



## Review article

## Landscape and research trends of sarcopenic obesity research: A bibliometric analysis

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## ABSTRACT

**Background:** Sarcopenic obesity (SO) is a condition characterized by the coexistence of sarcopenia (loss of muscle mass and function) and obesity. This condition has emerged as a public health concern, particularly with the aging population. Despite an approximately 30-year history of SO research, detailed quantitative analysis of existing research was never undertaken. We aimed to depict the landscape of SO research using bibliometric analysis of literature.

**Methods:** We searched the Web of Science Core Collection on January 15, 2023. The following bibliometric indicators were included: publication trend, the most influential country, the most active discipline, productive institutions, productive journals, prolific and highly cited authors, and highly cited publications. We constructed co-authorship network to explore individual-level, institutional-level, and international-level collaborative patterns in the VOSviewer or Sci2 software. Furthermore, keywords co-occurrence network was extracted by the VOSviewer software, and the burst-detection analysis of keywords was performed using the CiteSpace software.

**Results:** A total of 2023 original articles were retrieved for data analysis. The publications increased dramatically in the last decade. The United States had the highest number of publications on SO (n = 904). The Seoul National University Hospital was the most prolific institution (n = 54) among the 2675 institutions analyzed. As for journals, *Clinical Nutrition* had the highest number of publications on SO (n = 75). Kim JH was the most prolific author (n = 25), while Cederholm T authored the most cited publication (9381 citations). More than 80 disciplines were involved in SO research, of which, "Geriatrics and Gerontology" was the most activated discipline. The European Working Group on Sarcopenia in Older People (EWGSOP) consensus was the most cited publication (7209 citations). Moreover, the hotspots of SO have been shifting from its biology, prevalence, and risk factors to its outcomes, prognostic factors, complications, and quality of life. Its relationships also evolved from being between SO and aging to being between SO and other diseases.

**Conclusions:** Our study provided a comprehensive landscape of SO research, which may help researchers better identify key information and research trends in this field.

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### 1. Introduction

As early as 1996, Heber et al. [1] coined the term “sarcopenic obesity (SO)” to describe obese patients with reduced lean body mass measured by bioelectrical impedance analysis. In 2000, Baumgartner et al. [2] first proposed the concept of SO characterized by the simultaneous presence of both sarcopenia (loss of muscle mass and muscle function) and obesity. With the acceleration of aging and the change of lifestyle (such as sedentary and lack of regular exercise), SO is increasingly prevalent and has become an important global public health problem [3].

The reported prevalence of SO varies from 0.1 % to 48.0 %, according to different study population, definitions, and cut-off values [4]. It was estimated that up to 30.0 % of older adults may be affected by this condition [5], increasing risk of adverse health-related outcomes. Hirani et al. [6] found that men with SO had an increased risk of frailty (OR = 2.00, 95%CI = 1.42–2.82), activities of daily living disability (OR = 1.58, 95%CI = 1.12–2.24), and instrumental activities of daily living disability (OR = 1.36, 95%CI = 1.05–1.76). Studies have shown that SO individuals had a 55.0 % increase in mortality risk compared with non-sarcopenic, non-obese individuals over a follow-up period of 6 years [7], negatively impacting the quality of life of older adults [8].

Furthermore, in recent years, the relationship between SO and diseases has gained increasing attention from researchers across a range of disciplines. Yin et al. [9] found that the occurrence of SO was related to hypertension, diabetes, and abnormal lipid metabolism. It was reported that individuals with SO had a higher risk of knee osteoarthritis (OR = 2.705, 95%CI = 1.079–6.779), compared to individuals with nonsarcopenic nonobese, sarcopenic only, and obese only [10]. Another retrospective analysis indicated that nonalcoholic steatohepatitis was associated with 6-fold increased risk of suffering SO in patients with cirrhosis undergoing liver transplant [11]. Recently, SO was recognized as a novel prognostic factor for mortality in several cancer types [12–14]. Given the close

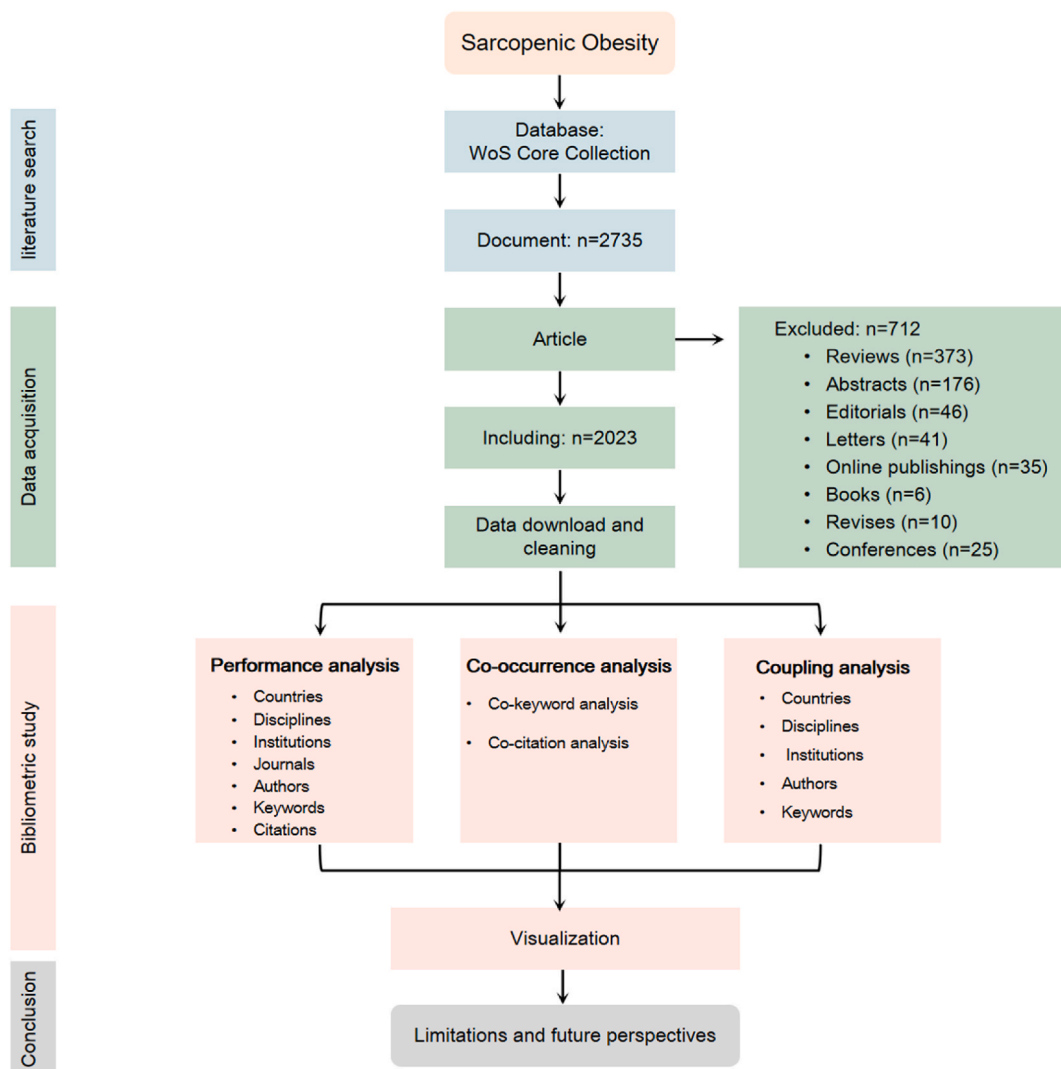


Fig. 1. The flow chart of this study.

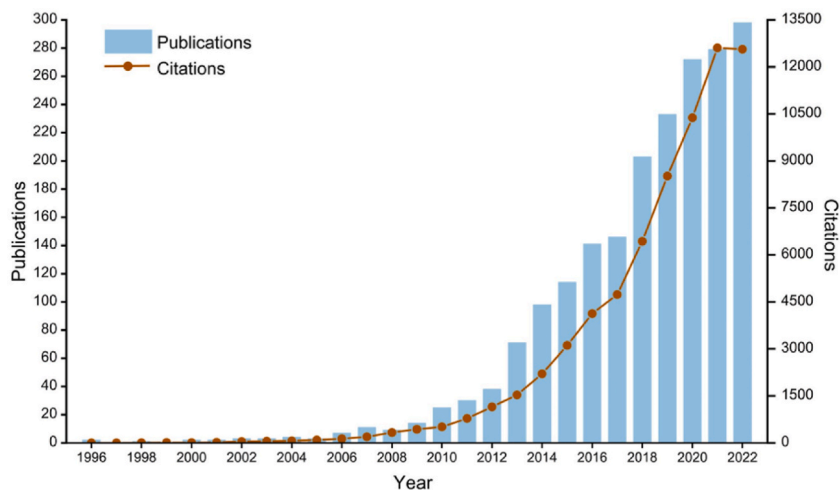


Fig. 2. Number of annual publications/citations in the sarcopenic obesity field.

relationship between SO and diseases, the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) recently proposed to stratify SO into two stages, according to the presence of complications (e. g., metabolic diseases, functional impairment, cardiovascular diseases, and respiratory diseases [15].

Intervention strategies of SO have either nutritional, or exercise, or a combination of the both. Camajani et al. [16] reported that calorie restriction, protein supplementation, combined with L-leucine maintained muscle mass and improve muscle strength in post-menopausal women with SO. A meta-analysis showed that aerobic exercise and resistance exercise could reduce fat mass, meanwhile resistance exercise had the benefit of improving grip strength [17]. Although there have been numbers of clinical trials, evidence about ideal pharmacotherapy for SO is limited.

However, Despite the three decades of research on SO, a comprehensive quantitative analysis of the existing literature has not yet been conducted to provide a research map of evidence on this topic. Bibliometrics is "a set of methods to quantitatively analyze scientific and technological literature using bibliographic data" [18]. With bibliometric analysis, different aspects of literature, such as researchers, publications, journals, institutions, and countries, can be used to shape "the contemporary landscape of science" [19]. A bibliometric analysis of literature is also able to provide insight into areas where the evidence is robust and to identify areas where publication deficits exist.

To provide an overview of the research landscape on SO, we conducted a bibliometric analysis of the existing literature. We aimed to identify key information, hotspots, and future research trends in this field, which could help researchers, both novice and experienced, to design their future work.

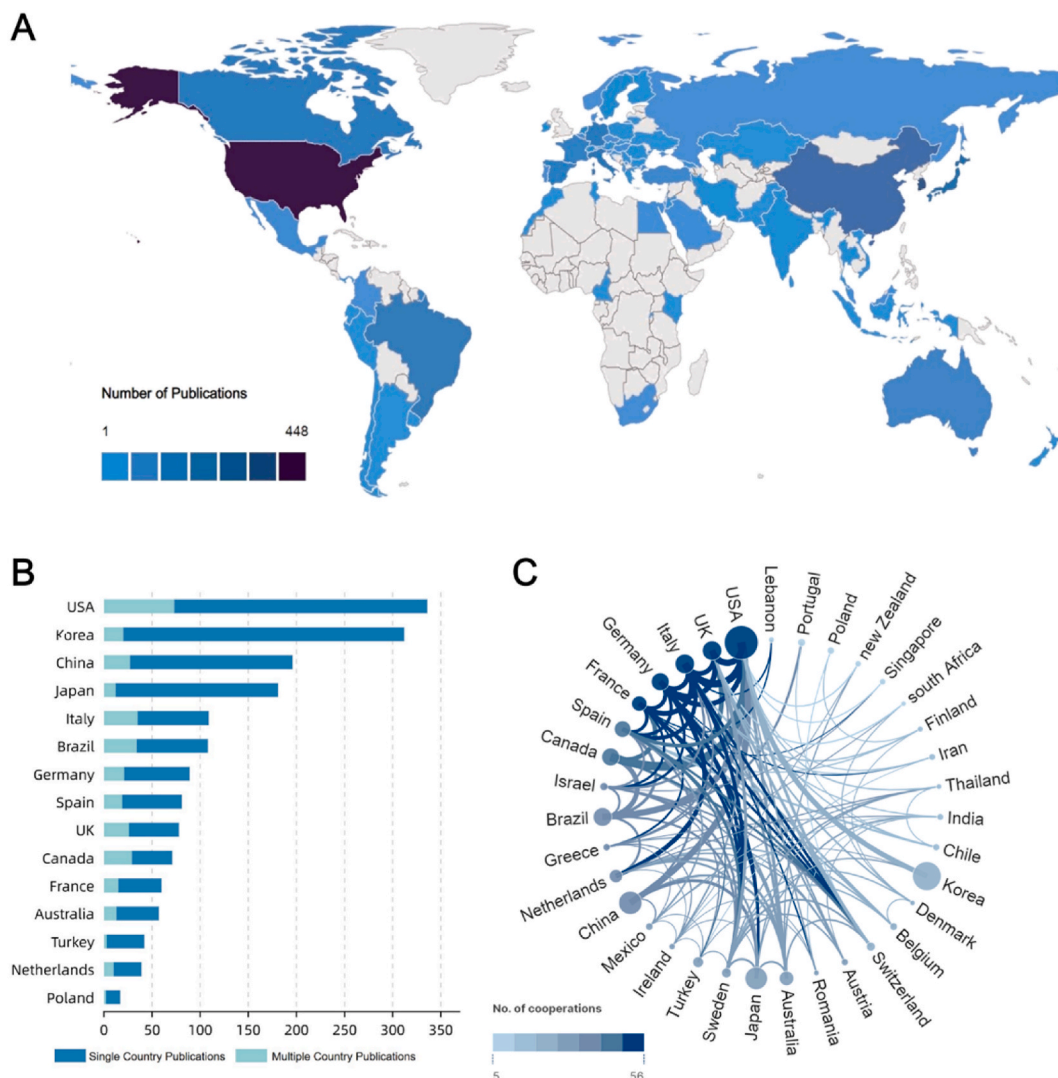
## 2. Materials & methods

### 2.1. Data source and search strategy

We searched the Web of Science (WoS) Core Collection (WoSCC) using the terms 'sarcopenic obesity' OR 'obese sarcopenia' as the keywords in the "Topic" field on January 15, 2023. Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (AHCI), Conference Proceedings Citation Index-Science (CPCI-S), Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH), Emerging sources Citation Index (ESCI), Current Chemical Reactions (CCR-EXPANDED), and Index Chemicus (IC) were all included. Using the search strategy, all publications containing terms derived from 'sarcopenic obesity' OR 'obese sarcopenia' in the title, abstract, keywords, and keywords plus were extracted from the WoSCC database. It is worth mentioning that we did not restrict language in our search. The search results were limited to records from 1996 to 2023 as the term was first coined in 1996. To collect more comprehensive literature, we did not restrict the discipline, and thus, all disciplines involved in SO were included. We excluded reviews, meeting abstracts, editorials, letters, case reports, reference materials, patents, corrections, and books. The search results were downloaded and saved as plain text files for the subsequent data analysis. Fig. 1 presented the literature search, selection, and analysis process. Ethical approval was not needed for this bibliometric study.

### 2.2. Bibliometric analysis

We used Microsoft Excel version 2019 (Microsoft Corporation, Redmond, WA, USA), R software version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria), VOSviewer (Leiden University, Leiden, Netherlands) [20], SCIENCE of SCIENCE (Sci2, Bloomington, IN) [21], and CiteSpace version 5.7 (Drexel University, Philadelphia, PA, USA) [22] to process, analyze, and visualize the data. Since a particular author or institution or keyword could be presented with different names, we manually screened and merged



**Fig. 3.** (A) Geomap visualization of publications on sarcopenic obesity by countries. (B) Number of single/multiple country publications of the top 15 countries. (C) International collaboration network between the top 35 countries with at least 10 publications on sarcopenic obesity. The size of each node represents the number of publications in the country. The bigger the node, the more the number of publications the country has contributed. The color and thickness of the links between the nodes indicates the size of the collaboration between every two countries. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

the same information before formal analysis. Then, we extracted collaboration networks, co-occurrence networks, and co-citation networks. In the networks, the size of nodes was determined by the number of publications, the frequency of keywords, or the number of citations, while the thickness of the lines indicated the strength of the co-authorship, co-occurrence, or co-citation. The co-authorship analysis of countries, institutions, authors, and disciplines was used to help uncover the core contributors to this field. The co-occurrence analysis and burst-detection analysis of keywords were performed to reveal the hotspots and research trends in SO research.

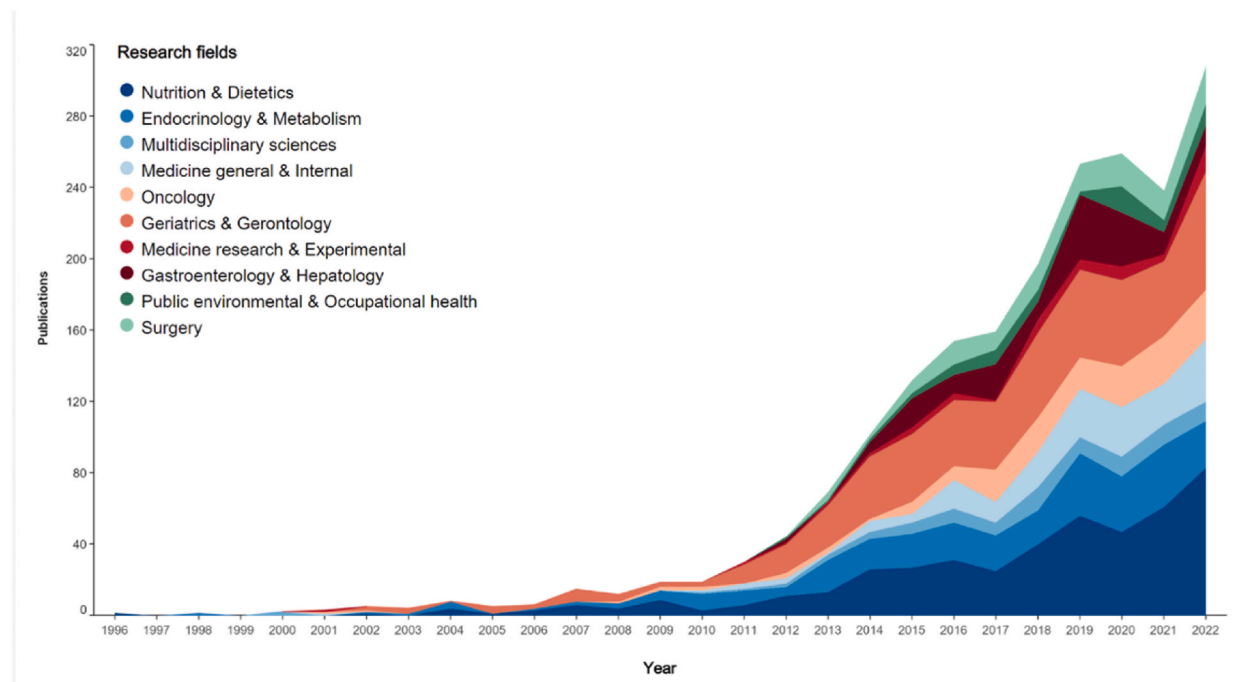
### 3. Results

#### 3.1. General information

We initially retrieved 2735 records, of which, 2023 original articles were included for the following analysis. The bibliometric analysis of these publications showed that the number of annual publications increased dramatically after 2009, from 14 to the highest number of 298 in 2022 (Fig. 2). These publications were cited 70,497 times in total, with the mean citation per publication being 34.85.

**Table 1**  
The top 10 countries ranked by the number of publications on sarcopenic obesity.

| Rank | Country | Number of Publications | Number of Citations | H-index |
|------|---------|------------------------|---------------------|---------|
| 1    | USA     | 447                    | 23892               | 76      |
| 2    | Korea   | 322                    | 7504                | 44      |
| 3    | China   | 211                    | 4150                | 31      |
| 4    | Japan   | 197                    | 5148                | 36      |
| 5    | Italy   | 146                    | 13041               | 36      |
| 6    | UK      | 145                    | 14071               | 40      |
| 7    | Brazil  | 135                    | 3187                | 26      |
| 8    | Germany | 123                    | 11544               | 32      |
| 9    | Canada  | 122                    | 11170               | 41      |
| 10   | Spain   | 105                    | 9603                | 23      |



**Fig. 4.** Trend in growth of the top 10 disciplines in sarcopenic obesity research.

### 3.2. Country contributions and international collaborations

A total of 68 countries contributed to the SO publications. The density map of publications on SO for each country is shown in Fig. 3A. The darker the blue, the more publications the country published. Among the analyzed countries, the United States had the highest number of publications with a total of 447 publications. Korea and China followed with 322 and 211 publications, respectively.

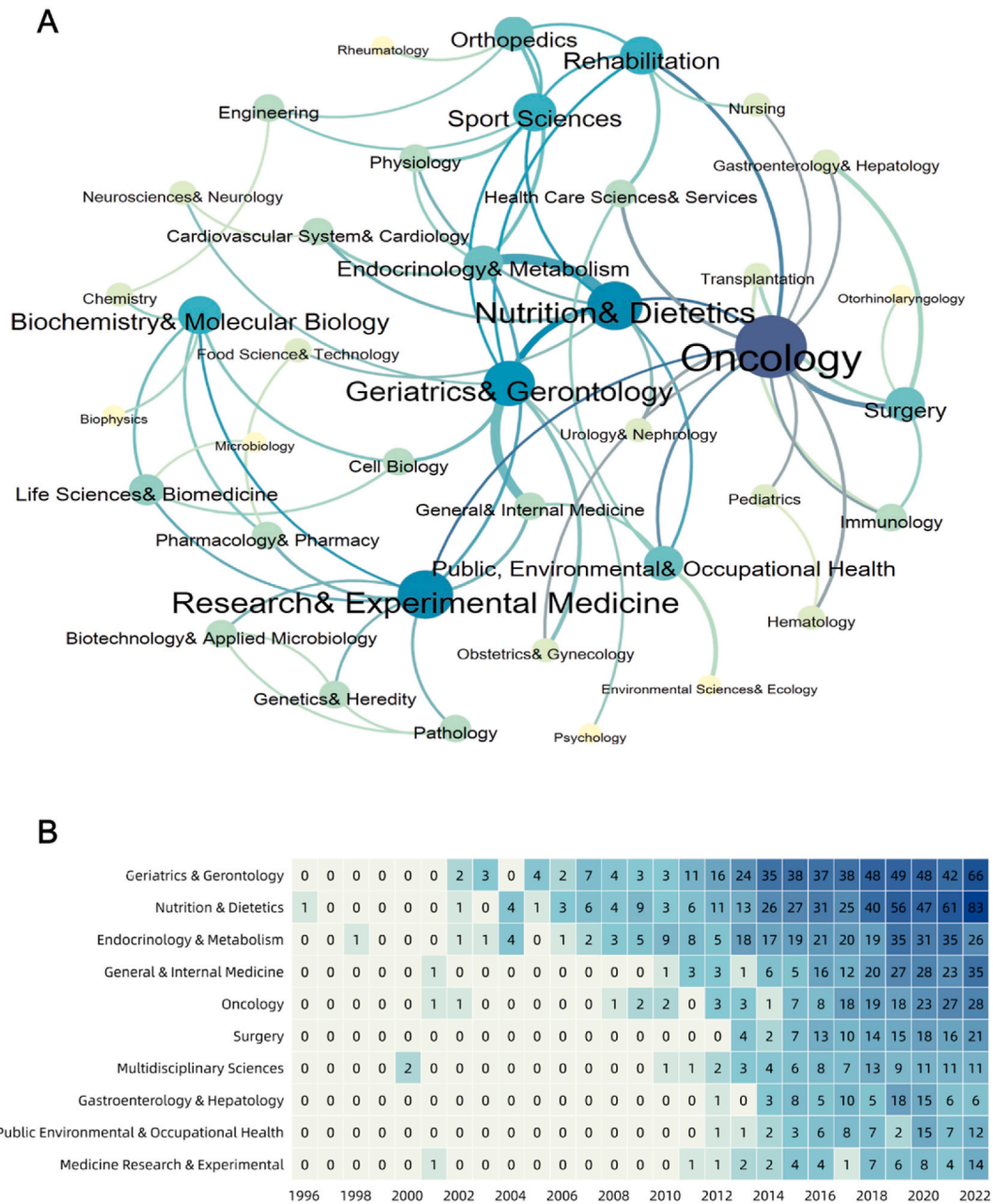
According to the total number of citations, the United States was the most influential country with 23,892 citations. The United Kingdom was ranked second with 14,071 citations, followed by Italy in third place with 13,041 citations (Table 1).

We conducted a co-authorship analysis of countries to explore international collaborations in this field. As shown in Fig. 3B and C, the United States had the highest number of multiple-country publications, and worked closely with countries such as the UK, Italy, and Germany, whereas China and Korea less frequently collaborated with other countries.

### 3.3. Discipline contributions and collaborations

Fig. 4 shows the unequal growth trends across the top 10 disciplines in SO research. Some disciplines, such as “Nutrition and Dietetics” and “Geriatrics and Gerontology”, emerged in the field of SO research as early as 1996 to 2002, and increased significantly thereafter, especially after 2012. “Medicine General and Internal”, and “Oncology” also emerged in the 2000s, but began to grow dramatically in the last five years. Other disciplines, such as “Public environmental and Occupational health” and “Medicine research and Experimental” failed to grow significantly throughout the entire period.

Fig. 5A shows the collaborative network of different disciplines involved in SO research. In addition to “Geriatrics and

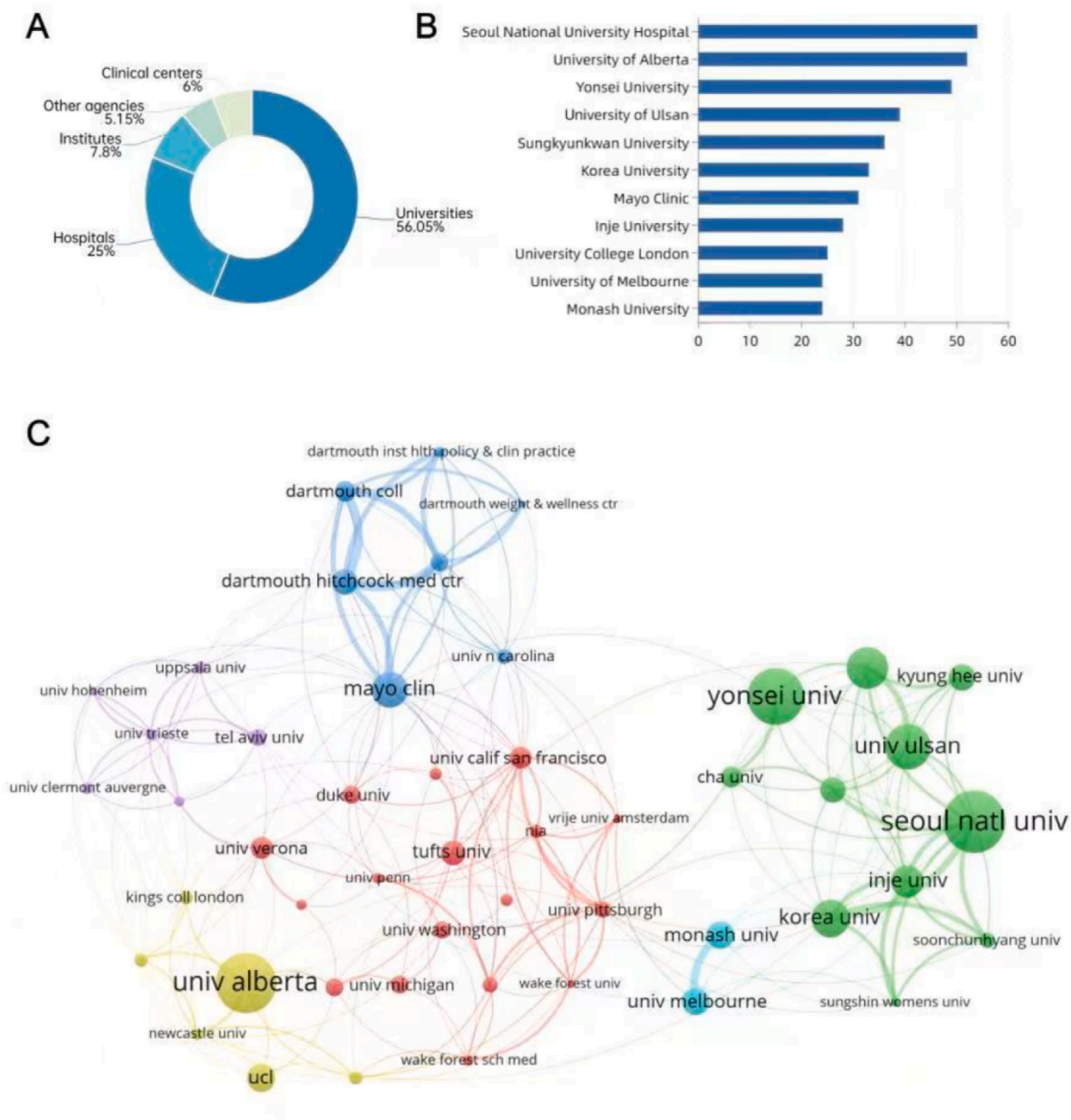


**Fig. 5.** (A) Citation network of disciplines involved in sarcopenic obesity research. Each node represents a research field determined in the Web of Science database. The size of each node represents the number of publications. The bigger the node, the more the number of publications in the research field. The link between the nodes represents the citation relationship. The thicker the link, the more the citation instances existing between the nodes. (B) Heat map showing the number of publications of the top 10 disciplines over time.

Gerontology”, more than 80 other disciplines, including “Oncology”, “Nutrition and Dietetics”, “Endocrinology and Metabolism”, and “Surgery”, were included in this field. “Geriatrics and Gerontology” closely collaborated with “Nutrition and Dietetics” and “General and Internal Medicine”, while “Oncology” closely collaborated with “Surgery” and “Rehabilitation”. Fig. 5B illustrated the annual output of publications of the top 10 disciplines, and as expected, “Geriatrics and Gerontology” represented the greatest number of publications, approximately 24.2 %.

### 3.4. Institution contributions and collaborations

A total of 2675 institutions contributed to SO research, with universities accounting for the majority of participation (56.05 %),



**Fig. 6.** (A) Distribution of institution types involved in the sarcopenic obesity field. (B) The top 10 institutions ranked by the number of publications on sarcopenic obesity. (C) Co-authorship of the top 50 institutions ranked by the number of publications on sarcopenic obesity. Each node represents one institution. The bigger the size of nodes, the greater the number of publications. The link between two nodes represents the co-author relationship between the two corresponding institutions.

followed by hospitals (25.00 %), institutes (7.80 %), clinical organizations (6.00 %), and other agencies (5.15 %) (Fig. 6A).

Fig. 6B presents the top 10 institutions ranked by the number of publications on SO research. Seoul National University Hospital ( $n = 54$ ), University of Alberta ( $n = 52$ ), and Yonsei University ( $n = 49$ ) were the top 3 institutions, of which, the University of Alberta was the most cited (7904 citations). The collaboration networks of the top 50 institutions ranked by the number of publications are shown in Fig. 6C.

**Table 2**

The top 10 journals ranked by the number of publications on sarcopenic obesity.

| Journal                                   | Publications | Total citation counts | Mean citation counts | Impact factors 2021 | Impact factors (five years) |
|---|--------------|-----------------------|----------------------|---------------------|-----------------------------|
| Clinical Nutrition                        | 75           | 3346                  | 44.61                | 7.643               | 8.230                       |
| Nutrients                                 | 53           | 272                   | 5.13                 | 6.706               | 7.185                       |
| Journal of Cachexia Sarcopenia and Muscle | 52           | 1663                  | 31.98                | 12.063              | 12.879                      |
| PLoS One                                  | 45           | 1916                  | 42.58                | 3.752               | 4.069                       |
| Journal of Nutrition Health & Aging       | 35           | 1248                  | 35.66                | 5.285               | 4.697                       |
| Scientific Reports                        | 33           | 593                   | 17.97                | 4.997               | 5.516                       |
| Journal of Clinical Medicine              | 31           | 210                   | 6.77                 | 4.964               | 5.098                       |
| Journals of Gerontology: Series A         | 29           | 1847                  | 63.69                | 6.591               | 6.735                       |
| Experimental Gerontology                  | 27           | 455                   | 16.85                | 4.253               | 4.565                       |
| BMC Geriatrics                            | 26           | 300                   | 11.54                | 4.070               | 5.267                       |

### 3.5. Top journals

A total of 671 journals published original articles on SO. The top 10 journals ranked by the number of publications on SO are listed in Table 2. These journals published 20.1 % of the total number of publications. *Clinical Nutrition* had the highest number of publications on SO (n = 75), followed by *Nutrients* (n = 53), and *Journal of Cachexia Sarcopenia and Muscle* (n = 52).

### 3.6. Top authors and collaborations

Among the authors who contributed to the published literature on SO, Kim JH had the highest number of publications (n = 25), followed by Batsis JA, Kemmler W, and Prado CM, all of whom had 24 publications each. The three most highly cited authors in the field of SO research were Cederholm T with 9381 citations, Boirie Y with 8316 citations, and Schneider SM with 8129 citations. Fig. 7A shows the co-author network of the top 50 highly cited authors ranked by the number of citations. Additionally, Fig. 7B presents the authors who were likely to be the emerging influential researchers.

### 3.7. Highly cited publications

The top 10 highly cited publications on SO are listed as shown in Table 3. The most cited publication was the European Working Group on Sarcopenia in Older People (EWGSOP) consensus with 7209 citations so far.

### 3.8. Hotspots and trends in SO research

Keywords are commonly used to reflect the core content and theme of research papers. We conducted a co-occurrence analysis of keywords with at least 40 times frequency. As shown in Fig. 8, the size of the node represents the frequency of the corresponding keyword over time, and the links between the two nodes represent the frequency of co-occurrence of the two keywords. The keywords that emerged earlier are labeled with purple colors, while the keywords labeled with yellow color reflect the emerging research direction.

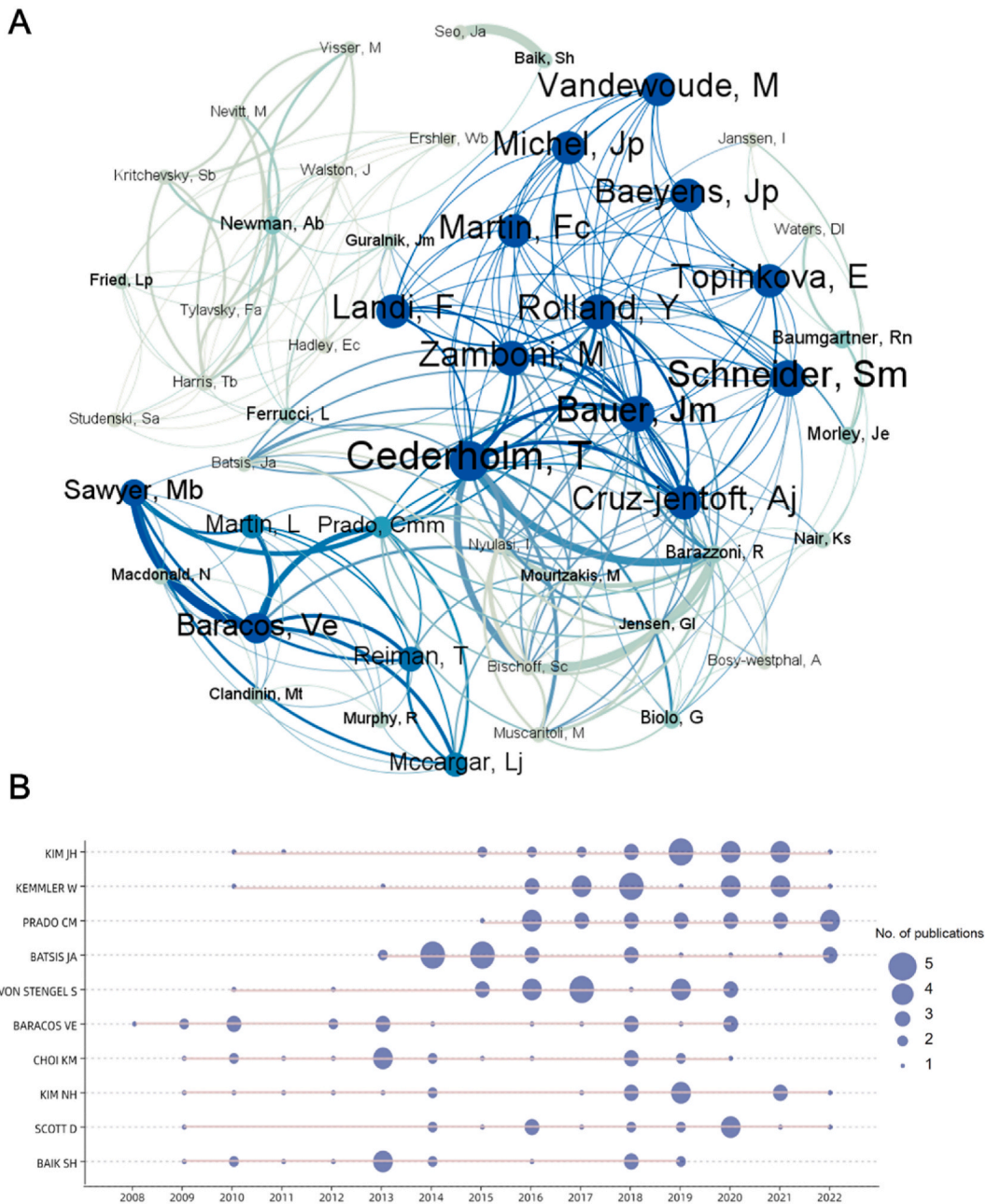
Based on Fig. 8, we demonstrated that the earlier-studied hotspots were the sarcopenia components (such as 'skeletal muscle', 'fat', 'muscle strength', 'physical function', and 'physical performance') and the 'prevalence' of SO. Another hotspot of SO was pathogenesis, by the implication of the core keywords: 'older adult', 'insulin resistance' and 'inflammation'. The association between SO and other geriatric syndromes (such as 'disability' and 'frailty') was also highlighted in Fig. 8. It is noteworthy that there has been significant research interest in the topics of 'consensus', 'cancer', 'resection', 'prognostic factors', and 'complications' in the past three years. These findings suggest that the current research focus has been on the prognosis of SO, as well as the fields of oncology and surgery.

Furthermore, we extracted the top 25 keywords with the strongest citation bursts using CiteSpace software to address the change in research frontiers over time. As shown in Fig. 9, the burst words have changed over time. In recent years, the burst words were 'body composition', 'nonalcoholic fatty liver disease (NAFLD)', 'fibrosis', and 'Asian Working Group for Sarcopenia (AWGS)', implying that the definition and diagnosis of SO remain unclear, and the associations between SO and other diseases might be the next research hotspots.

## 4. Discussion

Our study depicted the landscape of SO research based on original studies retrieved from the WoSCC database. Over the past 10 years, annual publications of SO have increased dramatically. Among the high-impact countries, the USA contributed to the most publications and citations. Over 80 disciplines were involved in SO research, of which, "Geriatrics and Gerontology" was the most active discipline. Additionally, it is noteworthy that five out of the top 10 most productive institutions were located in Korea. However, their citation counts were relatively low, indicating that while these institutions have shown increased interest in this field, they may not yet have achieved significant influence in the field of SO research.





**Fig. 7.** (A) Co-authorship network of the top 50 highly cited authors. Each node represents an author. The color of the nodes represents the number of publications of the corresponding authors. The size of each node represents the citations of the corresponding author. The bigger the node, the more citations the author had. The link between nodes represents the number of co-authored publications. The thicker the links, the greater the number of publications being co-authored. (B) The bubble chart of the number of publications of the top 10 “prolific” authors over time. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Our study identified that the hotspots regarding SO diagnosis were ‘body composition’ and ‘physical function’. This finding is in accordance with a recent consensus statement published by ESPEN/EASO [15], which pointed out “both altered skeletal muscle functional parameters and altered body composition are needed to establish a firm diagnosis of SO”. With regard to muscle functional parameters, the consensus group supported the assessment of ‘muscle strength’, such as ‘grip strength’, which was consistent with the co-occurrence analysis of keywords in our study.

Magnetic resonance imaging (MRI) and computed tomography (CT) are considered the gold standard for measuring body composition [23], but dual-energy X-ray absorptiometry (DXA) was relatively early and more frequently used [24]. CT is a commonly used diagnostic method for cancer. With the emergence and rapid growth of the discipline of “Oncology” in SO research, CT has

**Table 3**  
The top 10 highly cited publications in the sarcopenic obesity research field.

| Rank | Publication titles  | First author     | Publication year | Journal                                     | Impact factor 2021 | Total citation counts | Citation counts per year |
|------|---|------------------|------------------|---|--------------------|-----------------------|--------------------------|
| 1    | Sarcopenia: European consensus on definition and diagnosis  | Cruz-Jentoft, AJ | 2010             | Age and Ageing                              | 12.782             | 7209                  | 514.93                   |
| 2    | Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study  | Prado CMM        | 2008             | Lancet Oncology                             | 54.433             | 1858                  | 116.13                   |
| 3    | Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index  | Martin L         | 2013             | Journal of Clinical Oncology                | 50.739             | 1481                  | 134.64                   |
| 4    | Research agenda for frailty in older adults: toward a better understanding of physiology and etiology: summary from the American Geriatrics Society/ National Institute on Aging Research Conference on Frailty in Older Adults | Walston J        | 2006             | Journal of the American Geriatrics Society  | 7.538              | 1014                  | 56.33                    |
| 5    | ESPEN guidelines on definitions and terminology of clinical nutrition   | Cederholm T      | 2017             | Clinical Nutrition                          | 7.643              | 907                   | 129.57                   |
| 6    | Protein intake and exercise for optimal muscle function with aging: Recommendations from the ESPEN Expert Group   | Deutz NEP        | 2014             | Clinical Nutrition                          | 7.643              | 765                   | 76.5                     |
| 7    | Sarcopenia as a determinant of chemotherapy toxicity and time to tumor progression in metastatic breast cancer patients receiving capecitabine treatment  | Prado CMM        | 2009             | Clinical Cancer Research                    | 13.801             | 710                   | 47.33                    |
| 8    | From the Chicago Meetings: Sarcopenia   | Morley JE        | 2001             | Journal of Laboratory and Clinical Medicine | NA                 | 707                   | 30.74                    |
| 9    | Body composition in healthy aging   | Baumgartner RN   | 2000             | Annals of the New York Academy of Sciences  | 6.499              | 631                   | 26.29                    |
| 10   | Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly   | Baumgartner RN   | 2004             | Obesity Research                            | NA                 | 582                   | 29.1                     |

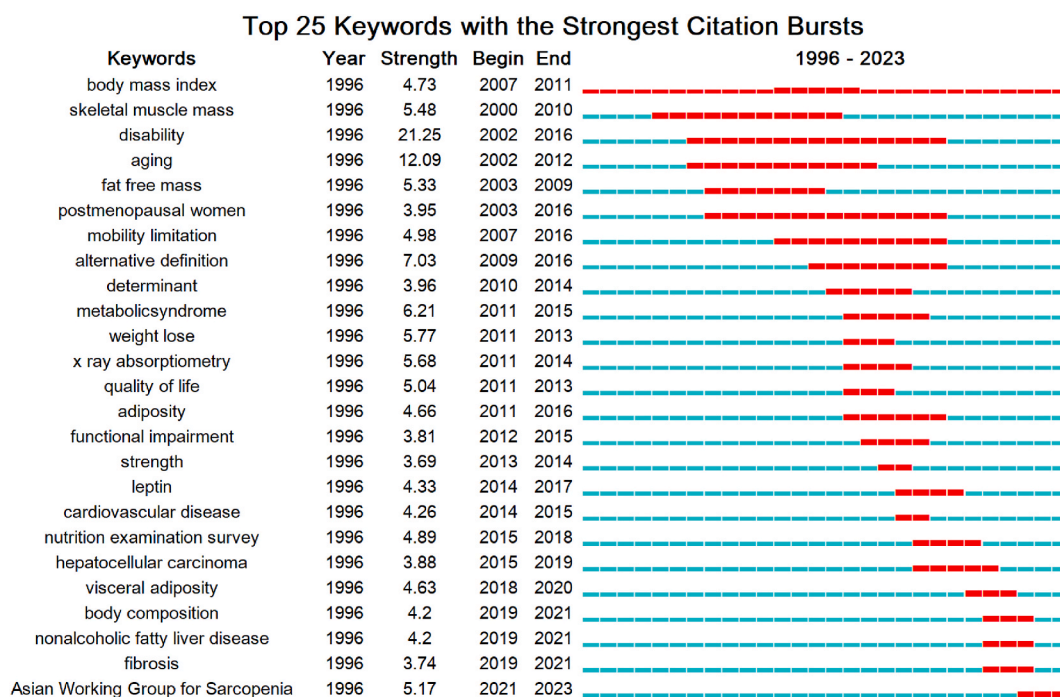
become increasingly utilized in clinical studies as a means of measuring body composition [15].

According to a theory proposed by Shneider [25], the evolution of a research specialty can be divided into four stages, and SO research remains in its pubertal period (stage II to III) at present. On the one hand, researchers have developed numerous screening and diagnostic techniques and tools, which have been employed to investigate various research questions. On the other hand, innovative techniques and tools, particularly those related to interventions, continue to emerge and pave the way for further advancements in the field [26]. Similarly, we found that the hotspots of SO have been shifting from biology, prevalence, and risk factors to outcomes, prognostic factors, complications, and quality of life. The reported prevalence of SO varies widely according to different study population, definitions, and cut-off values [4]. A number of evidences have showed that SO was associated with increased risk of adverse health-related outcomes, including disability [6], functional impairment [27], comorbidities [28,29], mortality [7,30], hospitalization [6], and reduced quality of life [8]. Moreover, SO in patients with chronic diseases or cancer were emerging research hotspots. We demonstrated that chronic liver disease was identified as a subfield of SO. One of the reasons was the prevalence of NAFLD increased significantly over time, from 25.3 % between 1999 and 2005 to 33.9 % between 2012 and 2017 [31]. Furthermore, due to the changes of lifestyle, patients with chronic liver disease, even those with liver cirrhosis, tend to be obesity [32]. Carias et al. [11] founded that SO was greatly prevalent (42.0 %) in patients with liver cirrhosis. Other chronic diseases, such as chronic obstructive pulmonary disease (COPD) [28], diabetes [33], and chronic kidney disease (CKD) [29], were also associated with SO. These diseases enhanced the risk of loss of muscle mass and function, as well as nutritional derangements or anabolism and catabolic dysfunctions, potentially causing SO. Meanwhile, the development of SO in turn promoted or exacerbated the presence of complications. This finding was in line with the ESPEN/EASO consensus [15], which supported a two-level staging (stage I and stage II) based on the presence of complications after SO diagnosis was established, aiming to stratify patients based on clinical severity and higher risk of poor outcomes.

Our study identified the main research trends in the pathogenesis of SO, namely 'aging', 'inflammation', and 'insulin resistance'. Previous studies have highlighted that change in body composition with aging, including fat accumulation [34], and the age-related decline in resting metabolic and lean mass [35], were associated with the development of SO [36]. Additionally, many inflammatory pathways have been involved in SO. For example, obesity can result in an imbalanced secretion of hormones and inflammatory cytokines, such as leptin, tumor necrosis factor (TNF), and interleukin-6 (IL-6), leading to a state of chronic inflammation [37]. These changes would exacerbate insulin resistance, leading gain in fat mass and loss of muscle mass and function [38,39]. Notably, sex-specific hormonal changes and myocellular mechanisms may also play an important role in the development of SO [36]; however, our analysis failed to reveal the relevant contents.

Our study identified that the hotspots regarding SO interventions were 'nutrition' and 'exercise'. This finding is in line with the





**Fig. 9.** The top 25 keywords with the strongest citation bursts. The blue line represents the time interval of the entire publications included (from 1996 to 2023). The red line represents the time interval of a specific burst word. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

terms “sarcopenic obesity” or “obese sarcopenia”, it is possible that some relevant publications were not included, which may have introduced a risk of selection bias. Secondly, the dataset used in this study was limited to the WoSCC database. Therefore, we may omit some publications from other citation databases, such as SCOPUS and Google Scholar. However, a recent study found only minor differences between the coverage of the scientific literature in WoS and SCOPUS [43]. Google Scholar was criticized for including citations from non-scholarly sources, such as administrative notes and student handbooks [44]. Finally, some recent research of high quality might be undervalued due to fewer citations.

## 5. Conclusions

We provided a comprehensive landscape of SO research. Currently, SO research remains in its pubertal stages. This is a vibrant research area involving multiple disciplines, such as geriatrics and gerontology, nutrition, endocrinology, and oncology. Prognostic factors, complications, pathogenesis mechanisms, and interventions of SO might be the research frontiers in the near future.

Our study may serve as a navigation map of SO research, not only for researchers to identify key information on SO research but also for senior experts to build their collaboration networks or facilitate the design of future clinical trials.

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## Data availability statement

The raw data used in this article can be obtained from the corresponding author on reasonable request.

## Additional information

No additional information is available for this paper.

## CRedit authorship contribution statement

**Huiyu Tang:** Data curation, Formal analysis, Software, Visualization, Writing – original draft. **Rongna Lian:** Formal analysis,

Methodology, Software, Validation, Visualization, Writing – original draft. **Runjie Li:** Methodology, Writing – review & editing. **Jiaojiao Jiang:** Writing – review & editing. **Ming Yang:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

## Declaration of competing interest

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

## Acknowledgements

None.

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