REVIEW ARTICLE

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EXERCISE FOR LOW BACK PAIN: A BIBLIOMETRIC ANALYSIS OF GLOBAL RESEARCH FROM 1980 TO 2018

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Objective: To make a bibliometric analysis of global trends in research into exercise interventions for low back pain between 1980 and 2018.

Methods: Systematic literature, published from 1980 to 2018, was obtained from the Web of Science Core Collection database. CiteSpace software was used to analyse the relationship between publications and country, institution, journals, authors, references, and key words.

Results: A total of 1,140 publications were included in the analysis. Over the period studied there was an increase in the number of publications. A total of 276 academic journals focused on the categories Rehabilitation, Orthopedics, and Sports Science. The USA and the University of Sydney were the most productive country and institution, respectively. Spine, which is the main journal for research into exercise for managing low back pain, had the most publications. Burst key words showed that the stability, balance, and gait of individuals with low back pain have become the research development trend and focus in this field of research.

Conclusion: Overall, studies on exercise for low back pain have increased in number in the last 4 decades. This historical overview of research into exercise interventions for low back pain will be a useful basis for further research into potential collaborators, focus issues, and development trend.

LAY ABSTRACT

The aim of this study was to investigate the progress of global studies into exercise interventions for low back pain over the years from 1980 to 2018. The results show that the number of studies is increasing. Research into sports rehabilitation of low back pain emphasized musculoskeletal rehabilitation. Stability, balance, and gait of patients with low back pain have become the research development trend and focus in this field of research.

L ow back pain (LBP) is not a disease, but a worldwide pain syndrome, defined by pain location between the lower rib margins and the buttock creases (1). The prevalence of LBP is reported to be as high as 84%, of which chronic LBP accounts for approximately 23%, and the prevalence of activity-limiting LBP is 10–14% (2). With changes in social environment and lifestyle, and increasing physical inactivity, sedentary occupations, obesity, depressive symptoms, and other factors, the incidence of adolescents with LBP also shows an increasing trend (3). People with LBP experience unpleasant nociceptive sensations, activity limitations, work absence, and low quality of life. Globally, in 2017, LBP was one of the leading factors in terms of the number of years lived with disability (4), and this number increased by 54% between 1990 and 2015, especially in low- and middle-income countries (5). LBP has become the leading cause of disability worldwide and places a huge economic burden on society (6). Effective treatment of LBP has consistently been a research hotspot in rehabilitation and sports medicine.

Many studies have shown that exercise therapy is beneficial for LBP (7, 8). International evidence-based guidelines strongly recommend exercise therapy, with an emphasis on individualized exercise, as a core component of conservative treatment for LBP (9, 10). Many randomized controlled clinical trials have revealed that core stability exercise, resistance exercise, aquatic exercise, and whole-body vibration exercise reduce back pain and improve lumbar function (11–14). Various exercise therapies are used to treat LBP, but there is no clear evidence to support the superiority of any particular exercise intervention, and systematic analysis of global research into exercise for LBP is lacking. Therefore, there is a need to summarize the progress of research into exercise therapy for LBP over recent decades, and to provide objective data on which to base future research.

Bibliometric analysis is a quantitative statistical tool to study published literature. It has been applied to evaluate citation counts and collaboration in countries, institutions, journals, and authors, and to predict key word trends in the research field (15). High total citation counts demonstrate that an author's scientific achievements have been acknowledged by their peers (16). Liang et al. published a bibliometric analysis of the Web of Science (WoS) database from 1997 to 2016, evaluating the global utility of acupuncture for LBP (17). However, there is no targeted bibliometric analysis of global scientific research into exercise in-

tervention for LBP. Thus, the aim of the current study was to conduct a bibliometric analysis to summarize the progress and trends of global exercise therapy studies for LBP over the last 4 decades. This will provide a reference on which to base future research, by identifying the most frequently cited publications, co-cited journals, collaborations between countries/institutions/authors, and topic trends.

METHODS

Search strategy

The data for this study were obtained from articles in the WoS Core Collection database, which includes Social Science Citation (SCI)-EXPANDED, Social Science Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index – Science (CPCI-S), and Conference Proceedings Citation Index -Social Science and Humanities (CPCI-SSH), from 1980 to 2018. A complete online search was carried out on 1 March 2019, to avoid deviation due to updating because the database is still open.

The search key words were established in reference to Medical Subject Heading (MeSH) terms from PubMed. The search strategy was as follows: Title = (low back pain OR low back ache OR sciatic* OR lower back pain OR lower back ache OR low backache OR backache OR back pain) AND Title = (exercise OR train OR training OR physical activity OR physical activities OR strength OR endurance OR resistance OR stability OR walk* OR tai chi OR yoga OR motor control OR core control OR stretch* OR run* OR muscle energy technique OR Pilates* OR McKenzie therapy OR Williams gymnastics OR hydrotherapy OR water sports OR kinesitherapy) AND Language=English. Only peer-reviewed articles and reviews were accepted.

Analysis tools

CiteSpace 5.3.R4 (Drexel University, Philadelphia,USA), Microsoft Excel 2016, and IBM SPSS Statistics 20.0 software (SPSS Inc, Chicago, USA) were used to analyse the data. CiteSpace 5.3.R4 software, based on the Java platform, is usually applied to visualize and analyse networks. The most prominent function of this software is to generate visual knowledge maps of authors, countries, institutions, and references. The maps consist of different nodes and links. Links between nodes represent the correlation of collaboration or co-citations. The different colours represent different citation years. This software can identify research hotpots and new trends in a specific field by viewing the citation burst history and betweenness centrality (purple round) (18). Nodes with high betweenness centrality (value greater than 0.1) are usually considered pivotal areas in a particular research direction (18). This software also supports different types of bibliometric studies, such as geospatial visualization (19), which
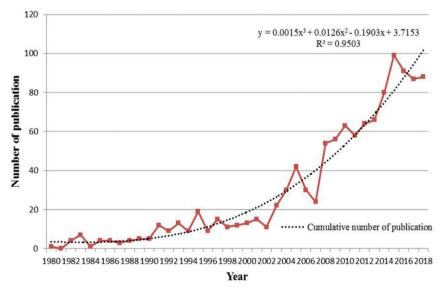
was not used in the current study. Microsoft Excel 2016 was used to tabulate data from the WoS core database and construct a trending figure of publication quantity with years. In addition, SPSS Statistics 20.0 software was used to carry out Pearson's correlation analysis of year and publication quantity.

Data extraction

After devising the search strategy, 2 authors (X-QW and RW) extracted the literature and bibliometric indicators, respectively. One person downloaded the published studies, and the other used CiteSpace 5.3.R4 and Microsoft Excel 2016 to extract the number of publications (including different journals, countries, institutions, and authors), citation frequency, and key word trends. Relational figures and tables were obtained, via data interpretation with the analysis tools described above.

This study interpreted global research reports on exercise interventions for LBP based on the following aspects:

- analysis of distribution and tendency according to journals, years, countries, institutions, and authors;
- assessment of collaboration between countries/institutions/authors;
- analysis of citations and the H-index, which refers to a journal or researcher having H published papers with at least H citations per paper (20);
- analysis of references and key words.

Moreover, this study assessed the first 20 subject categories of the WoS core collection for the included studies and calculated a percentage score every 5 years (number of publications per year divided by total number of publications for each category) for single- and multiple-authored publications.

RESULTS

Analysis of publication outputs and growth trend prediction

A total of 1,140 references were included. The number of publications increased over the years, but with some

$$y = 0.0015x^3 + 0.0126x^2 - 0.1903x + 3.7153$$
$$R^2 = 0.9503$$

Fig. 1. Annual number of publications and growth trend in exercise interventions for low back pain (LBP).

fluctuation. As shown in Fig. 1, the publication outputs increased from 11 in 2002 to 42 in 2005 (first rapid growth stage). However, the outputs decreased to 24 in 2007 and did not increase to 54 until 2008 (second stage). The third stage (2013–2015) was the period with the highest growth, which has been increasing since then. Analysis revealed that publication quantity correlated positively with publication year ($r = 0.897$, $p < 0.001$). Publication outputs demonstrated an increasing trend annually. This indicates that exercise intervention for LBP has received increasing attention, and further research into exercise therapy is ongoing.

Analysis of document type

This study only included articles and reviews. Journal articles (1,053 publications), which accounted for 92.4% of included papers, were the most common type of literature. Reviews accounted for 7.6%. The most frequently cited article was "Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominis", published in *Spine* (21). In this article (citation: 912), Hodges & Richardson reported that the cause of the defect in lumbar movement control was delayed contraction of the transversus abdominis and decreased stability of the spinal muscles. The most cited review was "Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain", published in *Annals of Internal Medicine*

(22). This review (citation: 375) included 43 trials of 72 exercise treatments, and reported that exercise interventions are slightly useful in reducing pain and improving lumbar function in patients with chronic LBP. Moreover, stretching and muscle strengthening seemed to be the most effective exercises for chronic LBP (22). The authors recommended an individualized regimen to treat LBP and achieve positive adherence.

In addition, a controlled trial, entitled "The treatment of acute low back pain: bed rest, exercise, or ordinary activity?" published in the *New England Journal of Medicine* (with an impact factor in 2018 of 70.67) was among the first 10 papers with the maximum citations in the studies on exercise for LBP. In this trial (citation: 421), patients who continued their daily activities within the limitation of pain had better and faster recovery than those who were still resting after 12 weeks (23). The application of this method to acute LBP has brought substantial savings in the clinical setting; for chronic LBP, strength/resistance and coordination/stabilization exercise programmes are more beneficial than other interventions (12).

Analysis of country and institution

CiteSpace software was used to generate a country map (Fig. 2A). The 1,140 references included in the
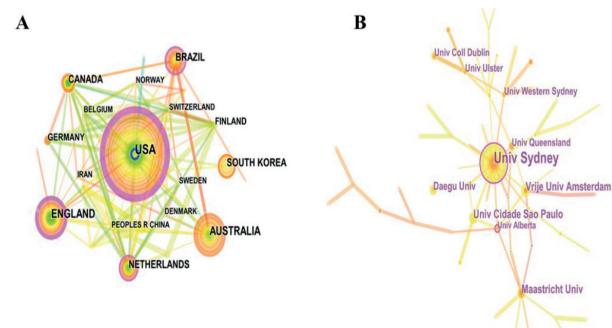

Fig. 2. Country and institution map of exercise interventions for low back pain (LBP). (A) Network map of country related to exercise for LBP. (B) Network map of institution related to exercise for LBP.

current study were published by 63 countries (Table SI[1]). In order of number of articles published, the top 5 coutries were: USA, Australia, England, Canada, and the Netherlands. In the matter of centrality (purple round), the first 5 countries were the USA (0.41), England (0.27), Brazil (0.13), the Netherlands (0.12), and Spain (0.12). Analyses of publication quantity and betweenness centrality indicated that the USA and England were the most influential researchers in exercise interventions for LBP. Northern Ireland, Ireland, New Zealand, People's Republic of China, Singapore, and Finland had the strongest collaboration. Overall, the USA (publications: 263 articles or 23.1%), which had the largest number of national partners and the most citations (8,119), led the research into exercise for LBP.

CiteSpace was also applied to generate an institution map (Fig. 2B). The top 5 institutions were the University of Sydney (New South Wales, Australia) (publications: 63), Vrije University Amsterdam (Amsterdam, Netherlands) (publications: 34), George Institution of Global Health (publications: 32), Maastricht University (publications: 30), and University of Queensland (Queensland, Australia) (publications: 23). In terms of centrality, the top 5 institutions were the University of Sydney (0.18), University of Alberta (Edmonton, Canada) (0.13), Maastricht University (Maastricht, Netherlands) (0.10), Australian Catholic University (New South Wales/ Victoria/Queensland/ Canberra, Australia) (0.06), and Zurich University of Applied Science (Zurich, Switzerland) (0.05). Analysis of publications and centrality indicated that the University of Sydney was the major research institution. The University of Western Sydney (New South Wales, Australia), University of Auckland (Auckland, New Zealand), Maastricht University, University of
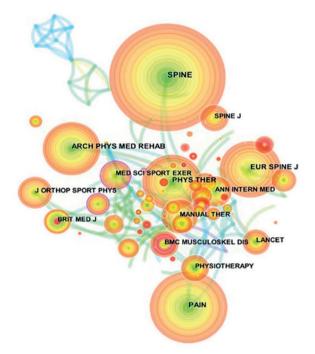

Fig. 3. Journal co-citation map of exercise interventions for low back pain (LBP).

Canberra (Canberra, Australia), and Care and Public Health Research Institut (CAPHRI) School of Public Health & Primary Care (Maastricht, Netherlands) had the collaboration with other institutions. Table SII[1] shows all the institutions that contributed to the studies.
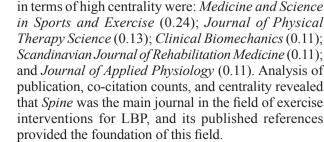
Analysis of journals and co-cited journals

The 1,140 references were published in 276 academic journals (Table SIII[1]). The top 20 journals accounted for 53.32% of the total publications (Table I). The

Table I. Origin of papers on exercise interventions for low back pain: the top 20 journals ranked by number of papers over the total period of study (1980-2018)

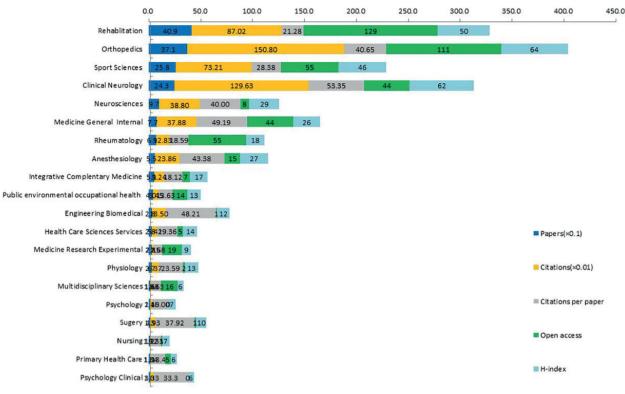| Journals	Papers n	Citations WoS n	Citations/paper n	Open access n	Impact factor (2018)	H-index
Spine	110	8,181	74.37	2	2.903	53
Journal of Physical Therapy Science	58	295	5.09	56	0.392	10
BMC Musculoskeletal Disorders	48	555	11.56	48	2.002	14
Journal of Back and Musculoskeletal Rehabilitation	47	277	5.89	1	0.814	10
Archives of Physical Medicine and Rehabilitation	31	1,271	41	2	2.697	17
Journal of Orthopaedic & Sports Physical Therapy	31	984	31.74	14	3.058	16
Physical Therapy	30	1,183	39.43	17	3.043	17
European Spine Journal	29	955	32.93	21	2.513	18
Clinical Rehabilitation	21	436	20.76	1	2.738	11
Pain	21	1,531	72.9	3	6.029	19
Journal of Manipulative and Physiological Therapeutics	20	309	15.45	0	1.274	9
Manual Therapy	19	1,171	61.63	1	2.622	15
Spine Journal	18	510	28.33	2	3.196	11
Clinical Biomechanics	17	1,246	73.29	0	1.977	11
British Journal of Sports Medicine	16	496	31.00	5	11.645	9
Physiotherapy	15	201	13.40	2	2.534	7
Plos One	15	136	9.07	15	2.776	6
Journal of Rehabilitation Medicine	14	532	38.00	14	1.907	12
European Journal of Pain	13	327	25.15	2	3.188	8
American Journal of Physical Medicine Rehabilitation	12	242	20.17	2	1.908	8

Fig. 4. The first 20 subject categories of journals related to exercise interventions for low back pain (LBP).

first 5 journals in terms of number of publications were: *Spine; Journal of Physical Therapy Science; BMC Musculoskeletal Disorders; Journal of Back and Musculoskeletal Rehabilitation;* and *Archives of Physical Medicine and Rehabilitation. Spine* had the highest H-index value and the highest number of citations per paper, followed by *Clinical Biomechanics* and *Pain*. Among the top 20 journals, 55% and 45% of the professional journals were the first Quartile (Q1) and the second Quartile (Q2) in the journal IF quartile category of WoS. The mean IF of the top 20 journals was 2.961, indicating that the included studies were highly reliable.

The co-citation journal map (Fig. 3) showed that the top 5 co-cited journals were: *Spine* (publications: 938); *Pain* (publications: 652); *Physical Therapy* (publications: 534); *European Spine Journal* (publications: 525); and *Archives of Physical Medicine and Rehabilitation* (publications: 513). The top 5 journals in terms of high centrality were: *Medicine and Science in Sports and Exercise* (0.24); *Journal of Physical Therapy Science* (0.13); *Clinical Biomechanics* (0.11); *Scandinavian Journal of Rehabilitation Medicine* (0.11); and *Journal of Applied Physiology* (0.11). Analysis of publication, co-citation counts, and centrality revealed that *Spine* was the main journal in the field of exercise interventions for LBP, and its published references provided the foundation of this field.

Analysis of subject categories of WoS

The research areas of the 1,140 papers on exercise for LBP were classified into 4 broa d WoS categories, which covered 64 subject categories. In the first 20 subject categories (Fig. 4), according to the number of publication outputs, the Rehabilitation subject category had the most publications and open-access papers. The Orthopedics subject category had the maximum citations in WoS and the highest H-index value. The subject category with the maximum citations per paper was Clinical Neurology. A total of 276 academic journals in the field of research into exercise therapy for LBP focused mainly on Rehabilitation, Orthopedics, and Sports Science. This indicates that research into sports rehabilitation of LBP emphasizes musculoskeletal rehabilitation, which is related to the aetiology of LBP (e.g. muscle strain and degenerative changes in the spine).

Analysis of authors and co-cited authors

Knowledge maps of papers' authors and co-cited authors can provide useful information on influential research teams and possible partners, which can enable researchers to establish cooperation. A total of 3,900 authors contributed to the 1,140 publications. As shown in Table II, Maher ranked first with regard to publication output, followed by Ferreira, Costa, and Hurley. The top 5 co-cited authors were Waddell,

Table II. The first 10 authors were ranked by number of papers, the first 10 co-cited authors and co-cited references were ranked by number of citation on exercise interventions for low back pain

Author	Published papers, *n*	Co-cited author	Cited times, *n*	Co-cited reference	Cited times, *n*
Maher CG	33	Waddell G	242	Airaksinen O, 2006, Eur Spine J, v15, p0	63
Ferreira PH	19	Hayden JA	208	Hayden JA, 2005, Ann Intern Med, v142, p765	62
Costa LOP	17	Deyo RA	181	Hayden JA, 2005, Ann Intern Med, v142, p776	61
Hurley DA	16	Roland M	177	Ostelo R, 2008, Spine, v33, p90	60
Hodges PW	14	Van Tulder M	176	Yelland MJ, 2004, Spine, v29, p9	44
Latimer J	14	Hodges PW	174	Hoy D, 2012, Arthritis Rheum-US, v64, p2028	42
Ferreira ML	12	Mannion AF	168	Macedo LG, 2009, Phys Ther,v89,p9	40
Mcdonough SM	11	Koes BW	144	Van Middelkoop M, 2011, Eur Spine J, v20, p19	39
Brox JI	10	Osullivan PB	144	Van Middelkoop M, 2010, Best Pract Res CL RH, v24, p193	39
Cabral CMN	10	Airaksinen O	137	Koumantakis GA, 2005, Phys Ther,v85, p209	35

Hayden, Deyo, Roland and Van Tulder. These authors were active authors in the field of exercise therapy for LBP. Fig. 5 shows the author map and co-cited author map. Waddell, who had the most co-citation counts and centrality, mainly studied outcome measures and evaluation of LBP management, which form the basis for future research. Collaborations were observed among Maher, Ferreira, Costa, and Ferreira. Moreover, the percentages of multiple authors (≥2) increased from 84.6% in 1980–1984 to 97.3% in 2014–2018. However, the centrality of such collaborations was less than 0.03, indicating that cooperation between research staff was insufficient.

Maher, working at the University of Sydney and studying the effect of different exercise interventions for LBP (e.g. motor control exercise, physiotherapist-directed exercise, tai chi, and pilates), was the most prolific author. One of his studies with the highest citation frequency was a randomized trial that included 240 subjects who had chronic LBP and who received 8 weeks of general exercise, movement control, or spinal manipulative therapy (24). The regular activities included muscle-strengthening, stretching, and aerobic exercises. The author concluded that movement control exercise and manipulative therapy provided a slightly better effect than regular activities at 8 weeks, but not at 6 and 12 months (24). Maher's other systematic review showed that movement control exercise, alone or as a supplementary treatment, was effective in easing pain and dysfunction in individuals with non-specific LBP; however, there was no evidence to show that movement control exercise was more valid than manual therapy, other exercises, or surgery (25). Although the "European guidelines for the management of chronic nonspecific low back pain" recommended various exercises and manipulative therapy for chronic LBP, few direct comparisons of different interventions were available (26).
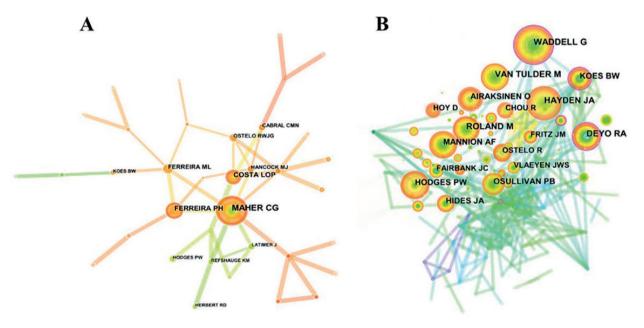

Fig. 5. Author and co-cited author map of exercise interventions for low back pain (LBP). (A) Network map of author related to exercise for LBP. (B) Network map of co-cited author related to exercise for LBP.
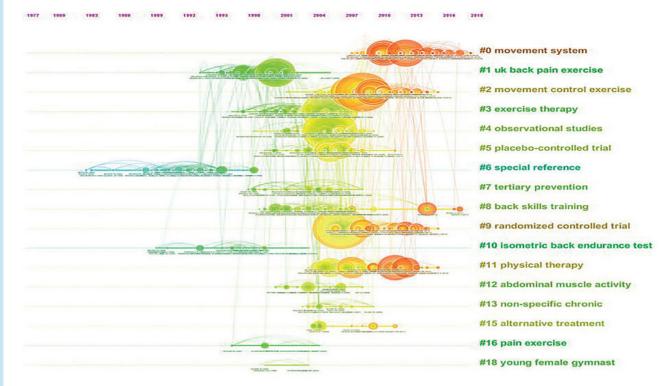
Fig. 6. Timeline view map related to exercise interventions for low back pain (LBP).

Analysis of references

Analysis of references is a significant indicator. In terms of co-citation counts and centrality, the reference timeline map in this study showed that the data on this field over the 4 decades studied were generally in the form of: (*i*) different exercise interventions for LBP; (*ii*) randomized controlled trials and observational studies; and (*iii*) alternative treatment and tertiary prevention. Fig. 6 shows the top 18 clusters in a timeline view. All clusters were extracted from the references by use of index terms. "Movement system," "back pain exercise," "movement control exercise," and "exercise therapy" were marked as the largest cluster #0, second-largest cluster #1, third-largest cluster #2, and fourth-largest cluster #3, respectively.

Table III. The first 10 papers with the maximum citations in the research into exercise for low back pain

Title	First author	Journal	Impact factor (2018)	Year	citations WoS, *n*
Inefficient muscular stabilization of the lumbar spine associated with low back pain – a motor control evaluation of transversus abdominis	Hodges, PW	*Spine*	2.903	1996	912
An index of the functional-condition of rat sciatic-nerve based on measurements made from walking tracks	Demedinaceli, L	*Experimental Neurology*	4.562	1982	779
Mechanical stability of the in vivo lumbar spine: Implications for injury and chronic low back pain	Cholewicki, J	*Clinical Biomechanics*	1.874	1996	619
Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis	O'Sullivan, PB	*Spine*	2.903	1997	590
The treatment of acute low-back-pain-bed rest, exercise, or ordinary activity	Malmivaara, A	*New England Journal of Medicine*	70.67	1995	421
Diagnosis and classification of chronic low back pain disorders: maladaptive movement and motor control impairments as underlying mechanism	O'Sullivan, P	*Manual Therapy*	2.622	2005	401
Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain	Hayden, JA	*Annals of Internal Medicine*	19.315	2005	375
Randomized clinical trial of lumbar instrumented fusion and cognitive intervention and exercises in patients with chronic low back pain and disc degeneration	Brox, JI	*Spine*	2.903	2003	347
Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program	Hicks, GE	*Archives of Physical Medicine and Rehabilitation*	2.697	2005	331
Exercise therapy for low back pain – a systematic review within the framework of the Cochrane Collaboration Back Review Group	van Tulder, M	*Spine*	2.903	2000	329

The 10 papers with the maximum citations are shown in Table III. In the last 2 years, the paper "Exercise for the prevention of low back pain:systematic review and meta-analysis of controlled trials" was in the top 1% in terms of number of citations in the academic field of Social Science and General Science. This review indicated that exercise could lower the risk of LBP and related disabilities. It also advised the general population to engage in strengthening exercise combined with stretching or aerobic exercises 2–3 times a week to prevent LBP (27).

Analysis of key words and strongest burst key words

A map of key words can reflect hot topics of research (Fig. 7). The top 10 key words that began in 1991 were: LBP, disability, exercise, randomized controlled trial, therapy, rehabilitation, clinical trial, reliability, management, and chronic LBP. The top 37 key words

Fig. 7. Key word map related to exercise interventions for low back pain (LBP).

Fig. 8. Top 37 key words with the strongest citation bursts. Red bars: some key words cited frequently; blue bars: key words cited infrequently.

with the highest citation bursts were the indicators of research frontier topics over time (Fig. 8). Between 1991 and 2007, the key words with the highest citation bursts were: low back pain, clinical trial, and exercise, but between 2012 and 2018, the key words with the strongest citation bursts were stability, quality of life, general exercise, balance, gait, and meta-analysis. This result indicates that stability, balance, and gait of patients with LBP have become the research development trend and focus in this field of research.

DISCUSSION

LBP has become the leading reason for activity limitation and absenteeism worldwide and, therefore, is of urgent global public health concern (28). The World Health Organization (WHO) has identified research into "reducing disabling LBP" as one of its global health priority programmes (28). In the biopsychosocial medical model, exercise therapy has been gradually recognized as an important part of physical therapy to treat LBP. Therapeutic exercise as an effective method is an indispensable part of the model of physiotherapy. The current analysis was based on studies published on exercise therapy for LBP over the last 4 decades. The retrieval strategy obtained 1,140 objective studies. The data were imported into CiteSpace software, which extracted bibliometric indicators (e.g. key words, countries, institutions, and other items). Relational figures, tables, and data interpretation were produced through processing using the analysis tools.

The results of this study provide a systematic narrative regarding global research into exercise therapy for LBP over the last 4 decades. The results show that, firstly, the percentage of publications increased gradually every 5 years, with the period 2005–2009 having the maximum number of citations (10,500) and the highest value of H-index (54). The period 1980–1984 had the maximum citations per paper (98), and 2014–2018, with the maximum number of total publications (450), had the minimum (5). It is worth noting that this growth in the literature does not imply improvement in the *quality* of papers, as the data extraction process obtained only the number of papers issued in this field, and could not judge their quality. High values for citations implies only that these papers received more attention from researchers. In addition, the rapid growth in publication outputs may have been related to the "exercise is medicine" health promotion programme co-launched in 2007 by the American College of Sports Medicine and the American Medical Association (29). This programme aimed for physical activity and exercise health promotion, with the core idea of spreading the belief that "exercise is beneficial to human bodies, and proper exercise prescription is needed". This programme improved the progress of research into preventing and treating chronic diseases or chronic/persistent pain. Secondly, 63 countries and 276 journals contributed to the 1,140 publications analysed. The USA was the top country, with the maximum number of publications and the most citations. The University of Sydney (63 publications) was the major research institution. The journal *Spine* had the highest H-index value (53) and the most citations per paper (74.37).

According to the current analysis of subject categories of WoS, research into exercise for LBP focused on Rehabilitation, Orthopedics, and Sports Science, and was well-developed in the USA and Australia. Spinal problems caused by sedentary lifestyle and inactivity are increasing due to population ageing and rapid urbanization. Physical inactivity was the fourth leading risk factor for global mortality (30). Over the years, researchers have been constantly improving the quality of evidenced-based research into exercise for treating LBP, in order to recommend a highly scientific management regimen. Considering that the idea that "exercise is medicine" is spreading, researchers have suggested an individualized exercise therapy, which emphasizes prescribing an exercise programme based on a patient's needs, preferences, and abilities (9, 29). This is consistent with the clinical guideline for the classification of treatment of LBP (31). A systematic review reported that multidisciplinary biopsychosocial rehabilitation was more beneficial than physical therapy and usual care in easing pain and disability in chronic LBP and had a positive impact on work status (32). However, another study showed that an exercise programme after functional multidisciplinary rehabilitation compared with usual care did not provide important long-term advantages in quality of life and total medical costs (33). Such programmes are economically impracticable and unacceptable, especially in many developing countries. Therefore, other effective, simple, and feasible methods to treat chronic LBP need to be identified.

Three major conclusions about exercise intervention for LBP can be drawn from the information provided by the timeline view map (Fig. 6), the key word map (Fig. 7), and the top 37 key words with the strongest citation bursts (Fig. 8). First, chronic or disabling LBP has been the focus of treatment of LBP. Acute back pain often transforms into chronic and persistent pain, which may result in depression, work absence, low quality of life, and large economic costs. Timely action is therefore important to prevent and resolve this pain syndrome. Secondly, the most effective research method is the randomized controlled clinical trial. The method used can easily provide the usual care group or supplemental control group, but it is

difficult to achieve blinding of subjects. Thirdly, the effectiveness comparison of different exercise therapies for LBP guides researchers to establish rapid and beneficial exercise therapies. According to clinical practice guidelines, physical coordination training, tai chi, yoga, and strength and progressive endurance training are highly recommended (10, 31). The current study found that, in recent years, the popular key words changed to stability, balance, gait, and quality of life, which reflects the focus of research. To date, global exercise therapy interventions for LBP mainly include aerobic exercise, muscle strength, core motor control, flexibility, proprioception, and combined exercise (12, 34–36). Meanwhile, yoga, tai chi, and qigong, which are mind–body exercises, bring many benefits to patients (37). Aboagye et al. reported, in 2015, that 6 weeks of yoga as an early intervention for managing non-specific LBP was more economical than exercise therapy or self-care advice (38). In 2017, Saper et al. found that yoga was not inferior to physical therapy for non-specific chronic LBP, especially in low-income areas (39). This result is useful in viewing structured yoga practice as a reasonable alternative therapy depending on patients' preferences and budgets. Although tai chi can be a secure and valid intervention for persistent LBP (40), comparable evidence between tai chi and clinical physical therapy is lacking. As an easy and low-cost exercise, tai chi may prove useful in treating chronic pain syndromes, such as LBP.

Strengths and limitations

This study is the first bibliometric analysis to summarize the progress and trends of global scientific research into exercise for LBP in the last 4 decades, based on WoS data. The 1,140 papers were derived from 276 academic journals and enriched these results. In addition to analysing the number of publications, citations, journals, and collaborations between countries/institutions/authors, this study also analysed subject categories, references, authors, and key words.

This study also has some limitations. First, the retrieval strategy was limited to WoS core databases and excluded non-English papers. Only articles and reviews were included. These factors may therefore lead to a publication bias. Secondly, the study did not perform geospatial visualization with CiteSpace software, however, this did not affect our results. The third limitation was that some influential papers may not have had high citation levels, whereas others may have been cited frequently such that their results were well known.

Conclusion

This analysis of studies into exercise interventions for LBP, published over the last 4 decades, may prove useful as a basis for developing improved exercise interventions for LBP and further research into the therapeutic mechanism of this exercise. This analysis may enable research teams to collaborate in promoting the application of exercise therapy in the clinical management of LBP. Exercise interventions for LBP have received increasing attention. Many high-quality randomized controlled trials are also ongoing. Although this study has several limitations, it offers an historical insight into exercise interventions for LBP and provides information for researchers regarding potential collaboration with other institutions and researchers, popular topics, and development trend.

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