Review article

Heart failure with Sarcopenia: A Bibliometric review from 1995 to 2022

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ABSTRACT

This study aimed to dynamically track the priorities and potential research hotspots in the field of heart failure with sarcopenia. Using CiteSpace, we analyzed the literature on heart failure with sarcopenia from the Web of Science database from 1995 to 2022. The analysis encompassed 507 records, revealing an overall upward trend in annual publication volume. Europe and the United States emerged as the primary regions for publishing, particularly driven by contributions from developed countries such as the United States, Germany, and Italy. Productive institutions included the Charite Universitatsmedizin Berlin, University Medical Center Gottingen, the German Center for Cardiovascular Research (DZHK), Universita Cattolica del Sacro Cuore, and the National Institute on Aging (NIA). Noteworthy academic groups have formed around these institutions; von Haehling S, Anker Stefan D, Springer J, and Doehner W frequently collaborated. The core journals that frequently published articles in this area included Circulation, European Heart Journal, and The Journals of Gerontology Series A-Biological Sciences and Medical Sciences.

Based on the keyword analysis, we identified three key research areas. First, the diagnosis and definition of sarcopenia emerged as significant themes. Second, researchers have focused on exploring the mechanisms underlying heart failure with sarcopenia, including inflammation, insulin resistance, and oxidative stress. Finally, treatment strategies, such as physical activity and nutritional support, constitute another critical research theme. Furthermore, potential research hotspots within this field include clinical randomized controlled trials, investigations into inflammatory mechanisms, cardiac rehabilitation, studies on physical activity, androgen receptor modulators, and investigations into clinical outcomes such as cognitive impairment.

1. Introduction

Heart failure (HF) is a complex clinical syndrome characterized by abnormal cardiac structure and function, leading to ventricular systolic and diastolic dysfunction. It significantly reduces quality of life and is a major global cause of morbidity and mortality [1]. The

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prevalence of HF exceeds 64 million individuals, imposing a substantial economic burden [2]. Research has shown that HF is associated with skeletal muscle abnormalities in both morphology and function, and contributes to exercise intolerance [3].

Sarcopenia is a condition characterized by the progressive loss of skeletal muscle mass and strength with age. This condition can result in disability, negatively impacting the quality of life, and potentially leading to cardiopulmonary failure or mortality. Based on current estimates, sarcopenia affects approximately 50 million individuals, and this number is projected to surpass 200 million within the next four decades [4].

HF and sarcopenia are closely related. According to the 2016 HF Guidelines of the European Society of Cardiology, sarcopenia is a crucial comorbidity of HF [5]. The prevalence of sarcopenia is increasing in patients with chronic heart failure (CHF) [6]. In a mixed cohort study conducted by von Haehling S on symptomatic HF patients, the prevalence of sarcopenia was 20%, which was significantly higher than that observed in healthy older adults [7]. Furthermore, a multicenter clinical trial led by von Haehling S concluded that lower skeletal muscle mass was strongly correlated with diminished exercise capacity in HF patients [8]. Sarcopenia has been shown to adversely affect the prognosis of HF patients [9]. Previous studies have identified sarcopenia as an independent risk factor for mortality in CHF [10,11]. Interestingly, a study by Niedziela et al. revealed that reduced muscle mass increased mortality in patients with CHF [12]. Current research on the pathophysiological mechanisms underlying HF with sarcopenia primarily revolves around inflammation, hormonal changes, and oxidative stress, among others [13]. The key treatment modalities include dietary modifications, rehabilitation exercises, and medications.

CiteSpace software, a robust visualization tool, has been specifically developed to provide an intuitive representation of the most current and innovative knowledge within a specific field. In this regard, the present study utilized the CiteSpace software to conduct a comprehensive knowledge map analysis of the existing literature on HF with sarcopenia. The objective was to provide relevant stakeholders with ample information and insight into this area of research.

2. Materials and methods

2.1. Database selection and search strategy

Data for this study were obtained from the Web of Science Core Collection (WOS) database (http://apps.webofknowledge.com), which is the most user-friendly and easy-to-use database and is more representative of a wider range of research areas than the Scopus and PubMed databases [14]. Two authors (TTM and XYL) conducted a literature search with the following search strategy: TS= (Sarcopenia OR Sarcopenias) AND ("Heart Failure" OR "Cardiac Failure" OR "Heart Decompensation" OR "Myocardial Failure" OR "Congestive Heart Failure"). The language was restricted to English. The time span covered ranged from January 1995 to September 2022.
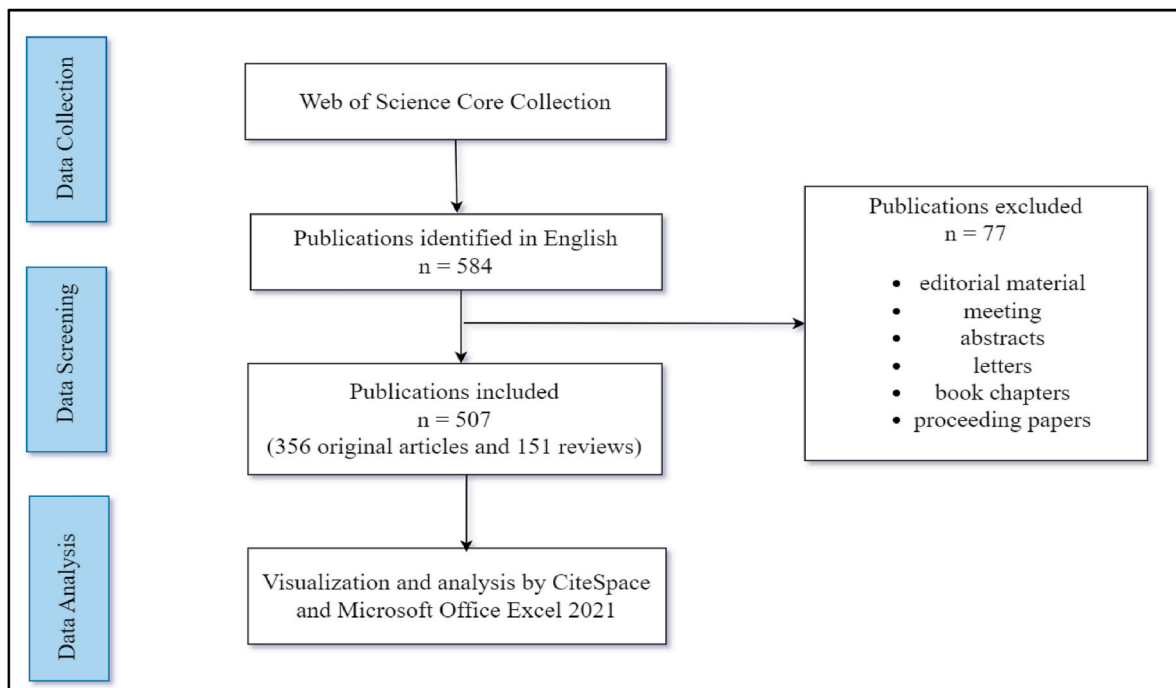

Fig. 1. Flowchart of literature selection for heart failure with sarcopenia.

2.2. Inclusion and exclusion criteria and screening strategy

A total of 584 documents published in English were retrieved. After limiting the types of articles to original articles and reviews and excluding editorial material, meeting abstracts, letters, book chapters, and proceedings papers, 507 documents were finally included in the analysis (Fig. 1).

2.3. Data analysis

Countries, institutions, authors, journals, keywords, and references were selected as elements of the analysis. In the CiteSpace framework, graph nodes represent the objects under examination, and node size is positively correlated with the frequency of the studied items. The connections between the nodes signify their co-occurrence (or co-citation) relationships, with thicker lines indicating stronger co-occurrence (or co-citation). Furthermore, CiteSpace incorporates the concept of betweenness centrality (BC), which assesses the significance of nodes to identify and measure the impact and importance of a research project in a relevant field. Nodes with a BC greater than 0.1 are denoted by a purple ring in the chart, signifying their crucial nature and deserving of attention [15]. Additionally, BC is often regarded as a turning point by CiteSpace. CiteSpace facilitates data analysis through clustering. Clustering results are generally evaluated using modularity (Q) and silhouette (S). Q indicates network modularity, with a higher value suggesting a more effective clustering outcome. S measures the homogeneity within a cluster after clustering. It is widely accepted that $Q > 0.3$ represents significant clustering structure, $S > 0.5$ demonstrates reasonable clustering, and $S > 0.7$ signifies convincing clustering [16]. Microsoft Office Excel 2021 was used for descriptive analysis.

3. Results

3.1. Analysis of annual publication volume

In total, 507 articles, consisting of 356 original articles and 151 reviews, were included in this study. This highlights the integral role of original research in this field. Fig. 2 presents the annual publications pertaining to HF with sarcopenia. Overall, there has been a consistent increase in the number of articles published over the past two decades, albeit with minor fluctuations. As shown in Fig. 2, the correlation coefficient R^2 is 0.816. Subsequently, manual segmentation divided the timeframe into three distinct stages. In the initial phase (1995–2012), the number of annual publications gradually increased, with fewer than 10 articles published each year. Fig. 2 illustrates a steady upward trend in publication output from 2013 to 2018, demonstrating the sustained attention devoted to this field by relevant researchers. Notably, from 2019 to 2021, there was a significant surge in the number of publications, which peaked in 2020. This period signified a phase of rapid development within the field, as researchers had already recognized the close association between HF and sarcopenia. The lower number of articles in 2022 was because the search was conducted until September and not for the entire year. Additionally, recent studies may not have been published by then.

3.2. Analysis of countries

Fig. 3 and Table 1 present a national analysis of HF with sarcopenia. The United States had the highest number of published articles, followed by Japan and Germany, with annual publication rates of 136, 111, and 88, respectively. Moreover, developed countries
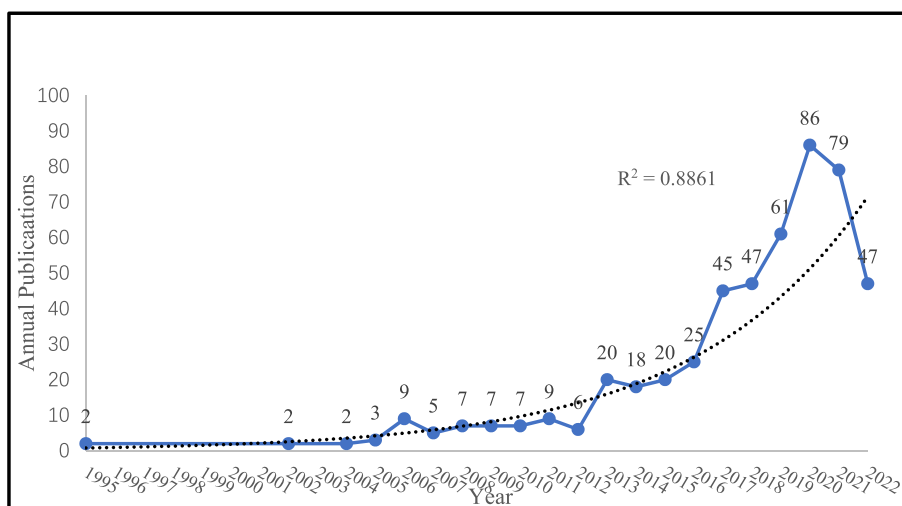

Fig. 2. Annual quantitative distribution of publications on heart failure with sarcopenia.

predominantly had centrality values greater than 0.1. Notably, the top four countries in terms of centrality were the United States, Germany, England, and Italy with values of 0.38, 0.25, 0.19, and 0.18, respectively. Japan, China, and other nations ranked among the top 10 in terms of publications in this field; their BC values were relatively low, or even zero. These findings suggest the need to enhance innovative research endeavors in this area in these countries. Country analysis underscores Europe and the United States as the primary regions for article publications in this field.

3.3. Analysis of institutions

Fig. 4 and Table 2 present the institutional analysis of HF with sarcopenia. Fig. 4 displays a co-occurrence graph of the institutions, while Table 2 outlines the top 10 institutions actively researching in this field. Charite University Medicine Berlin holds the first position, followed by University Medical Center Gottingen, and the German Center for Cardiovascular Research (DZHK). In terms of BC, the top three institutions were the German Center for Cardiovascular Research (DZHK), Charite Universitatsmedizin Berlin, and Universita Cattolica del Sacro Cuore. Notably, Fig. 4 shows the close collaboration between Charite University Medicine Berlin and the German Center for Cardiovascular Research (DZHK) or Universita Cattolica del Sacro Cuore, emphasizing their joint efforts to study HF with sarcopenia.

3.4. Analysis of authors and cited authors

Fig. 5 and Table 3 illustrate the co-occurrence profiles of the authors in the field of HF with sarcopenia. In terms of publication count, von Haehling S emerged as the most prolific author, followed by Anker Stefan D, Springer J, and Doehner W.

CiteSpace employs the frequency of author citations within article references as a key indicator of their contributions [17]. Fig. 6 displays the top 10 authors cited in these references, with each author being cited more than 60 times. The three most cited authors are Cruz-jentoft AJ, von Haehling S, and Anker Stefan D, with citation counts of 185, 162, and 143, respectively.

In terms of BC, Anker Stefan D attains the highest ranking, followed by Baumgartner RN, Morley JE, and Argiles JM, with respective values of 0.27, 0.13, 0.12, and 0.11. A comprehensive analysis underscores the significance of von Haehling S and Anker Stefan D as the most prominent authors in the field of HF with sarcopenia.

In addition, according to Fig. 5, there exists a certain level of cooperation among authors in this field. For example, von Haehling S, Anker Stefan D, Springer J, and Doehner W frequently collaborate. Maekawa E, Kamiya K, Nozaki K, and Matsunaga A also have a cooperative relationship.

3.5. Analysis of cited journals

An analysis of journal co-citations revealed that "Circulation" was the most frequently cited journal, with 302 citations, followed by "Eur Heart J″ with 272 citations and "J Gerontol A-Biol" with 262 citations (Fig. 7). Among the top 10 most frequently cited journals,
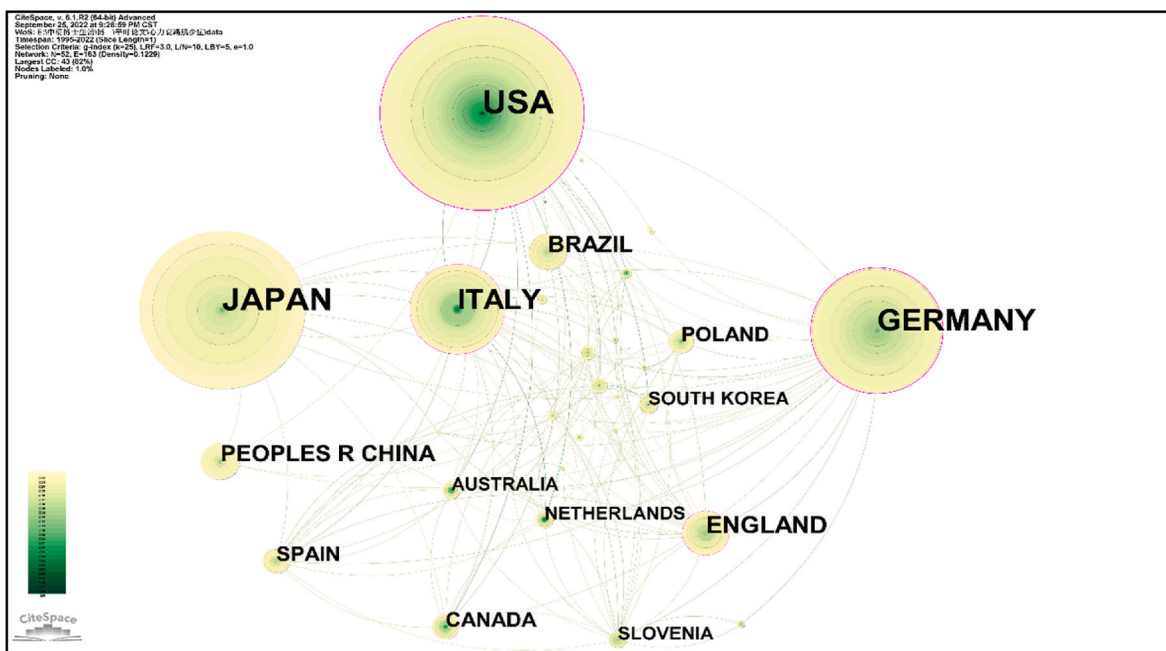

Fig. 3. Countries with publications on heart failure and sarcopenia.

Table 1
Top 10 countries with regard to heart failure with sarcopenia.

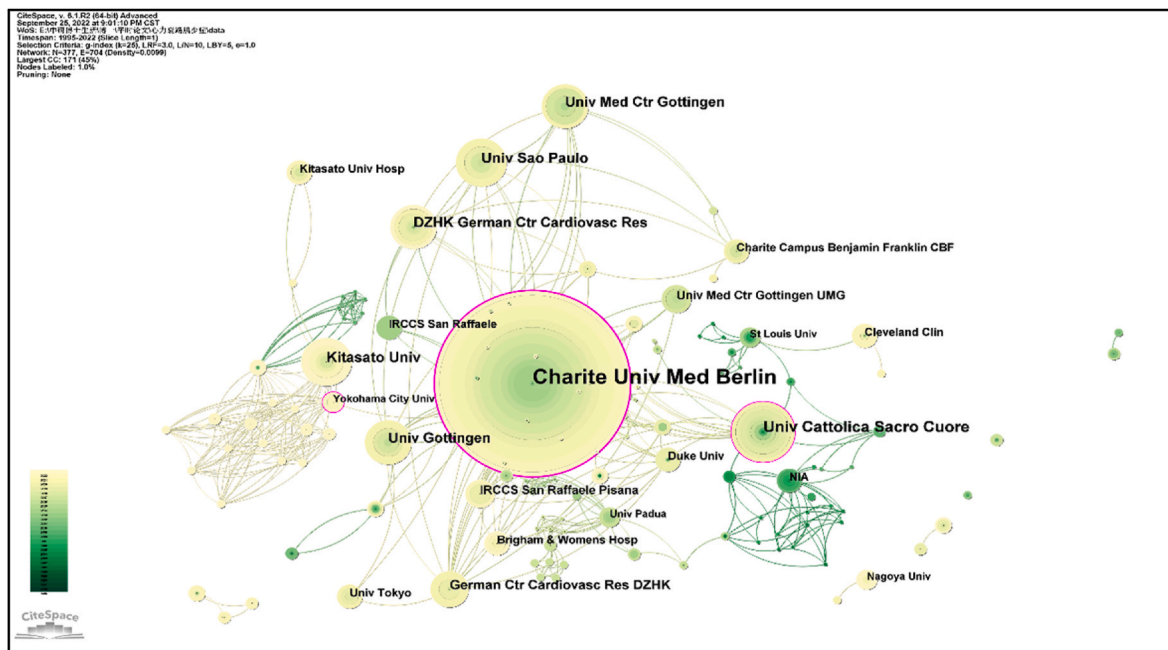| Rank	Countries	Frequency	Betweenness Centrality
1	the United States	136	0.38
2	JAPAN	111	0.1
3	GERMANY	88	0.25
4	ITALY	63	0.18
5	ENGLAND	31	0.19
6	BRAZIL	26	0.08
7	PEOPLES R CHINA	26	0
8	SPAIN	18	0.06
9	CANADA	18	0.01
10	POLAND	17	0.02

Fig. 4. Institutions researching heart failure with sarcopenia.

Table 2
Top 10 most productive institutions for study of heart failure with sarcopenia.

Rank	Frequency	Betweenness Centrality	Institutions
1	46	0.23	Charite Universitatsmedizin Berlin
2	20	0.02	University of Gottingen Medical Center
3	19	0.07	German Center for Cardiovascular Research (DZHK)
4	15	0.14	Universita Cattolica del Sacro Cuore
5	12	0.01	Kitasato University
6	12	0	Universidade de Sao Paulo
7	11	0.04	University of Gottingen
8	7	0.03	IRCCS San Raffaele Pisana
9	6	0.04	National Institute on Aging
10	6	0.02	Duke University

"Circulation" has the highest impact factor (IF) of 39.918. Furthermore, among these 10 journals, approximately 80% are classified as Q1, indicating their high scholarly influence, while the remaining 20% are classified as Q2 (Table 4).

3.6. Analysis of keywords

Keywords serve as crucial indicators of the subject matter being studied and provide a concise reflection of the content [18]. Fig. 8
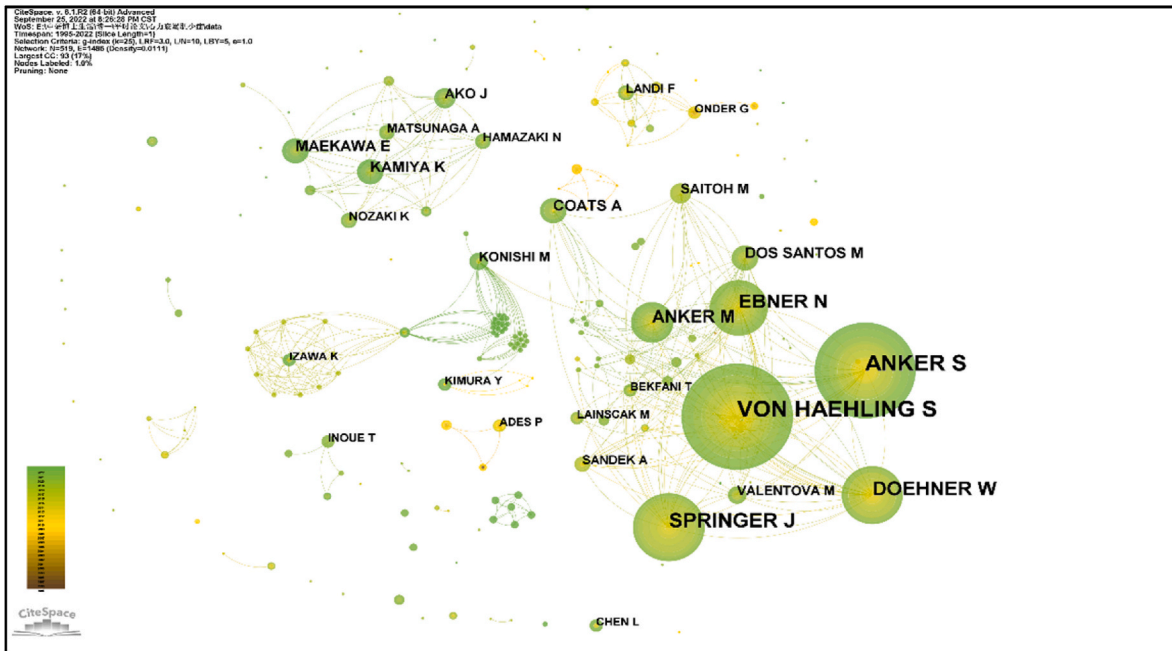
Fig. 5. Co-occurrence of authors on heart failure with sarcopenia.

Table 3
Top 10 most productive authors for heart failure with sarcopenia.

Rank	Author	Frequency	Institution
1	von Haehling, S	42	University Gottingen
2	Anker, Stefan D	38	Charite Universitatsmedizin Berlin
3	Springer, J	27	Charite Universitatsmedizin Berlin
4	Doehner, W	23	Charite Universitatsmedizin Berlin
5	Ebner, N	22	University of Gottingen Medical Center
6	Anker, Markus S	16	Charite Universitatsmedizin Berlin
7	dos Santos, M	10	Universidade de Sao Paulo
8	Kamiya,	10	Kitasato University
9	Maekawa, E	10	Kitasato University
10	Coats, Andrew J. S	10	Monash University

and Table 5 show that research on HF with sarcopenia primarily focuses on the diagnosis, mortality, and treatment of the disease. The primary experimental aspect revolves around investigating oxidative stress.

Clustering was employed to address the challenge of summarizing numerous keywords [19]. The clustering outcomes were divided into nine clusters: #0 diagnosis, #1 muscle atrophy, #2 muscle wasting, #3 obesity paradox, #4 older adults, #5 amino acid, #6 diabetes mellitus, #7 anabolism, and #8 computed tomography (Fig. 9). Consequently, research in this field has concentrated on the diagnosis, risk factors, treatment methods, and detection techniques associated with sarcopenia.

To provide a visual representation of the evolutionary trends and interactions of research topics related to HF with sarcopenia over time, we presented the clustering results in a timeline format based on natural clustering. Fig. 10 shows the timeline of the keywords. Early studies explored the relationship between HF and sarcopenia with a focus on diagnosing and detecting sarcopenia. The diagnosis of sarcopenia primarily involves the loss of skeletal muscle mass and strength, which can lead to adverse consequences such as physical disability, cachexia, frailty, and even death. In the mid-term, research shifted towards investigating oxidative stress, tumor necrosis factor-alpha (TNF-α), growth hormone, double-blind trials, and exercise therapy. Subsequent studies investigated the mechanisms, diagnosis, and prognosis of HF with sarcopenia, including insulin resistance, inflammation, nutritional treatment, vitamin D, and cardiac rehabilitation.

A keyword burst is a significant increase in keyword frequency within a relatively short period. By examining the frequency changes in keywords, we can determine the frontiers and trends of research. Fig. 11 illustrates that early burst keywords for HF with sarcopenia primarily focused on mechanistic studies involving growth factor I, TNF-α, and C-reactive protein. Subsequently, research on HF with sarcopenia has predominantly focused on three areas: treatments (such as amino acids, androgen receptor modulators, vitamin D, physical activity, and protein synthesis), clinical trials (e.g., double-blind trials), and outcomes (including cognitive impairment).
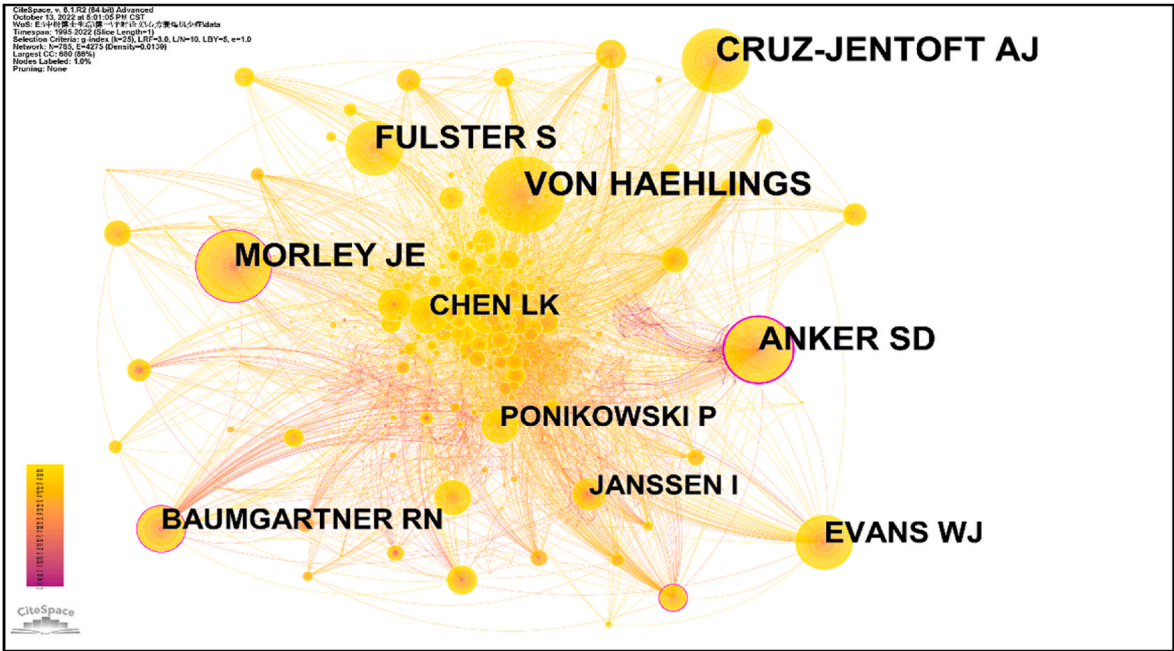
Fig. 6. Top 10 influential co-cited authors.
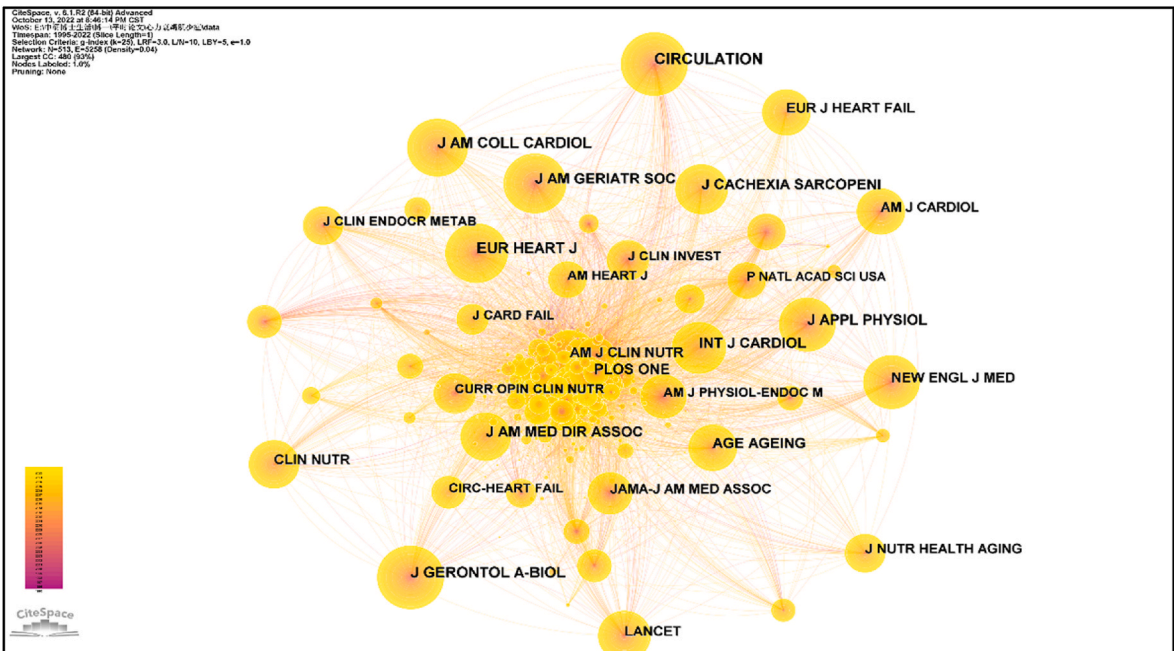
Fig. 7. Core journals for heart failure with sarcopenia.

3.7. Analysis of reference Co-citation

Reference co-citation occurs when multiple references are cited simultaneously by a third piece of literature [20]. By analyzing the frequency of literature co-citation, we identified highly cited authors and extracted core topics within this field. The subject matter of interest of the co-cited articles is attached in Table 6 and Table 7.

Table 4
Top 10 most cited journals for heart failure with sarcopenia.

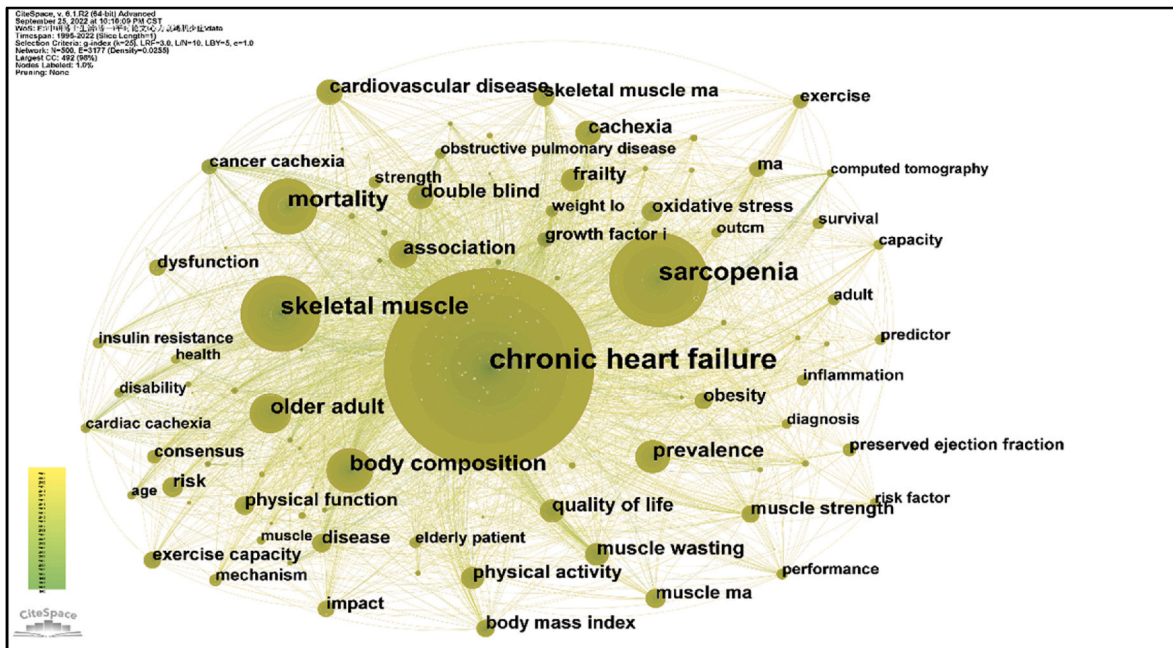| Rank	Frequency	Cited Journal	IF (2021)	JCR Partitions
1	302	CIRCULATION	39.918	Q1
2	272	EUR HEART J	35.855	Q1
3	268	J GERONTOL A-BIOL	6.591	Q1
4	261	J AM COLL CARDIOL	27.203	Q1
5	243	INT J CARDIOL	4.039	Q2
6	241	J CACHEXIA SARCOPENI	12.063	Q1
7	232	AGE AGEING	12.872	Q1
8	205	J AM MED DIR ASSOC	7.802	Q1
9	205	J AM GERIATR SOC	7.538	Q1
10	205	J APPL PHYSIOL	3.88	Q2

Fig. 8. Keyword co-occurrence network.

4. Discussion

The aim of this article was to organize and analyze the literature on HF combined with sarcopenia using CiteSpace software. The results show that the annual publication volume in this field has been increasing annually, with the main research institutions concentrated in Europe. This study focused on guidelines and consensus regarding HF combined with sarcopenia, drug therapy, and the pathogenesis of the disease.

The annual publication trends of HF with sarcopenia indicate a general increase in the number of articles published from 1995 to 2022, with slight fluctuations. Notably, in the 2010 European consensus on sarcopenia, the focus shifted towards assessing physical function in patients with sarcopenia [21]. Consequently, there has been a modest single-digit increase in the number of annual publications in this area. In 2013, the number of publications sudden surged from the single digits to 20 due to the emergence of an Asian consensus on "sarcopenia" and the expanding involvement of researchers studying the condition [22]. However, progress in this field was hindered by the need for clearer diagnostic criteria and definitions of sarcopenia. Since 2016, "sarcopenia" has been included in the International Classification of Diseases (ICD) as a separate disease, with a diagnostic code of ICD-10 [23], leading to an exponential increase in annual publications exceeding 40.

In terms of regional distribution, developed countries, such as the United States, Germany, Italy, and Britain, exert greater influence in this field. A precise definition of sarcopenia has been widely cited by researchers and professionals. Additionally, Asian countries, including Japan and China, rank among the top 10 contributors to research in this field. The incidence of sarcopenia among the elderly population in Asia ranges from 6.8% to 25.7%, representing a significant public health burden [24,25]. Research institutions in this field are mainly concentrated in Europe and the United States. Developing countries such as Asia and Africa also have a high

Table 5
Top 20 keywords with high frequency about heart failure with sarcopenia.

| Rank	Frequency	Betweenness Centrality	Keywords
1	330	0.16	chronic heart failure
2	156	0.1	sarcopenia
3	126	0.18	skeletal muscle
4	93	0.08	mortality
5	74	0.1	body composition
6	66	0.07	older adult
7	55	0.03	prevalence
8	46	0.03	association
9	42	0.05	cardiovascular disease
10	41	0.05	cachexia
11	41	0.04	double blind
12	39	0.03	quality of life
13	38	0.1	muscle wasting
14	38	0.02	frailty
15	37	0.07	physical activity
16	34	0.06	skeletal muscle mass
17	33	0.05	oxidative stress
18	32	0.04	muscle mass
19	31	0.03	physical function
20	29	0.06	body mass index
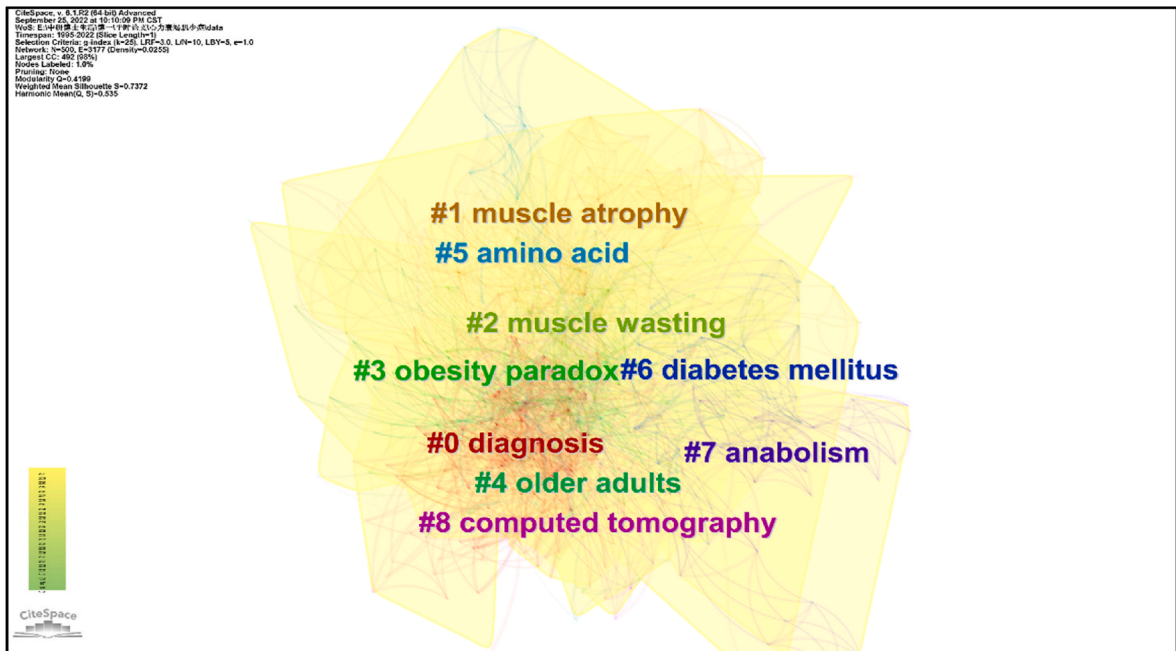
Fig. 9. Cluster analysis of co-occurring keywords.

prevalence of HF combined with sarcopenia, but have fewer outputs, probably due to the following reasons: the first one is the insufficient allocation of resources, as more pressing health challenges often need to be prioritized, such as infectious disease control and basic sanitation construction; the second one may be the lack of specialized personnel and facilities. Therefore, there is a need to raise awareness about this research gap regarding the conditions affecting vulnerable aging populations that may promote more equitable dialogue in the field.

Journals play a crucial role in the dissemination of scholarly information and publishing of academic findings. To some extent, a journal's reputation is indicative of the quality of the research it publishes [26]. The IF is commonly used as a measure of a journal's reputation. In this field, 50% of the most popular publications had an IF greater than 10, underscoring the need for high-quality research on HF patients with sarcopenia.

The analysis of keywords and document co-citation provides insights into research hotspots and knowledge structures concerning HF with sarcopenia. The results of both analyses were relatively consistent, allowing us to summarize the following key aspects: First, the definition and diagnosis of sarcopenia have consistently emerged as research themes in the study of HF patients with sarcopenia. As
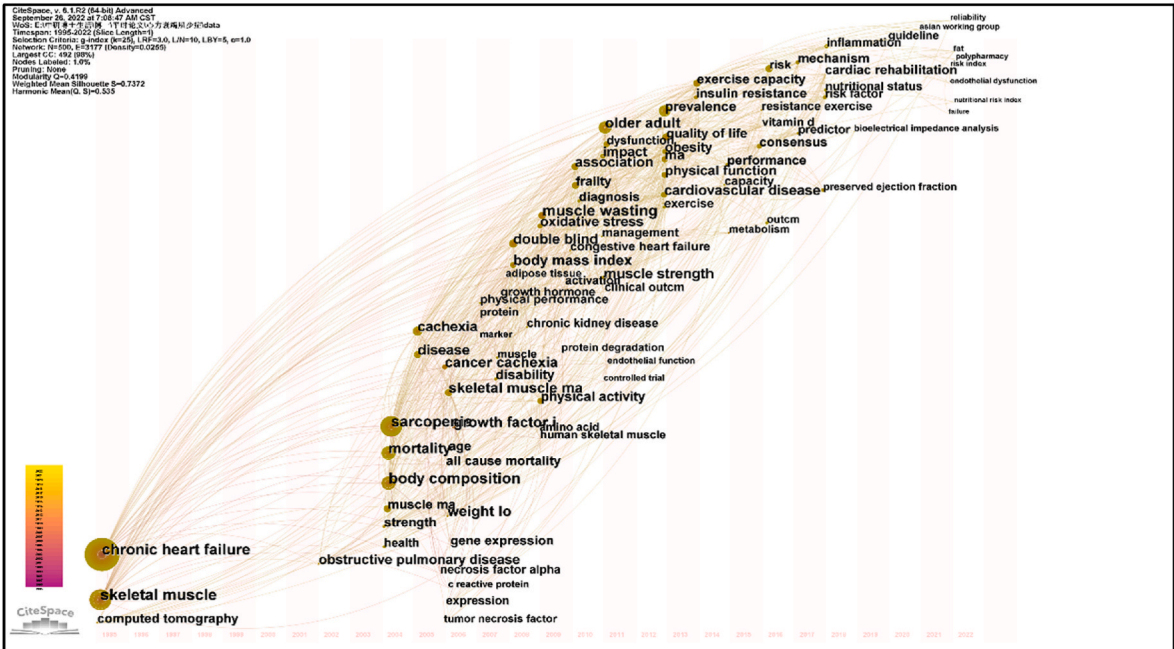
Fig. 10. Timeline graph of keywords.

Fig. 11. Keywords with the strongest burst.
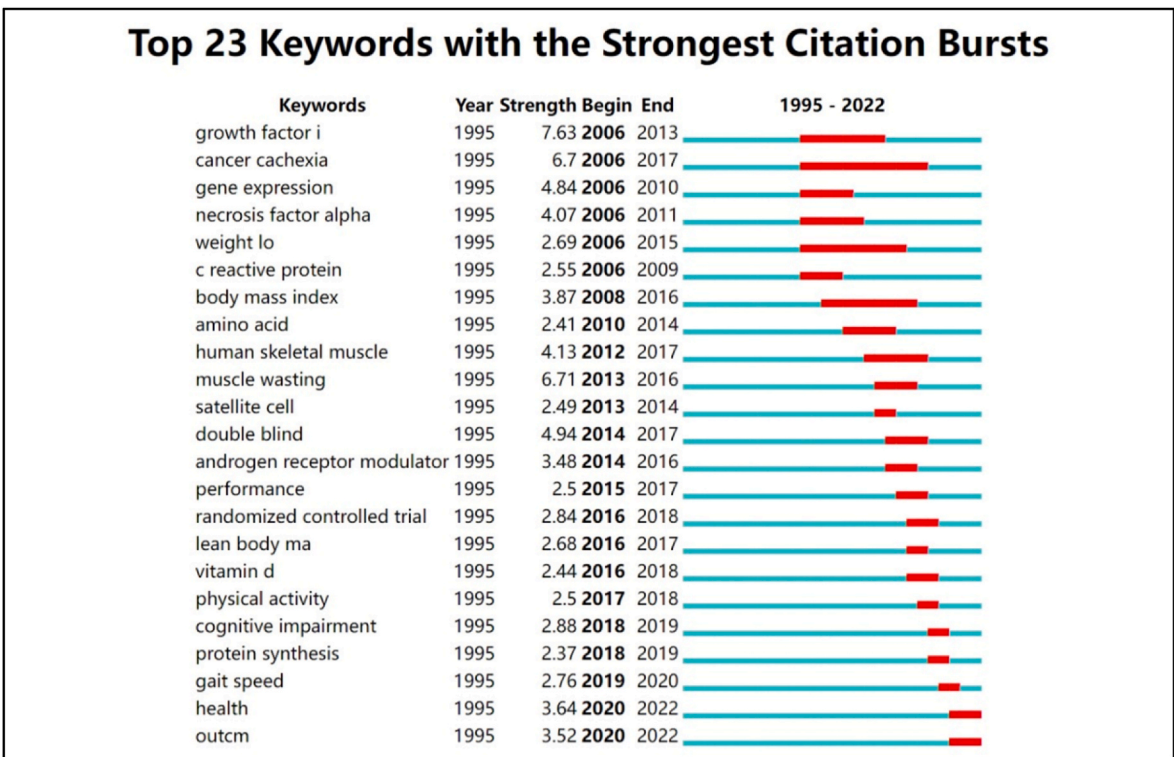
our understanding of muscle function has deepened, experts from the European Working Group on Sarcopenia in Older People (EWGSOP) have updated the diagnostic criteria for sarcopenia [27]. In 2019, the Asian Working Group for Sarcopenia released an updated consensus regarding sarcopenia. These guidelines incorporate assessments of physical performance, such as usual gait speed

Table 6
Top 10 most cited references about heart failure with sarcopenia and focus of the article.

Rank	First Author	Title	Frequency	Focus of the article
1	Cruz-jentoft AJ	Sarcopenia: revised European consensus on definition and diagnosis	62	the European consensus on sarcopenia
2	Fulster S	Muscle wasting in patients with chronic heart failure: results from the studies investigating comorbidities aggravating heart failure (SICA-HF)	47	the interaction between HF and sarcopenia
3	Ponikowski P	2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure	45	guidelines for acute and chronic HF
4	Bekfani T	Sarcopenia in patients with heart failure with preserved ejection fraction: impact on muscle strength, exercise capacity and quality of life	44	the interaction between HF and sarcopenia
5	von Haehling S	Muscle wasting and cachexia in heart failure: mechanisms and therapies	37	the pathophysiology, pathogenesis, and treatment of sarcopenia and cachexia in patients with HF
6	Emami A	Comparison of sarcopenia and cachexia in men with chronic heart failure: results from the Studies Investigating Comorbidities Aggravating Heart Failure (SICA-HF)	29	
7	Springer J	Muscle wasting and sarcopenia in heart failure and beyond: update 2017	29	the interaction between HF and sarcopenia
8	von Haehling S	The wasting continuum in heart failure: from sarcopenia to cachexia	27	the pathophysiology, pathogenesis, and treatment of sarcopenia and cachexia in patients with HF
9	Hajahmadi M	Muscle wasting in young patients with dilated cardiomyopathy	24	the interaction between HF and sarcopenia
10	Chen LK	Sarcopenia in Asia: Consensus Report of the Asian Working Group for Sarcopenia	24	The Asian consensus on sarcopenia

Table 7
Top 10 references with high betweenness centrality about heart failure with sarcopenia and focus of the article.

Rank	First Author	Title	High-Betweenness Centrality	Focus of the article
1	Akamizu T	Ghrelin for cachexia	0.43	the pharmacological treatment of HF with sarcopenia —ghrelin
2	Akashi YJ	Cachexia in chronic heart failure: prognostic implications and novel therapeutic approaches	0.38	the pharmacological treatment of HF with sarcopenia —ghrelin
3	Josiak K	Skeletal myopathy in patients with chronic heart failure: significance of anabolic-androgenic hormones	0.16	the pharmacological treatment of HF with sarcopenia —anabolic-androgenic hormones
4	Coats AJS	The ACT-ONE trial, a multicenter, randomized, double-blind, placebo-controlled, dose-finding study of the anabolic/catabolic transforming agent, MT-102 in subjects with cachexia related to stage III and IV non-small cell lung cancer and colorectal cancer: study design	0.15	the pharmacological treatment of HF with sarcopeni —the anabolic/catabolic transforming agent (MT-102)
5	Anker SD	Inflammatory mediators in chronic heart failure: an overview	0.15	the inflammatory mechanisms and
6	Dos SANTOSMR	Sarcopenia and endothelial function in patients with chronic heart failure: results from the studies investigating comorbidities aggravating HF (SICA-HF)	0.13	endothelial dysfunction in patients with HF and sarcopenia
7	Argiles JM	Cancer-associated malnutrition	0.13	the pharmacological treatment of HF with sarcopenia —nutrients
8	Clark AL	Effect of beta-adrenergic blockade with carvedilol on cachexia in severe chronic heart failure: results from the COPERNICUS trial	0.12	the pharmacological treatment of HF with sarcopenia —beta-adrenergic blockade (carvedilol)
9	Farkas J	Cachexia as a major public health problem: frequent, costly, and deadly	0.12	the public health burden caused by HF with sarcopenia
10	Baumgartner RN	Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly	0.12	instrumental activities of daily living disability in older adults

and 6-min walking speed. Additionally, low muscle mass is a defining characteristic of sarcopenia. Satellite cells, which play a vital role in muscle growth and maintenance of muscle mass, play a central role in muscle regeneration. Numerous studies have reported a decline in satellite cell proliferation and regenerative capacity following aging-associated tissue damage.

The mechanism underlying HF in patients with sarcopenia is a topic of interest. Oxidative stress is the first mechanism to be discussed. With aging, respiratory chain function and cellular antioxidant defense weaken, leading to increased production of reactive oxygen species (ROS) [28]. Evidence suggests that ROS can induce mitochondrial dysfunction, accelerate skeletal muscle damage and degeneration, and contribute to the development of sarcopenia in patients with HF and animal models [29,30]. The second mechanism worth mentioning is inflammation, particularly regarding TNF-α. Studies have shown elevated TNF-α levels in patients with HF [31]. TNF-α has been found to impair mitochondrial function, resulting in muscle atrophy. This process may involve adiponectin,

AMP-activated protein kinase, and downstream signaling pathways [32]. Additionally, other pro-inflammatory factors, such as interleukin 6 and interleukin 1, can exacerbate hemodynamic abnormalities. The inflammatory mechanisms underlying HF with sarcopenia have been the focus of many studies. Insulin resistance is another cause of concern. Gorshunova et al. observed increased insulin resistance indices in hypertensive patients with low muscle mass and strength, accompanied by signs of left ventricular myocardial dysfunction and HF, possibly due to glucose entering the heart and skeletal muscle cells [33]. Malnutrition is another contributing factor. Evidence suggests that anorexia is independently associated with decreased muscle mass and strength [34].

Third, researchers have focused on treating HF patients with sarcopenia, including nutritional support (such as essential amino acids or vitamin D supplementation) and physical activity. Clinical studies have demonstrated that supplementation with essential amino acids and vitamin D improves muscle mass and lower limb function in patients with HF and sarcopenia [35,36]. Physical activity and exercise training are also crucial. Studies have indicated that aerobic, resistance, and combined exercise training can enhance heart and skeletal muscle function in patients with HF and sarcopenia [37].

Finally, the appearance of keywords related to cardiac rehabilitation or rehabilitation on the timeline graph indicates increasing recognition of the importance of cardiac rehabilitation in managing patients with HF and sarcopenia. Cardiac rehabilitation is an integrated approach that encompasses nutrition, exercise, and medication for the treatment of patients with HF and sarcopenia. This retrospective cross-sectional analysis demonstrated the potential benefits of cardiac rehabilitation in the prevention and treatment of HF with sarcopenia [38]. Additionally, a clinical trial conducted by Takata revealed that conventional cardiac rehabilitation combined with branched-chain amino acid therapy was effective in improving cardiopulmonary and skeletal muscle functions in patients with HF and sarcopenia [39].

Keyword burst analysis provides insights into the cutting-edge knowledge in specific research fields. Previous studies have primarily focused on growth factors, TNF-α, C-reactive protein, gene expression, and skeletal muscle. It has been observed that sarcopenia leads to a decrease in anabolic hormones and an increase in catabolic hormones, as highlighted by Jiayu Yin [40]. The growth hormone (GH)/insulin-like growth factor-1 (IGF-1) axis is considered a crucial regulator of body composition, with skeletal muscles secreting IGF-1 [41,42]. IGF-1 production may respond to GH and testosterone [43,44]. Lower levels of GH and IGF-1 contribute to poor physical function and muscle loss [45,46]. Furthermore, evidence suggests that chronic ACE inhibitor therapy with enalapril can restore the IGF-1 plasma levels in patients with CHF [47]. In recent years, there has been an increase in the number of double-blind randomized controlled trials focusing on androgen receptor modulators, vitamin D, physical activity, protein synthesis, and health outcomes. These directions represent the potential frontiers for future research.

There is growing interest in androgen receptor modulators among researchers. Selective androgen receptor modulators (SARMs) are considered to have fewer serious side effects than testosterone while exhibiting similar anabolic effects, making them a promising treatment option [48]. Animal experiments have shown that SARMs have the potential to treat sarcopenia; however, this requires confirmation through clinical trials. A clinical trial demonstrated that MK-0773, a selective androgen receptor modulator, increased IGF-1 levels and improved muscle function in women; however, this was terminated because of increased cardiovascular risk [49]. Further clinical trials are required to establish the safety and efficacy of SARMs.

Physical activity has significant therapeutic advantages in patients with HF and sarcopenia. A consensus statement from the European Association for Cardiovascular Prevention and Rehabilitation highlighted that regular physical activity could prevent wasting syndrome in patients with HF [50]. Evidence suggests that physical activity has a positive impact on patients with HF and sarcopenia, leading to improvements in proinflammatory cytokine levels and oxidative stress [51,52]. Randomized controlled double-blind trials provide robust evidence within an evidence-based medicine framework, ensuring the reliability of the study findings in this field. Researchers have also directed their attention towards health outcomes, indicating a strong concern for disease prevention and prognosis, aligning with the introduction of cardiac rehabilitation therapy.

Furthermore, cognitive impairment has emerged as a recent focus in studies on patients with HF and sarcopenia. A meta-analysis indicated an association between sarcopenia and risk of cognitive impairment [53]. Hu et al. discovered a causal relationship between sarcopenia and cognitive impairment [54]. In elderly patients with HF, cognitive impairment independently predicts poor clinical outcomes, emphasizing the importance of early identification of sarcopenia to prevent cognitive decline and improve clinical outcomes [55].

5. Limitation

Owing to the limitations of CiteSpace, integrating data from multiple databases is challenging; therefore, we relied solely on the WOS database for our analysis. Consequently, there is a possibility that we may have overlooked relevant literature by relying on a single database. In future studies, we intend to explore the possibility of incorporating additional databases to enhance the comprehensiveness of our analyses.

6. Conclusion

Bibliometric analysis revealed a growing interest in HF with sarcopenia among researchers in this field. This study examines the key contributors, prominent regions, and significant publications within the research domain. Research on HF and sarcopenia can be categorized into three main areas: diagnosis and definition of sarcopenia; mechanisms underlying HF with sarcopenia, including inflammation and insulin resistance; and treatment strategies such as physical exercise and nutritional support. Recent trends suggest that potential future research hotspots may include randomized double-blind trials, investigations into inflammation, exploration of the effects of physical activity and cardiac rehabilitation, studies on androgen receptor modulators, and investigations into clinical

outcomes, such as cognitive impairment.

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Yaping You: Writing – review & editing, Writing – original draft. **Tiantian Meng:** Writing – original draft. **Xinyu Lu:** Writing – original draft. **Xueping Zhu:** Visualization, Software, Data curation. **Meng Lv:** Visualization, Software, Data curation. **Xintian Shou:** Visualization, Software, Data curation. **Qingyong He:** Writing – review & editing, Supervision, Conceptualization. **Yuanhui Hu:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that might influence the work reported in this paper.

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References

[1] G.C.M. Siontis, D.L. Bhatt, C.J. Patel, Secular trends in prevalence of heart failure diagnosis over 20 Years (from the US NHANES), Am. J. Cardiol. 172 (2022) 161–164.
[2] G. Savarese, P.M. Becher, L.H. Lund, et al., Global burden of heart failure: a comprehensive and updated review of epidemiology, Cardiovasc. Res. 118 (17) (2023) 3272–3287.
[3] W.J. Tucker, M.J. Haykowsky, Y. Seo, et al., Impaired exercise tolerance in heart failure: role of skeletal muscle morphology and function, Curr. Heart Fail. Rep. 15 (6) (2018) 323–331.
[4] A.J. Cruz-Jentoft, G. Bahat, J. Bauer, et al., Sarcopenia: revised European consensus on definition and diagnosis, Age Ageing 48 (4) (2019) 601.
[5] P. Ponikowski, A.A. Voors, S.D. Anker, et al., ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC). Developed with the special contribution of the Heart Failure Association (HFA) of the ESC, Eur. J. Heart Fail. 18 (8) (2016) 891–975, 2016.
[6] J. Springer, J. Springer, S. Anker, Muscle wasting and sarcopenia in heart failure and beyond: update 2017, ESC Heart Fail 4 (2017) 492–498.
[7] S. Fulster, M. Tacke, A. Sandek, et al., Muscle wasting in patients with chronic heart failure: results from the studies investigating comorbidities aggravating heart failure (SICA-HF), Eur. Heart J. 34 (7) (2013) 512–519.
[8] T. Bekfani, P. Pellicori, D.A. Morris, et al., Sarcopenia in patients with heart failure with preserved ejection fraction: impact on muscle strength, exercise capacity and quality of life, Int. J. Cardiol. 222 (2016) 41–46.
[9] S. von Haehling, Muscle wasting and sarcopenia in heart failure: a brief overview of the current literature, ESC Heart Fail 5 (6) (2018) 1074–1082.
[10] S.D. Anker, P. Ponikowski, S. Varney, et al., Wasting as independent risk factor for mortality in chronic heart failure, Lancet 349 (9058) (1997) 1050–1053.
[11] S. von Haehling, T.G. Macedo, M. Valentova, et al., Muscle wasting as an independent predictor of survival in patients with chronic heart failure, J. Cachexia Sarcopenia Muscle 11 (5) (2020) 1242–1249.
[12] J.T. Nedziela, B. Hudzik, K. Strojek, et al., Weight loss in heart failure is associated with increased mortality only in nonobese patients without diabetes, J. Cachexia Sarcopenia Muscle 10 (6) (2019) 1307–1315.
[13] J. Yin, X. Lu, Z. Qian, W. Xu, X. Zhou, New insights into the pathogenesis and treatment of sarcopenia in chronic heart failure, Theranostics 9 (14) (2019) 4019–4029.
[14] S.A.S. AlRyalat, L.W. Malkawi, S.M. Momani, Comparing bibliometric analysis using PubMed, Scopus, and Web of science databases, J. Vis. Exp. 152 (2019), https://doi.org/10.3791/58494.
[15] C. Chen, The centrality of pivotal points in the evolution of scientific networks, Proceedings of the International Conference on Intelligent User Interfaces (2005) 98–105.
[16] T. Liu, L. Yang, H. Mao, et al., Knowledge domain and emerging trends in podocyte injury research from 1994 to 2021: a bibliometric and visualized analysis, Front. Pharmacol. 12 (2021) 772386.
[17] D. Chen, G. Zhang, J. Wang, et al., Mapping trends in moyamoya angiopathy research: a 10-year bibliometric and visualization-based analyses of the Web of science core collection (WoSCC), Front. Neurol. 12 (2021) 637310.
[18] Y.J. Zhu, M.C. Kim, C.M. Chen, An investigation of the intellectual structure of opinion mining research, Inf. Res. 22 (1) (2017) 20.
[19] G.Z. Yuan, J.J. Shi, Q.L. Jia, et al., Cardiac rehabilitation: a bibliometric review from 2001 to 2020, Front. Cardiovasc. Med. 8 (2021) 672913.
[20] H. Small, Co-citation in the scientific literature: a new measure of the relationship between two documents, J. Am. Soc. Inf. Sci. 24 (4) (1973) 265–269.
[21] A.J. Cruz-Jentoft, J.P. Baeyens, J.M. Bauer, et al., Sarcopenia: European consensus on definition and diagnosis: report of the European working group on sarcopenia in older People, Age Ageing 39 (4) (2010) 412–423.
[22] L.K. Chen, L.K. Liu, J. Woo, et al., Sarcopenia in Asia: consensus report of the asian working group for sarcopenia, J. Am. Med. Dir. Assoc. 15 (2) (2014) 95–101.
[23] J.P. Hardee, G.S. Lynch, Current pharmacotherapies for sarcopenia, Expet Opin. Pharmacother. 20 (13) (2019) 1645–1657.
[24] A. Kitamura, S. Seino, T. Abe, et al., Sarcopenia: prevalence, associated factors, and the risk of mortality and disability in Japanese older adults, J. Cachexia Sarcopenia Muscle 12 (1) (2021) 30–38.
[25] P.M. Cawthon, L.Y. Lui, B.C. Taylor, et al., Clinical definitions of sarcopenia and risk of hospitalization in community-dwelling older men: the osteoporotic fractures in men study, J. Gerontol. A Biol. Sci. Med. Sci. 72 (10) (2017) 1383–1389.

[26] S. Highhouse, M.J. Zickar, S.R. Melick, Prestige and relevance of the scholarly journals: impressions of SIOP members, Industrial and Organizational Psychology: Perspectives on Science and Practice 13 (3) (2020) 273–290.

[27] A.J. Cruz-Jentoft, J.P. Baeyens, J.M. Bauer, et al., Sarcopenia: European consensus on definition and diagnosis: report of the European working group on sarcopenia in older People, Age Ageing 39 (4) (2010) 412–423.

[28] J. Viña, C. Borras, K.M. Abdelaziz, et al., The free radical theory of aging revisited: the cell signaling disruption theory of aging, Antioxidants Redox Signal. 19 (8) (2013) 779–787.

[29] S. Fulle, F. Protasi, G.D. Tano, et al., The contribution of reactive oxygen species to sarcopenia and muscle aging, Exp. Gerontol. 39 (1) (2004) 17–24.

[30] G.G. Mentesana, A. Báez, M. Presti, et al., Functional and structural alterations of cardiac and skeletal muscle mitochondria in heart failure patients, Arch. Med. Res. 45 (3) (2014) 237–246.

[31] B. Levine, J. Kalman, L. Mayer, et al., Elevated circulating levels of tumor necrosis factor in severe chronic heart failure, N. Engl. J. Med. 323 (4) (1990) 236–241.

[32] T. Sente, A.M. Van Berendoncks, E. Fransen, et al., Tumor necrosis factor-α impairs adiponectin signaling, mitochondrial biogenesis, and myogenesis in primary human myotubes cultures, Am. J. Physiol. Heart Circ. Physiol. 310 (9) (2016) H1164–H1175.

[33] N. Gorshunova, N. Medvedev, Significance of insulin resistance in the pathogenesis of sarcopenia and chronic heart failure in elderly hypertensive patients, Adv. Gerontol. 29 (2) (2016) 324–328.

[34] B. İlhan, G. Bahat, T. Erdoğan, et al., Anorexia is independently associated with decreased muscle mass and strength in community dwelling older adults, J. Nutr. Health Aging 23 (2019) 202–206.

[35] S. Nichols, G. Mcgregor, A. Al-Mohammad, et al., The effect of protein and essential amino acid supplementation on muscle strength and performance in patients with chronic heart failure: a systematic review, Eur. J. Nutr. 59 (5) (2020) 1785–1801.

[36] P. Ambarish, D.W. Kitzman, D.K. Houston, et al., Vitamin D status and exercise capacity in older patients with heart failure with preserved ejection fraction, Am. J. Med. 131131 (12) (2018) 1515, e11-. e19.

[37] J. Cho, Y. Choi, P. Sajgalik, et al., Exercise as a therapeutic strategy for sarcopenia in heart failure: insights into underlying mechanisms, Cells 9 (10) (2020).

[38] H. Harada, H. Kai, H. Niiyama, et al., Effectiveness of cardiac rehabilitation for prevention and treatment of sarcopenia in patients with cardiovascular disease - a retrospective cross-sectional analysis, J. Nutr. Health Aging 21 (4) (2017) 449–456.

[39] M. Takata, E. Amiya, M. Watanabe, et al., An exploratory study on the efficacy and safety of a BCAA preparation used in combination with cardiac rehabilitation for patients with chronic heart failure, BMC Cardiovasc. Disord. 17 (1) (2017) 205.

[40] J.Y. Yin, X. Lu, Z.Y. Qian, et al., New insights into the pathogenesis and treatment of sarcopenia in chronic heart failure, Theranostics 9 (14) (2019) 4019–4029.

[41] D.L. DeVol, P. Rotwein, J.L. Sadow, et al., Activation of insulin-like growth factor gene expression during work-induced skeletal muscle growth, Am. J. Physiol. 259 (1 Pt 1) (1990) E89–E95.

[42] W.H. Daughaday, Growth hormone axis overview–somatomedin hypothesis, Pediatr. Nephrol. 14 (7) (2000) 537–540.

[43] S. Bhasin, L. Woodhouse, R. Casaburi, et al., Testosterone dose–response relationships in healthy young men, Am. J. Physiol. Endocrinol. Metab. 281 (6) (2001) E1172–E1181.

[44] C.L. Sadowski, T.T. Wheeler, L.H. Wang, et al., GH regulation of IGF-I and suppressor of cytokine signaling gene expression in C2C12 skeletal muscle cells, Endocrinology 142 (9) (2001) 3890–3900.

[45] L. Dalla Libera, B. Ravara, M. Volterrani, et al., Beneficial effects of GH/IGF-1 on skeletal muscle atrophy and function in experimental heart failure, Am. J. Physiol. Cell Physiol. 286 (1) (2004) C138–C144.

[46] G. Onder, R. Liperoti, A. Russo, et al., Body mass index, free insulin-like growth factor I, and physical function among older adults: results from the ilSIRENTE study, Am. J. Physiol. Endocrinol. Metab. 291 (4) (2006) E829–E834.

[47] R. Corbalan, M. Acevedo, I. Godoy, et al., Enalapril restores depressed circulating insulin-like growth factor 1 in patients with chronic heart failure, J. Card. Fail. 4 (2) (1998) 115–119.

[48] T. Suzuki, S. Palus, J. Springer, Skeletal muscle wasting in chronic heart failure, ESC Heart Fail 5 (6) (2018) 1099–1107.

[49] D. Papanicolaou, S. Ather, H. Zhu, et al., A phase IIA randomized, placebo-controlled clinical trial to study the efficacy and safety of the selective androgen receptor modulator (SARM), MK-0773 in female participants with sarcopenia, J. Nutr. Health Aging 17 (6) (2013) 533–543.

[50] M.F. Piepoli, V. Conraads, U. Corra, et al., Exercise training in heart failure: from theory to practice. A consensus document of the heart failure association and the European association for cardiovascular prevention and rehabilitation, Eur. J. Heart Fail. 13 (4) (2011) 347–357.

[51] N.A. Smart, M. Steele, The effect of physical training on systemic proinflammatory cytokine expression in heart failure patients: a systematic review, Congest. Heart Fail. 17 (3) (2011) 110–114.

[52] T.F. Cunha, A.V. Bacurau, J.B. Moreira, et al., Exercise training prevents oxidative stress and ubiquitin–proteasome system overactivity and reverse skeletal muscle atrophy in heart failure, PLoS One 7 (8) (2012).

[53] T.-C. Peng, W.-L. Chen, L.-W. Wu, et al., Sarcopenia and cognitive impairment: a systematic review and meta-analysis, Clin. Nutr. 39 (9) (2020) 2695–2701, https://doi.org/10.1016/j.clnu.2019.12.014.

[54] Y. Hu, W. Peng, R. Ren, et al., Sarcopenia and mild cognitive impairment among elderly adults: the first longitudinal evidence from CHARLS, J. Cachexia Sarcopenia Muscle 13 (6) (2022) 2944–2952.

[55] K. Harkness, G.A. Heckman, R.S. McKelvie, The older patient with heart failure: high risk for frailty and cognitive impairment, Expert Rev. Cardiovasc Ther. 10 (6) (2012) 779–795.