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Musculoskeletal Ultrasound Research Over the Past Two Decades (2005–2025): Global Bibliometric and Knowledge Network Analysis

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Abstract: *Objective*: To conduct a comprehensive bibliometric and knowledge network analysis of musculoskeletal ultrasound (MSK US) research from 2005 to 2025, with a focus on publication trends, influential authors, institutions, and thematic hotspots. *Methods*: Articles related to MSK US were retrieved from the Web of Science Core Collection using the search strategy TS = ("musculoskeletal ultrasound" OR "MSK ultrasound" OR "musculoskeletal ultrasonography") AND (tendon OR ligament). Eligible studies included English-language original research and review articles published between 2005 and 2025. Bibliometric analyses were performed using VOSviewer to evaluate publication trends, co-citation networks, author collaborations, institutional and country partnerships, and keyword co-occurrence. *Results*: A total of 570 articles (476 original research papers and 94 reviews) were included. The annual number of publications increased exponentially, peaking in 2020. Co-citation analysis identified Wakefield (2005), Naredo, and Filippucci as foundational contributors. Author collaboration networks highlighted a strong European core centered on Italy and Spain, while institutional and country analyses revealed a "Europe–North America" dual-center pattern with growing contributions from China. Keyword co-occurrence analysis revealed three main research pillars: inflammatory arthropathies, sports-related injuries, and degenerative conditions, with emerging interest in advanced imaging techniques and artificial intelligence. *Conclusion*: T MSK US research has demonstrated sustained growth and diversification over the past two decades. Europe remains a traditional leader, but increasing output from North America and Asia reflects a shift toward global, multicenter collaboration. Future research should prioritize methodological standardization, integration of novel imaging technologies, and alignment with clinically meaningful outcomes to optimize diagnostic accuracy and clinical utility.

Keywords: Musculoskeletal ultrasound; Bibliometric analysis; Research trends

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1. Introduction

Musculoskeletal ultrasound (MSK US) has become an indispensable imaging modality in rheumatology, sports medicine, and orthopedics due to its non-invasiveness, portability, and ability to provide real-time dynamic assessment of tendons, ligaments, and joints. Over the past two decades, MSK US has undergone remarkable advancements, including the development of standardized scoring systems, improved Doppler sensitivity, and integration of artificial intelligence, which have significantly enhanced its diagnostic accuracy and clinical applicability [1]. Recent guidelines, such as the 2023 EULAR recommendations, have emphasized the role of ultrasound in the diagnosis and monitoring of crystal-induced arthropathies, further consolidating its place in evidence-based clinical practice [2]. Concurrently, bibliometric analysis has emerged as a powerful tool to evaluate research trends, collaboration networks, and knowledge structures across medical specialties [3]. However, no comprehensive bibliometric study has yet systematically mapped the global research landscape of MSK US over the past twenty years. Therefore, this study aims to provide a quantitative and visualized overview of publication trends, influential authors, institutions, and thematic hotspots in MSK US research between 2005 and 2025, thereby informing future directions in clinical practice and academic collaboration.

2. Methods

2.1. Data sources and literature retrieval strategy

A systematic literature search was conducted using the Web of Science Core Collection database. The search strategy was designed to capture relevant studies on musculoskeletal ultrasound (MSK US) related to tendons and ligaments. The search terms used were: TS = ("musculoskeletal ultrasound" OR "MSK ultrasound" OR "musculoskeletal ultrasonography") AND (tendon OR ligament).

This search query ensured that articles related to musculoskeletal ultrasound, particularly those focused on tendon and ligament analysis, were included in the study.

2.2. Inclusion and exclusion criteria

The articles included in this study were published between 2005 and 2025 to analyze recent trends in the field. Only English-language articles were considered, and both original research papers and review articles were included. After the initial screening, a total of 637 articles were identified. Following further refinement based on the inclusion criteria, 570 articles were retained for the final analysis, comprising 476 original research papers and 94 review articles.

2.3. Data analysis and visualization of results

This study conducted bibliometric analysis using VOSviewer software, covering publication trends, co-citation, author co-occurrence, institutional and country collaboration networks, and keyword co-occurrence. The analysis examined the annual publication outputs from 2005–2025 to identify trends in musculoskeletal ultrasound (MSK US) research. Co-citation analysis revealed core literature and frequently cited articles, while author co-occurrence networks assessed collaboration patterns among prolific authors. Institutional and country collaboration networks highlighted key contributors and international partnerships. Keyword co-occurrence analysis identified emerging research hotspots and thematic directions. To visually represent the research landscape, the VOSviewer generated visualizations, including publication trend graphs, author co-occurrence networks, co-citation networks, institutional and country collaboration networks, and keyword co-occurrence networks.

3. Results

3.1. Publication trends

The publication trend graph illustrates the temporal evolution of research on musculoskeletal ultrasound (MSK US) between 2005 and 2025 (**Figure 1**). Overall, the annual number of publications shows a steady upward trajectory. From 2005 2010, the field was in its exploratory stage, with fewer than 15 articles published annually. Between 2011 and 2015, the output increased markedly, exceeding 20 articles per year, indicating growing academic attention. Since 2016, MSK US research has entered a rapid development phase, with annual publications consistently ranging between 30 and 50, reaching a peak of 54 in 2020. The cumulative publication output followed an exponential growth curve, with the fitted equation showing a high coefficient of determination, suggesting that the overall growth pattern aligns well with an exponential model. These findings indicate that MSK US research has maintained steady and robust growth over the past two decades, and future scholarly output in this field is expected to remain active, underscoring its increasing importance in both scientific research and clinical applications.

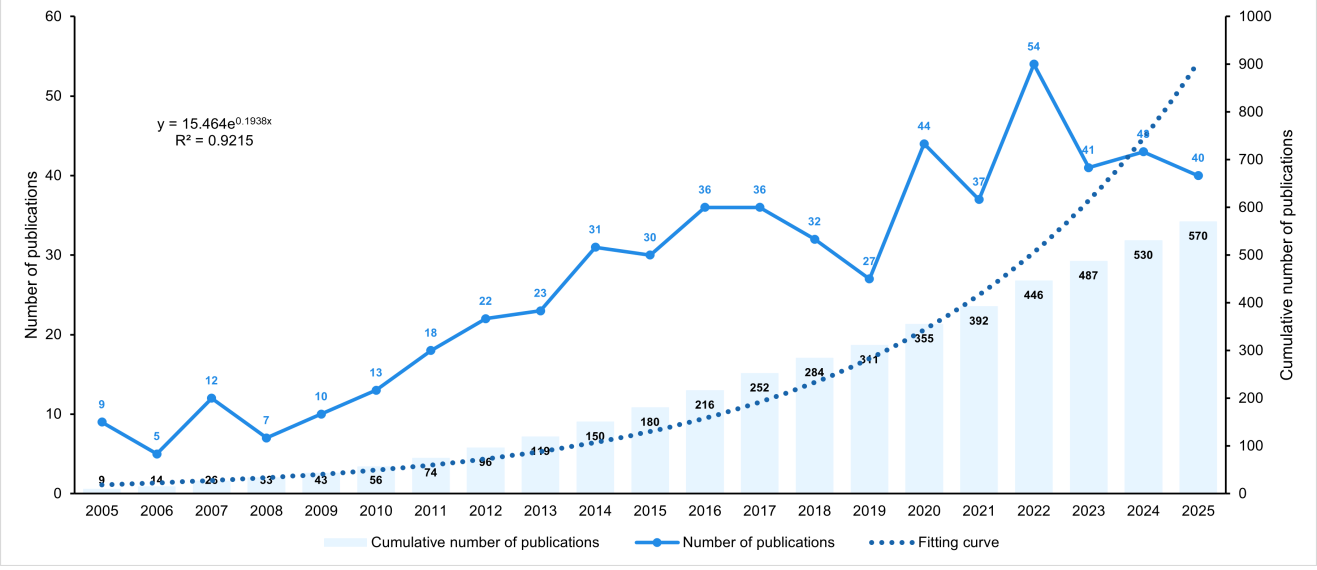

Figure 1. The publication trend graph that illustrates how research on musculoskeletal ultrasound (MSK US) has developed over the period 2005–2025.

3.2. Co-citation analysis

The co-citation network revealed the academic connections and foundational literature in the field of musculoskeletal ultrasound (MSK US) (**Figure 2**). In the network, node size represented citation frequency, and links indicated co-citation relationships. Wakefield (2005) occupied a central position, underscoring its seminal role in shaping the evolution of the field. This study was tightly clustered with the works of Naredo (2006, 2011, 2013), Gutierrez (2010, 2011), and a series of studies by Filippucci (2006–2019), reflecting their strong relevance to methodological development and clinical application. In addition, Scheel (2005) and Filippucci (2009) showed high centrality, consolidating their authoritative positions in the domain.

The network exhibited a multi-cluster structure, with distinct colors representing different research directions. The green cluster, represented by Smith (2009), Jacobson (2005, 2009), and Grant (2005), mainly focused on imaging diagnostics and technological advancements. The yellow cluster, led by Gabba (2012) and Ceccarelli

(2018), centered on inflammation and imaging manifestations. Collectively, the co-citation map illustrated the knowledge base of MSK US research, showing that early methodological studies laid the foundation for disciplinary development, while subsequent studies propelled progress through technological innovation and expanded clinical applications.

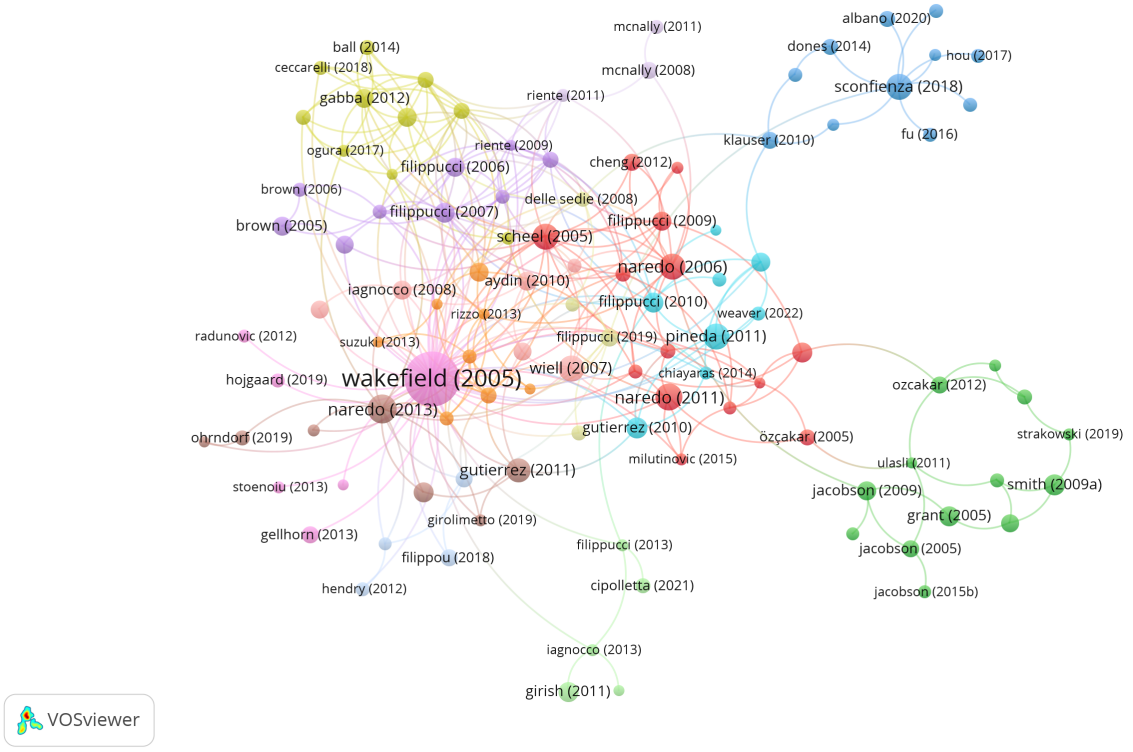

Figure 2. Through the co-citation network, the academic relationships and core literature underpinning musculoskeletal ultrasound (MSK US) were identified.

3.3. Author collaboration network

The author co-occurrence network reflected the collaborative relationships and academic structures among scholars in the field of musculoskeletal ultrasound (MSK US) (**Figure 3**). At the core of the network, Filippucci, Emilio, Grassi, Walter, and Naredo, Esperanza formed a central collaboration cluster, demonstrating a high concentration of research output and academic influence. They were closely connected with Gutierrez, Marwin, Guerrero, Tomas, and Hernandez-Diaz, Cristina, highlighting the concentrated development of MSK US research in European countries, particularly Italy and Spain.

Different colors in the network represented distinct collaborative subgroups. The green cluster, led by Fodor, Daniela and Vlad, Violeta, reflected the contributions of Eastern European scholars. The purple cluster, dominated by Ceccarelli, Fulvia and Valesini, Guido, emphasized collaborations in clinical research and applied studies. The blue cluster, including Caso, Francesco and Salvarani, Carlo, was more closely associated with emerging research topics.

Overall, the author collaboration network demonstrated a transnational academic structure centered on European scholars. It not only highlighted the leading role of core authors but also underscored the diversity and tightness of regional and international collaborations in the field.

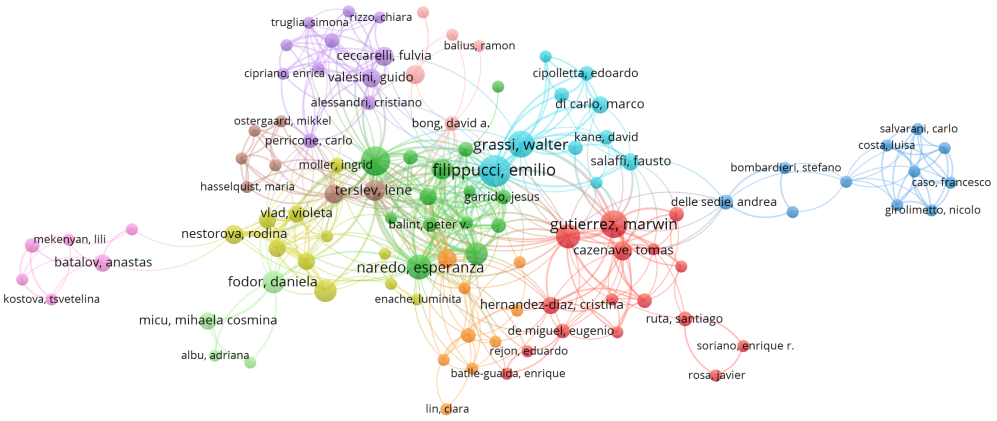

Figure 3. Author co-occurrence network.

3.4. Institutional and country collaboration networks

The country co-occurrence network demonstrated the academic contributions and international collaborations among countries in the field of musculoskeletal ultrasound (MSK US) (**Figure 4**). The United States, Italy, and Spain occupied central positions in the network, with high publication output and frequent collaborations, reflecting their leading roles in this domain. In recent years, China has shown a steady increase in research contributions and has maintained close collaborations with both the United States and European countries. Distinct clusters revealed regional cooperation patterns, such as a European cluster centered on Italy, Spain, and France, and a North American cluster led by the United States and Canada. Countries such as Turkey, Belgium, and the Netherlands also played notable roles in regional collaboration. Meanwhile, East Asian countries like Japan and South Korea, though producing fewer publications, have gradually enhanced their academic influence through collaborations with China and Western countries. Overall, the network structure highlighted the strong research foundation and leadership of Western countries, while also reflecting the rapid rise of emerging nations, which is driving the internationalization and multi-center development of the field.

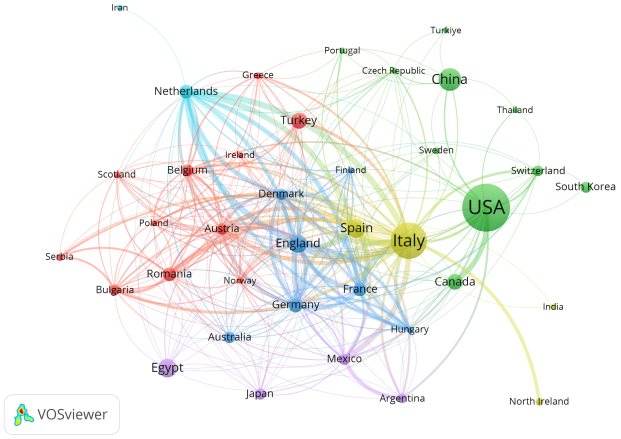

Figure 4. Country co-occurrence network.

The institutional co-occurrence network further revealed collaborations among leading global research institutions. Italian universities such as Univ Politecn Marche, Univ Pisa, and Univ Roma La Sapienza formed the core of the network, establishing a highly cohesive European academic cluster (**Figure 5**). Univ Genoa and Univ Milan were closely connected with these institutions, underscoring Italy's central role in this research area. In contrast, American institutions, including Mayo Clinic and Univ Michigan, formed a relatively independent cluster but maintained collaborations with Boston Univ and Univ Pittsburgh, reflecting the strength of U.S. institutions in clinical applications. In addition, Hacettepe Univ (Turkey), Taiwan Univ (Taiwan, China), and Univ Toronto (Canada) served as important regional nodes in the collaboration network. Collectively, the structure revealed a "Europe–North America" dual-center pattern, with Europe demonstrating strengths in methodological and foundational research, while North America played a leading role in clinical applications and dissemination.

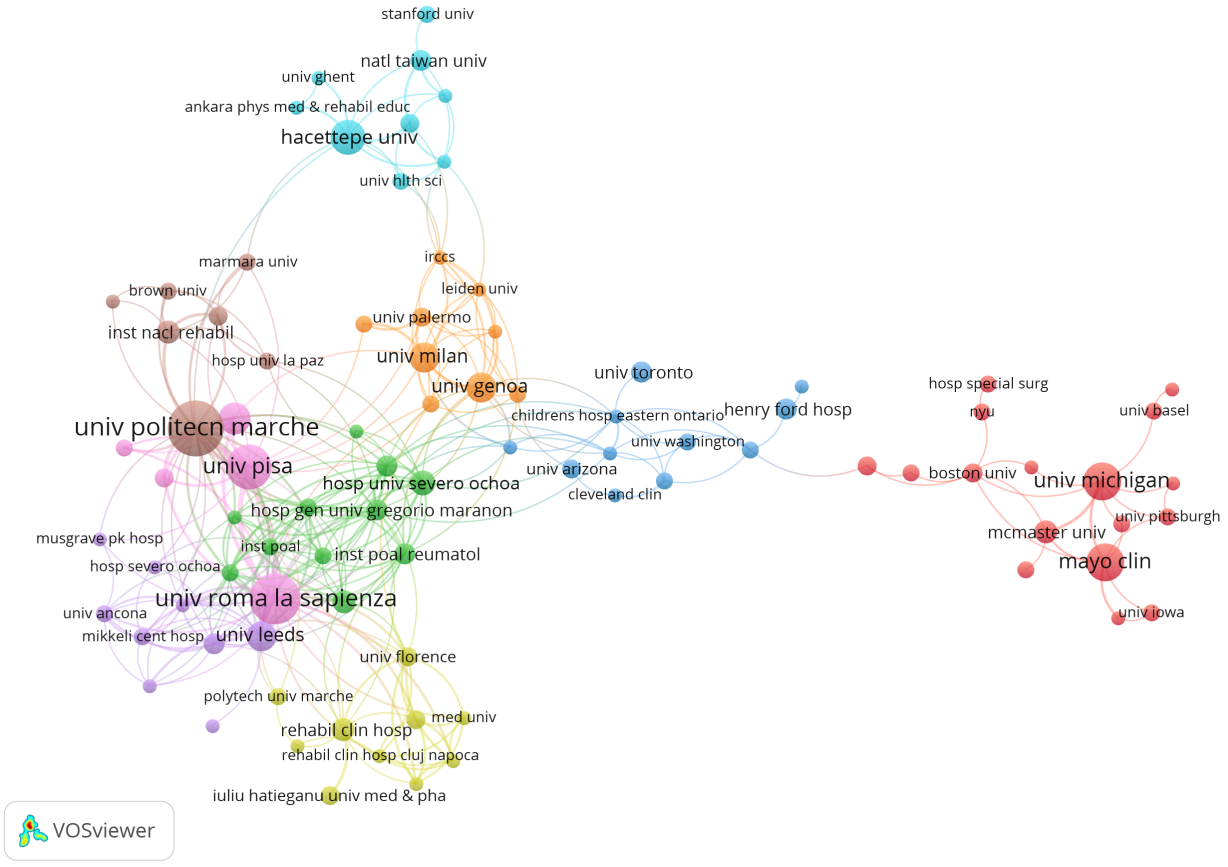

Figure 5. Institutional co-occurrence network.

3.5. Keywords co-occurrence analysis

The keyword co-occurrence network revealed the evolution and clustering of research themes in musculoskeletal ultrasound (MSK US) (**Figure 6**). "Musculoskeletal ultrasound," "ultrasound," and "ultrasonography" occupied the core positions in the network, with the highest frequency and centrality, underscoring that the main focus of this field lies in the clinical applications and imaging value of MSK US. Several thematic clusters were identified. The green cluster centered on "synovitis," "tenosynovitis," and "rheumatoid arthritis," reflecting the focus on the ultrasound diagnosis of inflammatory diseases. The red cluster highlighted "tendon," "shoulder," and "rotator

cuff," emphasizing musculoskeletal injuries, sports medicine, and rehabilitation. The blue cluster, represented by "ankle" and "Achilles tendon," related to lower limb joint disorders. The yellow cluster connected to "osteoarthritis" and "reliability," indicating attention to degenerative diseases and the consistency of diagnostic evaluations.

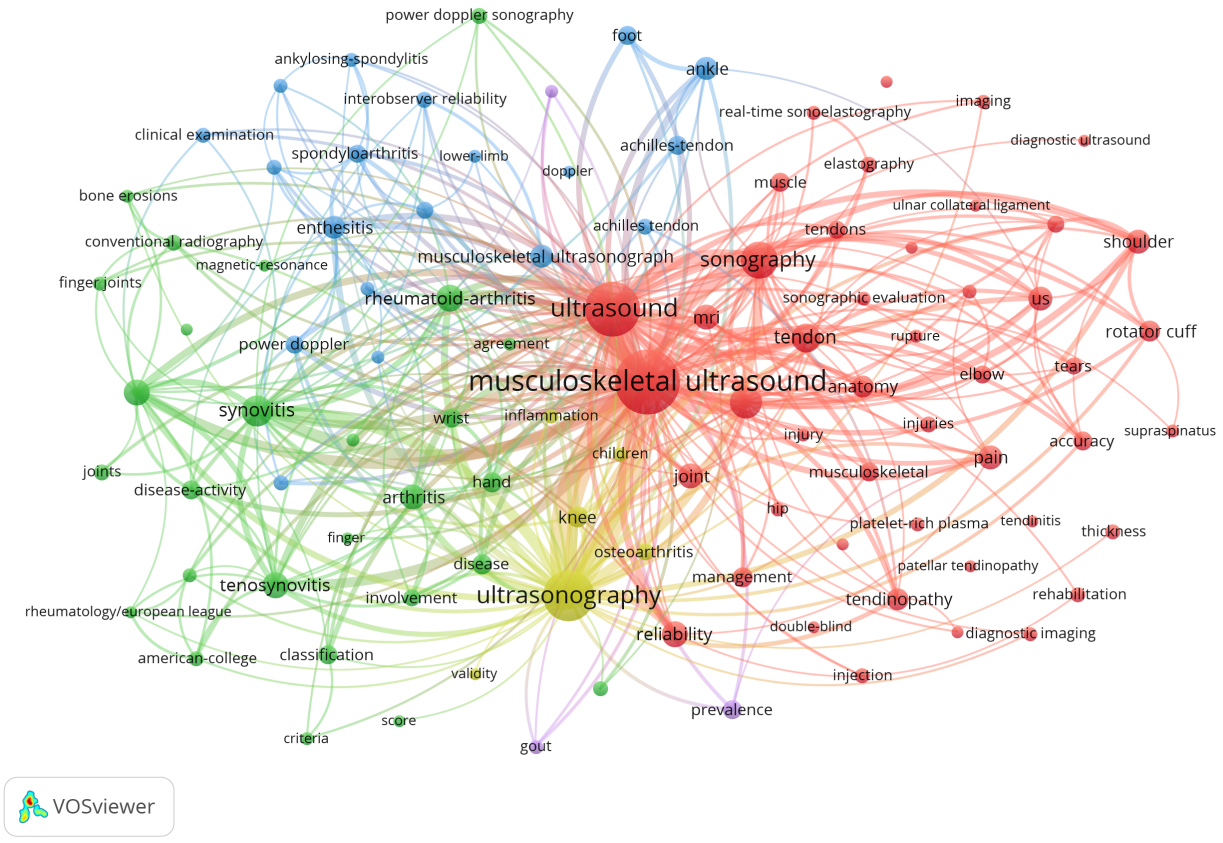

Figure 6. Keyword co-occurrence network.

Table 1 further confirmed these findings by listing the most frequent keywords. "Musculoskeletal ultrasound" ranked first with 293 occurrences, followed by "ultrasonography" (111), "rheumatoid arthritis" (97), and "ultrasound" (76). Other frequently used terms included "diagnosis" (60), "sonography" (52), and "Achilles tendon" (45), highlighting the dual emphasis on methodological terms and clinical conditions. Keywords such as "tendon" (35) and "pain" (35) also appeared among the top ten, reflecting growing interest in musculoskeletal injuries and patient-reported outcomes. Taken together, the keyword analysis demonstrated a diversified research landscape in MSK US, encompassing the diagnosis of inflammatory and degenerative diseases, the evaluation of sports-related injuries, and methodological optimization aimed at enhancing imaging reliability.

Table 1. Top 10 keywords by co-occurrence frequency

Rank	Frequency	Centrality	Time	Keyword
1	293	0.05	2005	Musculoskeletal Ultrasound
2	111	0.09	2005	Ultrasonography
3	97	0.07	2005	Rheumatoid Arthritis
4	76	0.15	2005	Ultrasound
5	60	0.16	2005	Diagnosis
6	52	0.12	2005	Sonography
7	45	0.18	2005	Achilles Tendon
8	36	0.16	2005	Us
9	35	0.08	2010	Tendon
10	35	0.05	2014	Pain

3.6. Top authors, institutions, and journals

The bibliometric analysis identified the most influential authors, institutions, and journals in the field of musculoskeletal ultrasound (MSK US) (**Table 2**). Among authors, Filippucci, Emilio ranked first with 14 publications, 889 citations, and an average of 63.5 citations per article, followed by Iagnocco, Annamaria (12 articles, 639 citations) and Gutierrez, Marwin (11 articles, 544 citations). Grassi, Walter (10 articles, 502 citations) and Naredo, Esperanza (9 articles, 648 citations, average 72 citations) were also highly influential. Notably, Terslev, Lene achieved the highest average citation rate (93.7 citations per article) despite having fewer publications, highlighting the quality and impact of her contributions.

Table 2. Top 10 authors by publication output

Author name	Total number of articles	Total citations	Average citations
Filippucci, Emilio	14	889	63.5
Iagnocco, Annamaria	12	639	53.25
Gutierrez, Marwin	11	544	49.4545
Grassi, Walter	10	502	50.2
Naredo, Esperanza	9	648	72
Pineda, Carlos	8	353	44.125
Micu, Mihaela C.	7	123	17.5714
Fodor, Daniela	7	93	13.2857
Moeller, Ingrid	7	597	85.2857
Terslev, Lene	6	562	93.6667

Institutional analysis showed that Italian universities played a leading role in MSK US research (**Table 3**). Univ Politecn Marche ranked first with 31 publications and 1,879 citations, followed by Univ Roma La Sapienza with 26 publications and the highest total citations (2,340) and average citations (90 per article). Univ Pisa also contributed significantly with 21 publications. Outside Italy, Univ Michigan and Mayo Clinic (both with 16

publications) were the most productive institutions in the United States. Other notable contributors included Hacettepe Univ (Turkey, 14 articles) and Univ Leeds (UK), which demonstrated outstanding impact with 1,740 citations from only 11 publications (average 158.2 citations per article).

Table 3. Top 10 institutions by publication output

Institution name	Total number of articles	Total citations	Average citations
Univ Politecn Marche	31	1879	60.6129
Univ Roma La Sapienza	26	2340	90
Univ Pisa	21	726	34.5714
Univ Michigan	16	391	24.4375
Mayo Clin	16	384	24
Hacettepe Univ	14	425	30.3571
Univ Pavia	12	334	27.8333
Univ Milan	11	407	37
Univ Leeds	11	1740	158.1818
Univ Genoa	11	382	34.7273

Journal analysis revealed that publications were concentrated in several specialized outlets (**Table 4**). Catheterization and Cardiovascular Interventions led with 33 publications, followed by Headache (29) and Cephalalgia (25). In terms of academic influence, Stroke stood out with 1,796 citations across 13 publications, averaging 138.2 citations per article. Other journals with notable contributions included Neurology (848 citations, 16 publications), Journal of Headache and Pain, and European Journal of Neurology.

Table 4. Top 10 journals by publication output

Journal Name	Total Number of Articles	Total Citations	Average Citations
Catheterization and Cardiovascular Interventions	33	757	22.9394
Headache	29	681	23.4828
Cephalalgia	25	932	37.28
Frontiers In Neurology	22	158	7.1818
Neurological Sciences	21	217	10.3333
Neurology	16	848	53
Journal of Headache and Pain	15	467	31.1333
Stroke	13	1796	138.1538
European Journal of Neurology	10	158	15.8
International Journal of Cardiology	10	171	17.1

4. Discussion

Musculoskeletal ultrasound (MSK US) has developed rapidly over the past two decades, with steadily

increasing publication outputs from 2005–2025. The bibliometric patterns observed in this study reflect not only technological advances but also paradigm shifts in evidence-based imaging, methodological standardization, and interdisciplinary collaboration. In this discussion, we interpret these findings in the context of recent high-impact literature, highlight methodological and clinical implications, and propose directions for future research.

The exponential growth of MSK US publications underscores the maturation of the field. Beyond hardware improvements, a major driver has been the establishment of evidence-based frameworks. The 2023 EULAR recommendations on imaging in crystal-induced arthropathies have provided graded evidence for the diagnostic and monitoring value of US in gout and calcium pyrophosphate deposition disease [2]. This guidance has increased the consistency of study design, enhanced comparability across trials, and positioned MSK US as an essential tool in both research and clinical pathways. Such evidence-based endorsement explains why research output has continued to accelerate and become more impactful in recent years.

Operator dependence and variability in acquisition and interpretation have historically limited the generalizability of MSK US research. Recent advances highlight a shift from "can do" to "do well." Scoring systems: Composite measures such as GLOESS (Global OMERACT-EULAR Synovitis Score) have been validated across diseases. In hand osteoarthritis, GLOESS performed comparably to single synovial hypertrophy scores in detecting change, demonstrating that composite metrics are not inherently superior but must be tailored to disease context [4].

Training and competency: Structured curricula and standardized assessment tools such as OSAUS, EULAR training frameworks which can now provide evidence of reliability and validity, allowing cross-institutional comparability [5,6]. These developments facilitate multicenter research, enhance reproducibility, and improve translation of imaging results into clinical practice.

The past three years have witnessed remarkable progress in advanced imaging techniques. Ultrafast Doppler (UFD) significantly improves sensitivity for detecting early synovitis and low-grade vascularity, which are often missed by conventional power Doppler. Although promising, specificity thresholds need refinement to avoid overdiagnosis [1]. Shear-wave elastography (SWE) has shown consistent reductions in velocity in diseased tendons compared to healthy controls. A recent meta-analysis highlighted high heterogeneity and low certainty of evidence, underscoring the urgent need for standardized acquisition protocols and large-scale prospective cohorts [7]. Contrast-enhanced ultrasound (CEUS) provides quantitative perfusion data for muscles, tendons, and inflamed joints. However, the lack of unified analytic parameters and reference thresholds currently limits routine clinical adoption [8]. 3D ultrasound and AI represent the frontier of integration. A systematic review reported that AI models for rotator cuff pathology on US and MRI achieved diagnostic accuracy comparable to expert radiologists [9]. Meanwhile, 3D US of the shoulder has demonstrated favorable diagnostic performance and could improve standardization of volume measurements [10]. Nevertheless, external validation, dataset bias, and interpretability remain obstacles for widespread clinical application.

Our keyword and co-citation analyses showed three major research pillars: inflammatory arthropathies, sports-related injuries, and degenerative conditions. Convergence: In crystal-induced arthropathies, imaging features such as the double contour sign and hyperechoic deposits have been validated and incorporated into clinical decision-making pathways [2]. This demonstrates a successful translation from imaging detectability to clinical actionability.

Divergence: For rotator cuff disease, the literature remains divided. Some studies advocate US as a cost-effective first-line imaging modality [10], while systematic reviews indicate MRI retains superior sensitivity and

overall diagnostic accuracy [11]. The appropriate imaging strategy should therefore be contextualized, depending on clinical questions, resource availability, and pre-surgical requirements.

Collaboration analyses revealed a dense European core, particularly in Italy and Spain, where early methodological frameworks and training initiatives fostered cohesive research communities. Italian institutions such as Univ Politecn Marche and Univ Roma La Sapienza were central hubs, consistent with their high publication and citation output. In parallel, North America and China have rapidly expanded both productivity and collaboration intensity. Importantly, interdisciplinary work incorporating AI, biomechanics, and biomedical engineering has emerged as a growth engine, potentially enabling multicenter data sharing and external validation of novel algorithms [6]. This trend suggests a transition from a Eurocentric landscape to a truly multicenter, international research ecosystem.

The integration of bibliometric findings with recent advances yields several practical implications: Prioritize standardization over complexity: Composite scores should be adopted cautiously and only when they provide clear gains in sensitivity or responsiveness [4]. Link quantification to outcomes: SWE and CEUS metrics must be validated against clinical endpoints such as pain, function, and structural progression [1,7]. Real-world validation for AI: Translation of AI into practice requires prospective, multicenter trials and continuous post-deployment monitoring [9]. Contextualized decision-making: For common clinical scenarios such as rotator cuff tears, ankle or Achilles injuries and inflammatory arthritis. Tiered pathways starting with US and escalating to MRI, CEUS, or UFD when appropriate may optimize both diagnostic yield and cost-effectiveness [10,11].

This bibliometric study was restricted to the Web of Science Core Collection and English-language publications, which may have excluded relevant literature from other databases or languages. In addition, the focus on tendon and ligament topics potentially underestimated contributions from other MSK US subfields, such as neuromuscular and oncologic imaging. Visualization parameters, including clustering algorithms and thresholds, may also influence network outputs. Future work should incorporate multiple databases, non-English literature, and sensitivity analyses of visualization parameters to enhance robustness.

5. Conclusion

Over the past 20 years, MSK US research has grown into a robust and diversified field characterized by methodological standardization, technological innovation, and expanding international collaboration. While Europe remains a traditional leader, emerging contributions from North America and Asia are reshaping the landscape into a more globalized, multicenter enterprise. Future progress will depend on aligning technical advances with standardized protocols, clinically meaningful outcomes, and globally validated decision-making frameworks.

Disclosure statement

The authors declare no conflict of interest.

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