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Global Research Trends in Spinal Biomechanics: A Bibliometric and Visual Analysis

Wen Ji[1], Wu Tao[1], Gao Yuhao[1], Liu Hualv[1], Han Pengfei[2], Xu Yunfeng[3]

[1]Graduate School of Changzhi Medical College, Changzhi, Shanxi, 046000, China
[2]Affiliated Heping Hospital of Changzhi Medical College, Changzhi, Shanxi, 046000, China
[3]Changzhi Yunfeng Hospital, Changzhi, Shanxi, 046000, China

Abstract: *Research in Spinal Biomechanics has gained increasing attention. This study aims to investigate the current status and trends in this field globally. Publications on Spinal Biomechanics from January 1, 2005, to November 1, 2024, were retrieved from the Web of Science - Science Citation Index Expanded. Bibliometric methods were used to analyze the source data, and VOSviewer version 1.6.19 software was employed for co-authorship, co-occurrence, bibliographic coupling, and co-citation analyses. The overall trends in Spinal Biomechanics research in recent years were also analyzed. A total of 3,812 articles were identified. The number of global research and publications on Spinal Biomechanics has increased annually. The United States contributes the most to global research in this field, with the highest number of citations and the highest h-index. The Journal of Biomechanics and Clinical Biomechanics have the highest publication rates. The University of British Columbia, the University of Montreal, the University of Pittsburgh, and St. Joseph's Hospital are the top four contributing institutions. Research can be classified into four categories: sports biomechanics, tissue engineering, clinical research, and mechanism research. Clinical research is predicted to be the next hot topic in this field. Based on current global research trends, the number of publications related to Spinal Biomechanics is expected to continue increasing. The United States is currently the largest contributor to research in this field. Most research efforts will focus on clinical studies of Spinal Biomechanics, which may be the next hotspot in this research area.*

Keywords: *Spinal Biomechanics; Global trends; Bibliometrics; Visual analysis*

1. Introduction

Spinal Biomechanics, an important branch of biomechanics[1], focuses on applying physical and mechanical principles to study the biological characteristics and mechanical laws of the spine and its accessory structures[2]. The spine, as the central axis of the human body[3], not only supports body weight but also protects the spinal cord and nerve roots[4]. Its complex structure and function make research in this field particularly important[5].

Significant progress has been made in Spinal Biomechanics research[6]. Researchers have delved into the mechanical behavior of the spine under different conditions using advanced experimental techniques and computational models. The finite element analysis method, as a crucial research tool, has been widely used in Spinal Biomechanics research[7]. This method can simulate complex biomechanical environments, reveal the stress distribution and deformation of the spine and surrounding tissues, and provide important theoretical basis for the prevention and treatment of spine-related diseases[8]. Moreover, with the development of imaging and computer technology, Spinal Biomechanics research has gradually achieved the transition from two-dimensional to three-dimensional[9], making the research results more accurate and reliable. In the future, Spinal Biomechanics research will pay more attention to interdisciplinary collaboration and integration[10]. As our understanding of the structure and function of the spine deepens, researchers will focus more on the mechanical changes of the spine under different physiological and pathological states and their impact on the occurrence and development of spine-related diseases[11]. Meanwhile, with the rapid development of fields such as biomaterials, tissue engineering, and regenerative medicine, Spinal Biomechanics research will gradually expand into areas such as spinal repair and reconstruction, providing more effective means for the treatment of spine-related diseases[12].

However, the global development trends of Spinal Biomechanics have not been fully studied[6]. Therefore, it is necessary to summarize the current status of Spinal Biomechanics research and predict promising keywords and trend directions. Publications, as the core of scientific research[13], are important

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indicators for measuring research contributions. Bibliometric analysis can provide information based on literature databases and bibliometric characteristics for qualitative and quantitative assessment of research activities over time[10]. It provides a way to grasp the development of a field and compare the contributions of scholars, journals, institutions, and countries. Bibliometric analysis has also been used in the development of policies and clinical practice guidelines. In addition, this feasible method has been successfully used to assess research trends in osteoarthritis, hypertension, diabetes, and injuries. To the best of our knowledge, the quantity and quality of research in the field of Spinal Biomechanics have not been reported. Therefore, the purpose of this study is to evaluate the current status and global trends of Spinal Biomechanics research.

2. Materials and Methods

2.1 Data Source

Bibliometric analysis of the data source was based on the Web of Science - Science Citation Index Expanded (WOS), which is considered the best database for bibliometrics.

2.2 Search Strategy

In this study, the search terms were as follows: Topic = (Spinal Biomechanics) and Publication Year = (2005-01-01—2024-11-01) and Language = (English) and Document Type = (Article).

2.3 Data Collection

Complete detailed information (including title, publication year, author name, country, publication journal name, affiliation, keywords, and abstract) was obtained and analyzed from the WOS database and uploaded to Microsoft Office Excel 2016. Two authors (WJ and LJY) independently filtered, extracted, input, and collected the data. The data in Microsoft Office Excel 2016 and GraphPad Prism 9 were manually cleaned and analyzed.

2.4 Bibliometric Analysis

Bibliometric analysis has become an important tool for global analysis and investigation in various scientific fields, using mathematical and statistical methods to analyze a large number of documents or research trends. The functions of WOS have been used to describe the basic characteristics of the above-qualified articles. The h-index, as an alternative to existing metrics, is the best method to quantify the impact of scientific research. The h-index indicates that a scientist or country has published h articles, and other publications have been cited at least h times. The logistic growth model: $f(x) = a/(1+eb-cx)$ has stable applicability and the ability to predict future trends. The chart of the number of publications over time was created using GraphPad Prism 9. The independent variable x represents the year, and the dependent variable f(x) represents the total number of publications. Annual publication numbers, the top 20 countries globally, authors, institutions, funding agencies, research directions, total citation frequency, journals, average citation frequency, and h-index were examined using Microsoft Office Excel 2016. For the visual analysis of publications, VOSviewer software (VOS) was used, which has been used for bibliographic coupling, co-citation analysis, co-occurrence analysis, and co-authorship analysis in the past.

3. Results

3.1 Global Publication Trends

3.1.1 Total Number of Global Publications

A total of 3,812 articles met the search criteria from January 1, 2005, to November 1, 2024. Most of the studies were published between 2016 and 2022 (773 items, 41.49%), and the annual publication volume was examined. From 2005 to 2024, a significant trend can be seen in the increasing number of global publications each year. In addition, in the past few years, there has been an upward trend in the relative research interest in this field (Figure 1a).

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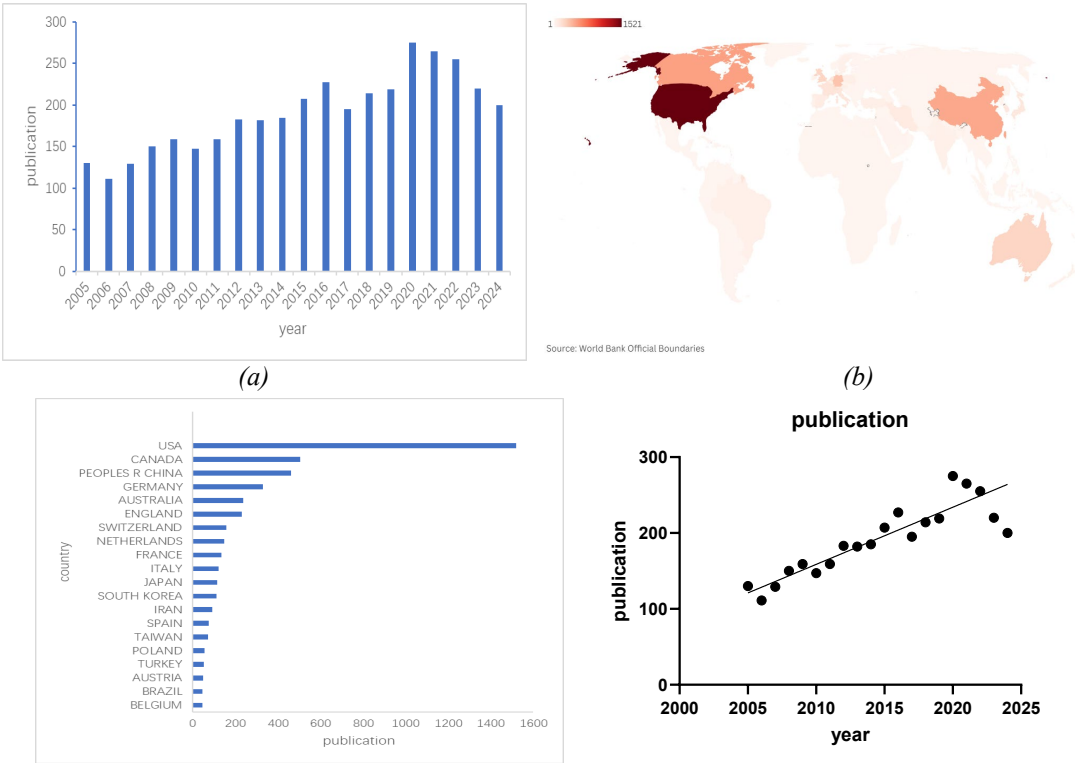
3.1.2 Contributions by Countries

A total of 85 countries and regions have contributed to this field. Among these countries, the United States published the most relevant articles (1,734, 39.195%), followed by Canada (578, 13.065%), China (511, 11.573%), Germany (392, 8.861), and Australia (273, 6.171%) (Figure 1b, c).

3.1.3 Global Publication Trends

The global publication trends were created using a logistic regression model to predict future trends. Figure 1c shows the fitted curve of the growth trend model for the number of global publications in the coming years(Figure 1d)..



(a) *(b)*

(c) *(d)*

(a) Total number of publications on spinal biomechanics and related research interests (b) World distribution map on spinal biomechanics and related research (c) Total number of spinal biomechanics-related publications in the top 20 countries (d) A fitting graph of projected growth trends in the number of global publications in the coming years

Figure 1: Global publications on spinal biomechanics and related research Physical tendency

3.2 Publication Quality by Country

3.2.1 Total Citation Frequency

The United States had the highest total citation frequency (24,471) for its publications. Canada ranked second in total citation frequency (7,312), followed by Germany (5,497), Australia (5,065), and China (5,002) (Figure 2a).

3.2.2 Average Citation Frequency

The Netherlands had the highest average citation frequency (27.75) for its publications. Australia ranked second in average citation frequency (25.17), followed by Germany (23.28), South Korea (23.86), and the United States (23.55) (Figure 2b).

3.2.3 h-index

The United States had the highest h-index (81), followed by Canada (49), Germany (48), Australia (40), and England (38) (Figure 2c).

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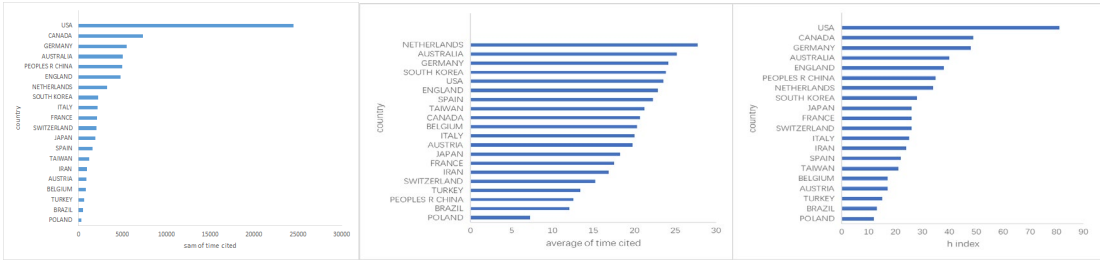


(a) *(b)* *(c)*

(a) Total citation frequency of national publications on spinal biomechanics and related research (b) Average citation frequency of national publications on spinal biomechanics and related research (c) H-Index of national publications on spinal biomechanics and related

Figure 2: Quality of publications in different countries

3.3 Global Publication Assessment

3.3.1 Journal Analysis

The top journal for publishing Spinal Biomechanics research is the Journal of Biomechanics (Impact Factor [IF] =2.5), with 490 articles published. Clinical Biomechanics had 339 articles (IF =1.8), Spine had 275 articles (IF =3.2), and the European Spine Journal had 140 articles (IF =3.1) related to Spinal Biomechanics research. The top 20 journals with the most published research are shown in Figure 3a.

3.3.2 Funding Sources

Figure 3b describes the top 20 funding sources. The U.S. Department of Health and Human Services supported 339 studies (ranked first), while the National Institutes of Health supported 301 studies (ranked second).

3.3.3 Authors

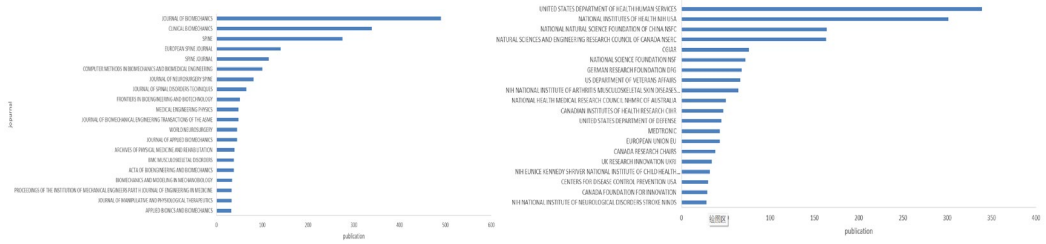
The top 20 authors published a total of 709 articles, accounting for 19.31% of all publications in the field (Figure 3c). Wilke, Hans-Joachim published 65 articles on Spinal Biomechanics, followed by Schmidt, Hendrik with 48 articles, and Arjmand, Navid and Crawford, Neil R. with 48 and 47 articles, respectively.

3.3.4 Publishing Institutions

The top 20 research institutions published a total of 1,719 articles, accounting for 45.09% of all articles in the field (Figure 3D). The Université de Montréal and the University of California System published 163 and 114 articles, respectively.

3.3.5 Research Directions

The distribution of research directions related to Spinal Biomechanics is shown in Figure 3e. Engineering, Orthopedics, Neurosciences Neurology, Biophysics, and Sports Sciences are the most popular research areas.



(a) *(b)*

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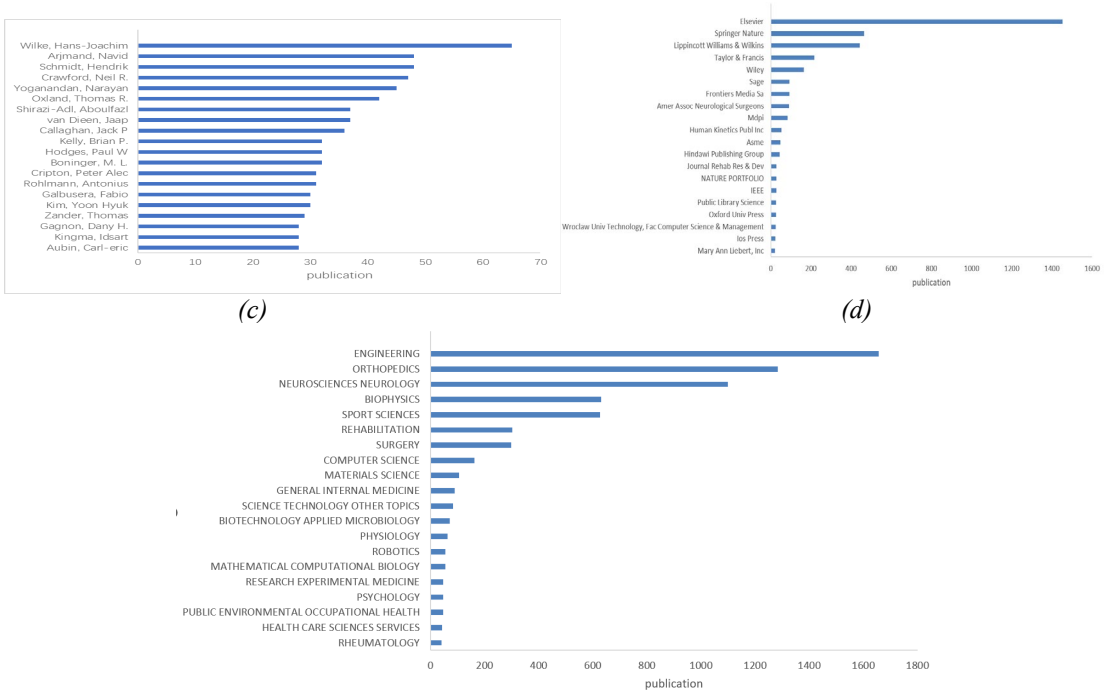

(a) Number of articles on spinal biomechanics-related research published in the top 20 journals (b) Number of articles on spinal biomechanics-related research published by the top 20 funding sources (c) Number of articles on spinal biomechanics-related research published by the top 20 authors (d) Number of articles on spinal biomechanics-related research published by the top 20 publishing institutions (e) Number of articles on spinal biomechanics-related research published by the top 20 publications Research directions related to column biomechanics

Figure 3: Evaluation of global publications on spinal biomechanics

3.4 Bibliographic Coupling Analysis

3.4.1 Journals

VOSviewer was used to analyze the journal names in all articles (defined as the minimum number of articles used more than 5 times) (Figure 4a). A total of 112 identified journals appeared in the total link strength. The top five journals with the highest total link strength are as follows: Journal of Biomechanics (total link strength = 13,304 times), Clinical Biomechanics (total link strength = 8,655 times), Spine (total link strength = 5,048 times), Spine Journal (total link strength = 3,0701 times), and Computer Methods in Biomechanics and Biomedical Engineering (total link strength = 2,836 times).

3.4.2 Countries

VOSviewer was used to analyze articles from 29 countries (defined as the minimum number of articles used more than 5 times) (Figure 4b). The top five countries with the highest total link strength are as follows: the United States (total link strength = 43,333 times), Canada (total link strength = 33,886 times), Germany (total link strength = 15,427 times), China (total link strength = 13,048 times), and Australia (total link strength = 10,248 times).

3.4.3 Institutions

VOSviewer was used to analyze articles from 100 institutions (defined as the minimum number of articles used more than 5 times) (Figure 4c). The top five institutions with the highest total link strength are as follows: Univ British Columbia (total link strength = 9,754 times), Sharif Univ Technol (total link strength = 6,097 times), Ecole Polytech (total link strength = 5,854 times), Univ Montreal (total link strength = 5,323 times), and Univ Pittsburgh (total link strength = 4,481 times).

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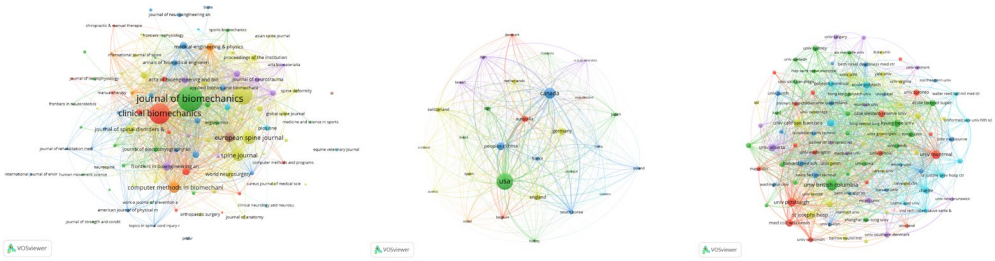


(a) *(b)* *(c)*

(a) Network of 59 journals on spinal biomechanics-related research (b) Network of 22 countries on spinal biomechanics-related research (c) Network of 181 institutions on spinal biomechanics-related research

Figure 4: Bibliographic coupled analysis on spinal biomechanics research

3.5 Co-Authorship Analysis

3.5.1 Authors

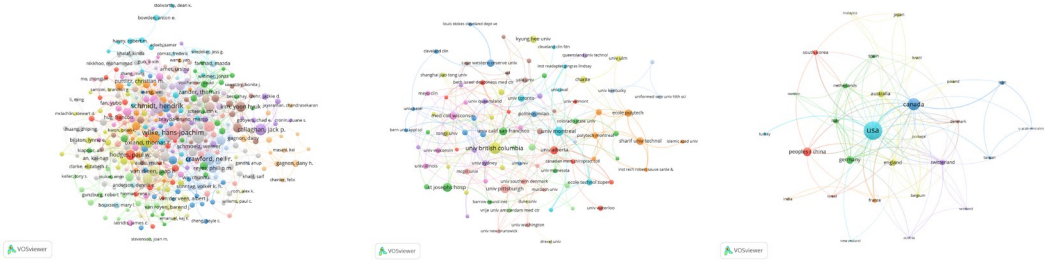
Co-authorship analysis indicates that the relevance of a project depends on the number of co-authored papers; VOSviewer was used to analyze 455 authors (defined as the minimum number of articles used more than 5 times) (Figure 5a). The top five authors with the highest total link strength are as follows: Kelly, Brian P. (total link strength = 139 times), Crawford, Neil R. (total link strength = 131 times), Schmidt, Hendrik (total link strength = 122 times), Yoganandan, Narayan (total link strength = 113 times), and Wike, Hans-Joachim (total link strength = 112 times).

3.5.2 Institutions

VOSviewer was used to analyze research from 100 institutions (defined as the minimum number of articles used more than 5 times) (Figure 5b). The top five institutions with the highest total link strength are as follows: Univ Montreal (total link strength = 36 times), Univ British Columbia (total link strength = 28 times), Ecole Polytech (total link strength = 23 times), Macquarie Univ (total link strength = 21 times), and Med Coll Wisconsin (total link strength = 21 times).

3.5.3 Countries

VOSviewer was used to analyze publications from 29 countries (defined as the minimum number of articles used more than 5 times) (Figure 5c). The top five countries with the highest total link strength are as follows: the United States (total link strength = 152 times), Canada (total link strength = 112 times), Australia (total link strength = 58 times), Germany (total link strength = 47 times), and the United Kingdom (total link strength = 43 times).



(a) *(b)* *(c)*

(a) Map of 407 co-authors on spinal biomechanics research (b) Map of collaborative spinal biomechanics analysis by 181 institutions (c) Map of collaborative spinal biomechanics research by 22 countries

Figure 5: Co-analysis of spinal biomechanics research

3.6 Co-Citation Analysis

3.6.1 Articles

According to the co-citation analysis, the relevance between objects depends on the number of times

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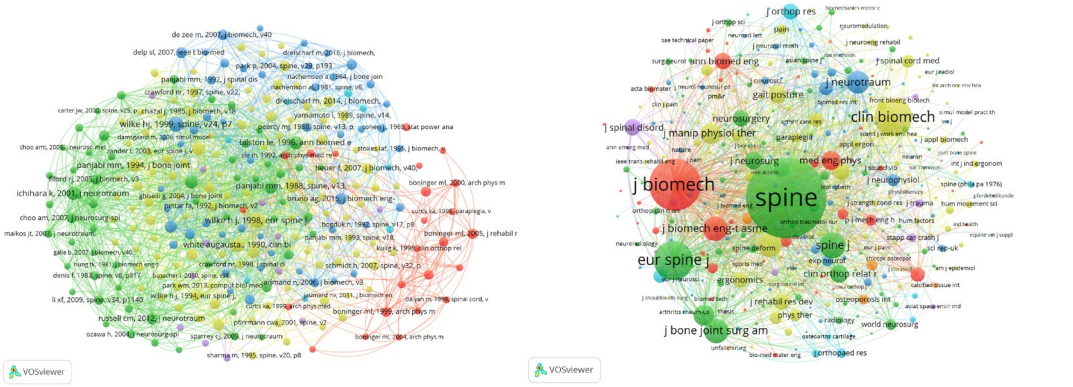
they appear in common citations. VOSviewer was used to analyze 54 articles (defined as the minimum number of articles used more than 20 times) (Figure 6a). The top five studies with high total link strength are as follows: Greaves Y, 2008, Ann Biomed Eng, v36, p396, doi 10.1007/s10439-008-9440-0, Ichihara K, 2001, J Neurotraum, v18, p361, doi 10.1089/08977150151071053, Maikos JT. 2008, J Neurotraum, v25, p795, doi 10.1089/neu.2007.0423, Bilston LE, 1996, Ann Biomed Eng, v24, p67, doi 10.1007/bf02770996, Wilke H J. 1998, Eur Spine J [. p148, doi 10.1007/s005860050045.

3.6.2 Journals

VOSviewer was used to analyze the journal names in co-citation analysis (defined as the minimum number of journals used more than 20 times) (Figure 6b). A total of 198 identified journals appeared in the total link strength. The top five journals with the highest total link strength are as follows: Spine (total link strength = 171,521 times), Journal of Biomechanics (total link strength = 89,515 times), European Spine Journal (total link strength = 51,433 times), Clinical Biomechanics (total link strength = 50,750 times), and Journal of Biomechanical Engineering Transactions of the ASME (total link strength = 25,353 times).

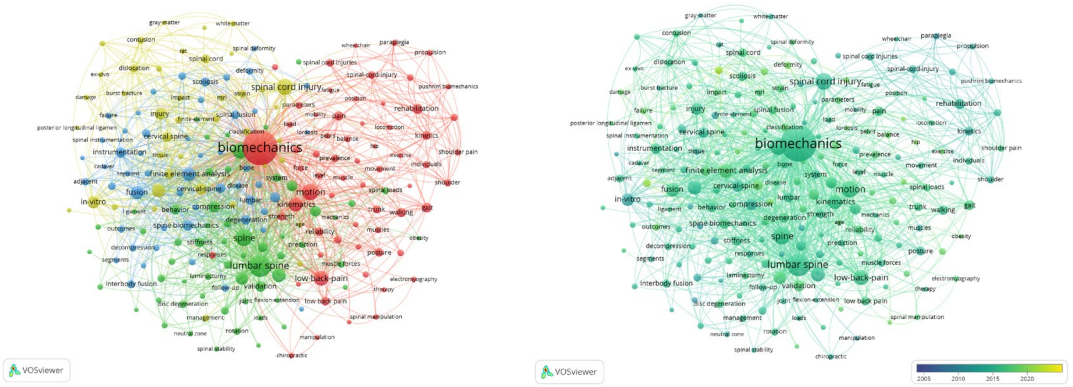


(a) *(b)*

(a) Network diagram of co-cited references in the field (b) Network diagram of co-cited journals in the field

Figure 6: Co-cited network diagram of spinal biomechanics

3.7 Co-Occurrence Analysis



(a) *(b)*

(a) Network of keywords in spinal biomechanics research (b) Distribution network of average occurrence frequency of keywords

Figure 7: Co-occurrence analysis of spinal biomechanics research

The purpose of co-occurrence analysis is to discover research directions and hot topics (defined as the minimum number of keywords used more than 10 times), which is important for the development of scientific research directions. As shown in Figure 7a, 214 identified keywords were classified into four clusters, roughly as follows: “Sports Biomechanics”, “Tissue Engineering”, “Clinical Research”, “Mechanism Research” (Figure 7a). In Cluster 1, the commonly used keywords are: Biomechanics,

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motion, low-back-pain. For Cluster 2, the main keywords are: lumber spine, spine, model. For Cluster 3, the main keywords are: fusion, finite element analysis, risk-factors. For Cluster 4, the main keywords are: spine cord injury, injury, mechanical properties.

These results indicate that the most prominent areas in Spinal Biomechanics research include the above four directions. VOSviewer color-codes the keywords based on their average occurrence time in all included publications (Figure 7b). Blue indicates that the keywords appeared earlier, while yellow indicates that the keywords appeared later. In the early stages of the research before 2016, most studies focused on “Sports Biomechanics”. The latest trends indicate that Cluster 2, namely “Clinical Research”, will receive widespread attention in the future.

4. Discussion

4.1 Global Publication Status and Quality

The research trends of Spinal Biomechanics reference and visual analysis can show the progress of the current research field and make predictions. Therefore, this study aims to evaluate the contributing countries, institutions, funding agencies, and research focuses of Spinal Biomechanics research[14].

Recently, the progress in the field of Spinal Biomechanics is an exciting and rapidly developing research area. As shown in this study, the number of publications published each year has been steadily increasing. In addition, in the past few years, research interest in Spinal Biomechanics has increased sharply[15]. A total of 80 countries have published relevant research in this field. Based on the current data, we predict the number of future publications, and more in-depth research on Spinal Biomechanics will be published in the coming years[16]. The current optimistic results, in turn, will enable researchers to conduct further high-quality research.

4.2 Research Trends in Spinal Biomechanics

According to the analysis of national contributions, the United States has the most publications. In terms of medical scientific research, Greaves Y, 2008, Ann Biomed Eng, v36, p396, doi 10.1007/s10439-008-9440-0 has made the largest contribution[17]. The U.S. Department of Health and Human Services and the National Institutes of Health rank first and second in terms of the number of papers published in research directions and funding. The United States has made the most important contribution to the total number of published papers on Spinal Biomechanics, with the highest total citation frequency and h-index, and may be considered a pioneer and leader in this topic globally. Canada ranks second overall in terms of publications. On the other hand, the United States ranks first in overall citation frequency and first in the h-index. China ranks third in terms of publication volume, fifth in total citation frequency, 18th in average citation frequency, and sixth in the h-index, with a differentiation in the quantity and quality of publications. In fact, China's academic evaluation system tends to focus on quantity rather than quality, which can explain why there is a differentiation in the quantity and quality of publications, leading researchers and doctors to rush to submit articles and ignore research quality. China's gradually expanding research funding will greatly improve the quality of publications (National Natural Science Foundation of China: ranked third with 164 publications, 4.302% of the total), gradually catching up with the global quality of publications in this field[18].

Bibliographic coupling occurs when two books have a reference to a third book in their bibliographies. We used bibliographic coupling to establish similarity links between different articles in this work from three perspectives: journals, institutions, and countries. The core journals for Spinal Biomechanics research are the Journal of Biomechanics, Clinical Biomechanics, Spine, Spine Journal, and European Spine Journal. These journals are more likely to report the latest research progress in the field. At the same time, the Journal of Biomechanics and Clinical Biomechanics are the journals with the most papers, indicating that these journals are at the forefront of international Spinal Biomechanics research. The University of Montreal has the highest total link strength and is considered a leading institution in Spinal Biomechanics research. The top three institutions that publish the most articles are all from the United States, which is consistent with the United States' leading position in this field. Almost all of the top 20 institutions are from the top five countries. Therefore, it can be seen that the establishment of first-class research institutions plays an indispensable role in improving a country's academic level. As shown in Figure 3d, Wilke, Hans-Joachim, and Schmidt, Hendrik are among the most important contributors. We should closely monitor their further research and the latest progress in new published articles in Spinal Biomechanics research[14]. Co-authored publications are of great significance in promoting scientific

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development, research innovation, knowledge sharing, and improving the quality of scientific research. The co-author analysis method evaluates cooperation between different countries, institutions, and authors. Authors, institutions, and countries with higher total link strength are more willing to collaborate. For example, Kelly, Brian P., the University of Montreal, and the United States are the best choices for our joint efforts. The purpose of this co-citation analysis is to determine the impact of research based on the number of times cited studies. The current research results show that the landmark study in Spinal Biomechanics have a high total citation frequency and provide many meaningful references. It is well known that Spine and the Journal of Biomechanics are the most widely mentioned in this topic.

4.3 Research Focuses in Spinal Biomechanics

We used co-occurrence analysis to discover research directions and hot topics in this field. A co-occurrence network map was created using all terms in research titles and abstracts. (Figure 7a) shows four research directions, including“Sports Biomechanics”, “Tissue Engineering[19]”, “Clinical Research[20]”, “Mechanism Research[21]”. These studies can help clarify future research directions. Keywords such as “Biomechanics” are more common and occupy an important position in the co-occurrence network map. Therefore, additional high-quality research on Spinal Biomechanics is still necessary in these four aspects. The overlay visualization map is similar to the co-occurrence map, with colors (Figure 7b) indicating the year of research publication, but the color of each item is different, corresponding to the time of occurrence. This method points out the exact direction for tracking research. Based on the survey results, Clinical Research may be the next hot topic in this field. Based on the results, Clinical Research may become a popular direction for research on Spinal Biomechanics, especially in research directions involving Spinal Biomechanics in recent years, and the term appears widely. Therefore, the Clinical Research of Spinal Biomechanics may be the main focus of this field[22].

4.4 Advantages and Limitations

This study evaluated the current status and trends of Spinal Biomechanics research through visual analysis, but several limitations must be acknowledged. First, the research was based on the English language literature sourced from the Web of Science - Science Citation Index Expanded database, potentially omitting non-English literature and introducing language bias. Second, there may be discrepancies between real-world conditions and the results presented here. For instance, some recently published high-quality papers may not have received sufficient attention due to their low citation frequency shortly after publication. Hence, it is imperative to remain vigilant about the latest primary research and non-English studies in our daily research endeavors.

5. Conclusion

This study demonstrates the global trends in Spinal Biomechanics research[22]. The United States is the leading contributor to research in this field and dominates global advancements. The Journal of Biomechanics has published the most articles on this topic. It is anticipated that an increasing number of studies on Spinal Biomechanics will be released in the coming years[23]. Notably, Clinical Research on Spinal Biomechanics is expected to garner significant attention and become the next major area of focus.

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