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Research Article

Exercise training for heart failure patients with cognitive impairment: A bibliometric analysis

Hanyan Tao, Ruchao Nan and Xiaoyu Wang*

Department of Pharmacy, Zhongshan Hospital Affiliated to Fudan University, Shanghai, China

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***Corresponding authors:** Xiaoyu Wang, Department of Pharmacy, Zhongshan Hospital Affiliated to Fudan University, Shanghai, China,
E-mail: xiaoyuwang1125@163.com

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Abstract

This study, using bibliometric methods, examines exercise training for Heart Failure (HF) patients with cognitive impairment, discussing the current state and trends. 2,077 articles and reviews from the Web of Science Core Collection were analyzed, revealing the United States and Duke University Research Institute as major contributors. "*Circulation*" and "*American Journal of Cardiology*" were the selected and most-cited journals. Kitzman DW emerged as the most productive author. VOSviewer and Microsoft Excel 2019 were employed for comprehensive analysis, categorizing keywords into heart failure, cardiovascular disease, mortality, and exercise clusters. The findings provide valuable insights into the landscape and evolving dynamics of exercise training in the context of HF and cognitive impairment.

Introduction

The number of Heart Failure (HF) patients has been increasing worldwide. According to the American Heart Association, the prevalence of HF will increase by 46% from 2012 to 2030, with the number of HF cases estimated to reach > 8 million worldwide [1]. This represents a challenge for the healthcare systems. HF Patients experience a range of changes in cardiovascular function that are closely associated with the presence of cognitive dysfunction and directly affect cardiac autonomic control [2]. Cognitive impairment is a common co-morbidity in HF patients [3]. Several studies have shown that cognitive impairment in HF varies from 20% to 80% [3,4]. Cognitive impairment is increasingly recognized as a standard and significant independent predictor of poor clinical outcomes, higher readmission rates, and higher mortality in HF patients, and the risk of cognitive impairment appears to increase with the increasing severity of HF [5].

Cognitive impairment is closely related to executive function in HF patients. Self-care in HF is complex and includes preventive measures (daily weight management and medication administration) and symptom management (dyspnea, fatigue) [6]. A cognitive impairment inhibits the ability of HF patients to care for themselves, and the most pronounced changes can be observed in executive functions, affecting patients' working memory, attention, situational memory, and speed of handling things [7]. These behaviors are critical to HF management and improving quality of life. Therefore, early preventive interventions for cognitive impairment in HF patients are an important and feasible aspect of improving patients' quality of life.

A growing body of research suggests that cognitive impairment in HF is partially reversible. A key mechanism for cognitive improvement is improved cerebral blood flow, which may be achieved through exercise in HF patients [8]. Evidence suggests that regular exercise over time can benefit cardiovascular health [9]. Exercise mediates this by increasing vagal tone, decreasing sinus node sympathetic activity, improving vascular function, and cardiac remodeling. A study of older adults with cardiovascular disease found that 12 weeks of exercise was associated with improved cerebral blood flow velocity, as were improvements in attention, executive

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function, and memory performance [10]. Some of the cognitive dysfunction in HF due to unfavorable brain changes can likewise be improved by exercise. The main manifestations are cognitive improvement by increasing cerebral blood flow, increasing hippocampus, vascular endothelial growth factor, brain-derived neurotrophic factors, angiogenic areas, and altering unfavorable changes in brain structure [11]. In addition, exercise may improve cognitive function in HF patients through other mechanisms. Studies have shown that [12] elevated C-Reactive Protein (CRP) levels are associated with impairment in executive functions and memory areas. Exercise is thought to reduce the activation of the sympathetic nervous system, which in turn inhibits the release of inflammatory markers. It was found that [13] 13 after six months of structured exercise, CRP levels were significantly lower in HF patients than in sedentary controls.

An increasing number of HF-related guidelines recommend that all patients with a cardiac function I ~ III be considered for a supervised, tailored exercise training program to improve exercise tolerance and quality of life, but the optimal exercise dose for improving cognitive function in HF patients has not been determined [14,15]. Tanne, et al. [16] found benefits of aerobic exercise at 60 ~ 70% of maximum heart rate on cognitive function in HF patients in terms of exercise modalities. Most of the current evidence supports that aerobic exercise benefits cognitive function, but some studies have shown ambiguous results. Several potential reasons for these conflicting findings include differences in exercise, the way cardiorespiratory fitness and cognitive function are measured, and the age, gender, and health status of the participants [17]. However, studies related to cognitive impairment in HF patients' Resistance Exercise (RE) are scarce. The efficacy is currently unknown, and future randomized controlled trials with adequate sample sizes are needed to elucidate the effects of RE on cognitive function and physical function [18]. In terms of exercise frequency, Larson, et al. [19] study evaluated the frequency of activity in 1,740 older adults and found that those who exercised more than three times per week were 34% less likely to be diagnosed with dementia than those who exercised less than three times per week. Exercise intensity is the core element of exercise training. A recent study of 2354 men and women with an average age of 53 years found that light-intensity physical activity effectively improved cognitive function in patients [20]. Ruscheweyh, et al. [21] showed no difference in cognitive levels between participants who exercised at moderate intensity and those who exercised at low intensity, but both groups had higher memory function scores than the sedentary control group. In terms of the time for exercise, evidence suggests that starting exercise early in midlife may reduce the risk of cognitive decline in later life [22]. Regular exercise is necessary to optimize the patient's cognitive performance. Overall, further research is needed to improve the optimal dose of exercise for HF patients. Researchers need to identify other trends and hot spots related to exercise training on cognitive impairment in patients.

Bibliometrics, as a method that allows quantitative and qualitative assessment of trends in research in a field over time, relies on literature databases and metrics. It is mainly based on a comprehensive analysis of elected articles by authorship, country, number of citations, and time of publication. Combined with a comprehensive analysis of the keywords contained in the articles, high-frequency words and hot words that have appeared in recent years are selected. At the same time, an objective evaluation of the contributions of academic groups and individual researchers can help researchers quickly understand the trend of a specific field and the ranking of academic groups and individual researchers. Likewise, bibliometrics can provide supporting evidence that can be used to create strategies and make decisions [23].

In this study, we conducted a bibliometric analysis of the literature related to exercise training for HF patients with cognitive impairment using the Web of Science core database to determine the current status and development trend of research in this field and to provide theoretical reference and data support for later research on exercise training for HF patients with cognitive impairment.

Materials & methods

Data sources

All publications were searched from the Web of Science Core Collection. The search terms include: "heart failure", "cognitive impairment", "cognition disorder", and "exercise". Inclusion criteria: 1) publication date 1900 ~ 2021; 2) document types were limited to research articles or reviews. 3) no limitation on language. Exclusion criteria: 1) duplicate material; 2) conference abstract, protocol, corrections, letter. A total of 2,307 articles were searched, and a total of 2,077 articles were finally included for analysis by removing duplicates and unrelated topics. The complete record of search results with the cited references in plain text format was exported. The search was performed in a single day (October 1, 2021) to avoid bias caused by daily database updates. The publications screening process is shown in Figure 1.

Bibliometric analysis

All included publications in the Web of Science Core Collection were imported to Microsoft Excel 2019 and VOSviewer (version 1.6.16) for performing visual analysis. VOSviewer is a

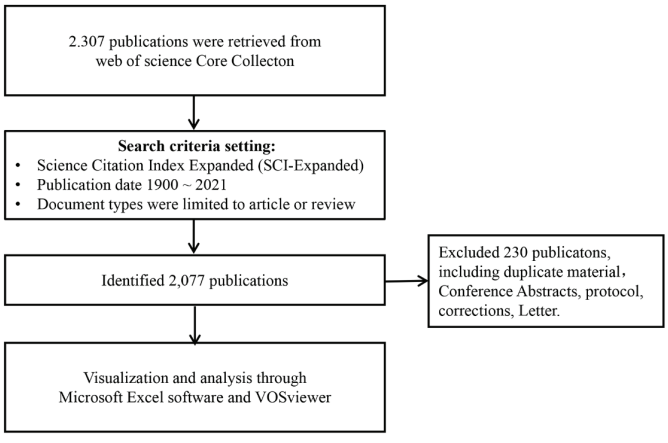

Figure 1: A flowchart of the publications screening process.

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scientific knowledge mapping software developed by VanEck and Waltman [24]. The VOSviewer was used to build a co-citation map by analyzing the country/institution/journal/author/reference. The same color represents the same cluster; different nodes represent different elements, such as cited literature, journals, and authors, and the node size reflects the number or frequency of citations. The distance between nodes and the number of connected lines indicates the closeness of the relationship between nodes. The Impact Factor (IF) was obtained from the information provided by the Journal Citation Reports (JCRs) published in 2020.

In addition, the unique advantage of VOSviewer software is the implementation of keyword co-occurrence, which can perform cluster analysis based on the construction of a co-occurrence matrix for keywords and obtain cluster label mapping, thus presenting different clustering themes intuitively and visually. Before the software analysis, two researchers are required to extract the keywords from the literature into an Excel sheet and clean the data for the presence of singular and plural keywords, synonyms or near-synonyms, and abbreviations. For example, the keywords with the same semantic meaning, such as quality of life, quality-of-life, and QOL, are combined into quality-of-life. Thus the final results of keyword frequency statistics and clustering analysis are reasonable and accurate.

The cleaned keywords are presented in three visual co-occurrence analyses using VOSviewer software. 1) Network visualization mapping, the greater the weight of the keyword, the larger its labels and circles, indicates that the more frequently this keyword appears in the research literature in the field, the more influential the term is in the field under study; 2) Overlay visualization mapping, where different colors represent the early and late appearance of keywords. The colors range from blue (the earlier the year) to green to yellow (the later the year). This view allows visual observation of the distribution of the years in which different keywords appear, i.e., the changes of research hotspots in the field within different years; 3) Density visualization mapping, the size of the density on the map depends on the number of elements in the surrounding area and the importance of these elements. The higher the density, the closer to yellow; conversely, the lower the density, the closer to green. The change from the more excellent region (green) to the warmer region (yellow) indicates that the keywords co-occur more and more frequently, i.e., the research content is getting hotter and hotter, and the darker the warm region, the more the keywords are hot in the research area.

Results

Trends in global publications

A total of 2,077 articles and reviews related to exercise training for HF patients with cognitive impairment were retrieved from the database. From one article (0.48%) in 1990 to 116 articles (5.58%) in 2021, global publications in the field exhibited a strong growth trend (Figure 2A). The cumulative data on annual publication volume reveals that the field is currently in a phase of steady growth in global publication output (Figure 2B).

Distribution of countries/regions

The analysis found that 49 countries and regions contributed to publications in this field. The highest number of publications were from the United States (751, 36.16% of all publications). Followed by Germany (200, 9.63%), the same number as Italy (200, 9.63%), the United Kingdom (160, 7.7%), France (132, 6.36%), and Canada (121, 5.83 %) (Figure 3A). Studies from the United States had the highest number of citations (53,232 citations), followed by Canada (12,943 citations), the United Kingdom, Germany (10,590 citations), and Italy (10,273 citations) (Figure 3B).

A total of 17 countries that published more than five papers in this area were analyzed in the co-authorship analysis (Figure 4A). The United States (total link strength = 398), the United Kingdom (245), Italy (236), Germany (195), and Canada (121) were the top five countries with the highest total link strength.

Distribution of institutions

A total of 70 institutions were involved in this field. Duke University (34 records, 1.64% of all publications) had the most published articles, followed by Johns Hopkins University (32, 1.54%), University of Toronto (27, 1.29%), Harvard University (26, 1.25%), and Mayo Medical Center (25, 1.20%).

The co-authorship of 49 institutions with more than ten publications was analyzed (Figure 4B). There are the top five institutions with the highest total link strength: Brigham and Women's Hospital (45), the same number as Case Western Reserve University Novartis (45), the University of Pittsburgh (43), Johns Hopkins University (41) and Mayo Medical Center (39).

Analysis of journals

A total of 2,077 publications were published in 921 journals. The top ten popular journals published in this field are detailed

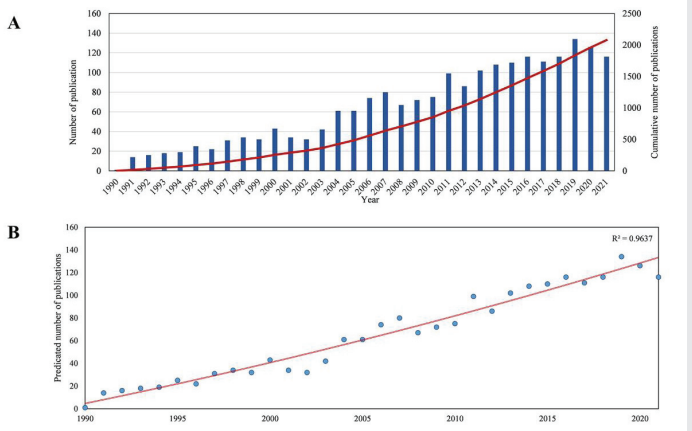

Figure 2: Global trends in publications on exercise training for HF complicated with cognitive impairment research. (A) Annual publications from 1990 to the present. (B) Model fitting curves of growth trends in publications.

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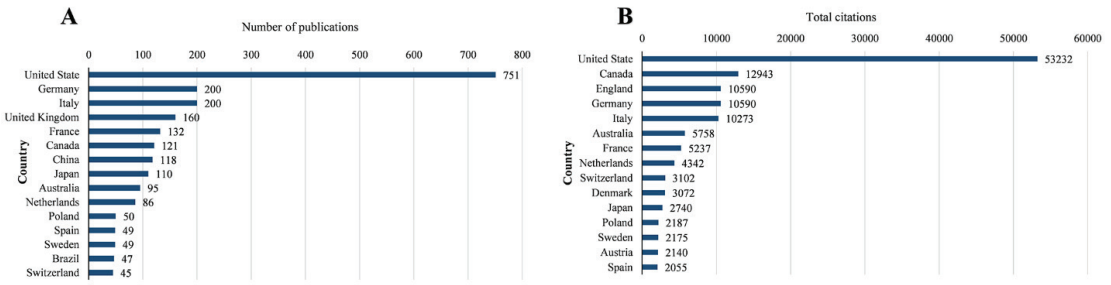

Figure 3: Countries are contributing to the field. (A) Top 15 countries with the most significant number of publications. (B) Total citations of related publications from different countries.

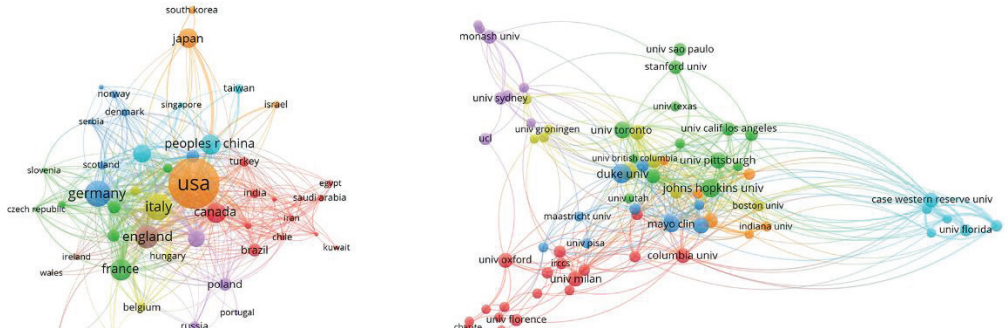

Figure 4: Co-authorship analysis of countries and institutions. (A) Network map of co-authorship between countries with more than five publications. (B) Network map of co-authorship between institutions with more than ten publications.

Table 1: Top Ten Popular Journals and Co-cited Journals.

Rank	Journals	Records (n)	2020 IF	Co-cited Journals	Citations (n)	2020 IF
1	Circulation	33	29.690	Circulation	7,898	29.690
2	American Journal of Cardiology	24	2.778	Journal of the American College of Cardiology	4,133	24.093
3	European Journal of Heart Failure	23	15.534	New England Journal of Medicine	3,406	91.253
4	International Journal of Cardiology	23	4.164	American Journal of Cardiology	2,443	2.778
5	Journal of the American College of Cardiology	20	24.093	Circulation Research	2,382	17.367
6	American Journal of Physiology-Heart	19	4.733	Journal of Biological Chemistry	2,170	5.157
7	Journal of Molecular and Cellular Cardiology	19	5.000	European Heart Journal	1,931	29.983
8	Chest	17	9.410	American Journal of Respiratory and Critical Care Medicine	1,895	21.405
9	Journal of the American Geriatrics Society	16	5.562	Lancet	1,828	79.323
10	Journal of Cardiovascular Nursing	15	2.083	Chest	1,766	6.205

in Table 1. Circulation (33 records, 1.59% of all publications) had the most publications, followed by the American Journal of Cardiology (24, 1.16%), European Journal of Heart Failure (23, 1.12%), the same number as the International Journal of Cardiology (23, 1.12%), and Journal of the American College of Cardiology (20, 0.96%).

We analyzed 421 journals for all publications co-cited in more than 50 publications (Figure 5). The top 10 cited journals publishing relevant publications are shown in Table 1. Circulation had the most significant number of citations (7,898 citations), followed by the Journal of the American College of Cardiology (4,133 citations), New England Journal of Medicine (3,406 citations), and American Journal of Cardiology (2,443 citations), and Circulation Research (2,382 citations).

Analysis of authors

Regarding the number of publications, Kitzman DW was the most productive author, with 15 publications (0.72% of all publications), followed by Gunstad J (14, 0.67%), Alosco ML (12, 0.58%), the same number as Josephson R, Spitznagel MB, and Hughes J (11,0.53%) (Figure 6A).

In terms of citations in this field, Somers VK was ranked first (1,114 citations), followed by Anker SD (995 citations),

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Kitzman DW (990 citations), Bradley TD (851 citations), and Esler M (812 citations) (Figure 6B).

We analyzed a total of 80 authors that were co-authored in more than three publications. The five authors with the highest total link strength were Kitzman DW (total link strength 43), Mentz RJ (29), Pastva, AM (27), Reeves GR (27), Whellan DJ (27), Emdin M (23), Passino C (23) (Figure 6C).

Citation and co-citation analysis

The citation analysis showed that 460 documents had more than 50 citations (Figure 7A). Table 2 lists the top ten publications with the highest citations. There were 3,033 citations for "Heart Disease and Stroke Statistics-2019 Update: A Report from the American Heart Association" (Benjamin et al.,2019), followed by "Heart Disease and Stroke Statistics-2017 Update: A Report from the American Heart Association" (Benjamin et al.,2017), with 3,022 citations. The third-ranked article was "Heart Disease and Stroke Statistics - 2020 Update: A Report from the American Heart Association" [1], with 1,137 citations.

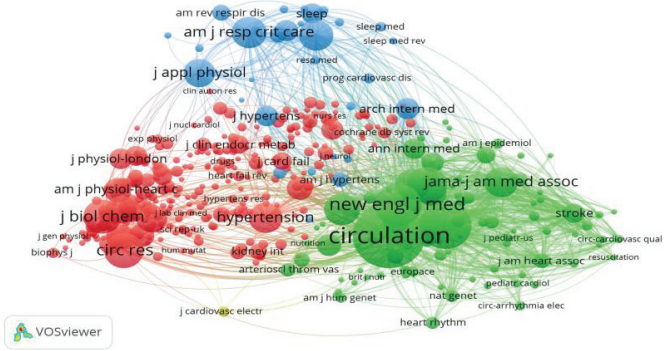

Figure 5: Network map of journals that were co-cited in more than 50 publications.

Forty-six references that were co-cited more than 20 times were analyzed (Figure 7B). The top ten most cited references are shown in Table 3. The top five cited references are as follows: Folstein MF (1975 Journal of Psychiatric Research; 47 citations), Javaheri S (1998, Circulation; 43 citations), Ponikowski P (2016, European Heart Journal; 42 citations), Peppard PE (2000, New England Journal of Medicine; 40 citations), and Cohn JN [29] (1984, New England Journal of Medicine; 39 citations).

Co-occurrence analysis of keywords

We analyzed 163 keywords that were identified as having occurred more than 20 times. As shown in Figure 8A, the keyword analysis was identified and classified into four clusters, namely heart failure, cardiovascular disease, mortality, and exercise. The greenish or yellowish part shows that most of the keywords in the research were published after 2010 in Figure 8B.

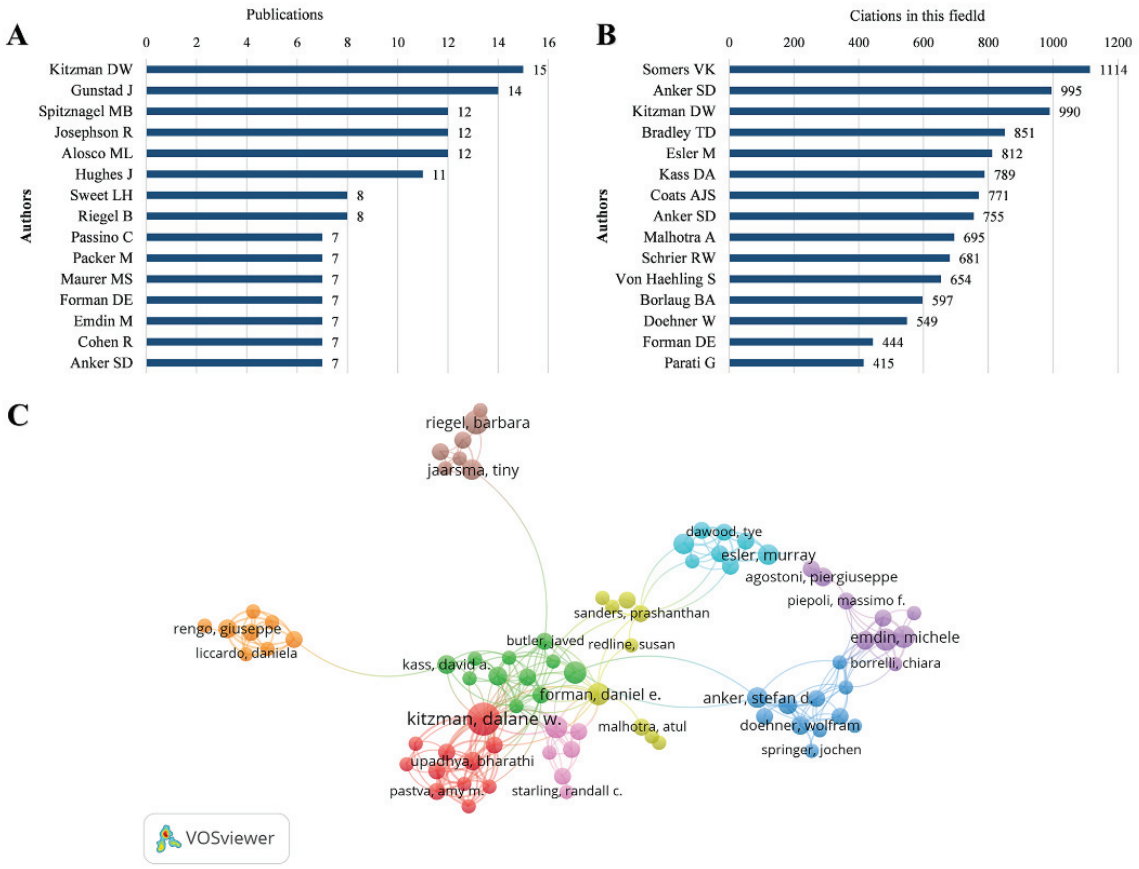

Figure 6: Analysis of authors. (A) The number of publications from different authors. (B) Total citations in the field from different authors. (C) Network map of co-authorship between authors with more than three publications.

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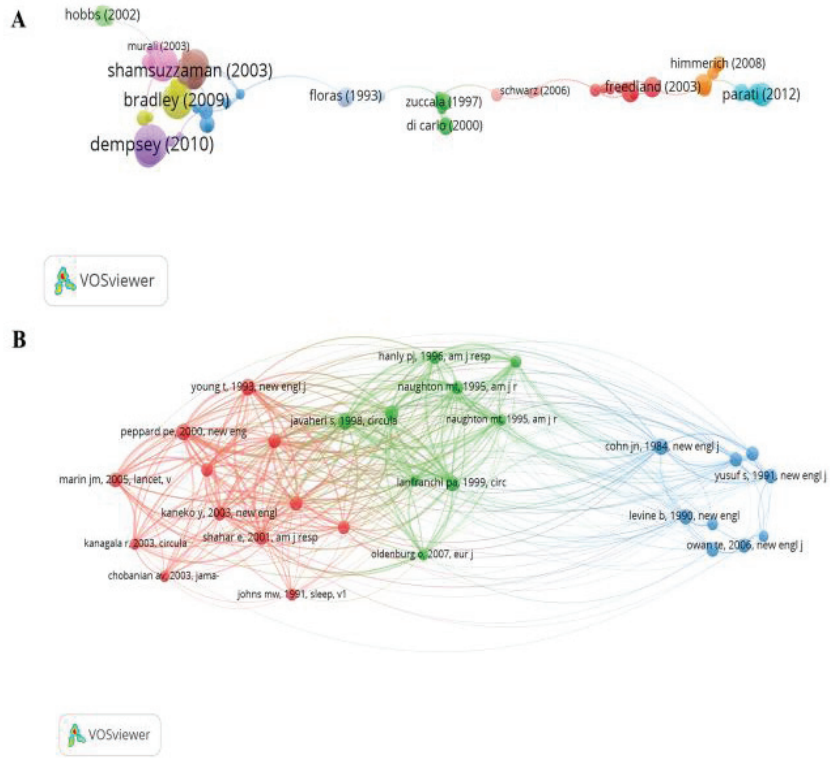

Figure 7: (A) Network map of citation analysis of publications with more than 50 citations. (B) Network map of co-citation analysis of references with more than 20 citations.

Table 2: Top Ten Citation Analysis of Publications in The Field.

Rank	Title	First Author	Publication Year	Source	Citations (n)
1	Heart Disease and Stroke Statistics-2019 Update: A Report from the American Heart Association	Benjamin EJ	2019	Circulation	3,033
2	Heart Disease and Stroke Statistics-2017 Update: A Report from the American Heart Association	Benjamin EJ	2017	Circulation	3,022
3	Heart Disease and Stroke Statistics-2020 Update: A Report from the American Heart Association	Salim SV	2020	Circulation	1,137
4	Clinical Features and Outcomes of Takotsubo (Stress) Cardiomyopathy	Templin C	2015	New England Journal of Medicine	1,020
5	Evidence for prescribing exercise as therapy in chronic disease	Pedersen BK	2006	Scandinavian Journal of Medicine & Science in Sports	1,013
6	Pathophysiology of sleep apnea	Dempsey JA	2010	Annual Review of Biomedical Engineering	988
7	Lack of exercise is a major cause of chronic diseases	Booth FW	2012	Comprehensive Physiology	912
8	Twenty years of research on cytokine-induced sickness behavior	Robert D	2007	Brain Behavior and Immunity	828
9	Obstructive sleep apnoea and its cardiovascular consequences.	Bradley TD	2009	British Journal of General Practice	813
10	Obstructive sleep apnea: implications for cardiac and vascular disease	Shamsuzzaman AS	2003	JAMA	799

Discussion

Exercise training has become an accepted adjunct therapy for HF patients with cognitive impairment. In this study, we combined bibliometric analysis and network visualization to describe the current state of exercise training in HF patients with cognitive impairment, to analyze countries, regions, institutional, journal, and author contributions to this emerging field, and to predict hot topics that continue to be of research interest in the coming years.

General trends in exercise training for HF patients with cognitive impairment

The annual publication volume of research in this area has steadily increased, with the most significant growth in the last decade. Research institutions in developed countries, represented by the United States, have been engaged in this field for a long time, with the highest number of publications and citations and a large international influence. However, the collaboration among research institutions mainly exists

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Table 3: Top Ten Co-Citation Analysis of Cited Reference in This Field.

Rank	Title	First author	Source	Publication year	Citations
1	"Mini-mental state." A practical method for grading the cognitive state of patients for the clinician	Folstein MF	Journal of Psychiatric Research	1975	47
2	Sleep apnea in 81 ambulatory male patients with stable heart failure. Types and their prevalences, consequences, and presentations	Javaheri S	Circulation	1998	43
3	2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure	Ponikowski P	European Heart Journal	2016	42
4	Prospective study of the association between sleep-disordered breathing and hypertension	Peppard PE	New England Journal of Medicine	2000	40
5	Plasma norepinephrine as a guide to prognosis in patients with chronic congestive heart failure	Cohn JN	New England Journal of Medicine	1984	39
6	The occurrence of sleep-disordered breathing among middle-aged adults	Young T	New England Journal of Medicine	1993	39
7	A new method of classifying prognostic comorbidity in longitudinal studies: development and validation	Charlson ME	Chronic Diseases and Injuries in Canada	1987	37
8	Prognostic value of nocturnal Cheyne-Stokes respiration in chronic heart failure	Lanfranchi PA	Circulation	1999	36
9	Elevated circulating levels of tumor necrosis factor in severe chronic heart failure	Levine B	New England Journal of Medicine	1990	35
10	Effects of continuous positive airway pressure on cardiovascular outcomes in heart failure patients with and without Cheyne-Stokes respiration	Sin DD	Circulation	2000	35

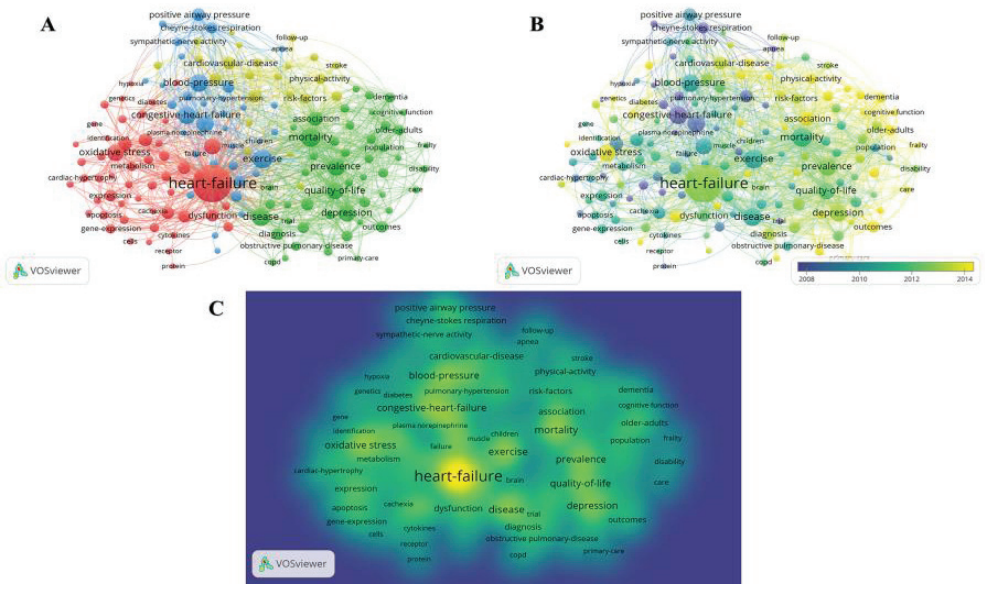

Figure 8: Co-occurrence analysis of keywords. (A) Mapping of keywords studies. (B) Distribution of keywords according to average publication year (blue: earlier, yellow: later). (C) Distribution of keywords according to the mean frequency of appearance. Keywords in yellow occurred with the highest frequency.

within the country, showing a "local concentration and overall dispersion" trend. This trend reflects the fact that there is no uniform research pattern in this field, and each country is exploring a model of movement suitable for its nationals. It is recommended that the U.S. and other countries strengthen cooperation and exchange among national institutions to improve the overall contribution of scientific research in this field.

Authors and studies with implications for exercise training in HF patients with cognitive impairment

Dr. Kitzman DW of Wake Forest University is a pioneer in exercise rehabilitation for cardiovascular disease, serving as the American College of Cardiology Presidential Professor and Professor in the Institute for Clinical and Translational Science. Dr. Kitzman DW has been practicing for more than 20 years and his publications and citations rank among the top, demonstrating his experience in this field of research. Dr. Kitzman's research focuses on exercise physiology in HF Patients with Preserved Ejection Fraction (HFPEF) and exercise intervention studies. Since current research data have not yet elucidated the mechanisms by which exercise training improves the cognitive prognosis of HF patients, identifying the physiological mechanisms by which exercise training improves the prognosis of HF patients is critical to further understanding. Dr. Kitzman DW and his research team found

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that patients with HFPEF are most common in the elderly population and that cognitive dysfunction is prevalent in HF patients. Cognitive dysfunction is associated with severe physical functional deficits in HF patients, and Dr. Kitzman DW, et al. [25] have suggested that HF co-morbidities are independently associated with cognitive impairment in HF patients. His team recommends clinical screening for cognitive impairment and identifying those patients who require tailored care to reduce the incidence of adverse events [26]. They also found that exercise training improved exercise intolerance, cognitive impairment, and QOL in HF patients [27]. In mechanism studies, exercise training was a safe and effective treatment to improve peak VO2, cardiovascular and skeletal muscle function, quality of life, and readmission rates in patients. The team's research focuses mainly on aerobic training (moderate-intensity interval exercise and high-intensity interval training), but its research on resistance training and other combined training modalities is fewer [28]. In addition, Dr. Kitzman DW has also attempted to combine exercise training with new non-pharmacological interventions (diet) that have been shown to improve cardiac function and prognosis in patients with HFpEF.

Published articles with the highest citation frequencies have the most significant academic impact in a particular field. The citation analysis of documents and co-cited analysis of references found that the top three articles were all published in the same journal, Circulation, and they are all a copy of the American Heart Association (2017 - 2020) Update, which describes the findings in risk factors for disease and exercise rehabilitation in HF patients. Cohn, et al. [29] reports a summary of evidence on exercise in patients with HF, including mechanisms by which exercise produces effects, types of exercise, exercise levels, and contraindications. Exercise training is increasingly receiving the attention of many researchers. Other articles mainly deal with Obstructive Sleep Apnea (OSA). OSA is a sleep-related breathing disorder that significantly impacts cardiovascular function. It is associated with hypertension, coronary artery disease, arrhythmias, sudden cardiac death, and HF [30]. HF patients with OSA often have poor sleep quality, and understanding this lack of sleep perception is critical to identifying and treating OSA cases in patients at risk for HF [31]. There is growing evidence that OSA may contribute to cognitive impairment in multiple domains, including attention, alertness, episodic memory, working memory, and executive function [32]. HF patients exhibiting an elevated ratio of minute ventilation over CO output (VE/VCO slope) during exercise correlated significantly with the severity of OSA. Studies have found that OSA is associated with impaired motor ability and that exercise training can be effective in improving OSA symptoms [33] This may be because OSA can cause impaired vascular function. Moreover, exercise may achieve cardioprotection by improving vascular health [34]. Indirect improvement of cognitive impairment in HF patients by improving OAS symptoms through exercise training has increased attention. However, further evidence is needed to elucidate the mechanism.

According to the map based on the analysis of all keywords (Figures 8A,8B), we found that these keywords were divided into four clusters: heart failure (oxidative stress, inflammation, gene expression), cardiovascular disease (risk-factors, obesity, epidemiology), mortality (quality-of-life, anxiety, depression) and exercise (blood-pressure, positive airway pressure, exercise capacity). The heart failure cluster has the highest distribution density on the keyword map (Figure 8C). Most of the current research in this field is still focused on exploring the physiological mechanisms that improve cognitive impairment. Currently, there is uncertainty regarding the mechanisms by which HF causes cognitive impairment, but multiple potential mechanisms are thought to be contributing factors. First, the decrease in cerebral blood flow in HF is partly the result of decreased cardiac regulation and vascular function. In particular, reduced cardiac output, cerebral autoregulation, and impaired endothelial function may reduce cerebral perfusion and ischemic injury in HF patients [35]. Reduced cerebral blood flow was expected in HF patients, with reductions of up to 30% compared to healthy individuals, with the greatest reductions in posterior cortical areas. Also, it was observed in other brain regions necessary for cognitive function in the frontal, temporal, and parietal lobes, which were associated with poorer overall cognition, and visual and verbal memory in patients [36,37]. In addition, cognitive dysfunction in HF is likely to be caused by several unfavorable brain changes. Most commonly, HF patients exhibit increased cortical atrophy, cerebral infarction, white matter changes, metabolic alterations periventricular white matter hyperplasia, and an increased number of basal ganglia compared to healthy controls [38-40]. Other studies have found that damage to the hippocampus, caudate nucleus, and corpus callosum, and a decrease in papilla volume and cross-sectional area of the fornix fibers decreases in patients [41,42]. Pathophysiological models of cognitive impairment point to a range of factors such as hypoxia, increased inflammatory cytokines, thromboembolic disease, and hemodynamic abnormalities that can likewise lead to mass brain atrophy and produce cognitive deficits [43]. To address these potential mechanisms, exercise training can effectively improve cardiac function and vascular health status, increase blood supply to the brain of patients, and improve blood supply to key brain areas to indirectly improve cognitive function, but there is a paucity of high-quality research on the mechanisms [44]. Further research on the potential mechanisms of exercise on cognitive improvement in HF patients is needed to develop effective interventions for this rapidly growing population [45].

Analysis of the main keywords in the exercise and cardiovascular disease cluster revealed that research hotspots focused on studying factors associated with exercise training to improve cognitive impairment in HF patients. Among them, blood pressure, as an important factor influencing the development of HF, has received a great deal of attention from clinicians [46]. Endothelial dysfunction is a feature of systemic arterial hypertension and an early marker of atherosclerosis. A 12-week aerobic exercise program also demonstrated that exercise effectively reduced 24-hour blood pressure in hypertensive patients [47]. In addition, OSA symptoms in patients with HF are associated with impaired motor and cognitive function [48,49], and appropriate treatments such as continuous positive airway pressure and exercise training have

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significant effects on several cognitive domains in patients with OSA, especially working long-term nonverbal memory and short-term visuospatial memory. Therefore, controlling blood pressure and sleep conditions through exercise to prevent cognitive impairment in HF patients is a new hot spot for future research.

Anxiety, depression, and quality of life in the mortality cluster have received extensive attention from researchers. This suggests that researchers are increasingly interested in studying the emotional psychology and prognosis of HF patients who have cognitive impairment. An exploratory study of 69 symptomatic HF patients found a meaningful effect of exercise on patients' cognitive improvement, while changes in depressive symptoms predicted cognitive scores. However, the mechanism remains unclear [50].

Limitations

In search terms and criteria selection, we aim for thoroughness and objectivity. However, the diverse research field may lead to overlooking certain keywords, impacting the search's comprehensiveness. Subjectivity in inclusion/exclusion criteria poses a potential threat to external validity. Subjective judgments in publication selection may introduce selection bias, and constraints in time and resources may result in missing relevant literature, affecting the overall study scope. Bibliometric tools like VOSviewer and Microsoft Excel have inherent limitations, with results influenced by keyword choices. Interpreting bibliometric data acknowledges the potential impact of publication bias, self-citation, and the influence of specific journals or authors, cautioning readers about potential biases in conclusions. While there are no language restrictions, language bias may influence results. We transparently present our approach to handling minority language publications, though translation and interpretation may introduce errors. By discussing these limitations thoroughly, we aim to enhance readers' understanding of the study's reliability and applicability, fostering further exploration of these aspects in future research.

Conclusion

Our findings suggest that developed countries, centered on the United States, are the significant contributors to research on exercise training for HF patients with cognitive impairment and that Dr. Kitzman DW of Wake Forest University is a leader in the field of exercise rehabilitation for cardiovascular disease, with most of his relevant research published in high-quality journals that are important to the field. The keyword view was analyzed and found that most of the research in this field was published in high-quality journals. An analysis of keyword views reveals that the focus of research in this area is gradually shifting from mechanistic studies to studies on related influences and prognoses of psychological disorders. Controlling blood pressure and improving patients' sleep through exercise training and other factors to prevent cognitive impairment in HF patients are new hot spots for future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Conceptualization, Hanyan Tao and Ruchao Nan; methodology, Xiaoyu Wang; software, Xiaoyu Wang; data curation, Xiaoyu Wang; writing-original draft preparation, Hanyan Tao and Ruchao Nan; writing-review and editing, Hanyan Tao and Ruchao Nan. All authors have read and agreed to the published version of the manuscript.

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