Original Article

The relationship between muscular atrophy/sarcopenia and cardiovascular diseases in the elderly: a bibliometrics study

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Background: As the aging population continues to increase worldwide, the prevalence of cardiovascular diseases and muscular dystrophy/sarcopenia in the elderly has escalated significantly. Cardiovascular diseases elevate the risk of muscular atrophy/sarcopenia, which results in increased disability and mortality of patients. This study analyzed the current available literature related to the relationship between cardiovascular diseases and muscular atrophy/sarcopenia in the aging population.

Methods: The Science Citation Index Expanded (SCI-E) database was searched for related literature published between 1900 and March 14, 2021. The subject search was performed using the search terms "muscular atrophy" and "sarcopenia". The search formula was "muscular atrophy OR sarcopenia". The search scope was limited to "cardiovascular diseases OR cardiac & cardiovascular systems". All search results and cited references were exported in plain text format and Citespace software was used to analyze the publications in terms of year of publication, country and institution, journal of publication, authors, and keywords.

Results: A total of 1,004 related research documents were obtained, with a citation frequency of 26,705 times. The top five countries for the highest number of published documents were the United States, Japan, Germany, South Korea, and Italy. The top five countries involved in research cooperation were the United States, Japan, the United Kingdom, Spain, and Germany, however, overall, there was little cooperation between countries, institutions, and authors. A number of researchers from Germany published the most documents. The author with the most cited publication was Cruz-Jentoft et al. from Spain, which deserves special attention. Professional journals of in the field of geriatrics play a significant role in this research topic. Analysis of the keywords showed that current researchers are mainly concerned with the associated risk of death.

Conclusions: The relationship between muscular atrophy/sarcopenia and cardiovascular diseases is currently a hot topic of research in geriatrics and cardiovascular disease, and further studies examining the mechanisms involved and potential prevention strategies are warranted.

Keywords: Muscular atrophy; sarcopenia; cardiovascular diseases; elderly; bibliometrics study

Introduction

Improvements in the standard of living and advancements in medicine have increasingly led to an aging society in many countries. According to China's seventh national census published on May 11, 2021, there are over 264.02 million people aged 60 years and over in China, accounting for 18.70% of whole population. Furthermore, the population of people aged 65 years and over is 190.64 million, accounting for 13.50% of the population. Compared with 2010, the proportion of the population aged 60 and over has increased by 5.44% (1). In the 27 European Union (EU) member states, the proportion of the population aged 65 years and over was about 20.3% in 2019 and is expected to reach 24.2% by 2030. The 2019 and projected 2030 figures are 18.5% and 21.5%, respectively, for the United Kingdom; 16.2% and 20.3%, respectively for the United States; 28.0% and 30.95%, respectively for Japan; and 15.1% and 24.7%, respectively for South Korea (2). Therefore, aging in the major countries is accelerating rapidly. In fact, many medical studies in recent years have changed the classification standard for the elderly from the previous 60 years to the current 65 years (3). Age is an independent risk factor for many diseases, especially cardiovascular disease. An increase in age elevates the risk of hypertension, coronary heart disease, myocardial infarction, heart failure, and death (4-7). Concurrently, the intake of nutrients by the elderly tends to decrease, often resulting in muscle atrophy (8-12). Sarcopenia is a clinical syndrome characterized by progressive and extensive decline in skeletal muscle mass and hypofunction (13). In October 2016, the U.S. Centers for Disease Control and Prevention established the ICD-10-CM code (M62.84) for sarcopenia. Sarcopenia is defined as a dysfunction caused by decreased skeletal muscle mass and strength in the elderly (8,14). Interestingly, cardiovascular disease is closely related to muscle wasting and muscle reduction (15), and both cardiovascular disease and muscle atrophy/ muscle reduction can seriously affect the quality of life of elderly patients and increase the risk of morbidity and mortality (16,17). Especially in patients with heart failure, the incidence of sarcopenia is high and these two conditions often deteriorate each other (18). For now, most scholars recommend enough nutrition and reasonable physical exercise are benefit for prevention of muscular atrophy/ sarcopenia (19). Bibliometrics provides a method to analyze the current literature in a certain field, thereby imparting an important reference point for researchers (20). This current study examined the general situation of research in the field of muscular atrophy/sarcopenia and cardiovascular diseases.

Methods

Data source

The Science Citation Index Expanded (SCI-E) database is the core data set in the Web of Science. It includes the titles of papers published by important journals in the field of natural sciences and their cited information. SCI-E is an important tool for bibliometrics and scientific research evaluation. This research used SCI-E as the data source to search relevant literature. The target publication time of the literature was not limited, and thus, included literature published from 1900 to the time of this study, that is, March 14, 2021.

Strategy of the literature search

In this study, the subject search was used. The search terms were "muscular atrophy" and "sarcopenia", and the search formula was "muscular atrophy OR sarcopenia". The search scope was limited to "cardiovascular diseases OR cardiac & cardiovascular systems".

Analysis

Records of all the search results and cited references were exported in plain text format and Citespace software was used to analysis the year of publication, the country and institution of publication, the journal of publication, the authors, and the use of keywords. The results reflect the current research status of the relationship between muscle reduction, muscle atrophy, and cardiovascular disease in the field of geriatrics.

Statistical analysis

This research is a descriptive study. The ratio (percentage) of each indicator reflects the distribution and changing trends of different years, countries, institutions, journals, and authors without statistical comparison. Conference abstracts, conference documents, and duplicate revision documents were excluded.

Results

General information

A total of 1,040 articles were obtained from the database

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Table 1 An analysis of the document types in the literature

Literature type	Records	Percentage (%)
Article	668	66.5
Review	215	21.4
Meeting Abstract	70	7.0
Editorial Material	29	2.9
Letter	21	2.1
Proceedings Paper	20	2.0
Book Chapter	8	0.8
Early Access	8	0.8
Correction	1	0.1

Table 2 The distribution of literature according to publication year

Publication year	Records	Percentage (%)
2021	23	2.3
2020	205	20.4
2019	163	16.2
2018	127	12.6
2017	97	9.7
2016	77	7.7
2015	60	6.0
2014	45	4.5
2013	41	4.1
2012	28	2.8
2011	21	2.1
2010	20	2.0
2009	10	1.0
2008	20	1.0
2007	15	1.5
2006	9	0.9
2005	4	0.4
2004	6	0.6
2003	4	0.4
2002	2	0.2
2001	4	0.4
2000	3	0.3
1999	4	0.4
1998	4	0.4
1997	3	0.3
1996	1	0.1
1995	3	0.3
1994	1	0.1
1993	1	0.1
1991	3	0.3

search, including 668 original articles, 215 review articles, 70 meeting abstracts, 29 editorial materials, 21 letters, 20 proceeding articles, 8 books, 8 articles of early access and 1 correction. There was 1 correction publication and 36 duplicate literature. After exclusions, a total of 1,004 articles were included in this investigation (*Table 1*). Analysis of the number of documents published each year revealed an accelerated growth trend, especially after 2009 (*Table 2, Figure 1*). These papers were cited 28,142 times in total, with an h-index of 83, and the average number of citations per literature was 28.0 (*Figure 2*).

Distribution of countries and institutions

The results showed that the top 5 countries with the greatest number of publications were the United States, Japan, Germany, South Korea, and Italy. The top 5 countries in terms of research cooperation were the United States, Japan, the United Kingdom, Spain, and Germany (*Tables 3,4*). The following institutions published more than 20 articles: the Charité-Universitätsmedizin Berlin, University Medical Center Göttingen, and Yonsei University. The 4 institutions with the highest centrality scores (which implies increased cooperation) were Charité-Universitätsmedizin Berlin, Duke University, National Institute on Aging (NIA) and Columbia University (*Tables 5,6*). The CiteSpace V software was used to generate the visualization atlas of the countries (*Figure 3*) and institutions of publication (*Figure 4*). The main countries researching this field were all developed countries with an obvious aging population, especially the United States and Japan. Although there was some cooperation between institutions, it can be

seen that the nodes are relatively scattered.

Author analysis

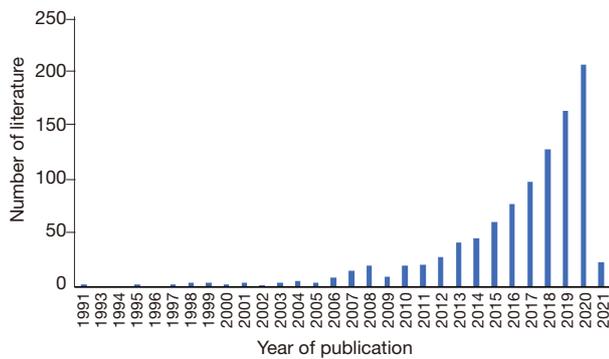At the time of this study, the authors with more than 10 publications included Von Haehling S, Anker SD,
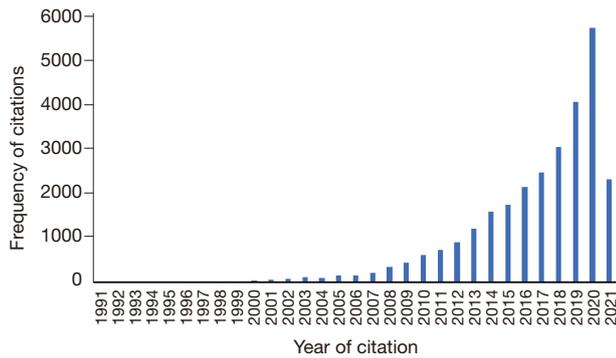
Figure 1 Number of publications per year.

Figure 2 Number of citations per year.

Table 3 The top 10 countries in terms of the number of publications in this field

Rank	Countries	Frequency
1	USA	243
2	Japan	172
3	Germany	106
4	South Korea	91
5	Italy	85
6	China	62
7	Canada	59
8	England	50
9	Brazil	49
10	Spain	38

Table 4 The top 10 countries for centrality

Rank	Countries	Centrality
1	USA	0.53
2	Japan	0.25
3	England	0.19
4	Spain	0.17
5	Germany	0.15
6	Italy	0.12
7	Brazil	0.12
8	Canada	0.10
9	Australia	0.08
10	China	0.06

Table 5 The top 10 institutions in terms of the number of publications

Rank	Institutions	Frequency
1	Charite Univ Med Berlin	33
2	Univ Med Ctr Gottingen	21
3	Yonsei Univ	21
4	Univ Sao Paulo	15
5	Sungkyunkwan Univ	12
6	National Institute on Aging	11
7	Kitasato Univ Hosp	10
8	Johns Hopkins Univ	10
9	Univ Melbourne	9
10	DZHK German Ctr Cardiovasc Res	9

Table 6 The top 10 institutions by centrality

Rank	Institutions	Centrality
1	Charite Univ Med Berlin	0.08
2	Duke Univ	0.08
3	National Institute on Aging	0.07
4	Columbia Univ	0.07
5	Korea Univ	0.06
6	Univ Pittsburgh	0.06
7	Kyung Hee Univ	0.06
8	McGill Univ	0.05
9	Sungkyunkwan Univ	0.04
10	Inje Univ	0.04

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Figure 3 A visual map of cooperation between countries.

Figure 4 A visual map of the cooperation relationship between institutions.

Table 7 The top 10 authors by number of publications

Rank	Authors	Frequency
1	Von Haehling S	30
2	Anker SD	25
3	Springer J	15
4	Doehner W	13
5	Matsunaga A	9
6	Nozaki K	8
7	Ako J	8
8	Hamazaki N	8
9	Maekawa E	8
10	Matsuzawa R	8

Springer J, and Doehner W. In fact, these four authors are all from Germany, and with the exception of Doehner W who is from Charité-Campus Virchow, all others are from the University Medical Centre Göttingen. A similar distribution of institutions was observed. In this study, no

author centrality score reached 0.01, indicating that there was relatively little collaboration between authors from different institutions (*Table 7*, *Figure 5*). There were 6 authors who have been cited more than 100 times, including Cruz-Jentoft AJ, Baumgartner RN, Janssen I, Morley JE, Fried LP, and Chen LK (*Table 8*). Further analysis showed that in this field, Professor Cruz-Jentoft AJ often published important papers in top journals with an extremely high frequency of citations. Professor Baumgartner RN's basic research mainly focused on the body composition of the human being within the field of muscular atrophy and sarcopenia, and is also often cited. The top 3 authors by centrality were Baumgartner RN, Anker SD, and Morley JE (*Table 9*, *Figure 6*).

Journal distribution

The 1,004 documents retrieved from this database search covered 426 journals, all of which are widely distributed. Among them, there were 17 journals with more than 10 articles (*Table 10*). These journals published 264 articles in this field, accounting for 26.3% of the total number


Figure 5 A visual map of the collaboration between authors. The grid at bottom represents authors with fewer collaboration compared with authors above (the software didn't show the authors' name automatically).

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Table 8 The top 10 most cited authors by frequency of citations

Rank	Authors	Frequency
1	Cruz-Jentoft AJ	303
2	Baumgartner RN	153
3	Janssen I	149
4	Morley JE	146
5	Fried LP	116
6	Chen LK	106
7	Newman AB	99
8	Visser M	93
9	Von Haehling S	93
10	Cesari M	92

Table 9 The top 10 cited authors by centrality

Rank	Authors	Centrality
1	Baumgartner RN	0.11
2	Anker SD	0.10
3	Morley JE	0.09
4	Busquets S	0.08
5	Visser M	0.08
6	Bhasin S	0.07
7	Aubertin-Leheudre M	0.05
8	Blair SN	0.05
9	Coats AJS	0.05
10	Adams V	0.04
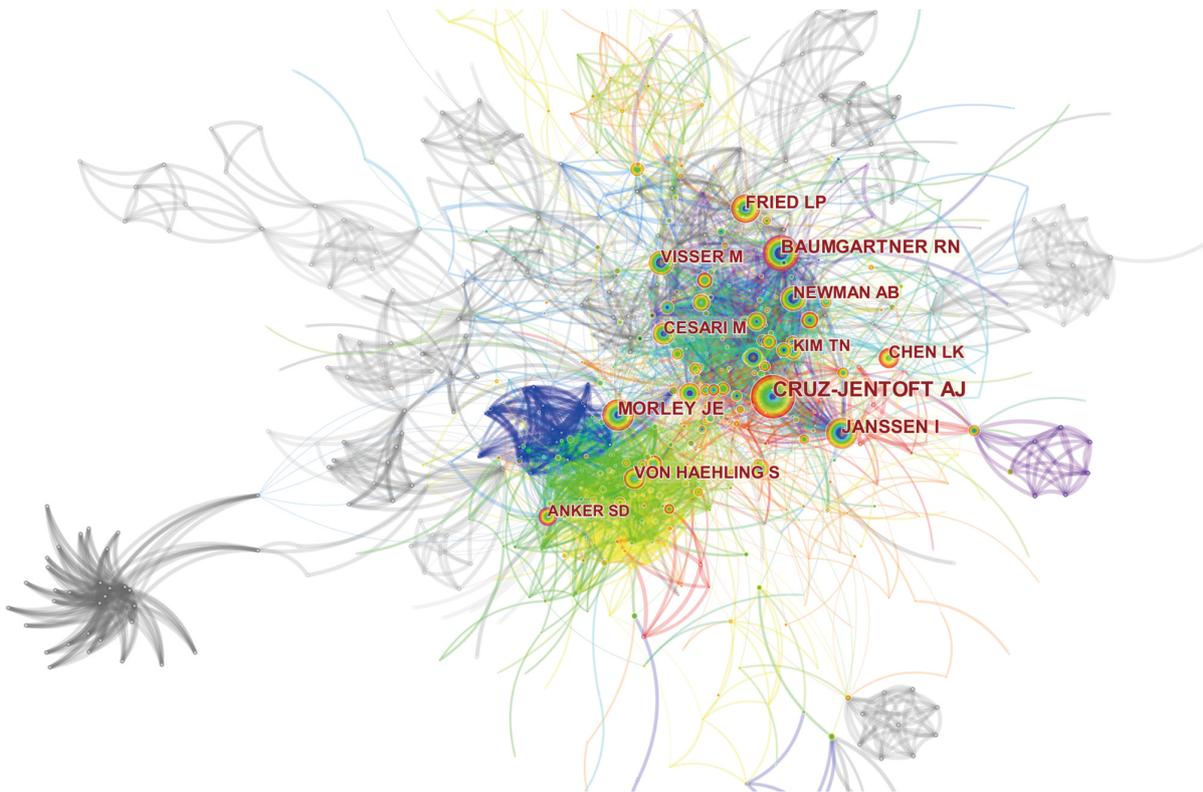
Figure 6 A visual map of co-cited authors.

of documents (*Table 10*). The top 6 journals with the greatest number of published papers in this field were all cardiovascular journals (*Table 10*). However, the top 5 journals with the highest citation frequency only included one cardiovascular journal, and the others were geriatric journals and related professional journals (*Table 11*). The top 3 journals with the highest centrality scores were *American Journal of Medicine*, *American Journal of Pathology*, and *Circulation* (*Table 12*). A comparison of the number of citations (*Table 11*) and the number of articles (*Table 10*), revealed that the top 10 journals according to the number of citations, with the exception of Circulation, had fewer

Table 10 The top 17 journals by number of publications in this field

Rank	Journals	Records	Percentage (%)
1	International Journal of Cardiology	30	3.0
2	Circulation	25	2.5
3	Esc Heart Failure	24	2.4
4	European Heart Journal	18	1.8
5	Annals of Thoracic Surgery	17	1.7
6	Journal of The American College of Cardiology	17	1.7
7	Journal of Nutrition Health Aging	15	1.5
8	Journal of Heart and Lung Transplantation	14	1.4
9	PLoS One	14	1.4
10	Nutrients	13	1.3
11	American Journal of Cardiology	12	1.2
12	J Gerontol A-Biol	12	1.2
13	Journal of Cardiology	11	1.1
14	Nutrition Metabolism and Cardiovascular Diseases	11	1.1
15	Scientific Reports	11	1.1
16	Experimental Gerontology	10	1.0
17	Journal of The American Medical Directors Association	10	1.0

Table 11 The top 10 journals by citation frequency

| Rank	Journals	Frequency
1	Journals of Gerontology Series A: Biological Sciences And Medical Sciences	437
2	Age Ageing	396
3	Circulation	391
4	Journal of American Geriatric Society	388
5	Am J Clinical Nutrition	357
6	PLoS One	347
7	New England Journal of Medicine	333
8	Lancet	333
9	Journal of The American College of Cardiology	301
10	J Applied I Physiology	297

published articles. This suggested that the average number of citations of these journals was high (for example, the 12 articles in J Gerontol A-Biol had a citation frequency of 437 times, with an average of 36.4 times per article), and thus, its academic value may be higher.

Keywords reflect the research hotspots and frontiers in this field

CiteSpace V software was used to generate a keyword co-occurrence map (*Figure 7*). The keyword statistical analysis results showed that the top 5 commonly used keywords

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Table 12 The top 10 journals by centrality

Rank	Journals	Centrality
1	American Journal of Medicine	0.11
2	American Journal of Pathology	0.08
3	Circulation	0.07
4	American Journal of Cardiology	0.06
5	American Journal of Physiology-Endocrinology and Metabolism	0.05
6	Archive of Internal Medicine	0.05
7	Annals of The New York Academy of Sciences	0.05
8	Journal of Biological Chemistry	0.05
9	American Heart Journal	0.05
10	Age Ageing	0.04
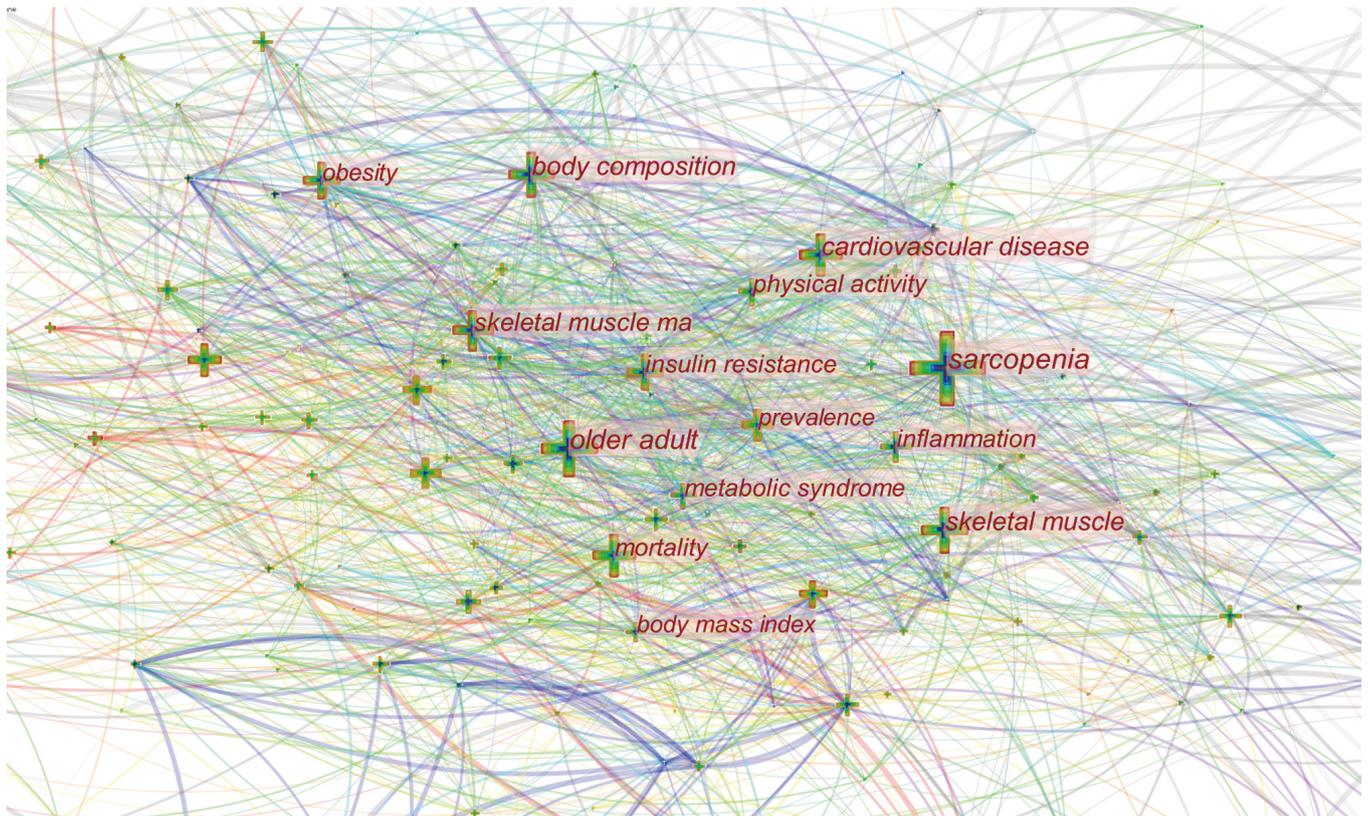
Figure 7 Keyword co-occurrence map.

Table 13 The top 10 most frequently used keywords

Rank	Keywords	Frequency
1	Sarcopenia	550
2	Older adult	262
3	Cardiovascular disease	202
4	Skeletal muscle	196
5	Mortality	186
6	Body composition	165
7	Obesity	131
8	Skeletal muscle ma	130
9	Frailty	118
10	Risk	107

Table 14 The top 10 keywords for centrality

Rank	Keywords	Centrality
1	Sarcopenia	0.19
2	Older adult	0.15
3	Skeletal muscle	0.14
4	Body composition	0.13
5	Cardiovascular disease	0.11
6	Disability	0.10
7	Chronic heart failure	0.07
8	Spinal muscular atrophy	0.07
9	Acute myocardial infarction	0.07
10	Skeletal muscle ma	0.06

were sarcopenia, older adult, cardiovascular disease, skeletal muscle, and mortality. The centrality ranking results were similar (see *Tables 13* and *14* for details). CiteSpace was then used to perform burst detection on high-frequency keywords, and the results are shown in *Figure 8*.

Discussion

The SCI-E database was searched to obtain relevant literature on muscular atrophy/sarcopenia and cardiovascular diseases. This study revealed that the number of publications in this field has been escalating in recent years, showing that the medical community is increasingly concerned about related issues. Analysis of the sources of

the literature revealed that the countries that conducted the most research in this field were mainly developed countries in Europe, the United States, and Japan and South Korea in Asia. The main research institutions were also from these countries, but the cooperation between institutions and countries was relatively limited. The analysis of collaboration was based on few guidelines and consensus (8,21,22). A number of researchers from Germany have published a significant number of documents. Cruz-Jentoft AJ from Spain was the most cited author and is an important researcher in this field. Many articles have been published in top journals and are worthy of attention (23), in particular, journals in the field of geriatrics. The keyword analysis results showed that a main concern of current researchers is the associated risk of death.

Considering the population growth trend of numerous countries in recent years, the accelerated increase in the number of publications after 2009 is likely to be closely related to the aging society of countries worldwide, especially Japan, South Korea, and several developed countries in Europe and America. As the life expectancy of the elderly is gradually prolonged, the prevalence of various chronic diseases is also expected to gradually increase, especially cardiovascular disease, which is currently the leading cause of death in developed countries (24). Despite improvements in living conditions and medical advances, there are still many elderly people who suffer from muscle atrophy and muscle loss due to various reasons (25,26). These factors have led to a large number of elderly people presenting with both muscular atrophy/sarcopenia and cardiovascular diseases. Insufficient blood supply to the heart or decreased heart function, coupled with atrophy/decrease of muscle tissue, leads to a significant decline in the quality of life of these elderly people, and at the same time increases the risk of falling (13,27,28). In the past, we often use "frailty", "muscular atrophy" to describe the status of old people with sarcopenia. Until 2016, ICD-10-CM give sarcopenia a code of M62.84 and a clear definition (29). Compared with old people, young patients with sarcopenia are often on dialysis or have comorbid disease, such as cancer, tuberculosis and inflammatory bowel disease (30-32). Sarcopenia can also inflict significant burden in terms of medical expenses (33). Therefore, relevant research into the prevention and treatment of muscular atrophy/sarcopenia complicated with cardiovascular diseases is warranted, so as to improve the quality of life of elderly patients and reduce the risk of disability and mortality. Besides cardiovascular diseases, other diseases, including chronic obstructive
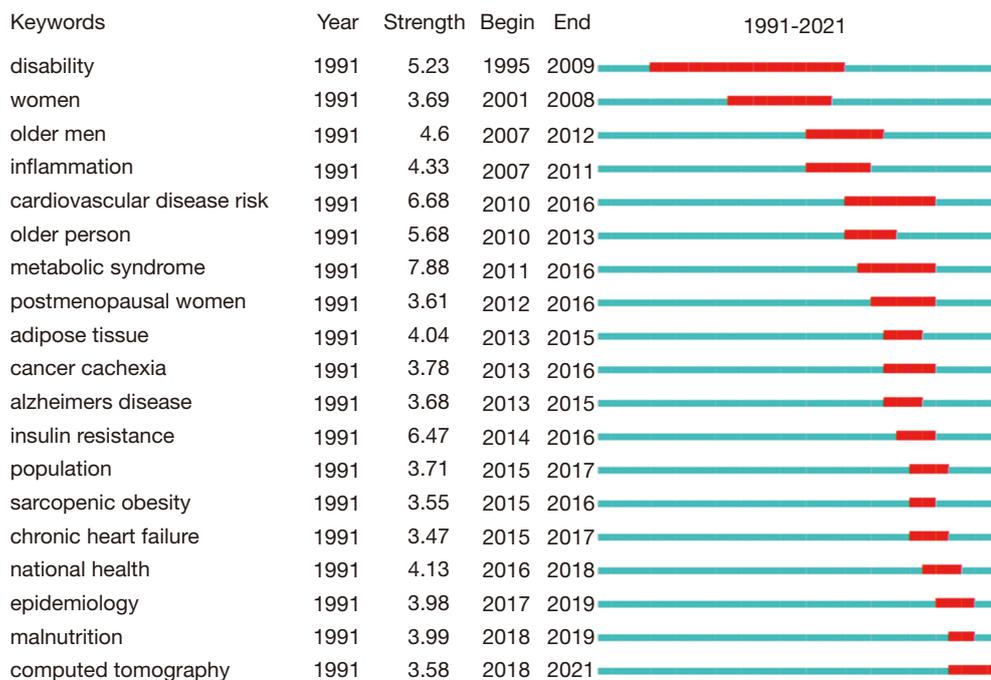
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Keywords	Year	Strength	Begin	End	1991-2021
disability	1991	5.23	1995	2009	
women	1991	3.69	2001	2008	
older men	1991	4.6	2007	2012	
inflammation	1991	4.33	2007	2011	
cardiovascular disease risk	1991	6.68	2010	2016	
older person	1991	5.68	2010	2013	
metabolic syndrome	1991	7.88	2011	2016	
postmenopausal women	1991	3.61	2012	2016	
adipose tissue	1991	4.04	2013	2015	
cancer cachexia	1991	3.78	2013	2016	
alzheimers disease	1991	3.68	2013	2015	
insulin resistance	1991	6.47	2014	2016	
population	1991	3.71	2015	2017	
sarcopenic obesity	1991	3.55	2015	2016	
chronic heart failure	1991	3.47	2015	2017	
national health	1991	4.13	2016	2018	
epidemiology	1991	3.98	2017	2019	
malnutrition	1991	3.99	2018	2019	
computed tomography	1991	3.58	2018	2021	

Figure 8 The top 19 keywords with the strongest citation bursts.

pulmonary diseases, cancers and renal diseases are all often seen with sarcopenia in the elderly (23).

Our analysis revealed that there is little cooperation between researchers in this field, and this may be related to the different living habits and causes of aging in various countries and regions. Indeed, the diet and living habits of the European Mediterranean countries, the United States, Japan, and South Korea are vastly different (34). Second, in an aging country, the elderly forms a large proportion of the population and thus, it is relatively easy to meet the sample size requirements of research without having to collaborate with other research groups. In addition, the welfare benefits and medical insurance systems for the elderly in different countries vary greatly (35). Especially in developing or poor countries, muscular atrophy/sarcopenia is very common in the elderly (26). Unfortunately, few studies in this field have examined the mechanisms involved and potential treatments. Investigating the relationship between sarcopenia and cardiovascular diseases in elderly patients is vital and should involve inter-institutional and inter-country cooperation.

To date, research into the relationship between muscular atrophy/sarcopenia and cardiovascular diseases has revealed several key findings. First, patients with sarcopenia obesity have an increased incidence of cardiovascular

disease and mortality, especially heart failure (36). Experts have come to a consensus that sarcopenia is significantly prevalent in patients with heart failure, resulting in its poor prognosis (37). Second, skeletal muscle reduction is an important factor in the occurrence of sarcopenia in patients with cardiovascular disease (38). Third, in patients with sarcopenia, the main mechanisms of heart failure include the ubiquitin-protease system, autophagy, apoptosis, inflammation, and oxidative stress (37). For patients with muscular atrophy/sarcopenia, the main form of treatment is reasonable nutritional support. For patients with cardiovascular diseases, exercise rehabilitation is the treatment of choice for the prevention and treatment of sarcopenia. Unfortunately, to date, there has been little medical breakthrough in terms of treatment regimens (37,39).

Therefore, it is recommended that future related studies further explore the mechanisms, sports rehabilitation, drug treatment options, and other early preventive measures in elderly patients with atrophy/sarcopenia and cardiovascular disease.

There were some limitations to this study. First, the concept of muscular atrophy/sarcopenia has undergone some changes and this may have caused the omission of some early literature. However, the inclusion of the

publication by Baumgartner *et al.* in our search results suggested that important early documents were not omitted. Second, some basic research articles may not have been classified as cardiovascular disease-related literature and may have been omitted. Future research should include in-depth analysis of the citations listed in the related documents to supplement the search results.

Acknowledgments

Footnote

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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