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Nutrition and sarcopenia: Current knowledge domain and emerging trends

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Objective: Non-pharmacological management like nutrient supplements has shown positive impacts on muscle mass and strength, which has burgeoned clinical and research interest internationally. The aim of this study was to analyze the current knowledge domain and emerging trends of nutrition-related research in sarcopenia and provide implications for future research and strategies to prevent or manage sarcopenia in the context of aging societies.

Materials and methods: Nutrition- and sarcopenia-related research were obtained from the Web of Science Core Collection (WoSCC) database from its inception to April 1, 2022. Performance analysis, science mapping, and thematic clustering were performed by using the software VOSviewer and R package "bibliometrix." Bibliometric analysis (BA) guideline was applied in this study.

Results: A total of 8,110 publications were extracted and only 7,510 (92.60%) were selected for final analysis. The production trend in nutrition and sarcopenia research was promising, and 1,357 journals, 107 countries, 6,668 institutions, and 31,289 authors were identified in this field till 2021. Stable cooperation networks have formed in the field, but they are mostly divided by region and research topics. Health and sarcopenia, metabolism and nutrition, nutrition and exercise, body compositions, and physical performance were the main search themes.

Conclusions: This study provides health providers and scholars mapped out a comprehensive basic knowledge structure in the research in the field of nutrition and sarcopenia over the past 30 years. This study could help them quickly grasp research hotspots and choose future research projects.

KEYWORDS

nutrition, sarcopenia, VOSviewer, co-words, bibliometric analysis

Introduction

People worldwide are living longer. According to World Health Organization (WHO), people aged 65 and over would nearly account for 17% of the population by 2050 (1). Aging is always along with a series of physiological and psychological changes, among them, the most conserved hallmarks are the decline of functional capabilities, which strew great challenges to health. Sarcopenia is an age-related disease that is defined as a decrease in muscle quantity and quality, as well as physical performance (2). Sarcopenia and frailty are closely related and there is a diagnostic overlap between sarcopenia and frailty (3, 4), especially in the concept of nutritional frailty (5). It is estimated that the global prevalence of sarcopenia is ranged from 3.3 to 17.5% depending on various diagnostic criteria and assessment tools (6, 7). Compared with the individuals without sarcopenia, those having low grip strength, lean mass, strength, power, or physical function have more grave physiological and clinical consequences (8) and have high risks of mobility, fall, and disability (9). Although some research suggests that hormonal changes (10), oxidative stress (11, 12), and mitochondrial dysfunction (13) may play a great role in the development of sarcopenia, the pathophysiology of the disease is complex and not yet fully elucidated (4). Accordingly, understanding more about sarcopenia's risk factors and its coping strategies is of great interest.

Non-pharmacological management like nutrient supplements has shown positive impacts on muscle mass and strength, which has burgeoned clinical and research interest internationally. Notably, due to the decline of physical exercise and a lower need for energy intake, as well as the difficulty in the assessment of nutritional status in frailty phenotype (3), community-dwelling older adults have a high risk of being at nutritional or becoming malnourished (14), and a large body of evidence has linked malnutrition with the negative health effects of the old on muscles (15, 16). Based on the International Clinical Practice Guidelines for Sarcopenia (ICFSR) (17), preserving or restoring adequate nutritional status is of great significance for the prevention and optimal management of sarcopenia. Studies have proved that prevent of general malnutrition or micronutrient deficiencies has some potential to promote the physical performance (18–20). Moreover, serval randomized controlled trials conducted in older adults with sarcopenia showed that nutrition intervention was not only feasible (21) but also safe (22). Given that nutrition may influence the development of sarcopenia, this topic deserves further discussion. However, despite the approximately 30-year history of sarcopenia research, a detailed quantitative analysis of the existing research has not been undertaken to elucidate the body of evidence on the nutrition research in the sarcopenia field. Thus, we aimed to analyze the current knowledge domain and emerging trends of the evidence that associates nutrition with muscle quality and quantity, and physical performance. Our study helps to bridge this gap and provide implications for future research and strategies to prevent or manage sarcopenia for clinical health providers, and attribute to gain a one-stop overview for the readers in the sarcopenia literature.

Materials and methods

Study design

As an important carrier of scientific research, academic publications could clearly reflect the basic knowledge domain and emerging trends of a certain discipline (23). Bibliometric analysis (BA) is a quantitative and comprehensive method associated with academic publications (24). This method could reveal the current knowledge domain through performance analysis with publication-related and citation-related metrics (25). In addition, mathematics, statistics, and philology methods are used to identify emerging trends through science mapping with citation, co-citation, or co-word analysis (26). To date, BA has been widely used to analyze the progress of research fields and to predict the development of disciplines due to its objectivity, quantitative, and macro characteristics compared to systematic or meta-analysis (27). Thus, BA and its guideline (28) were applied in this study, as shown in **Figure 1**. This study was not reviewed by the ethics committee for neither patients nor members of the public were involved.

Data source

Different databases (e.g., Scopus and Web of Science) have their own format of bibliometric data. BA guideline suggested that choose one appropriate database to mitigate the need of consolidation, as minimizing unnecessary action items can help to prevent potential human errors (28). The Web of Science Core Collection (WoSCC) of Clarivate Analytics including Science Citation Index Expanded, Social Sciences Index, and Arts & Humanities Citation Index, is regarded as one of the most complete and reliable databases for BA (29), which can retrieve the references of publications and track the latest citation (30). Therefore, all data used in this study were retrieved from the WoSCC.

Search strategy

On April 1, 2022, the WOSCC was searched using topic words and keywords plus. The search terms were "nutrition intake," "dietary supplements," "sarcopenia," "muscle strength," "muscle function," and "muscle mass." The strategy of Behnaz et al. (31) and Dongliang et al. (32) were mainly referenced during the process of string construction. After

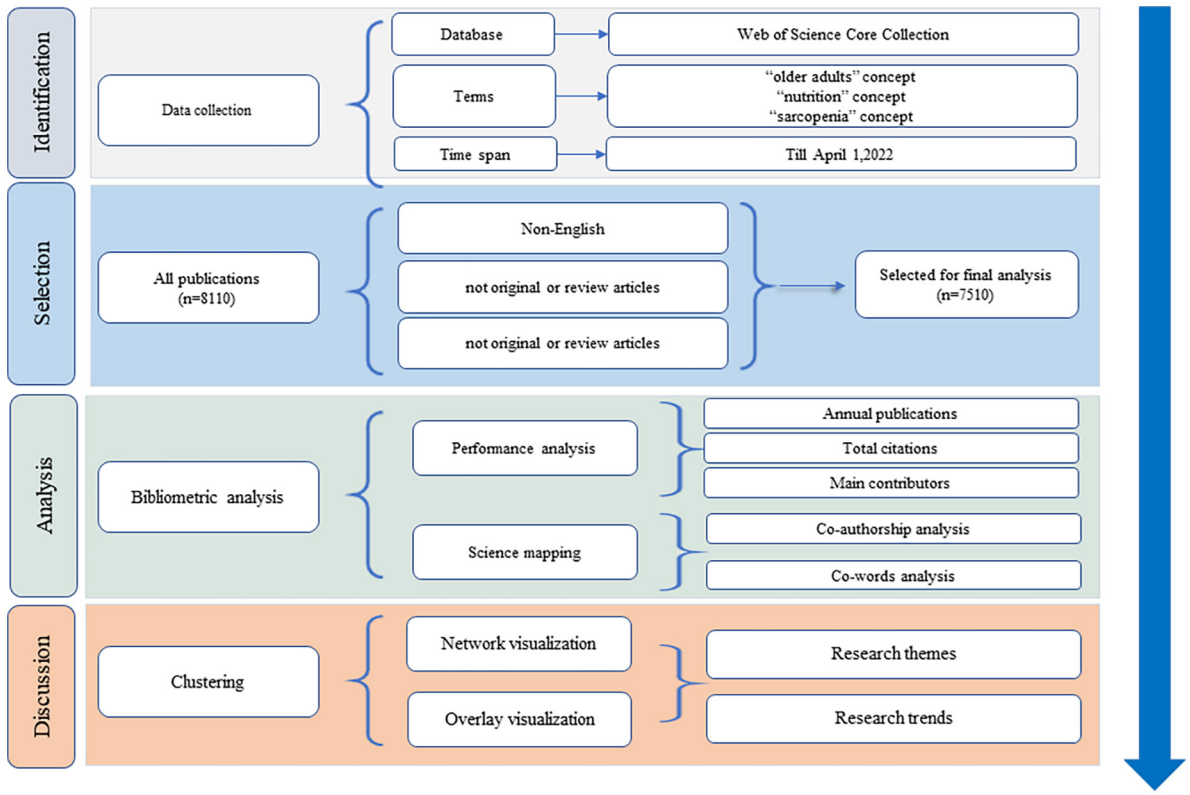

FIGURE 1
Flow chart of the research framework.

selecting all the relevant search terms and their combinations, Boolean operators and a general review were performed. English language, incorporated animal and human studies were acceptable, and no restrictions on the dates of publications.

Data collection

Two authors manually and independently evaluated the title and abstract of the selected publications. Publications without abstracts were full-text reviewed. The third author verified the consistency of the results. Finally, a total of 8,110 publications were identified from WoSCC and only 7,510 were selected for final analysis, 180 non-English documents, 110 were not original or review articles were excluded after general reviewing, and 310 were excluded for not associated with the topic of nutrition or sarcopenia after evaluated the title and abstract. **Figure 2** showed the flow chart of the data collection procedure.

Bibliometric analysis

Full records and cited references of the publications were downloaded in txt format, and then input to the VOSviewer version 1.6.15 (Leiden University, The Netherlands) and R package "bibliometrix" version 4.1.2, thesaurus file was used for data cleaning. The steps of analysis were as follows: (A) performance analysis was conducted to explore the current knowledge domain, which includes the annual publications, total citations, and main contributors, such as topics, journals, and core authors. Core authors was defined by Price's Law (33), that is, $m_p = 0.749\sqrt{n_{pmax}}$ in which $n_{p\,\max}$ is the output of the most prolific authors, m_p is the minimum number of output of core authors in the selected period. (B) Science mapping was conducted to analysis the emerging trends on science collaboration and research hotpots, which including co-authorship and co-words. (C) The thematic clustering was used to identify the research themes and evolution features according to Zipf's Law (34) by network and overlay visualizations.

Results

Annual publications and total citations

A total of 7,510 publications were selected for final analysis. As shown in **Figure 3**, though the publications have dropped slightly in some years, annual publications related to nutrition

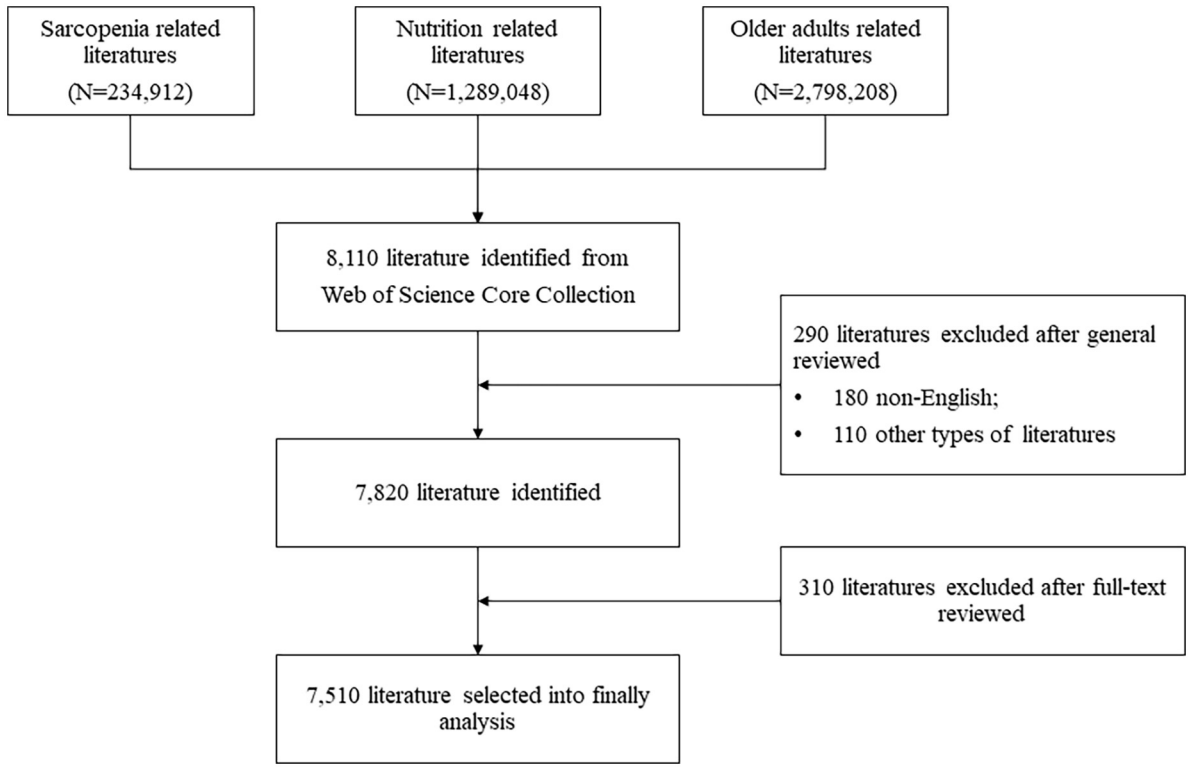

FIGURE 2
Flow chart of the data collection procedure.

in the sarcopenia field quickly increase from 58 in 1999 to 995 in 2021, showing a clear trend for growth. The correlation between the number of publications and the year was significant (R^2 = 0.9912). The total citations also showed a similar upward trend, with a correlation coefficient of 0.9703, the number jumped from 30 in 1999 to 44,585 in 2021. Convincingly, the publication and citation in the filed of nutrition- and sarcopenia-related research would reach a new milestone at 2022.

Main contributors

Topics and journals

Figure 4A showed the top 10 category in the nutrition- and sarcopenia-related research, among which the main topics were nutrition dietetics, followed by geriatrics gerontology, endocrinology metabolism, and sport science, covering a wide range of academic disciplines, indicating this filed was a multi-disciplinary work.

Journals are an important carrier of scientific research. Analyzing the source journals helps understand the research field it belongs to, and for other scholars to evaluate the development potential of this hotspot. Figure 4B showed the top 100 productive journals, in which color bubbles represent the number of publications in each journal, and lines indicate cooperation between two journals. Among which, *Nutrients* (406, 5.41%) from MDPI press ranked first in production, followed by *Clinical Nutrition* (319,4.25%), and *PLoS One* (174, 2.32%). Table 1 lists the ten journals with the largest number of nutrition-related research in sarcopenia field and their academic influence index. Almost all belonged to Q1 in JCR, and with an average influence factor of 5.92. Besides, *the Journal of Cachexia Sarcopenia and Muscle* have highest impact factor with 12.91.

Countries, institutions, and authors

After reviewing the contributors, a total of 107 countries, 6,668 institutions, and 31,289 authors were identified in the nutrition- and sarcopenia-related research field. Among those, the most productive country was the USA (2,284, 30.41%), followed by the United Kingdom (UK), Japan, Italy, and Canada, counting for 10.48, 8.08, 7.79, and 7.18% of the total publications, respectively. And Maastricht University (n = 138) and McMaster University (n = 104) were the leading institutions in terms of productivity.

Besides, Professor van Loon L.J.C. from Maastricht University Medical Centre was found to be the most productive with 96 publications. And according to Price's Law, core authors should publish at least 7.34 publications, that is, those who publish 8 articles or more could be identified as core authors.

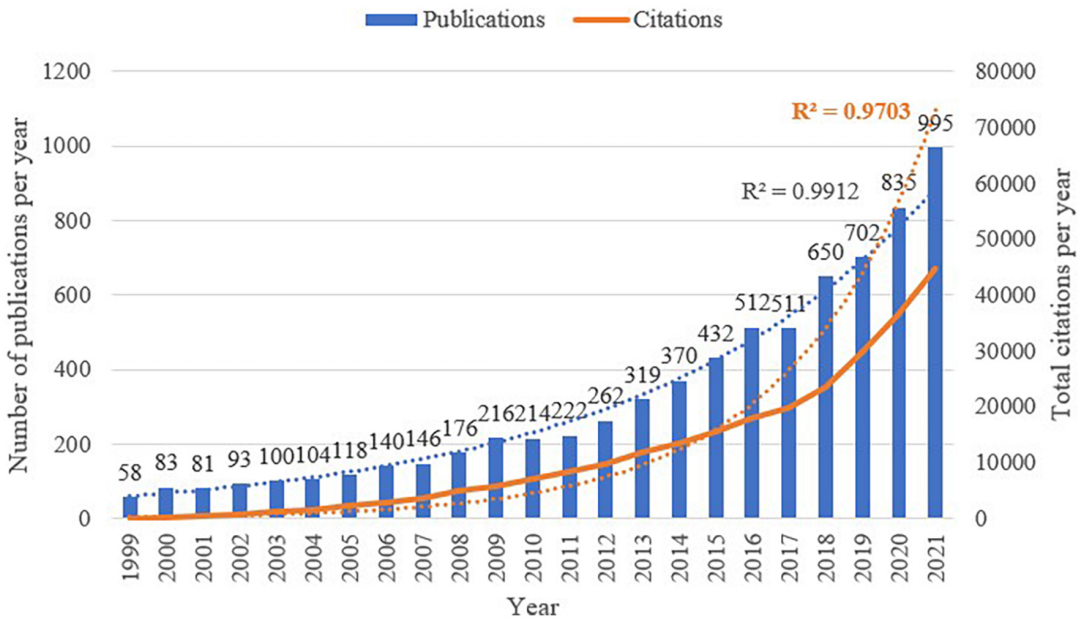

FIGURE 3
Annual publications and total citations number from 1999 to 2021.

In other words, there were 437 core authors in the field of nutrition-related research in sarcopenia. Figure 5 showed the top 20 most prolific authors and their academic impact, in which Professor van Loon L.J.C with the highest H index of 43 and most local citations as well.

Co-authorship analysis

Scientific cooperation occurs when scholars in relevant research fields work together to innovate scientific knowledge (35). Figure 6 showed the collaboration among countries among (A) productive countries, (B) countries, (C) authors, and (D) institutions on nutrition-related research in sarcopenia, in which each circle and label forms an element, the size of the element depends on the number of publications of the contributor, the strength of the element depends on the frequency of collaboration between two contributors, the color of the element represents the cluster of the research topic to which it belongs. In general, Figure 6 implied that compared with a country's collaboration, institutions and authors' collaboration provides a measure to examine interactions between agencies at a more granular level (36, 37).

Co-words analysis

One of the main functions of keywords is to provide core information about the article. At the same time, keywords are important for bibliometric analyses of the knowledge structure in an academic field, for similar articles are prone to adapt to neighbor keywords (38). Thus, research mapping was explored by investigating the co-occurrence of all keywords in the titles and abstracts of 7,510 documents, and clustering was applied to identify the emerging trend.

Figure 7 was a bubble chart of the co-words network of top 500 keywords. Figure 7A showed the network visualization, in which keywords were divided into four categories (red, blue, yellow, and green), indicating the four mainstream research topics in this filed: the first one in green centered on health and sarcopenia, associated with malnutrition, risk, and mortality; the second in red on metabolism and nutrition, associated with oxidative stress, insulin resistance, and obesity; the third in blue on nutrition and exercise, mainly associated with resistance exercise; and lastly in yellow, on body compositions and physical performance, associated with skeletal strength, vitamin D, calcium, magnesium (39, 40). Figure 7B showed the overlay visualization and colors represented the time of evolution, in which clusters of green and yellow were the hotpot and future research trends in the nutrition- and sarcopenia-related field.

Discussion

Bibliometric analysis method offers a one-stop overview to identify evolutionary nuances in different fields and capture emerging trends (41). In this study, we used BA quantitative method to analyze the development of nutrition-

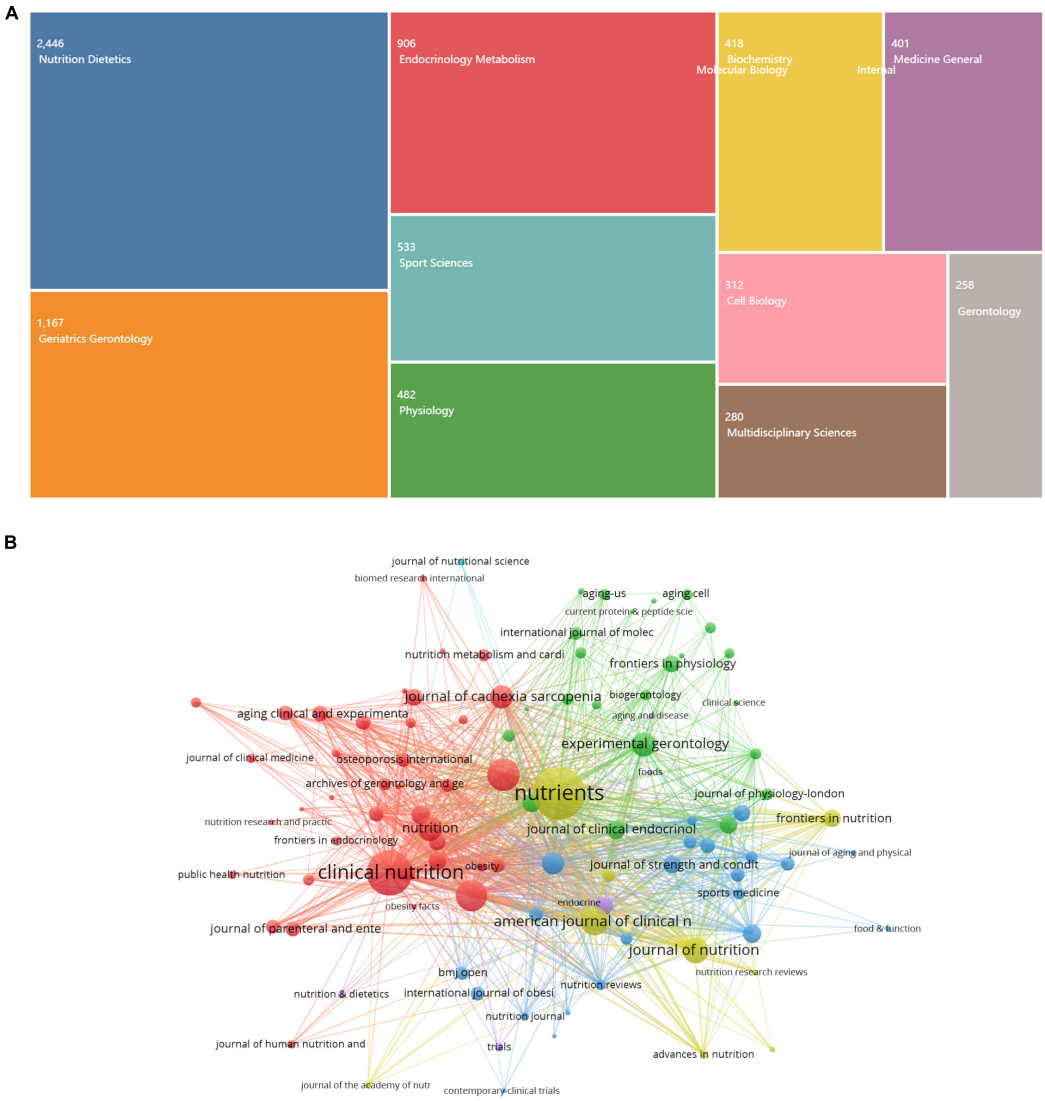

FIGURE 4
The main categories and journals in the nutrition-related sarcopenia research. **(A)** The top 10 journal citation reports (JCR) category of topic themes. **(B)** The top 100 most productive journals.

TABLE 1 Top 10 productive journals in the nutrition-related sarcopenia research.

Rank	Source	Documents	Counts	Citations	IF (2021)	JCR	Region
1	Nutrients	406	5.41%	5,869	5.719	Q1	Switzerland
2	Clinical nutrition	319	4.25%	14,651	7.325	Q1	Scotland
3	PLoS One	174	2.32%	4,260	3.24	Q2	USA
4	Journal of nutrition health and aging	171	2.28%	4,870	4.075	Q2	France
5	American journal of clinical nutrition	134	1.78%	12,980	7.047	Q1	USA
6	Journal of nutrition	117	1.56%	5,250	4.798	Q1	USA
7	Nutrition	104	1.38%	2,588	4.008	Q2	USA
8	Experimental gerontology	102	1.36%	2,630	4.032	Q2	England
9	Journal of cachexia sarcopenia and muscle	98	1.30%	2,683	12.91	Q1	Germany
10	Journals of gerontology series A-biological sciences and medical Science	92	1.23%	5,579	6.053	Q1	USA

IF, impact factor; JCR, journal citation reports; the US, The United States.

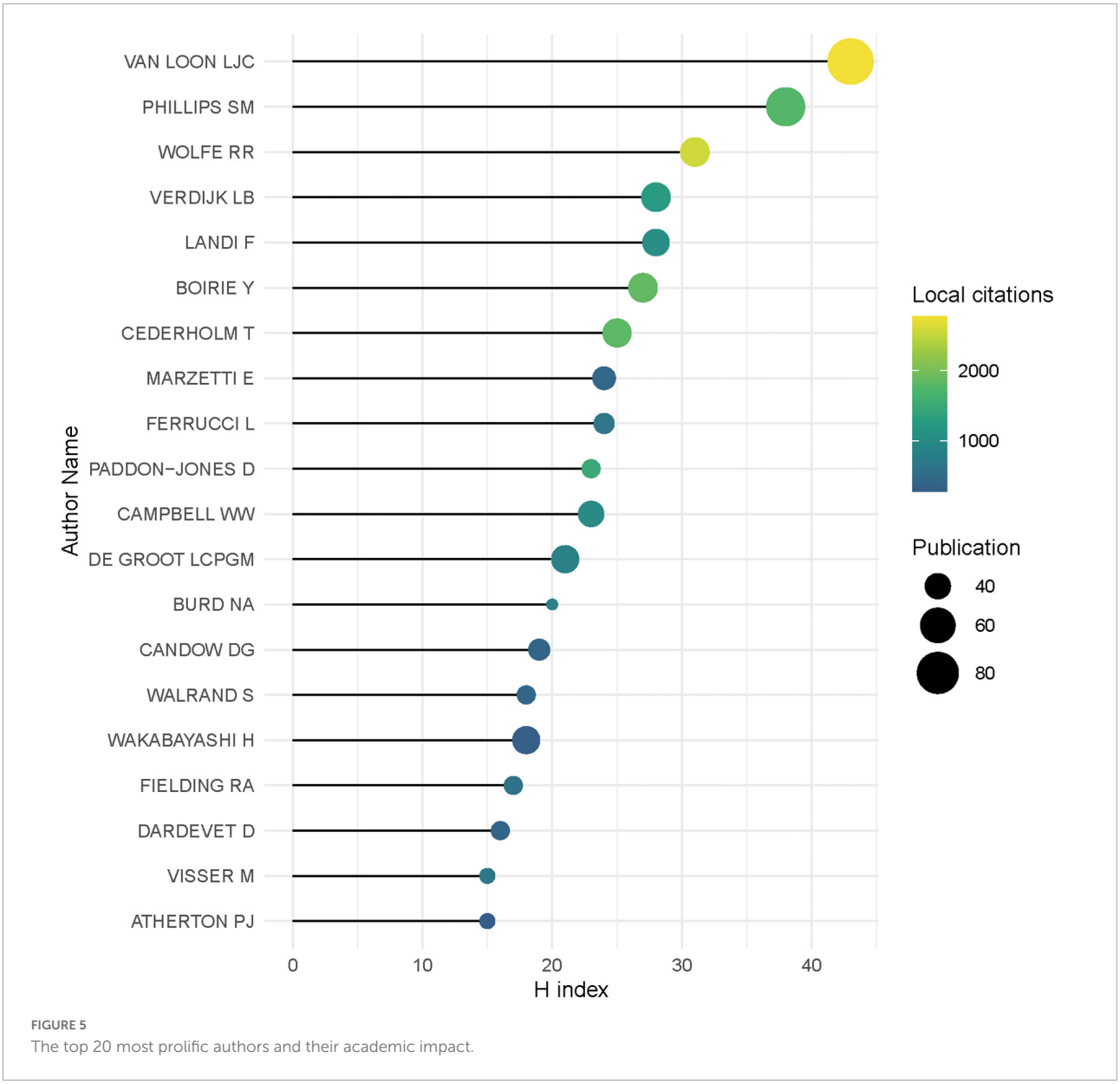

FIGURE 5
The top 20 most prolific authors and their academic impact.

and sarcopenia-related research at a global level, which would help sarcopenia and nutrition researchers gain a more comprehensive understanding of the current state of this topic and thus guide the direction of future research. Compared with other BA studies that only focus on single journals (42, 43) or are restricted to a specific time (32, 44), and unlike Meta-analysis or systematic literature review (45, 46) that aim to summarize and synthesize the findings of small literature on a specific research topic or field, our study provides scholars with a comprehensive basic knowledge structure and research trend.

We found that the nutrition- and sarcopenia-related field has shown a growing trend over the past 30 years. A similar trend was also observed in a few BA studies on sarcopenia along, which found the publication number rise dramatically between 2008 and 2010 (44, 47). One of the reasons is the incrassating recognition of the definition and diagnosis of sarcopenia. Actually, sarcopenia has a relatively short history, it was not until 1989 that Irwin Rosenberg proposed the term "sarcopenia" (48). The European Working Group on Sarcopenia in Older People (EWGSOP) was established in 2009 and developed the first practical clinical definition and consensus diagnostic criteria for this disease in 2010 (49) and, therefore, increased research interests in this field.

Our BA results also demonstrated that nutrition-related sarcopenia studies have become a research hotspot in not only nutrition dietetics and geriatrics gerontology but also multiple disciplines, like endocrinology metabolism and sports science. In fact, up to 108 Web of Science categories were

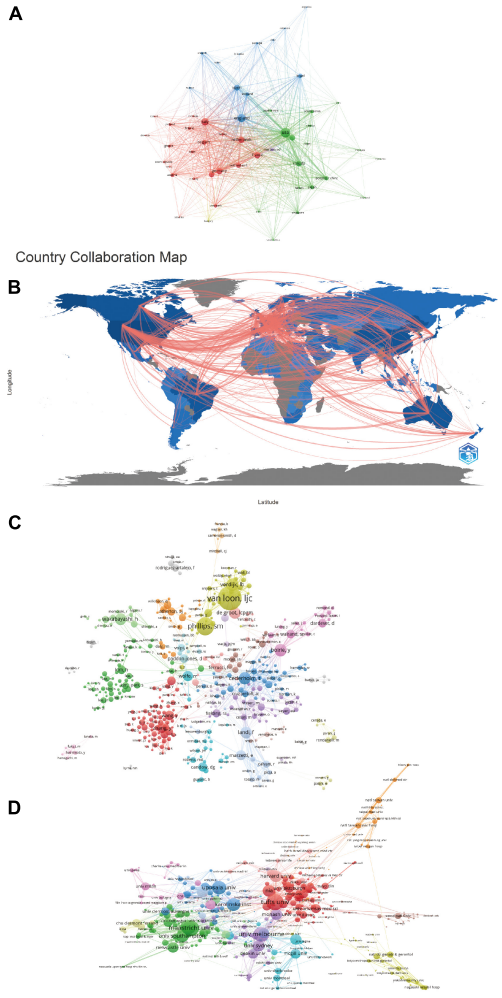

FIGURE 6
Co-authorship map among **(A)** productive countries, **(B)** countries, **(C)** authors, and **(D)** institutions on nutrition-related research in sarcopenia.

identified in this field. The potential explanation is that skeletal muscle is not only affecting the energy and protein metabolism throughout the body, but also plays an essential role in body movement and daily actions such as chewing, swallowing, and breathing (50). Overall, we emphasize the important role of close multidisciplinary collaboration in the prevention and treatment of sarcopenia. In addition, studies in this field are published in a wide range of journals covering many specialties, among which a large number of publications from *Nutrients* were impressive. Notably, *Nutrients* also own high citations in this field, which means the findings reported have been useful to other researchers for initiating, performing, or interpreting their own research.

We focused on the main contributors with productive performance in this field, the USA stands out from all countries as hegemony in the production of knowledge, followed by the UK, Japan, Italy, and Canada, and this may be due to those mentioned countries stepped into aging at the earliest. We also identified the most productive academic institutions in the relevant studies, and the result is similar to the finding on the contribution of countries. Interestingly, we recognized the core authors in the nutrition-related sarcopenia studies for the first time according to Price's Law, such as Loon L.J.C. We also ranked who with a comprehensive index, like total publications, local citations, and H index, which would provide more insights on the most influential author. It is important to note, however, that we only included the studies published in English, thus some individuals' productivity may be underestimated.

Moreover, from the perspective of macro-geographical distribution, the results of co-authorship analysis suggest that several relatively stable cooperation networks have been formed in the field of nutrition -related research in sarcopenia, but they are mostly divided by region and research topics. Therefore, cross-institutional and cross-border collaboration between main contributors needs to be further strengthened.

From a methodological standpoint, our study allows us to identify themes using co-word analysis. Compared with other publications, the results refreshed the ideas of some highly cited articles relating nutrition to sarcopenia (51–53). On the other hand, our study provided a larger database size for analysis, moreover, we not only analyzed the relationship between selected publications and clustered those with a quantitative method (54, 55), but also revealed the intellectual bases and research hotspots in this field.

Focusing on the current knowledge domain and emerging trends, nutrition-related sarcopenia studies would continue to conduct more in-depth large sample study and mechanism research in hotspots and fronts field. First, in terms of health and sarcopenia, it is expected more raw, longitudinal data and publicly available secondary data will be applied to explore the negative results and risk factors of malnutrition among the sarcopenia population. Second, is the discussion of the potential metabolism pathway of nutrition. As the major organ of insulin-induced glucose metabolism in the body, the loss of quantity and quality of skeletal muscle is associated with a complex of pathologies (56). Thus, those findings could provide an insight into the molecular pathogenesis of sarcopenia and a potential target for new nutrition interventions. Third, the combined intervention and mutual effect among nutrition and exercise, in which randomized controlled trial designs were overwhelming and promising. Last, is the research on body compositions and physical performance. It is relatively broad and has an obvious overlap with the other three clusters. However, the overlay visualization emphasizes its frontier, indicating that this theme is playing a vital role in the field, and the supplements and consumption of Vitamin D, and

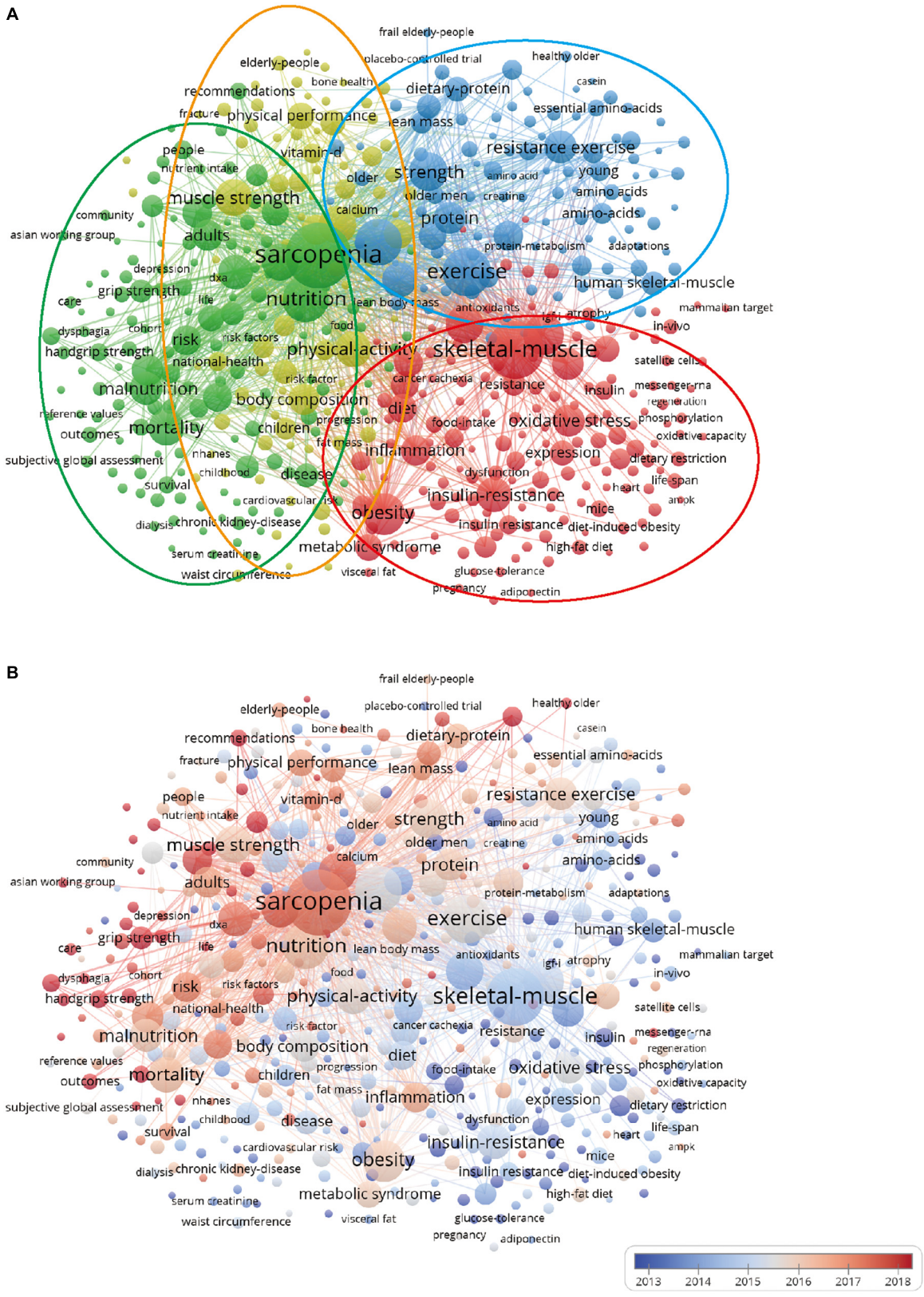

FIGURE 7
The co-words analysis of the top 500 keywords. **(A)** Network visualization; **(B)** overlay visualization.

minerals (57) (magnesium, selenium, iron, zinc et al.) are possible directions for breakthroughs in the future.

Limitations

Although efforts have been made to retrieve various publications relevant to nutrition-related sarcopenia studies, as a novel disease, the terms included in this study and the period may not be extensive enough. In addition, this study only searched in one database and restricted the language to English, which may limit the inclusion of relevant studies, especially those published in other languages. Last but not least, the practical implementation of citation analyses and co-words requires appreciable expertise. Thus, in subsequent studies, we will further optimize data sources and data filtering to improve the quality of overall data analysis and prediction, and synthetic knowledge synthesis would be applied to formally define themes, categories, and concepts.

Conclusion

In this study, a comprehensive BA of the nutrition-related sarcopenia study was performed using WoSCC data. Different visualization methods were used to interactively explore and understand specific data sets. Based on the above results and discussions, some valuable results for the nutrition and sarcopenia study were obtained, including the knowledge domain and emerging trends. In conclusion, the role of nutrition in sarcopenia has received growing research attention, with the USA having the largest number of publications. This study has also identified the main contributors involved in this research globally, and at the same time, it is reasonable to believe that the collaboration between different contributors will be strengthened when the core group is formally established among countries, institutions, and core authors. In addition, the themes of nutrition- and sarcopenia-related research currently could be divided into four categories, more in-depth large sample studies and mechanism research in hotspots and fronts field are needed.

Data availability statement

The raw data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contributions

HHH: conceptualization and writing – original draft. ZYC: formal analysis and review and editing. QHZ: funding acquisition. HHH and LJC: methodology. SMC and QHZ: project administration. DQB and QX: supervision. MZX and QHZ: validation. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. NIH-funded Census Bureau. *World's Older Population Grows Dramatically. National Institutes of Health (NIH)*. (2016). Available online at: https://www.nih.gov/news-events/news-releases/worlds-older-population-grows-dramatically (accessed on June 6, 2022).

2. Chen L-K, Woo J, Assantachai P, Auyeung T-W, Chou M-Y, Iijima K, et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *J Am Med Dir Assoc.* (2020) 21:300–7.e2. doi: 10.1016/j.jamda.2019.12.012

3. Zupo R, Castellana F, Bortone I, Griseta C, Sardone R, Lampignano L, et al. Nutritional domains in frailty tools: working towards an operational definition of nutritional frailty. *Ageing Res Rev.* (2020) 64:101148. doi: 10.1016/j.arr.2020.101148

4. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *Lancet.* (2019) 393:2636–46. doi: 10.1016/S0140-6736(19)31138-9

5. Zupo R, Castellana F, Guerra V, Donghia R, Bortone I, Griseta C, et al. Associations between nutritional frailty and 8-year all-cause mortality in older

adults: the Salus in Apulia study. *J Intern Med.* (2021) 290:1071–82. doi: 10.1111/joim.13384

6. Petermann-Rocha F, Balntzi V, Gray SR, Lara J, Ho FK, Pell JP, et al. Global prevalence of sarcopenia and severe sarcopenia: a systematic review and meta-analysis. *J Cachexia Sarcopenia Muscle.* (2022) 13:86–99. doi: 10.1002/jcsm.12783

7. Chen Z, Li W-Y, Ho M, Chau P-H. The prevalence of sarcopenia in Chinese older adults: meta-analysis and meta-regression. *Nutrients.* (2021) 13:1441. doi: 10.3390/nu13051441

8. Suetta C, Haddock B, Alcazar J, Noerst T, Hansen OM, Ludvig H, et al. The Copenhagen sarcopenia study: lean mass, strength, power, and physical function in a Danish cohort aged 20-93 years. *J Cachexia Sarcopenia Muscle.* (2019) 10:1316–29. doi: 10.1002/jcsm.12477

9. Billot M, Calvani R, Urtamo A, Sánchez-Sánchez JL, Ciccolari-Micaldi C, Chang M, et al. Preserving mobility in older adults with physical frailty and sarcopenia: opportunities, challenges, and recommendations for physical activity interventions. *Clin Interv Aging.* (2020) 15:1675–90. doi: 10.2147/CIA.S253535

10. Gungor O, Ulu S, Hasbal NB, Anker SD, Kalantar-Zadeh K. Effects of hormonal changes on sarcopenia in chronic kidney disease: where are we now and what can we do? *J Cachexia Sarcopenia Muscle.* (2021) 12:1380–92. doi: 10.1002/jcsm.12839

11. Rosa CGS, Colares JR, da Fonseca SRB, Martins GDS, Miguel FM, Dias AS, et al. Sarcopenia, oxidative stress and inflammatory process in muscle of cirrhotic rats - Action of melatonin and physical exercise. *Exp Mol Pathol.* (2021) 121:104662. doi: 10.1016/j.yexmp.2021.104662

12. Zocchi M, Béchet D, Mazur A, Maier JA, Castiglioni S. Magnesium influences membrane fusion during myogenesis by modulating oxidative stress in C2C12 myoblasts. *Nutrients.* (2021) 13:1049. doi: 10.3390/nu13041049

13. Ferri E, Marzetti E, Calvani R, Picca A, Cesari M, Arosio B. Role of age-related mitochondrial dysfunction in sarcopenia. *Int J Mol Sci.* (2020) 21:5236. doi: 10.3390/ijms21155236

14. Norman K, Haß U, Pirlich M. Malnutrition in older adults-recent advances and remaining challenges. *Nutrients.* (2021) 13:2764. doi: 10.3390/nu13082764

15. Robinson S, Granic A, Sayer AA. Nutrition and muscle strength, as the key component of sarcopenia: an overview of current evidence. *Nutrients.* (2019) 11:2942. doi: 10.3390/nu11122942

16. Carbone JW, McClung JP, Pasiakos SM. Recent advances in the characterization of skeletal muscle and whole-body protein responses to dietary protein and exercise during negative energy balance. *Adv Nutr.* (2019) 10:70–9. doi: 10.1093/advances/nmy087

17. Dent E, Morley JE, Cruz-Jentoft AJ, Arai H, Kritchevsky SB, Guralnik J, et al. International clinical practice guidelines for sarcopenia (ICFSR): screening, diagnosis and management. *J Nutr Health Aging.* (2018) 22:1148–61. doi: 10.1007/s12603-018-1139-9

18. Zupo R, Castellana F, De Nucci S, Sila A, Aresta S, Buscemi C, et al. Role of dietary carotenoids in frailty syndrome: a systematic review. *Biomedicines.* (2022) 10:632. doi: 10.3390/biomedicines10030632

19. Damanti S, de Souto Barreto P, Rolland Y, Astrone P, Cesari M. Malnutrition and physical performance in nursing home residents: results from the INCUR study. *Aging Clin Exp Res.* (2021) 33:2299–303. doi: 10.1007/s40520-021-01798-y

20. Ramsey KA, Meskers CGM, Trappenburg MC, Verlaan S, Reijnierse EM, Whittaker AC, et al. Malnutrition is associated with dynamic physical performance. *Aging Clin Exp Res.* (2020) 32:1085–92. doi: 10.1007/s40520-019-01295-3

21. Jyväkorpi SK, Ramel A, Strandberg TE, Piotrowicz K, Błaszczyk-Bębenek E, Urtamo A, et al. The sarcopenia and physical frailty in older people: multi-component treatment strategies (SPRINTT) project: description and feasibility of a nutrition intervention in community-dwelling older Europeans. *Eur Geriatr Med.* (2021) 12:303–12. doi: 10.1007/s41999-020-00438-4

22. Bauer JM, Mikušová L, Verlaan S, Bautmans I, Brandt K, Donini LM, et al. Safety and tolerability of 6-month supplementation with a vitamin D, calcium and leucine-enriched whey protein medical nutrition drink in sarcopenic older adults. *Aging Clin Exp Res.* (2020) 32:1501–14. doi: 10.1007/s40520-020-01519-x

23. Chen C. CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature. *J Am Soc Inform Sci Technol.* (2006) 57:359–77. doi: 10.1002/asi.20317

24. Pritchard A. Statistical bibliography or bibliometrics? *J Doc.* (1969) 25:348–9.

25. Agarwal A, Durairajanayagam D, Tatagari S, Esteves SC, Harlev A, Henkel R, et al. Bibliometrics: tracking research impact by selecting the appropriate metrics. *Asian J Androl.* (2016) 18:296–309. doi: 10.4103/1008-682X.171582

26. Ding Y, Chowdhury GG, Foo S. Bibliometric cartography of information retrieval research by using co-word analysis. *Inform Process Manage.* (2001) 37:817–42. doi: 10.1016/S0306-4573(00)00051-0

27. Yu D, Xu Z, Pedrycz W, Wang W. Information sciences 1968–2016: a retrospective analysis with text mining and bibliometric. *Inform Sci.* (2017) 418:619–34.

28. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: an overview and guidelines. *J Bus Res.* (2021) 133:285–96. doi: 10.1016/j.jbusres.2021.04.070

29. Romanelli JP, Gonçalves MCP, de Abreu Pestana LF, Soares JAH, Boschi RS, Andrade DF. Four challenges when conducting bibliometric reviews and how to deal with them. *Environ Sci Pollut Res Int.* (2021) 28:60448–58. doi: 10.1007/s11356-021-16420-x

30. Kulkarni AV, Aziz B, Shams I, Busse JW. Comparisons of citations in web of science, scopus, and google scholar for articles published in general medical journals. *JAMA.* (2009) 302:1092–6. doi: 10.1001/jama.2009.1307

31. Abiri B, Vafa M. Nutrition and sarcopenia: a review of the evidence of nutritional influences. *Crit Rev Food Sci Nutr.* (2019) 59:1456–66. doi: 10.1080/10408398.2017.1412940

32. Yuan D, Jin H, Liu Q, Zhang J, Ma B, Xiao W, et al. Publication trends for sarcopenia in the world: a 20-year bibliometric analysis. *Front Med.* (2022) 9:802651. doi: 10.3389/fmed.2022.802651

33. Zhong W. Evaluation about the core authors based on price law and comprehensive index method——take journal of library development as an example. *Sci Technol Manage Res.* (2012) 32:57–60. doi: 10.3969/j.issn.1000-7695.2012.02.015

34. Contreras-Barraza N, Madrid-Casaca H, Salazar-Sepúlveda G, Garcia-Gordillo MÁ, Adsuar JC, Vega-Muñoz A. Bibliometric analysis of studies on coffee/caffeine and sport. *Nutrients.* (2021) 13:3234. doi: 10.3390/nu13093234

35. Katz JS, Martin BR. What is research collaboration? *Res Policy.* (1997) 26:1–18.

36. Yan E, Sugimoto CR. Institutional interactions: exploring social, cognitive, and geographic relationships between institutions as demonstrated through citation networks. *J Am Soc Inform Sci Technol.* (2011) 62:1498–514. doi: 10.1002/asi.21556

37. Harande YI. Author productivity and collaboration: an investigation of the relationship using the literature of technology. *Libri.* (2001) 51:124–7. doi: 10.1515/LIBR.2001.124

38. Romero L, Portillo-Salido E. Trends in sigma-1 receptor research: a 25-year bibliometric analysis. *Front Pharmacol.* (2019) 10:564. doi: 10.3389/fphar.2019.00564

39. Ratajczak AE, Rychter AM, Zawada A, Dobrowolska A, Krela-Kaźmierczak I. Do only calcium and vitamin D matter? micronutrients in the diet of inflammatory bowel diseases patients and the risk of osteoporosis. *Nutrients.* (2021) 13:525. doi: 10.3390/nu13020525

40. Bayle D, Coudy-Gandilhon C, Gueugneau M, Castiglioni S, Zocchi M, Maj-Zurawska M, et al. Magnesium deficiency alters expression of genes critical for muscle magnesium homeostasis and physiology in mice. *Nutrients.* (2021) 13:2169. doi: 10.3390/nu13072169

41. Mukherjee D, Lim WM, Kumar S, Donthu N. Guidelines for advancing theory and practice through bibliometric research. *J Bus Res.* (2022) 148:101–15. doi: 10.1016/j.jbusres.2022.04.042

42. Anker MS, Anker SD, Coats AJS, von Haehling S. The journal of cachexia, sarcopenia and muscle stays the front-runner in geriatrics and gerontology. *J Cachexia Sarcopenia Muscle.* (2019) 10:1151–64. doi: 10.1002/jcsm.12518

43. von Haehling S, Ebner N, Anker SD. Oodles of opportunities: the journal of cachexia, sarcopenia and muscle in 2017. *J Cachexia Sarcopenia Muscle.* (2017) 8:675–80. doi: 10.1002/jcsm.12247

44. Yang M, Tan L, Li W. Landscape of sarcopenia research (1989–2018): a bibliometric analysis. *J Am Med Dir Assoc.* (2020) 21:436–7. doi: 10.1016/j.jamda.2019.11.029

45. Hsu K-J, Liao C-D, Tsai M-W, Chen C-N. Effects of exercise and nutritional intervention on body composition, metabolic health, and physical performance in adults with sarcopenic obesity: a meta-analysis. *Nutrients.* (2019) 11:2163. doi: 10.3390/nu11092163

46. Hanach NI, McCullough F, Avery A. The impact of dairy protein intake on muscle mass, muscle strength, and physical performance in middle-aged to older adults with or without existing sarcopenia: a systematic review and meta-analysis. *Adv Nutr.* (2019) 10:59–69. doi: 10.1093/advances/nmy065

47. Suzan V, Suzan AA. A bibliometric analysis of sarcopenia: top 100 articles. *Eur Geriatr Med.* (2021) 12:185–91. doi: 10.1007/s41999-020-00395-y

48. Rosenberg IH, Roubenoff R. Stalking sarcopenia. *Ann Intern Med.* (1995) 123:727–8. doi: 10.7326/0003-4819-123-9-199511010-00014

49. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European working group on sarcopenia in older people. *Age Ageing.* (2010) 39:412–23. doi: 10.1093/ageing/afq034

50. Argilés JM, Campos N, Lopez-Pedrosa JM, Rueda R, Rodriguez-Mañas L. Skeletal muscle regulates metabolism via interorgan crosstalk: roles in health and disease. *J Am Med Direct Assoc.* (2016) 17:789–96. doi: 10.1016/j.jamda.2016.04.019

51. Ganapathy A, Nieves JW. Nutrition and sarcopenia-what do we know? *Nutrients.* (2020) 12:1755. doi: 10.3390/nu12061755

52. Bloom I, Shand C, Cooper C, Robinson S, Baird J. Diet quality and sarcopenia in older adults: a systematic review. *Nutrients.* (2018) 10:308. doi: 10.3390/nu10030308

53. Robinson SM, Reginster JY, Rizzoli R, Shaw SC, Kanis JA, Bautmans I, et al. Does nutrition play a role in the prevention and management of sarcopenia? *Clin Nutr.* (2018) 37:1121–32. doi: 10.1016/j.clnu.2017.08.016

54. Liu, Y, Li X, Ma L, Wang Y. Mapping theme trends and knowledge structures of dignity in nursing: a quantitative and co-word biclustering analysis. *J Adv Nurs.* (2022) 78:1980–89. doi: 10.1111/jan.15097

55. Pourhatami A, Kaviyani-Charati M, Kargar B, Baziyad H, Kargar M, Olmeda-Gómez C. Mapping the intellectual structure of the coronavirus field (2000-2020): a co-word analysis. *Scientometrics.* (2021) 126:6625–57. doi: 10.1007/s11192-021-04038-2

56. Nishikawa H, Asai A, Fukunishi S, Nishiguchi S, Higuchi K. Metabolic syndrome and sarcopenia. *Nutrients.* (2021) 13:3519. doi: 10.3390/nu13103519

57. van Dronkelaar C, van Velzen A, Abdelrazek M, van der Steen A, Weijs PJM, Tieland M. Minerals and sarcopenia; the role of calcium, iron, magnesium, phosphorus, potassium, selenium, sodium, and zinc on muscle mass, muscle strength, and physical performance in older adults: a systematic review. *J Am Med Dir Assoc.* (2018) 19:6–11.e3. doi: 10.1016/j.jamda.2017.05.026