



## RESEARCH ARTICLE

# Global Cluster Analysis and Network Visualization in Musculoskeletal Pain Management: A Scientometric Mapping

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**Objective:** Musculoskeletal pain is the most prominent clinical manifestation of more than 150 musculoskeletal disease conditions, and its effective long-term management poses a great challenge to healthcare systems globally. For this, it is important to understand current research progress on musculoskeletal pain management. The purpose of the present study is to provide a comprehensive insight into the current state of research and global trends in musculoskeletal pain management.

**Methods:** Publications on musculoskeletal pain management from 1972 to 2021 were retrieved from the Science Citation Index-Expanded (SCIE) database. Included articles were any article type related to aspects of musculoskeletal pain management, including etiology, mechanisms, epidemiology, treatment, outcomes, side effects, and patient compliance. Publication data were analyzed using bibliometric methods. The software VOSviewer was employed to perform bibliographic coupling, co-authorship, co-citation, and co-occurrence analysis, and to visualize publication tendencies in musculoskeletal pain management.

**Results:** A total of 5475 articles were included in this study. The number of global publications on musculoskeletal pain management has escalated annually. Based on the number of publications and citations from the published literature, as well as the H-index, the United States led global contributions in this area. The institutions making the highest contributions were the League of European Research Universities (LERU), the University of Sydney, and Harvard University. The journal *BMC Musculoskeletal Disorders* published the highest number of articles in this area. The published studies fall under six groups: "Prevention and rehabilitation," "Etiology and diagnosis," "Clinical study," "Epidemiology," "Mental health," and "Education." High-quality primary studies and epidemiology are predicted to be the next prevailing topics in this field of research.

**Conclusions:** Based on current global trends, the number of publications on musculoskeletal pain management will continue to increase. Future studies will likely place more emphasis on high-quality randomized controlled trials (RCTs) and epidemiological studies.

**Key words:** Cluster analysis; Musculoskeletal; Pain management; Visualization

## Introduction

The global burden of disease profile is transforming from communicable diseases to non-communicable diseases (NCDs). Also known as chronic diseases, NCDs are predominated by cardiovascular diseases, cancers, chronic

respiratory diseases, diabetes, and musculoskeletal disorders. From 1990 to 2019, a higher share of the disease burden has transitioned towards the cost of years lived with disability (YLDs) rather than years of life lost (YLLs).<sup>1</sup> The contribution of NCDs to global disability-adjusted life years (DALYs)

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rose from 43.9% in 1990 to 61.4% in 2016 according to the Global Burden of Disease study.<sup>2</sup> DALYs of musculoskeletal diseases ascended dramatically by 61.6% between 1990 and 2016, in which a 19.6% increase has occurred since 2006, making musculoskeletal conditions the second leading cause for YLDs in 2016 and only preceded by spinal pain.<sup>3</sup> These trends suggest that chronic conditions such as musculoskeletal diseases are likely to have the greatest impacts on patients, and also have the highest demand for healthcare resources globally in the coming years.

Musculoskeletal conditions comprise a heterogeneous collection of more than 150 NCDs, including back and neck pain, osteoarthritis, rheumatoid arthritis, and bone fractures. Musculoskeletal pain is one of the most common clinical manifestations of musculoskeletal disorders, which can affect the bones, joints, ligaments, tendons, and associated soft tissues.<sup>4,5</sup> Musculoskeletal pain accounts for the largest proportion of patients with chronic pain in all geographical regions globally and in all age groups. Studies have shown that the overall prevalence of chronic musculoskeletal pain in Europe is 35.7%, ranging from 18.6% in Switzerland to 45.6% in France.<sup>6,7</sup> The prevalence of musculoskeletal disorders in the United States in 2011 astonishingly matched the prevalence of cardiovascular disease and chronic respiratory disease combined, with musculoskeletal pain affecting one in two people over the age of 18 and nearly three in four over the age of 65.<sup>8</sup> This costed the US healthcare system a staggering \$213 billion in 2011, accounting for 1.4% of the gross domestic product.<sup>5</sup> This prevalence is expected to continue to expand at an increased rate on a global scale due to the aging population.

Despite age being one of the main drivers for developing musculoskeletal disease and associated pain, the disease burden in adolescents has been rising in recent years. The Global Burden of Disease study reported that in 2019, despite the low mortality rate and low YLL rate of musculoskeletal disorders among other major NCDs in adolescents aged 10–24 years in EU member states, their YLD rate was the second highest following mental disorders, and DALY rate ranked the second or third highest depending on the country.<sup>9</sup> Contrary to common perceptions, musculoskeletal diseases are increasingly becoming a significant challenge to global health not just in aged people, but also in much younger patients who may be affected by such conditions due to age and be subjected to lifetime suffering.

Musculoskeletal pain is often the primary driver for hospital visits by affected patients, which is frequently accompanied by weakened physical function and mobility, all leading to lower quality of life and participation in the workforce. This has even more profound impacts in lower-income countries as individuals lose their economic independence.<sup>2,3</sup> Another complicating factor is that although the pain itself does not lead to mortality, reduced mobility due to pain can increase the risk of mortality by up to two-fold from other concurrent conditions such as cardiovascular disease and diabetes.<sup>10</sup> From a treatment perspective, pain is a

good indicator of the severity and progress of musculoskeletal disease, and may guide the therapeutic modality and health resources used. Therefore, it is important to understand current research progress in musculoskeletal pain management and intervention strategies.

The treatment of musculoskeletal pain remains a major medical challenge despite its high prevalence and associated burden.<sup>11</sup> Treatment options may include osteopathy,<sup>12</sup> chiropractic interventions,<sup>13</sup> medications,<sup>14</sup> acupuncture,<sup>15</sup> and massage therapy,<sup>16</sup> but there is no convincing evidence that any of these interventions are effective for the long-term integrated management of musculoskeletal pain. Among them, pharmacotherapy is used extensively due to its simplicity and short-term effectiveness in pain relief, but its application is becoming more limited in recent years as the risks of polypharmacy are being increasingly recognized. For instance, the recent opioid crisis and safety issues arising from over-reliance on opioids in many countries have aroused widespread concern and increased caution for opioid prescriptions.<sup>17</sup> Opioids are now no longer recommended for the long-term treatment of musculoskeletal pain due to the increased risk of adverse effects and treatment interruption.<sup>18,19</sup> The chronic and persistent nature of musculoskeletal disorders make the management of musculoskeletal pain a constant topic of interest and debate among the scientific and clinical communities. However, global research trends on this topic have not yet been well-investigated.

Publications are an important index of research propensity and direction in musculoskeletal pain management, and the extent of contributions of different countries and institutions. Bibliometrics is increasingly used as a viable method to qualitatively and quantitatively appraise trends in research over time based on information from literature databases and bibliometric attributes. This analysis can help researchers grasp past and current developments in the area of interest, and evaluate the respective contributions of journals, institutes, and countries.<sup>20</sup> Knowledge of the top contributing entities can help guide the development of new research or therapeutic intervention decisions. Bibliometric studies can also be used as a reference for formulating clinical policies and standards.<sup>21</sup> The aim of this study was to provide a comprehensive insight to the current state of research and global trends in musculoskeletal pain management.

## Methods

### Data Sources and Search Strategy

The bibliometric analysis was performed using Science Citation Index-Expanded (SCIE) of Web of Science (WOS), which are considered the best databases for bibliometrics and cover more than 12,000 of the most influential and highest quality scientific international journals, providing comprehensive data on publications.<sup>22</sup> All publications from 1972 to 2021 were searched in SCIE of WOS, which includes articles from the last 50 years in the field. The search strategy

was as follows: (topic = musculoskeletal AND topic = pain AND topic = management). All identified publications were in English.

### **Selection Criteria and Data Collection**

Included articles were any article type and related to aspects of musculoskeletal pain management, including etiology, mechanisms, epidemiology, treatment, outcomes, side effects, and patient compliance. Excluded articles were assessed to be not related to musculoskeletal pain management (e.g. false positive data). Two reviewers independently read the title and abstracts of all searched publications, included the articles that met the selection criteria, and excluded the articles not related to musculoskeletal pain management. Disagreements were reconciled by a third reviewer to reach consensus. We also excluded clinical studies or trials published only as abstracts, where no additional data was available from other sources.

Information on all eligible articles was downloaded from the SCIE database, including title, author, year of publication, country or region of publication, affiliations, journal, keywords, and abstract. Two reviewers independently verified the data collection process. Disagreements were reconciled by a third reviewer to reach consensus.

### **Bibliometric Analysis**

The WoS eigenfunction was used to describe the basic characteristics of publications and the H-index. The H-index is an indication of the number of publications and citation impact of publications for a researcher. The H-index designates a H value for the researcher when they have authored H articles which have been cited a minimum of H times in other publications.<sup>23,24</sup> Relative research interest (RRI) is defined as the number of publications per year in a research field divided by the sum of publications in that field. The origin software (version 2021) was used to analyze the temporal trend of publication volume. A logistic regression model:  $f(x) = A2 + (A1-A2)/(1 + (x/x0)^p)$  was used to model the cumulative volume of literature. In this equation, the symbol  $x$  denotes the year and  $f(x)$  denotes the cumulative volume of papers. The model fit was calculated by  $R^2$ .

### **Visualization Analysis**

A bibliometric visualization analysis of the literature was performed using VOSviewer software (Leiden University, Leiden, The Netherlands).<sup>25</sup> This study used VOSviewer for bibliographic coupling, co-authorship, co-citation, and co-occurrence analysis. During the keyword co-occurrence analysis, the first five high-frequency keywords of the same color were used for cluster classification and definition.

## **Results**

### **Global Publication Trends**

#### *Number of Publications*

A total of 5475 publications from 1972 to 2021 have been published on musculoskeletal pain management as of May 30, 2022. There was a steady annual increase in the number of global publications, from one in 1972 to 749 in 2021 and peaked in 2021 (749, 13.68%) (Figure 1A).

#### *National and Regional Contributions*

A total of 113 countries or regions have been published in this field, with the United States contributing the highest proportion (1845, 33.70%), followed by England (800, 14.61%), Australia (684, 12.49%), and Canada (550, 10.05%) (Figure 1B).

#### *Global Trends in Publications*

A chronological plot of the number of publications was constructed with a logistic regression model, which also displayed a predicted future trend from the model fitting curve (Figure 1C). This figure clearly shows that the number of publications in this field has increased exponentially in the past 20 years ( $R^2 = 0.992$ ), with the number of publications rising from 53 in 2002 to 749 in 2021. The model predicts that the number of publications in this field will exceed 1000 in 2023. In 10 years, the annual average will exceed 3000.

#### *Citation Frequency and H-Index*

Publications from the United States had the highest frequency of citations (51,710). England ranked second in total citations (22,968), followed by Australia (18,025), Canada (15,565), and the Netherlands (9789) (Figure 2A). The average citation frequency of the top 20 countries or regions is shown in Figure 2B. The Netherlands had the highest average frequency of citations (38.39), followed by Norway (34.44) and Sweden (34.09). A H-index of 104 placed the United States above other countries or regions, followed by England (72), Australia (66), Canada (65), and the Netherlands (50) (Figure 2C).

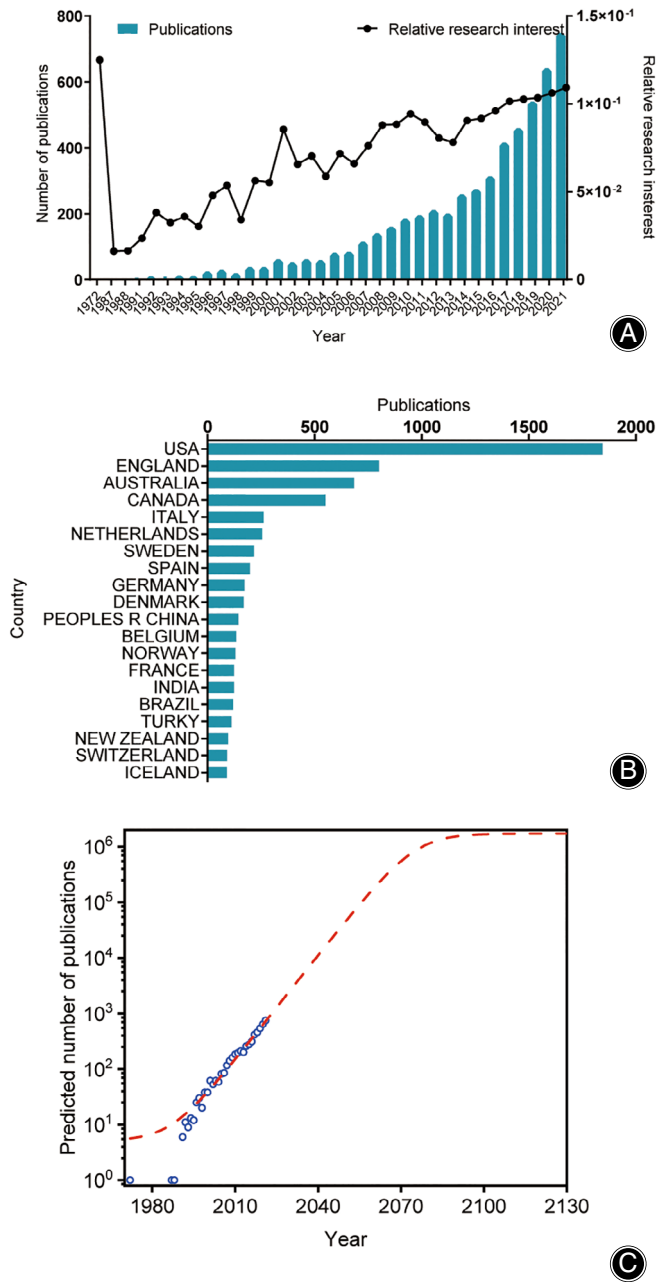
### **Characteristics of Publications**

#### *Journals*

Journals that issued the highest number of articles in musculoskeletal pain management were *BMC Musculoskeletal Disorders* (156), *BMJ Open* (123), *Pain Medicine* (98), *Best Practice & Research Clinical Rheumatology* (91), and *Journal of Occupational Rehabilitation* (91). The top 20 journals are listed in Figure 3A.

#### *Research Orientation*

The top 20 research aspects on musculoskeletal pain management are listed in Figure 3B. The most prominent

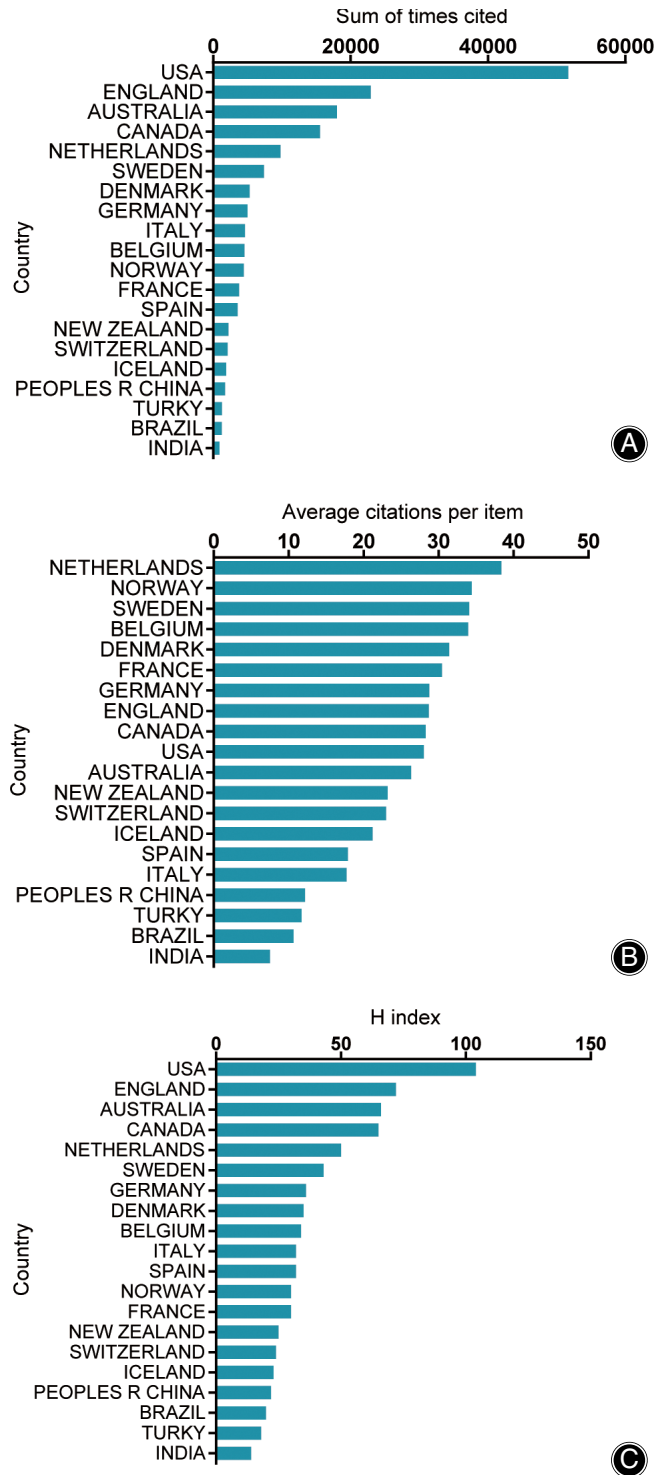


**FIGURE 1** (A) Total number of publications and RRIs associated with musculoskeletal pain management research, with blue bars indicating the number of publications per year and black curves indicating RRIs. (B) Top 20 countries or regions by total number of publications. (C) Model-fitted curves of global trends in publication numbers

research themes are rehabilitation, medicine general internal, orthopaedics, and clinical neurology.

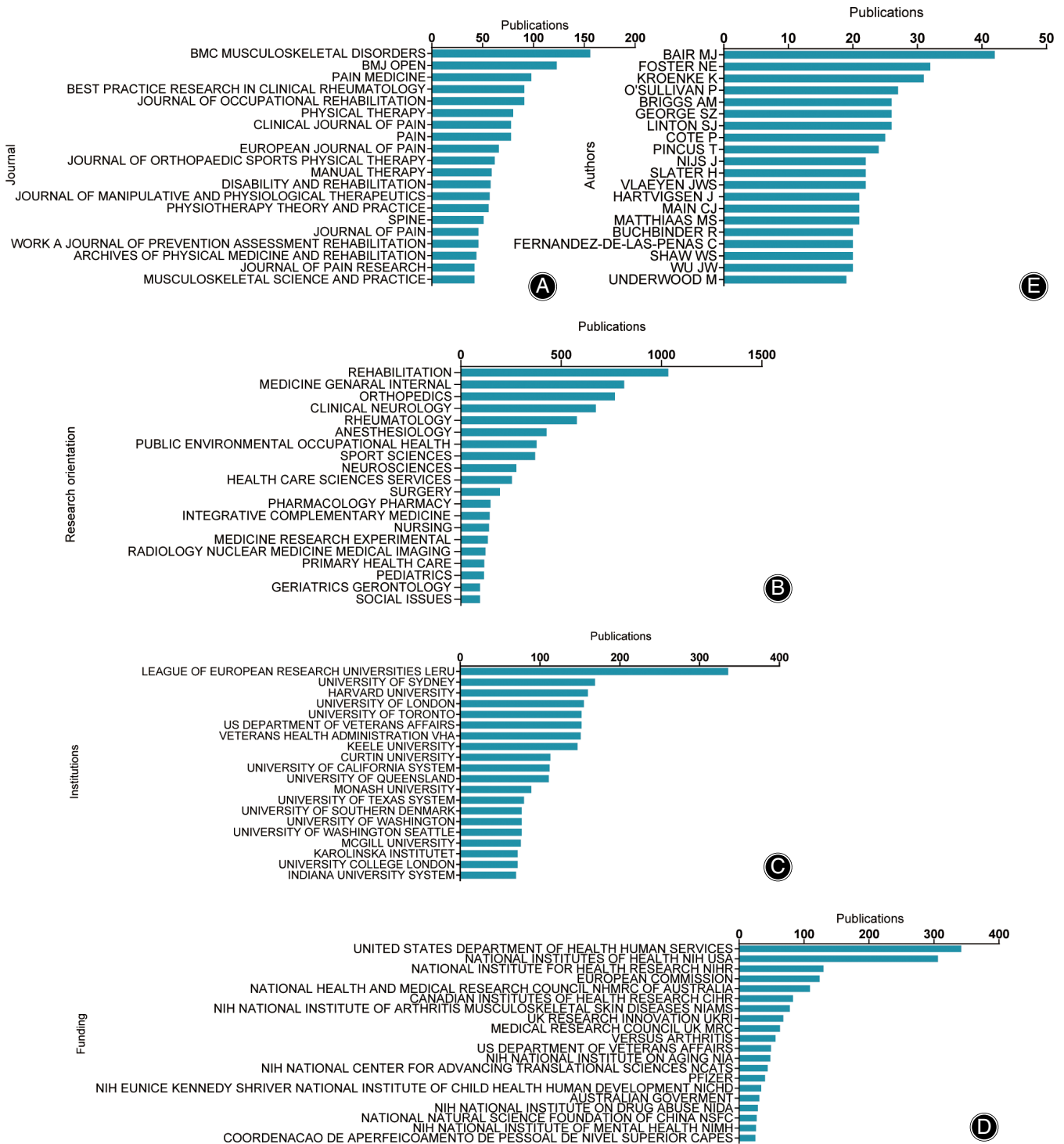
*Institutional Output*

The League of European Research Universities (LERU) published double the number of papers compared to other institutions with 336 papers, followed by the University of Sydney



**FIGURE 2** (A) Top 20 countries or regions by total citations. (B) Top 20 countries or regions by average number of citations per article. (C) Top 20 countries or regions by H-index

(169 papers) and Harvard University (160 papers). The top 20 institutions with the highest number of papers on musculoskeletal pain management are shown in Figure 3C.



**FIGURE 3** (A) Top 20 journals with the highest number of publications on musculoskeletal pain management. (B) Top 20 main research orientations and the number of publications in each orientation. (C) Top 20 institutions of high-impact and the number of their publications. (D) Top 20 institutions sponsoring the most research publications related to musculoskeletal pain management. (E) Top 20 authors with the highest number of publications in this field

### Funding

The top 20 institutions with the highest number of sponsored publications (Figure 3D) have a higher chance to focus on and invest in musculoskeletal pain research. The United States Department of Health and Human Services (342 papers) and National Institutes of Health (NIH United States) (306 papers) both doubled the number of publications sponsored by other organizations. Ranked third, the National Institute for Health Research (NIHR) produced funded articles that were close to a third of the top two institutions (130 papers).

### Authors

The top 20 authors published 487 papers, accounting for 8.89% of all literature in the field (Figure 3E). The most influential author with highest journal output in musculoskeletal pain management was Bair MJ (42), followed by Foster NE (32) and Kroenke K (31). In this analysis, we included all authors on each included publication and did not consider the relative contribution of authors.

### Bibliographic Coupling Analysis

#### Journals

Bibliographic coupling analysis is a well-established method that helps to establish the resemblance relationships in the literature based on the number of references they share. VOSviewer was used to investigate the titles of journals for the full range of publications. A total of 226 journals appeared in the bibliometric map (Figure 4A). The top five journals with the highest total link intensity were: *BMC Musculoskeletal Disorders* (59,078 times), *BMJ Open* (48,367 times), *Physical Therapy* (40,873 times), *Clinical Journal of Pain* (38,698 times), and *Best Practice & Research Clinical Rheumatology* (38,491 times). These journals connected the majority of the articles in musculoskeletal pain management and were the most influential journals.

#### Institutions

A total of 585 institutions were included, where they each had a minimum of five publications in the field, and their publications were analyzed by VOSviewer (Figure 4B). The top five institutions with the highest total connection power were: The University of Sydney (179,940 times), Curtin University (158,660 times), Keele University (138,918 times), University of Toronto (112,645 times), and the University of Queensland (104,534 times).

#### Countries or Regions

A total of 66 countries or regions were included which had a minimum of five publications in the field, and their publications were analyzed by VOSviewer (Figure 5C). The top five countries or regions with the highest total number of links were: the United States (639,542 times), England (457,368 times), Australia

(457,179 times), Canada (344,192 times), and the Netherlands (201,787 times).

### Co-Authorship Analysis

#### Authors

Co-authorship analysis appraises the number of co-authored publications, which is indicative of the connectedness between authors. This study identified 383 authors with a minimum number of five publications in the field, and investigated co-authorship with VOSviewer (Figure 5A). The top five authors with the highest total link power were: Bair MJ (123 times), Cote P (120 times), Yu H (99 times), Taylor-Vaisey A (97 times), and Wong JJ (94 times).

#### Institutions

Publications of the 585 identified institutions were investigated with VOSviewer (Figure 5B). The top five institutions with the highest total connection intensity were: University of Toronto (326 times), University of Sydney (307 times), Curtin University (219 times), Keele University (219 times), and Monash University (187 times).

#### Countries or Regions

Publications from the 66 identified countries or regions were examined with VOSviewer (Figure 5C). The top five countries or regions with the highest total link power were: the United States (782 times), England (743 times), Australia (651 times), Canada (501 times), and Belgium (326 times).

### Co-Citation Analysis

#### Publications

Co-citation analysis is used to suggest relationships between entities based on the number of times they are co-cited. A publication was included if the minimum number of citations exceeded 20. A total of 591 publications were analyzed using VOSviewer (Figure 6A). The top five publications with the highest total link strength were: Vlaeyen *et al.*<sup>26</sup> (2461 times), Sullivan *et al.*<sup>27</sup> (2118 times), Waddell *et al.*<sup>28</sup> (1730 times), Hill *et al.*<sup>29</sup> (1582 times), and Leeuw *et al.*<sup>30</sup> (1518 times).

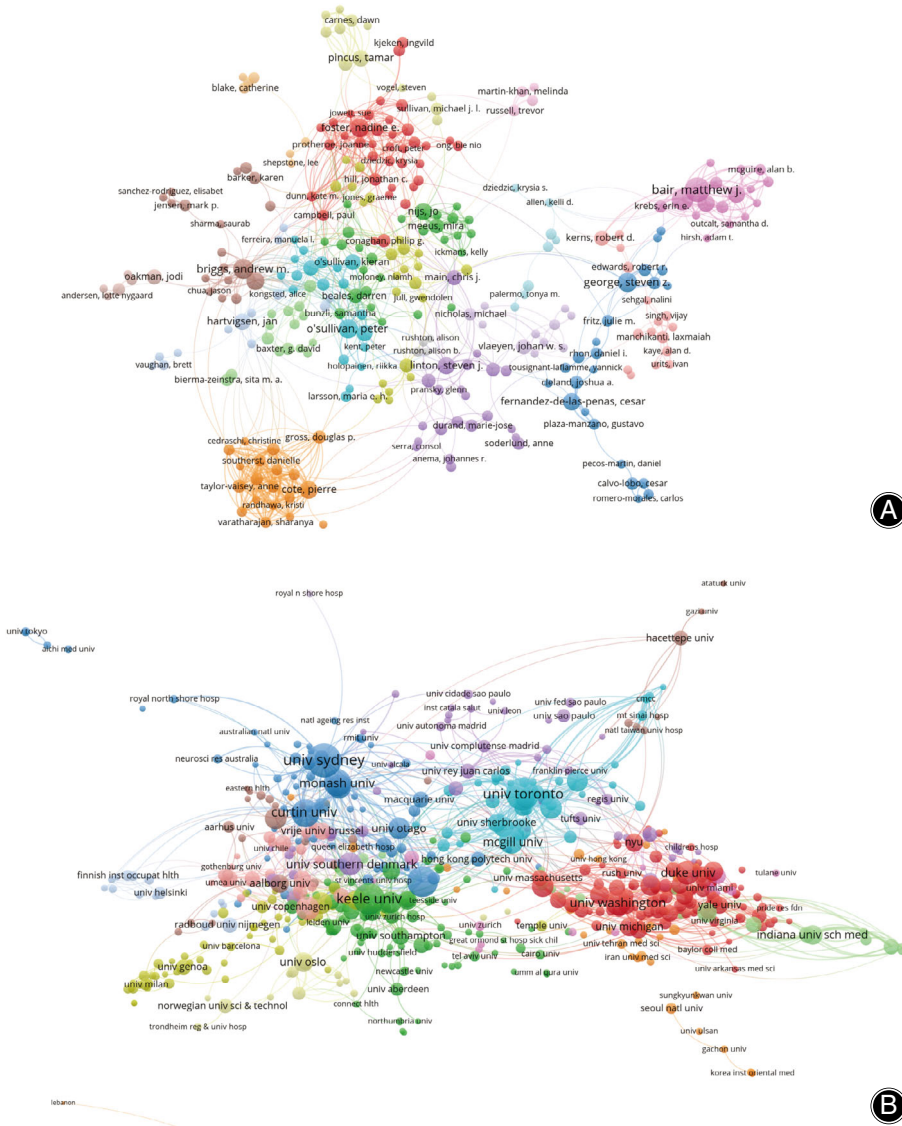
#### Journals

A journal was included for co-citation analysis by VOSviewer if the minimum number of citations for a source exceeded 20. From 1445 journals (Figure 6B), the top five journals with the highest total link strength were: *Pain* (730,450 times), *Spine* (455,025 times), *Clinical Journal of Pain* (242,767 times), *Journal of Pain* (194,858 times), and *Cochrane Database of Systematic Reviews* (181,986 times).

### Co-Occurrence Analysis

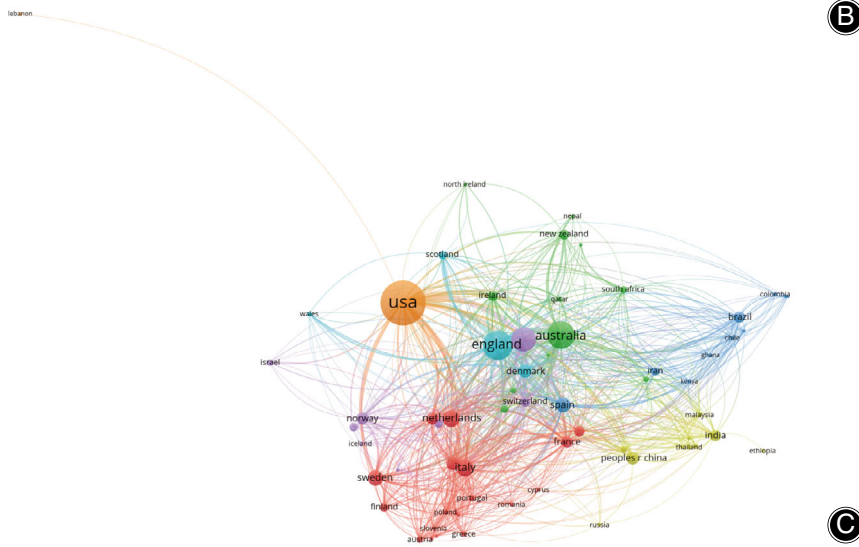
Co-occurrence analysis computes the number of occurrences that phrases appear concurrently within publications in a





(A)

(B)

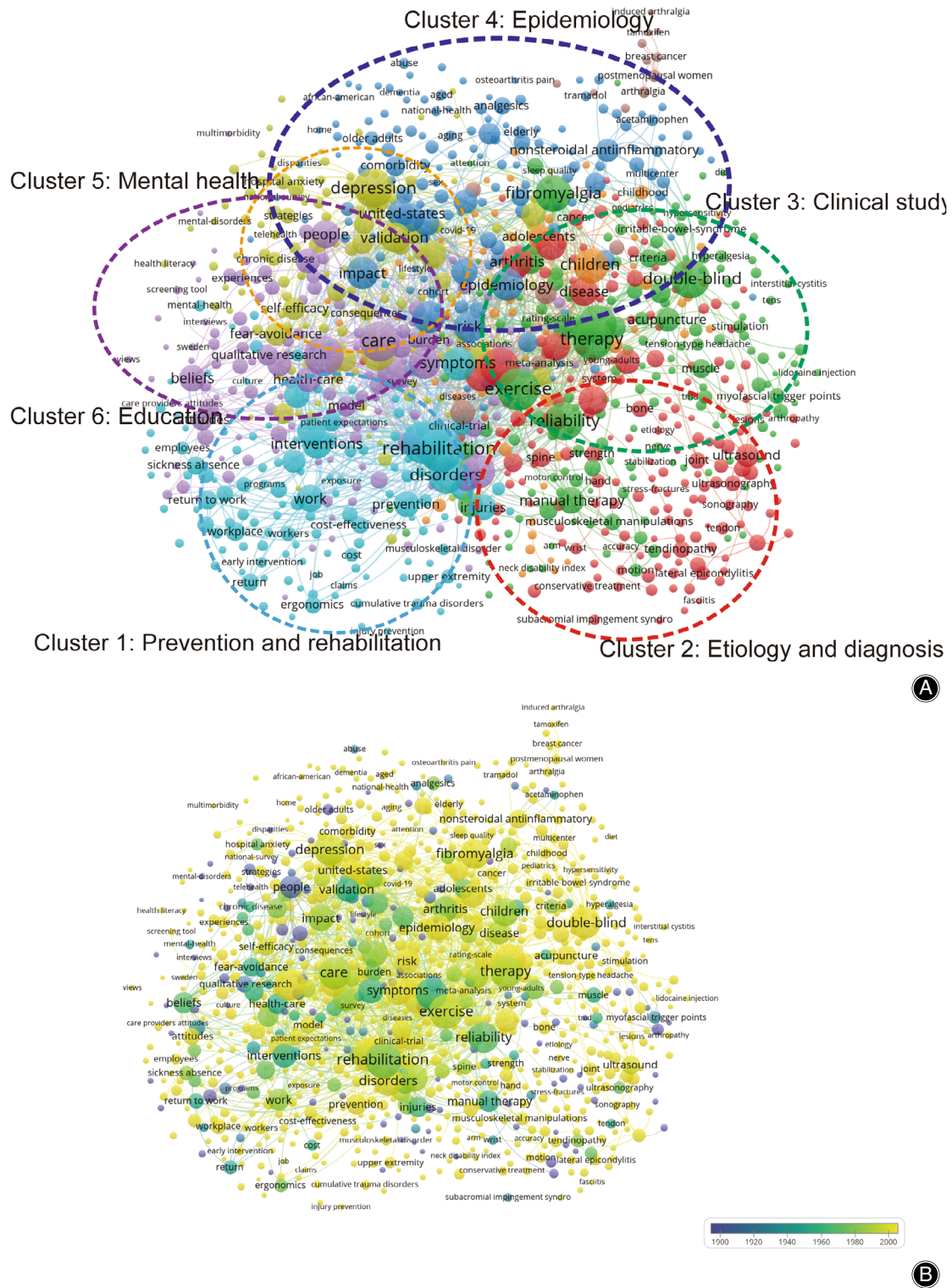


(C)

**FIGURE 5** Co-authorship analysis of global research on musculoskeletal pain management, mapping: (A) 383 identified authors, (B) 585 identified institutions, (C) 66 identified countries or regions. The size of the icons indicates the co-authorship frequency. The line between two icons in the figure indicates that two entities had established collaboration. (Developed from VOSviewer software [Leiden University, Leiden, The Netherlands])







**FIGURE 7** Co-occurrence analysis of musculoskeletal pain management. (A) Mapping of keywords within publications on musculoskeletal pain management. The size of icons indicates the frequency of appearance, and the keywords are classified into six clusters: Prevention and rehabilitation (cyan), Etiology and diagnosis (red), Clinical study (green), Epidemiology (blue), Mental health (yellow), and Education (purple). (B) Distribution of keywords according to their time of appearance. Keywords in purple appeared earlier than those in green, and keywords in yellow appeared later. (Developed from VOSviewer software [Leiden University, Leiden, The Netherlands])

given field.<sup>31</sup> Keywords (with minimum of five occurrences in included publications) related to musculoskeletal pain management were analyzed with VOSviewer (Figure 7A). The 1764 identified keywords can be divided into six groups: “Prevention and rehabilitation,” “Etiology and diagnosis,” “Clinical study,” “Epidemiology,” “Mental health,” and “Education.” In the “Prevention and rehabilitation” cluster, the most commonly used keywords were rehabilitation, disorders, interventions, and work. In “Etiology and diagnosis,” the main keywords were hip, knee, shoulder, and ultrasound. In “Clinical study,” the main keywords were exercise, therapy, double-blind, and reliability. In “Epidemiology,” the main keywords were epidemiology, risk, impact, and population. In “Mental health,” the main keywords were depression, validation, fear-avoidance, and self-efficacy. In “Education,” the main keywords were primary-care, care, guidelines, and beliefs.

Different colors were assigned to keywords according to their average time of appearance in the literature (Figure 6B). Prior to 2000, in the early stages of musculoskeletal pain as an established research area, most studies focused on “Education” and “Etiology and diagnosis.” Recent trends suggest that the categories of “Epidemiology” and “Clinical study” are likely to be studied more in the future.

## Discussion

### *Global Research Trends in Musculoskeletal Pain Management*

The initiation of research interest in musculoskeletal pain management can be dated back to 1972 and has been increasing since. The exponentially rising number of publications in this field has led to 749 published articles in 2021, as recent articles continued to build on from previous literature, with attempts to address unmet challenges or delving deeper into a specific research theme in this field. This flourishing research is presumably due to the increasing prevalence of musculoskeletal conditions in the general population and rising YLD and DALY rates,<sup>7,9</sup> coupled with safety issues around opioid over-reliance,<sup>17</sup> which provoke effort in developing more effective novel therapies that have long-term therapeutic efficacy. However, the number of publications alone is not sufficiently informative for painting an overall picture on the involvement of countries, institutions, journals, and authors worldwide, and is not reflective of the traditional and modern research questions in this topic area. This study resolved some of these viewpoint limitations by providing a comprehensive overall outlook of publication, and envisioned future prospects through union of bibliometric and visualization analyses. RRIs and the logistic regression model in this study have demonstrated a prominent upward trend in publication number pertaining to the future, with more than 1000 studies predicted to be published in 2023.

### *Status and Quality of Publications Worldwide*

#### *Countries or Regions*

The research momentum of different countries or regions was analyzed with various indexes including number of publications, citation frequency and H-index, bibliographic coupling, and co-authorship analysis. The United States, England, Australia, and Canada were the countries or regions yielding the highest number of articles on musculoskeletal pain management. This ranking profile was also seen in total citation frequency, H-index, bibliographic coupling, and co-authorship results, suggesting that these countries or regions had the highest weight in literature volume, research quality, and collaboration, speaking to their leading positions in this field. Moreover, the bibliographic coupling results suggested that publications from these countries or regions are likely to have more power on global research orientation and interest. Interesting results from co-authorship analysis suggested intimate collaboration among English-speaking countries or regions or countries or regions with good English education systems. Hence, language may be an important factor driving effective collaboration in this topic area.

An interesting observation was that the Netherlands also made substantial contributions to the field, reflected by its sixth position in total publication number, and fifth in total citation frequency, H-index, and coupling analysis, but first in average citations per item among countries or regions worldwide. This could imply that papers from the Netherlands were of higher quality and impact. More interestingly, the average citation frequency of the United States, England, Australia, and Canada did not fall into the top seven. It could be that articles from these countries or regions were of relatively lower impact due to the large size of the publication sum. A lower average citation rate was not directly correlated to lower academic impact. In contrast, the H-index was reflective of research impact, as it accounted for both the sum of publications and the average citation rate.

Overall, research in musculoskeletal pain management is led by developed countries. This is possibly due to the intrinsic differences in the academic evaluation system and available research resources (such as funding, infrastructure) between developed and developing countries. First, the bias of academic evaluation frameworks towards quantity rather than quality is striking in developing countries, inevitably driving researchers to accommodate to the evaluation framework for academic rewards and reputation. Researchers may need to accelerate productivity at the cost of individual paper quality. Second, developing countries have relatively smaller research communities, which renders insufficient independence in peer review criteria. This is exacerbated when literature is published in languages other than English, which further limits the number of peer reviewers and increases peer evaluation time. Third, developed countries have more advanced infrastructures and generally higher research funding that not only accelerate the speed and quality of

publications, but also grant them power to set research themes and evaluation criteria. Hence, popular research themes in developed countries are supported while topics more relevant to local contexts or developing countries may be suppressed. Therefore, the high impact of developed countries in the field of musculoskeletal pain research might be partially reinforced by autonomy in research evaluation system and fundings.<sup>32</sup>

#### *Institutions*

The contributions of individual institutions in the field of musculoskeletal pain management were investigated using publication number, bibliographic coupling, and co-authorship analysis. As expected, institutions with top rankings were based in the top high-impact countries or regions: the United States, England, Australia, and Canada. Interestingly, Harvard University from the United States only ranked third in publication number and no US institutions reached the top five in bibliographic coupling and co-authorship analysis. Nevertheless, two US institutions, the United States of Health Human Services and the National Institutes of Health, occupied the top two positions in the number of funded publications, validating our suggestion above that developed countries may provide more research funding in this field. Australia, which ranked third in country impact, had surprisingly high rankings in bibliographic analyses, with three universities occupying the top five positions in both coupling and co-authorship analysis. The two Australian universities that appeared in the top three ranks in both coupling and co-authorship analyses were the University of Sydney and Curtin University. The University of Sydney also ranked second in publication volume, preceded by League of European Research Universities (LERU). England and Canada each contributed to one of the top five rankings in bibliographic analyses.

These results suggest that the University of Sydney is one of the most active pioneers in the field of musculoskeletal pain management. The discrepancies we found between the country and institution rankings reveal that top-notch institutions can amplify the research impact of their native countries in this topic area.

#### *Journals*

The research impacts of specific journals in the field of musculoskeletal pain management were studied using publication number, bibliographic coupling, and co-citation indexes. *BMC Musculoskeletal Disorders* and *BMJ Open* had the highest publication volume and coupling link power. *Best Practice & Research Clinical Rheumatology* was also a high-achieving journal as its publication volume ranked fourth and coupling connection strength ranked fifth. Interestingly, these journals disappeared in the top five co-citation ranking.

The mismatch between coupling and co-citation rankings for top journals may reflect the level of unique or novel arguments in the published literature. Since coupling analysis

is a measure of links between publications that reference the same articles, high similarity may result mainly from common citations for background knowledge of musculoskeletal pain management, rather than from articles with novel arguments, as a high proportion of references are used for general information. In contrast, co-citation is a metric for links between publications that have been cited together in other journals, where there is a greater chance that journals are cited together due to their unique propositions rather than common knowledge in the field. Therefore, journals with high co-citation link strength may be associated with higher degrees of novel discussions.

Nearly all top-ranking journals in coupling and co-citation analyses were specialized journals, either in pain (*Pain Medicine*, *Clinical Journal of Pain*, *Pain*, *Journal of Pain*) or musculoskeletal-related research (*BMC Musculoskeletal Disorders*, *Best Practice Research in Clinical Rheumatology*, *Journal of Occupational Rehabilitation*, *Spine*), highlighting the importance of expertise in journal impacts.

Bair MJ, Foster NE, and Kroenke K are the top three authors with the most publications in this field. The top 20 authors may be considered pioneers in musculoskeletal pain management. Their future research may have a substantial impact on the development of the field and should be closely followed to keep abreast of the latest developments.

#### *Future Prospects*

Co-occurrence network maps bundled by topic themes and publication time can be used to examine the mainstream research topics and predict future prospects in the field of musculoskeletal pain management. The prevailing themes in this field can be broadly categorized into six clusters, each enclosing a family of sub-themes. Field-specific themes orchestrated by publication year open a window into future research directions. Keywords color-coded with yellow signifying themes emerging after 2000 mostly fell under the “Epidemiology” and “Clinical study” categories, while keywords colored towards the blue end of the color scope signifying older topics fell under the “Education” and “Etiology and diagnosis” groups. The current focus of publications suggest that research in musculoskeletal pain management is orienting towards double-blinded clinical studies, fibromyalgia, qualitative research, and epidemiology.

Musculoskeletal pain imposes a considerable social burden in many countries due to its chronic disabling nature.<sup>33,34</sup> The results of double-blind treatment studies may be able to help address this problem in the future, and as research develops, new and more effective therapies may become available from opioids,<sup>35</sup> to oral NSAIDs,<sup>36,37</sup> topical NSAIDs,<sup>38,39</sup> antidepressants,<sup>40,41</sup> Chinese massage physiotherapy,<sup>16</sup> acupuncture therapy,<sup>15</sup> exercise therapy,<sup>42</sup> and surgical treatment.<sup>43</sup> More research is needed to find individualized therapies suitable for different characteristics of pain, and to translate these approaches into clinical practice. The epidemiology of musculoskeletal pain is also gaining attention as the global population ages and the

incidence of musculoskeletal pain continues to rise with a significant economic burden.<sup>5-8</sup> Studies have concluded that the occurrence of musculoskeletal pain is associated with age, gender, education, and body mass index,<sup>44</sup> and data from 2011 indicate that the prevalence in China (31.73%)<sup>45</sup> is significantly higher than that in the United States (20.4%),<sup>46</sup> France (20.2%),<sup>47</sup> Japan (17.5%),<sup>48</sup> and other countries.<sup>49</sup> A systematic review suggested that the prevalence of pain ranged from 0% to 24% globally.<sup>50</sup> Studies have estimated huge economic losses due to musculoskeletal pain, which in China alone were 353–614 billion yuan, 1052–1327 billion yuan, and 959–1439 billion yuan in 2011, 2013, and 2015, respectively.<sup>45</sup> Currently, investigating the epidemiology of musculoskeletal pain remains the focus of this research area.

Based on our findings, a growing number of publications suggest that the management of musculoskeletal pain requires increasing and coordinated attention worldwide, and further research by more investigators is still needed. Bibliometric and visual analyses can provide researchers with knowledge of leading countries or regions, authors, and institutions in the field. With this information, researchers can have “primary access” to advanced knowledge and future discoveries. In addition, co-occurrence analysis overlaid with a visual map specifying hot spots and future research directions can help funding agencies develop more rational investment plans and inform healthcare policy.

### Strengths and Limitations

Through the use of bibliometrics and visualization analysis, this study provides insight into current research trends on musculoskeletal pain management worldwide. However, it is important to consider a few limitations in the interpretation of our results. First, database discrepancies are a limitation of bibliometric analysis. It is well-known that the publications of major databases such as WoS, PubMed, Embase, and Cochrane Library are different. Considering the baseline level of the articles included in the literature database and the previous research<sup>51-53</sup> conducted by the team, we chose to use the SCIE databases for literature search. Some publications may have been missed in our analysis due to database bias. In addition, we only included English-language studies based on WoS, while non-English publications have been excluded. Considering the large number of patients with musculoskeletal pain in primarily non-English speaking countries, including many countries in Asia, the exclusion of non-English publications may lead to language bias. Second, there may be discrepancies between the results of the bibliometric analysis and realistic study conditions. For example, some recently published high-quality papers may not be valued due to low citation frequency. Therefore, increasing attention may need to be diverted to recent publications and non-English publications in routine research on this topic area.

Also, worth noting is that although publication quantity and citation-based indexes including coupling and co-citation picture the overall profile of current research contributions in the field, they are not direct representations of the true quality

or impact of the published journals, institutions, and countries. Small groups of researchers that focused on uncommon themes for local contexts may deviate from mainstream research attention, but their work is nevertheless significant in their local contexts, although the impact of their publications may be diminished with citation-based indicators.

### Conclusion

This study shows the current status and trends in musculoskeletal pain management worldwide. The United States is the leading country in number of publications and total citation frequency. The journal *BMC Musculoskeletal Disorders* has published the highest number of papers on this topic. It can be predicted that the number of papers will continue to rise in the next decade. In particular, studies on high-quality RCTs and epidemiology of musculoskeletal pain will likely be the next subject areas to receive more research attention.

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### Declarations

### Author Contributions

Project conceptualization: Mei FY, Xing D, and Li ZC.  
Study design: Mei FY and Xing D.  
Data collection/validation: Mei FY and Xing D.  
Data analysis: Mei FY, Dong SJ, and Xing D.  
Result interpretation: Mei FY, Li JJ, and Xing D.  
Reporting and editing: Mei FY, Li JJ, Xing D, and Li ZC.  
Final approval of the version to be submitted: Mei FY, Li JJ, Xing D, and Li ZC.  
Project guarantor: Xing D and Li ZC.  
All authors have read and approved the manuscript.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing Interests

The authors declare no competing interests.

### Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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