

Visualization Analysis of Research Progress and Trends in Coronary Heart Disease Cardiac Rehabilitation Based on Bibliometrics

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Abstract

Purpose: Coronary Heart Disease (CHD) remains a leading cause of global mortality, and Cardiac Rehabilitation (CR) is a core component of secondary prevention to improve patient outcomes. This study employed bibliometric methods to visually analyze the research status, hotspots, and evolutionary trends in CHD cardiac rehabilitation over the past 26 years, providing references for future research directions.

Methods: Using the Web of Science Core Collection (WoSCC) as the data source, we searched for literature on CHD cardiac rehabilitation with the query: TS = (("Coronary Heart Disease" OR "CHD") AND ("Cardiac Rehabilitation" OR "CR")) covering the period from 1999 to August 2025. After excluding non-English studies, conference proceedings, retracted publications, and book chapters, 1,885 valid articles were included. Bibliometric analysis was performed using VOSviewer and CiteSpace to explore publication trends, contributions of countries, institutions, authors, and journals, as well as keyword co-occurrence, clustering, and burst dynamics.

Results: A total of 1,885 articles were published by 8,492 authors from 2,767 institutions across 82 countries, in 531 journals, with 53,513 citations from 11,695 sources. The annual publication volume showed a steady upward trend, increasing from ≤ 60 articles in the early 2000s to over 100 articles annually after 2017. The top three countries in terms of publication quantity were the USA (484 articles), the United Kingdom (293 articles), and China (277 articles); Canada had the highest average citation frequency (72.1 citations/article). The most productive institutions were the University of Sydney (62 articles) and the University of Queensland (45 articles). The leading authors were Lavie, Carl J. (36 articles) and Taylor, Rod S. (27 articles, with an average citation frequency of 173.9). The journal with the most publications was Journal of Cardiopulmonary Rehabilitation and Prevention (113 articles), while HEART had the highest average citation frequency (82.1). High-frequency keywords included "coronary heart disease" (1,208 times), "cardiac rehabilitation" (1,106 times), and "secondary prevention" (443 times); keywords with high centrality were "coronary heart disease" (0.13) and "quality of life" (0.10). Keyword clustering identified six research hotspots: myocardial infarction, congenital heart disease, physical activity, risk factors, health, and quality of life. Recent burst keywords (2020–2025) included "percutaneous coronary intervention", "systematic review", "mobile health", and "European Society".

Conclusion: CHD cardiac rehabilitation research has shown continuous growth, with the USA and European countries leading in academic influence. Current research focuses on exercise-based rehabilitation, secondary prevention, and quality of life improvement; future directions may emphasize personalized rehabilitation programs, digital health applications, and long-term efficacy of rehabilitation after percutaneous coronary intervention.

Keywords: Coronary Heart Disease, Cardiac Rehabilitation, Bibliometrics, VOSviewer, CiteSpace

Introduction

Coronary Heart Disease (CHD), characterized by myocardial ischemia and hypoxia due to coronary artery stenosis or occlusion, is one of the most prevalent cardiovascular diseases globally. According to the World Health Organization, CHD accounts for approximately 19.8 million deaths annually, accounting for 32% of all cardiovascular-related deaths, and of these deaths, 85% were due to heart attack and stroke [1]. Despite advances in interventional

therapies and drug treatments, CHD patients often face long-term challenges such as reduced exercise capacity, psychological distress (anxiety, depression), and recurrent cardiovascular events, imposing a heavy burden on individuals and healthcare systems [2,3].

Cardiac Rehabilitation (CR), a comprehensive intervention integrating exercise training, psychological support, dietary guidance, and risk factor management, has been proven to reduce mortality, improve exercise tolerance, and enhance quality of life in

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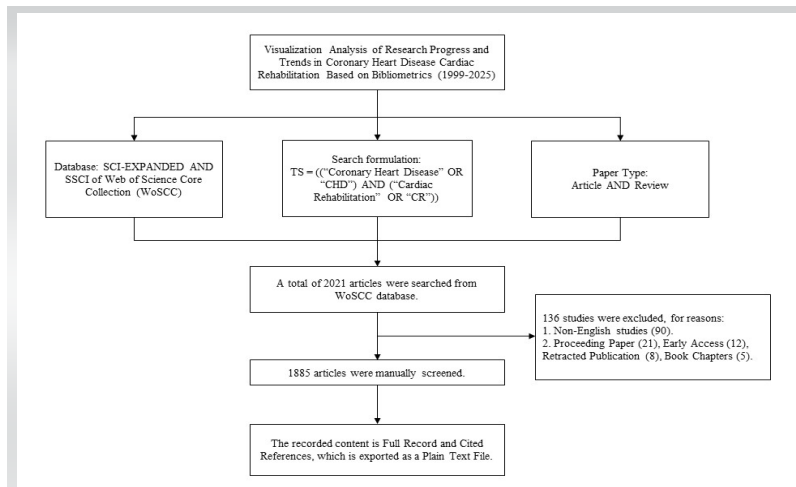


Figure 1: The literature search and screening flowchart.

by analyzing publication data, author collaborations, and keyword dynamics [10,11]. This study used VOSviewer and CiteSpace to conduct a visual analysis of CHD cardiac rehabilitation research from 1999 to 2025, aiming to provide a comprehensive understanding of the field and guide future research.

Methods

Literature Retrieval and Screening

The Web of Science Core Collection (WoSCC), including SCI-EXPANDED and SSCI, was selected as the data source due to its comprehensive coverage of high-quality academic journals and standardized citation data [12,13]. The retrieval formula was: Topic search TS = (('Coronary Heart Disease' OR 'CHD') AND ('Cardiac Rehabilitation' OR 'CR')). The retrieval period was set from 1999 to August 2025, and

CHD patients [4,5]. The European Society of Cardiology (ESC), and American Heart Association (AHA) have included CR in clinical practice guidelines as a Class I recommendation for CHD secondary prevention [6,7]. With the growing emphasis on "patient-centered" healthcare, the scope of CR has expanded from traditional hospital-based programs to community and home-based models, and the integration of digital technologies has further broadened its accessibility [8,9].

In recent decades, the volume of research on CHD cardiac rehabilitation has increased significantly, covering diverse topics such as rehabilitation protocols, efficacy evaluation, and barriers to participation. However, a systematic overview of the field's evolutionary trends, core research teams, and emerging directions is lacking. Bibliometrics, a quantitative analysis method for academic literature, can objectively identify research hotspots and trends

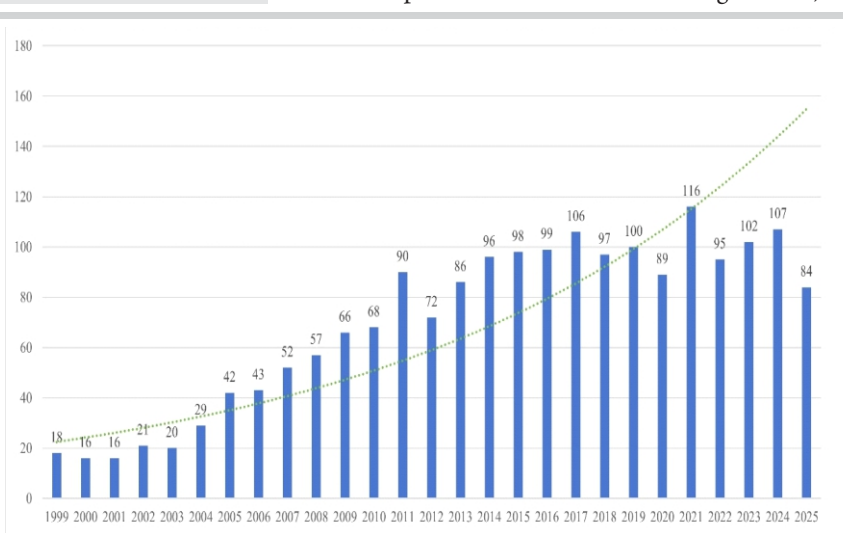


Figure 2: Publication trends in the field of coronary heart disease cardiac rehabilitation (1999–2025).

document types were limited to "Articles" and "Reviews" to ensure research depth and academic rigor. Non-English studies, conference proceedings, retracted publications, and book chapters were excluded to avoid data heterogeneity.

After initial retrieval, 2,021 records were obtained. A total of 136 records were excluded for the following reasons: 90 non-English studies, 21 conference proceedings, 12 early access articles, 8 retracted publications, and 5 book chapters. Finally, 1,885 valid articles were included for bibliometric analysis. The literature screening process is shown in Figure 1.

Research Tools and Analysis Indicators

Two widely used bibliometric tools were employed. VOSviewer (Version 1.6.20): Used to construct visual networks for country collaborations, author co-authorships, journal co-citations, and keyword co-occurrence, with node size representing publication quantity/citation frequency and line thickness representing collaboration strength or co-occurrence frequency [11-13].

CiteSpace (Version 6.3.R1): Used to analyze keyword clustering, burst keywords, and timeline evolution, with clustering modularity (Q) > 0.3 indicating significant

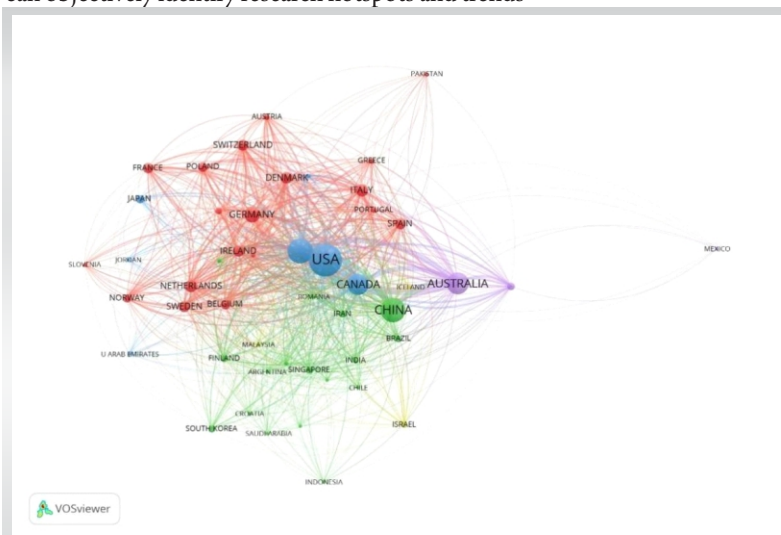
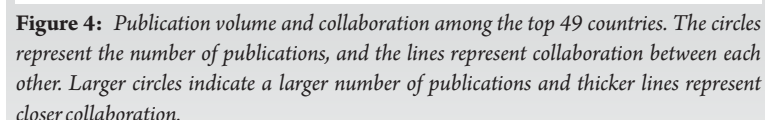


Figure 3: Co-occurrence map of top 49 countries. It shows the number of publications and the correlation between different countries in the field of coronary heart disease cardiac rehabilitation. Each node in the figure represents a country. Larger size presents a higher number of publications. The connection between each node represents the correlation degree. Thicker connection presents closer collaboration



The annual publication volume of CHD cardiac rehabilitation research showed a steady upward trend from 1999 to 2025 (Figure 2). In the early stage (1999–2008), the annual publication volume was relatively low (≤ 60 articles), reflecting the initial development of the field. From 2009 to 2016, the volume increased gradually, reaching 60–100 articles annually, indicating growing academic attention. After 2017, the publication volume exceeded 100 articles per year, with peaks in 2021 (116 articles) and 2024 (107 articles), demonstrating that the field has entered a phase of rapid development. The lower number of publications in 2025 (partial data up to August) is due to the incomplete calendar year.

The main analysis indicators included: Basic quantitative indicators: Number of publications, authors, institutions, countries, journals, and citations. Temporal trends: Annual publication volume to reflect the field's development stage. Contribution analysis: Publication quantity and citation frequency of countries, institutions, authors, and journals to identify core contributors. Keyword analysis: Co-occurrence frequency, centrality, clustering, and burst dynamics to identify research hotspots and emerging trends.

Basic quantitative information

[illegible]

Figure 5: Keyword co-occurrence network of the top 121 keywords. Node size represents occurrence frequency; line thickness represents co-occurrence strength.

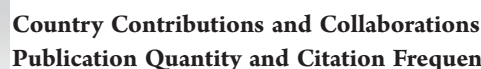


Table 1 shows the top five countries in terms of publication quantity and citation indicators. The USA ranked first with 484 articles (25.7% of total publications) and 32,888 citations, accounting for 61.5% of total citations. The United Kingdom ranked second (293 articles, 15.5%), followed by China (277 articles, 14.7%). Notably, Canada had the highest average citation frequency (72.1 citations/article), higher than the USA (68.0) and the United Kingdom (60.8), indicating strong academic influence despite a smaller publication volume (202 articles). China, while ranking third in publication quantity, had a relatively low average citation frequency (21.5), suggesting a gap in the international influence of its research. Table 1.

Figure 3 shows the co-occurrence map of the top 49

Figure 6: Clustering map of keywords. Different colors represent different clusters; cluster labels reflect core research topics.

Table 1. The top five countries in the field of coronary heart disease cardiac rehabilitation

Rank	Country	Documents	Citations	Average Citation Frequency
1	USA	484	32888	68
2	United Kingdom	293	17820	60.8
3	China	277	5964	21.5
4	Australia	224	11761	52.5
5	Canada	202	14559	72.1

USA: the United States of America; United Kingdom: The United Kingdom of Great Britain and Northern Ireland; China: the People's Republic of China; Australia: the Commonwealth of Australia; Canada: The Dominion

Table 2. The top five authors in the field of coronary heart disease cardiac rehabilitation

Rank	Author	Documents	Citations	Average Citation Frequency
1	Lavie, Carl J.	36	4314	119.8
2	Grace, Sherry L.	34	1470	43.2
3	Gallagher, Robyn	30	718	23.9
4	Redfern, Julie	29	1669	57.6
5	Taylor, Rod S.	27	4695	173.9

University of Exeter (UK) had the highest average citation frequency (157.0 citations/article) with 26 articles. Chinese institutions, such as the Chinese University of Hong Kong (33 articles), ranked eighth, with research focusing on regional CR implementation and cultural adaptation.

Keyword Analysis

Keyword Co-occurrence

Figure 5 shows the co-occurrence network of the top 121 high-frequency keywords (occurrence frequency ≥ 20 times). The node size represents the occurrence frequency, and the line thickness represents the co-occurrence strength. Then, we utilized Citespace to acquire the top 10 keywords in terms of count and centrality (Table 5). The top five high-frequency keywords were "coronary heart disease" (1,208 times), "cardiac rehabilitation" (1,106 times), "secondary prevention" (443 times), "myocardial infarction" (344 times), and "exercise" (342 times). These keywords reflect the core research objects (CHD, myocardial infarction) and intervention methods (CR, exercise, secondary prevention) in the field. In terms of centrality (a measure of keyword influence in the network), the top five keywords

were "coronary heart disease" (0.13), "quality of life" (0.10), "secondary prevention" (0.09), "cardiac rehabilitation" (0.08), and "myocardial infarction" (0.08). High centrality of "quality of life" indicates that patient-reported outcomes have become a key evaluation indicator in CR research, reflecting the shift from "disease-centered" to "patient-centered" healthcare.

Keyword Clustering

Using CiteSpace, keyword clustering was performed with $Q = 0.38$ (> 0.3 , significant clustering) and $S = 0.76$ (> 0.7 , high homogeneity), resulting in six distinct clusters (Figure 6):

#0 Myocardial infarction: Focuses on CR for post-myocardial infarction patients, including rehabilitation timing, exercise intensity, and long-term event prevention.

#1 Congenital heart disease: Explores CR strategies for patients with congenital heart disease complicated by CHD, emphasizing age-specific rehabilitation protocols.

#2 Physical activity: Investigates the role of aerobic exercise, resistance training, and physical activity adherence in CR.

#3 Risk factors: Analyzes the management of CHD risk factors during CR.

#4 Health: Focuses on comprehensive health management, including dietary guidance, smoking cessation, and psychological intervention.

#5 Quality of life: Evaluates the impact of CR on patient quality of life, using tools such as the SF-36 and MLHFQ questionnaires.

Keyword Burst Dynamics

Figure 7 shows the top 20 keywords with the strongest citation bursts, reflecting the field's evolutionary trends over time. Burst keywords can be divided into three phases:

Early phase (1999–2008): Burst keywords included "acute myocardial infarction" (burst strength 18.78), "myocardial infarction" (11.34), and "artery disease" (7.52), indicating that early research focused on CR for severe CHD complications.

Middle phase (2009–2019): Burst keywords included "metabolic syndrome" (10.93), "cardiovascular events" (9.59), and "all-cause mortality" (7.54), shifting the focus to risk factor management and long-term outcome evaluation.

Recent phase (2020–2025): Burst keywords included "percutaneous coronary intervention" (10.49), "systematic review" (8.12), "mobile health" (7.49), and "European Society" (7.48). These reflect emerging trends: (1) CR for patients after percutaneous coronary intervention;

Table 3. The top ten journals in the field of coronary heart disease cardiac rehabilitation

Rank	Journal	Documents	Citations	Average Citation Frequency
1	Journal of Cardiopulmonary Rehabilitation and Prevention	113	2606	23.1
2	European Journal of Preventive Cardiology	66	4553	69
3	BMJ Open	56	574	10.3
4	European Journal of Cardiovascular Nursing	46	1165	25.3
5	EUROPEAN JOURNAL OF CARDIOVASCULAR PREVENTION & REHABILITATION	40	2152	53.8
6	JOURNAL OF CLINICAL NURSING	36	814	22.6
7	BMC Cardiovascular Disorders	33	594	18
8	International Journal of Cardiology	31	1076	34.7
9	HEART	30	2462	82.1
10	Journal of Cardiovascular Nursing	29	649	22.4

Table 4: The top ten institutions in the field of coronary heart disease cardiac rehabilitation				
Rank	Institution	Documents	Citations	Average Citation Frequency
1	The University of Sydney	62	3100	50
2	The University of Queensland	45	3705	82.3
3	University of Alberta	44	2912	66.2
4	University of Toronto	40	2248	56.2
5	York University	40	1648	41.2
6	University Health Network	36	1434	39.8
7	University of Vermont	33	3197	96.9
8	The Chinese University of Hong Kong	33	2416	73.2
9	The University of Melbourne	27	1749	64.8
10	University of Exeter	26	4081	157

(2) evidence-based medicine (systematic reviews/meta-analyses); (3) digital health applications; and (4) guideline development by international societies.

Keyword Timeline Evolution

Figure 8 shows the timeline evolution of keywords, reflecting the dynamic changes in research hotspots. From 1999 to 2008, keywords such as "myocardial infarction" and "artery disease" dominated, focusing on basic CR efficacy. From 2009 to 2019, keywords such as "metabolic syndrome" and "quality of life" emerged, expanding the research scope to risk factors and patient-reported outcomes. After 2020, keywords such as "percutaneous coronary intervention", "mobile health", and "systematic review" became prominent, indicating a shift toward personalized rehabilitation, digital health, and evidence synthesis. The continuous presence of "cardiac rehabilitation" and "coronary heart disease" across all phases confirms their core status in the field.

Cited Reference and Journal Analysis

Top Cited References

Table 6: The top five cited references in the field of coronary heart disease cardiac rehabilitation			
Rank	Cited reference	Publication year	Citations
1	Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials [20]	2011	343
2	Exercise-based cardiac rehabilitation for coronary heart disease [21]	2005	232
3	Cardiac rehabilitation and secondary prevention of coronary heart disease: an American Heart Association scientific statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity), in collaboration with the American association of Cardiovascular and Pulmonary Rehabilitation [22]	2005	170
4	Meta-analysis: secondary prevention programs for patients with coronary artery disease [23]	2005	164
5	Use of cardiac rehabilitation by Medicare beneficiaries after myocardial infarction or coronary bypass surgery [24]	2007	128

Table 5: The top five keywords in frequency and centrality in the field of coronary heart disease cardiac rehabilitation				
Rank	keyword	count	keyword	centrality
1	coronary heart disease	1208	coronary heart disease	0.13
2	cardiac rehabilitation	1106	quality of life	0.1
3	secondary prevention	443	secondary prevention	0.09
4	myocardial infarction	344	cardiac rehabilitation	0.08
5	exercise	342	myocardial infarction	0.08

Table 6 lists the top five most cited references, all of which are high-impact systematic reviews or guideline documents, laying the evidence foundation for the field [20-24]. The most cited reference was a 2004 systematic review published in Am J Med (343 citations) [20]. A 2011 update of this review (232 citations) further validated the long-term efficacy of CR [21]. The 2005 AHA scientific statement (170 citations) provided standardized recommendations for CR program design, becoming a key clinical guideline. These references reflect the field's reliance on evidence-based medicine and guideline-driven practice.

Cited Journal Network

Figure 9 shows the co-citation network of the top 121 cited journals. Nodes with larger sizes represent journals with more citations, and thicker lines represent stronger co-citation relationships. The core cited journals included Circulation (AHA), European Heart Journal (ESC), Journal of Cardiopulmonary Rehabilitation and Prevention (specialized CR journal) and European Journal of Preventive Cardiology. These journals form the main knowledge source of the field, covering basic cardiovascular research, clinical practice, and specialized CR studies. The dense co-citation network between these journals indicates high academic integration in the field.

Discussion

This study systematically analyzed 1,885 articles on CHD cardiac rehabilitation from 1999 to 2025, revealing three core findings. The annual publication volume has increased continuously, with rapid growth after 2017, reflecting growing global attention to CHD secondary prevention. The USA and European countries dominate the field, with strong academic influence, while China's research volume is increasing but lacks international impact, possibly due to language barriers and limited collaboration with core research teams. The field focuses on six clusters: myocardial infarction, congenital heart disease, physical activity, risk factors, health, and quality of life. Exercise-based rehabilitation is the core intervention, with increasing attention to patient-reported outcomes and long-term outcomes. Recent research emphasizes personalized rehabilitation, digital health, and evidence synthesis [5,12]. International societies play a key role in guideline development, promoting standardized CR practice [6,7,22].

The findings have important implications for clinical practice and

research. Clinical practice programs should integrate exercise training, risk factor management, and psychological support, with personalized adjustments for patient subgroups. Digital tools can improve rehabilitation adherence, especially for patients with limited access to hospital-based programs [9,12,14]. Future studies should focus on: Long-term efficacy of digital rehabilitation; CR for elderly and comorbid patients; cost-effectiveness of community-based CR; and cultural adaptation of CR programs in non-Western countries. China and other non-Western countries should strengthen collaboration with core research teams to improve the international influence of their research, such as participating in multi-center randomized controlled trials and publishing in high-impact English journals.

Limitations

This study has several limitations. Only WoSCC was used, excluding articles from other databases, which may have missed some relevant studies. Non-English articles were excluded, potentially omitting research from non-English-speaking countries with regional significance. VOSviewer and CiteSpace parameter settings may affect

network visualization results, although we used standard thresholds to minimize bias. The 2025 data only covers up to August, which may underestimate the annual publication volume.

Conclusion

CHD cardiac rehabilitation research has shown continuous growth over the past 26 years, with the USA and European countries leading in academic influence. The core research focuses on exercise-based rehabilitation, risk factor management, and quality of life improvement, while emerging trends include personalized rehabilitation, digital health, and evidence synthesis. Future research should prioritize long-term efficacy of digital rehabilitation, personalized programs for special populations, and international collaboration to promote standardized, accessible CR practice globally.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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