





REVIEW ARTICLE

## Low Back Pain Risk Among Athlete: A Scientometric Study

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### Abstract

Low back pain (LBP) emerges as a prevalent concern within the athletic community, characterized by a noteworthy proclivity for recurrence. The repeated occurrence of LBP substantially impedes athletes and adversely affects their performance. As such, it becomes imperative to discern the underlying factors contributing to injuries in the lumbar region. The scientometric analysis will provide a clear pathway for researchers to understand the current state and evolution of the theme research area of low back pain risk among athletes. No scientometric study on this theme has been undertaken until today. Therefore, this research objective was to collect data from the database to identify the present trend of low back pain risk, development patterns, and current research. Software that has been utilized for commonness, co-occurrence, clustering, co-citation and analysis of burst was CiteSpace. A scientometric review of studies on athletes' low back pain risk from 2000 to 2023 finds considerable additional studies in the amount of literature, the citation frequency, and the hotspots available. The most influential author is Douglas W. Jackson, the most influential article is Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Thoracolumbar spine is the most common cluster, whereas the most popular keyword is spondylolisthesis. In conclusion, low back pain is becoming one of the future study topics. Furthermore, many stakeholders must be aware of current trends and advances in the athlete's low back pain risk.

### Keywords

Low Back Pain, Risk, Athletes, Visualization, Scientometric

## INTRODUCTION

The escalating low back pain (LBP) among athletes prevalence has emerged as a worldwide concern. LBP is a common occurrence in sports, with prevalence estimates spanning from 1% to over 30% (Bono, 2004). Further corroborating this, a literature review indicates that LBP's prevalence in athletes falls within the range of 1% to 30%, with low back trauma accounting for 10-15% of all sports-related injuries (Mortazavi et al., 2015). As a result, athletes' performance could be negatively impacted by injuries, which also add to the club's

expenses and, more importantly, impact the individual athlete (De Visscher et al., 2021). Elite athletes who are frequently injured may struggle to achieve their peak performance levels throughout their careers due to missed training sessions and a lack of competitive exposure (Pfirrmann et al., 2016).

LBP is generally linked to high activity levels, smoking, obesity, poor overall health, and low socioeconomic position (Hartvigsen et al., 2018). Psychosocial factors such as stress, exhaustion, worry, poor sleep, and mood swings may make athletes more susceptible to low back

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pain (LBP), even though they are less likely to be impacted by them (Hainline et al., 2017; O'Sullivan et al., 2018). Apart from psychological factors, other aspects are contributing to low back pain (LBP) among athletes, as shown in previous research. According to studies, the type of sport plays a crucial role in developing LBP (Bahr et al., 2004; Hangai et al., 2010). Additionally, repetitive loads contribute to stress and strain on the lower back (Horton et al. 2001; Memari et al., 2014). The frequency of training sessions is another factor that shows a connection between regular training and the occurrence of LBP (Maselli et al., 2015; Kordi et al. 2011). Moreover, athletes may get LBP due to stress reactions in epiphyseal rings, spondylolysis/spondylolisthesis or disc degeneration (Schmidt et al., 2014). Understanding these factors emphasizes the need for a comprehensive approach to prevent and manage LBP among athletes.

Identifying the risks of LBP is essential because it can impair athletes' performance (Pfirrmann et al., 2016). Injury can affect postural control (Steffen et al., 2017), and influence the biomechanics of the entire body which will influence the osteokinematics and arthrokinematics that can lead to a decrease in performance level (Krosshaug et al., 2005). It has been proven by previous literature that reported low back pain (LBP) can negatively impact performance and is linked to recurring episodes in popular sports in Netherlands which are field hockey, football and speed skaters (van Hilst et al., 2015). In addition, LBP is a prevalent issue in sports and it tends to happen again in the future (Pasanen et al., 2014). Future episodes of LBP can be reliably predicted from past episodes (Hoy et al., 2010). Because of that, it is crucial to identify possible risk factors that contribute to LBP.

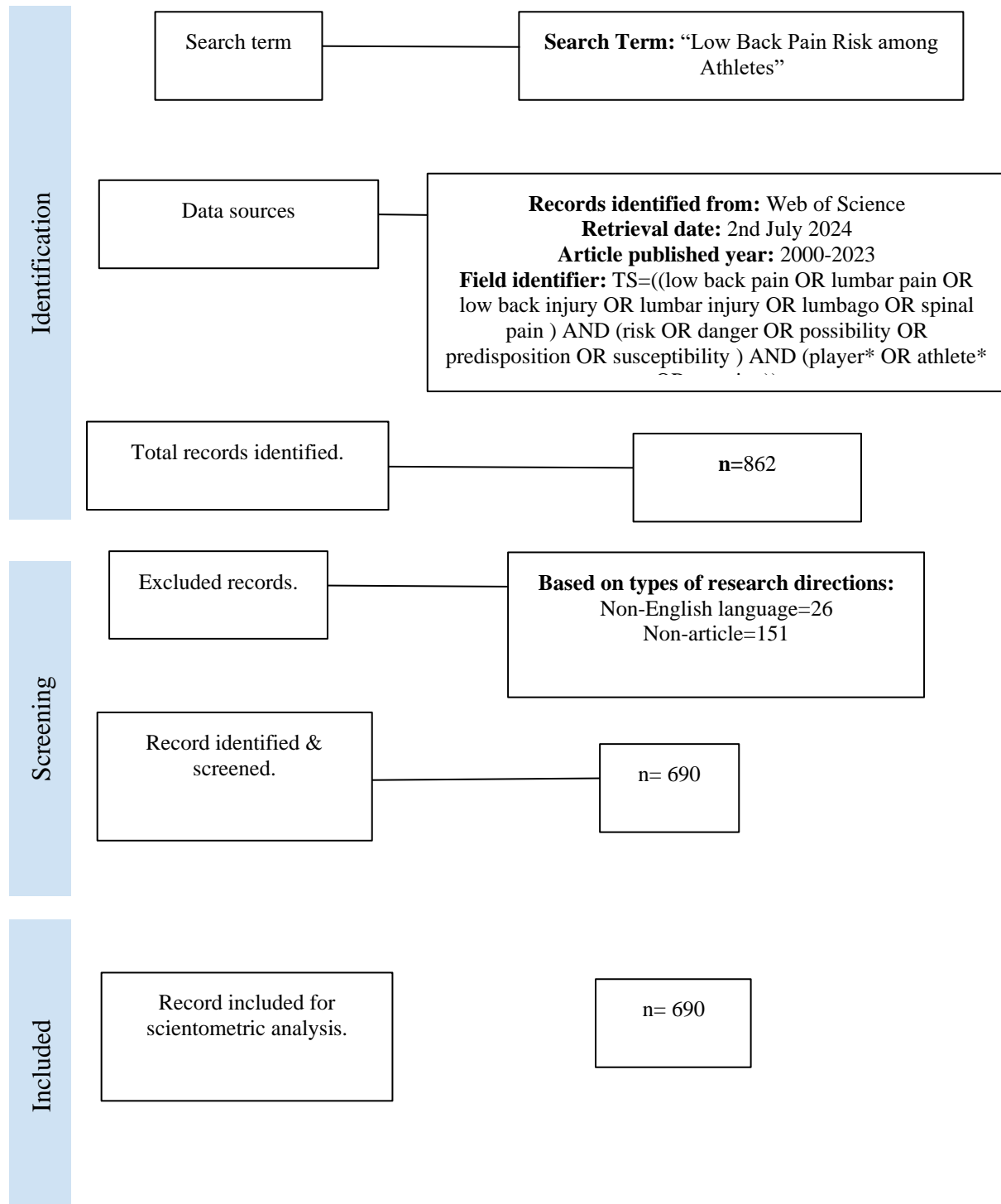
Scientometrics has evolved into a vital instrument for studying and evaluating academics' exploration and growth, their output, and the partnership between institutions and intellectual excellence (Moral-Muñoz et al., 2020). This data assists the scientific society in updating the growth of linked data and education over time, the relationship between numerous fields (particularly targeting low back pain and athlete concerns), and the rational critical point of the specialty (Chen, 2017). Because of the opportunity of big corporate databases such as Web of Science, Scopus and PubMed, as well as visualization and software that

utilized text mining packages (Adriaanse & Rensleigh, 2013; Bar-Ilan, 2008; Martín-Martín et al., 2018; Xu et al., 2021), scientometrics analysis was selected for the suggested research. The scientometrics study's anticipated outcomes can contribute to analytical and accurate results analysis by decreasing human bias (Chen & Leydesdorff, 2014; Chen et al., 2010; Xu et al., 2021). Scientometrics or bibliometric comprehensively synthesizes research growth, collaborations, and knowledge foundations, addressing the critical need for integration in this multifaceted field (Azizan, 2024). Hence, scientometrics is a valuable tool for analyzing data on research topics, advancement in a field, literature production patterns, and the most prolific institutions, countries, and researchers in a certain issue, such as low back pain among athletes (Kokol et al., 2021).

Furthermore, as the growing reputation of low back pain among athletes-relevant publication theme and the potential risk, a scientometrics study that systematic is required to assess imminent patterns as well as ongoing challenges including vital changing points in the focus study aim. It can also help policymakers and academicians discover new changes in difficulties and issues of low back pain risk among athletes, particularly at the worldwide level. Moreover, the findings of this study can inform the development of more effective prevention and management strategies for low back pain in athletes.

Thus, our study's primary goal is to use scientometric analysis to ascertain the global research trends concerning low back pain risk among athletes which can help in identifying potential impact on athlete health, performance, and overall sports participation. In particular, we focused on publication trends, influential authors and affiliations related, countries that actively engaged, and co-citation analysis of references as well as impactful articles and keywords. This will support the development of future funding proposals on these populations, the identification of research needs, and future opportunity prediction. We also hope that our assessment will encourage more researchers to get involved in this valuable low back pain injury prevention in the future, particularly postgraduate students and early career researchers.

## METHODS



**Figure 1.** Methodological framework

### Source of Data

Web of Science (WOS) is the database that has been used for the search. The "topic" (TS) field comprises titles of the articles, keywords, abstracts and "KeyWords Plus" was used for the WOS searches (phrases will be produced based on cited article titles accordingly). According to current

sources, WOS is a prominent largest scientific database with about 34,000 publications with over one billion references that have been cited. All the articles are peer-reviewed as well as indexed publications with good standard journals and contain a wide range of disciplines (Aryadoust & Ang, 2021). Moreover, WOS has been the only

citation database and publication that covers all disciplines of research for many years (Chadegani et al., 2013).

### Article Searching

The associated keywords were identified using online literature from previous studies as well as keywords provided by Web of Sciences. The hunt took place on July 2, 2024. Below is the search string.

TS=((low back pain OR lumbar pain OR low back injury OR lumbar injury OR lumbago OR spinal pain ) AND (risk OR danger OR possibility OR predisposition OR susceptibility ) AND (player\* OR athlete\* OR sporting))

### Eligibility Criteria

#### Inclusion Criteria

Articles found using WOS searches were included in the following analyses only if the publication had been made in English and in peer-reviewed journals. The timeframe was set from 2000-2023.

#### Exclusion Criteria

We rejected studies that were not original study, non-peer-reviewed publication journal and in language other than English. Proceedings reviews, articles, abstracts, book reviews, editorial papers, correspondence, or news may have been included in such studies.

#### Data Analysis

**Table 1.** Analysis of approaches and instruments applied to address research questions

ID	Research Question Focus	Software	Summary of approaches / tools
RQ1	Output trends of publication	Excel	Descriptive Analysis for amount of publications, journal publications, authors, institutions, and region/country
RQ2	Dominant knowledge carriers	CiteSpace	Co-citation Analysis for (Author and Articles) to identify growth status and each variable scientific structure
RQ3	Dominant topic/cluster	CiteSpace	Analysis of Document Cluster to determine the top research cluster in target theme.
RQ4	Impactful keyword and publications	CiteSpace	Burstness metric was utilized to identify the impactful publications and famous keywords.

### Analysis of Scientometric

Citespace enables the building of numerous bibliometric associates and the utilization of numerous ways of analysis (Chen & Leydesdorff, 2014; Chen, 2004). Because of that, CiteSpace was utilized for knowledge graph visualization and analysis. As a result, CiteSpace showed the top 50 most referenced articles and ranked accordingly. "Time Slicing" was fixed at 2000-2023, and "Years per slice" was fixed to one year. The "Pruning" parameter was used to prune the produced network. For text processing, all term sources available were picked, including abstract, title, keywords plus and author keywords.

#### Co-citation Analysis

The position of scientific advancement and development in scientific hierarchy are determined via analysis of co-citation. The analysis of co-citation provides nodes with a scientific map, links, and values of density to depict the overall structure of the variables under consideration.

#### Analysis of Document Cluster

Clustering in multidimensional was utilized to determine research clusters in priority scope based on the papers collected. The log-likelihood

ratio (LLR) was utilized to straightaway take out the label of cluster since it may deliver the best outcome in terms of distinctiveness and coverage. The "timeline view" and "cluster view" of Document Cluster Analysis were utilized to see the network form and shape. The "timeline view" presented a vertical range time periods in chronology, from left to right, and the "cluster view" visualized a landscape-formatted spatial network of color-coded and automatically annotated description (Aryadoust & Ang, 2021; Chen & Leydesdorff 2014; Chen 2004).

To examine the standard and the document cluster analyses homogeneity, the particular clusters, average silhouette meter and the modularity Q index, centrality metric were utilized (Chen & Song, 2019; Chen, Chen, Horowitz, et al., 2009; Chen, Ibekwe-SanJuan, & Hou, 2010). The modularity Q index ranges from 0 to 1, with a higher index suggesting greater dependability. The average silhouette measure with higher values than 0 attributing better uniformity, the range of the value is between -1 and 1. Centrality is an influence measure that proves how close publications or journals are to one another, with high centrality

publication having more reliability on the network due to more publications and journals are connected to them, which allows more data and channels to flow over them.

### Analysis of Burstness

Both sigma and citation burstness, which are temporal measures, were employed to describe prominent articles and top keywords. A red ring surrounding the node indicates burst existence, which is defined as "an abrupt elevation of the frequencies [of citations] over a specific time interval" (Chen & Song, 2019; Chen, Chen, Horowitz, et al., 2009; Chen, Ibekwe-SanJuan, & Hou, 2010). High-value research articles have the greatest sigma value. The total of the centrality and burstness values is known as sigma, which vary

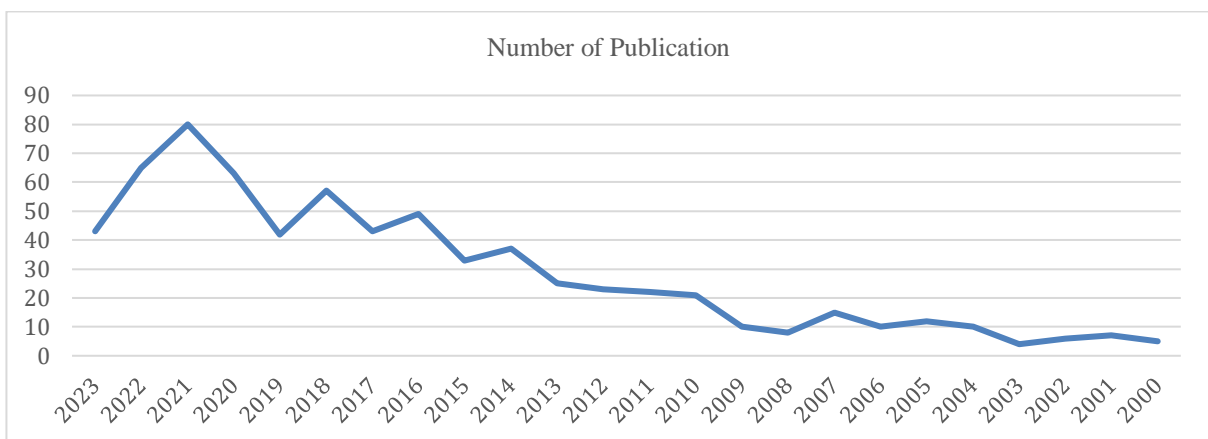
from 0 to 1 (Chen & Song, 2019; Chen, Chen, Horowitz, et al., 2009; Chen, Ibekwe-SanJuan, & Hou, 2010).

## RESULTS

### Descriptive Statistics

#### Publication Evolution

Only scientific articles published between 2000 and 2023 were included in the study (Fig. 2). A total of 690 articles were gathered throughout this period. There is an inconsistent publication trend in terms of publication numbers, but still, we can observe quite an obvious increasing trend from 2000 until 2023 and a significant decreasing trend from 2021 to 2023.

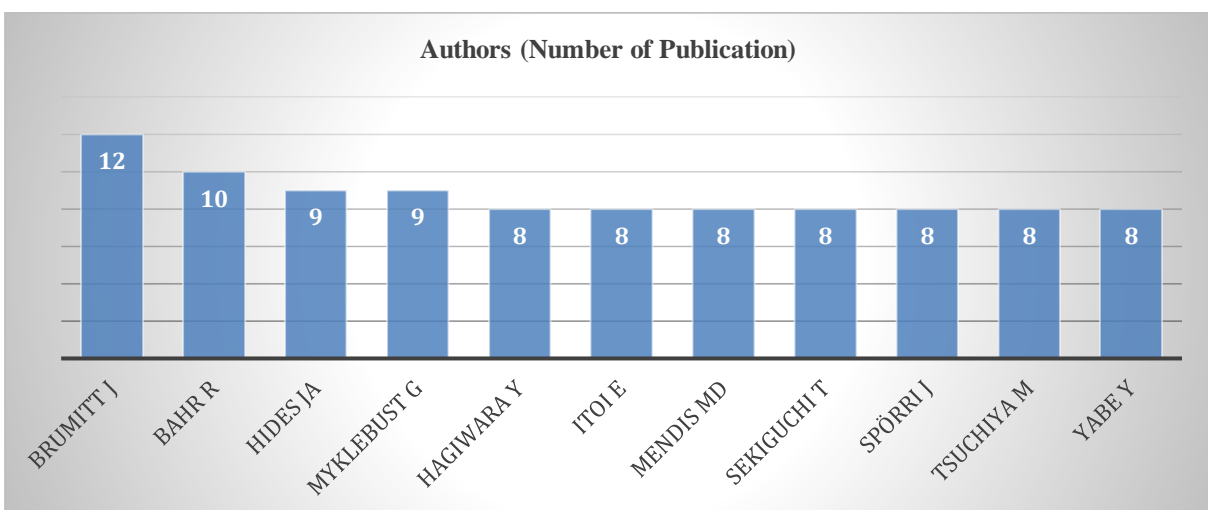


**Figure 2.** Number of articles published since 2000

### Productive Authors

There is a total of 96 publications regarding low back pain risk among athletes by top eleven

authors since 2000. (Fig. 3). Brumitt J had the most publications (12), followed by Bahr R (10) and Hides JA (9).

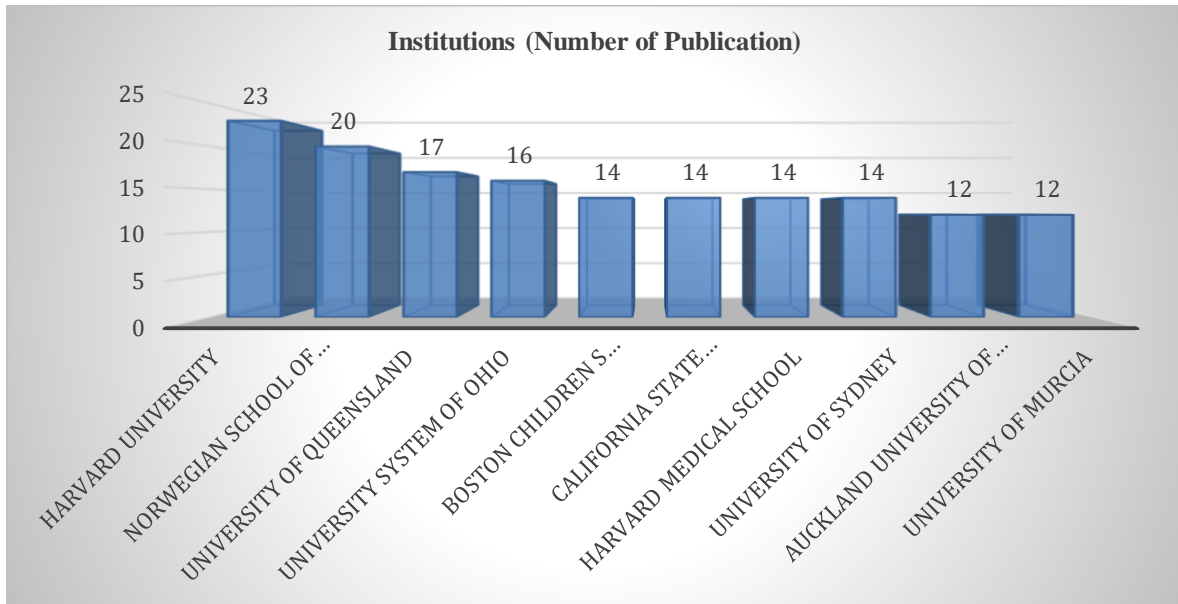


**Figure 3.** Top 11 most productive authors (2000-2023)

**Best Universities**

Fig. 4 shows the top 10 universities in terms of the overall number of publications. Harvard University was the highest publisher, with 23 publications, followed by the Norwegian School of

Sport Science (20), and last but not least University of Queensland (17). In a nutshell, there are a total of 156 publications by the top ten institutions between 2000 to 2023.

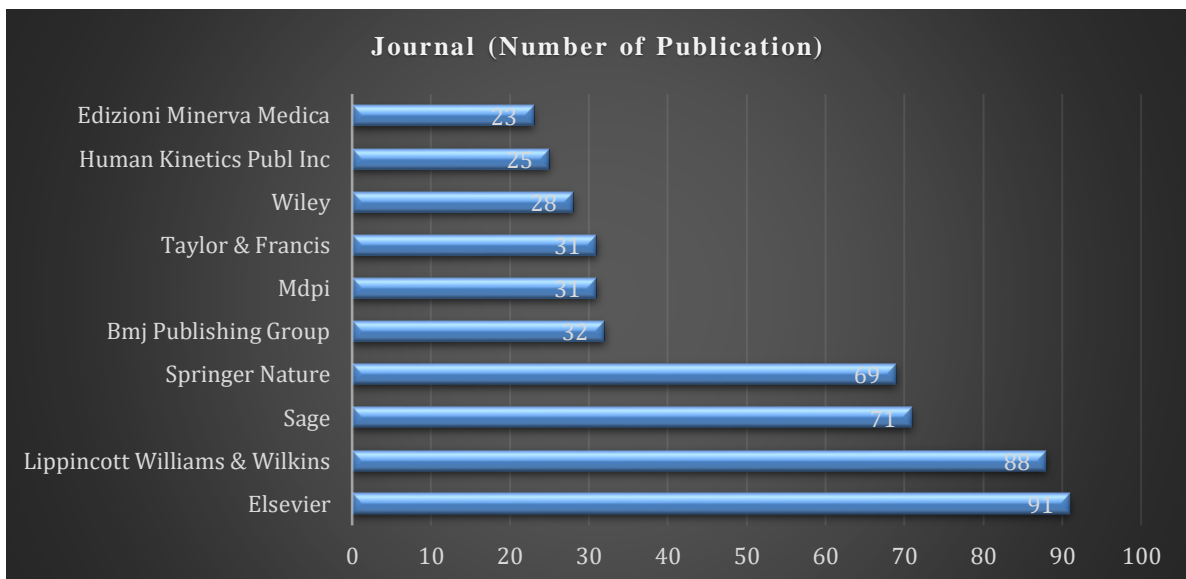


**Figure 4.** Top ten number of publications (institutions)

**Productive Journals**

The top ten journal publications number are visualized in Fig. 5. Elsevier published the highest (91), followed by Lippincott Williams & Wilkins

(88) and Sage (71). Between 2000 and 2023, the top ten journals contribute 70.87% of total number of publications.

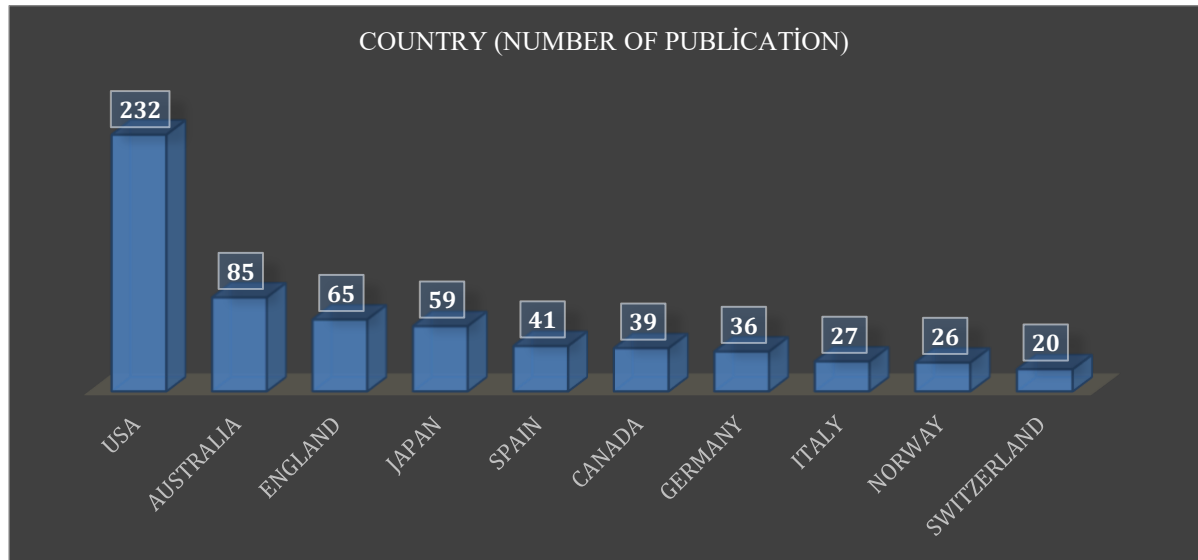


**Figure 5.** Total publications number (2000-2023) from the top ten journal

**Distribution of Region**

Fig. 6 lists the ten countries with the highest publication numbers. 25 countries had publications with the top ten countries contributing to 91.304%

of total publications. The United States of America had the highest number of publications (232), followed by Australia (85), and England (65).



**Figure 6.** Number of publications (2000-2023) from the top ten country/region

### Scientometric Analysis

#### Co-Citation Analysis

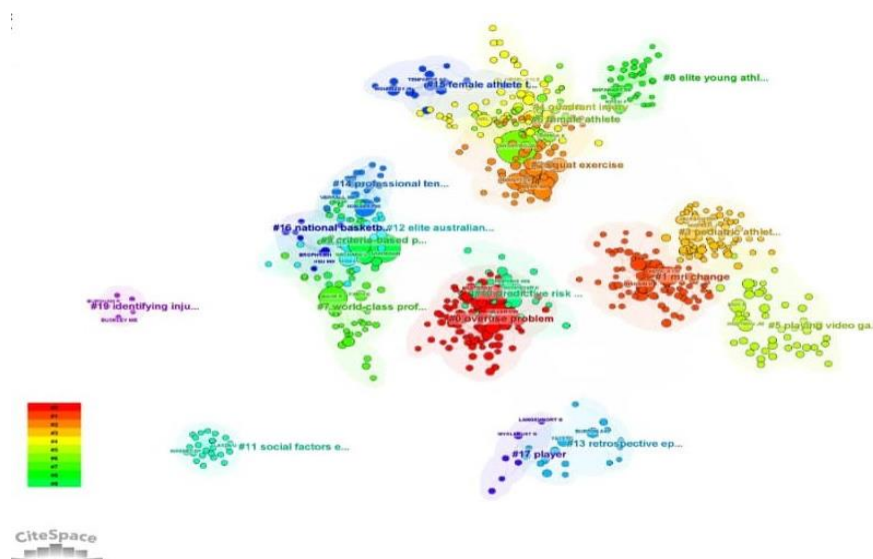
Co-citation analysis creates a scientific map that shows the evolution of a variable's fundamental structure over time, complete with nodes, linkages, and value of density. Below are the findings of the analysis of co-citation for the author and the document.

#### Author Co-citation Analysis

The author co-citation network included 2970 connections and 787 nodes. The density of the co-citation network is 0.0096. Three factors are utilized to decide which author is the most influential: degree, centrality, and sigma in that order. A higher degree indicates more citations. Degree parameters show how many citations that particular author obtains from others for the same

works. Centrality parameters evaluate how many times an author is positioned "between" two or more authors. The highest "betweenness centrality" author has the most impact on the focus areas. A sigma number higher than 1 indicates that the author is in the center of the focus area. The sigma value is a mixture of the degree and centrality characteristics.

Table 2 shows the top ten most popular authors from 2000 to 2023. The most influential author is Jackson DW (Degree: 47; Centrality: 0.08, Sigma: 1.57), followed by Hwett TE (Degree: 39; Centrality: 0.08, Sigma: 1.48) and third place Clarsen B (Degree: 19; Centrality: 0.07, Sigma: 1.46). Besides that, Fig. 7 shows the author network co-citation.



**Figure 7.** Authors Co-citation network

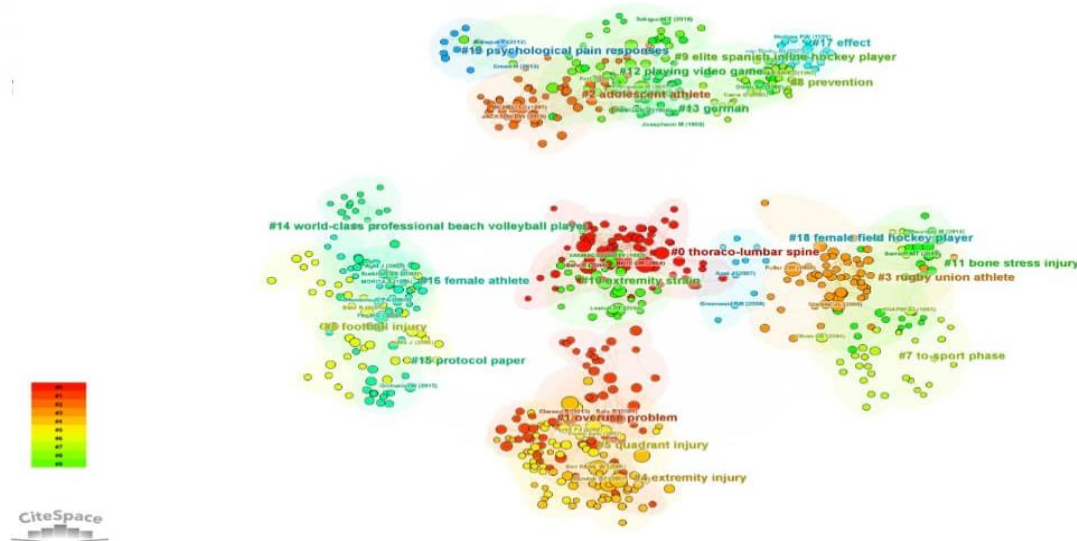
**Table 2.** Influential authors

Author	Degree	Centrality	Sigma
JACKSON DW	47	0.08	1.57
HEWETT TE	39	0.08	1.48
CLARSEN B	19	0.07	1.46
HOY D	20	0.04	1.18
TAIMELA S	17	0.03	1.18
CROISIER JL	25	0.04	1.16
BIERINGSORENSEN F	20	0.04	1.16
HUTCHINSON MR	26	0.03	1.15
HOPKINS WG	20	0.03	1.13
BRUMITT J	14	0.02	1.12

### Document Citation Analysis

The document co-citation network included 2756 connections and 876 nodes. The density of the co-citation network is 0.0072. Table 3 shows the top ten most influential papers from 2000 to 2023. The most influential paper is Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a

prospective study (Degree: 41; Centrality: 0.18, Sigma: 18), followed by Delayed Trunk Muscle Reflex Responses Increase the Risk of Low Back Injuries ( Degree: 24; Centrality: 0.18, Sigma: 1.72) and third place Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries (Degree: 15; Centrality: 0.07, Sigma: 1.34). Furthermore, Fig. 8 shows the document network co-citation.



**Figure 8.** Document Co-citation network

### Document Cluster Analysis

The Modularity Q Index and Mean Silhouette measures of the Document Cluster Analysis were 0.8364 and 0.9209, respectively, showing that homogeneity is above-average and network dependability. The investigation produced a total of 24 co-citation clusters. The clusters were grouped and numbered according to size, with the largest cluster being cluster #0. A yellow line indicates the duration of each cluster. Using CiteSpace software's text mining and keyword analysis technique, the cluster labels were calculated. In order to name

these clusters, the loglikelihood ratio (LLR) was utilized.

The four largest clusters identified by Document Cluster analysis are displayed in Table 4. The number of articles in the cluster is determined by its size. Cluster #0 shows the highest number of publications (70). The publications within each cluster had a significant degree of similarity, as indicated by the cluster silhouette scores ranging from 0.768 to 0.943 (a number higher than 0 implies homogeneous).



**Table 3.** Document co-citation score

Title	Source	Year	Degree	Centrality	Sigma
Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes	AM J SPORT MED	2005	41	0.18	1.8
Delayed Trunk Muscle Reflex Responses Increase the Risk of Low Back Injuries	SPINE	2005	24	0.18	1.72
Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries	BRIT J SPORT MED	2006	15	0.07	1.34
Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players	AM J SPORT MED	2008	17	0.06	1.3
A Prospective Study Low Back Pain Among Endurance Athletes With and Without Specific Back Loading—A Cross-Sectional Survey of Cross-Country Skiers, Rowers, Orienteers, and Nonathletic Controls	SPINE	2004	18	0.08	1.29
Risk factors for sports injuries—a methodological approach	BRIT J SPORT MED	2003	18	0.05	1.19
Dynamic Balance Performance and Noncontact Lower Extremity Injury in College Football Players: An Initial Study	SPORTS HEALTH	2013	26	0.05	1.17
The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability, and spinal pathology among men	SPINE	1995	15	0.04	1.16
Deficits in Neuromuscular Control of the Trunk Predict Knee Injury Risk	AM J SPORT MED	2007	14	0.03	1.14
A Prospective Biomechanical-Epidemiologic Study Can serious injury in professional football be predicted by a preseason functional movement screen?	N AM J SPORTS PHYS THER	2007	22	0.03	1.12

**Table 4.** Research Cluster

ClusterID	Size	Silhouette	Label (LLR)	Average Year
0	70	0.768	thoraco-lumbar spine	2004
1	61	0.824	overuse problem	2010
2	56	0.943	adolescent athlete	1996
3	53	0.914	rugby union athlete	2006

**Burst Analysis**

To find the most popular or impactful papers as well as keywords, we used a burst analysis. The

trends between studies and keywords are shown here.

**Document Burst****Table 5.** Top ten key articles with the highest citation burst

Title	Journal	Year	StrenBegin gth	End	2000-2023
The Long-Term Effects of Physical Loading and Exercise Lifestyles on Back-Related Symptoms, Disability, and Spinal Pathology Among Men	Spine	1995	3.83	<b>2006</b>	2012
Back Pain in Young Athletes: Significant Differences From Adults in Causes and Patterns	Archives of pediatrics & adolescent medicine	1995	3.63	<b>2006</b>	2014
Spondylolysis in the Female Gymnast.	Clinical Orthopaedics and Related Research	1976	3.59	<b>2006</b>	2013
Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes	The American journal of sports medicine	1991	3.35	<b>2006</b>	2012
Delayed trunk muscle reflex responses increase the risk of low back injuries	Spine	2005	3.3	<b>2007</b>	2017
MRI study of the size, symmetry and function of the trunk muscles among elite cricketers with and without low back pain	British journal of sports medicine	2008	4.09	<b>2010</b>	2011
Deficits in Neuromuscular Control of the Trunk Predict Knee Injury Risk: Prospective Biomechanical-Epidemiologic Study	The American journal of sports medicine	2007	4.52	<b>2012</b>	2018
Core Stability Measures as Risk Factors for Lower Extremity Injury in Athletes	Medicine & Science in Sports & Exercise	2004	3.55	<b>2012</b>	2018
Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study	The American journal of sports medicine	2005	3.53	<b>2012</b>	2015
Can serious injury in professional football be predicted by a preseason functional movement screen?	North American journal of sports physical therapy: NAJSPT	2007	3.73	<b>2013</b>	2020

### Document Burst

The highest citation burst from top ten articles with are depicted in Table 5. The highest burst article is The Long-Term Effects of Physical Loading and Exercise Lifestyles on Back-Related Symptoms, Disability, and Spinal Pathology Among Men from Spine (strength: 3.83) that begin from 2006 and end in 2012. The lowest burst article is Can serious injury in professional football be predicted by a preseason functional movement

### Document Burst

**Table 6.** Top ten popular keywords with the highest citation burst

Keywords	Strength	Begin	End	2000-2023
Spondylolisthesis	3.79	2000	2006	
Spondylolysis	4.41	2002	2006	
Follow-up	3.89	2005	2011	
Cross sectional area	3.55	2007	2011	
Fast bowlers	3.28	2010	2016	
Motion	5.3	2012	2015	
Kinematics	5.31	2013	2015	
Professional football	4.35	2014	2018	
Physical activity	3.84	2016	2019	
Sport	3.64	2017	2020	

## DISCUSSION

A descriptive analysis was carried out on the publication numbers, published journals, authors, universities, and countries where authors were connected at the time the articles were published to address the publication output trends research question. In terms of number of publications, there is an increasing trend from 2000 until 2021 with the highest number in 2021 with 80 publications. However, there is a subsequent decline from 2021 to 2023 due to potential shifts in research focus, changes in funding priorities, or the emergence of new research areas. There is a total of 96 publications regarding low back pain risk among athletes have been published by the top eleven authors since 2000. In terms of authors, Brumitt J had the most publications (12), followed by Bahr R (10) and Hides JA (9). For institutions, there are 156 publications by the top ten institutions between 2000 to 2023 with Harvard University achieving the highest publisher, with 23 publications. Dr. Jason Brumitt graduated with a Bachelor of Science in Business Administration from Southern Oregon State College, a Master of Science in Physical Therapy from Pacific University, and a PhD in

screen? From North American journal of sports physical therapy (strength: 3.73) that begin during 2013 and end in 2020.

Top ten keywords with the strongest citation burst are shown in Table 6. The highest burst keyword is spondylolisthesis (strength: 3.79) that begin from 2000 and end in 2006. The lowest burst article is sport (strength: 3.64) that begin during 2017 and end in 2020.

Orthopedic and Sports Science from Rocky Mountain University of Health Professions. Although orthopedic and sports physical therapy constitute his clinical expertise, he has also rendered therapy services in acute and skilled nursing settings. Dr. Brumitt is the author of several textbooks, textbook chapters, and numerous research publications in sport physiotherapy.

In the meantime, between 2000 and 2023, the top ten journals contribute 70.87% of total number of publications, with Elsevier publishing the highest (91). In terms of country, the highest number of publications is United States of America (232). Although affluent nations and prestigious universities may have had greater resources available to carry out scientific assessments, we are advocating for more global scientific research collaboration and exchanges be carried out in the future.

To answer the dominant knowledge carriers research question, a co-citation analysis of the author and articles was done. Douglas W. Jackson, M.D is the most influential author. He is an orthopedic surgery specialist in Long Beach, CA with over 57 years of medical experience. He is also part of the research team at Noyes-Giannestra

Biomechanics Laboratory, University of Cincinnati, Cincinnati, Ohio. The second most influential author is Timothy Hewett, Ph.D. He is a Professor and Director of Research in the Department of Orthopaedic Surgery at Marshall University's School of Medicine. Dr. Hewett is described as a "pioneering researcher, expert team builder, and collaborative leader" on the plaque he received when Mayo Clinic awarded him an Endowed Professorship. He has held numerous leadership posts, including Director of the Sports Medicine Research Center, Biomechanics Laboratories, and the Biomechanics Institute. The third place goes to Ben Clarsen. Ben Clarsen works as a physiotherapist at the Norwegian Olympic Training Centre (Olympiatoppen) and as a postdoctoral research fellow at the Oslo Sports Trauma Research Center at the Norwegian School of Sports Sciences. He served as senior editor for the textbook Brukner and Khan's Clinical Sports Medicine, Fifth Edition, and has experience working as a team physiotherapist for a number of major cycling teams. His research interests are sport and overuse injury prevention.

Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study article from The American Journal of Sports Medicine is the most influential article. This study became popular at that time due to it was proven that motion of knee and knee loading during a landing task are one of the predictors of injury risk in female athletes as well as kinetic chain association between lumbo-pelvic-hip (LPH) complex with knee and lower limb complex. The second highest article with co-citation score is the Delayed Trunk Muscle Reflex Responses Increase the Risk of Low Back Injuries from Spine. It has become one of the most popular articles due to the outcome of this study indicating that the delayed muscle reflex reaction considerably increases the likelihood of suffering a low back injury. These delayed latencies appear to represent a preexisting risk factor rather than the result of a low back injury which can be one of the risk factors for low back pain. The third most popular article is Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries from BJSM. It's become popular due to the paper was discussing the definitions of injury, recurring injury, severity, training and match exposures in football, as well as criteria for

determining injuries in terms of location, nature, diagnosis and etiology, which include low back area.

To answer the fourth research question which is the dominant cluster, document cluster analysis was performed. Its revealed 24 clusters and the top four clusters are shown above. Publications were grouped together because the same publications group mentioned them, proving a co-citation connections. According to our findings, "thoracolumbar spine," "overuse problem," and "adolescent athlete" were the most preferred research subjects and directions. This indicates that most of the research prioritizes on spinal issues with risk of low back pain and proves that thoracolumbar becomes the main topic when research is done related to risk of low back pain. Hence, future researchers need to incorporate subjects with spinal issue in order to determine risk of low back pain among athletes.

Document burst analysis was done to answer the fifth research question which is impactful keywords. The top ten strongest are revealed above. The burst analysis of documents indicated a design of a new research area arising, with earlier burst publications slowly being displaced by the latest ones. Spondylolisthesis was the strongest keyword that started from 2000 and end in 2006, followed by spondylosis (start:2002; end: 2006) and third place keyword is follow-up (start: 2005; end: 2011). This proves that spinal condition always becomes the main topic when studies have been done for risk of low back pain among athletes. Starting 2014, new pattern on research topics appears with the topics more related to sports and physical activity being used. The shift indicates that previous study focuses more on spinal conditions as risk for low back pain and current research focuses more on the relationship between sports activity and risk of low back pain. The result is not the same as the document co-citation result. The gap between the co-citation and burst scores emphasizes the necessity of broadening the scope of the study as new findings are discovered. This will require more funding or a different strategy to guarantee that a significant amount of scientific innovation research is published in this area.

### **Conclusions**

We may have introduced publication bias into our analysis by using Web of Science (WOS) databases articles only. Another possible restriction is that using CiteSpace software instead of manually collecting data may have led to the

inclusion of some unimportant subjects, hence biasing the dataset. Upcoming research with a reliable accuracy target must utilize more rigid keyword searches to limit the possibility of inappropriate studies.

Furthermore, the names of the principal authors are the only ones mentioned in the co-citation analyses in this study. Regardless of the fact that there was no such restriction on citing articles, the databases of cited papers that WoS provided did not contain the identities of other contributing authors. In spite of these limitations, this analysis provides a complete assessment of current studies on athletes with low back pain risk. We are advocating the necessity for more collaboration globally, as addressing the risk of low back pain is crucial to the research agenda in the long term.

With the world still trying to figure out what causes low back pain in athletes, athletes are still suffering from low back pain and damage. We gathered related research from several fields, as well as a determined major gap in the research and goals of the future. Future researchers can benefit from this study by referring to the influential authors, popular keywords, and top articles. Our research outcome indicates that a considerable gap still exists that demands deeper investigation and collaboration. Coaches, trainers, and healthcare providers working with athletes also will have clear direction to construct preventative and therapeutic strategies for managing LBP in athletes. Last but not least, the present study may have been inadequate due to only the English language being used and the choice of journals without considering grey literature.

### **Conflict of Interest**

The authors declare that they have no competing interests.

### **Availability of Data and Materials**

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

### **Author Contributions**

Conceptualization, Methodology, Writing - Original Draft, Funding acquisition, MAH; Software, Formal analysis, Writing - Original Draft, Investigation, SAB; Validation, Formal analysis, Writing - Review & Editing, Investigation, MIMN; Validation, Writing - Review & Editing, Investigation, NAMN; Data Curation, Writing - Review & Editing, Funding acquisition, Project

administration, UMMA; Validation, Writing - Review & Editing, Investigation, HM. All authors have read and agreed to the published version of the manuscript.

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