Original article

The Spinal Mouse as an instrument for analyzing spinal curvature: a bibliometric study

O Spinal Mouse como instrumento de análise da curvatura da coluna vertebral: um estudo bibliométrico

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ABSTRACT | INTRODUCTION: Global concern about spinal health is increasing due to the growing number of young people affected by conditions such as scoliosis, hyperkyphosis, and hyperlordosis, which can lead to pain, stiffness, functional limitations, and reduced quality of life. **OBJECTIVE:** To analyze global research trends related to the use of the Spinal Mouse in the evaluation of posture and spinal curvature using a bibliometric approach. **METHOD:** A bibliometric study was conducted based on documents indexed in the Web of Science and Scopus databases, covering publications up to January 2025. The variables analyzed included year of publication, citation metrics, journals, authorship and collaboration patterns, and the countries and institutions with the highest scientific output. **RESULTS:** A total of 227 references were analyzed. Most of the publications on the Spinal Mouse were scientific articles, with an annual growth rate of 6.33% and a mean of 12.09 citations per document. Spain and Japan were the countries with the highest number of publications, although international collaboration was found to be limited. **CONCLUSIONS:** Interest in the Spinal Mouse is growing, particularly in the context of non-invasive assessment of posture and spinal alignment. Greater international collaboration is recommended to strengthen research in this area, as the device has shown potential due to its ease of use, accuracy, and applicability in both clinical and research settings.

KEYWORDS: Posture. Spine. Thoracic Vertebrae. Bibliometrics. Outcome Assessment. Health Care.

RESUMO | INTRODUÇÃO: A preocupação global com a saúde da coluna vertebral tem vindo a aumentar devido ao número crescente de jovens afetados por condições como escoliose, hipercifose e hiperlordose, que podem provocar dor, rigidez, limitações funcionais e redução da qualidade de vida. **OBJETIVO:** Analisar as tendências globais da investigação científica relacionada com a utilização do Spinal Mouse na avaliação da postura e da curvatura da coluna vertebral, recorrendo a uma abordagem bibliométrica. **MÉTODO:** Foi realizado um estudo bibliométrico com base em documentos indexados nas bases de dados Web of Science e Scopus, abrangendo publicações até janeiro de 2025. As variáveis analisadas incluíram o ano de publicação, métricas de citação, revistas científicas, padrões de autoria e colaboração, bem como os países e instituições com maior produção científica. **RESULTADOS:** Foram analisadas 227 referências. A maioria das publicações sobre o Spinal Mouse corresponde a artigos científicos, registando-se uma taxa de crescimento anual de 6,33% e uma média de 12,09 citações por documento. Espanha e Japão foram os países com maior número de publicações, embora a colaboração internacional se tenha revelado limitada. **CONCLUSÕES:** O interesse pelo Spinal Mouse tem vindo a crescer, especialmente no contexto da avaliação não invasiva da postura e do alinhamento da coluna vertebral. Recomenda-se um reforço da colaboração internacional para fortalecer a investigação nesta área, dado o potencial do dispositivo, comprovado pela sua facilidade de utilização, precisão e aplicabilidade tanto em contextos clínicos como de investigação.

PALAVRAS-CHAVE: Postura. Coluna Vertebral. Vértebras Torácicas. Bibliometria. Avaliação de Resultados. Cuidados de Saúde.

Submitted June 2nd, 2025, Accepted Sept. 9th, 2025,
Published Oct. 31st, 2025
J. Physiother. Res., Salvador, 2025;15:e6288
https://doi.org/10.17267/2238-2704rpf.2025.6288 | ISSN: 2238-2704
Assigned editor: Bruno Goes

How to cite this article: Oliveira-Costa E, Alonso-Fernández D, Gutiérrez-Sánchez Á. The Spinal Mouse as an instrument for analyzing spinal curvature: a bibliometric study. J Physiother Res. 2025;15:e6288. https://doi.org/10.17267/2238-2704rpf.2025.6288

1. Introduction

The spine is a vital structure of the human skeleton that plays a key role in supporting the body, performing three essential functions: facilitating movement between body parts (head, thorax, and pelvis), bearing external and internal loads, and protecting the spinal cord, which is a critical component of the central nervous system[1].

A healthy and well-aligned spine contributes to proper posture, which not only improves physical appearance but also reduces the risk of developing back pain and other posture-related issues[2-9], a reality that is especially relevant for younger, school-aged populations, as their musculoskeletal systems are still developing and may be negatively impacted by poor posture habits adopted in their daily lives[10,11]. Early diagnosis of spinal health is crucial for applying appropriate treatments for various clinical conditions, such as scoliosis, abnormal kyphosis (either increased or reduced), and abnormal lordosis (either increased or reduced).

Bibliometric studies have gained prominence in recent years as powerful tools for mapping scientific production and identifying research trends. Among the available resources, Bibliometrix software, developed for the R programming language, stands out for its wide range of functionalities to analyze and visualize bibliographic data[12]. Integrated with Biblioshiny, this tool enables comprehensive, objective, and reproducible analyses that contribute to scientific advancement[13]. A key feature of Bibliometrix is its ability to import and process large volumes of data from sources such as Web of Science and Scopus, allowing researchers to conduct in-depth analyses of citation patterns, author collaborations, and the temporal evolution of research topics. This methodology also enables the mapping of major themes and subthemes, revealing networks of relationships among key concepts. Such visualizations help identify emerging trends, potential collaborations, and provide a clearer understanding of the structural dynamics within a given research area[14].

Despite the growing use of the Spinal Mouse (SM) in spinal assessment within both clinical and research contexts, no bibliometric studies have been published that systematically analyze the scientific output related to this instrument. The absence of such an analysis represents an important gap, given the significant increase in publications in recent years and the need to map key authors, journals, thematic areas, and collaboration networks. A bibliometric study makes it possible to identify emerging patterns, assess the temporal evolution of research, and highlight pathways for future collaborations and clinical applications. Therefore, this work provides an unprecedented contribution to the field by integrating bibliometric and network analysis techniques focused exclusively on the SM.

In this context, the present study focuses on analyzing the global scientific literature related to the SM, a portable, non-invasive, computer-assisted device[15-25] that uses ultrasound technology to measure spinal curvature in various postures[26-29]. The SM has gained recognition for its accuracy and ease of use, offering advantages over invasive methods like X-rays[21], particularly considering the risks associated with radiation exposure[30]. In addition to being non-invasive and radiation-free, the SM is considered a highly reliable and painless device for patients, capable of measuring spinal curvatures in three dimensions—lumbar, thoracic, and cervical[15,21,22,31]. This bibliometric and network analysis aims to provide a structured overview of research output involving the SM device, helping to identify thematic trends, influential contributors, and potential areas for further investigation.

Co-word analysis proves to be a powerful tool for exploring and understanding conceptual relationships within the field of the SM instrument. By constructing a co-occurrence network, normalizing the connections (edges), and identifying subfields, it becomes possible to gain a comprehensive and structured view of key concepts and their interconnections. This approach significantly contributes to advancing knowledge and identifying research opportunities in this area of study.

Therefore, the present study aims to determine the current state of research on spinal curvature assessment using the SM instrument, through a bibliometric and network analysis based on a quantitative evaluation of peer-reviewed articles.

2. Method

2.1 Search strategy

This work employs bibliometric analysis as its foundation and was shaped by the methodologies applied in previous studies[32,33]. The keyword "Spinal Mouse*" was used in the title field during the search process, as this concept is the central focus of the investigation. A search for articles published from the inception of the databases through January 2025 was conducted in the international databases Web of Science Core Collection (WoS) and Scopus. Since WoS includes relatively few sources in languages other than English, this limitation is offset by Scopus, published by Elsevier, which offers a broader range of journals and is recognized as one of the largest repositories of peer-reviewed literature[34]. Scopus also provides more comprehensive language and geographic coverage, with a stronger representation of literature from Europe, Latin America, Asia, and the Pacific[34].

2.2 Data collection

The Bibliometrix software was used, and the data were exported in BibTeX format for import into Biblioshiny. At the time of this research, no published articles were found on the SM using bibliometric tools. Two independent reviewers (E.O.C. and A.G.S.) screened the studies based on titles and abstracts. The search strategy, document selection process, and exclusion of duplicates are illustrated in a flowchart.

This study analyzes the evolution of scientific output in a specific area through the study of various metrics. First, the year of publication of the documents was examined to determine the growth rate of publications over time. An authorship and collaboration index analysis was also conducted, identifying the most prolific authors and distinguishing between individual and collaborative publications. This helped to identify leading researchers in the field and potential working networks or research groups.

The documents were classified into different publication types, following the categories defined by WoS, such as original articles, conference abstracts, proceedings, news items, and literature reviews. Additionally, the most frequently used journals for disseminating knowledge in this area were identified, providing insight into the most relevant and productive titles. Another aspect analyzed was the language of publication, offering insight into linguistic preferences in scientific communication.

A reference and citation analysis was conducted to evaluate the impact of the publications and their influence within the field of study. Finally, a network analysis was carried out, including co-authorship and co-citation networks, with the aim of visualizing the collaborative structure and thematic connections within the research domain. Figure 1 illustrates the search strategy and terms used.

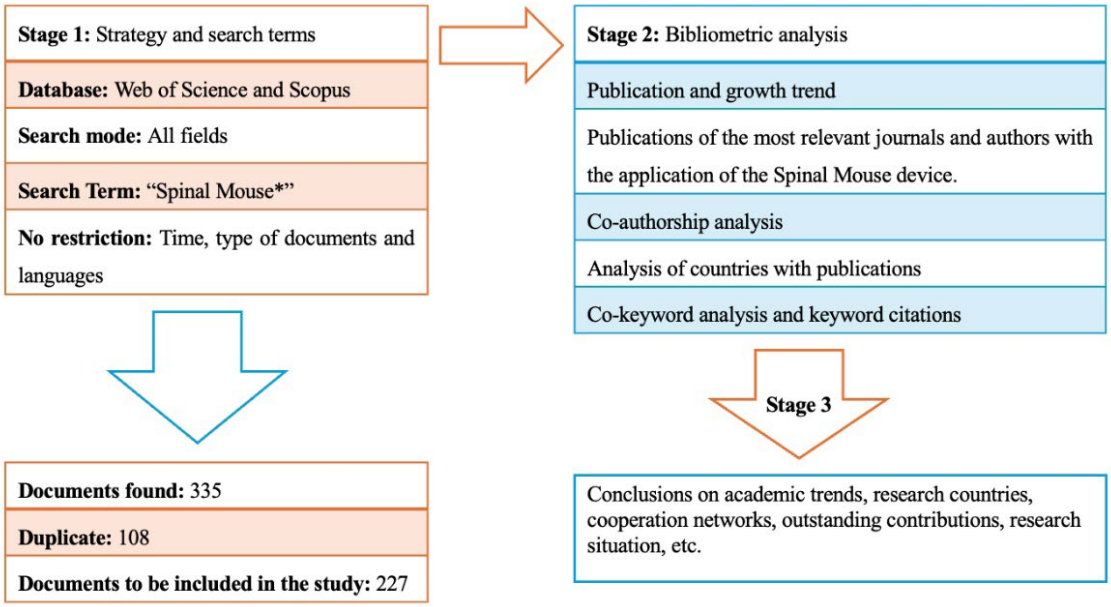
2.3 Data analysis

In this study, descriptive statistics and frequency distribution analysis were applied to evaluate bibliometric indicators related to the topic. The Bibliometrix package, within the R programming environment (version 12.0+467), is a widely recognized tool for its efficiency in data analysis and bibliometric visualization. For the graphical representation and visualization of connections between indexing terms, its advanced functionalities were used, enabling the generation of interactive bibliometric maps and co-occurrence networks. This approach facilitated a strong and clear visual analysis of the interrelationships among the studied concepts, offering a deeper interpretation of the knowledge structure within the research domain. Detailed information on authors, countries of origin of the publications, and publication years were extracted directly from the aforementioned databases, ensuring the integrity and accuracy of all analyzed data. To structure and map the data, information was collected, organized, and processed using Microsoft Excel for Mac, version 16.91, thus facilitating the organization and interpretation of observed trends.

3. Results

A total of 335 documents were initially retrieved from the Web of Science (*n* = 141) and Scopus (*n* = 194) databases. After merging the datasets and removing 108 duplicates, 227 unique publications were included in the bibliometric analysis. No additional exclusion criteria were applied, as the objective of the study was to conduct a comprehensive bibliometric analysis using all available scientific literature indexed under the term "Spinal Mouse*". The complete document selection process, including identification, screening, and inclusion stages, is visually summarized in figure 1.

Figure 1. Flowchart of the document selection process for the bibliometric analysis. Data retrieved from Web of Science and Scopus (all fields, no restriction), search term "Spinal Mouse*", in January 2025

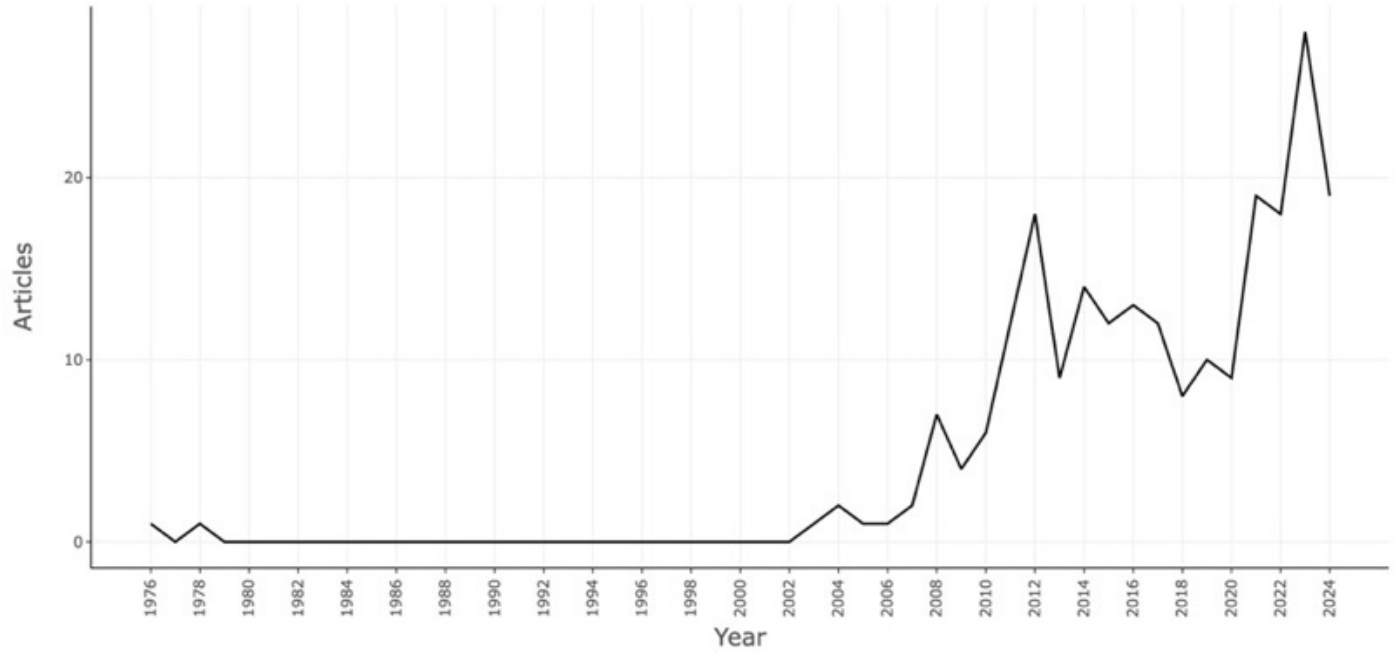


Source: the authors (2025).

3.1 Years and number of publications

The analysis revealed that 94.27% of the publications were articles, indicating that this topic has a relatively recent history of publications. The annual growth rate was 6.33%, with an average of 12.09 citations per document. The most commonly used language was English, present in 84.58% of the publications (192 documents), followed by Japanese at 7.93% (18 publications) and Spanish at 4.85% (11 publications). Additionally, two publications were recorded in French and one each in Portuguese, Italian, Slovak, and Slovenian. The analysis of the number of publications is an important indicator to understanding the progress of scientific research. The number of publications in the first 30 years, starting from 1976, was scarce or nonexistent; however, there has been growing interest in this field since 2006 (Figure 2).

Figure 2. Annual scientific production, extracted by Biblioshiny (1976-2024)

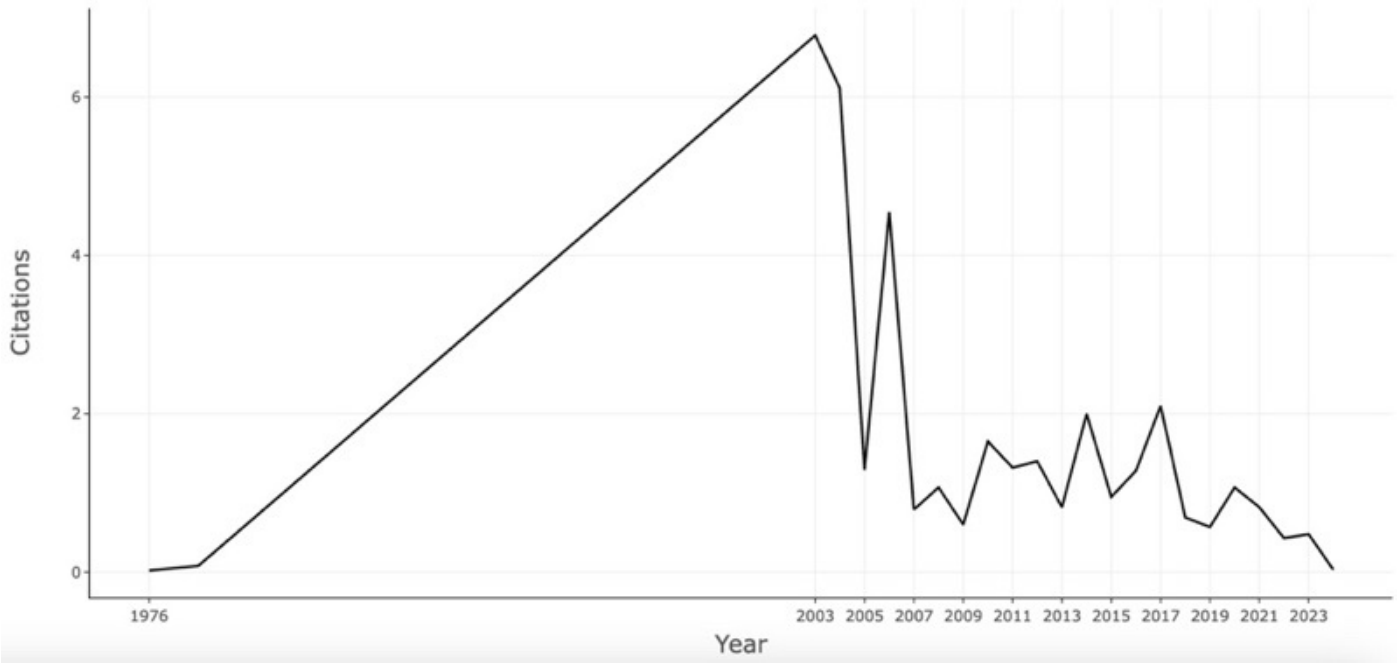


Source: the authors (2025).

It was found that between 1979 and 2002 there were no publications related to the SM. In contrast, one article was published in 2003[35]. In 2023, the highest number of scientific publications was recorded, with a total of 28, followed by 19 publications in 2024.

Figure 3 shows the evolution of the average number of citations per year between 1976 and 2023. The highest average citation rate occurred in 2003, with 6.8 citations per year. After that, a decrease in average citations was observed, with fluctuations over time and a value of 0.5 citations per year in 2023.

Figure 3. Average citations per year, extracted by Biblioshiny (1976-2024)



Source: the authors (2025).

3.2 Authorship and collaboration index

In the analysis of the 227 documents, a total of 746 authors were identified, of whom 3.96% published individually and 2.20% in co-authorship. The most prolific authors are presented in table 1, which includes researchers with six or more publications.

Table 1. Top 5 authors in the field based on bibliometric indicators (1976–2024), extracted using Biblioshiny

Top 5	Author	Institution	H_Index	TC	NP	PY_Start
Top 1	Muyor JM[23,27-29,36-38]	Department of Education, Health Research Center, Laboratory of Kinesiology, Biomechanics and Ergonomics (KIBIOMER Lab), University of Almeria, Spain	16	565	34	2010
Top 2	López-Miñarro PA[23,27-29,36-38]	Department of Physical Education, University of Murcia, Spain	13	472	29	2010
Top 3	Alacid F[23,27-29,36-38]	Department of Education, Health Research Center, University of Almeria, Spain	13	387	18	2010
Top 4	Masaki M[41]	Department of Physiotherapy, Niigata University of Health and Welfare, Japan	4	178	9	2015
Top 5	Casimiro-Andújar AJ[45]	Area of Body Expression, Faculty of Education, University of Almeria, Spain	4	77	6	2012

Source: the authors (2025).
Note: H_Index - Impact of Publications; TC: Total citations; NP: Publication Number; PY_Start: The year of the first publication in the area of research.

The three most prominent authors published their first article together through the application of this instrument in 2010[36], which has been cited 31 times. The most cited article by the leading author was published in 2011[37], in collaboration with the second- and third-ranked authors, accumulating 53 citations—an average of 3.533 citations per year. Muyor JM has already published 34 articles (14.98%) using the SM, the most recent of which was in 2024[38].

3.3 Journal analysis

The included studies were distributed across 128 journals. The top 10 scientific journals in the fields of health, physical therapy, and medical sciences were identified based on bibliometric indicators that assess the impact and relevance of publications. The key parameters analyzed include the H_Index, which reflects the minimum number of articles with at least that number of citations; the G_Index, which places greater weight on highly cited articles; and the M_Index, which adjusts the H_Index according to the time elapsed since the first considered publication. Additionally, the total number of citations (TC), number of publications (NP), and the year of the first publication (PY_Start) were examined. European Spine Journal stands out with the highest number of citations (418) and a high G_Index (10), indicating significant impact in the field. The International Journal of Morphology has the highest H_Index (8), suggesting a more even distribution of citations across its articles. Meanwhile, the Journal of Physical Therapy Science (2014) shows growing impact, as evidenced by the number of publications and accumulated citations within a short period. The M_Index analysis reveals that the International Journal of Morphology (0.533) and the Journal of Back and Musculoskeletal Rehabilitation (0.400) have shown relatively steady growth in impact over time. In contrast, older journals such as Electromyography and Clinical Neurophysiology show lower M_Index values, suggesting a less pronounced increase in influence over the years (Table 2).

Table 2. Top 10 scientific journals by bibliometric performance (1976–2024), extracted using Biblioshiny

Top 10	Journals	H_Index	G_Index	M_Index	TC	NP	PY_Start
Top 1	*International Journal of Morphology*	8	10	0.533	102	10	2011
Top 2	*Journal of Back and Musculoskeletal Rehabilitation*	6	7	0.400	120	7	2011
Top 3	*European Spine Journal*	5	10	0.227	418	10	2004
Top 4	*Electromyography and Clinical Neurophysiology*	4	4	0.211	62	4	2007
Top 5	*Journal of Physical Therapy Science*	4	5	0.333	31	6	2014
Top 6	*Plos One*	4	6	0.286	86	6	2012
Top 7	*Turkish Journal of Medical Sciences*	4	5	0.400	68	5	2016
Top 8	*International Journal of Environmental Research and Public Health*	3	4	0.429	19	4	2019
Top 9	*Journal of Manipulative and Physiological Therapeutics*	3	3	0.167	98	3	2008
Top 10	*Kinesiology*	3	3	0.231	39	3	2013

Source: the authors (2025).
Note: H_Index - Impact of Publications; G_Index - Variant of the H_Index that gives more weight to highly cited articles; M_Index – H_Index divided hairs years from first publication; TC: Total citations; NP: Publication Number; PY_Start: The year of the first publication in the area of research.

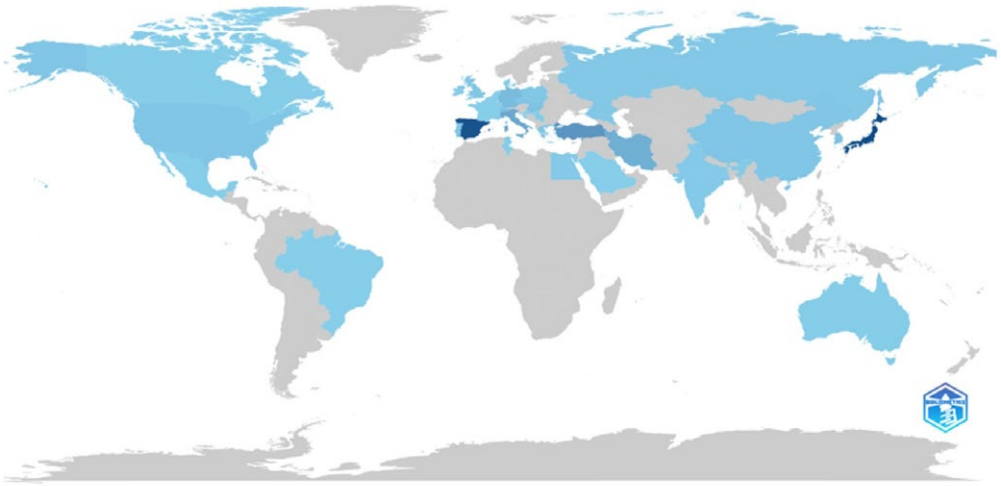
This finding highlights the importance of identifying the highest-impact journals in the field, considering that selecting a publication for article submission should be based not only on citation indices, but also on the journal's relevance to the scope of the research and its visibility within the scientific community.

3.4 Geographic distribution

Figure 4 illustrates the geographic distribution of scientific production and the extent of international collaboration. Figure 4a, the distribution of research output is shown based on the affiliations of all authors. A total of 33 countries contributed to the publications, indicating that the application of the SM instrument has gained attention worldwide. The color intensity reflects productivity, with darker shades of blue representing higher output and gray indicating no contributions. Japan emerged as the most productive country, followed by Spain. Figure 4b explores international collaboration using the indicators Single Country Publications (SCP) and Multiple Country Publications (MCP), based on the country of the corresponding author. SCPs refer to articles authored entirely within the same country, while MCPs involve co-authors from different countries. Of the 41 documents published by Japan, only one was classified as an MCP. Spain and Italy each produced two MCPs, suggesting that, despite growing interest, cross-border collaboration in this field remains at an early stage. The limited number of MCPs highlights the need for stronger international research networks to support the advancement of this topic.

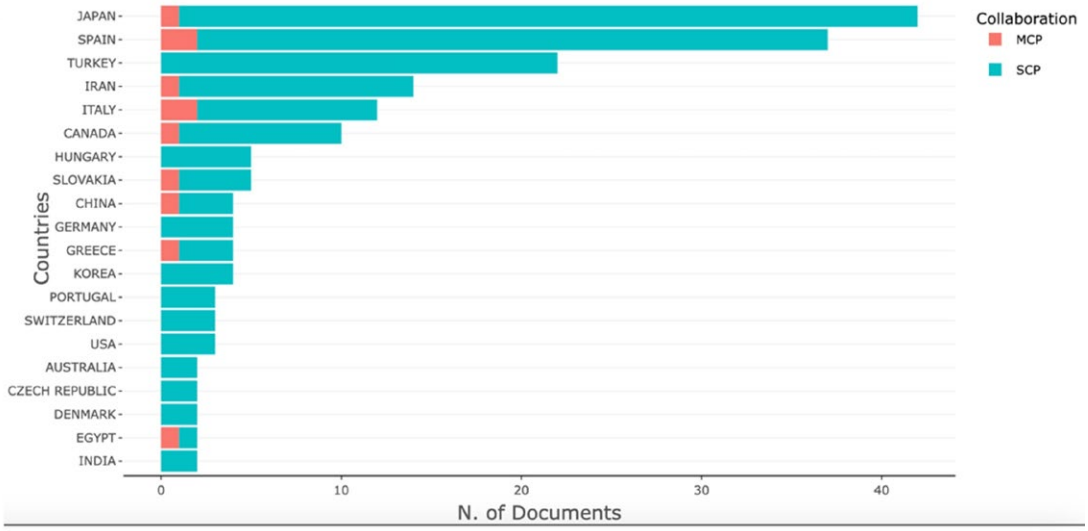
Figure 4. Scientific output and collaboration by country (a: distribution by affiliation; b: corresponding author), 1976–2024, extracted using Biblioshiny

a. Distribution by country of scientific production



Top 10	Countries	Frequency	Top 10	Countries	Frequency
1	Japan	146	6	Germany	20
2	Spain	139	7	Hungary	14
3	Turkey	61	8	Slovakia	14
4	Italy	40	9	South Korea	3
5	Iran	33	10	Switzerland	13

b. Country of the corresponding author. SCP - Single Country Publication; MCP - Multiple Country Publication



Source: the authors (2025)

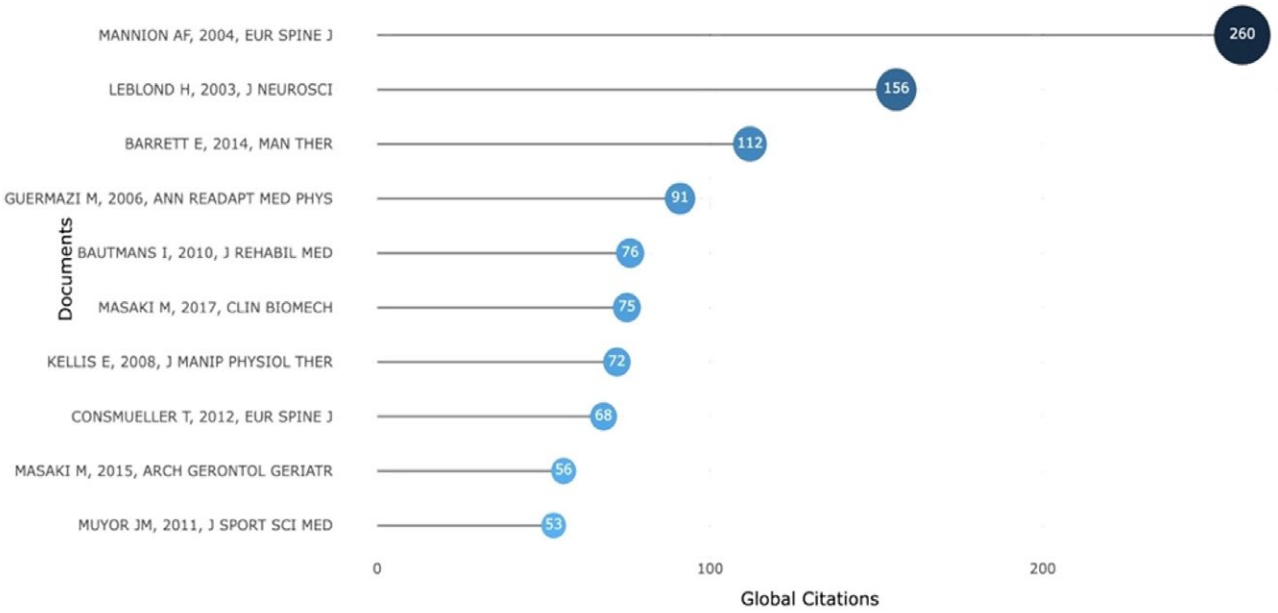
3.5 Distribution of global citations by articles and countries

Figure 5 presents citation-related indicators that contribute to understanding the intellectual and geographic influence within the field. Figure 5a shows the 10 most globally cited documents identified through the bibliometric analysis. These documents provide a solid foundation for understanding the central topics and key contributions in this research area. The article by Mannion et al.[26], published in the European Spine Journal, stands out significantly with 260 citations, making it the most influential among the analyzed sample. It is followed by the work of Leblond et al.[35], published in the Journal of Neuroscience, with 156 citations, and Barrett et al.[15], in Manual Therapy, with 112 citations. Other documents with notable impact include the studies by Guermazi et al.[39] with 91 citations, Bautmans et al.[40] with 76 citations, and two articles by Masaki et al.[41], each with 75 and 56 citations.

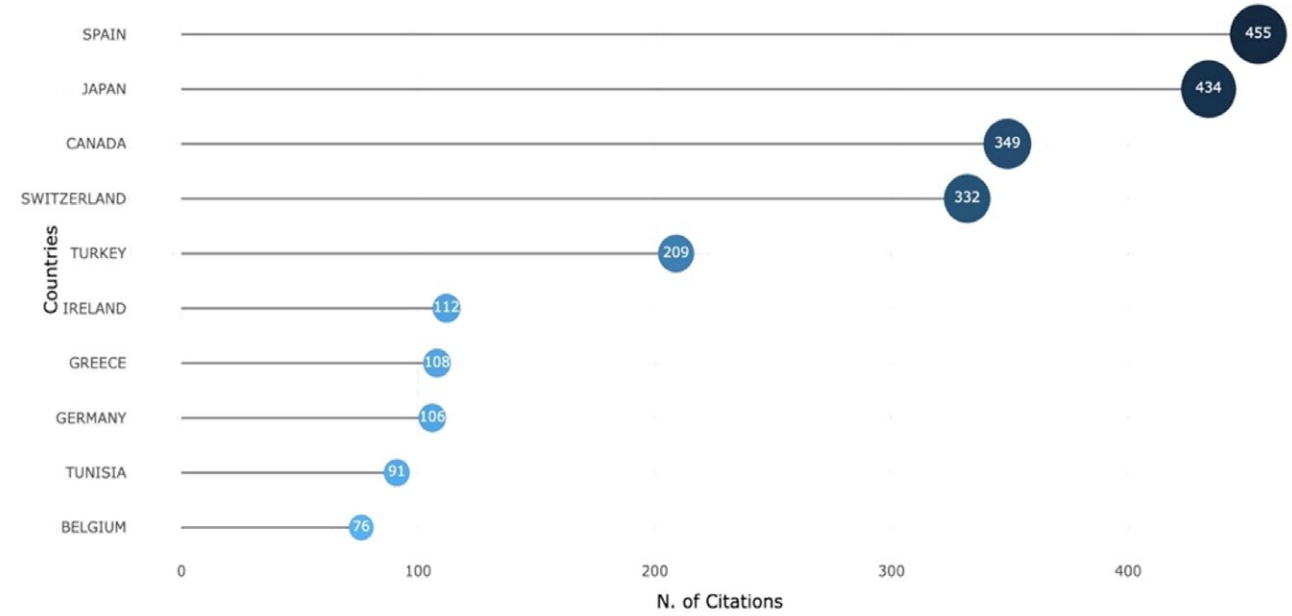
Also noteworthy are the works of Kellis et al.[42], Consmüller et al.[43], and Muyor et al.[37], all with over 50 citations. This chart highlights the authors and publications that have most significantly contributed to the advancement of knowledge in the field, serving as essential references for future research. In the figure 5b displays the distribution of citations by country, offering insight into the national contributions to the field's academic impact. Spain leads the ranking with a total of 455 citations, followed closely by Japan with 434. Other countries with notable citation counts include Canada, Switzerland, and Turkey. This data reflects not only the scientific productivity but also the visibility and relevance of research outputs at the international level.

Figure 5. Citation distribution by document and country (a–b), 1976–2024. Extracted using Biblioshiny

a. Most globally cited documents



b. Most cited countries

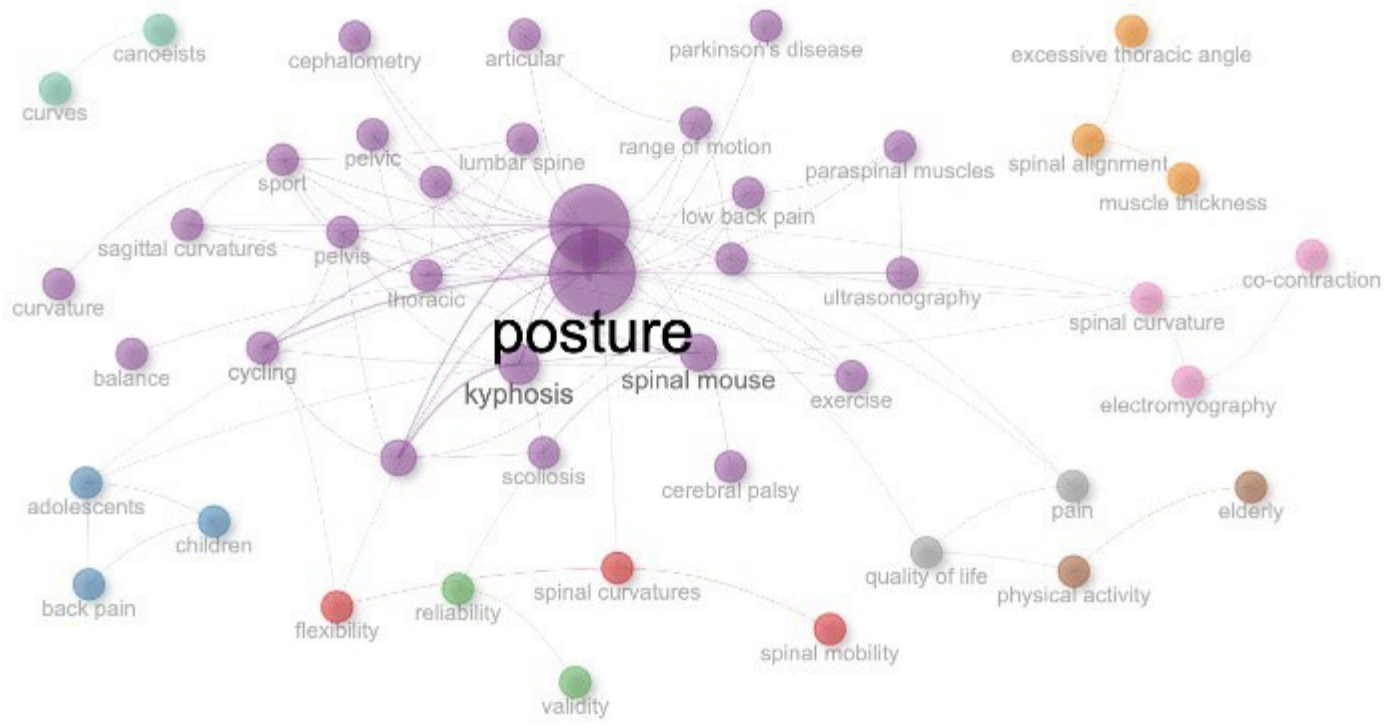


Source: the authors (2025).

3.6 Keyword co-occurrence and thematic structure

The bibliometric analysis identified a total of 466 keywords defined by the authors in their research. Among them, "Spinal Mouse" ranked as the third most frequent keyword, with a total frequency of 25. A threshold of 50 terms was applied to generate the visualization. Figure 6 presents the keyword co-occurrence network based on author-defined terms. The size of each node (vertex) reflects the frequency of the keyword, while its color indicates thematic clustering. This graphical representation highlights central research terms and reveals conceptual connections within the field. The network displays nine distinct thematic clusters. Notably, the purple cluster, consisting of 16 terms, includes keywords such as Scoliosis, Posture, Kyphosis, Thoracic, and Lumbar, which are closely associated with the use of the SM instrument. This cluster emphasizes a specific focus on spinal and postural analysis, particularly in contexts where the SM is applied as a measurement and evaluation tool.

Figure 6. Co-occurrence network of author keywords (1976–2024), extracted using Biblioshiny



Source: the authors (2025).

4. Discussion

Considering the results obtained, this study provides a comprehensive analysis of the use of the SM device in spinal curvature assessment. Our findings reinforce the central role of the SM in clinical and biomechanical research, a conclusion consistent with previous works that highlight its value in non-invasive spinal evaluation[19,22,24,31,44].

Several studies have confirmed the reliability and validity of the SM in the sagittal plane, particularly in the measurement of thoracic kyphosis and lumbar lordosis[15,21,22]. The annual increase in publications, as shown in our analysis, aligns with global trends in postural assessment research and the increasing demand for radiation-free methods in both pediatric and geriatric populations[19,26].

Our co-word analysis confirms the prominence of clinical concerns such as "posture," "scoliosis," and "kyphosis" within the field, aligning with the dominant themes in current literature. Journals such as the European Spine Journal and International Journal of Morphology emerged as central platforms for disseminating research on this topic, corroborating trends identified in previous bibliometric studies on postural health[14].

The sustained volume of citations over time indicates consistent scholarly interest in the SM, particularly for evaluating spinal curvature and mobility[19,22,24,31,39,44]. However, some evidence points to reduced accuracy in frontal plane measurements[19,31], suggesting the need for further refinement and validation in this domain.

The network visualizations derived from the bibliometric analysis offered insight into the conceptual structure of this research field. Limiting the keyword analysis to the top 50 terms ensured clarity and focus, while citation metrics provided an overview of academic influence, though they do not capture methodological quality, underscoring the value of complementary critical appraisal.

This study presents some limitations that should be considered. The inclusion of documents was based exclusively on the presence of the term "Spinal Mouse*," which may have led to the exclusion of relevant studies that used the device under different names or descriptors. Furthermore, the analysis was purely bibliometric, allowing for the identification of scientific production patterns and collaboration networks, but not for the evaluation of the methodological quality of the included studies. Future research could benefit from combining bibliometric analysis with systematic reviews to provide a more critical and comprehensive understanding of the available evidence.

Despite the limitations mentioned, this study provides a novel contribution to the scientific literature by systematically mapping the global research output related to the use of the SM in spinal curvature assessment. By identifying key authors, journals, keywords, and collaboration networks, this analysis offers a structured overview of research trends in the field and highlights the growing interest in non-invasive tools for postural evaluation. These findings may help guide future editorial decisions, strengthen interinstitutional research networks, and support the development of new clinical and investigative applications of the SM.

5. Conclusion

The results confirmed the growing scientific interest in the SM, especially in recent years, and its central role in research focused on spinal curvature, posture, and rehabilitation. Despite some limitations, such as reduced accuracy in the frontal plane, its use continues to expand across diverse health contexts. This study contributes original insights that may guide future research, foster international collaboration, and support the broader clinical adoption of the SM.

Authors' contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

Indexers

The Journal of Physiotherapy Research is indexed by DOAJ, EBSCO, LILACS and Scopus.

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