Int J Clin Exp Med 2019;12(6):6617-6635
www.ijcem.com /ISSN:1940-5901/IJCEM0090627

Original Article

Knowledge mapping visualization analysis of Tai chi research published in web of science over the past 20 years

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Received December 29, 2018; Accepted February 11, 2019; Epub June 15, 2019; Published June 30, 2019

Abstract: Objective: The aim of this study was to demonstrate state of the art trends concerning the worldwide use of Tai chi in prevention, treatment, and rehabilitation. Methods: Literature relating to Tai chi from 1999 to 2018 was retrieved from Web of Science Core Collection (WoSCC). CiteSpace was used to analyze authors, institutions, countries, keywords, cited references/authors/journals, core journals, active authors, foundation references, hot topics, and frontiers, according to time period. Results: A total of 794 references were obtained. The total number of publications increased before 2014 and decreased in the past 4 years. Journal articles were the only document type included. The most productive countries and institutions in this field were the USA (334), Chinese University of Hongkong (38), and Harvard University (37), respectively. Evidence-Based Complementary and Alternative Medicine (27) was the most productive journal. Journal of the American Geriatrics Society (497) was the most co-cited journal, which reflected the nature of the research. The six hot topics of Tai chi included balance, musculoskeletal system, chronic diseases, psychological well-being, research methods, and cost-effectiveness. Conclusion: This study provides insight into Tai chi, containing valuable information for researchers in identifying new perspectives on potential collaborators and cooperative institutions, hot topics, and research frontiers.

Keywords: Tai chi, knowledge mapping, visualization analysis, CiteSpace, hotpot

Introduction

"Cleanse your mind and concentrate on the slowness and evenness of your movements". ------Tai chi, also known as Tai chi Chuan/quan or taijiquan, is a Chinese conditioning exercise. It is well known for its slow, harmonious, meditative, and "energetic" movements. It has been combined with a perspective of use based on hand-fighting and traditional weapons, making Tai chi a unique oriental corporal body practice. Tai chi is the late Qing Dynasty sum of martial, corporal, cosmogonic, religious, and historical Chinese elements [1], reflecting oriental characteristics and wisdom. It uses TaiJi and Yin-Yang as core ideas. It is also related to the five elements and meridian and collateral theory in Traditional Chinese Medicine. Tai chi has health care effects with physical fitness, integrating the function of self-cultivation, physical fitness, and aggression confrontation.

In the past 20 years, because of its health benefits, apparent safety, and low costs, Tai chi has gradually gained popularity in both Eastern and Western countries, as a promising mind-body exercise. An increasing number of clinical studies have documented the safety and health benefits of Tai chi intervention [2]. Several systematic reviews have examined available evidence from randomized controlled trails or non-randomized clinical trials on Tai chi concerning a variety of specific diseases and health conditions.

Tai chi has been applied to many kinds of physical and mental problems in many countries. However, bibliometric analysis of its worldwide use has been rare. In this study, analyzing trends concerning the worldwide use of Tai chi in the past 20 years, CiteSpace was used to conduct a bibliometric analysis of related references derived from the Web of Science data-

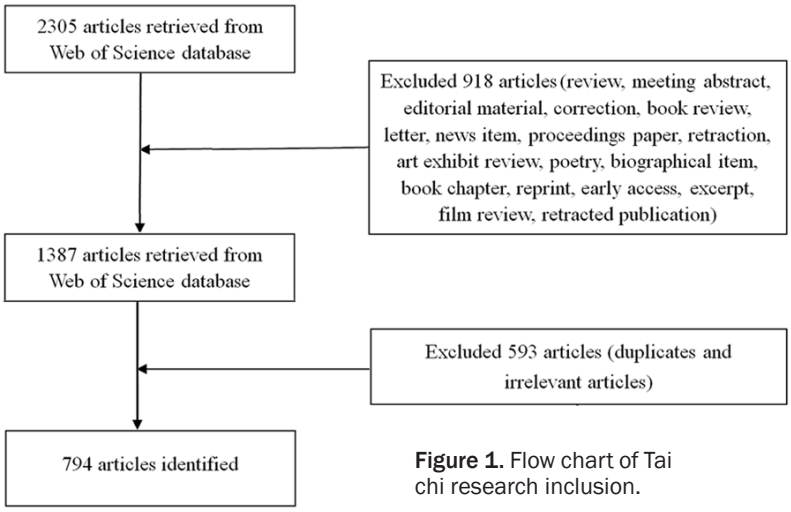

Figure 1. Flow chart of Tai chi research inclusion.

base. This study aimed to analyze authors, institutions, countries, keywords, cited references/authors/journals, core journals, active authors, foundation references, hot topics, and frontiers, according to time period.

Materials and methods

Data source and search strategy

Literature retrieval was conducted online through Science Citation Index-Expanded (SCI-E), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (A & HCI) of the Web of Science Core Collection (WoSCC) on September 14, 2018. Searches were conducted on the same day, avoiding bias caused by daily database updates. The time span ranged from 1999 to 2018. Data retrieval strategy [3]: Topic = ("tai chi") OR = ("taichi") OR = ("tai chi quan") OR = ("taichichuan") OR = ("tai ji") OR = ("taiji") OR = ("tai ji quan") OR = ("taijiquan") OR = ("tai chi quan") OR = ("taichiquan"); Document type = article. Only original papers were included and there were no language or data category restrictions. A total of 1,387 references were ultimately obtained.

Study selection

To ensure the accuracy of retrieval results, manual verification was necessary. Two authors (PYZ and RRY) screened the titles and abstracts of the hits (browsed full texts when necessary). If there was uncertainty or discrepancies, a third author (YY) was consulted. After study selection, duplicate and irrelevant articles were removed. After repeated screening, a total of 794 references were obtained (**Figure 1**).

Analysis tool

CiteSpace was used to perform bibliometric analysis. Visualization knowledge maps consist of nodes and links. Nodes represent different elements, like authors, institutions, countries, and cited references. Links represent relationships of collaboration or co-citations. Colors of the nodes and lines represent different years. Centrality is usually regarded as a turning point or pivotal point in a field, representing the importance of nodes in a network [4, 5]. A key node is defined as a node with an intermediary centrality greater than or equal to 0.1 in the network.

Parameters of CiteSpace included time slicing (1999-2018), years per slice (1), term source (all selection), node type (choose one at a time), selection criteria (10/30/50), pruning (pathfinder/minimum spanning tree/pruning the merged network), and visualization (cluster view-static, show merged network).

Results and discussion

Analysis of publication output

The total number of publications increased over the study period, with some fluctuations. The number of publications by year is presented in **Figure 2**. Until 2000, there were few studies on Tai chi. The period of 2000 to 2014 was a rapid development period. The overall trend raised from 6 articles in 2000 to 92 articles in 2014. Although the growth rate of publication output decreased in 2002, 2005, and 2008, the total number of publications showed a rising trend during this period. After 2014, the number of original papers declined. There has been a decrease in the number of original studies in the past 4 years.

Analysis of document type

There were 15 documents types identified in a total of references related to Tai chi. Only original articles were included to avoid duplicated and incomplete knowledge content. Selected journal articles (794) were all closely related to Tai chi research.

Figure 2. The number of Tai chi publications indexed from 1999 to 2018.

Analysis of countries and institutions

Generating an institution map using CiteSpace resulted in 103 notes and 95 links (**Figure 3**). The 794 publications were distributed among 103 research institutions. The top 10 institutions are listed in **Table 1**. The top 10 institutions, in terms of centrality, (≥0.1) were Hong Kong Polytechnic University (0.30), Harvard University (0.28), Fujian University of Traditional Chinese Medicine (0.28), Willamette University (0.17), Brigham & Women's Hospital (0.15), University of Illinois (0.14), Shanghai University Of Sport (0.13), University of Sydney (0.13), Harvard medical school (0.11), and Chinese University of Hongkong (0.10). Publication and centrality analysis indicated that Harvard University, Hong Kong Polytechnic University, and Chinese University of Hongkong were the core research institutions. However, collaborations among them were not evident. The network map demonstrated few connections between institution nodes. Colleges and health research institutions are the main research forces of Tai chi, with obvious scientific research advantages.

Generating a country map using CiteSpace resulted in 41 nodes and 81 links (**Figure 4**). The 794 references were contributed by 41 countries. According to the top 10 countries (**Table 1**) engaged in Tai chi research, the USA contributed the most publications (334). They were followed by China (298) and Australia (60). The top 8 countries, in terms of centrality (≥0.1), were China (0.38), USA (0.32), England (0.26), Spain (0.26), Italy (0.17), Netherlands (0.16), Australia (0.11), and South Korea (0.10). Analysis, in terms of publication and centrality, indicated that China and the USA were the main research powers. Extensive collaborations were observed between China, USA, Australia, England, Spain, and Canada. Apart from China, developed countries are the main forces in Tai chi research.

Analysis of journals and co-cited journals

Knowledge maps can provide information concerning core professional journals in the field. **Table 2** shows the top 5 scholarly journals that published articles related to Tai chi research. They were professional and core journals in this field. Of these, the average impact factor (IF) was 2.900. However, there were some articles published in high-IF journals, like *New England Journal of Medicine* (IF=79.258), *Journal of Clinical Oncology* (IF=23.303), *Annals of Internal Medicine* (IF=19.384), and *Annals of the Rheumatic Diseases* (IF=12.350). *New England Journal of Medicine* reported that Tai chi is an effective intervention in Parkinson's disease and fibromyalgia [6, 7], while the *Journal of Clinical Oncology* reported that Tai chi could improve insomnia symptoms in survivors of breast cancer [8]. These high-IF papers represent the high quality and major influence of Tai chi research.

Next, this study selected the top 10 most cited journals from each year, generating a co-cited journal map using CiteSpace, resulting in 46 notes and 67 links (**Figure 5**). The top 10 co-cited journals are listed in **Table 3**. The average IF was 15.8509. The top 5, in terms of centrality, were Arch Phys Med Rehab (0.87), Med SCI Sport Exer (0.67), Am J Occup Ther (0.63), J Am Geriatr Soc (0.53), and Phys Ther (0.52). The most co-cited journal was the *Journal of the American Geriatrics Society,* cited 497 times. It reported that Tai chi is an effective exercise in reducing incidence of falls [9], augmenting immune response [10], and improving cognitive

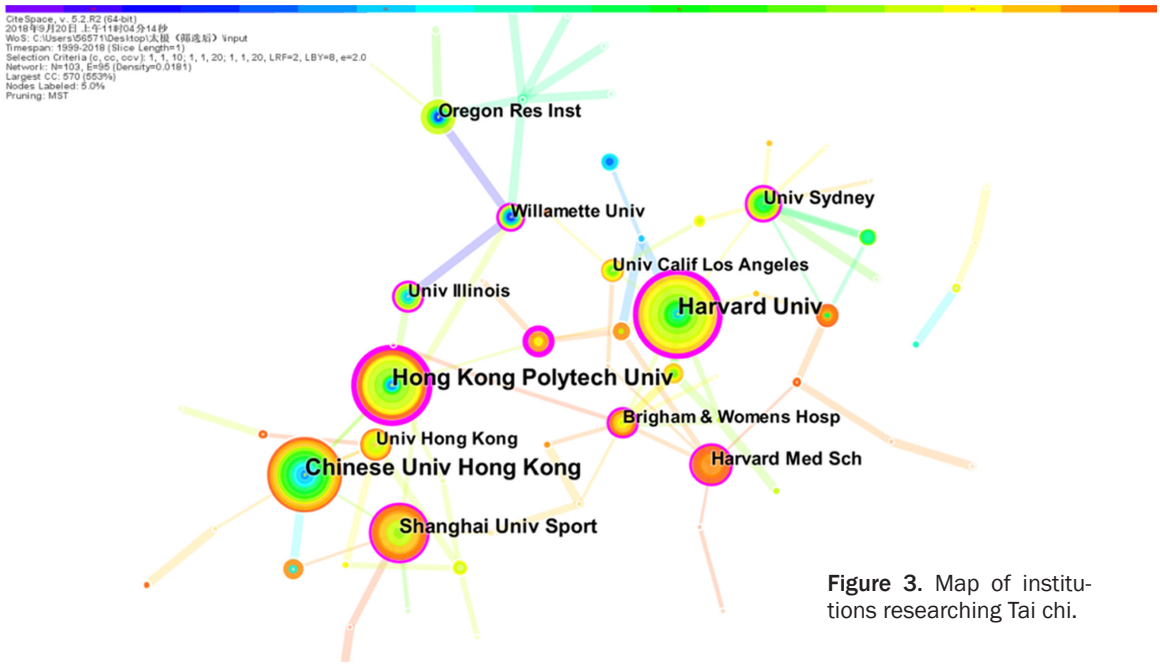

Figure 3. Map of institutions researching Tai chi.

Table 1. Top 10 prolific institutions and countries researching Tai chi

Ranking	Publications	Institution	Ranking	Publications	Country
1	38	Chinese University of Hongkong	1	334	USA
2	37	Harvard University	2	298	China
3	25	The Hongkong Polytechnic University	3	60	Australia
4	25	Shanghai University Of Sport	4	44	Canada
5	19	Oregon Research Institute	5	31	South Korea
6	18	University of Sydney	6	24	England
7	16	Harvard Medical School	7	24	Japan
8	15	Brigham & Women's Hospital	8	21	Germany
9	15	University of Hong Kong	9	12	Switzerland
10	14	University of Illinois	10	12	Brazil

function [11]. However, this journal also published a randomized clinical trial with results showing that Tai chi was ineffective in fall prevention in elderly people living at home [12]. *The Journal of the American Geriatrics Society and Archives of Physical Medicine and Rehabilitation* have been identified as core journals in Tai chi research field, with objective and impartial attitudes. Published articles reflect the fundamentals of the research field.

Analysis of authors and co-cited authors

The top 30 most published authors from each year were selected, generating a co-author map using CiteSpace. This resulted in 193 notes and 364 links (**Figure 6**). The 794 publications were mainly published by 193 research authors. **Table 4** shows the top 10 authors that published articles related to Tai chi. They were active and professional authors in this field. Of these authors, Wayne PM was ranked first. He is from Osher Center for Integrative Medicine and Harvard Medical School. He is committed to studying the treatment of chronic heart failure with Tai chi, as well as vestibular rehabilitation. There were some collaborations between Wayne PM, Wolf SL, Yeh GY, and Davis RB, as well as between Wang CC, HARVEY WF, and PRICE LL, and between Li FZ and Harmer P. However, the centrality for such collaborations was less than 0.1, suggesting that collaboration between research authors was not yet enough.

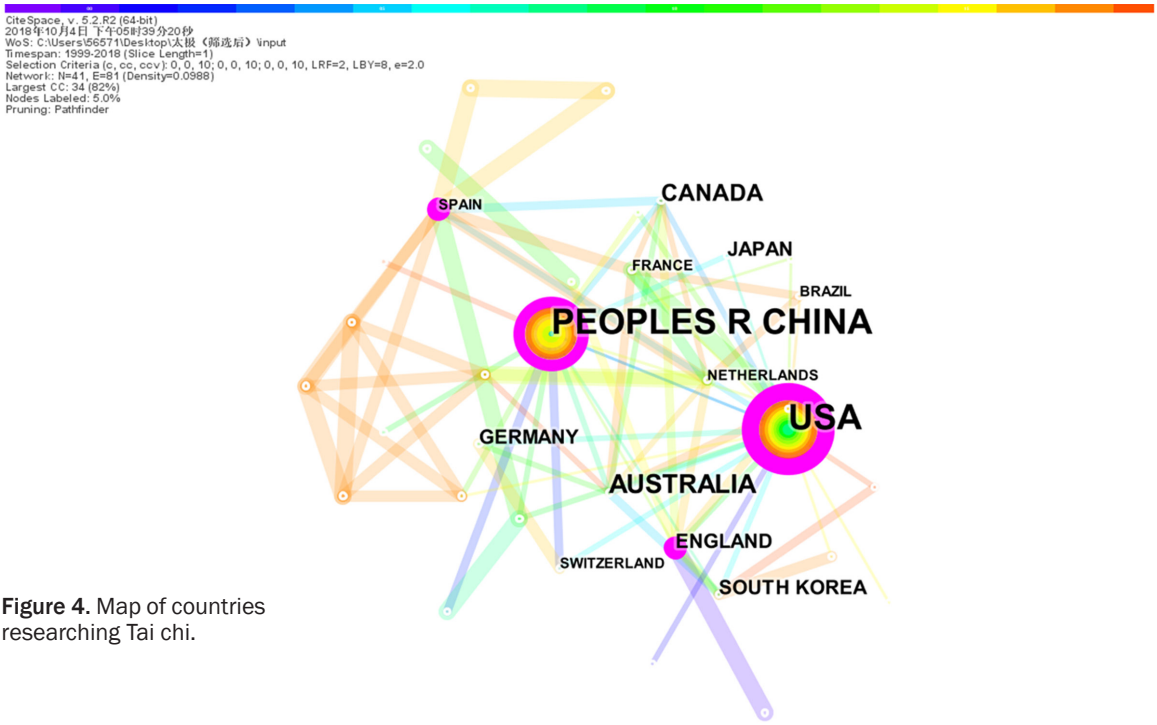

Figure 4. Map of countries researching Tai chi.

Table 2. Top 5 scholarly journals related to Tai chi research

Ranking	Publications	Journal	IF (2018)
1	27	Evidence-Based Complementary and Alternative Medicine	2.064
2	26	Archives of Physical Medicine and Rehabilitation	3.077
3	20	American Journal of Chinese Medicine	3.120
4	18	Journal of the American Geriatrics Society	4.155
5	17	Complementary Therapies in Medicine	2.084

Note: IF (impact factor) in category according to Journal Citation Reports (2017).

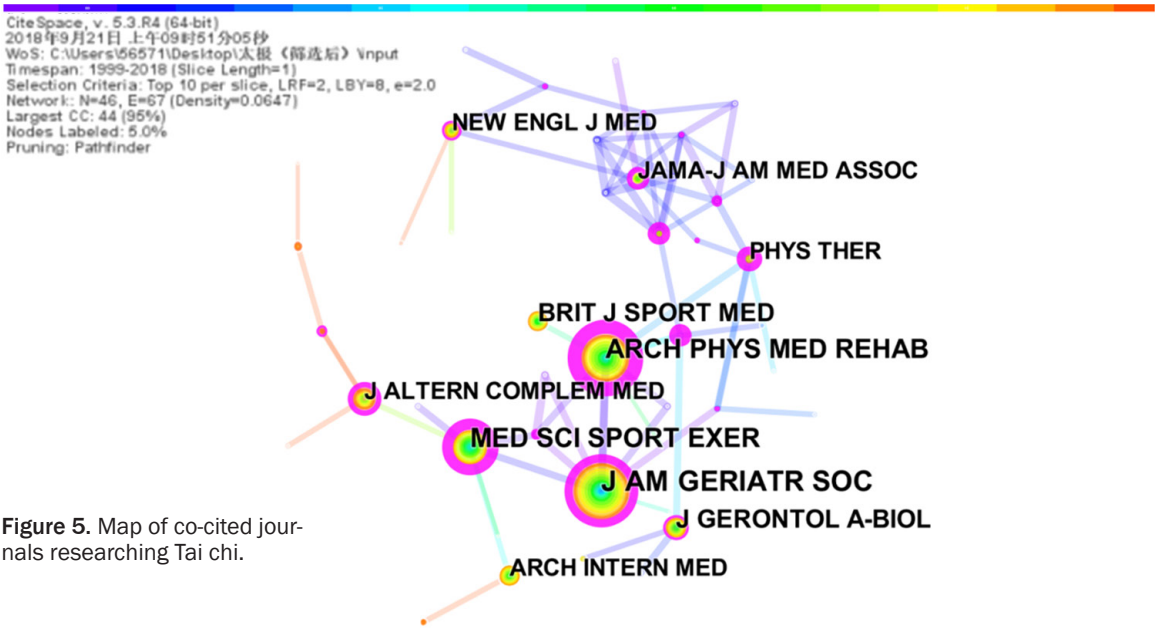

Figure 5. Map of co-cited journals researching Tai chi.

Table 3. Top 10 co-cited journals related to Tai chi research

Ranking	Co-cited counts	Co-cited journals	IF (Q) 2018
1	497	Journal of the American Geriatrics Society	4.155
2	396	Archives of Physical Medicine and Rehabilitation	3.077
3	344	Medicine and Science in Sports and Exercise	4.291
4	279	Journals of Gerontology Series a-Biological Sciences and Medical Sciences	4.902
5	255	British Journal of Sports Medicine	7.867
6	220	Archives of Internal Medicine	/
7	191	Journal of Alternative and Complementary Medicine	1.498
8	191	Jama-journal of the American Medical Association	47.661
9	187	Physical Therapy	2.587
10	178	New England Journal of Medicine	79.258

Note: *Archives of Internal Medicine* is not included in the latest JCR (Journal Citation Reports, 2017). IF (impact factor) in category according to Journal Citation Reports (2017). The data has been taken from the publication year to retrieved date (September 14, 2018).

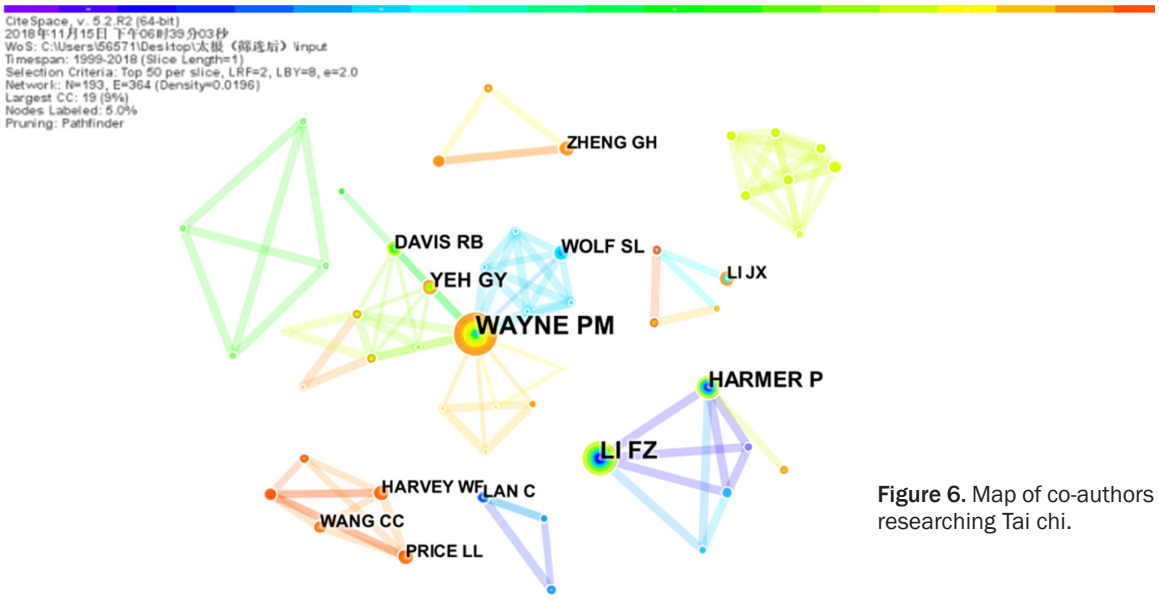

Figure 6. Map of co-authors researching Tai chi.

Table 4. Top 10 active authors in Tai chi research

Ranking	Publications	Author	Ranking	Publications	Author
1	24	Wayne PM	6	9	Davis RB
2	19	Li FZ	7	9	Wolf SL
3	14	Harmer P	8	8	Hui-Chan CWY
4	13	Tsang WWN	9	7	Wang CC
5	10	Yeh GY	10	7	Zheng GH

The top 10 most cited authors were selected from each year, generating a co-cited author map using CiteSpace. This resulted in 60 notes and 180 links (**Figure 7**). The top five co-cited authors, in terms of co-citation counts and centrality, are listed in **Table 5**. Analysis revealed that Wolf SL, Li FZ, and Wang CC were "core strength" researchers. Their studies showed an important influence on the field. Wolf SL is the Professor and Director of Research, Department of Rehabilitation Medicine. He is committed to the study of Tai chi, concerning motor control, geriatrics, and stroke biofeedback. Li FZ is from Oregon Research Institute, Eugene. He studied Tai chi in terms of physical activity, health promotion, and exercise intervention in preventing falls and injuries in the elderly. Wang CC is from Tufts Medical Center

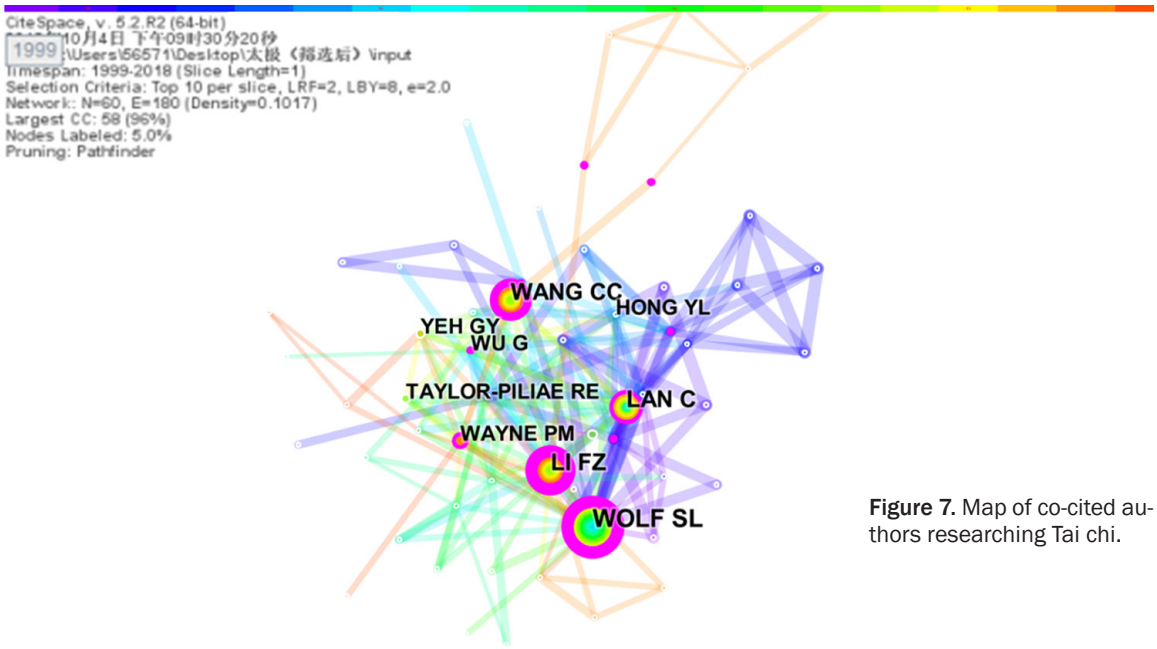

Figure 7. Map of co-cited authors researching Tai chi.

Table 5. Top 5 active authors in terms of co-citation counts and centrality

Ranking	Co-citation counts	Cited author	Ranking	Centrality	Cited author
1	269	Wolf SL	1	0.56	Wolf SL
2	243	Lan C	2	0.49	Li FZ
3	242	Li FZ	3	0.22	Wang CC
4	205	Wang CC	4	0.19	Kutner NG
5	121	Taylor-Piliae RE	5	0.14	Wolfson L

Note: The data has been taken from the publication year to retrieved date (September 14, 2018).

(USA), studying the effects of Tai chi on different disease, such as fibromyalgia, knee osteoarthritis, and rheumatic diseases.

Analysis of co-cited references

The top 10 most cited references were selected from each year, generating a cited reference co-citation map. This resulted in 120 nodes and 269 links (**Figure 8**). According to scientific metrology, studies of key nodes with relatively high centrality represent the foundation of the research field [5]. The top five co-cited references related to co-cited counts and centrality are listed in **Tables 6** and **7**, respectively.

The most cited article was "The effect of Tai chi on health outcomes in patients with chronic conditions - a systematic review" in 2004, indicating that Tai chi appears to have physiological and psychosocial benefits. It also appears to be safe and effective in promoting balance control, flexibility, and cardiovascular fitness in older patients with chronic conditions. However, most indications in which Tai chi was applied lacked a theoretical foundation concerning the mechanisms of benefit. More well-designed studies are needed [13].

The cited article with the highest centrality was "Challenges inherent to Tai chi research: Part I - Tai chi as a complex multicomponent intervention". The research team believed that Tai chi is a complex multicomponent intervention that integrates numerous physical, cognitive, and ritualistic components. They discussed additional challenges inherent to the study of Tai chi, including Tai chi's pluralism, the concept of Tai chi dosage, and long-term versus short-term evaluations of Tai chi's efficacy and safety. Furthermore, they outlined the benefits and limitations of commonly employed clinical research methods [14].

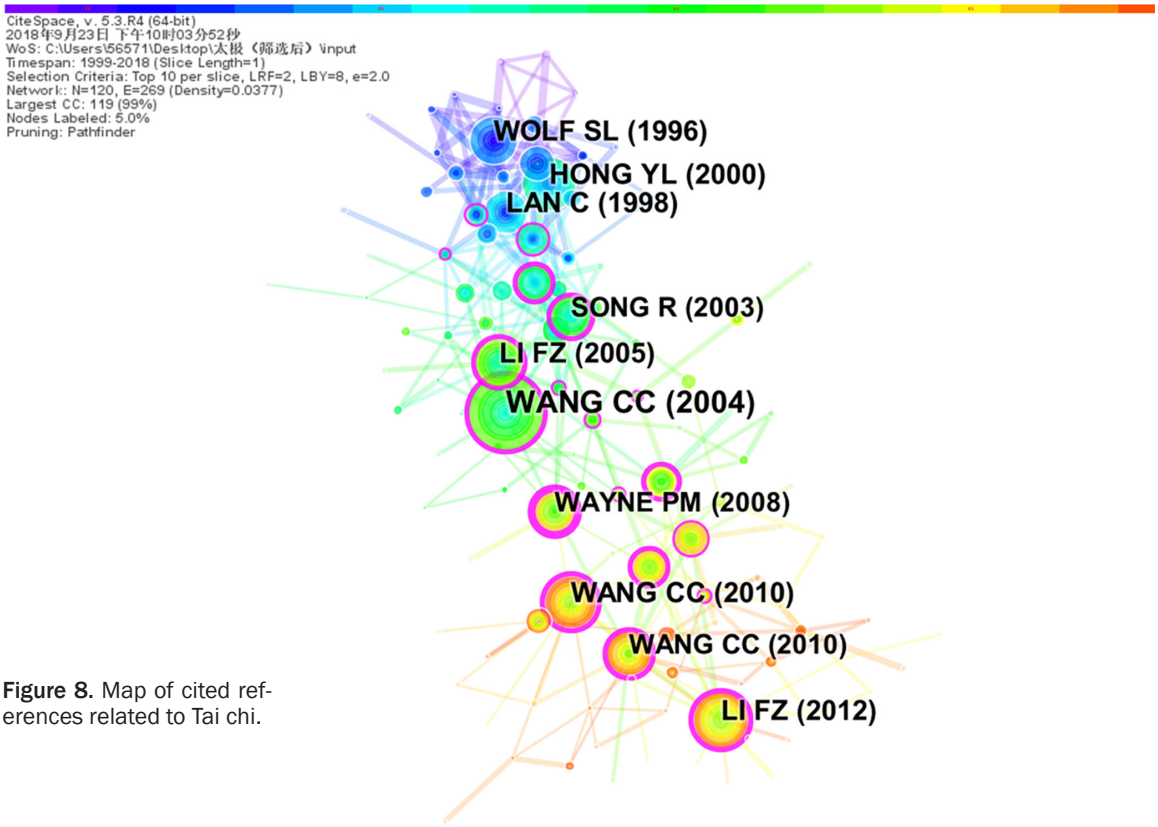

Figure 8. Map of cited references related to Tai chi.

Table 6. Top five co-cited references related to Tai chi research

Ranking	Co-cited Counts	Cited reference	Representative Author (publication year)
1	64	The effect of Tai chi on health outcomes in patients with chronic conditions - A systematic review	Wang CC (2004) [13]
2	49	Tai chi and Postural Stability in Patients with Parkinson's Disease	Li FZ (2012) [6]
3	48	Balance control, flexibility, and cardiorespiratory fitness among older Tai chi practitioners	Hong YL (2000) [81]
4	46	Tai chi on psychological well-being: systematic review and meta-analysis	Wang CC (2010) [82]
5	43	Reducing frailty and falls in older persons: An investigation of Tai chi and computerized balance training	Wolf SL (1996)
	43	Tai chi and fall reductions in older adults: A randomized controlled trial	Li FZ (2005) [16]

Note: The data has been taken from the publication year to retrieved date (September 14, 2018).

Table 7. Top five co-cited references in terms of centrality

Ranking	Co-cited Counts	Cited reference	Representative Author (publication year)
1	64	The effect of Tai chi on health outcomes in patients with chronic conditions - A systematic review	Wang CC (2004) [13]
2	49	Tai chi and Postural Stability in Patients with Parkinson's Disease	Li FZ (2012) [6]
3	48	Balance control, flexibility, and cardiorespiratory fitness among older Tai chi practitioners	Hong YL (2000) [81]
4	46	Tai chi on psychological well-being: systematic review and meta-analysis	Wang CC (2010) [82]
5	43	Reducing frailty and falls in older persons: An investigation of Tai chi and computerized balance training	Wolf SL (1996) [83]
	43	Tai chi and fall reductions in older adults: A randomized controlled trial	Li FZ (2005) [16]

Note: The data has been taken from the publication year to retrieved date (September 14, 2018).

Citations of periodical papers were relatively old, showing that research literature in the field of Tai chi urgently needs intervention from new visual angles, new ideas, and new methods.

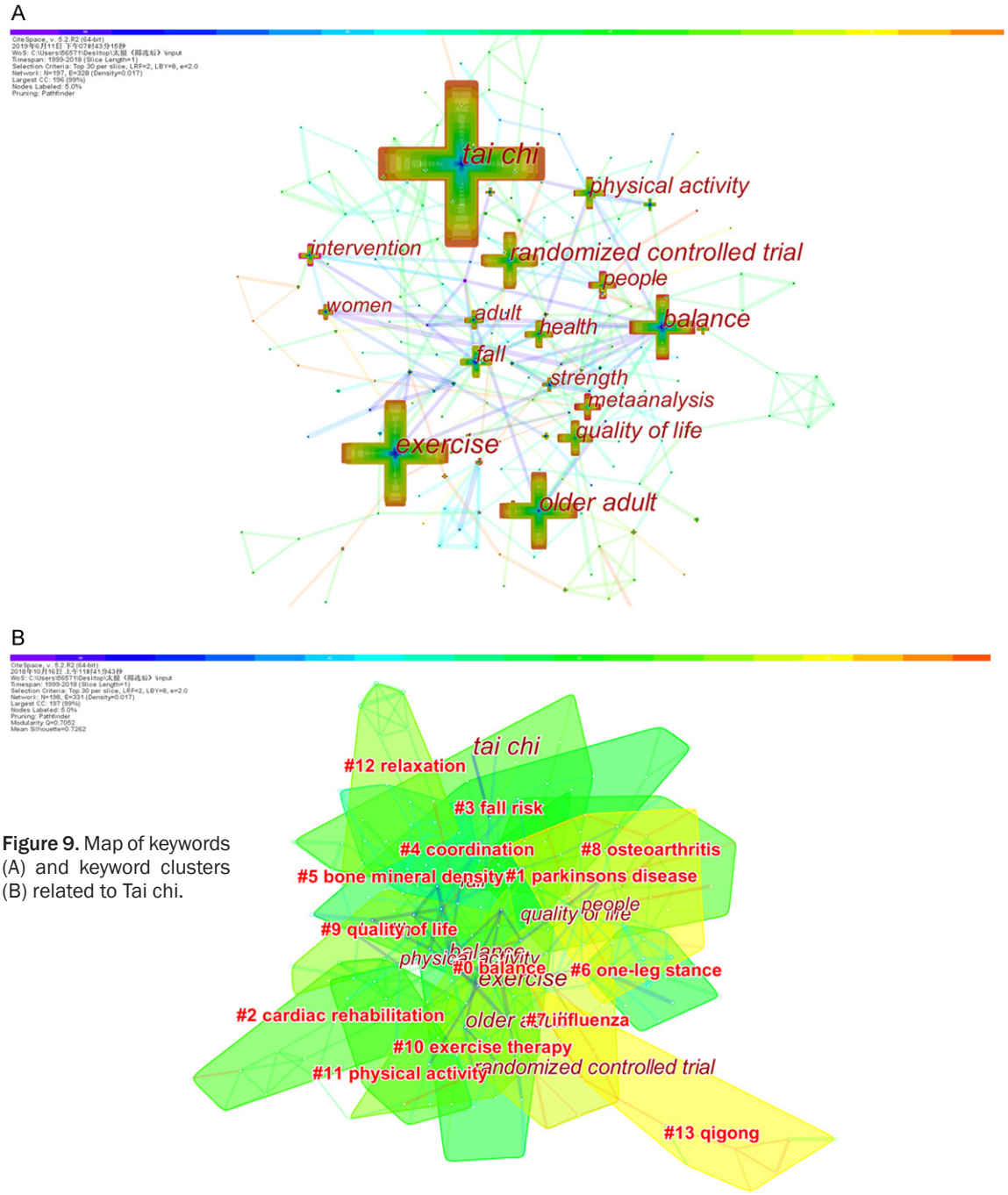

Figure 9. Map of keywords (A) and keyword clusters (B) related to Tai chi.

Analysis of keyword co-occurrence and burst keywords

A knowledge map of keyword co-occurrence reflects hot topics, while burst keywords (keywords that are cited frequently over time) indicate frontier topics over time. Since the same keywords might have different meanings in different studies, keywords of same or similar meaning were grouped together in CiteSpace. For example, “Tai chi”, “Tai chi Chuan”, and “Tai chi exercise” were grouped together, as well as “older people” and “elders”.

The top 30 keywords from each year were selected, generating a keyword co-occurrence map. This resulted in 198 nodes and 793 links (**Figure 9A**). As shown in **Table 8** and **Figure 9A**, randomized controlled trials were the main research method. Tai chi exercise research

Table 8. Top 20 keywords in terms of frequency and centrality

Ranking	Frequency	Keyword	Ranking	Centrality	Keyword
1	446	Tai chi	1	0.43	Balance
2	303	Exercise	2	0.29	People
3	230	Older adult	3	0.25	Women
4	210	Balance	4	0.20	Physical activity
5	177	Randomized controlled trial	5	0.20	Intervention
6	127	Physical activity	6	0.20	Meta-analysis
7	124	Fall	7	0.19	Community
8	123	Quality of life	8	0.19	Aged
9	106	Health	9	0.17	Gait
10	91	People	10	0.17	Practitioner
11	89	Intervention	11	0.17	Qigong
12	81	Meta-analysis	12	0.13	Risk factor
13	78	Adult	13	0.13	Performance
14	74	Strength	14	0.12	Rehabilitation
15	71	Women	15	0.12	Aerobic exercise
16	55	Rehabilitation	16	0.12	Yoga
17	54	Clinical trial	17	0.12	Efficacy
18	48	Risk	18	0.12	Postural balance
19	48	Program	19	0.11	Aging
20	45	Aging	20	0.11	Arthritis

mainly focused on balance, quality of life, falls, and strength. Test subjects were mainly adults, older adults, and women.

Clustering analysis brings closely-related topics together to display research fields. In this paper, keywords cluster analysis was conducted using the pathfinder algorithm via CiteSpace (**Table 9**). From the clustering map (**Figure 9B**), 14 clusters were generated, forming 6 knowledge groups (hot topics).

Tai chi and balance (#0, #4, #6): "Balance" was the keyword with the most centrality and highest frequency (210). It was closely related to occurrence of falls. Of Americans aged 65 years and older, falls are the leading cause of injury death and disability. Finding effective methods to prevent older adults from falling has become a public health priority [15]. Tai chi is an effective intervention that can improve the balance of older people, decreasing the number of falls and risk of falling [16, 17]. Previous studies have found that Tai chi could improve balance through better proprioception [18], enhance postural control ability [19, 20], and coordination of gait [21]. In addition, it has potential benefits and safety for balance in people with cerebellar ataxia, peripheral vestibular hypofunction patients, Parkinson's disease, and strokes [22-25].

Intervention of Tai chi on bones, muscles, and joints (#3, #5, #8): Tai chi intervention on the musculoskeletal system has been a hot topic in Tai chi research. In the past 20 years, Tai chi has been proven to be an effective intervention on bones, muscles, and joints. For example, it improves muscle strength [26, 27], relieves pain, improves the physical function of knee osteoarthritis (KOA) [28], exerts positive effects on bone loss [29], increases bone formation [30], and prevents osteoporosis and related fractures [31, 32].

Tai chi promotes health and the quality of life in people with chronic diseases (#1, #2, #7, #9, #11, #13): In recent years, people with chronic diseases have been the key research target population. Tai chi was included in one of the clinical policy recommendations for non-pharmacological methods of chronic pain [33, 34]. More and more researchers have found Tai chi to be an effective complementary and alternative intervention to many kinds of chronic diseases, involving Parkinson's disease [35, 36], type 2 diabetes [37], COPD [38], chronic heart failure [39, 40], hypertension [41, 42], chronic

Table 9. Keywords clustering analysis of Tai chi Research

Cluster ID	Silhouette	Terms
#0	0.726	Balance, falls, physical training, ventilatory threshold, exercise intervention
#1	0.715	Parkinson's disease, vestibular rehabilitation, Pittsburgh sleep quality index, general health questionnaire, multidirectional gait initiation
#2	0.768	Cardiac rehabilitation, alternative medicine, coronary heart diseases, vagal activity, autonomic regulation
#3	0.811	Fall risk, myocardial infarction, arterial compliance, rehabilitation, postural balance
#4	0.769	Coordination, proprioception, knee position, plasmacytoid, dendritic cell
#5	0.797	Bone mineral density, bone-specific alkaline phosphatase, ntx, remodeling index, osteoblasts, resistance exercise
#6	0.875	One-leg stance, center of pressure, muscles, balance control, muscle activation, cost-effectiveness, cost-utility
#7	0.755	Influenza, antibody, capacity, heart failure
#8	0.834	Osteoarthritis, fibromyalgia, mindfulness, knee osteoarthritis, pain, rheumatoid arthritis
#9	0.693	Quality of life, Tai chi qigong, multidimensional scale of perceived social support, St. George's respiratory questionnaire
#10	0.596	Exercise therapy, randomized controlled trials, accident prevention, placebo effect
#11	0.885	Physical activity, physical fitness, blood pressure, aspirations, self-defense, health promotion
#12	0.766	Relaxation, obesity, meditation, adolescents, dissociative disorder, ptsd (post-traumatic stress disorder)
#13	0.904	Qigong, fatigue, cancer, traditional Chinese exercises, acupuncture, breast cancer

lumbar muscle strain [43], rheumatic diseases [44], osteopenia [45], strokes [46, 47], hyperlipidemia [48], asthma [49], and end-stage renal disease (ESRD) [50]. In addition, Tai chi practice could improve immune function and prevent influenza [51]. Recent studies have found that Tai chi is more suitable for long-term exercise, indicating that its short-term effects are not obvious [52].

Cancer has been a hot topic of Tai chi research in recent years. Studies have suggested that Tai chi offers an exercise capacity benefit in several types of cancers [53]. It has positive effects on the quality of life in cancer survivors, involving decreasing side effects undergoing chemotherapy, as well as improved fatigue, immune function, and cortisol levels [54-57].

Tai chi and psychological well-being (#12): As a mind-body therapy, like qigong or yoga, Tai chi shows psychological benefits [58], such as improved emotion regulation and altered self-awareness [59]. These benefits reduced the severity of depression, anxiety, and stress in obese adults and university students [60, 61], improved mental states and sleep quality of elderly patients [62], and highlighted the positive impact on the psychology of Parkinson's disease (PD) patients [63], stroke survivors [64, 65], and individuals with posttraumatic stress disorder [66]. Many studies have shown that the psychological effects of Tai chi might be related to intervention on the structure and function of the brain [67-69].

Research methods of Tai chi (#10): "Randomized controlled clinical trials" was a high-frequency keyword. It was the most common and effective research method of Tai chi research. However, almost all RCTs were single-blinded. It is not easy to enforce double blinding. There were many deficiencies in studies concerning Tai chi, such as heterogeneity and risk of bias, as well as a lack of blinding, poor allocation, small sample size, and incomplete outcome data [70]. Reliance on the placebo-controlled design might not be feasible. Due to Tai chi's multiple potential "active ingredients", each with evidence supporting potential therapeutic effects, it would be practically impossible to construct a credible dummy control that mimics the array of active components of Tai chi [71]. Accordingly, some promising multi-variate analytical tools have been suggested by whole-systems researchers, including path analyses, structural equation modeling, and confirmatory factor analysis [72].

Cost-effectiveness of Tai chi (#6): Cost-effectiveness analysis has become a well-accepted component of clinical trials, with the capture of health resource usage and health state utilities directly from study subjects [73]. Fall-related injuries among older adults, especially among older women, have been associated with substantial economic costs [74]. Studies have suggested that Tai chi intervention could provide a more positive return on investment [75, 76]. A single intervention study indicated that, concerning the cost-utility of seven interventions reported as effective for preventing falls in older adults, Tai chi greatly reduced costs [77].

So-called "burst words" represent words that are cited frequently over a period of time. CiteSpace was used to detect burst keywords, considered to be indicators of research frontier topics over time. As shown in **Figure 10**, the strongest citation burst keywords appeared between 1999 to 2014. Analysis in terms of the strongest citation burst keywords and timeline view (**Figure 11**) of the 14 clusters revealed the hot topics and frontiers in different periods. In the past 20 years, Tai chi research could be divided into 3 periods: elementary period, rapid growth period, and stable development period.

Before 2000, the total number of publications was relatively small. The strongest citation burst keyword was "balance". Most studies were more about balance, rehabilitation, physical activity, exercise, older adults, falls, health, and strength. Balance was the research frontier of the relationship between Tai chi and health promotion of the elderly during this period. The musculoskeletal system was the most studied system.

There was rapid growth from 2000 to 2014, with a marked increase of articles published and a wide of diseases/conditions addressed in clinical studies. The strongest citation burst keywords were about rehabilitation, falls, cardiorespiratory function, postural stability, and flexibility. Bursts showed that the musculoskeletal system was still a hot topic in Tai chi research. At the same time, more keywords, like randomized control trail, quality of life, bone mineral density, rheumatoid arthritis, de-

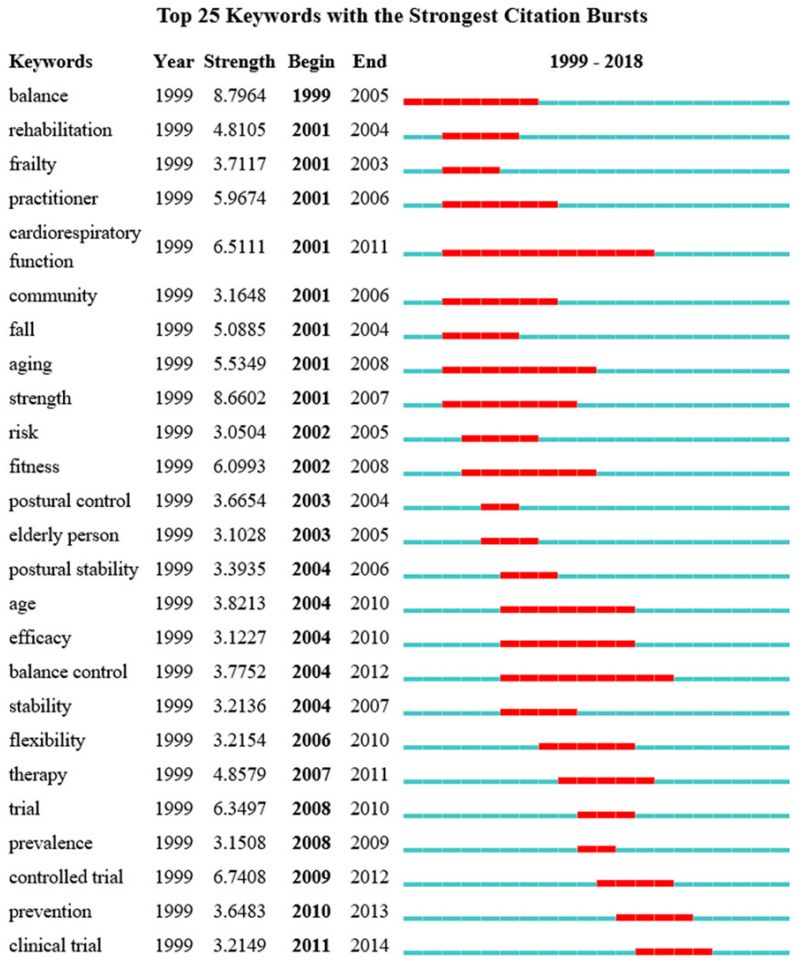

Figure 10. Top 25 keywords with the strongest citation bursts of Tai chi from 1999 to 2018. The red bars mean some keywords cited frequently, while the green bars are keywords cited infrequently.

mentia, depression, osteoarthritis, and chronic heart failure, appeared. This indicates that the emphasis of the research had gradually changed from health promotion to clinical research on the intervention of disease. As shown in **Figure 11**, most lines were found in this period, indicating that this period was a hot period of Tai chi research.

After 2014, new high-frequency keywords, such as recommendations, guidelines, chronic pain, mindfulness, cancer, mood, and mechanisms, were representative of research hot topics. Tai chi intervention is currently included as a non-pharmacologic treatment recommendation in many guidelines of chronic disease, such as chronic lower back pain [78], knee osteoarthritis [79], and chronic pain [33]. Tai chi has obtained more acceptance all over the world. Based on clinical research, mechanism studies gradually became the breakthrough-point for further research. With the intervention of modern operational biomechanics, neurobiology, and other scientific research techniques, research content of this stage was sublimated from the previous stage.

In the past 4 years, no burst keywords were generated in CiteSpace (**Figure 10**). The number of publications shows a decline (**Figure 2**), indicating that the 4 years had no obvious frontiers. The timeline view map (**Figure 11**) suggests that Tai chi research involves more diseases and has been transformed from therapeutic effects to "how" and "why" it works. The bursts and timeline view revealed that Tai chi research is more extensive and in-depth but still not enough. More research is necessary. As far as current research is concerned, research barriers need to be overcome, conducting further study based on previous outcomes due to the limitations of Tai chi research. For example, reductions in falls following Tai chi training probably results from multiple mechanisms, including increasing leg strength and flexibility, changing in neuromuscular patterning/control, reduced fear of falling, improved body awareness and concentration, and many cognitive strategies. These factors are likely to interact with one another, change in relative importance over time, and differ for different practitioners [80]. Studies attempting to understand the mechanisms of underlying therapeutic effects of Tai chi might need to draw on the tools used in disciplines, such as epidemiology, sociology, and ecology, which commonly deal with complex and multivariate phenomena [14].

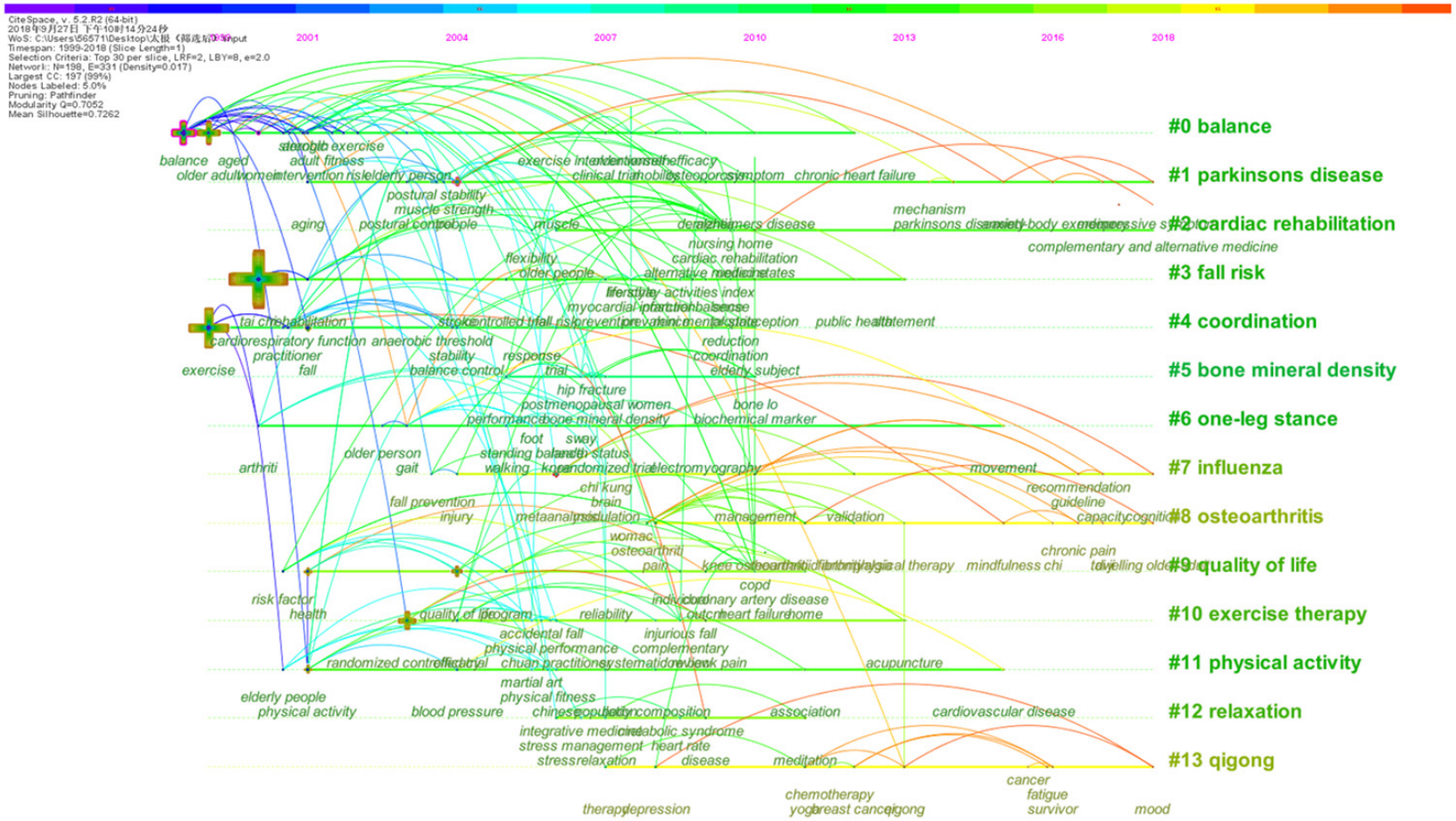

Figure 11. Timeline view of 14 clusters about Tai chi research from 1999 to 2018.

Conclusion

All included studies demonstrated the important health benefits of Tai chi in prevention, treatment, or rehabilitation. Geriatric disease has always been a hot topic of Tai chi research. China and the USA, with high publication rates and centrality, were demonstrated to be the main research powers in this field. The strongest collaborations were identified between many developed countries and famous institutions. These were beneficial to the development of Tai chi research. Although the average IF of professional and core journals related to Tai chi was <3, there were some articles published in high-IF journals. Some articles received many citations. The average IF of high cited journals was >15, indicating that Tai chi research had high influence and received international attention. It is valuable and significant. The exchange and cooperation among authors are not enough, however. It should be done to strengthen the cooperation and exchange among scientific research teams, enhance the depth and breadth of Tai chi research cooperation, improve the quality of research, and realize the sharing of resources. During the 20 years, the 6 hot topics of Tai chi concerned balance, musculoskeletal system, chronic diseases, psychological well-being, research methods, and cost-effectiveness. The bursts showed no obvious frontiers in the past 4 years. However, from the timeline view, it could be speculated that mechanisms and chronic diseases are important points. Also, the elderly remained the main subjects of research. Researchers should pay close attention to relevant studies in the coming years.

In conclusion, this study provides insight into Tai chi research, providing valuable information for researchers in identifying new perspectives concerning potential collaborators and cooperative institutions, hot topics, and research frontiers.

Acknowledgements

The authors would like to express their appreciation to professor CM Chen. He invented CiteSpace, which is free to use. Tingting Zhang and Ying Ye are co-first authors. ZTT and YY collected the literature and wrote the article. PYZ, RRY, and YMN revised the article, while ZQ designed the study. All authors read and approved the final article. All authors contributed toward data analysis, drafting, and critically revising the paper and agree to be accountable for all aspects of the work. This work was supported by a grant from National Natural Science Foundation of China (No 61801058).

Disclosure of conflict of interest

None.

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