

# Research Trends and Foci in Osteoarthritis Pain from 2012 to 2022: Bibliometric and Visualization Study

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**Background:** Osteoarthritis (OA) is a painful and complex joint disease. The unique mechanisms and potential interventions of OA-induced pain have attracted researchers' attention in recent years. Bibliometric and visualization analysis is a comprehensive scientific method that integrates mathematical and statistical approaches to explore research priorities in a specific field. However, there are few studies on OA pain using bibliometric analysis.

**Purpose:** This study aimed to explore research trends and hotspots in OA pain research field, offer practical guidance to researchers looking for top-notch scholars/institutions/countries, and provide suggestions for journal submissions by analyzing the existing literature.

**Methods:** Raw data were extracted from Web of Science Core Collection. Microsoft Excel, the R package "bibliometrix", VOSviewer and CiteSpace software were used to analyze data and visualize relevant results.

**Results:** A total of 2493 articles were included for further bibliometric and visualization analysis. During the investigated period, 2021 with 343 publications was the most productive year. Fillingim, Roger B. and Bennell, Kim L. with 32 articles were the most productive authors. Most publications were from the USA (797 articles, 20,727 citations). Rehabilitation and treatment of OA pain were the hotspots in OA pain research area. The top-contributing journal was *Osteoarthritis and Cartilage*. Boston University (91 articles; 4050 citations) was the most active institution.

**Conclusion:** The total publications of OA pain generally increasing over the time in the last decade, and the escalating rate remained a high level. This is the first comprehensive bibliometric study in OA pain research field, and it will offer practical guidance to researchers in this field.

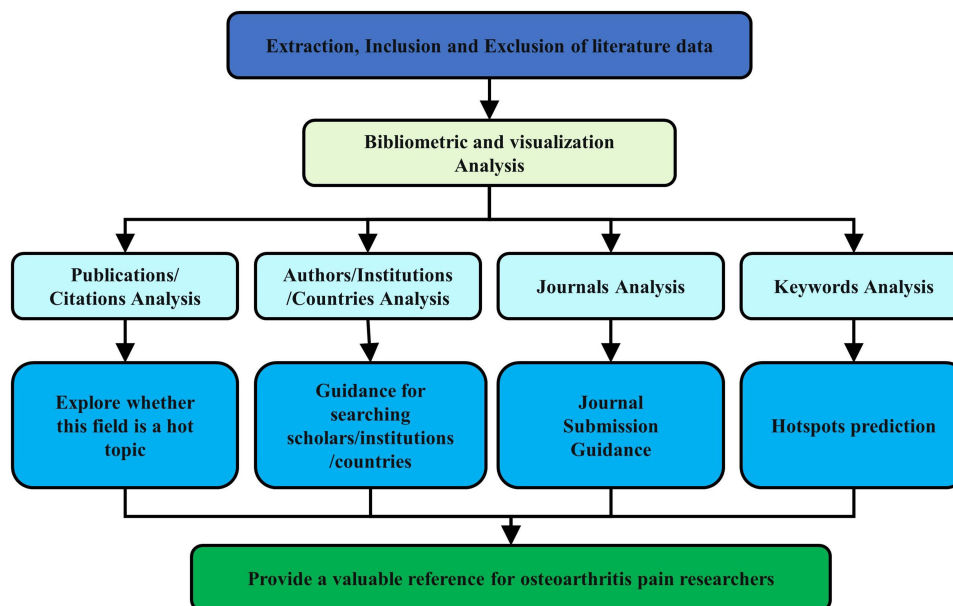
**Keywords:** osteoarthritis pain, bibliometric analysis, research trends, VOSviewer, CiteSpace

## Introduction

Osteoarthritis (OA) is a common disease which leads to disability by causing multiple joint injury including knee, hand and hip.<sup>1</sup> Systematic analysis has demonstrated a growing number of patients diagnosed with OA, with its incidence increasing over the past few decades.<sup>2</sup> In certain regions, OA affects more than 10% of the population,<sup>3,4</sup> causing significant suffering for patients and imposing a substantial economic burden on families and governments.

OA pain, the most common symptom of OA, has attracted researchers' attention in recent years. OA is considered as a whole-joint<sup>5</sup> disease, cartilage, subchondral bone, and synovium probably all have key roles in disease pathogenesis.<sup>6</sup> Pain in OA may be due to local and central sensitization of pain pathways causing normal stimuli to be perceived as painful.<sup>7</sup> Periosteum, subchondral bone, periosteum, ligaments, synovium, and the joint capsule are all densely innervated and contain nerve endings that could be the potential source of nociceptive stimuli in OA.<sup>8</sup>

## Graphical Abstract



Risk factors of OA pain have been emphasized. A multiple logistic regression suggests that body mass index (BMI), increasing age, suffering years of OA and many other factors can be used to predict the flare of knee OA pain.<sup>9</sup> Also, some of the risk factors mentioned above are crisis of OA itself,<sup>10</sup> which indicates the pain can hardly be avoided when OA occurs. These risk factors generated OA pain by different mechanisms. Studies have shown that sources of OA pain can be nociceptive, inflammatory and neurogenic,<sup>11</sup> and concrete mechanisms include the sensitization of afferent neurons in OA joint by nerve growth factor, cytokine and neuronal injury.<sup>11,12</sup> Clinical phenotypes of OA pain also gained increasing attraction as it can result in different health outcomes.<sup>13</sup> Different subtypes of OA pain have been classified by various clinical indicators, as well as diverse respond to treatment,<sup>14,15</sup> while exploration of phenotypes and their clinical significance is still not enough.

In order to alleviate the pain and disability of joint function caused by OA, diverse therapies have been carried out. Pharmacotherapy occupies the most important position, demonstrated by the extensive utilization of nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen and opioids.<sup>16</sup> However, traditional drugs gradually show their shortages, such as gastrointestinal complications, reduced liver function and headache, which activates the generation of novel pharmacotherapy.<sup>17</sup> Antibodies against neuron growth factor and inflammatory cytokines prevent the activation of OA pain, while ion channels appear on the stage as the driving effect of hyperexcitability of neuron.<sup>18,19</sup> Besides, surgical treatment such as total knee replacement shows positive effects, and more desirable outcomes are seen when it is combined with non-surgical therapies.<sup>20</sup> Osteotomy and cooled radio frequency ablation are also indicated to perform expectable efficacy.<sup>21,22</sup> Furthermore, clinical trials tell us that physical activity and massage can lead to recovery of body function and anesis of OA pain.<sup>23,24</sup>

In consideration of the current status of OA pain research, a growing number of scientists have found that bibliometrics can be applied in this field. However, most of present bibliometric analysis lay emphasis on the pain management and recovery instead of the overall research status of OA pain.<sup>25-27</sup> In order to offer practical guidance to researchers who focused on OA pain research, this study conducted a bibliometric and visualization analysis in this field.

## Methods

### Data Source and Search Strategy

Existing literature data were collected from the Science Citation Index Expanded (SCI-expanded) of Web of Science (WOS) Core Collection database on 31 December 2022. The publications time of the published articles ranged from 2012 to 2022. The search strategy was as follow: [TI = (Osteoarthritis OR OA) AND (pain OR painful)] AND [PY = (2012-01-01 to 2022-12-31)] (TI: title, PY: Publication Year).

### Inclusion Criteria and Exclusion Criteria

Inclusion Criteria and Exclusion Criteria is represented in Figure 1. English is the chosen language, and four types of publications were included: articles, review articles, editorial materials and letters. A total of 4054 articles were identified

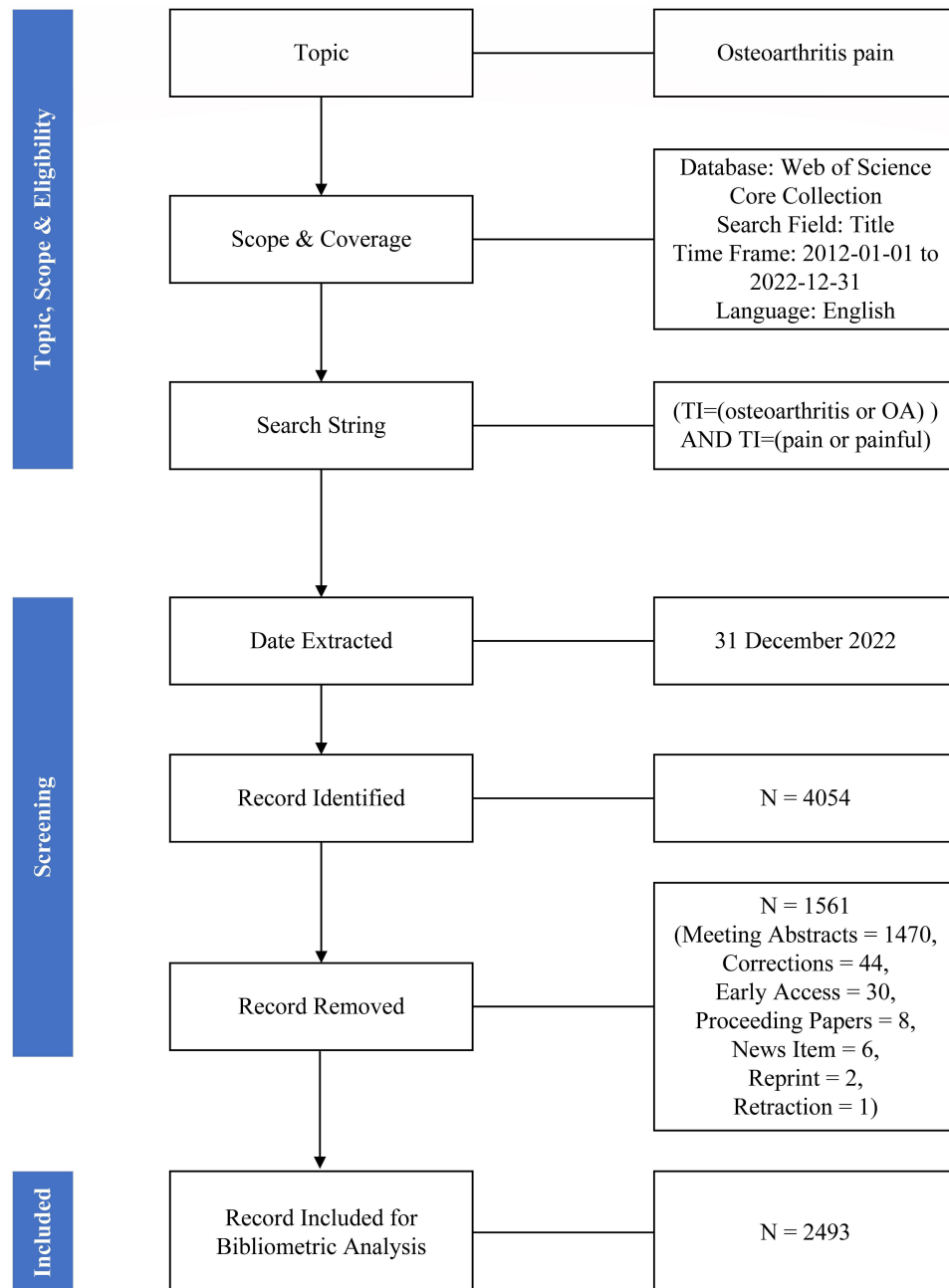


Figure 1 Flow diagram of search strategy.

from the Web of Science Core Collection. Meeting abstracts, corrections, proceedings papers and new items were excluded. Finally, after excluding 1561 articles, 2493 articles were included.

## Data Extraction

We obtained bibliometric indicators by calculating the number of publications, journals, references citations, extracted H-index and keywords. The H-index means that a journal or researcher has at least H published papers that are cited at least H times per paper. Former indicators were produced by for kinds of software in this study:

- (I) Microsoft Excel 2019 for calculating the frequencies and percentage of the published materials;
- (II) VOSviewer (version 1.6.17) for the bibliometric networks;
- (III) R4.2.1 and bibliometrix package was used to calculate the citations metrics;<sup>28</sup>
- (IV) CiteSpace (version 5.1.R6) for Keywords citation burst map.

## Results

### Description of Retrieved Published Articles

A total of 2493 articles were identified from the WOS database, including 2053 Article-type articles, 258 Review-type articles, along with 97 editorial materials, 85 letters (Table 1).

### Temporal Trends of Citations and Publications

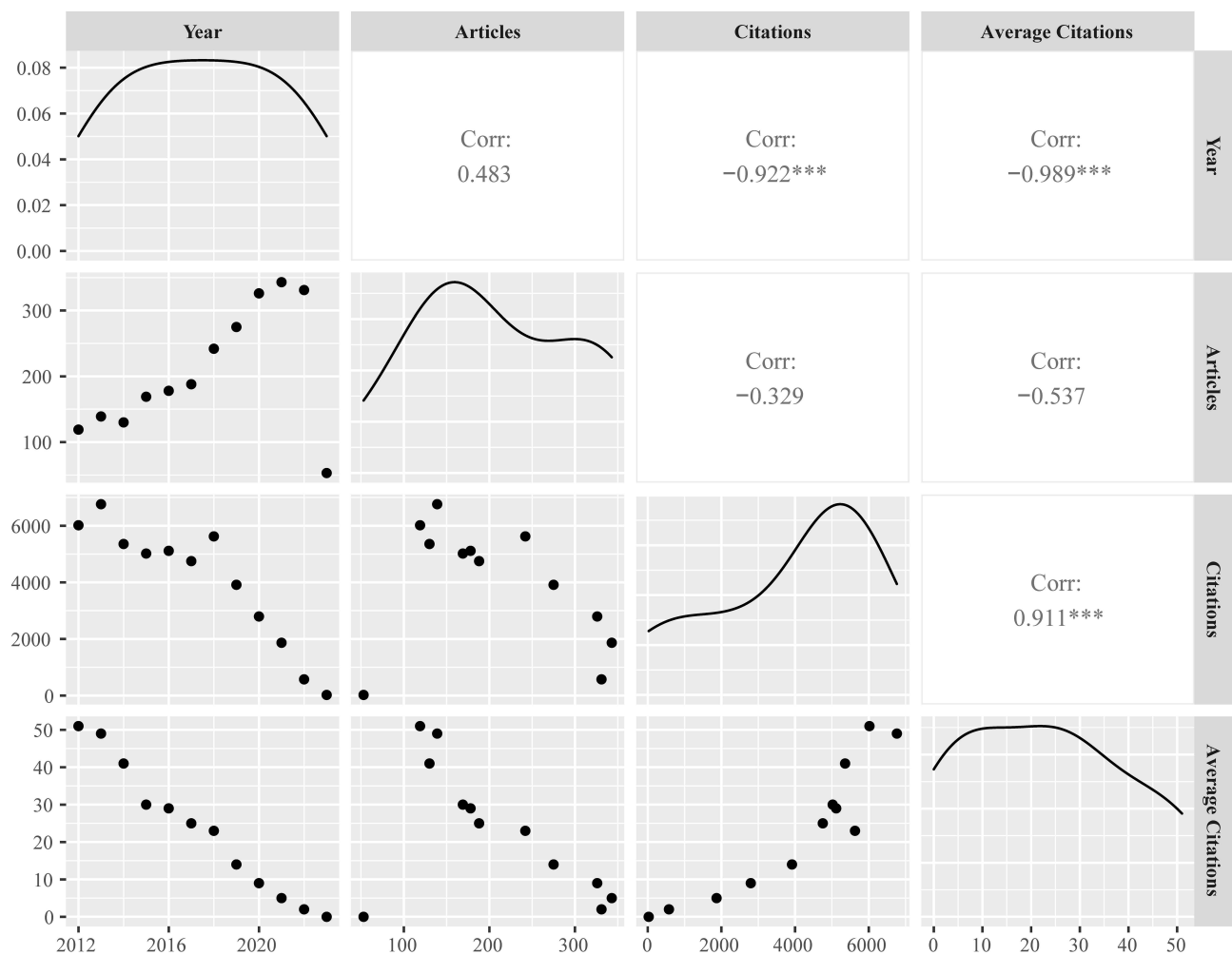
According to Figure 2, the overall trend of the number of productions has continued to increase. The number of publications which peaked in 2021 (343) has become nearly three times more than the number of them in 2012 (119). The number of citations kept reducing during the investigated years, except for an uptrend in 2018, and average citations showed the largest number was 51 in 2012, while Figure 3 shows that the total average citations per article is 19. The specific number of annual scientific productions and citations are shown in Table 2. The results of Pearson correlation analysis from RStudio indicated that the number of publications showed positive correlation with year, with a Pearson correlation coefficient of 0.483, and the number of citations showed passive correlation with year, with a Pearson correlation coefficient of  $-0.922$  ( $p < 0.01$ ). Average citations per year showed obvious passive correlation with year ( $-0.989$ ), number of publications ( $-0.537$ ) and positive correlation with number of citations (0.911).

### Productive Authors and Co-Authorship

A total of 11,041 authors were contained in the documents included in this study. Table 3 describes the Top 10 authors distributed by publications and citations. Fillingim, Roger B. (University of Florida, USA) and Bennell, Kim L. (The University of Melbourne, Australia) both published 32 articles, and they tied for the first place ranked by publications in OA pain field. Fillingim, Roger B. completed 1 of 32 articles as the first author, while Bennell, Kim L. completed 9 of the 30 articles as the first author. Actually, Bennell, Kim L had the highest Dominance Factor (DF) among the top 10 authors. Authors distributed by citations showed difference compared with authors distributed by publications, Neogi, T. with a total of 1049 citations were the first in the rank. Malfait, Anne-Marie (Rush University, USA) with a total of 984 citations was in the second place but had higher H-index than Neogi, T. Bennell, Kim L. with a total of 699 citations shared the highest H-index (13) with Malfait, Anne-Marie. VOSviewer software was used to analyze the co-authorship

**Table 1** Types of Retrieved Documents (2012-01-01 to 2022-12-31)

Document Type	Total Publications	Percentage (%)
Articles	2053	82.35
Review Articles	258	10.35
Editorial Materials	97	3.89
Letters	85	3.41
Total	2493	100

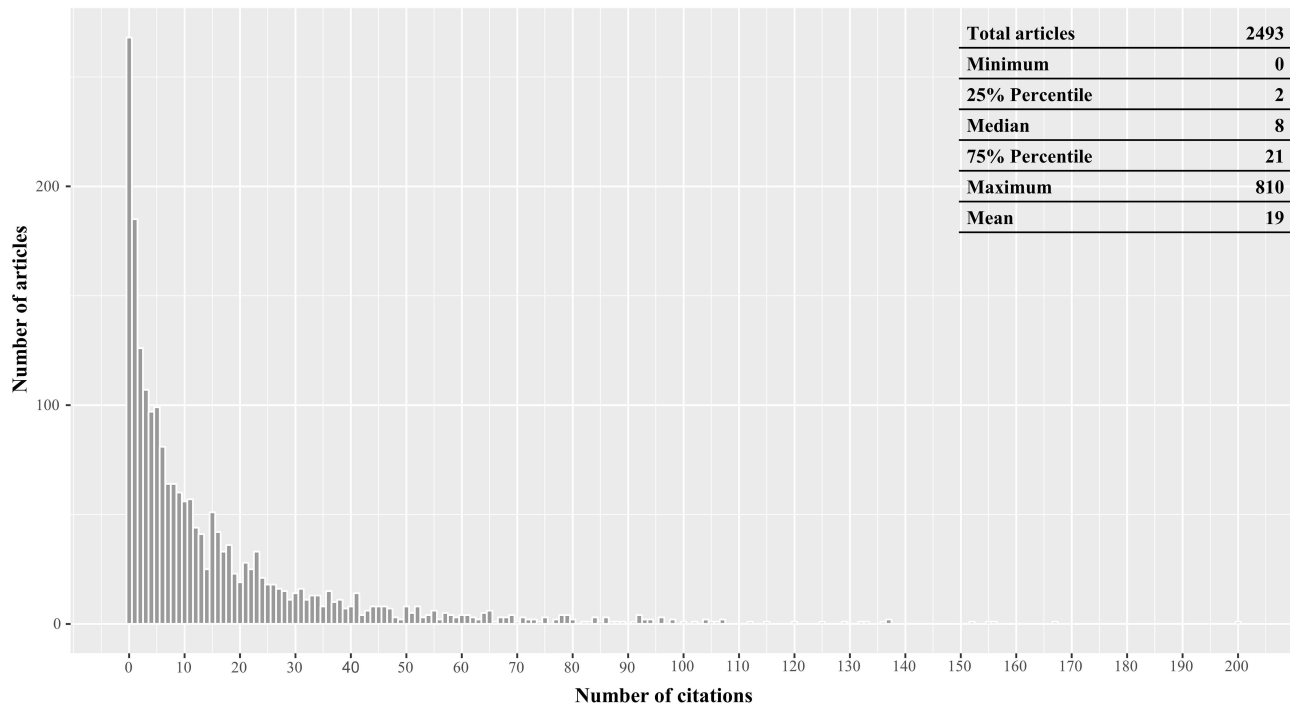


**Figure 2** Correlation analysis between citation and publication metric. \*\*\* $p < 0.01$ .

and construct a visual map to show influential researchers and potential collaborators (Figure 4), the larger the author's tag, the more articles the author has published. The thickness of the lines between each author is proportional to the number of times they appear together in the same document. The thicker the lines between tags, the more times they appear in the same item.

## Geographical Distribution of Publications and Citations

A total of 82 countries was included in this study, research output was mainly concentrated in the United States, England, China, Australia and a few other countries. The top 10 countries in terms of research output were respectively the USA (797 articles, 20,727 citations), England (310 articles, 9412 citations), China (281 articles, 3547 citations), Australia (254 articles, 5884 citations), Canada (186 articles, 4664 citations), Japan (140 articles, 1952 citations), Netherlands (128 articles, 2560 citations), Denmark (105 articles, 3288 citations), Spain (98 articles, 2494 citations), Italy (97 articles, 1691 citations). All these results are available in Table 4. Countries such as Denmark (31 average citations) and England (30 average citations) seemed more popular in OA pain research field. The USA, as the leading authority in this field, was the country that conducts the most scientific cooperation with other countries (Figure 5). Countries of corresponding authors are ranked by RStudio, which identified articles as SCP as long as their corresponding authors are from one country. Following this principle, Korea had almost no cooperative relationship with other countries (Figure 6). Although Japan ranked eighth in



**Figure 3** Articles–citations histogram.

publication, Japanese articles receive fewer citations and do not seem to receive much attention from other countries worldwide.

## Keywords Analysis

### Research Foci Summarized from Keywords

The frequency of a keyword’s occurrence makes a positive correlation with the degree which the keyword is of interest to researchers. The more frequently a keyword appears, the more likely it is to be a research hotspot in the field. VOSviewer was used to calculate keywords from 2493 retrieved documents, the total number of Author Keywords (DE) and Author Keywords-Plus (ID) was 3343 and 3560, respectively. In Author Keywords (DE) group, the keywords used at high frequency were: “Osteoarthritis”, “Pain”, “Knee Osteoarthritis”, “Knee”, “Chronic Pain”, “Knee Pain”, “Exercise”, “Meta-analysis”, “Inflammation”, “Quality of Life”. But in Author Keywords-Plus (ID) group, “Hip”, “Management”, “Knee Osteoarthritis”, “Prevalence”, “Arthritis”, “Efficacy”, “Older-adults”, “Double-blind”, “Association”, “Disability”

**Table 2** Annual Scientific Productions and Citations

Year	Articles	Citations	Average Citations
2012	119	6020	51
2013	139	6764	49
2014	130	5358	41
2015	169	5021	30
2016	178	5116	29
2017	188	4752	25
2018	242	5627	23
2019	275	3916	14
2020	326	2797	9
2021	343	1868	5
2022	331	575	2

**Table 3** Top 10 Authors Distributed by Publications and Citations

Rank	Author	Publications	Country	Institution	First Author	DF	DF Rank	Author	Total Citations	Country	Institution	H-Index	Publications	PY_Start
1	Fillingim, Roger B.	32	USA	University of Florida	1	0.03	6	Neogi, T.	1049	USA	Boston University	7	12	2013
2	Bennell, Kim L.	32	Australia	The University of Melbourne	9	0.28	1	Malfait, Anne-Marie	984	USA	Rush University	15	19	2012
3	Hunter, David J.	29	Australia	The University of Sydney	2	0.07	3	Conaghan, Philip G.	891	England	University of Leeds	13	22	2012
4	Neogi, Tuhina	24	USA	Boston University	2	0.08	4	Wylde, Vikki	802	England	University of Bristol	3	3	2012
5	Felson, David T.	23	USA	Boston University	1	0.04	7	Keefe, Francis J.	794	USA	Duke University	14	22	2012
6	Staud, Roland	22	USA	University of Florida	0	0.00	8	Price, Lori Lyn	787	USA	Tufts Medical Center	6	9	2013
7	Keefe, Francis J.	22	USA	Duke University	0	0.00	9	Bennell, Kim L.	775	Australia	The University of Melbourne	15	32	2012
8	Conaghan, Philip G.	22	England	University of Leeds	6	0.27	2	Arendt-Nielsen, L.	769	Denmark	Aalborg University	9	10	2012
9	Arendt-Nielsen, Lars	21	Denmark	Aalborg University	2	0.10	5	Dieppe, Paul	765	England	University of Exeter	2	2	2012
10	Sibille, Kimberly T.	20	USA	University of Florida	0	0.00	10	Felson, David T.	757	USA	Boston University	13	23	2013

**Abbreviations:** DF, dominance factor, the frequency with which the author is the first author of a co-authored article; TC, total citations of the author; PY\_start, the year that researcher published his first article during the investigated period.

**Table 4** Top 10 Countries Distributed by Publications and Citations

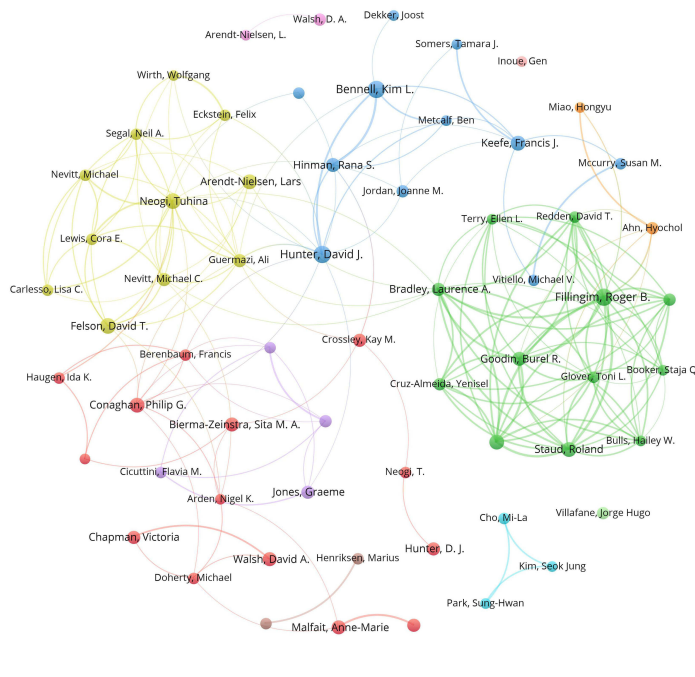
Ranked by Publications	Country	Articles	Citations	Average Citations (AC)	Corresponding Author (CA)			/2493%	Rank by AC
					SCP	MCP	Non-CA		
1	USA	797	20,727	26	475	115	207	31.97%	3
2	England	310	9412	30	236	41	33	12.43%	2
3	China	281	3547	13	121	70	90	11.27%	10
4	Australia	254	5884	23	84	80	90	10.19%	6
5	Canada	186	4664	25	115	15	56	7.46%	5
6	Japan	140	1952	14	78	40	22	5.62%	9
7	Netherlands	128	2560	20	69	29	30	5.13%	7
8	Denmark	105	3288	31	67	10	28	4.21%	1
9	Spain	98	2494	25	42	33	23	3.93%	4
10	Italy	97	1691	17	57	14	26	3.89%	8

**Abbreviations:** SCP, single-country publications; MCP, multiple-country publications.

occurred more frequently. The frequency results are presented in Table 5. To further demonstrate the hot keywords for each year from January 1, 2012 to December 31, 2022, the top 50 keywords citation burst map (Figure 7) was built to exhibit the annual hotspots.

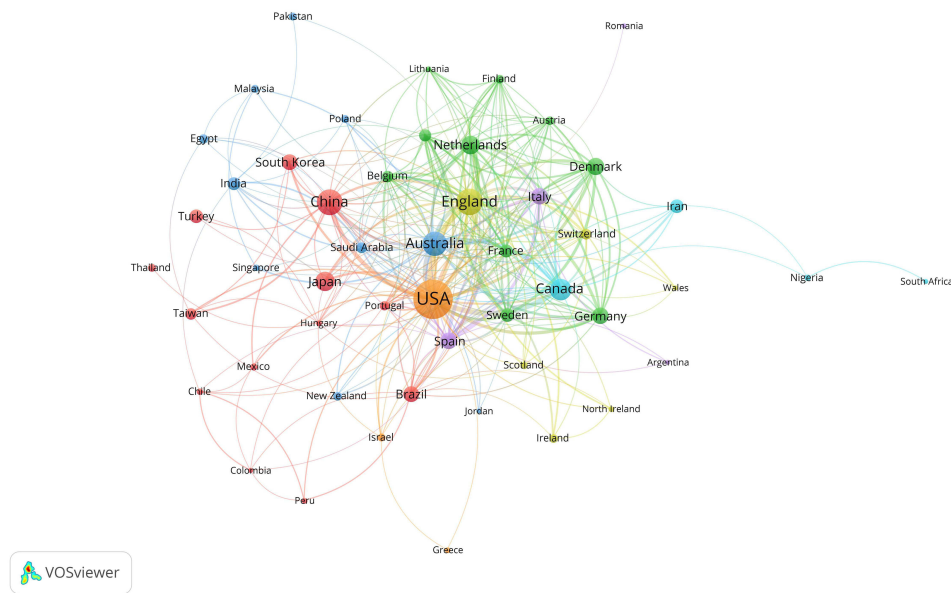
### Subdisciplines Summarized from Keywords Co-Occurrence Map

Mapping with the VOSviewer technique of author keywords with minimum occurrences of 20 divided keywords into 4 clusters, which was expressed as circles in four different colors in Figure 8. Specifically, the red cluster concentrated on “Clinical feature, Diagnosis, Therapy and Rehabilitation”, which can be concluded by knee osteoarthritis, hip osteoarthritis, knee pain, hip pain, chronic pain, low back pain, gait analysis, quantitative sensory testing, physiotherapy. Keywords in yellow cluster, such as magnetic resonance imaging, mri, ultrasonography, ultrasound were related to “Imageological Examination”. Keywords in green cluster can be concluded as “Prognosis”, proved by keywords like quality of life, sleep, disability, obesity and depression. Keywords in blue

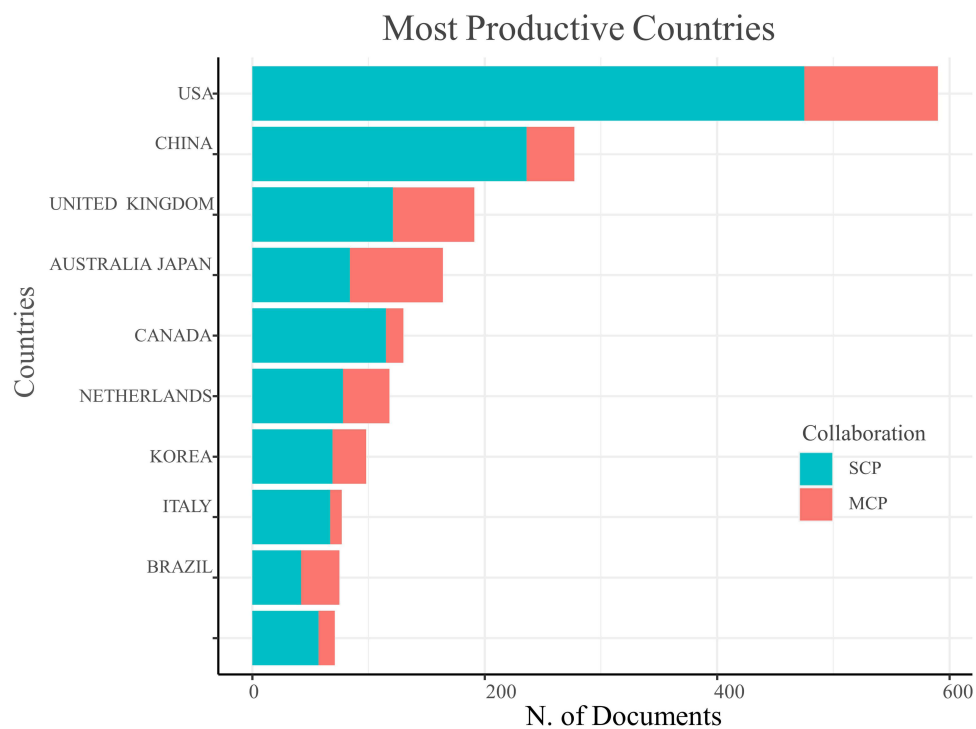


**Figure 4** Network visualization map of co-authorship in osteoarthritis pain research.





**Figure 5** Network visualization map of international collaboration among countries.



**Figure 6** Publication distributed by single-country publications (SCP) and multiple-country publications (MCP).  
**Abbreviations:** SCP, single country publications; MCP, multiple country publications.

clusters, such as monosodium iodoacetate, inflammation, nerve growth factor and hyaluronic acid were related to the topic “Pathogenesis”. Pain, Knee osteoarthritis, and osteoarthritis were the first three keywords which frequently appeared in early 2012–2021, but with the development of OA pain field, their subdisciplines became more and more (Figure 9).

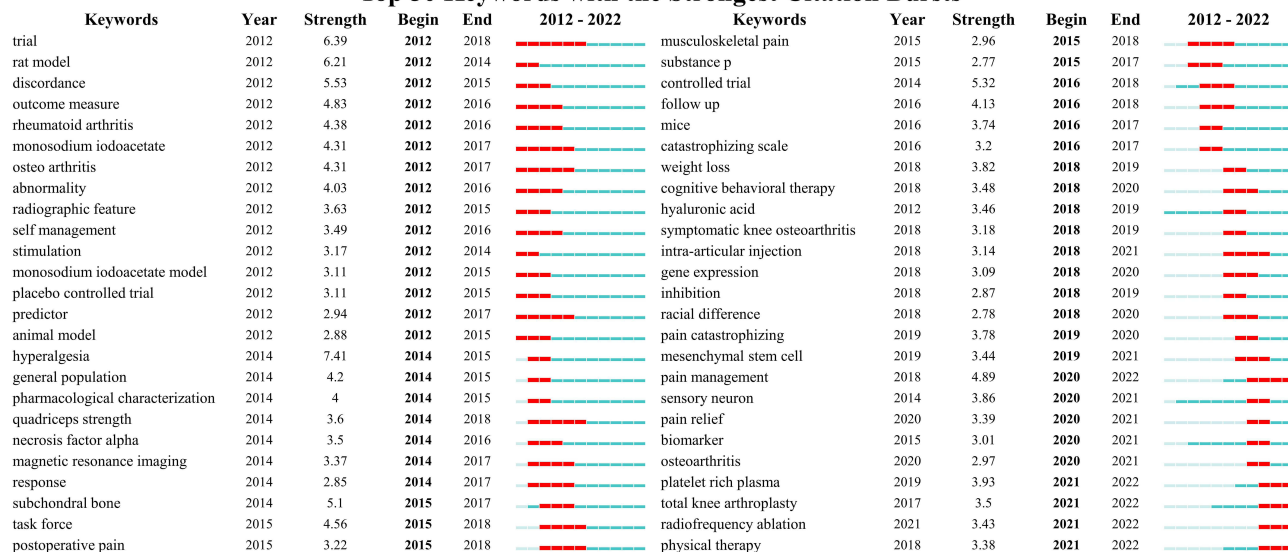
**Table 5** Keywords by Frequency

Rank	Author Keywords (DE)	Frequency	Keywords-Plus (ID)	Frequency
1	Osteoarthritis	975	Hip	466
2	Pain	653	Management	369
3	Knee Osteoarthritis	423	Knee Osteoarthritis	303
4	Knee	203	Prevalence	286
5	Chronic Pain	117	Arthritis	250
6	Knee Pain	77	Efficacy	214
7	Exercise	64	Old-adults	211
8	Meta-analysis	63	Double-blind	198
9	Inflammation	61	Association	171
10	Quality of Life	49	Disability	159

### Preferred Journals

The top 10 most cited and productive journals in OA pain research field are listed in Table 6. *Osteoarthritis and Cartilage* with a total of 178 publications obtained Publication Rank 1, followed by *Arthritis Care & Research* with a total of 87 articles. The third was *BMC Musculoskeletal Disorders* with a total of 85 articles. All other journals on the list include fewer than 80 articles, the 2021 Journal Citation Reports indicated that only *Osteoarthritis and Cartilage*, *Pain*, *Annals of the Rheumatic Disease*, *Arthritis Research Therapy* were listed in Q1 Journals. In the top 10 most cited journals list, *Osteoarthritis and Cartilage* with a total of 5964 citations won the Rank 1, followed by *Pain* with a total 2367 citations, most of the journals on this list were from the Q1–Q2. It was necessary to point out that the impact factor (IF) of *Arthritis and Rheumatism* was from 2015 JCR, because the IF in subsequent years was unavailable. During the investigated period, *Osteoarthritis and Cartilage* was the first journal to include the largest number of articles in the field according to Figure 10, and continues to be a leader in subsequent years. *Journal of Pain Research* was relatively a newcomer to the field, building its way to the forefront of the list based on the number of articles in the field in recent years.

**Top 50 Keywords with the Strongest Citation Bursts**

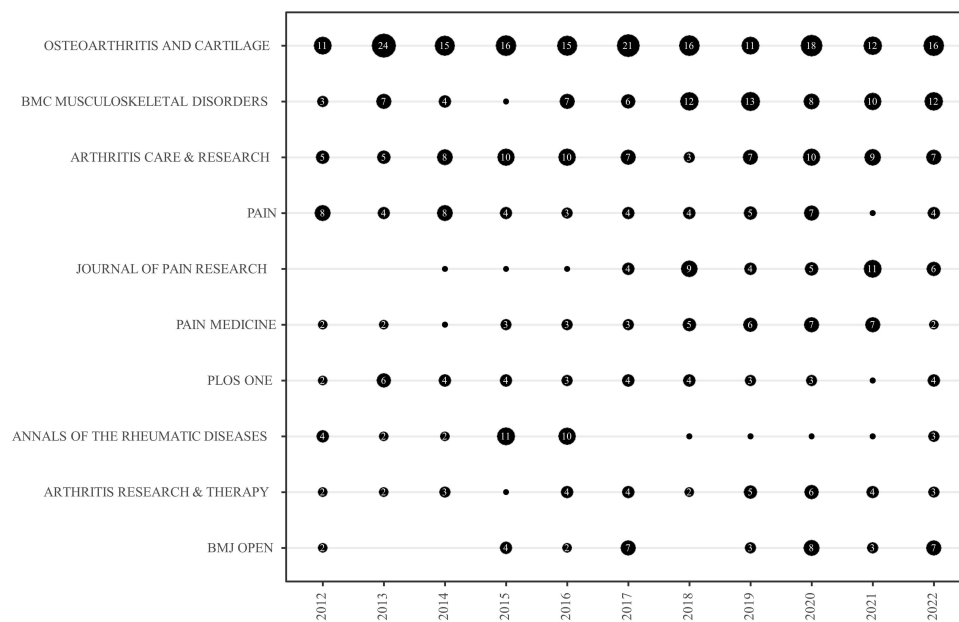


**Figure 7** Top 50 keywords with the strongest citation bursts.



**Table 6** Top 10 Journals Distributed by Publications and Citations

Rank	Journal	Publication	% of 2493	IF (JCR 2021)	JIF Quartile	Journal	Total Citation	Publications	Average Citations (AC)	H-Index	IF (JCR 2021)	JIF Quartile	AC Rank
1	<i>Osteoarthritis and Cartilage</i>	178	7.14%	7.507	Q1	<i>Osteoarthritis and Cartilage</i>	5964	178	34	41	7.507	Q1	6
2	<i>Arthritis Care &amp; Research</i>	87	3.49%	5.178	Q2	<i>Pain</i>	2367	52	46	31	7.926	Q1	3
3	<i>BMC Musculoskeletal Disorders</i>	85	3.41%	2.562	Q2	<i>Arthritis Care &amp; Research</i>	2356	87	27	28	5.178	Q2	8
4	<i>Pain</i>	52	2.09%	7.926	Q1	<i>JAMA – Journal of the American Medical Association</i>	1765	20	88	17	157.335	Q1	1
5	<i>Pain Medicine</i>	43	1.72%	3.637	Q2	<i>Annals of The Rheumatic Disease</i>	1435	36	40	20	27.973	Q1	4
6	<i>Journal of Pain Research</i>	42	1.68%	2.832	Q3	<i>Arthritis &amp; Rheumatology</i>	1242	34	37	19	15.483	Q1	5
7	<i>PLoS One</i>	39	1.56%	3.752	Q2	<i>BMC Musculoskeletal Disorders</i>	1132	85	13	19	2.562	Q2	10
9	<i>Arthritis Research &amp; Therapy</i>	37	1.48%	5.606	Q1	<i>BMJ Open</i>	1027	38	27	10	3.006	Q2	9
8	<i>BMJ Open</i>	38	1.52%	3.006	Q2	<i>Arthritis Research &amp; Therapy</i>	1070	37	29	19	5.606	Q1	7
10	<i>Annals of the Rheumatic Diseases</i>	36	1.44%	27.973	Q1	<i>Arthritis and Rheumatism</i>	969	12	81	12	8.955	Q1	2



**Figure 10** Visualization of top 10 prolific journals publications distribution.

journal with 7.507 IF. The following article was “What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients” created by Beswick, AD in 2012 and obtained a total of 751 citations. The Rank 3 in the list was “Incidence, prevalence, costs, and impact on disability of common conditions requiring rehabilitation in the United States: stroke, spinal cord injury, traumatic brain injury, multiple sclerosis, osteoarthritis, rheumatoid arthritis, limb loss, and back pain” with a total of 533 citations. In this list, most of the documents were article-type articles except two review-type articles. The last five on the list were respectively “Impact of exercise type and dose on pain and disability in knee osteoarthritis”, “Effectiveness of non-steroidal anti-inflammatory drugs for the treatment of pain in knee and hip osteoarthritis: a network meta-analysis”, “Efficacy and safety of paracetamol for spinal pain and osteoarthritis: systematic review and meta-analysis of randomised placebo controlled trials”, “An efficient randomised, placebo-controlled clinical trial with the irreversible fatty acid amide hydrolase-1 inhibitor PF-04457845, which modulates endocannabinoids but fails to induce effective analgesia in patients with pain due to osteoarthritis of the knee”, “2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures”. The average number of citations for the top 10 most cited articles was 449.

## Most Influential Institutions

As illustrated in Table 8, the top 10 most productive organizations distributed by publication were respectively Boston University (91 articles; 4050 citations), University of Sydney (87 articles; 2223 citations), The University of Melbourne (71 articles; 1710 citations), University of Nottingham (68 articles; 2330 citations), University of Florida (59 articles; 1153 citations), The University of Alabama at Birmingham (50 articles; 1356 citations), Duke University (55 articles; 1206 citations), University of Oxford (50 articles; 1034 citations), University of California San Francisco (44 articles; 1123 citations), Monash University (43 articles; 901 citations). Among them, Boston University, University of Nottingham and the University of Sydney were the top three institutions ranked by citations. Tufts University (23 publications, 1254 citations) had relatively low total citations among the listed 10 organizations, however, they had the highest two average citation (55). Organizations including Boston University, University of Sydney, University of Nottingham were the leading authority in this field, in addition, articles born from Boston Univ were preferred by more other institutions in this field (Figure 11).

**Table 7** Top 10 Cited Literatures

Rank	Authors	Citations	Article Title	Journal Abbreviation	Date	Volume	DOI	Article Type	PubMed Id
1	Neogi, T	810	The epidemiology and impact of pain in osteoarthritis <sup>29</sup>	<i>Osteoarthr Cartilage</i>	2013	21	10.1016/j. joca.2013.03.018	Article	23973124
2	Beswick, AD	751	What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients <sup>30</sup>	<i>BMJ Open</i>	2012	2	10.1136/ bmjopen-2011- 000435	Review	22357571
3	Ma, VY	533	Incidence, prevalence, costs, and impact on disability of common conditions requiring rehabilitation in the United States: stroke, spinal cord injury, traumatic brain injury, multiple sclerosis, osteoarthritis, rheumatoid arthritis, limb loss, and back pain <sup>31</sup>	<i>Arch Phys Med Rehab</i>	2014	95	10.1016/j. apmr.2013.10.032	Review	24462839
4	Krebs, EE	513	Effect of opioid vs nonopioid medications on pain-related function in patients with chronic back pain or hip or knee osteoarthritis pain The SPACE Randomized Clinical Trial <sup>32</sup>	<i>JAMA – J Am Med Assoc</i>	2018	319	10.1001/ jama.2018.0899	Article	29509867
5	McAlindon, TE	393	Effect of intra-articular triamcinolone vs saline on knee cartilage volume and pain in patients with knee osteoarthritis a randomized clinical trial <sup>33</sup>	<i>JAMA – J Am Med Assoc</i>	2017	317	10.1001/ jama.2017.5283	Article	28510679
6	Juhl, C	322	Impact of exercise type and dose on pain and disability in knee osteoarthritis <sup>34</sup>	<i>Arthritis Rheumatol</i>	2014	66	10.1002/ art.38290	Article	24574223
7	da Costa, BR	303	Effectiveness of non-steroidal anti-inflammatory drugs for the treatment of pain in knee and hip osteoarthritis: a network meta-analysis <sup>35</sup>	<i>Lancet</i>	2017	390	10.1016/S0140- 6736(17)31744-0	Article	28699595
8	Machado, GC	296	Efficacy and safety of paracetamol for spinal pain and osteoarthritis: systematic review and meta-analysis of randomised placebo controlled trials <sup>36</sup>	<i>BMJ – BRt Med J</i>	2015	350	10.1136/bmj. h1225	Article	25828856
9	Huggins, JP	289	An efficient randomised, placebo-controlled clinical trial with the irreversible fatty acid amide hydrolase-1 inhibitor PF-04457845, which modulates endocannabinoids but fails to induce effective analgesia in patients with pain due to osteoarthritis of the knee <sup>37</sup>	<i>Pain</i>	2012	153	10.1016/j. pain.2012.04.020	Article	22727500
10	Crossley, KM	275	2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures <sup>38</sup>	<i>Brit J Sport Med</i>	2016	50	10.1136/bjsports- 2016-096384	Article	27343241

**Table 8** Top 10 Institutions Distributed by Publications and Citations

Rank	Institutions	Publications	Total Citations	% of 2493	Institutions	Total Citations	Publications	Average Citation (AC)	AC Rank
1	Boston University	91	4050	3.65%	Boston University	4050	91	45	2
2	The University of Sydney	87	2223	3.49%	University of Nottingham	2330	68	34	6
3	The University of Melbourne	71	1710	2.85%	The University of Sydney	2223	87	26	8
4	University of Nottingham	68	2330	2.73%	Aalborg University	1754	42	42	4
5	University of Florida	59	1153	2.37%	Rush University	1717	40	43	3
7	The University of Alabama at Birmingham	50	1356	2.01%	Northwestern University	1403	35	40	5
6	Duke University	55	1206	2.21%	The University of Melbourne	1710	71	24	9
8	University of Oxford	50	1034	2.01%	The University of Alabama at Birmingham	1356	50	27	7
9	University of California San Francisco	44	1123	1.76%	Tufts University	1254	23	55	1
10	Monash University	43	901	1.72%	Duke University	1206	55	22	10

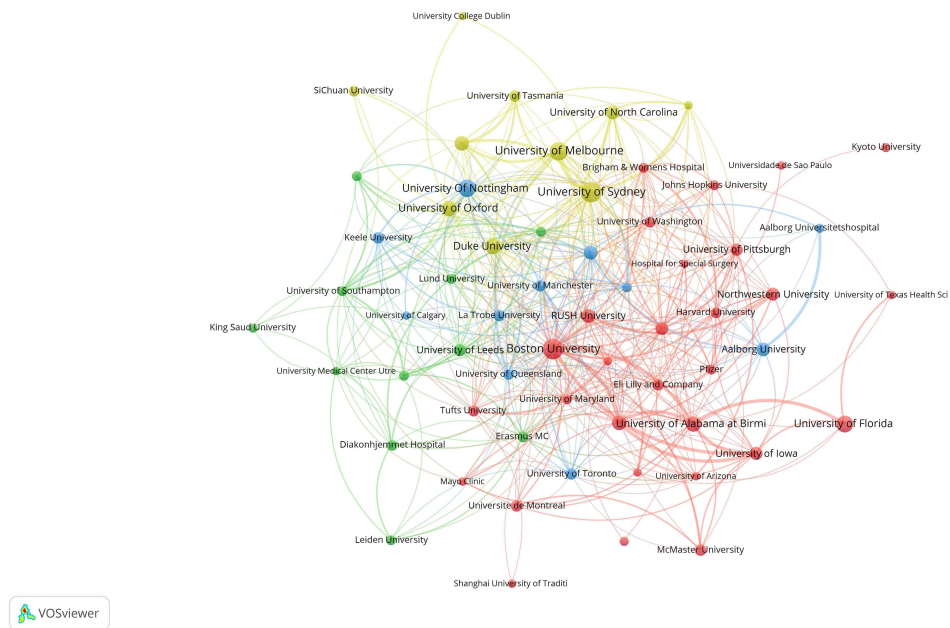


Figure 11 Network visualization of institutions collaboration.

## Discussion

### Global Trends of the Research on OA Pain

This study presents a comprehensive overview by using bibliometric analysis to access the published articles on OA pain in the last decades. From January 1, 2012 to December 31, 2022, the overall trend of the number of published articles has continued to increase, and the fastest growth rate of investigated publications appeared from 2016 to 2021. The results showed that research in OA pain attracted wide attention from researchers. The growing number of existing literatures will provide a solid basis for the following exploration. The downtrend of number of citations can be attributed to the citation lag, the earlier the articles were published, the more cited chance they will get.

The majority of the top 10 most productive authors were from The United States, and only four authors were from other countries, reflecting that it was a dominated player in this field. Fillingim, Roger B. and Bennell, Kim L. were two most productive authors, while the latter had higher DF. In order to describe the most influential authors in this research field, the authors' citations ranking was also taken in consideration. Despite the fact that Fillingim, Roger B. was the most productive author, his name was not seen in the citations rank, while Neogi, T. became the top candidate of the list with 1049 total citations. Besides, half of the top 10 productive authors distributed by citations were from the USA, suggesting that it was also a main contributor in OA pain research.

The United States had a dominative contribution to both publications and citations, and it was the country with the most cooperation with other others. Besides, England, China and Australia have published more than 200 articles in this research field. But these productive countries had fewer average citations compared with Denmark.

*Osteoarthritis and Cartilage* seemed to be the most influential journal in OA pain research field with both the largest number of publications and citations. Consistently, the most highly cited article was from *Osteoarthritis and Cartilage*. *Arthritis Care & Research* was the second productive journal and the third most cited journal. *BMC Musculoskeletal Disorders* also showed its advantage in publication, while *Pain* released less paper but was cited more frequently. All in all, after considering 2021 JCR, publications and citations, *Osteoarthritis and Cartilage* was still the authoritative journal in this field.

Boston University ranked first in both publication list and citation list, indicating it had outstanding contribution to this field. The University of Sydney also showed its advance by ranking second in publication list and third in citation list. University of Nottingham was also influential because of its fourth place in publication rank and second in citation



rank. In addition, The University of Melbourne and Duke University were also seen in both lists. Compared to the study of Cheng et al, Monash University and University of California San Francisco have dropped out the top five, demonstrating the rising two institutions had greater efforts in more recent years.<sup>25</sup>

## Hotspots and Frontiers

Based on the top keywords and literature, we ascribe the research hotspots as follows:

Affected body part of OA pain: “Osteoarthritis” and “Pain” were the top two author keywords mainly because of the search term [(TI = [(Osteoarthritis OR OA)] AND [TI = (pain OR painful)]]. They were followed by “Knee Osteoarthritis” and “Knee”, and these two words were also the only words whose frequency was beyond 100 after “Osteoarthritis” and “Pain”. In addition to give a general accession of keywords, Author Keywords-Plus were also referred. Both “Hip” ranked first and “Knee Osteoarthritis” ranked third in this list revealed these two body parts suffered from osteoarthritis most frequently. Hand is also a main pathogenic position but gets much less attention than knee and hip,<sup>39</sup> possibly because osteoarthritis in larger joints tends to cause more severe pain.

Rehabilitation of OA pain: According to the top 10 keywords, “Exercise” and “Rehabilitation” were active keywords in Author Keywords list, and “Management” ranked second in Keywords-Plus list, indicating that rehabilitation of OA pain had shown its importance. Keywords which related to rehabilitation formed green cluster in [Figure 9](#). This opinion was also approved by the facts that one of the top 10 cited literature focused on this field. This article written by Juhl et al compared several exercise types and got the conclusion that single-type exercise was more effective in reducing pain and disability than mixing types of exercise.<sup>34</sup> In addition, there are also a large number of studies concentrating on the efficacy of exercise in total knee and hip arthroplasty.<sup>40,41</sup>

Treatment of OA pain: It can also be seen from [Table 7](#) that five of the publications were related to OA pain’s treatment. Kerbs et al verified opioids showed no special effect than nonopioid so that it was not an appropriate therapy for knee OA pain.<sup>32</sup> In a network meta-analysis, diclofenac was considered to be the most effective non-steroid anti-inflammatory drug to deal with pain and disability in OA patients.<sup>35</sup> Another research indicated that intra-articular injection of triamcinolone acetonide was not suitable for patients with symptomatic knee Osteoarthritis.<sup>33</sup> Huggins, J. P. found that the irreversible fatty acid amide hydrolase-1 inhibitor PF-04457845 was invalid for knee osteoarthritis pain by clinical trials, which was opposed to the results obtained by animal models.<sup>37</sup> Treatment of paracetamol showed negative therapeutic effect as well.<sup>36</sup> According to the mentioned four most cited papers, we can draw a conclusion that clinical trial may be the main research method in treatment of OA pain, and the correction of traditional therapies occupy a major part. Physiotherapy for osteoarthritis pain is also receiving increasing attention, many researchers engaged in exploring new physiotherapy methods and evaluating the clinical efficacy of physiotherapy.<sup>42,43</sup>

## Strengths and Limitations

Various artificial intelligence software such as VOSviewer and CiteSpace were used for visualization of co-authorship, country and institutional collaboration, keywords co-occurrence and keywords citation burst map, it provides a practical method for global data analysis in international medical systems. Besides, we employed systematic searching and quantitative statistical analysis, our bibliometric study was significantly more intuitive and comprehensive than a literature review would have been. There are some defects in this study. VOSviewer cannot visualize keywords along with relevant time data in the same figure, resulting in deflective predictions in hotspots. The research term limited relevant words like “Osteoarthritis” and “pain” to title, which may lead to incomplete searching results to this study, and it also can be redundant if authors did not put the search terms in the article title. Our study only included literature indexed in WOS, which may result in potential inaccuracies when predicting research hotspots due to the absence of literature from other databases.

## Conclusion

This study identified OA pain-related publications from January 1, 2012 to December 31, 2022 and presented their global trends and current status. The total publications of OA pain generally increasing over the time in the last decade, and the escalating rate remained a high level. Many researchers contributed to OA pain field, while Bennell, Kim L. and Neogi, Tuhina were two main

contributors. The United States ranked first in total publications, total citations and international collaboration. Analysis of keywords showed rehabilitation and treatment of OA pain were the hotspots in this area, and the main force concentrated on hip osteoarthritis and knee osteoarthritis, which means hand osteoarthritis needs to be further studied. *Osteoarthritis and Cartilage* was the major publishing journal for OA pain exploration. “The epidemiology and impact of pain in osteoarthritis” and “What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients” were the most influential article and review in this field, respectively. Boston University made greatest contribution to OA pain research. Reference learning showed tight correlation between OA pain and central sensitization, hip and neuromuscular exercise, indicating that relative work might have a bright future.

## Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

## Funding

This work was supported by National Natural Science Foundation of China (No.82072506, 82272611, 92268115), National Key R&D Program of China (No.2019YFA0111900), National Clinical Research Center for Geriatric Disorders (Xiangya Hospital, Grant No.2021KFJJ02 and 2021LNJJ05), National Clinical Research Center for Orthopedics, Sports Medicine and Rehabilitation (No.2021-NCRC-CXJJ-PY-40), Science and Technology Innovation Program of Hunan Province (No.2021RC3025), Provincial Clinical Medical Technology Innovation Project of Hunan (No.2020SK53709), the Administration of Traditional Chinese Medicine of Hunan Province (No.2021075), Wu Jieping Medical Foundation (No.320.6750.2020-03-14), CMA•Young and Middle-aged Doctors Outstanding Development Program–Osteoporosis Specialized Scientific Research Fund Project (No.G-X-2019-1107-12).

## Disclosure

All authors declare that there are no conflicts of interest in this work.

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