Original Article

Advancing insights: a bibliometric analysis of evolutionary patterns and research frontiers in ultrasound-derived quantitative assessment of skeletal muscle

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Background: Quantitative ultrasound has emerged as a promising tool for measuring skeletal muscle mass and quality. Given the growing need for early detection of muscle dysfunction and sarcopenia, this study aims to provide a comprehensive bibliometric analysis of the current state of knowledge in this field, identifying key trends, gaps, and themes to guide future research and clinical applications.

Methods: A bibliometric analysis was performed on articles retrieved from the Science Citation Index-Expanded (SCI-EXPANDED) database within the Web of Science Core Collection up to April 28, 2024. The 'bibliometrix' R package was utilized to synthesize main findings, quantify the occurrences of top keywords, and visualize international collaboration networks. Keyword co-occurrence and co-authorship were analyzed utilizing VOSviewer. Additionally, CiteSpace facilitated the identification of cited references and keywords exhibiting highest citation bursts.

Results: A total of 3,379 publications were analyzed. The United States, Japan, and China emerged as the leading contributors to this field. The European Journal of Applied Physiology was identified as the most prolific journal, and Takashi Abe was distinguished for achieving the leading H-index. "Strength" and "reliability" topped the keyword frequency list. "Insulin resistance", "impact", "shear wave elastography", "risk", and "sarcopenia" were keywords that continued to burst as of 2024, which indicated the potential emerging research topics and future frontiers.

Conclusions: This bibliometric analysis, encompassing over forty years of literature on quantitative ultrasound assessment of skeletal muscle, delineated key contributions from countries, institutions, authors, and journals. The findings highlight the utility of quantitative ultrasound as a critical tool in assessing skeletal muscle mass and function, demonstrating its global impact and research trends.

Keywords: Quantitative ultrasound; skeletal muscle; bibliometric analysis; VOSviewer; CiteSpace

Submitted Aug 06, 2024. Accepted for publication Jan 15, 2025. Published online Feb 26, 2025.
doi: 10.21037/qims-24-1607
View this article at: https://dx.doi.org/10.21037/qims-24-1607

Introduction

Skeletal muscle plays a pivotal role in human health, serving not only as the primary tissue for movement and physical force but also as a significant regulator of metabolic processes and overall bodily function (1). Reduced appendicular skeletal muscle mass may result in sarcopenia: this includes age-related primary sarcopenia as well as disease-related secondary sarcopenia from diabetes mellitus, cancer, chronic obstructive pulmonary disease, or heart failure (2). Due to its portability, radiation-free, and ease of use, ultrasound has gained a significant attention for application in the quantitative assessment of skeletal muscle (3-6). Meanwhile, the body of literature on the topic is growing. A thorough bibliometric analysis of articles, nations, organizations, journals, authors, and keywords is still necessary.

Bibliometrics studies the creation and dissemination of academic literature using statistical and quantitative methods. This area of study involves compiling, arranging, and analyzing bibliographic data, including citation counts, co-authorship trends, and the journals that publish research (7). Bibliometrics provides multiple advantages, including the ability to evaluate and assess the impact of academic work, enable evidence-based reviews of scientific achievements, and chart the progression and influence of research over time. Furthermore, bibliometrics offers important insights for strategic decision-making and resource allocation inside research organizations and makes it easier to identify emerging trends, new academic fields, and cooperative initiatives (8). Bibliographic analysis and evaluation of research will continue to depend heavily on bibliometrics as the corpus of scientific knowledge increases and the importance of evaluating the impact of research grows.

The goal of this bibliometric study is to elucidate the current insights and findings concerning the quantitative assessment of skeletal muscle through ultrasonography. The following research question is addressed in this study: what is the current state of knowledge in the field of quantitative ultrasonography assessment of skeletal muscle, and what are the key themes within this body of research? A comprehensive bibliometric study was undertaken to delineate the patterns, discoveries, and gaps in the current body of research, focusing on specific variables such as the explored themes, publication counts by country and institution, the impact of journals and authors, co-citations, and keyword analysis. This research seeks to bridge the existing gaps through a synthesis of contemporary findings and trends, offering researchers, sonographers, and clinicians an exhaustive synthesis of the prevailing insights into quantitative ultrasound assessment of skeletal muscle. We present this article in accordance with the PRIBA reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1607/rc).

Methods

Data acquisition and search methodology for literature

For this study, Web of Science was chosen as the main data source, recognized for its comprehensive inclusion of over 12,000 scholarly journals and widespread usage among researchers. It provides the most thorough and dependable bibliometric analysis compared to other databases like Scopus, MEDLINE, and PubMed (9). Associated articles from the Web of Science Core Collection (WoSCC) were retrieved using the Science Citation Index-Expanded (SCI-EXPANDED) database on April 28, 2024 (10). After consultation with a senior literature retrieval expert, the authors developed a search strategy using "TI", "AB", and "AK" as field tags, focusing on "ultrasound" and "muscle indicators" (11). The detailed search formula is presented in *Table 1* and Table S1. To facilitate subsequent analysis, only articles and reviews written in English were included. Complete records and reference citations were extracted from pertinent publications and preserved in plain text format for further analysis.

Software for bibliometric analysis

This study employed R version 4.3.1 (12), VOSviewer (13), and CiteSpace (14) as the software tools for bibliometric analysis. The Bibliometrix R package (version 4.1.4) was employed to analyze a variety of metrics, including annual publication counts, high citation papers, keyword

Table 1 The search strategy summary

Items	Specification
Date of search	28 April 2024
Databases and other sources searched	SCI-EXPANDED database within the Web of Science Core Collection
Search terms used	Sarcopenia, muscular atroph*, muscle atroph*, muscle mass*, muscle size*, muscle diameter*, muscle volume*, muscle thickness*, muscle wasting, muscle quality, skeletal muscle index, ultrasonography, ultrasound, ultraso* imaging, medical sonography, echography, elastography, sonoelastography, echo intensity
Timeframe	From 1980 to 28 April 2024
Inclusion criteria	Study type: articles and reviews
	Language: English

SCI-EXPANDED, Science Citation Index-Expanded.

frequency, collaboration frequencies between countries, and publication counts by country, institution, journal, and author. Additionally, the H-index for both journals and authors was calculated (15).

Journal Impact Factor (JIF) and JIF quartile (Q1–Q4) were retrieved from the 2023 version of the Journal Citation Reports (JCR) website.

Co-authorship networks, keyword co-occurrence, and collaboration networks among countries and institutions were constructed and visualized through the embedded clustering algorithm of VOSviewer (16).

CiteSpace was employed to detect highly cited references and keywords exhibiting notable citation growth within a defined timeframe.

Utilizing the bibliometrics platform (https://bibliometric.com/), international collaborations among countries were visualized. Additionally, an exponential growth model applied in Excel facilitated the analysis of publication trends (17).

Result

Evaluation of publication trends and scholarly metrics

As illustrated in *Figure 1*, a total of 3,379 articles and reviews were encompassed in this study. *Figure 2* presents the yearly and overall publication counts pertinent to the ultrasound-derived quantitative assessment of skeletal muscle. The count of publications grew from one in 1980 to 22 by the year 2005, illustrating a gradual increment. As scholars concentrated on the subject, publication numbers surged across the subsequent 18 years, culminating at 3,379 by April 2024. The orange solid line represents the cumulative number of articles per year, while the dotted line represents the exponential growth function applied to evaluate the correlation between publication year and cumulative publications, closely matching the actual progression of cumulative publications (R^2=0.95). This robust correlation demonstrates that the field of ultrasound-derived quantitative assessment of skeletal muscle has experienced significant growth and development.

National analysis of publication contributions

An analysis of national publication counts was conducted to pinpoint which regions are most influential in this field. *Figure 3A* illustrates that the United States leads with 590 publications, with Japan (n=446), China (n=235), UK (n=210), and Brazil (n=201) trailing closely. The remaining countries/regions have fewer than 200 publications.

As part of the study, we illustrated the collaboration across nations in *Figure 3B*. The findings show that the US is at the forefront of this topic. The highest number of collaborations is observed between the US and Japan (with a frequency of 55). The following collaborators are Brazil (frequency =48), Canada (frequency =46), Australia (frequency =35), and the UK (frequency =30). All the collaborators from these nations are from the US. *Figure 3C* visually displays the aforementioned international collaborations. A co-authorship analysis of publications from the specified 33 countries (*Figure 3D*) was conducted to explore collaborative patterns. In the cluster diagram, the circle sizes directly reflect the number of publications. The degree of cooperation between the research groups in the cluster network is reflected in the line thickness. As shown

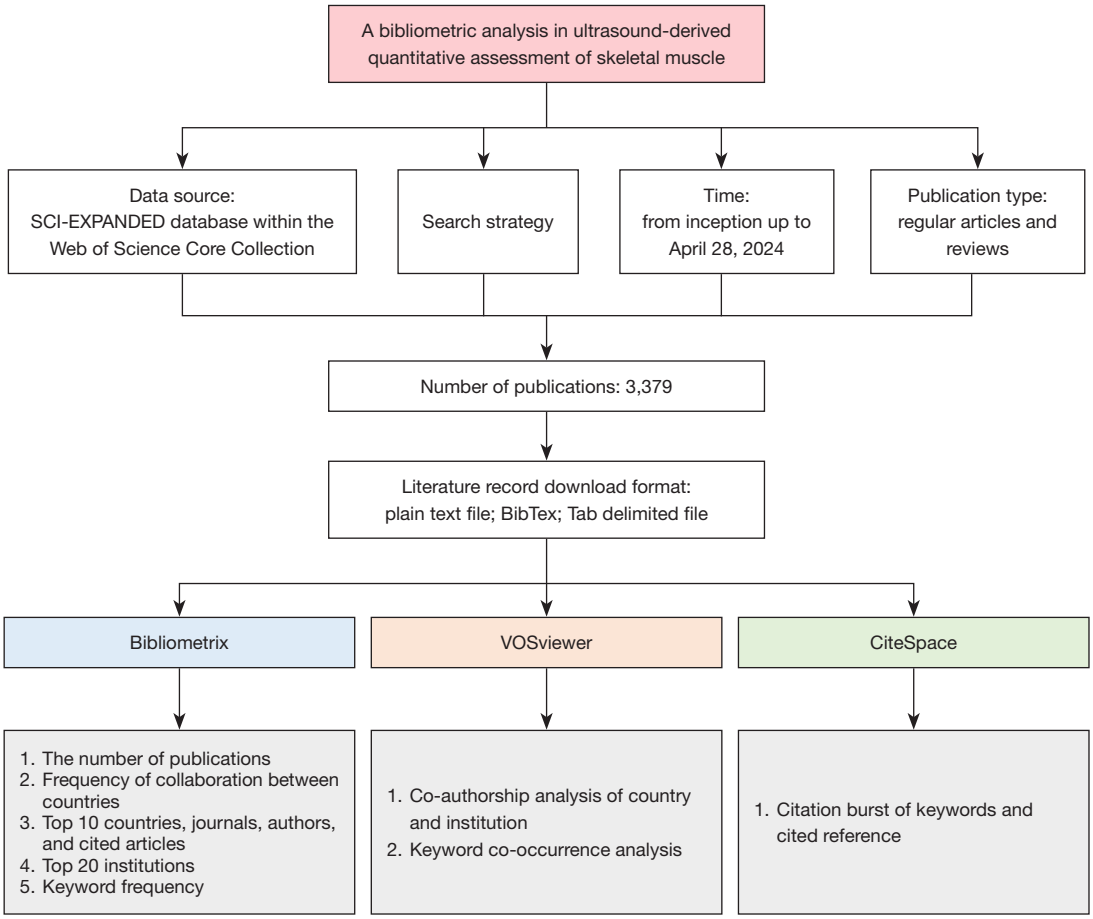


Figure 1 Study flowchart. SCI-EXPANDED, Science Citation Index-Expanded.

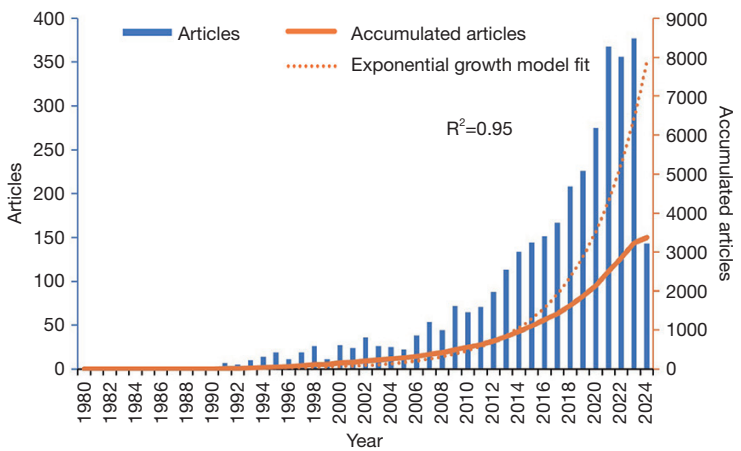
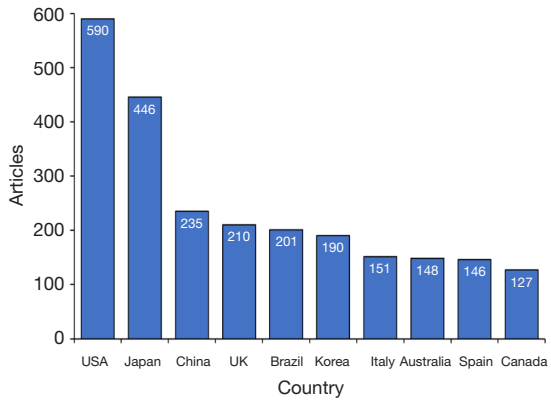


Figure 2 Number of publications annually and total amount over time.

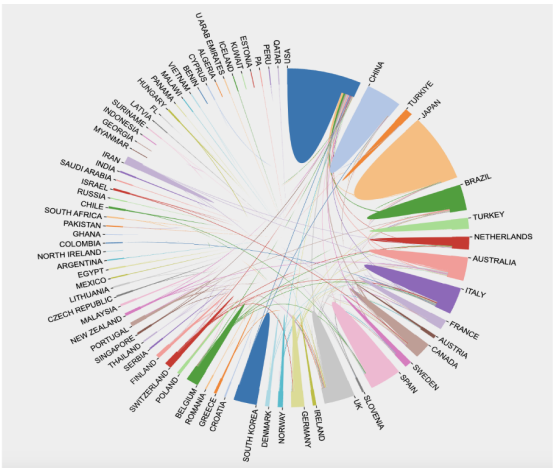
A



B

From	To	Frequency
USA	Japan	55
USA	Brazil	48
USA	Canada	46
USA	Australia	35
USA	UK	30
Brazil	Australia	29
UK	Australia	29
UK	Italy	25
Australia	Canada	18
UK	Canada	18

C



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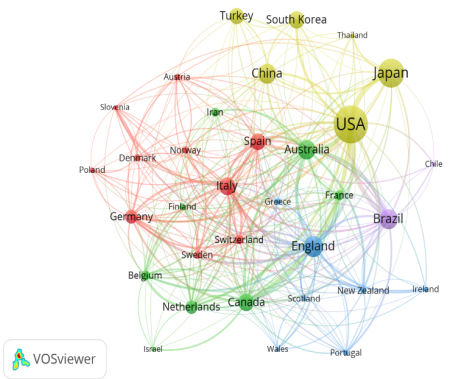

Figure 3 Country's contribution to the field of ultrasound-derived quantitative assessment of skeletal muscle. (A) Top 10 countries in the field; (B) the frequency of collaboration among nations in the field; (C) global collaborations in the field; (D) graphical representation of country co-authorship analysis by network clustering.

in *Figure 3D*, five clusters are formed by 33 countries. The red cluster includes the majority, comprising 10 countries.

Institutional analysis of publication contributions

The contributions of institutions to this field were assessed by analyzing their respective publication counts. Approximately 3,826 institutions worldwide have engaged in publishing studies on the ultrasound-derived quantitative assessment of skeletal muscle. As shown in *Figure 4A*, 4 research institutions are from Japan, three from the US, three from the UK, and the rest from other countries. With 127 articles published, Yonsei University ranked first.

A co-authorship analysis of all publications was conducted to further explore collaboration among institutions. *Figure 4B* illustrates that 75 institutions contributed a minimum of 15 papers. These institutions are grouped into eight clusters, with the largest, colored red, including 14 institutions mainly from the UK. Institutions such as the University of Tokyo and Manchester Metropolitan University have played significant roles in the initial advancements. In the time-overlapping network, the circle colors indicate the average publication year for each country within a specific research area. Since 2020, key institutions led by Hacettepe University in Turkey have increasingly become active (*Figure 4C*).

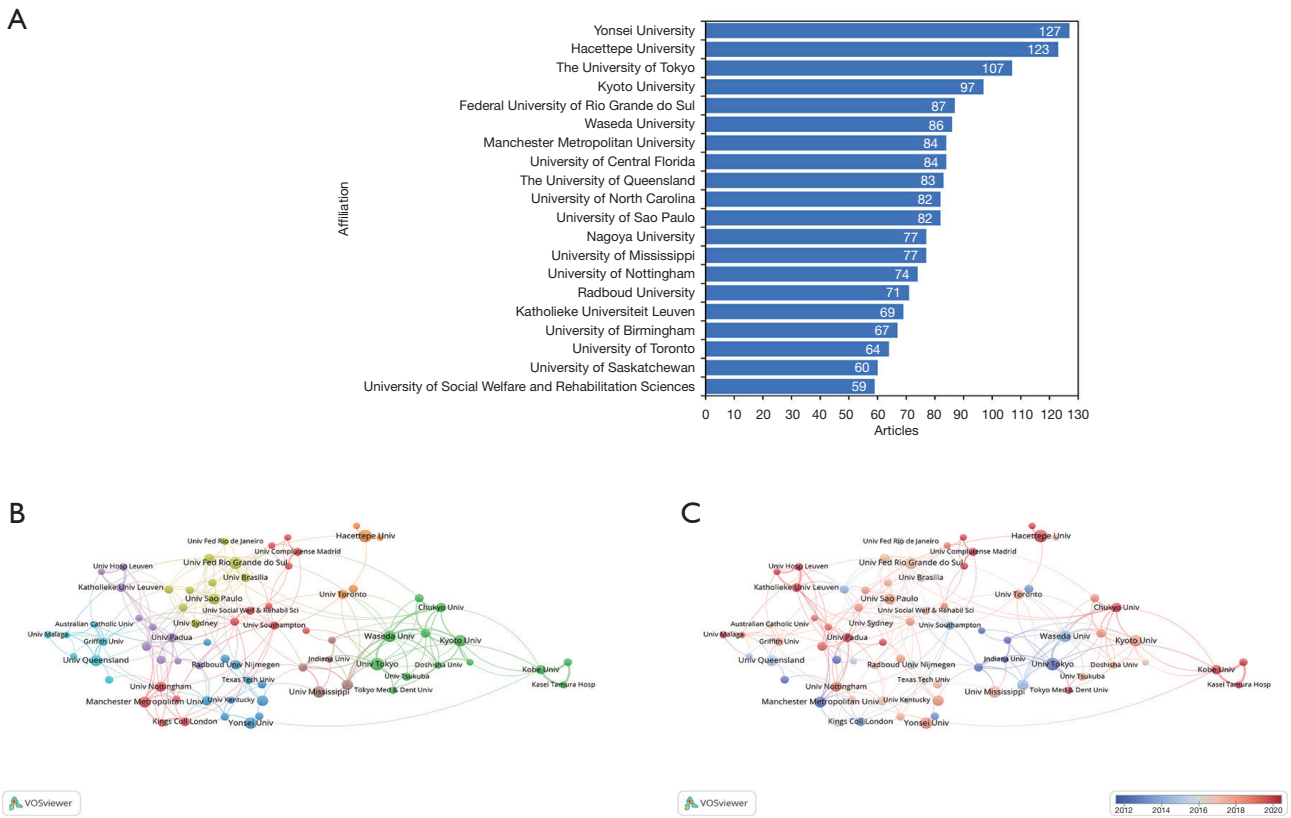

Figure 4 Institution's contribution to the field of ultrasound-derived quantitative assessment of skeletal muscle. (A) The top 20 institutions with the most publications in the field; (B) institution co-occurrence network; (C) time-overlapping co-occurrence analysis network of institutions. Univ, University; Hosp, Hospital.

Evaluation of journal impact and publication volume

The research encompassed 3,379 articles published in 821 journals. The top 10 journals, ranked by publication volume along with their recent 2023 JIF (18) are shown in *Table 2*. According to the JCR, three of the leading 10 journals ranked within the top quartile (Q1). There is one publisher each from Germany, Switzerland, and Japan, three publishers from the UK, and four publishers from the US.

Evaluation of author impact and contributions

Overall, 12,937 authors contributed to research on ultrasound-derived quantitative assessment of skeletal muscle. With 75 published articles and a 30 H-index, Takashi Abe is the most productive author, according to *Table 3*. H. Kanehisa (43 articles, H-index =22) and Jeremy P. Loenneke (45 articles, H-index =20) trailed closely behind.

Figure 5A shows the relationships between researchers who collaborate. Color denotes a cluster, whereas circle size indicates the total number of publications. Twenty-two clusters were created from sixty-five authors who had twelve or more publications. Cooperative linkages existed between the five clusters. Three clusters, apart from the more prominent community, had formed cooperative ties within it. The fact that only one or two authors were present in the remaining clusters suggests that research teams' cooperation has to be improved. *Figure 5B* displays the time-overlapping network. We noticed that US scholars are creating a new network for their studies. Future directions resulting from the insufficient cooperation between various research groups include national and institutional collaborations.

Research hotpot analysis

Most cited publications

Citation frequency within this field serves as a metric to ascertain the most referenced articles. As indicated in *Table 4*,

Table 2 Top 10 journals in the field of ultrasound-derived quantitative assessment of skeletal muscle

Rank	Source	Article	Country	JIF	H-index	JIF quartile
1	*European Journal of Applied Physiology*	86	Germany	2.8	39	Q2
2	*Muscle & Nerve*	77	USA	2.8	30	Q2
3	*Ultrasound in Medicine and Biology*	67	UK	2.4	13	Q2
4	*Journal of Strength and Conditioning Research*	66	USA	2.5	27	Q2
5	*Frontiers in Physiology*	49	Switzerland	3.2	15	Q2
6	*PLOS ONE*	47	USA	2.9	16	Q1
7	*Journal of Physical Therapy Science*	44	Japan	NA	13	NA
8	*Medicine & Science in Sports & Exercise*	42	USA	4.1	27	Q1
9	*Scientific Reports*	41	UK	3.8	10	Q1
10	*Clinical Physiology and Functional Imaging*	37	UK	1.3	17	Q4

JIF, Journal Impact Factor; NA, no available journal ranking or impact factor data for the journal.

Table 3 Top 10 authors in the field of ultrasound-derived quantitative assessment of skeletal muscle

Rank	Author	Country	Article	H-index
1	Takashi Abe	USA	75	30
2	Jeremy P. Loenneke	USA	45	20
3	H. Kanehisa	Japan	43	22
4	Tetsuo Fukunaga	Japan	39	25
5	Noriaki Ichihashi	Japan	30	18
6	Ronei Silveira Pinto	Brasil	28	16
7	Yasuo Kawakami	Japan	26	20
8	Levent Özçakar	Turkey	26	12
9	Julie A. Hides	Australia	23	16
10	Murat Kara	Turkey	23	12

each listed publication has accrued more than 350 citations, categorizing them among the top ten most cited works (2,19-27). Notably, the article titled "Acute Skeletal Muscle Wasting in Critical Illness" (19) has garnered the highest number of citations. Additionally, the second most cited publication was published in the *Clinical Rehabilitation* (20). From distinct perspectives, the two studies furnish robust evidence supporting the clinical application of quantitative ultrasound assessment of skeletal muscle.

Analysis of citation bursts

The 25 references with the highest citation counts are depicted in *Figure 6*. A citation burst is when a publication receives a significantly higher number of citations than usual, extending over a period of at least two years. The blue line tracks the observational span from 1980 to 2024, whereas the red line highlights the timeframe of the citation burst. The guideline "Sarcopenia: revised European consensus on definition and diagnosis", published in *Age and Ageing*, exhibits the most pronounced citation burst (citation burst =102.88) (28). Currently, 7 articles continue to experience significant citation bursts. Notably, "Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment", holds the burst

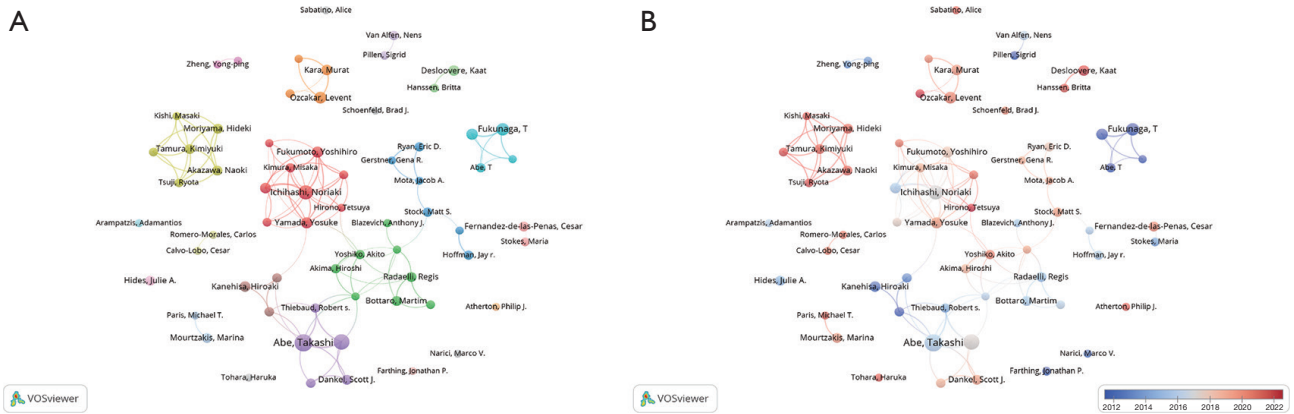

Figure 5 Visualization of co-authorship network analysis. (A) Network clustering; (B) time-overlapping network.

Table 4 Top 10 cited articles in the field of ultrasound-derived quantitative assessment of skeletal muscle

Rank	Title	Year, journal	First author	Total citations	TC per year
1	Acute skeletal muscle wasting in critical illness (19)	2013, *JAMA*	Zudin A. Puthucheary	1,158	96.50
2	Reliability of assessment tools in rehabilitation: an illustration of appropriate statistical analyses (20)	1998, *Clinical Rehabilitation*	Gabrielle Rankin	678	25.11
3	Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain (21)	1996, *Spine*	Julie A. Hides	650	22.41
4	Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain (22)	1994, *Spine*	Julie A. Hides	622	20.06
5	Measurement of muscle contraction with ultrasound imaging (23)	2003, *Muscle & Nerve*	P W Hodges	560	25.45
6	Lean tissue imaging: a new era for nutritional assessment and intervention (24)	2014, *Journal of Parenteral and Enteral Nutrition*	Carla M. M. Prado	371	33.82
7	Sarcopenia: A Time for Action. An SCWD Position Paper (2)	2019, *Journal of Cachexia, Sarcopenia and Muscle*	Juergen Bauer	367	61.17
8	Muscle volume is a major determinant of joint torque in humans (25)	2001, *Acta Physiologica Scandinavica*	T Fukunaga	366	15.25
9	Muscle-fiber pennation angles are greater in hypertrophied than in normal muscles (26)	1993, *Journal of Applied Physiology*	Yasuo Kawakami	357	11.16
10	Effect of aging on human muscle architecture (27)	2003, *Journal of Applied Physiology*	M. V. Narici	355	16.14

TC per year, total citations per year (the total number of citations a journal or article receives per year).

value of 35.72 (29).

Frequency and clustering analysis of keywords

Out of 5,288 keywords, 91 were evaluated after meeting the criterion of 50 occurrences. These keywords were combined if their meanings were comparable. The network representation of these keywords is displayed in *Figure 7A*. The size of the nodes indicates the frequency of a keyword, while the distance between them indicates the strength of a relationship. The 91 keywords were organized into three clusters to represent the important themes in ultrasound-derived quantitative assessment of s skeletal muscle. Related

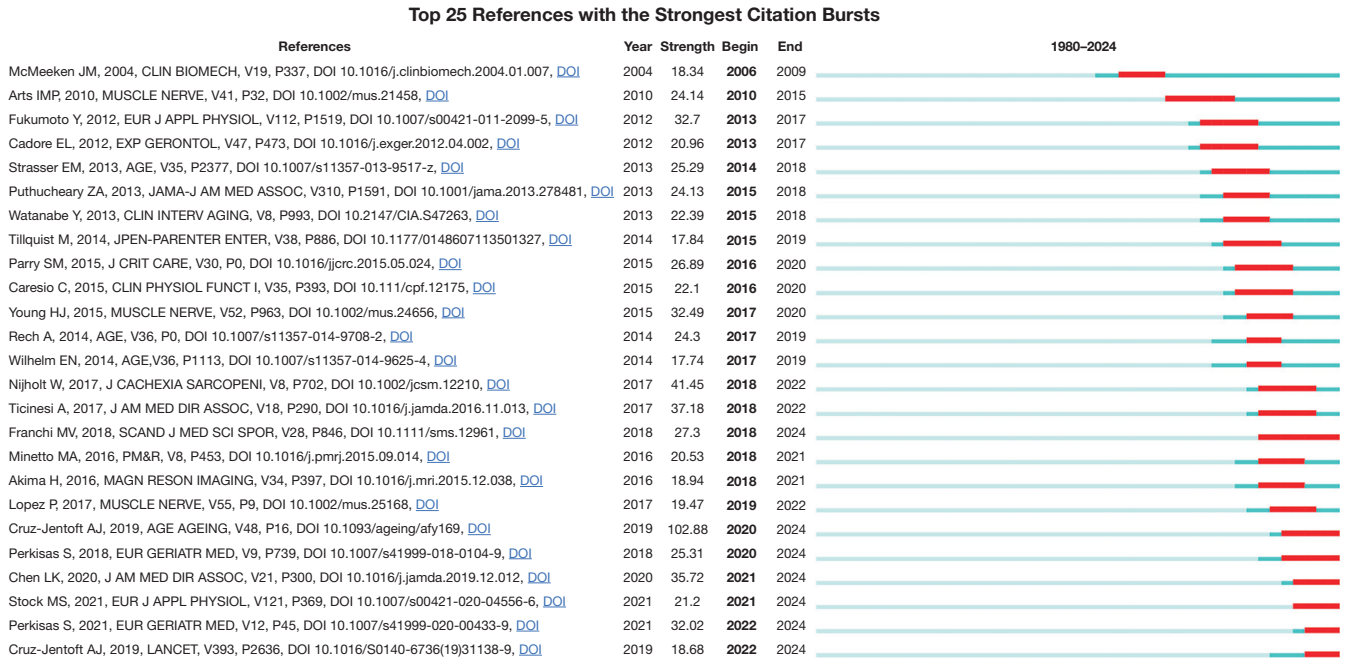

Figure 6 Top 25 most frequently cited references in the field of ultrasound-derived quantitative assessment of skeletal muscle.

keywords were grouped into clusters. Group 1, depicted in red, centered on sarcopenia, including "diagnosis", "body-composition", "aging", and "muscle mass". Group 2, represented in green, focused on ultrasonography indicators and muscle training. Relevant terms in this cluster were "skeletal muscle", "strength", "muscle thickness", and "muscle volume". Group 3, represented in blue, included diseases and symptoms evaluated by muscle ultrasound, with keywords such as "low-back-pain", "atrophy", and "stroke". The flowchart of keyword clustering based on co-occurrence analysis in VOSviewer, which summarizes the clustering process, is presented in Figure S1 in the supplementary materials. The time-overlapping of keywords is displayed in *Figure 7B*. Keywords that appeared early are shown in blue, whereas those emerging recently are in red. Initial studies focused on "electromyography", "low-back-pain", and "size". Recent studies have concentrated on topics such as "sarcopenia", "risk", "muscle quality". The top 20 keywords are shown in *Figure 7C*, ranked by frequency. "Strength" emerged as the keyword with the highest usage, recorded 726 times, followed by "ultrasound" (N=462) and "reliability" (N=446). With 258 appearances, the word "sarcopenia" ranked ninth.

Analysis of keywords bursts

The top 30 terms with the most significant citation bursts lasting over one year are shown in *Figure 7D*. The keywords "transversus abdominis" (2004–2016) attracted significant attention in its early years. In contrast, terms like "insulin resistance" (2019–2024), "shear wave elastography" (2020–2024), and "sarcopenia" (2022–2024) have emerged more recently, indicating potential future research directions.

Discussion

The growth pattern of the studies on ultrasound-derived quantitative assessment of skeletal muscle from 1980 to 2024 was examined using bibliometric methods. This field grows in two stages, depending on whether there are more than thirty publications annually for two years in a succession. A period of gradual expansion preceded 2006, except for 36 publications in 2002. There was a maximum of 26 publications in the remaining years. With more than 37 publications annually, ultrasound-derived quantitative assessment of skeletal muscle-related research has entered a rapid growth stage since 2006. By April 2024, the total publication volume has reached 3,379, the field of ultrasound-derived quantitative skeletal muscle measurement research has entered a phase of rapid development. Possible explanations for this increase could be the growing awareness of skeletal muscle dysfunction as a serious comorbidity and the developments

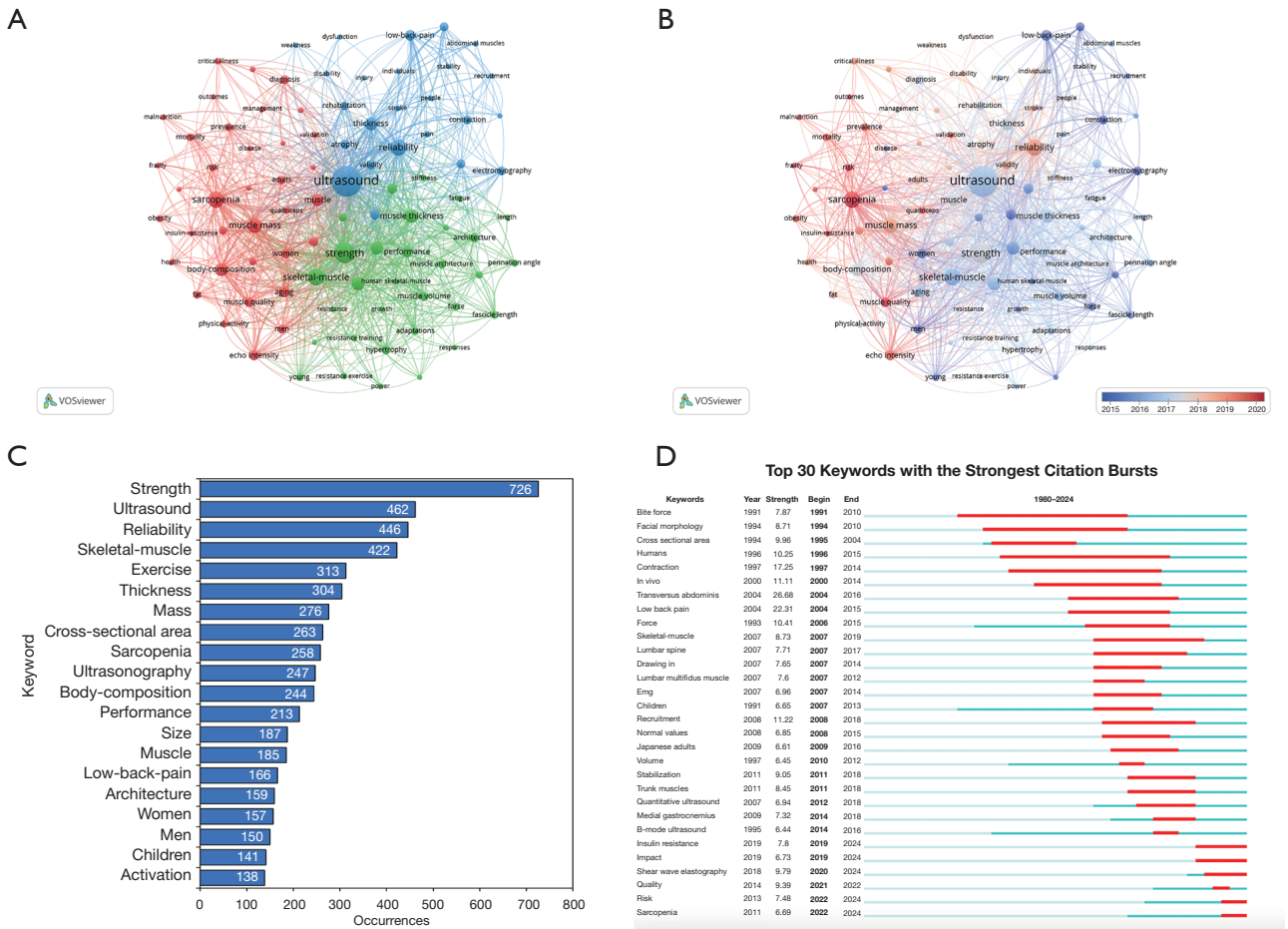

Figure 7 Research hotspots in ultrasound-derived quantitative assessment of skeletal muscle. (A) Keyword co-occurrence network; (B) time-overlapping co-occurrence analysis network of keywords; (C) list of the 20 most frequently used keywords; (D) top 30 keywords with the strongest citation bursts.

in musculoskeletal ultrasonography technologies. Therefore, research funding has increased, and research institutions have kept supporting research on ultrasound-derived quantitative skeletal muscle assessment, which has accelerated the field's development. While ultrasound has made significant advancements, magnetic resonance imaging (MRI) remains the current imaging standard for muscle assessment. It is increasingly being applied in muscle quantification, offering additional insights into muscle composition, volume, and fatty infiltration (30,31). This shift towards quantitative assessments across different imaging modalities reflects the broader trend in medical imaging towards objective, data-driven evaluations. Like the advancements in skeletal muscle imaging, other fields such as oncology and cardiology have also embraced a shift towards quantitative assessment. In oncology, imaging now extends beyond traditional qualitative measurements of size and morphology to quantify tumor volume, blood flow, stiffness, and other tissue characteristics (32-34). In cardiology, ultrasound has progressed in quantifying key aspects of heart function, such as myocardial strain and coronary artery measurements (35-37), reflecting a broader movement towards data-driven, quantitative methods in medical imaging.

In parallel to these advances, the field of ultrasound-derived quantitative assessment of skeletal muscle has witnessed significant international contributions, with certain countries playing a dominant role in shaping research trends. The top 10 countries published 2,444 papers in total, which makes up 72.33% of all articles. Out of the ten countries, the US and Japan dominate the number of publications. Moreover, US-led international

cooperation holds five positions among the 10 countries with the highest cooperation frequency. These findings validate the United States' pivotal roles and preeminent status in the quantitative assessment of skeletal muscle research by ultrasonography. Widespread international collaboration in this field will improve the standard for research quality.

The top 20 institutions are distributed quite widely throughout the world, with three research institutions in the US, three in the UK, and four in Japan. The remaining institutions are divided over several other nations. The structure of institutional distribution differs from that of the national distribution. In addition, most of these research focus on national collaboration rather than global cooperation. Even though there are just three US-based institutions, they are actively involved in worldwide cooperation. This implies that fostering broad inter-institutional collaboration could be essential for advancing research competitiveness despite economic or resource constraints.

Journals with peer review play a pivotal role in academic publishing. Valuable research findings in this field are typically published in core journals. Researchers can identify potential journals by referencing publication volumes within the field. With 86 publications, *European Journal of Applied Physiology* published the most, followed by *Muscle & Nerve* with 77. *Medicine & Science in Sports & Exercise* is the journal with the greatest impact factor (JIF 4.1). Based on their JIF, JCR classifies all journals into four quartiles (Q1–Q4). Q1 journals make up 33% of the top 10 journals by number of papers. This implies that most of the field's publications are of low quality and that there is a pressing need for superior clinical and basic research. Moreover, only one journal publisher resides in Japan, and Asian publishers are mostly absent from the top 10 journals, even though Japan and China contribute the second and third highest numbers of publications, respectively. Internationally recognized journals should be established and developed in Asia.

This study is designed to elucidate the research hotspots that have garnered significant attention over a specified period. Citation count serves as a key metric for gauging the academic impact of scholarly publications. Publications that have accrued a high number of citations typically reflect the foundational themes prevalent within a specific research domain. By analyzing citation counts and identifying publications that are frequently cited, it is possible to pinpoint the primary research hotspots. In the current analysis, the ten most cited papers span the years from 1993 to 2019, indicating a broad temporal range of influential research.

In 1998, Rankin *et al.* offered a helpful guide for doing suitable statistical analysis of a reliability research, utilizing real-time ultrasound as an example to measure muscle size (20). The authors advocated using both the Bland and Altman tests and the intraclass correlation coefficient (ICC) test for analysis of reliability studies with designs comparable to the one described. An outstanding reference for evaluating intra- and inter-operator consistency in ultrasound exams was made available by this study.

In 1996, Hides *et al.* examined the impact of low back pain on lumbar multifidus muscle size using real-time ultrasound imaging (21). They observed significant asymmetry in multifidus cross-sectional area (CSA), with the smaller muscle present on the side ipsilateral to symptoms (between-side difference of 31%±8%). However, this asymmetry was confined to a single vertebral level. Nevertheless, there was no discernible relationship between the degree of asymmetry and the severity of symptoms.

In 1993, Kawakami *et al.* observed significant correlations between muscle thickness and pennation angles for both the long (r=0.884) and medial (r=0.833) heads of the triceps, indicating that muscle hypertrophy involves an increase in fiber pennation angles (26). In 2001, Fukunaga *et al.* found that, independent of sports training, the upper arm's muscle volume is a significant factor in determining joint torque (TQ) (25). In 2003, Hodges *et al.* examined if ultrasonography might be used for estimating muscle activation (23). They observed that whereas ultrasonography can identify mild muscle activity, it is unable to distinguish between moderate and intense contractions. Thus, ultrasound has been extremely important in the field of sports medicine, especially for measuring the pennation angle, muscle thickness, and fiber length.

In 2014, the importance of lean soft tissue (LST) as an independent predictor of morbidity and mortality has been emphasized by Prado *et al.* through the growing application of imaging techniques, such as dual-energy X-ray absorptiometry, computerized tomography, MRI, and ultrasound imaging in clinical settings (24). Lean soft tissue is primarily composed of muscle. In 2013, Puthucheary *et al.* published a highly cited study titled "Acute Skeletal Muscle Wasting in Critical Illness" (19). The study discovered that muscle atrophy in critically ill patients started quickly within the first week of intensive care unit (ICU) admission, and that patients with multiple organ failure experienced more severe muscle atrophy than patients with single organ

failure. Sarcopenia is relevant because muscular mass and strength are essential for preserving physical function, mobility, and vitality. In 2019, Bauer *et al.* published an article titled "Sarcopenia: A Time for Action. An SCWD Position Paper". In this review, the authors noted that while ultrasonography is not the gold standard for sarcopenia diagnosis, ultrasonography of the quadriceps is becoming a viable tool to evaluate both the quantity and quality of muscle because it excludes intermuscular adipose tissue (2). Recently, a protocol for the application of ultrasound in sarcopenia has been developed by the European Geriatric Medicine Society (3).

Keywords encapsulate the central themes of research studies, and through co-occurrence analysis, it is possible to identify high-frequency keywords across various studies. This method facilitates the rapid identification of prevailing research trends. In the present study, the keywords "ultrasound" and "sarcopenia" emerged as the most frequent, which underscores the prominence of these topics within the field. Additionally, the keywords "muscle thickness", "muscle mass", and "muscle strength" were frequently encountered in the literature. It has been discovered that quantitative ultrasonic measurements of skeletal muscle can, to some extent, characterize muscular strength and reflect the quantity and quality of muscle. However, current knowledge regarding sarcopenia remains insufficient. Both the European and Asian Working Groups on Sarcopenia point out that sarcopenia involves not merely a considerable reduction in skeletal muscle mass and a decline in muscle function associated with aging but also necessitates the assessment of muscle quality (28,29). Furthermore, the utility of ultrasound for both qualitative and quantitative assessments of skeletal muscle is frequently underestimated by researchers. In summary, the analysis of frequently co-occurring keywords in research publications might draw attention to certain areas of interest, like sarcopenia. Increasing our knowledge of sarcopenia and the early quantitative assessment of skeletal muscle using ultrasonography can help detect sarcopenia earlier, slow the progression of the disease, and improve adverse prognoses.

The "burst detection" technique in CiteSpace identifies keywords or cited references that exhibit significant temporal variations. Researchers can investigate research hotspots by utilizing keywords and cited references with burst characteristics. In this study, "insulin resistance", "impact", "shear wave elastography", "risk", and "sarcopenia" were keywords that continued to burst as of 2024. This indicates that the quantitative assessment of diabetic sarcopenia using novel ultrasonic technologies could potentially emerge as a research hotspot in the future. Furthermore, seven cited references remained in a state of burst in 2024. Among these, two studies are updated versions of the European and Asian guidelines for sarcopenia (28,29), and two focused on ultrasound assessment of muscle thickness and muscle echogenicity (4,38). Two reviews by the Sarcopenia Special Interest Group of the European Geriatric Medicine Society were worth noting (3,39). The purpose of these two reviews was to offer an evidence-based standardization for ultrasound assessment of appendicular muscle. Through two comprehensive literature reviews, five known muscle parameters (muscle thickness, cross-sectional area, pennation angle, fascicle length, and echo intensity) and four new parameters (muscle volume, stiffness, contractile potential, and microcirculation) were defined. Additionally, various measurement techniques and locations used, as well as the different muscles assessed for these parameters, were summarized.

There are certain limitations in this study. Firstly, it exclusively considers articles and reviews written in English and indexed in the SCI-EXPANDED database. Since SCI-EXPANDED encompasses most high-quality studies, it does not influence the general trend of the findings. Secondly, high-quality studies published recently may not have received adequate recognition due to citation delays and should be updated in subsequent research. Furthermore, in selecting bibliometric indicators, this study incorporated various commonly used metrics (such as publication count, keyword co-occurrence analysis, collaboration between countries, institutions, and authors, citation burst, and keyword burst) to minimize bias that could result from relying on a single metric. The chosen indicators are considered to provide a broad and comprehensive representation of the field's development trends. This bibliometric analysis significantly contributes to the understanding of the development, hotspots, trends, and frontiers of ultrasound-derived quantitative assessment of skeletal muscle, as well as highlight areas requiring additional research. While ultrasonography has emerged as a valuable tool for evaluating both the quantity and quality of skeletal muscle, further efforts are needed to standardize assessment protocols across various ultrasound devices, muscle groups, anatomical locations, and measurement metrics. These standardization efforts will enhance the reliability and consistency of ultrasound-based muscle assessments, contributing to more robust research outcomes

and the continued advancement of the field.

Conclusions

Research on skeletal muscle assessment via ultrasound has received more attention in the last few years. The significant annual growth in publications is evidence of the field's increasing importance in research. This study identifies leading researchers and institutions globally engaged in this field. The European Journal of Applied Physiology emerges as the most prolific journal, while Takashi Abe stands out as the foremost influential author. Assessing muscle mass and quality in sarcopenia using innovative ultrasound technologies has become a promising topic to explore with the potential to become a major subject of future investigation. Consequently, a detailed overview of the development and cutting-edge advancements in the field is accessible to researchers new to this area.

Acknowledgments

We thank Leqi Shi for editing the manuscript during revision.

Footnote

Reporting Checklist: The authors have completed the PRIBA reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-1607/rc

Funding: This work was supported by the National High Level Hospital Clinical Research Funding (No. 2022-NHLHCRF-LX-01-0205), and CAMS Innovation Fund for Medical Sciences (CIFMS) (No. 2021-I2M-1-049).

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1607/coif). The authors have no conflicts of interest to declare.

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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Cite this article as: Sun Z, Tang J, Wang L, Ma J, Zhou T, Li H, Liu X, Yu X, Zhang B. Advancing insights: a bibliometric analysis of evolutionary patterns and research frontiers in ultrasound-derived quantitative assessment of skeletal muscle. Quant Imaging Med Surg 2025;15(3):1912-1926. doi: 10.21037/qims-24-1607