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Bibliometric and Visualized Analysis of Cardiac Rehabilitation Research for Coronary Heart Disease Patients

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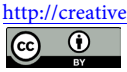

Abstract

Objective: This study visualizes and analyzes the current status, hotspots, and frontiers of cardiac rehabilitation for patients with Coronary Heart Disease (CHD) over the past decade (2012.01-2022.12), and explores the future development trend and research direction of the CR for CHD patients in China. **Methods:** Relevant literature was searched, screened and downloaded from the Web of Science (WOS) database, and bibliometric and visualization analyses were performed using CiteSpace VI software. **Results:** Through the search and screening of related literature, 2443 English articles were finally included. Among them, most of the Chinese publishers were mainly universities and had less connection with each other, while the foreign publishers were mainly universities and medical institutions in the United States and Europe, and had close connection with each other. The research content of Chinese scholars mainly focuses on the assessment of patients' life and psychological status, as well as the assessment of cardiac function. Foreign research focuses on physical training assessment, disease perception, etc. **Conclusion:** Through visualizing relevant research with CiteSpace VI software in the form of a knowledge map, the research frontiers and trends in the field of cardiac rehabilitation for coronary heart disease patients in China and abroad can be discovered more intuitively. Compared with foreign research, the development of cardiac rehabilitation for coronary heart disease patients in China is relatively slow and insufficient, and institutions lack cooperation. In the future, China should accelerate the connection between regions in the field of cardiac rehabilitation and develop a cardiac rehabilitation model suitable for coronary heart disease patients in China with its own characteristics.

Keywords

Coronary Heart Disease, Cardiac Rehabilitation, Knowledge Map, Visual Analysis

1. Introduction

According to statistics, the prevalence of coronary heart disease in China has exceeded double the global average [1]. The incidence and mortality rates of cardiovascular diseases in China are continuously rising. The current number of cardiovascular disease patients in China is approximately 330 million, including around 11 million coronary heart disease patients [2]. Cardiovascular diseases rank as the leading cause of death among both urban and rural residents, with an annual death toll of over one million people. Particularly, the prevalence of coronary heart disease among urban residents is higher than that among rural residents, and the age of onset is showing a trend of becoming younger, severely impacting the physical health and quality of life of the people [3]. Cardiac Rehabilitation (CR) is a comprehensive rehabilitation measure adopted during the treatment of cardiovascular diseases, aiming to restore myocardial function and cardiovascular health, reduce complications, improve quality of life, and prevent disease recurrence. It mainly includes exercise rehabilitation, psychological rehabilitation, and nutritional rehabilitation, among other methods, to help patients recover their health by reducing cardiac load, improving cardiopulmonary function, and promoting physical function recovery. CR plays a crucial role in the rehabilitation of coronary heart disease patients, helping them improve their quality of life, reduce the risk of cardiovascular events recurrence, enhance cardiopulmonary function, and alleviate psychological stress [3].

Compared to other countries, the development of Cardiac Rehabilitation (CR) research in China started relatively late and was limited. Understanding the development process and trends of coronary heart disease CR both domestically and internationally through bibliometric methods can help facilitate the development of CR in China. In this study, CiteSpace VI software [4] was utilized to conduct a visual analysis of relevant research in the field of coronary heart disease CR from 2012 to 2022. This analysis clarified the research hotspots and trends in this field, aiming to provide new methods and perspectives for the future development of CR in China.

2. Materials and Methods

2.1. Literature Sources

In this study, the literature was retrieved from the Web of Science (WOS) core database. The literature search strategy was as follows: TS = ("coronary heart disease") AND ("cardiac rehabilitation" OR "heart rehabilitation"), with the limitation of document type as "Article" and language as "English".

2.1.1. Literature Inclusion Criteria

1) The publication date of the literature is between January 2021 and December 2022.

2) The literature belongs to the journal type.

2.1.2. Literature Exclusion Criteria

1) The content of the literature is not related to the search terms.

2) Duplicate publications or literature that has been previously published.

2.2. Research Methods

CiteSpace software, developed by Dr. Chaomei Chen, is a tool used for visualizing and analyzing scientific literature in the form of a knowledge map. It is commonly used in bibliometric research to identify key research topics, major contributors, and emerging trends in specific fields [5]. In this study, CiteSpace VI software was used to conduct a visual analysis of the retrieved literature, presenting the development process, research hotspots, and trends of coronary heart disease CR both domestically and internationally in an intuitive knowledge map [6].

In this study, the literature was retrieved and selected from the WOS database and imported into the software in the full record reference text format for visual analysis. The time slice was set to 1 year, and a threshold of n = 50 was applied to filter out the highly cited or frequent literature each year. Nodes representing institutions, authors, and keywords were selected to generate a knowledge map for visualization analysis. The size of the nodes in the co-occurrence analysis represents the academic influence strength of the research authors/institutions/countries in the field. The connections between nodes represent collaborative relationships between research authors/institutions/countries, and the thickness of the connections indicates the strength of the collaboration [7].

3. Result

3.1. Statistics of Included Literature

After performing a subject term search in the WOS database, a total of 2875 articles were retrieved. Following the inclusion criteria mentioned earlier, 2443 articles were finally included.

3.2. Analysis of Research Institutions and Authors

3.2.1. Distribution of Research Institutions

This study conducted a visualization analysis of the research institutions included in the literature, as shown in **Figure 1**. Among the included Chinese publications, there were a total of 178 research institutions. Among them, 5 institutions have published more than 4 articles, all of which are domestic universities. They are Beijing University of Traditional Chinese Medicine (14 articles), Jilin University (7 articles), Shanxi Medical University (6 articles), Guangzhou University of Chinese Medicine (6 articles), and Chongqing Medical University (5 articles). The research on coronary heart disease in China is relatively

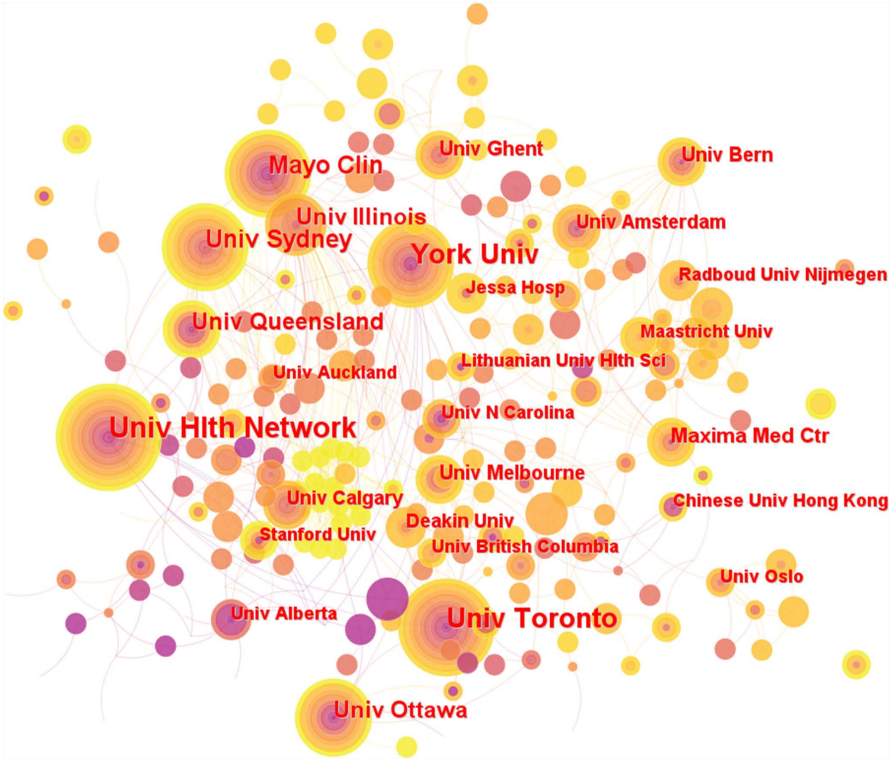

Figure 1. Co-occurrence of cardiovascular research institutions in Coronary Heart Disease (CHD) studies.

independent and decentralized among different institutions, with limited collaboration between them.

There are a total of 370 research institutions in foreign publications, and among them, 53 institutions have published more than 4 articles. The top five institutions in terms of publication volume are Toronto General Hospital (44 articles), York University (40 articles), University of Toronto (34 articles), University of Sydney (23 articles), and Mayo Clinic (22 articles). The number of foreign institutions is larger and more diverse, but the research on this topic is more closely collaborated compared to domestic institutions.

3.2.2. Distribution of Study Authors

The visualization analysis of research authors was conducted using CiteSpaceVI software, as shown in Figure 2. Among the domestic authors, only 4 individuals have published more than 4 articles. They are Liu Xun, Shi Xiaoming, Liu Boming, and Wang Yichun, along with their research teams. In contrast, there are a total of 33 foreign authors who have published more than 4 articles. The largest and most central research network in terms of publication volume is the research team led by Professor Sherry L. Grace, with 35 articles. This team has close collaborations with other major research teams in the field.

3.3. Study Country Distribution

This study conducted a co-occurrence analysis of the countries where English

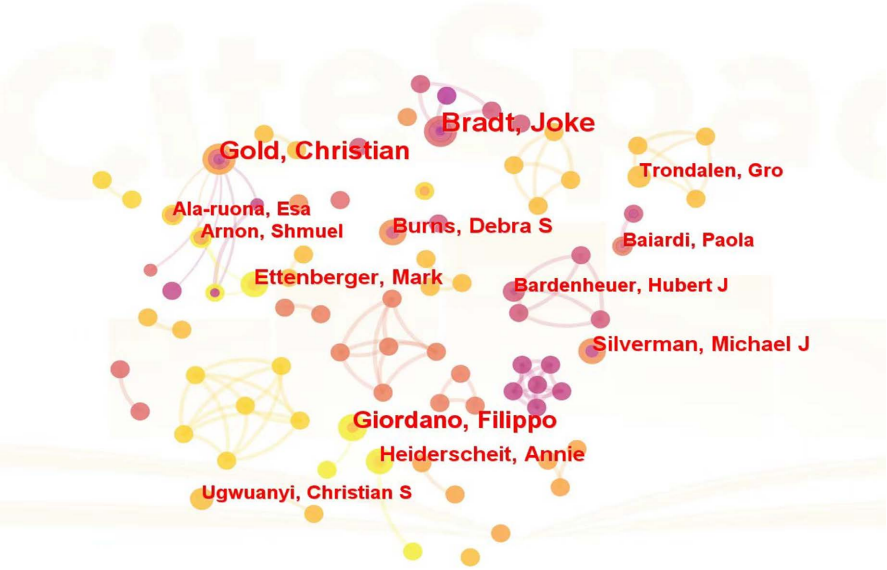

Figure 2. Authors' co-present of coronary heart disease cardiac rehabilitation studies.

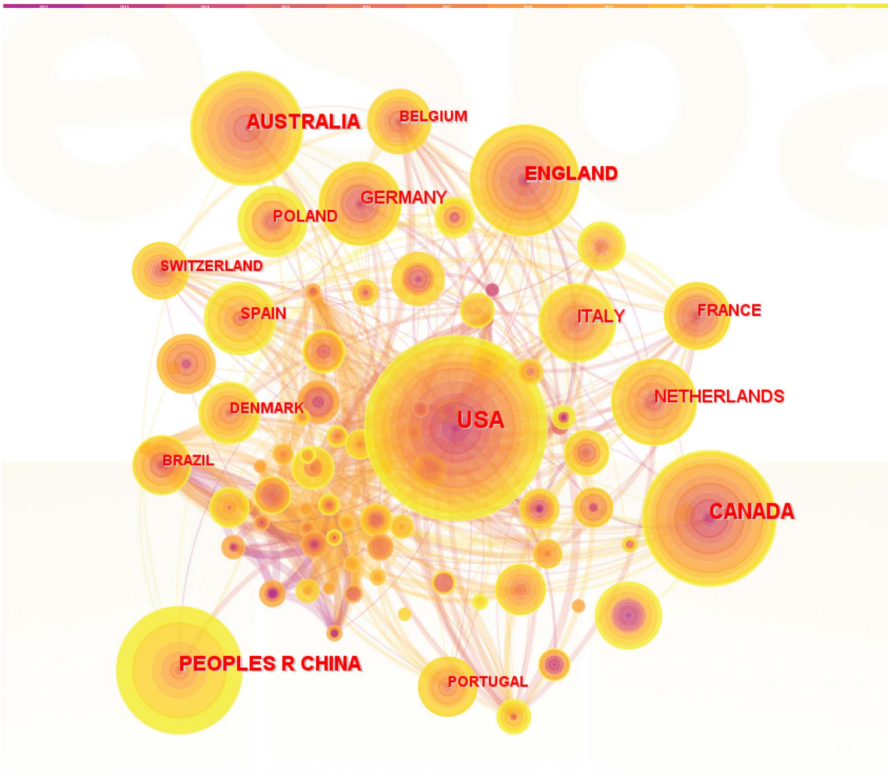

Figure 3. Country distribution and partnership networks of coronary heart disease cardiac rehabilitation studies.

literature included in the Web of Science (WOS) database was conducted, as shown in Figure 3. Through the knowledge graph, we can clearly see that the United States is the country with the highest publication volume in the field of Coronary Artery Disease (CAD) research. The software calculation shows that the betweenness centrality is 0.61 ≥ 0.1, indicating that the United States has a

strong influence in the field of CAD research [8]. China started relatively late in this field, and although China's publication volume in this field has been increasing year by year since 2013, it currently ranks third in the total publication volume. However, there is relatively little international collaboration and the collaboration intensity is low.

3.4. Visual Analysis of Research Hotspots

Keywords are a set of words or phrases used to describe the main themes of literature content. They provide a summary and description of the themes, content, and characteristics of the literature. Keywords are important elements used to identify and retrieve literature, as well as an important basis for literature evaluation and analysis. Therefore, through the use of CiteSpace VI software, co-occurrence analysis and cluster analysis are conducted on the included Chinese and English literature keywords. By calculating the frequency and relevance of keywords, the software reveals the associations between them and extracts research hotspots and trends from the data [9].

3.4.1. Keyword Co-Occurrence

Please refer to **Figure 4** for the detailed results of the co-occurrence of keywords in the included literature. Through software calculation, there are 8 core keywords with intermediary centrality ≥ 0.1 in the Chinese literature, namely "cardiac rehabilitation", "coronary heart disease", "myocardial infarction", "secondary prevention", "physical activity", "quality of life", "mortality", and "risk factor".

3.4.2. Keyword Clustering

The CiteSpace 6.3 software was utilized to cluster and label keywords using the Logarithmic Likelihood Ratio (LLR). The timeline view was employed to display the differences in different cluster periods. The modularity Q was used to evaluate the clustering structure, and the weighted mean silhouette was used to assess the rationality of the clustering. A modularity Q value greater than 0.3 indicates a clear and significant clustering structure, while a weighted mean silhouette value greater than 0.5 indicates a higher level of clustering rationality [10].

Please refer to **Figure 5** for the detailed timeline clustering graph of the included literature keywords. For Chinese literature keywords clustering, the modularity Q is 0.5603 (>0.3), and the weighted mean silhouette is 0.8713 (>0.5). For English literature keywords clustering, the modularity Q is 0.4986 (>0.3), and the weighted mean silhouette is 0.7725 (>0.5). These results indicate that both the Chinese and English literature clusters have clear and significant clustering structures, and the clustering rationality is convincing.

Through software calculation, a total of 9 clusters were obtained for the clustering of keywords in the included literature. Please refer to **Table 1** for details. In CiteSpace VI software, the smaller the number of the keyword cluster label, the larger and more important the cluster is in terms of the number of keywords

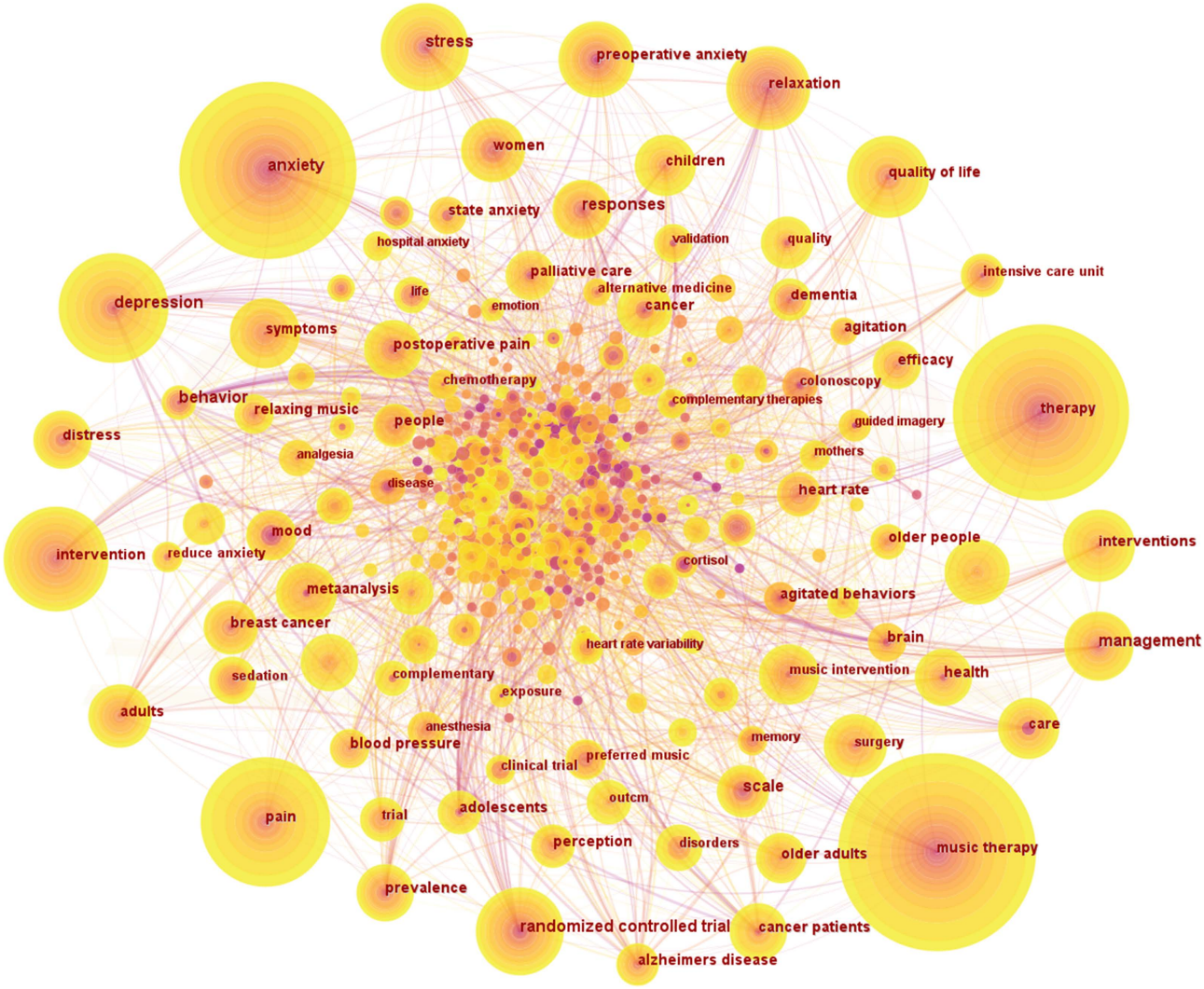

Figure 4. Keyword co-occurrence of coronary heart disease cardiac rehabilitation literature.

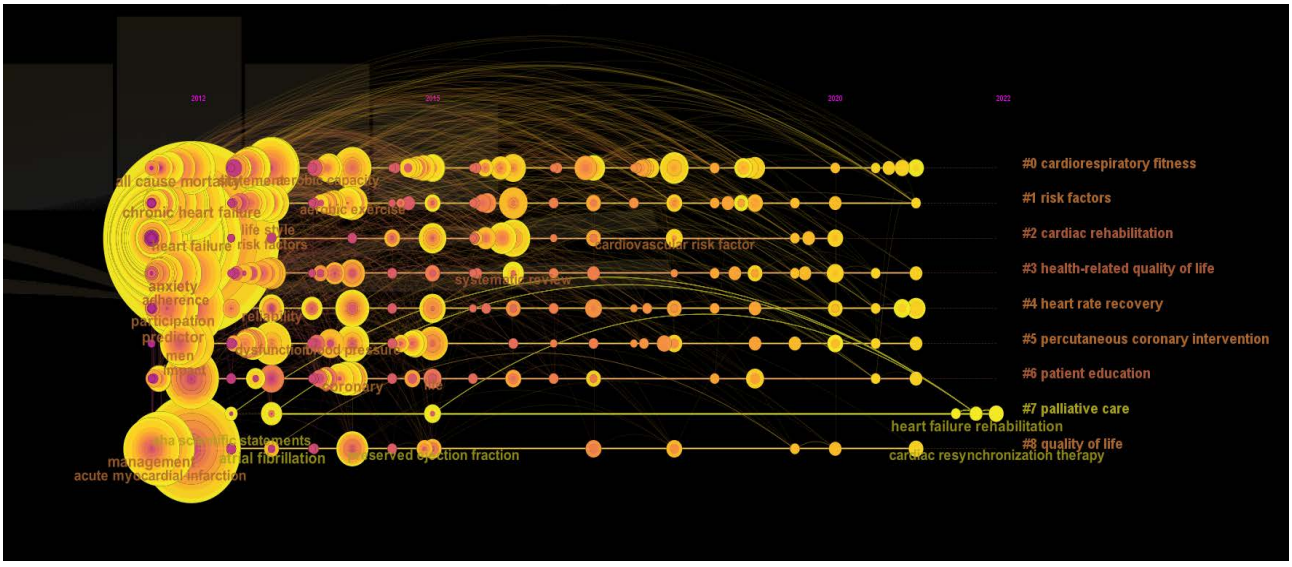

Figure 5. Keyword clustering schedule mapping of coronary heart disease cardiac rehabilitation.

Table 1. Keyword clustering results of coronary heart disease cardiac rehabilitation English text.

Clustering	Main keywords covered	Silhouette value	Average year
#0 cardio respiratory fitness	interval training, HIIT	0.722	2016
#1 risk factors	failure, systematic review, guideline	0.595	2015
#2 cardiac rehabilitation	secondary prevention, meta analysis	0.734	2013
#3 health-related quality of life	depression, meditation	0.752	2015
#4 heart rate recovery	heart rate recovery, smartphone	0.756	2016
#5 PCI	impact, physical training, angioplasty	0.729	2015
#6 patient education	knowledge, questionnaires	0.675	2015
#7 palliative care	palliative care, care pathways	0.995	2021
#8 quality of life	health satisfaction, life satisfaction	0.882	2015

it contains [11].

3.5. Research Trends and Frontier Visual Analysis

Based on the co-occurrence analysis of keywords, the software calculates the emergence of keywords, which refers to the phenomenon where the frequency of occurrence of a specific keyword suddenly increases in the textual data during a certain period of time. Keyword emergence can reflect the research hotspots and popularity in a particular field during a specific time period, and it can also be used to speculate on future research trends and frontiers through keyword emergence [12].

Keyword Emergence

A total of 25 keyword emergence events were calculated by the software from 2012 to 2022, as shown in **Figure 6**. In the initial stage, the research hotspots in Coronary Artery Disease (CAD) included keywords such as "follow up", "controlled trial", and "update", but they gradually faded out of the field around 2017. Keywords like "myocardial infarction patient", "stress", and "health-related quality of life" became active in the field of Coronary Artery Disease (CAD) but ceased to appear in research after 2019. Keywords such as "older adult," "prescription", "resistance exercises", "systematic review", "percutaneous coronary intervention", "European society", "cardiovascular risk", "intensity", and "strategy" emerged in 2019 and continue to be hot research topics, indicating that these themes are likely to be future research trends in the international field of cardiac rehabilitation for coronary artery disease.

4. Discussion

4.1. Current Status of Research on Cardiac Rehabilitation for Coronary Heart Disease at Home and Abroad

From 2012 to 2022, the number of publications related to CR of Coronary Artery

Keywords	Year	Strength	Begin	End	2012-2022
follow up	2012	3.33	2012	2013	
controlled trial	2012	3.05	2012	2015	
update	2013	3.59	2013	2015	
prevention program	2013	3.27	2013	2017	
life style	2013	3.19	2013	2014	
clinical cardiology	2012	3.04	2013	2014	
self efficacy	2014	3.44	2014	2015	
weight lo	2014	3.22	2014	2015	
enrollment	2014	2.92	2014	2017	
patient education	2015	3.33	2015	2017	
belief	2016	2.73	2016	2018	
myocardial infarction patient	2017	3.44	2017	2019	
benefit	2017	2.99	2017	2018	
stress	2017	2.92	2017	2018	
health-related quality of life	2013	2.91	2018	2019	
older adult	2014	3.84	2019	2022	
european association	2018	3.79	2019	2022	
prescription	2019	3.28	2019	2022	
resistance exercise	2019	2.92	2019	2022	
systematic review	2016	2.91	2019	2022	
percutaneous coronary intervention	2013	4.82	2020	2022	
european society	2013	4.8	2020	2022	
cardiovascular risk	2016	3.08	2020	2022	
intensity	2015	3.08	2020	2022	
strategy	2020	2.81	2020	2022	

Figure 6. Keyword emergence of coronary heart disease cardiac rehabilitation literature.

Disease has steadily increased, with over a hundred papers published in the past three years alone, indicating a significant amount of research attention directed towards CR. Most of these articles adopt experimental designs such as double-blind randomized controlled trials, have sufficient sample sizes for obtaining stable results, and undergo peer review processes to ensure scientific rigor and accuracy. These studies provide scientific evidence that guides clinicians in developing cardiac rehabilitation programs. Additionally, these studies drive the development of clinical practice guidelines, which help standardize and promote the implementation of cardiac rehabilitation. High-quality research also provides evidence-based support for policymakers, facilitating the provision of cardiac rehabilitation services and shaping insurance reimbursement policies. In conclusion, cardiac rehabilitation research is continuously advancing and has

made significant progress. High-quality research papers have far-reaching effects, providing valuable guidance for clinical practice, policy-making, and public health education.

Through software-based co-occurrence analysis of the publishing countries, it is evident that the United States holds a central position in this field, closely collaborating with countries such as Canada and the United Kingdom, among others, likely due to similarities in scientific capabilities, economic conditions, and social factors among these Western nations. Internationally, it is widely recognized that the core of CR lies in cardiac rehabilitation, although this is only one aspect of the overall rehabilitation process [13]. Additionally, psychological support, diet and nutrition, smoking cessation, and drug therapy are also indispensable components of CR [14] [15]. Therefore, foreign research in this field also emphasizes home-based rehabilitation and community-based rehabilitation. By promoting CR knowledge within homes and communities, the aim is to further enhance the effectiveness of rehabilitation outcomes [16] [17] [18].

Research on CR of Coronary Artery Disease in our country is relatively lagging behind. Despite the increasing number of publications in recent years, a literature review and analysis using CiteSpace software reveal that the researchers with the highest number of publications in our country over the past decade have only published five papers, while over 70% of researchers have published fewer than four papers. In comparison to foreign research, which commonly employs methods such as randomized controlled trials and systematic reviews, our country relies more on observational studies and clinical practice research, lacking systematicity in our studies. Further improvements are needed in research design and methodology. Through knowledge mapping, it is clear that there is limited collaboration between our country and the international community. In the future, it is crucial to align with international standards and enhance collaboration with other countries to promote the continuous development of the CR field in our country.

4.2. Analysis of Research Hotspots and Trends in Cardiac Rehabilitation for Coronary Artery Disease

4.2.1. Analysis of Research Hotspots in Domestic and Foreign Studies

According to the co-occurrence and clustering analysis of keywords in Chinese and English literature using CiteSpace software, the research hotspots in domestic and foreign studies from 2012 to 2022 can be categorized as follows:

1) Exercise rehabilitation: This includes various exercise modalities and methods such as HIIT, resistance training, and traditional Chinese exercise forms like Tai Chi, Ba Duan Jin, etc. Exercise rehabilitation is considered a fundamental aspect of cardiac rehabilitation for coronary artery disease rehabilitation as it improves patients' physical function [19] [20] [21]. Therefore, it is an absolute core hotspot in CR research both domestically and internationally.

2) Psychological assessment: Psychological factors play a significant role in CR, and timely psychological assessment can help patients alleviate anxiety and

depressive symptoms, thereby improving the overall rehabilitation outcomes [22] [23].

3) Personalized CR program assessment and development: Foreign studies have explored how to tailor interventions to individual differences and develop more personalized rehabilitation programs. In comparison to foreign research, there is limited research in China focusing on personalized CR for different population groups. This is an area that deserves further investigation in the future [24] [25].

4) Technological innovations in rehabilitation: With the continuous development of technology, CR is also incorporating new technologies such as virtual reality, smart wearable devices, etc., to enhance rehabilitation outcomes and experiences [26] [27].

4.2.2. Analysis of Research Trends in Domestic and Foreign Studies

In recent years, there has been an emergence of research focused on traditional Chinese exercise modalities as a form of exercise rehabilitation, and the number of publications in this area has increased. Existing studies have shown the beneficial effects of exercises such as Ba Duan Jin and Tai Chi on CR in patients with coronary artery disease. Tai Chi, also known as Tai Chi Chuan, is a gentle and slow-paced martial art that originated in ancient China [28]. Ba Duan Jin, also known as Eight Pieces of Brocade, is a series of eight gentle and rhythmic exercises that date back to the Song Dynasty in China [29]. Both Tai Chi and Ba Duan Jin are considered holistic forms of exercise that integrate body movements, breath control, and mental focus. They not only contribute to physical fitness but also have a positive impact on mental relaxation and overall wellness. Moreover, these practices have been extensively studied for their potential benefits in managing and preventing various health conditions, such as cardiovascular diseases, musculoskeletal disorders, and stress-related issues. In the future, researchers in China can continue to explore this direction and, taking into account the characteristics of our country, strengthen the integration of traditional Chinese and Western medicine to develop a coronary artery disease CR exercise model with Chinese characteristics [19] [30] [31].

The emergence of keywords in the included literature indicates that research focusing on the elderly population, social factors, and different exercise modalities will continue to be hot topics. Therefore, in the future, China can combine the research hotspots and frontiers in international CR studies and conduct relevant research that is tailored to our country's situation. This will help align China's coronary artery disease CR field with international standards and provide Chinese experiences to the international community in the field of CR research.

5. Conclusions

This study utilized bibliometric analysis and the scientific algorithms of CiteSpace software to visualize the research hotspots and frontiers in the field of co-

ronary artery disease cardiac rehabilitation both domestically and internationally. It provides a reference basis for future research and development in this field in China. While the prospects of related research in China are promising, there is still some distance to cover to catch up with the international field of coronary artery disease cardiac rehabilitation. Therefore, the following recommendations are proposed:

1) Foster multidisciplinary collaboration by establishing interdisciplinary teams to address the physiological, psychological, and social adaptation issues during the rehabilitation process for coronary artery disease patients.

2) Domestic research in coronary artery disease cardiac rehabilitation is relatively lagging, and international cooperation will be an important way to advance research in this field. At the same time, domestic researchers also need to engage in more international collaborations to foster academic exchange and jointly promote research progress in coronary artery disease cardiac rehabilitation.

3) Promote the integration of traditional Chinese and Western medicine by utilizing traditional Chinese exercise modalities to facilitate cardiac rehabilitation for patients, thus providing a Chinese approach to international coronary artery disease cardiac rehabilitation.

4) Foster technological innovation in rehabilitation by leveraging advancements in technology such as virtual reality and smart wearable devices to improve the effectiveness and experience of rehabilitation.

In addition, this study has certain limitations. Due to software restrictions, only relevant literature from the core databases could be included. The selected literature databases were CNKI and WOS core databases, which may be relatively narrow and may not cover all the literature that meets the inclusion criteria. Therefore, there may be a certain research bias. Future studies can include more relevant literature from various core databases to provide more favorable evidence and references for research in coronary artery disease cardiac rehabilitation, thus promoting the development of this field in China.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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