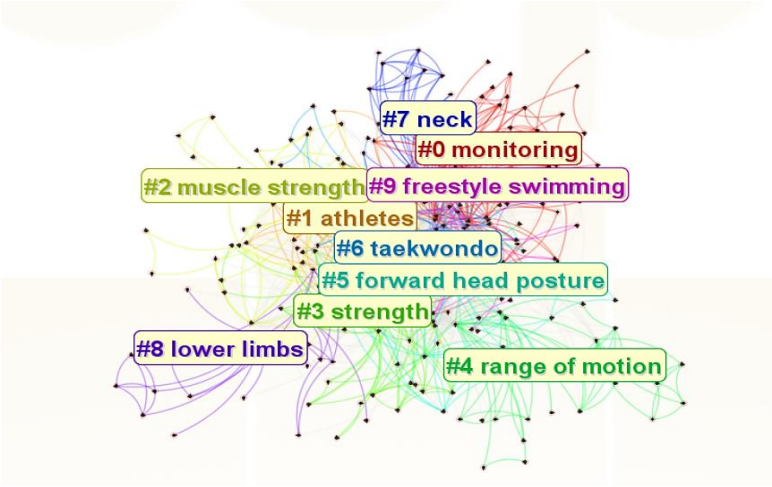


Figure 5. Keyword clustering map of swimmer's shoulder research.

Table 10. Swimmer's shoulder research keywords clustering analysis and research directions.

Cluster	Theme	Keywords	Research direction
#0	Monitoring and risk management	monitoring; injury monitoring; risk; management; surveillance	Tracks shoulder problems, training load, risk identification, and early-warning management.
#1	Athletes and population characteristics	athletes; swimmers; competitive swimmers; elite swimmers	Clarifies population-specific patterns among competitive and elite swimmers.
#2	Muscle strength and functional support	muscle strength; muscles; upper extremity; isokinetic strength	Highlights upper-extremity strength, local stability, and functional assessment.
#3	Strength training and injury prevention	strength; injury prevention; rotator cuff; training	Links strength-based intervention with shoulder stability, prevention, and rehabilitation.
#4	Range of motion and functional assessment	range of motion; flexibility; shoulder injuries; volume	Identifies mobility and flexibility as indicators of dysfunction, adaptation, and risk.
#5	Forward head posture and postural control	forward head posture; posture; alignment; biomechanics	Examines postural alignment and its influence on shoulder mechanics.
#6	Cross-sport comparison and functional transfer	taekwondo; athletes; strength; biomechanics	Uses cross-sport evidence to enrich interpretation of shoulder function.
#7	Neck and upper-body kinetic chain	neck; upper extremity; muscles; posture	Connects shoulder symptoms with cervical and proximal upper-body interactions.
#8	Lower limbs and whole-body coordination	lower limbs; motion; coordination; biomechanics	Extends analysis from local shoulder factors to integrated body mechanics.
#9	Freestyle swimming and stroke-specific features	freestyle swimming; stroke pattern; swimmers; technique	Emphasises stroke mechanics, repetitive technique, and style-specific loading.

Table 10 indicates that swimmer's shoulder research includes not only shoulder pain and injury, but also monitoring, muscle strength, range of motion, posture, stroke technique, and whole-body coordination. This thematic distribution shows that the field is gradually moving from symptom description toward a more comprehensive framework that includes mechanism explanation, functional assessment, risk monitoring, prevention, and rehabilitation management.

Keyword timeline analysis

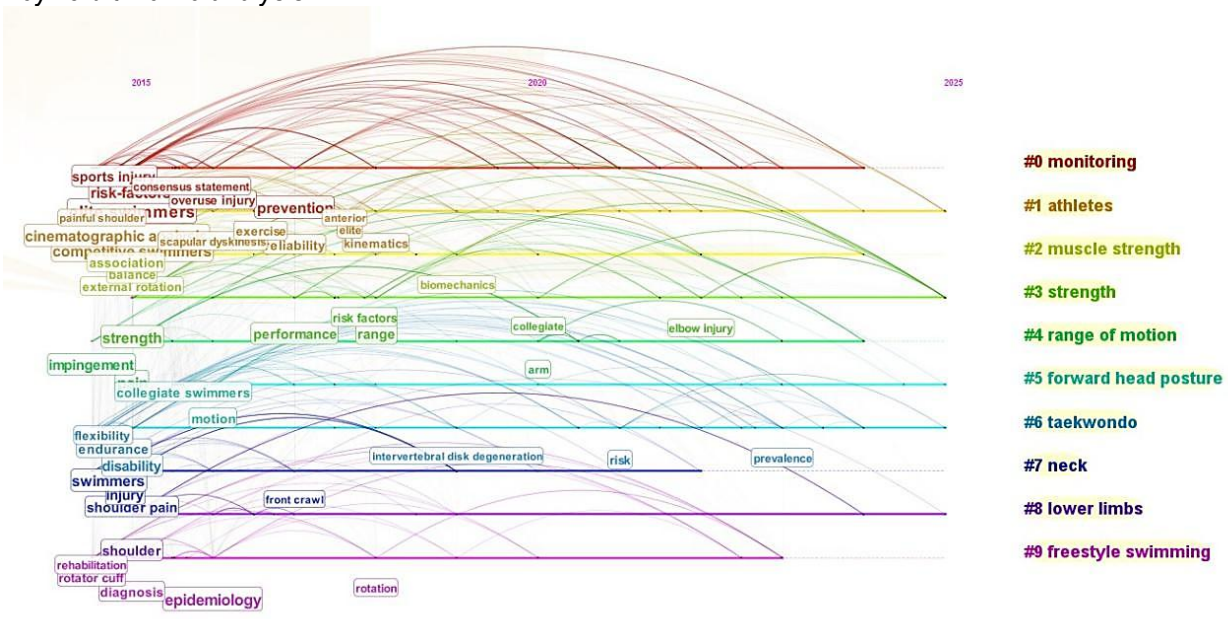


Figure 6. Keyword timeline view of swimmer's shoulder research.

Figure 6 shows how keyword clusters in swimmer's shoulder research changed between 2015 and 2025. Overall, the timeline suggests a coherent developmental pathway rather than a set of isolated topics. Early themes were mainly concerned with problem identification, whereas later themes increasingly focused on mechanisms, monitoring, prevention, and management. This temporal pattern supports the interpretation that swimmer's shoulder research has gradually evolved from recognising shoulder pain as a common problem toward explaining its causes and developing applied strategies to manage risk.

In the earlier stage, the research mainly focused on keywords such as swimmers, shoulder pain, injury, shoulder, diagnosis, and epidemiology. These topics suggest that the initial concerns of the field were centred on identifying the existence of shoulder problems in swimmers, describing their clinical manifestations, and clarifying their occurrence in athletic populations. In other words, early studies were mainly devoted to recognising shoulder pain and injury as a common and meaningful issue in competitive swimming.

As the field advanced, terms such as strength, muscle strength, range of motion, biomechanics, kinematics, and scapular dyskinesis gained prominence. This transition signifies a shift in research focus from merely describing pain and injury to investigating the functional and mechanical underpinnings of swimmer's shoulder. During this period, there was an increased emphasis on muscle support, joint mobility, movement pattern alterations, and scapular control, indicating a concerted effort to elucidate the aetiology of shoulder issues rather than solely documenting their existence.

In recent years, clusters such as monitoring, prevention, risk factors, performance, and forward head posture have remained active and become increasingly important. Monitoring appears to be one of the most active recent topics, suggesting growing interest in training surveillance, risk identification, and early management. This trend indicates a shift from retrospective injury description toward process-oriented management and preventive strategies. The timeline also includes themes such as freestyle swimming, neck function, and lower-limb coordination, indicating that the field is extending toward stroke-specific characteristics, kinetic-chain influences, and whole-body coordination.

The timeline view indicates that swimmer's shoulder research has progressed from describing pain and injury to interpreting these problems through functional and biomechanical mechanisms, and more recently to monitoring, prevention, and integrated management. This shift suggests a deepening of the field. Shoulder pain is increasingly understood not as an isolated symptom, but as the outcome of interacting factors within the training, performance, and recovery system.

DISCUSSION

Overall development pattern of swimmer's shoulder research

The present bibliometric findings indicate that swimmer's shoulder research has developed into a relatively mature and structured field over the past decade. Rather than focusing solely on shoulder pain as an isolated clinical symptom, current research increasingly situates swimmer's shoulder within a broader system that integrates training load, movement mechanics, functional capacity, and rehabilitation management (McKenzie et al., 2023; Kennedy et al., 2024).

From a developmental perspective, the discipline demonstrates a clear progression from phenomenon identification to mechanism exploration, ultimately resulting in process-oriented management. Early research primarily addressed the prevalence and characteristics of shoulder pain, while later studies shifted toward

biomechanical explanations and functional assessment. More recent work has emphasised monitoring, risk management, and preventive strategies (McKenzie et al., 2023; Yoma et al., 2022).

This transition reflects a broader paradigm shift in sports injury research, where complex conditions are no longer explained by single factors but are increasingly understood through integrated, multifactorial frameworks (McKenzie et al., 2023).

Structural and institutional interpretation of bibliometric patterns

The author, journal, and country analyses suggest that swimmer's shoulder research has developed through a relatively stable but uneven knowledge production structure. The author collaboration network indicates that the field is not organised around a single dominant research group. Instead, several partially connected clusters have emerged, each contributing to different dimensions of swimmer's shoulder research. Some authors appear to contribute mainly through sustained publication output, whereas others exert stronger influence through highly cited studies on risk factors, biomechanics, functional assessment, or rehabilitation. This distinction is important because productivity and academic influence do not necessarily represent the same form of contribution in bibliometric analysis (Donthu et al., 2021; Öztürk et al., 2024).

The collaboration network also suggests that swimmer's shoulder research has entered a stage of partial consolidation. The presence of stable author groups indicates that the field has moved beyond scattered individual studies and has begun to form recognisable research communities. However, the network remains heterogeneous, with several clusters showing stronger internal connections than external links. This pattern may reflect the interdisciplinary nature of swimmer's shoulder research. Researchers from sports medicine, physical therapy, biomechanics, athletic training, and rehabilitation science may address related but not identical research questions. As a result, knowledge development in this field is characterised by both specialisation and partial fragmentation. Future studies would benefit from stronger collaboration among biomechanical researchers, clinicians, rehabilitation specialists, and swimming performance scientists.

The core journal analysis further supports this interpretation. High-output journals such as Physical Therapy in Sport, Journal of Athletic Training, International Journal of Sports Physical Therapy, and Journal of Sport Rehabilitation indicate that swimmer's shoulder research is strongly rooted in applied sports rehabilitation, clinical assessment, and injury management. These journals provide important publication platforms for studies focused on functional evaluation, training-related shoulder problems, preventive exercise, and rehabilitation strategies. In contrast, journals with fewer publications but higher citation impact, such as the British Journal of Sports Medicine and the American Journal of Sports Medicine, appear to function as high-impact dissemination channels for studies with broader clinical or theoretical significance. This contrast indicates a dual publication structure in the field: rehabilitation-oriented journals support continuous topic development, while high-impact sports medicine journals amplify findings that influence the wider sports injury and clinical research community.

Country-level differences also require interpretation beyond simple publication counts. The United States produced the largest number of publications, suggesting a broad and active research base in sports medicine, athletic training, physical therapy, and university-based rehabilitation research. This high output may be partly associated with the extensive institutional infrastructure of sports science and clinical research in the United States, where shoulder injuries in athletes are studied across multiple professional contexts. Australia, by contrast, produced fewer publications but showed stronger citation influence. This pattern suggests that Australian research may be more concentrated in influential studies related to competitive swimming, sports physiotherapy, athlete monitoring, and clinically relevant injury prevention. Therefore, the national distribution

of swimmer's shoulder research should be understood through two dimensions: publication volume and citation influence.

The contrast between the United States and Australia is particularly important. A high number of publications reflects research activity and institutional breadth, whereas a high citation impact reflects international visibility and knowledge influence. The present findings suggest that swimmer's shoulder research is shaped not only by the amount of research produced but also by the degree to which this research is integrated into broader discussions on sports injury prevention, biomechanics, rehabilitation, and athlete health management. This interpretation strengthens the analytical value of the bibliometric findings and responds to the need to move beyond descriptive reporting.

Overall, the author, journal, and country analyses show that swimmer's shoulder research has become a structured and interdisciplinary field. Its development is supported by several stable author groups, a combination of rehabilitation-oriented and high-impact sports medicine journals, and a country level pattern in which publication output and citation influence are not always aligned. These findings suggest that future research should not only increase publication volume but also promote cross-group collaboration, international cooperation, and stronger integration between clinical, biomechanical, and training-related perspectives.

Conceptual contribution: A three level framework of swimmer's shoulder research

A central contribution of this study is the development of a three level framework for understanding the knowledge structure of swimmer's shoulder research. Previous reviews have examined specific aspects of swimmer's shoulder, such as training volume, injury risk factors, or exercise therapy interventions (Feijen et al., 2020; McKenzie et al., 2023; Yoma et al., 2022). However, these reviews generally focus on particular subtopics rather than the overall intellectual structure of the field. The present bibliometric analysis provides a broader view by showing how these subtopics are connected within the development of swimmer's shoulder research. Based on the keyword co-occurrence, clustering, timeline, author, journal, and citation results, swimmer's shoulder research can be organised into three interrelated levels: symptom identification, mechanism explanation, and intervention-oriented management.

The first level is symptom identification. At this level, the research focus is on shoulder pain, injury occurrence, epidemiology, diagnosis, and the recognition of swimmer's shoulder as a common problem in competitive swimming. The high frequency of keywords such as "*shoulder pain*," "*pain*," "*injuries*," "*swimming*," and "*competitive swimmers*" indicates that the field remains grounded in the practical problem of shoulder symptoms among swimmers. This level provides the clinical and sport-specific foundation for the field. Without the identification of shoulder pain and injury as persistent problems in swimming, later research on mechanisms and interventions would lack a clear problem base.

The second level is mechanism explanation. At this level, research moves beyond the description of pain and injury and attempts to explain why swimmer's shoulder occurs. The bibliometric findings show that keywords and clusters related to biomechanics, strength, range of motion, scapular dyskinesis, rotator cuff function, muscle activation, and stroke mechanics play an important role in the knowledge structure of the field. These themes indicate that swimmer's shoulder is increasingly understood as a multifactorial condition involving training load, movement patterns, local shoulder function, scapular control, muscular support, and individual adaptation. This mechanism-oriented level reflects a deeper scientific understanding of swimmer's shoulder and helps explain why similar training loads may lead to symptoms in some swimmers but not in others.

Table 11. Three-level framework of swimmer's shoulder research.

Level	Main focus	Bibliometric evidence	Scientific and practical meaning
Symptom identification	Shoulder pain, injury, diagnosis, epidemiology, competitive swimmers	High-frequency keywords such as "*shoulder pain," "pain," "injuries," "swimming*," and "*competitive swimmers*"	Establishes swimmer's shoulder as a persistent clinical and sport-specific problem
Mechanism explanation	Biomechanics, strength, range of motion, scapular dyskinesis, rotator cuff, stroke mechanics	Keyword co-occurrence and clustering around biomechanics, strength, movement, scapular control, and functional assessment	swimmer's shoulder as a multifactorial condition involving load, movement, function, and adaptation
Intervention-oriented management	Prevention, monitoring, rehabilitation, risk management, training modification	Recent timeline activity in monitoring, prevention, management, and rehabilitation-related themes	Connects bibliometric evidence with prevention, rehabilitation, training modification, and long-term athlete health management

The third level is intervention-oriented management. At this level, research focuses on prevention, monitoring, rehabilitation, training modification, risk management, and return-to-training strategies. The keyword timeline and clustering results suggest that recent research has become increasingly concerned with monitoring and prevention, indicating a shift from retrospective injury description toward proactive management. This level has strong practical value because it connects research findings with applied sport science, coaching, clinical assessment, and rehabilitation practice. In this sense, swimmer's shoulder research is no longer limited to identifying the existence of shoulder pain or explaining its mechanisms; it is increasingly concerned with how to reduce risk, guide training, support recovery, and protect long-term athlete health.

This framework advances current understanding in three ways. First, it integrates fragmented research themes into a coherent structure. Instead of treating shoulder pain, biomechanics, strength, prevention, and rehabilitation as separate topics, the framework shows that they represent different stages of knowledge development within the same field. Second, it clarifies the developmental trajectory of swimmer's shoulder research. The field has progressed from identifying symptoms to explaining mechanisms and then to developing prevention-oriented and rehabilitation-oriented approaches. Third, it strengthens the practical relevance of bibliometric findings. The framework can help researchers identify underdeveloped areas, clinicians design more comprehensive assessment and rehabilitation models, and coaches better understand the relationship between training load, movement quality, and shoulder health.

The three-level framework also highlights future research directions. At the symptom level, more longitudinal epidemiological studies are needed to clarify the incidence, recurrence, and severity of shoulder problems across different competitive levels and training stages. At the mechanism level, future studies should further examine how training load, stroke mechanics, scapular control, strength, range of motion, and recovery interact over time. At the intervention level, more field-based and longitudinal intervention studies are needed to test whether monitoring systems, preventive exercise programmes, and rehabilitation strategies can reduce shoulder symptoms while maintaining swimming performance. Therefore, the proposed framework does not simply summarise existing literature; it provides an organising model for future research and applied practice in swimmer's shoulder.

Overall, the present bibliometric study contributes to the field by transforming a dispersed body of literature into an integrated knowledge structure. The symptoms–mechanisms–intervention framework shows that swimmer's shoulder research has evolved from a symptom-focused topic into a multidisciplinary research area involving sports medicine, biomechanics, rehabilitation science, training monitoring, and athlete health

management. This conceptual contribution strengthens the originality of the study and demonstrates how bibliometric evidence can be used not only to describe a field but also to explain its intellectual development and practical significance.

Interdisciplinary integration and knowledge convergence

The findings demonstrate that swimmer's shoulder research exhibits strong interdisciplinary characteristics, involving sports science, biomechanics, clinical medicine, and rehabilitation science. The presence of both high-output rehabilitation journals and high-impact sports medicine journals indicates a bifurcated knowledge framework: one focused on practical application and the other on clinical and theoretical progress.

This interdisciplinary convergence enhances the explanatory capacity of the field and allows swimmer's shoulder to be understood within a more comprehensive framework that integrates training systems and clinical perspectives (McKenzie et al., 2023; Yoma et al., 2022).

Practical implications for training and rehabilitation

The findings of this study have important practical implications for training and rehabilitation in competitive swimming. Swimmer's shoulder should be managed through integrated prevention and rehabilitation rather than isolated symptom treatment. Coaches, clinicians, and practitioners should consider training load, stroke technique, shoulder strength, scapular control, range of motion, and recovery as interdependent components. Early identification of risk factors through monitoring and functional assessment is critical for preventing symptom progression. Strength training and movement correction should therefore be emphasised not only during rehabilitation but also as part of long-term injury prevention and athlete health management (Yoma et al., 2022; Tavares et al., 2025; Takayama et al., 2024).

Limitations and future directions

Despite its contributions, this study has several limitations. First, the analysis was based only on the Web of Science Core Collection, which may have excluded relevant studies indexed in other databases such as Scopus, PubMed, or SPORTDiscus. Second, the study included only English-language articles and review articles, which may have introduced language and document-type bias. Third, bibliometric analysis can reveal publication trends, citation relationships, and thematic structures, but it cannot directly evaluate the methodological quality or clinical effectiveness of individual studies. Future research should combine bibliometric analysis with systematic or scoping review methods to provide a more comprehensive understanding of swimmer's shoulder research. More longitudinal and intervention-based studies are also needed to clarify how training load, stroke mechanics, shoulder function, and recovery interact over time (Kennedy et al., 2024; Takayama et al., 2024; Tavares et al., 2025).

CONCLUSION

Main findings

This study conducted a bibliometric analysis of swimmer's shoulder research from 2015 to 2025 based on the Web of Science Core Collection. The findings reveal that the field has developed into a relatively structured and interdisciplinary research domain over the past decade. Research output showed a steady upward trend. A relatively stable yet heterogeneous academic network has emerged, with noticeable differences between high-output and high-impact contributors. Keyword and clustering analyses further indicate a transition from symptom-orientated research toward mechanism-based and intervention-orientated approaches.

Theoretical contributions

This study contributes to the literature by providing a structured bibliometric overview of swimmer's shoulder research from 2015 to 2025. By identifying publication patterns, citation differences, keyword relationships, and thematic evolution, the study shows how the field has shifted from symptom-oriented research toward mechanism-based and intervention-oriented approaches. The proposed three-level framework, comprising symptom identification, mechanism explanation, and intervention-oriented management, offers an integrative model for understanding the internal organisation and developmental trajectory of the field.

Practical implications

The findings have significant implications for training and rehabilitation practices in competitive swimming. Swimmer's shoulder should be regarded as a multifactorial issue resulting from the interplay of training load, technique, functional capacity, and recovery management, rather than as a singular clinical condition. Consequently, coaches and practitioners should implement an integrated approach that amalgamates workload regulation, technical optimization, strength development, and recovery monitoring (Yoma et al., 2022; Tavares et al., 2025).

Limitations and future research

Future research should integrate multiple databases and combine bibliometric analysis with systematic or scoping review methods to provide a more comprehensive understanding of the field. Increased focus should be directed towards tailored training and rehabilitation approaches, sophisticated monitoring technologies, and cohesive models that integrate biomechanics, physiology, and workload management (Kennedy et al., 2024; Tavares et al., 2025).

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows: Conceptualisation: Ming Lou. Methodology: Ming Luo. Formal analysis: Thariq Khan Bin Azizuddin Khan. Investigation: Bo Wang. Data curation: Bo Wang. Writing – original draft: Changqing Guo. Writing – review & editing: Changqing Guo. Supervision: Thariq Khan Bin Azizuddin Khan.

All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and

readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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