The 50 Most-Cited Publications in Research of Physical Therapy in Osteoarthritis

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Abstract

Background

This study is a bibliometric review of the literature, in order to identify and analyze the 50 most-cited publications in the field of physical therapy in osteoarthritis.

Methods

A three-step approach was applied in all databases from Web of Science in order to identify the 50 most-cited publications. Related information of the 50 most-cited studies was collected for further analysis, including title, authorship, geographic origin, journal of publication, year of publication, impact factor, and citation numbers.

Results

The 50 most-cited articles were cited from 970 to 174 times with a mean citation of 287.42 and published from 1989 to 2018 in 24 different journals. Overall, 24 countries contributed to 50 articles and the most productive country was United States with 18 articles and highest sum citations and H-index. A large part of 50 most-cited articles came from *Arthritis and Rheumatism*, which published 6 articles. Most of the studies focused on exercise therapy in osteoarthritis (n = 36) and randomized controlled clinical trials were reported most (n = 31). The most productive period was from 2001 to 2005. In total, 9 authors published more than two articles.

Conclusion

This bibliometric analysis is meant to provide a list of milestones in researches of physical therapy in osteoarthritis. Our study identified the most influential articles in the field of physical therapy in osteoarthritis and gave researchers an insight into the development of physical therapy in osteoarthritis.

Background

Osteoarthritis (OA) is a kind of common degenerative diseases involving articular and surrounding structures (including subchondral bone, joint capsule, ligaments and related muscles). The morbidity of osteoarthritis increases with the aging population in the whole world [1]. Osteoarthritis often involves joints of lower limb, especially for hip joint and knee joint. Common symptoms of osteoarthritis are joint stiffness, swelling, pain and limited movements. Although the progression of osteoarthritis is slow and gradual, it can finally lead to physical disability, which seriously affects the quality of life of patients and increases the economic burden of family and society [2, 3]. Therefore, more and more attentions have been paid to OA. The treatment of OA includes surgery, drug therapy and physical therapy. With the

progression of OA, different treatment should be applied. It has been generally acknowledged that physical therapies should be employed as fundamental for all patients with OA. Physical interventions like exercise, hyperthermia, hydrotherapy, wax therapy, ultrasound, microwave, transcutaneous nerve needle exciting, traction, acupuncture and massage have been used in OA treatment [4]. Compared with other therapies, the advantages of physical therapy in OA are considered as fewer side effects, less pain, a shorter course of treatment, and lower cost [5]. In order to help researchers better understand the trend of this field, we identified the 50 most-cited publications regarding to the application of physical therapy in the treatment of OA. In the meantime, a bibliometric analysis was employed to highlight the qualities of the influential publications in research of physical therapy in OA. Several methods can be applied to analyze a field which has quantitative articles, such as a review, a main path analysis and bibliometric analysis.[6] Bibliometric analysis, as a comprehensive method to explore frontiers in a variety of subjects, has aroused the interest of specialists.[7] VOSviewer is a bibliometric software whose excellent feature is the strong ability of proceeding quantities of data[]. The literature of physical therapy in osteoarthritis can be visually analyzed from different dimensions. Citespace is another software for visualized analysis and it can display the hotspots and predict the trends in a specific scientific field.

Methods

Search Strategy and Selection

Our study design was a bibliometric study and was performed on February 14, 2022. All databases in Web of Science (Web of Science Core Collection, BIOSIS Citation Index, KCI-Korean Journal Database, Medline, Russian Science Citation Index and SciELO Citation Index) were used to identify eligible studies published between 1951 and 2021. A three-step approach was applied to achieve a more comprehensive accurate study and was shown in Fig. 1. In the first step, all databases in Web of Science were searched by the following keywords: (osteoarthritis AND physical therapy modalities). The initial search yielded 2029 documents, which were then ranked by the times cited in a descending order. The first 200 publications were analyzed. To improve the investigation, two independent reviewers identified the 50 most-cited publications in the field of physical therapy in osteoarthritis based on the titles and abstracts. In order to ensure a more comprehensive study, the possible keywords were extracted from the 50 most-cited publications identified in the first step after a systematic analysis. Seven keywords were identified and a search query group was established for second topic research in all databases. The seven keywords were divided into two groups. The first group included “osteoarthritis,” “knee osteoarthritis,” and “hip osteoarthritis.” and the second group included “physical therapy modalities,” “exercise therapy,” “manual therapy,” and “gait modification.” In the second step, our search was conducted by inputting the following terms into topic search in Web of Science: (osteoarthritis OR knee osteoarthritis OR hip osteoarthritis) AND (physical therapy modalities OR exercise therapy OR manual therapy OR gait modification). A total of 8537 publications were shown in second research and they were also ranked by the citation times in a descending order. In the first 200 preliminary studies, 50 publications related to physical therapy in the treatment of osteoarthritis were collected according to the titles and abstracts.

Finally, the results of two searches were overlapped and the duplicate studies were removed. The 50 most-cited publications were then identified for further analysis. To better identify the 50 most-cited studies in the field of physical therapy in osteoarthritis, two independent listed authors checked each result manually and excluded out-of-scope research publications based on titles and abstracts. The exclusion criteria were as follows: (1) documents on a wide discussion of strategies of the treatment of osteoarthritis; (2) articles that extensively discuss the diseases treated by physical therapy; (3) articles describing physical therapy group serve as a control group. The 50 most-cited publications were further analyzed and the title, first author and last author, geographic origin, journal of publication, year of publication, impact factor, and citation numbers were extracted.

Data Analysis

All data were extracted from Web of Science. VOSviewer and GraphPad Prism 9 were used to perform visualization analysis. GraphPad Prism 9 was used to analyze the data. The number of papers published in different countries or journals. Indicators of the quality of articles, including total times of citation, average citation per item and H-index, were all protracted in graphs by GraphPad Prism 9. Meanwhile, by using VOSviewer (v.1.6.17.0), co-authorship analysis, co-citation analysis and co-occurrence analysis were finished, and visualized maps were produced.

Results

The most influential articles

The 50 most cited articles in research of physical therapy in OA were cited from 970 to 174 times in 24 different journals, for a total of 14371 citation times, with an average citation of 287.42 per article. “A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST),” published by Ettinger, W H Jr et al, [8] had the most citation times (cited 970 times). Published in 1989, “Efficacy of physical conditioning exercise in patients with rheumatoid arthritis and osteoarthritis,” was the earliest article (cited 399 times) whose authors were Minor, M A et al. [9] The most recent article was “2018 EULAR recommendations for physical activity in people with inflammatory arthritis and osteoarthritis,” published by Osthoff, AKR et al in 2018 and cited 217 times (Table 1). [10]

Table 1
The most cited 50 articles in research of physical therapy in osteoarthritis

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
1	Ettinger W.H.Jr.	1997	A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST).	Journal of the American Medical Association	970	37.31
2	Messier S.P.	2004	Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis - The arthritis, diet, and activity promotion trial	Arthritis and Rheumatism	690	36.32
3	Felson D.T.	1992	Weight loss reduces the risk for symptomatic knee osteoarthritis in women. The Framingham Study.	Annals of Internal Medicine	657	21.19
4	Deyle G.D.	2000	Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee. A randomized, controlled trial	Annals of Internal Medicine	438	19.04
5	Messier S.P.	2013	Effects of Intensive Diet and Exercise on Knee Joint Loads, Inflammation, and Clinical Outcomes Among Overweight and Obese Adults With Knee Osteoarthritis The IDEA Randomized Clinical Trial	Journal of the American Medical Association	425	42.50
6	Minor M.A.	1989	Efficacy of physical conditioning exercise in patients with rheumatoid arthritis and osteoarthritis.	Arthritis and Rheumatism	399	11.74

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
7	Berman B.M.	2004	Effectiveness of acupuncture as adjunctive therapy in osteoarthritis of the knee - A randomized, controlled trial	Annals of Internal Medicine	394	20.74
8	Christensen R.	2007	Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis	Annals of the Rheumatic Diseases	382	23.88
9	Kovar P.A.	1992	Supervised fitness walking in patients with osteoarthritis of the knee. A randomized, controlled trial.	Annals of Internal Medicine	372	12.00
10	Katz J.N.	2013	Surgery versus Physical Therapy for a Meniscal Tear and Osteoarthritis	New England Journal of Medicine	364	36.40
11	Roddy E.	2005	Evidence-based recommendations for the role of exercise in the management of osteoarthritis of the hip or knee - the MOVE consensus	Rheumatology	355	19.72
12	Fransen M.	2015	Exercise for osteoarthritis of the knee	Cochrane Database of Systematic Reviews	343	42.88
13	Messier S.P.	2005	Weight loss reduces knee-joint loads in overweight and obese older adults with knee osteoarthritis	Annals of Internal Medicine	328	18.22

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
14	Roos E.M.	2005	Positive effects of moderate exercise on glycosaminoglycan content in knee cartilage - A four-month, randomized controlled trial in patients at risk of osteoarthritis	Arthritis and Rheumatism	326	18.11
15	O'Reilly S.C.	1999	Effectiveness of home exercise on pain and disability from osteoarthritis of the knee: a randomised controlled trial	Annals of the Rheumatic Diseases	308	12.83
16	Van Baar M.E.	1999	Effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee - A systematic review of randomized clinical trials	Arthritis and Rheumatism	293	12.21
17	Fransen M.	2015	Exercise for osteoarthritis of the knee: a Cochrane systematic review	British Journal of Sports Medicine	288	36.00
18	Juhl C.	2014	Impact of Exercise Type and Dose on Pain and Disability in Knee Osteoarthritis	Arthritis & Rheumatology	284	31.56
19	Scharf H.P.	2006	Acupuncture and knee osteoarthritis - A three-armed randomized trial	Annals of Internal Medicine	284	16.71
20	Roddy E.	2005	Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review	Annals of the Rheumatic Diseases	277	15.39
21	Bennell K.L.	2011	A review of the clinical evidence for exercise in osteoarthritis of the hip and knee	Journal of Science and Medicine in Sport	256	21.33

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
22	Deyle G.D.	2005	Physical therapy treatment effectiveness for osteoarthritis of the knee: A randomized comparison of supervised clinical exercise and manual therapy procedures versus a home exercise program	Physical Therapy	256	14.22
23	Thomas K.S.	2002	Home based exercise programme for knee pain and knee osteoarthritis: randomised controlled trial	BMJ-British Medical Journal	252	12.00
24	Van Baar M.E.	1998	The effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: a randomized clinical trial.	The Journal of Rheumatology	241	9.64
25	Campbell R.	2001	Why don't patients do their exercises? Understanding non-compliance with physiotherapy in patients with osteoarthritis of the knee	Journal of Epidemiology and Community Health	240	10.91
26	Baker K.R.	2001	The efficacy of home-based progressive strength training in older adults with knee osteoarthritis: A randomized controlled trial	Journal of Rheumatology	228	10.36
27	Wilcox S.	2006	Perceived exercise barriers, enablers, and benefits among exercising and non-exercising adults with arthritis: Results from a qualitative study	Arthritis & Rheumatism-Arthritis Care & Research	226	13.29

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
28	Song R.	2003	Effects of tai chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: A randomized clinical trial	Journal of Rheumatology	221	11.05
29	Talbot L.A.	2003	A home-based pedometer-driven walking program to increase physical activity in older adults with osteoarthritis of the knee: A preliminary study	Journal of the American Geriatrics Society	218	10.90
30	Osthoff A.K.R.	2018	2018 EULAR recommendations for physical activity in people with inflammatory arthritis and osteoarthritis	Annals of the Rheumatic Diseases	217	43.40
31	Foley A.	2003	Does hydrotherapy improve strength and physical function in patients with osteoarthritis - a randomised controlled trial comparing a gym based and a hydrotherapy based strengthening programme	Annals of the Rheumatic Diseases	212	10.60
32	Penninx B.W.J.H.	2001	Physical exercise and the prevention of disability in activities of daily living in older persons with osteoarthritis	Archives of Internal Medicine	212	9.64

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
33	Katz P.	2001	Exercise prescription for older adults with osteoarthritis pain: Consensus practice recommendations - A supplement to the AGS clinical practice guidelines on the management of chronic pain in older adults	Journal of the American Geriatrics Society	212	9.64
34	Bjordal J.M.	2007	Short-term efficacy of physical interventions in osteoarthritic knee pain. A systematic review and meta-analysis of randomized placebo-controlled trials	BMC Musculoskeletal Disorders	207	12.94
35	Fransen M.	2007	Physical activity for osteoarthritis management: A randomized controlled clinical trial evaluating hydrotherapy or Tai Chi classes	Arthritis & Rheumatism-Arthritis Care & Research	201	12.56
36	Hurley M.V.	1998	Improvements in quadriceps sensorimotor function and disability of patients with knee osteoarthritis following a clinically practicable exercise regime.	British Journal of Rheumatology	199	7.96
37	Fransen M.	2001	Physical therapy is effective for patients with osteoarthritis of the knee: a randomized controlled clinical trial	Journal of Rheumatology	197	8.95
38	Keefe F.J.	2004	Effects of spouse-assisted coping skills training and exercise training in patients with osteoarthritic knee pain: a randomized controlled study	Pain	196	10.32

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
39	Uthman O.A.	2013	Exercise for lower limb osteoarthritis: systematic review incorporating trial sequential analysis and network meta-analysis	BMJ-British Medical Journal	194	19.4
40	Fransen M.	2008	Exercise for osteoarthritis of the knee	Cochrane Database of Systematic Reviews	191	12.73
41	Wang C.C.	2009	Tai Chi Is Effective in Treating Knee Osteoarthritis: A Randomized Controlled Trial	Arthritis & Rheumatism-Arthritis Care & Research	187	13.36
42	Shih M.	2006	Physical activity in men and women with arthritis - National Health Interview Survey, 2002	American Journal of Preventive Medicine	187	11.00
43	De J.	2003	Is a long-term high-intensity safe in patients with exercise program effective and rheumatoid arthritis? Results of a randomized controlled trial	Arthritis and Rheumatism	186	9.30
44	Jamtvedt G.	2008	Physical therapy interventions for patients with osteoarthritis of the knee: An overview of systematic reviews	Physical Therapy	184	12.27
45	Rogind H.	1998	The effects of a physical training program on patients with osteoarthritis of the knees.	Archives of Physical Medicine and Rehabilitation	183	7.32
46	Messier S.P.	2000	Exercise and weight loss in obese older adults with knee osteoarthritis: A preliminary study	Journal of the American Geriatrics Society	182	7.91

No.	First Author	Year	Title	Journal	Citation No.	Citation/Year
47	Wright A.A.	2011	A Comparison of 3 Methodological Approaches to Defining Major Clinically Important Improvement of 4 Performance Measures in Patients with Hip Osteoarthritis	Journal of Orthopaedic & Sports Physical Therapy	181	15.08
48	Hinman R.S.	2007	Aquatic physical therapy for hip and knee osteoarthritis: Results of a single-blind randomized controlled trial	Physical Therapy	180	11.25
49	Bartels E.M.	2007	Aquatic exercise for the treatment of knee and hip osteoarthritis	Cochrane Database of Systematic Reviews	178	11.13
50	Lange A.K.	2008	Strength Training for Treatment of Osteoarthritis of the Knee: A Systematic Review	Arthritis & Rheumatism-Arthritis Care & Research	174	11.60

Year of publication

All of the 50 most cited articles were published between 1989 and 2018. The articles published in between 2001 and 2005 made up the largest part in the sum of 50 most-cited studies with 18 articles, followed by the period from 2006 to 2010 with 12 articles. However, it is notable that only 3 articles were published between 1991 and 1995 (Table 2).

Table 2
Publishing year of the most cited 50 aricles in research of physical therapy in osteoarthritis

Publishing Year	Number of Articles	Total Citations	Mean Citations
1989–1990	1	399	399.00
1991–1995	2	1029	514.50
1996–2000	8	2814	351.75
2001–2005	18	4998	277.67
2006–2010	12	2579	214.92
2011–2015	8	2332	291.50
2016–2020	1	217	217.00

Distribution of journals

The 50 most cited studies were published in 24 different journals and the top 3 journals published 16 of all articles. Shown in Table 3, *Arthritis and Rheumatism* was responsible for the most studies (6 articles) and 2221 total citations, followed by *Annals of Internal Medicine* (5 articles and 2145 total citations) and *Annals of the Rheumatic Diseases* (5 articles and 1395 total citations). From Fig. 2A and Fig. 2B, it is easy to see that the top three co-cited journals were *Journal of Rheumatology*, *Annals of the Rheumatic Diseases* and *Arthritis and Rheumatism*.

Table 3
Journals with the top 50 cited articles in research of physical therapy in osteoarthritis

Journal Title	Number of Articles	Total Citations	Mean Citations	Impact Factor
Arthritis and Rheumatism	6	2646	378.00	8.955
Annals of Internal Medicine	5	2145	429.00	25.391
Annals of the Rheumatic Diseases	5	1395	279.00	19.103
Arthritis & Rheumatism-Arthritis Care & Research	4	787	196.75	8.955
Cochrane Database of Systematic Reviews	3	712	237.33	9.289
Journal of Rheumatology	3	646	215.33	4.666
Journal of the American Geriatrics Society	3	612	204.00	5.562
Physical Therapy	3	620	206.67	3.021
BMJ-British Medical Journal	2	446	223.00	39.890
Journal of the American Medical Association	2	1395	697.50	56.274
American Journal of Preventive Medicine	1	187	187.00	5.043
Archives of Internal Medicine	1	212	212.00	17.333
Archives of Physical Medicine and Rehabilitation	1	183	183.00	3.966
Arthritis and Rheumatology	1	282	282.00	10.995
BMC Musculoskeletal Disorders	1	207	207.00	2.355
British Journal of Rheumatology	1	199	199.00	3.949
British Journal of Sports Medicine	1	287	287.00	13.800
Journal of Epidemiology and Community Health	1	239	239.00	3.710
Journal of Orthopaedic & Sports Physical Therapy	1	181	181.00	4.751
Journal of Science and Medicine in Sport	1	256	256.00	4.319
New England Journal of Medicine	1	364	364.00	91.253
Pain	1	196	196.00	6.961

Journal Title	Number of Articles	Total Citations	Mean Citations	Impact Factor
Rheumatology	1	355	355.00	7.580
The Jounal of Rheumatology	1	241	241.00	4.666

Distribution Of Countries

The 50 most cited articles originated from 24 countries. United States made greatest contribution with 18 articles followed by Australia (11 articles), England (9 articles), Netherlands (5 articles), Denmark (4 articles), Canada (3 articles), Germany (3 articles) and Norway (3 articles). Authors from Belgium and Sweden published 2 articles respectively and made same contribution. Authors from Australia, Brazil, Bulgaria, Cyprus, Finland, Ireland, Italy, New Zealand, North Ireland, Portugal, Scotland, South Korea, Switzerland and Turkey published 1 article each (Fig. 3). As Fig. 4 shows, United States took an invincible lead in terms of total citations (51120 citations), followed by Australia (26720 citations) and England (23480 citations). With 310 citations per item, Germany played a leading role in regard to average citation, followed by United States (284) and Canada (272.67). When it comes to H-index, United States ranked first with 18 H-index, followed by Australia (11 H-index) and England (9 H-index).

Distribution of authors and co-cited authors

With regards to the authors, Fransen and Messier published most articles as first or last author (each of them published 5 articles), followed by Doherty who published 4 articles. Bennell, Christensen, Loeser, Mcconnell, Rejeski and Zhang also made great contribution to this field (each of them published 3 articles) (Table 4). In Fig. 5A, it is clear to see that Fransen M took a lead with regard to the sum of citation (1217 citations), followed by Messier SP (1841 citations) and Loeser RF (1301 citations). In terms of average citation, Loeser RF ranked first with 433.67 citations per item, followed by Messier SP (368.2) and Rejeski WJ (362.67). With regard to H-index, Fransen M and Messier SP were tied for the first with 5 H-index, followed by Doherty M (4 H-index). As shown in Fig. 5B, Fransen M collaborated frequently with Bennell KL, Mcconnell S, Harmer AR and Simic M. Messier cooperated closely with Rejeski WJ, Loeser RF, Ettinger WH and Pahor M. As shown in Fig. 5C, Fransen M had highest co-citations, followed by Messier SP and Felson DT, and all of their co-citations exceeded 800, which suggested that all of them had a good reputation in this field.

Table 4
Authors with more than two articles

Authors	Number of Articles	Total Citations	Mean Citations
Fransen M.	5	1219	243.80
Messier S.P.	5	1837	367.40
Doherty M.	4	1192	298.00
Bennell K.L.	3	886	295.33
Christensen R.	3	841	280.33
Loeser R.F.	3	1297	432.33
Mcconnell S.	3	821	273.67
Rejeski W.J.	3	1084	361.33
Zhang W.	3	914	304.67

Analysis of keywords

As shown in Fig. 6A, the red cluster mainly consisted of “osteoarthritis,” “disability,” “muscle,” and “physical function”. This cluster mainly explored the relationship between osteoarthritis and health. The blue cluster was constituted mainly of “exercise therapy,” “strength,” “rehabilitation,” and “criteria”. In this cluster, many researches focused on the effectiveness of exercise therapy and used a variety of criteria to evaluate the outcomes of exercise therapy. The green cluster focused on “older-adults,” “knee osteoarthritis,” and “randomized controlled trial”. It primarily probed the effectiveness of physical therapy for older-adults who have osteoarthritis. A lot of randomized controlled trials were carried out to explore the effectiveness of physical therapy for older osteoarthritis patients. According to the density map of keywords (Fig. 6B), “osteoarthritis,” “knee osteoarthritis,” “exercise therapy,” “older-adults,” and “randomized controlled trial” had high weight.

Types of physical therapy

There are 5 types of physical therapy described in the 50 most cited articles. 36 articles focused on exercise therapy and 4 articles focused on weight loss therapy. 2 of the articles paid attention to acupuncture and 2 of them focused on hydrotherapy. There were also 2 articles focusing on manual therapy. (Fig. 7)

Paper topics

Randomized controlled clinical trials were the most common paper topic (n = 31), followed by reviews (n = 15), clinical outcomes (n = 3) and basic research (n = 1). (Fig. 8)

Discussion

By utilizing a variety of methods, a bibliometric study can assess the value of a publication. This methodology determined the impact of literature according to the number of citations. However, in some cases, a study which is of inferior quality can be frequently cited. Bibliometric study can be applied to evaluate a topic with numerous articles. The topic of physical therapy in osteoarthritis has garnered great interest from orthopedists and patients. A great number of articles fill this topic, reflecting the strong interest in physical therapy in osteoarthritis. Therefore, it is almost impossible for us, even for the experts to determine which ones are the most significant ones to know about. Given in this situation, a bibliometric study is in an urgent need to evaluate the impact of publications in the field of physical therapy in osteoarthritis.

Theoretically, compared with other therapies, physical therapy can bring less side effect and less pain. In addition, osteoarthritis patients treated by physical therapy can have shorter course of treatment and less cost. other therapy, many researchers conducted randomized controlled clinical trials. Katz et al [11] reported results of a randomized controlled clinical trial in 2013. In this study, researchers compared the effectiveness of surgery and physical therapy and found that patients in both the standardized physical therapy group and the surgical group had improved physical functions. Patients from standardized physical therapy group or surgery group got similar scores in the Western Ontario and McMaster Universities Arthritis Index (WOMAC), which indicated that physical therapy can achieve the same effect as surgery and reduced the need for surgery. Researchers also compared the outcomes of different physical therapies. In another randomized controlled trial published in 2005, Roddy E et al [12] reported that both aerobic walking and home based quadriceps strengthening exercise can reduce pain and disability from knee osteoarthritis. Another randomized controlled trial by Fransen et al [13] showed the result of comparison of hydrotherapy and Tai Chi classes. According to the pain and physical function scores after 12 weeks treatment and 24 weeks treatment, patients in both hydrotherapy group and Tai Chi group made great improvements, which indicated that access to either hydrotherapy or Tai Chi classes can large improvements in physical function for many individuals with hip or knee osteoarthritis.

Through the combination of essential keywords and articles, we attributed that exercise therapy, as one of physical therapy for osteoarthritis, gained great popularity in this field. Before 2000s, many studies focused on exercise therapy. The study of Minor et al [9] published in 1989 concentrated on the effect of aerobic exercise therapy and reported the effectiveness of aerobic exercise for the treatment of osteoarthritis. In 1998, Van Baar et al [14] reported that exercise therapy is effective in reducing pain and disability in patients with keen or hip osteoarthritis. Another study published by Thomas et al [15] in 2002 showed that a simple home based exercise program can significantly reduce knee pain for knee osteoarthritis patients. Gradually, some new physical therapies intrigued researchers. A research conducted by Deyle et al [16] showed the effectiveness of manual physical therapy and exercise, indicating that the combination of manual physical therapy and supervised exercise gained physical benefits for osteoarthritis patients. Foley et al [17] reported that a hydrotherapy based strengthening program can achieve the same functional gains when compared with a gym based strengthening program. In addition, the hydrotherapy group significantly differed from the control group for walking distance and physical component of the Short-Form-Health-Survey-12 (SF-12). A study published by

Berman et al [18] in 2004 researched the effectiveness of acupuncture for osteoarthritis and found that participants in the true acupuncture group made greater improvement in WOMAC function scores than the sham acupuncture group at 8 weeks, which indicated that acupuncture seems to play a role in the treatment of osteoarthritis. However, in 2006, Scharf et al [19] reported that WOMAC scores of the traditional Chinese acupuncture group and the sham acupuncture group had no statistically significant difference, which suggested that the observed differences in the traditional Chinese acupuncture group could be attributed to a physiologic effect of needling. Therefore, further studies are needed to further investigate the effect of acupuncture in osteoarthritis.

2001 to 2005 was the most productive highly cited publishing period in the field of physical therapy in osteoarthritis, during which 18 out of the top 50 most-cited articles published. After that, 12 articles were published from 2006 to 2010. It is not surprising because the longer the period after articles publication, the greater chance the article could be cited.

In total, 24 journals published the top 50 most-cited studies. Among them, *Arthritis and Rheumatism* made greatest contribution with 6 publications. The reason why *Arthritis and Rheumatism* was the most productive journal may be related to the fact that Arthritis and Rheumatism is a top journal and its articles are influential. *Journal of Rheumatology*, *Annals of the Rheumatic Diseases* and *Arthritis and Rheumatism* were the top three co-cited journals in researches of physical therapy in osteoarthritis. Overall, 24 countries made contribution to the research of physical therapy in osteoarthritis. Among the countries which contributed to the most-cited 50 articles related to physical therapy in osteoarthritis, United States took a lead in total citations and H-index, while Germany ranked first in terms of average citations. The reason for this could be related to the investment of United States in scientific research and the hard work of researchers. We counted both first and last authors because of the fact that first authors usually make greatest contribution while last authors contribute less. After considering both authors, it is more convenient for us to clarify the contribution of authors. More importantly, some authors who are not included in our analysis could also contribute to the research of physical therapy in osteoarthritis. Fransen M contributed greatly to the most-cited 50 articles in this field with highest sum of citation and H-index. However, when it comes to the average citation per item, Loeser RF played a leading role.

There are several limitations in our study. Firstly, the literature search finished in February 14, 2022, which could theoretically impact the citation times by the time. However, the trend is unlikely to change sharply. In addition, although bibliometric analysis has been widely used in a variety of researches, the citation number can't reflect the quality of articles completely. Citation times can be affected by many factors, such as the date of publication and the impact of journal. What's more, a poorly done article will be cited when others criticize it, which will also add the citation number.

In conclusion, in spite of the shortages, bibliometric analysis is still one of the ideal tools to assess the influence of publications in some scientific fields. Furthermore, the contribution of authors and origins can also be evaluated. We believed that our study demonstrated a series of milestones in researches of physical therapy in osteoarthritis. Influential authors, countries and journals were identified in our study,

all of which have made outstanding contributions to the field of physical therapy in osteoarthritis. Moreover, this bibliometric analysis also provided interesting research directions for researchers who want to devote themselves to the field of physical therapy in osteoarthritis.

Conclusions

This bibliometric analysis aims to propose a list of important milestones in the field of physical therapy in osteoarthritis. The 50 most-cited articles were collected and analyzed. In addition, the contribution of authors and countries were identified. With the research of many new physical therapies, researchers many use the achievements of our predecessors to guide future researches of physical therapy in osteoarthritis.

Abbreviations

OA: osteoarthritis

WOMAC: Western Ontario and McMaster Universities Arthritis Index

SF-12: Short-Form-Health-Survey-12

Declarations

Ethics approval and consent to participate

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

Consent for publication

All authors read and approved the final manuscript.

Availability of data and materials

This study does not contain any third material.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JL: design and manuscript writing. ZC: provision of study material, data analysis, and provision of relevant references. YD and WW were responsible for revising the article and for data acquisition. RY and JZ: data analysis and interpretation. WX: conception, financial support, administrative support. YL: conception, financial support, administrative support.

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Figures

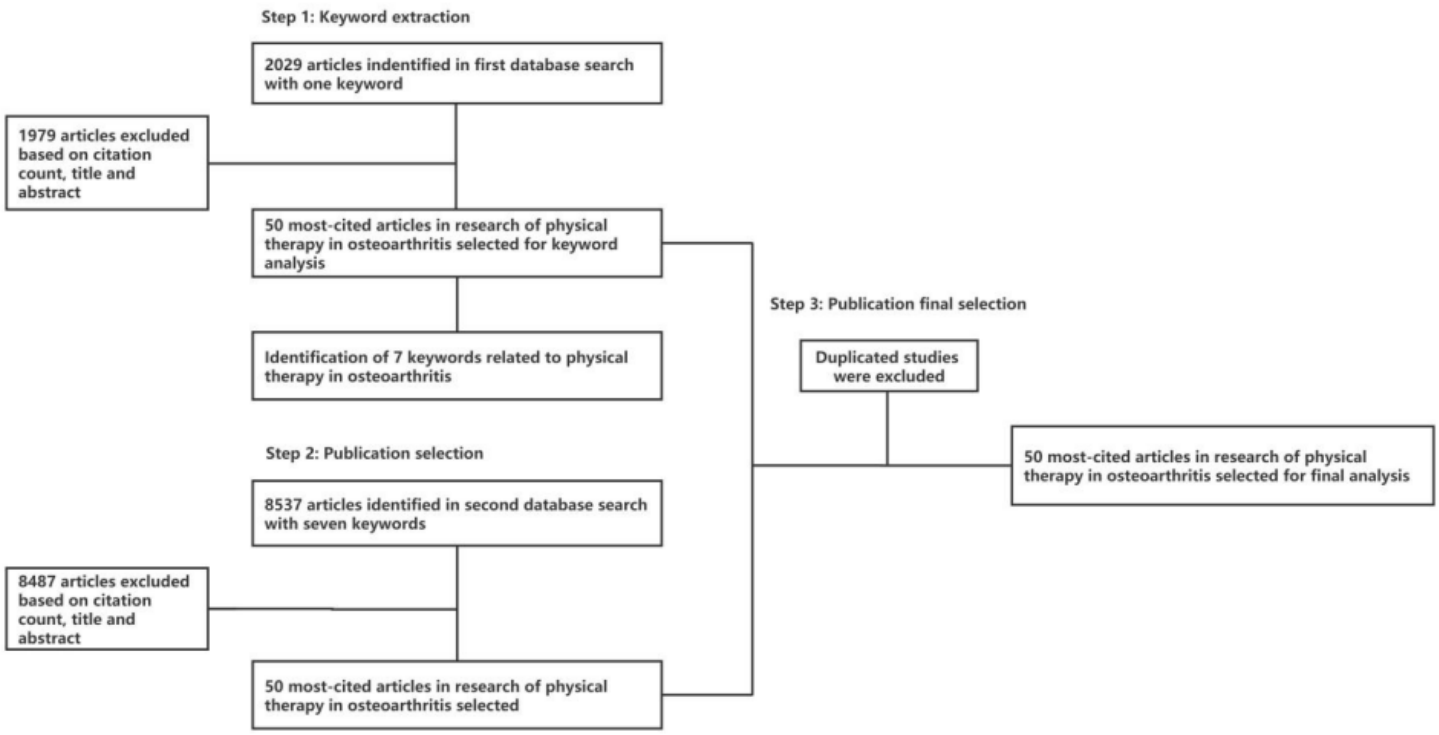

Figure 1

Three-step approach of the selection of articles related to physical therapy in osteoarthritis.

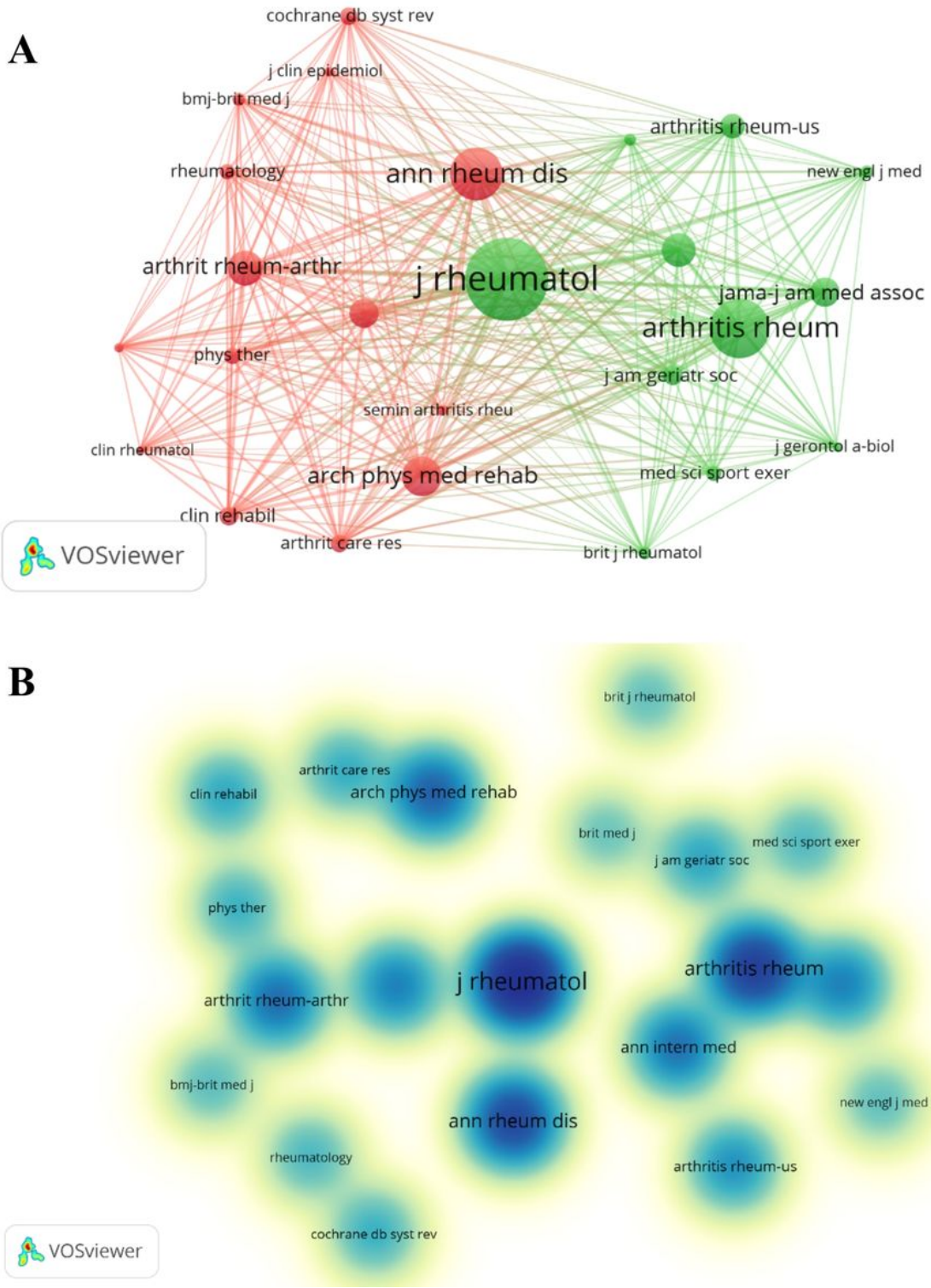

Figure 2

VOSviewer visualization map of most commonly cited journals related to research of physical therapy in osteoarthritis. **(A)** Co-citation network of journals. **(B)** The density map of the most commonly cited journals. The dark blue nodes represent journals with large numbers of citations.

Figure 3

Countries of the top 50 cited articles in research of physical therapy in osteoarthritis.

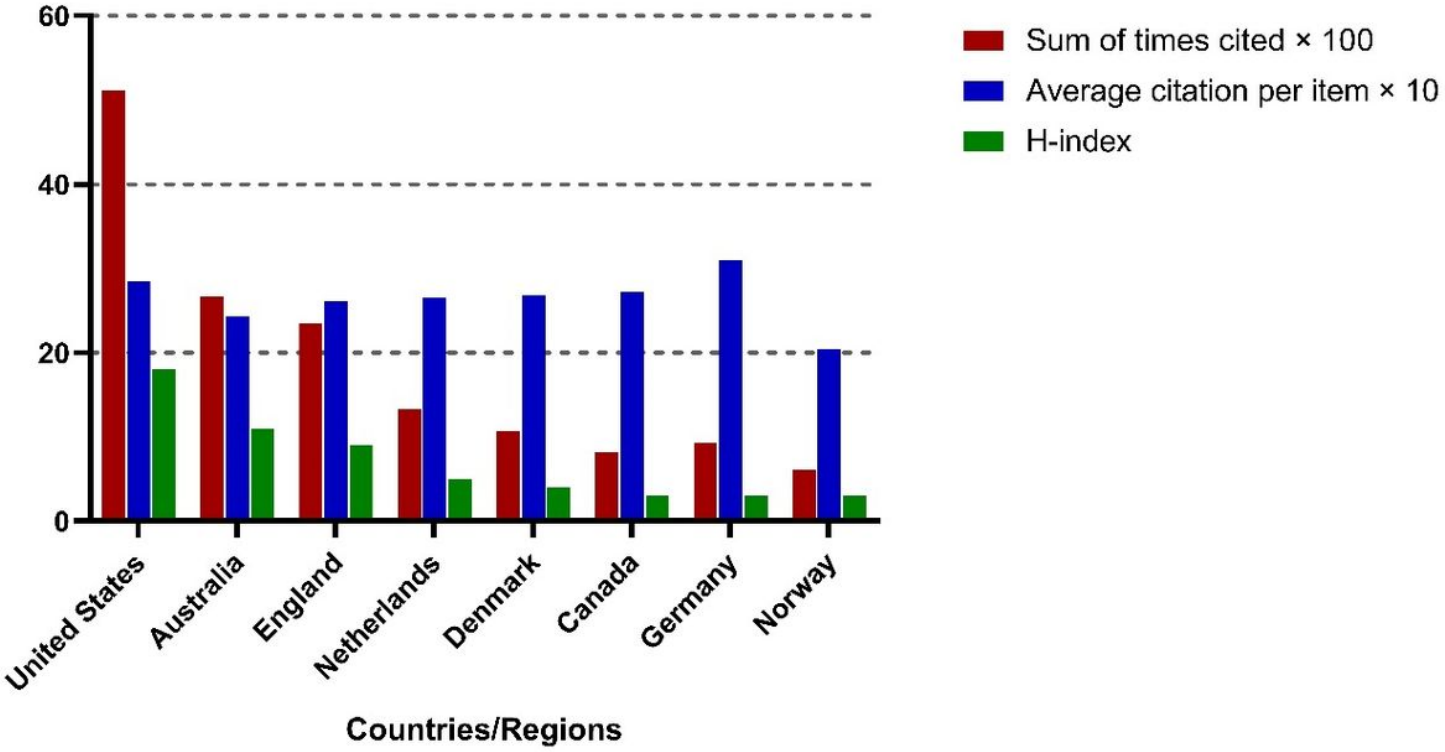

Figure 4

Analysis of citation and H-index of countries which published more than 2 articles.

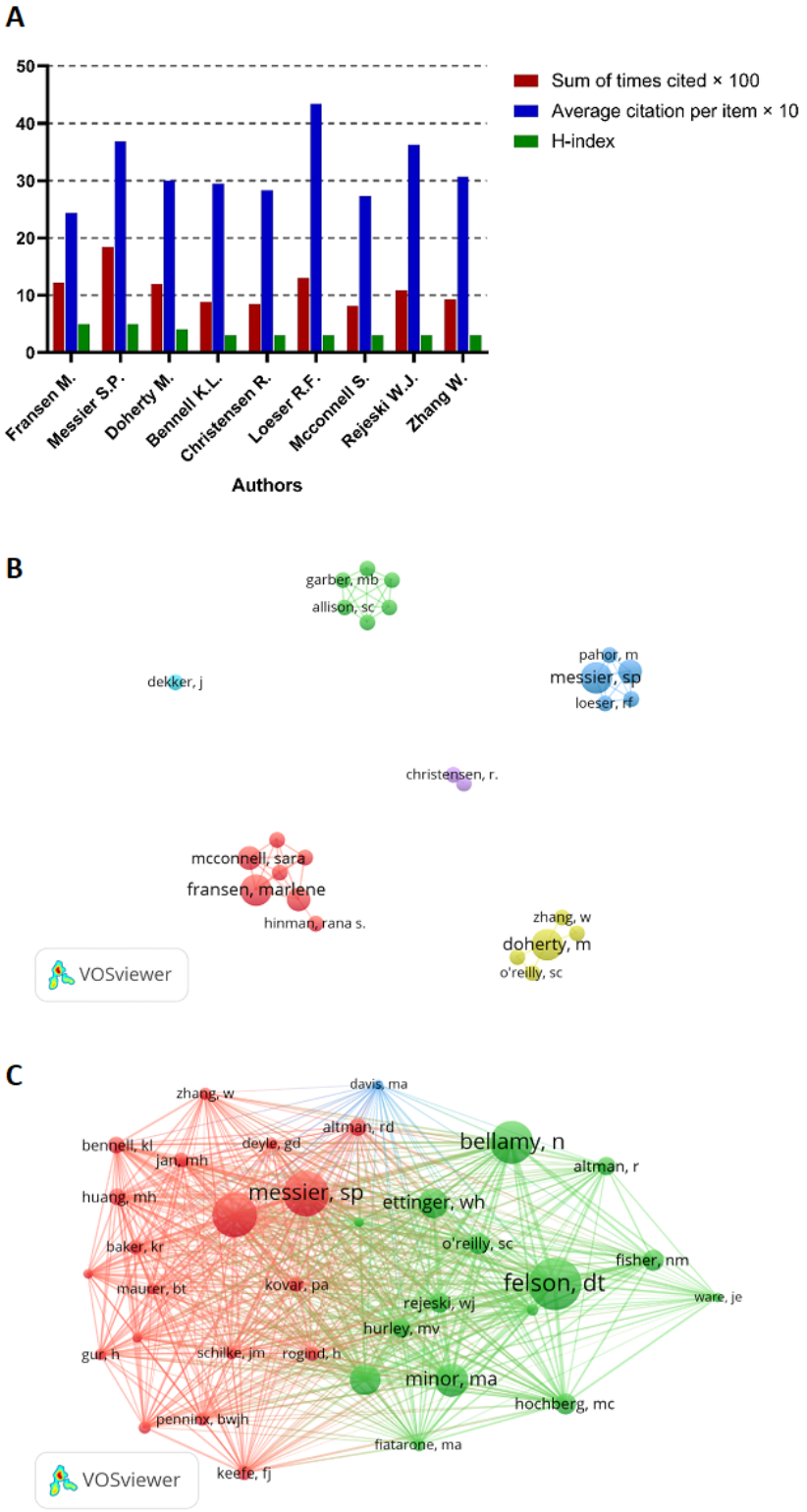

Figure 5

VOSviewer visualization map of authors and co-cited authors contributed to the field of physical therapy in osteoarthritis. **(A)** Analysis of citation and H-index of authors who published more than 2 articles. **(B)** Cooperation network of authors. **(C)** Co-citation network of authors.

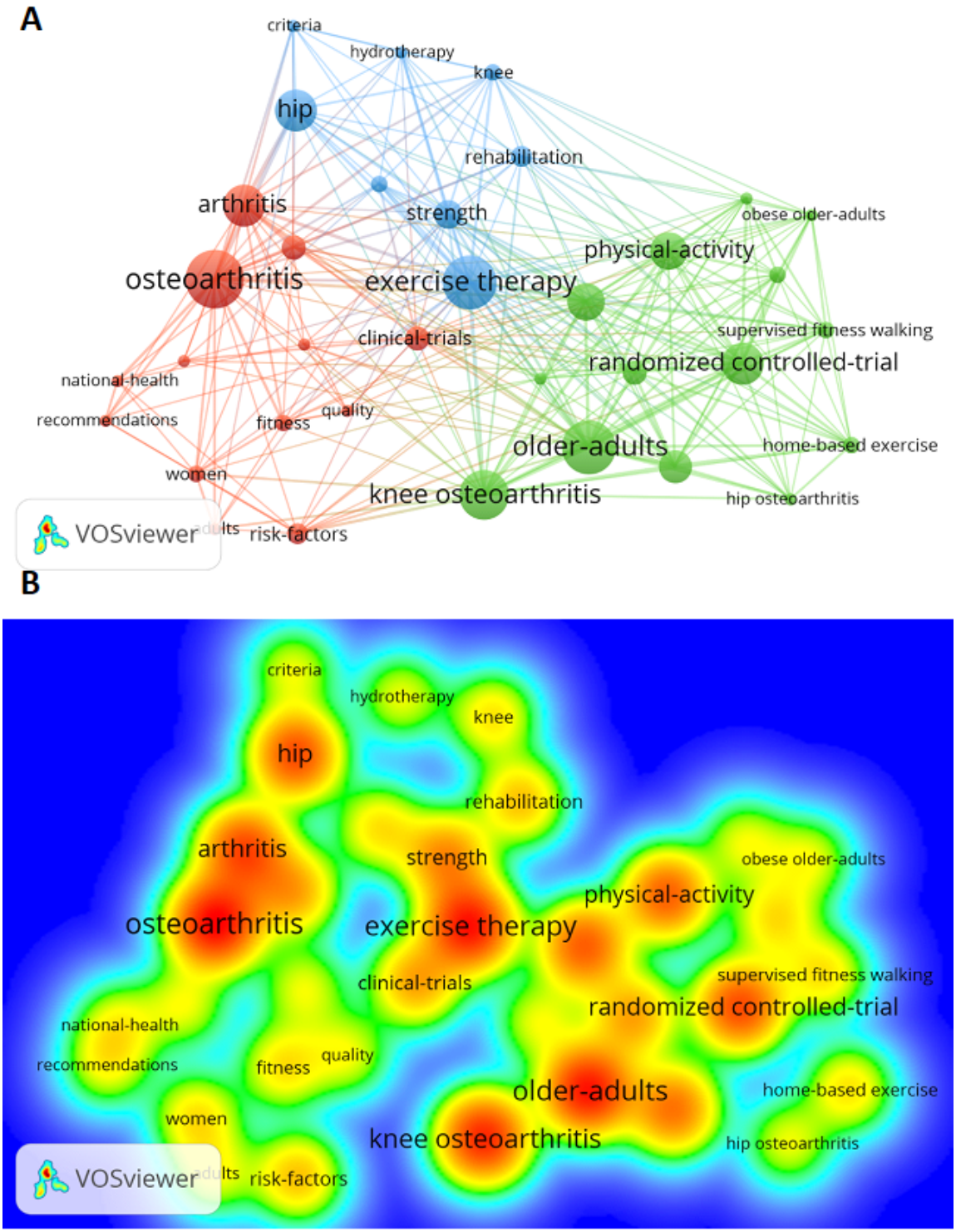

Figure 6

Analysis of all keywords in the most-cited 50 articles related to physical therapy in osteoarthritis. **(A)** VOSviewer visualization map of co-occurrence keywords. **(B)** The density map of keywords. The closer the keyword node color is to red, the higher the frequency of its co-occurrence.

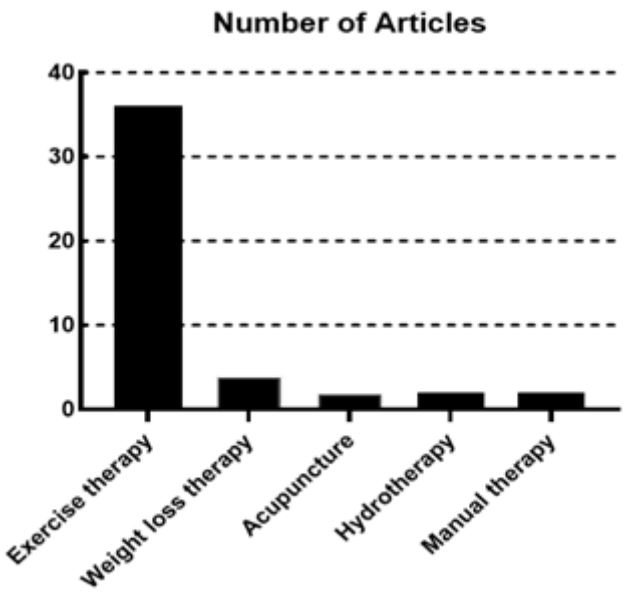

Figure 7

Types of physical therapy of the 50 most cited articles in research of physical therapy in osteoarthritis

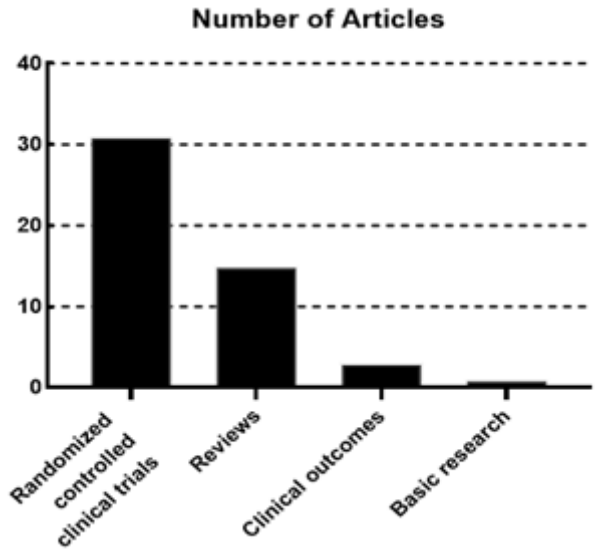

Figure 8

Subspecialty of the top 50 cited articles in research of physical therapy in osteoarthritis