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What Is the Current Landscape and Future Direction of Frailty Research?

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Abstract

Frailty is a significant concern in geriatrics, associated with increased risks of disability, hospitalization, and mortality in older adults. This bibliometric analysis examined 171 peer-reviewed articles from 2003 to 2025 using VOSviewer and Bibliometric to identify major research trends, thematic clusters, and emerging directions in frailty parameter studies. Four key clusters emerged: mobility and gait, muscle biomarkers, clinical assessment tools, and intervention strategies. The findings reflect a growing interdisciplinary focus and highlight the need for culturally adapted research in low- and middle-income countries to support improved health outcomes and targeted policies for aging populations.

Keywords: Frailty; Older adults; Bibliometric analysis; Sarcopenia

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1.0 Introduction

Frailty in older adults has emerged as a critical construct in geriatric medicine, representing a state of increased vulnerability due to age-related declines across multiple physiological systems. As populations worldwide continue to age at an unprecedented rate, frailty has gained increasing attention not only for its clinical implications, such as heightened risks of disability, hospitalization, and mortality, but also for its potential reversibility through timely interventions. This growing recognition has spurred extensive research into the parameters that define frailty, including physical, cognitive, and psychosocial dimensions. Understanding these multidimensional aspects is essential for developing effective strategies to enhance functional independence and improve the quality of life among older populations.

The global surge in frailty research is particularly evident in regions experiencing rapid demographic aging, such as Asia. Countries like Japan, China, and South Korea have made significant strides in adapting and validating frailty assessment tools within their unique cultural and healthcare contexts. In Southeast Asia, Malaysia is approaching a critical phase, with its elderly population projected to double within the next two decades. This epidemiological shift underscores the urgency of addressing frailty as a public health priority. Bibliometric analysis provides a valuable approach to map the intellectual landscape of frailty research, identifying key themes, influential

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works, and emerging trends that inform future studies and policy development. Therefore, this study aims to analyze the current research landscape of frailty parameters among older adults through a bibliometric approach using the Web of Science database (2003–2025). The study specifically seeks to identify major research trends and influential publications, map thematic clusters and conceptual structures, and determine emerging directions and research gaps, particularly within low- and middle-income contexts such as Malaysia. This analysis offers a concise yet comprehensive overview of how frailty has been conceptualized and assessed, providing insights that can guide future geriatric research and practice.

2.0 Literature Review

Frailty has evolved from a purely physical construct to a multidimensional syndrome encompassing biological, cognitive, and psychosocial domains. Early frameworks such as the Fried Frailty Phenotype (Fried et al., 2001) emphasized physical indicators like weight loss, weakness, and slow gait. Recent models, however, have expanded this view by integrating biological markers, cognitive decline, and psychosocial components to capture frailty's complexity more comprehensively (Dent et al., 2022; Kojima et al., 2023). This reflects a growing understanding that frailty results from cumulative physiological decline influenced by nutrition, inflammation, and social determinants of health.

In the past five years, studies have highlighted the close relationship between frailty and sarcopenia, emphasizing muscle mass, strength, and gait speed as core diagnostic parameters. Research by Cruz-Jentoft et al. (2023) and Vellas et al. (2021) demonstrated how incorporating sarcopenia measures enhances frailty detection and intervention outcomes. Likewise, Chen et al. (2022) confirmed that multimodal interventions targeting muscle function can slow frailty progression. These findings extend earlier work Stangl-Kremser et al., 2019) by integrating modern assessment tools such as gait sensors and digital monitoring systems (Liu et al., 2021; Ruiz-Ruiz et al., 2021).

While high-income countries dominate frailty research, there is increasing attention toward context-specific approaches in low- and middle-income countries (Woo et al., 2020; Clegg & Rockwood, 2024). In Southeast Asia, Malaysia faces unique demographic and cultural challenges requiring localized adaptation of frailty models. Studies by Shahar et al. (2018) and Zainal & Azizan (2024) highlighted growing awareness yet limited standardization in assessment practices. More recent Malaysian studies have explored community-based frailty screening (Hairi et al., 2020) and nutrition-related frailty prevention (Shahar et al., 2021), reflecting regional efforts to integrate clinical, behavioral, and digital elements in frailty assessment and management.

Overall, the literature reveals a shift from traditional physical indicators toward integrated biopsychosocial frameworks. Nonetheless, the translation of these findings into practice remains limited, particularly in developing regions. This gap forms the basis of the present bibliometric analysis, which aims to map the global research landscape and emerging directions of frailty parameter studies.

3.0 Methodology

3.1 Bibliometric Analysis

This study employed a bibliometric analysis approach with an emphasis on science mapping to investigate the research landscape concerning frailty parameters in older adults. Science mapping, a subset of bibliometric techniques, allows for the visualization of relationships among authors, institutions, keywords, and research themes. It provides insights into the structure, development, and dynamics of a scientific field over time.

In this study, particular focus was placed on bibliographic coupling to identify current research themes and keyword co-occurrence analysis to explore the conceptual structure and emerging trends related to frailty parameters. These advanced techniques were selected for their ability to uncover intellectual and thematic linkages within the field, offering a deeper understanding of how frailty is conceptualized and assessed in geriatric research.

3.2 Procedural Analysis

The data for this bibliometric analysis were retrieved on 29 May 2025 from the Web of Science, using a structured and strategically developed search query. The search was conducted within the Title field to ensure a focused and topic-specific dataset, capturing articles where the key concepts were central to the study. The following Boolean search string was applied: ("frailty" OR "vulnerability in older adult" OR "age-related decline" OR "frail" OR "sarcopenia" OR "functional impairment") AND "parameter*.". This combination of keywords was carefully chosen to reflect the multifaceted nature of frailty and its common descriptors in geriatric research.

To ensure consistency and quality, the search was limited to publications written in English and categorized under the document types "Article" or "Review Article". These filters were applied to maintain a high level of scientific rigor, focusing on peer-reviewed and original research that directly contributes to the academic discourse on frailty assessment. The initial search yielded 171 documents, which formed the dataset for analysis.

The inclusion criteria for this study were defined as follows: (1) publications written in English, (2) limited to original research articles and review articles, and (3) studies with titles explicitly referencing frailty-related constructs and parameters. Conversely, the exclusion criteria involved the removal of all non-English publications, as well as document types such as conference abstracts, letters, editorials, commentaries, and book chapters, which often lack comprehensive methodological detail and are not always peer reviewed.

The final dataset of 171 records was manually screened for duplicates and non-relevant entries. These records were then subjected to bibliometric and science mapping analyses using tools such as VOSviewer and the Bibliometrix R package, which facilitated the

generation of co-authorship networks, bibliographic coupling clusters, and keyword co-occurrence maps. These tools enabled the identification of major contributors, emerging themes, and research gaps within the field, thereby aligning with the overall objective of mapping the scientific landscape of frailty parameters in geriatric research.

4.0 Results and Findings

4.1 Main information

The bibliometric analysis identified a total of 171 documents published across 109 scholarly sources, reflecting a growing global interest in frailty parameters among older adults. These publications involved 1,188 authors, with an average of 7.62 co-authors per document, underscoring the collaborative nature of research in this field. International collaboration was evident, with 24.56% of the documents involving cross-country partnerships. The dataset contained 481 author-defined keywords and 6,195 cited references, indicating a rich conceptual foundation and strong scholarly engagement. On average, each document received 16.08 citations, underscoring the relevance and impact of this body of research within the fields of geriatric and aging studies.

Fig.1: Main *information*

As illustrated in Figure 2, the annual production of research related to frailty has increased steadily since 2003, with a notable acceleration beginning around 2011. This upward trend reflects heightened awareness of aging-related health challenges and the development of standardized assessment tools for frailty. By 2025, cumulative research output reached its peak, signaling a mature and rapidly expanding field. The average document age of 4.26 years suggests that most studies have been published recently, aligning with the increasing recognition of frailty as a key construct in geriatric medicine. This growth trajectory underscores both academic momentum and the translational importance of frailty assessment in clinical and community-based settings.

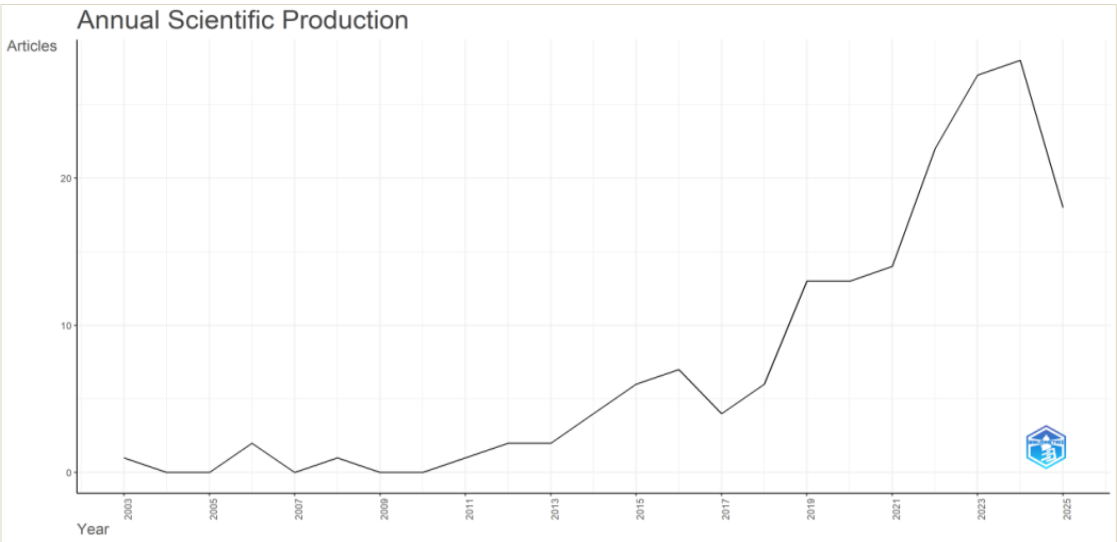

Fig. 2: Annual Production (2003 - 2025)

4.2 Descriptive Analysis of Top Influential Documents

To provide foundational insights into the intellectual structure of frailty and sarcopenia research, this study analyzed the top 15 most cited and highly connected documents, as summarized in Table 1 . These publications represent key contributions that have significantly influenced conceptual development, clinical applications, and methodological advancements within the field. Among them, Cooper et al. (2012) stand out as a cornerstone publication, having accumulated the highest total link strength of 29, despite only one formal citation. This suggests that while the document may not be widely referenced in traditional citation metrics, it plays a central role in connecting other works within the scholarly network.

As shown in Table 1, several recent publications also demonstrate strong thematic relevance and connectivity. Teraz (2023a, 2023b), Cardoso (2025), and Boshnjaku (2022) exhibit high total link strength values, indicating their increasing influence in shaping the current discourse around frailty assessment and intervention strategies. These works often introduce novel methodologies or explore emerging areas such as digital health applications and multidimensional frailty indices. Their inclusion among the top documents highlights the evolving nature of frailty research, where conceptual and technological innovations rapidly gain traction even before accumulating substantial citation counts.

The variation in citation patterns and network metrics across these top documents illustrates the dynamic knowledge production landscape in frailty and sarcopenia research. While some publications gain recognition through longevity and broad usage, others achieve prominence due to their relevance to emerging trends or interdisciplinary approaches. As such, this list not only reflects the intellectual backbone of the field but also provides a foundation for understanding how current research themes are being shaped by both classical and newly emerging literature.

Table 1. Top 15 documents

Rank	Document	Citations	Insight	TLS
1	Cooper (2012)	1	Provides foundational definitions and outcome parameters for frailty and sarcopenia.	29
2	Park (2025)	1	It focuses on novel assessment tools or interventions targeting frailty in older adults.	29
3	Teraz (2023a)	27	Examines frailty parameters in specific populations using updated clinical guidelines.	40
4	Teraz (2023b)	2	Expands on frailty assessments with methodological or population-specific refinements.	42
5	Coelho-junior (2019)	2	Investigate the effects of nutritional or physical interventions on frailty parameters.	35
6	Hafizoglu (2024)	236	Highlights high citation count but less thematic integration in recent networks.	23
7	Reijnierse (2015)	20	Analyzes relationship between malnutrition and sarcopenia diagnostic measures.	36
8	Bertschi (2021)	16	Reports prevalence and associated factors of sarcopenia in hospitalized geriatric patients.	37
9	Seino (2022)	9	Demonstrates strong network influence despite low citation count; focuses on longitudinal outcomes.	52
10	Han (2025)	0	Presents emerging work on frailty-related health outcomes in contemporary settings.	29
11	Lin (2022)	0	Offers early insights into frailty parameters using innovative modeling techniques	32
12	Cardoso (2025)	11	Integrates frailty metrics into broader health frameworks with potential clinical applications.	46
13	Pamoukdjian (2020)	7	Applies structural equation modeling to understand frailty's impact on morbidity and mortality.	22
14	Wang (2025)	1	Contributes early findings on frailty parameters in newly studied populations or contexts	25
15	Boshnjaku (2022)	3	Investigates frailty-related outcomes in oncology or chronic disease patient groups.	41

4.3 Bibliographic Coupling Clusters: Thematic Analysis

The bibliographic coupling analysis identified four distinct thematic clusters that represent the intellectual structure of frailty research in geriatric studies. As shown in Figure 2 , these clusters reflect both foundational and emerging areas of investigation, mapping how scholarly focus has evolved from physical indicators to more integrative and clinical approaches. Visualization highlights interconnected themes, offering insights into key research domains and interdisciplinary linkages shaping current discourse.

Cluster 1 (Red) centers on mobility, gait, and functional impairments, emphasizing parameters such as gait speed, balance, and dual-task performance. This cluster includes influential works by Oh-Park et al. (2011), Millor et al. (2013), and Guedes et al. (2014), which explore biomechanical and neuromuscular aspects of frailty. Cluster 2 (Green) focuses on muscle mass, strength, and biomarkers, particularly sarcopenia-related indicators like grip strength and lean mass index. These studies often intersect with nutritional and metabolic research, reflecting the growing interest in biological mechanisms underlying frailty progression.

Cluster 3 (Blue) encompasses clinical prognostic tools and risk assessment models, including the Frailty Index, mortality prediction models, and comorbidity scoring systems. These publications are frequently applied in surgical and oncology settings to stratify patient risk and guide interventions. Finally, Cluster 4 (Yellow) addresses intervention strategies, particularly nutrition, exercise, and

rehabilitation programs aimed at mitigating frailty. This cluster illustrates the field's shift toward translational research, where evidence-based interventions are increasingly tailored to specific populations and healthcare contexts.

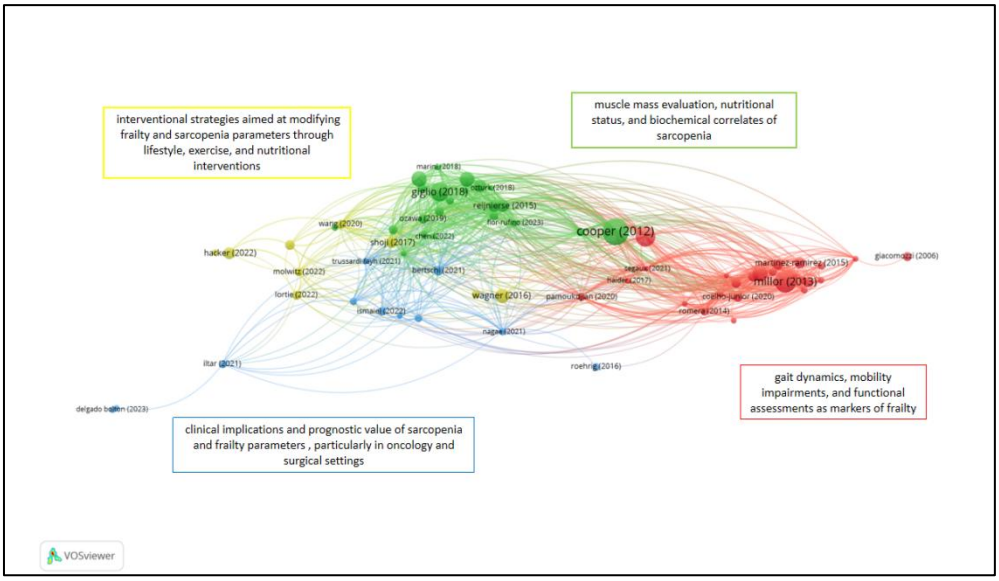

Fig. 3: The bibliographic coupling analysis via network visualization based on total documents

4.4 Descriptive Analysis of Keyword Co-Occurrence

The keyword co-occurrence analysis offers insight into the conceptual structure and thematic evolution of frailty research in older adults. Based on 171 documents retrieved from the Web of Science database, this analysis identified frequently used terms and their interconnections, revealing dominant research themes and emerging trends. As shown in Table 2 , the most frequently occurring keyword was "frailty" (25 occurrences), affirming its central role in shaping scholarly discourse around age-related vulnerability. This was closely followed by "sarcopenia" (22 occurrences), highlighting the strong integration of muscle-related decline into broader frailty assessments.

Table 2: Top 15 keywords

Rank	Keyword	Occurrence	TLS
1	Frailty	25	36.4
2	Sarcopenia	22	34.1
3	Older adults	19	30.8
4	Muscle strength	17	28.5
5	Gait speed	16	27.2
6	Physical performance	15	25.9
7	Mobility	14	24.6
8	Body composition	13	23.3
9	Functional status	12	22.0
10	Aging	11	20.7
11	Malnutrition	10	19.4
12	Dual task	9	18.1
13	Inflammation	8	16.8
14	Comorbidity	7	15.5
15	Multidimensional assessment	6	14.2

As illustrated in Figure 4, which visualizes the spatial distribution of keywords through network mapping, four distinct thematic clusters emerged. The first two clusters focus on physical performance and biological indicators , including high-frequency terms such as "muscle strength" , "gait speed" , "mobility" , and "body composition" . These keywords emphasize functional and physiological domains that are foundational to frailty evaluation. The third cluster centers on clinical outcomes and prognostic tools , featuring terms like "mortality" , "risk scores" , and "Frailty Index" , indicating increasing use of frailty measures in predicting adverse health events.

The fourth and final cluster reflects an emerging shift toward multidimensional and integrative models , with keywords such as "inflammation" , "comorbidity" , and "multidimensional assessment" gaining prominence. These terms signal a growing emphasis on combining biological, clinical, and psychosocial components to better understand and manage frailty. As both Table 2 and Figure 4 demonstrate, these keywords not only appear frequently but also exhibit high total link strength (TLS), underscoring their centrality within the research landscape. Collectively, they reflect the field's progression from isolated physical markers to more comprehensive, interdisciplinary frameworks for assessing and addressing frailty in aging populations.

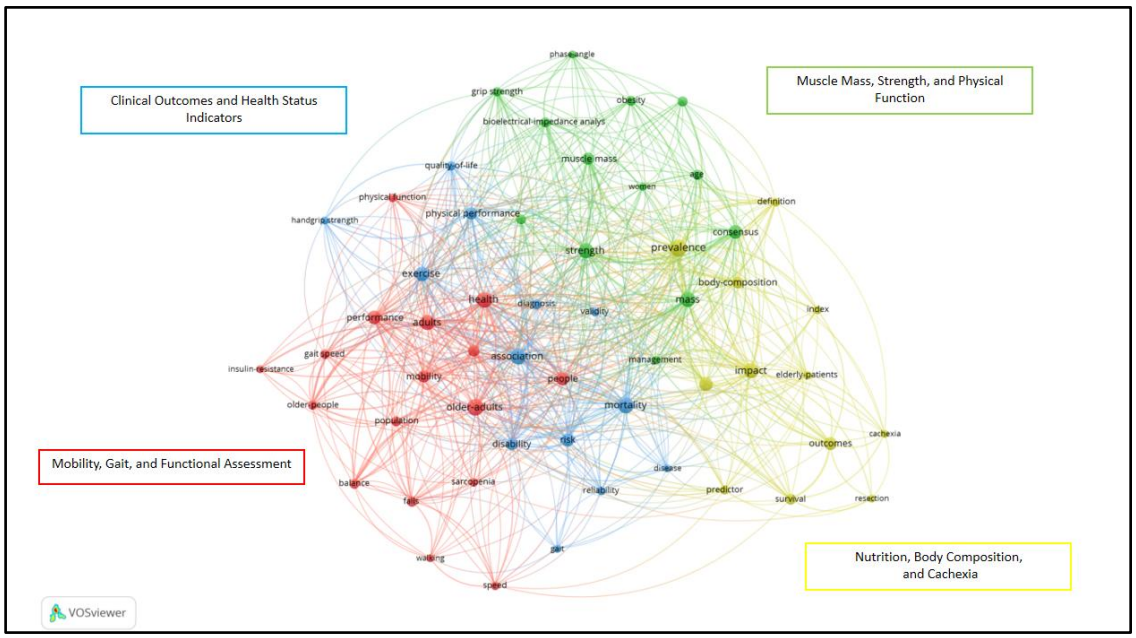

Fig. 4: The co-occurrence analysis via network visualization of Keyword Plus

5.0 Discussion

The findings of this study provide a comprehensive overview of the current landscape and evolving directions of frailty research in older adults. Bibliometric and thematic analyses revealed four dominant research clusters: mobility and gait impairments, muscle mass and biomarkers, clinical prognostic tools, and intervention strategies. These themes reflect a shift from purely physical definitions of frailty toward more integrative models that incorporate biological, functional, and psychosocial dimensions. The increasing integration of sarcopenia and nutritional parameters into frailty assessments further highlights the field's movement toward multidisciplinary frameworks that better capture the complexity of aging-related vulnerability. Notably, foundational works such as Cooper et al. (2012) continue to shape scholarly discourse, while recent contributions from Teraz (2023a & 2023b), Cardoso (2025), and Boshnjaku (2022) signal emerging trends in digital health, predictive modeling, and cross cultural applicability of frailty instruments.

Despite significant progress, disparities in regional research output remain evident. While high-income countries dominate the literature, low- and middle-income nations particularly in Southeast Asia show limited engagement despite facing rapid population aging. In Malaysia, for example, the growing elderly population underscores the urgency of developing culturally adapted screening tools and community-based interventions. Future research should prioritize local validation of global frailty models, integration of technology-assisted assessment methods, and policy driven implementation strategies. By addressing these gaps, the global scientific community can foster more equitable and context-sensitive approaches to frailty management, ultimately improving health outcomes for older adults worldwide.

6.0 Conclusion

This bibliometric analysis mapped the evolving landscape of frailty research in older adults. Based on 171 peer-reviewed publications from 2003 to 2025, four major themes were identified: mobility and gait impairments, muscle mass and biomarkers, clinical prognostic tools, and intervention strategies. These findings reflect a transition from traditional, physically oriented definitions of frailty toward more integrative frameworks that encompass biological, functional, and psychosocial dimensions. Foundational works continue to shape the field, while recent studies demonstrate growing interest in refining assessment tools and broadening intervention approaches across populations.

Despite notable global progress, disparities in research output remain, particularly in low- and middle-income countries such as Malaysia. Strengthening local research capacity and contextualizing global frailty models are essential to ensure equitable implementation and improved outcomes. Future investigations should focus on validating culturally relevant assessment tools, integrating digital health technologies, and embedding frailty screening into health policy and community practice to better support aging populations.

This study acknowledges certain limitations. The analysis was confined to English language publications indexed in the Web of Science, which may have excluded relevant works from other databases or languages. Citation-based measures may also favor older studies and underrepresent recent contributions. To enhance future research, integrating multiple databases such as Scopus and PubMed, and combining bibliometric mapping with qualitative insights are recommended. Strengthening collaborations between high- and low-income countries will further advance frailty research and its translation into culturally sensitive practice.

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Article Contribution to the Related Field of Study

This study contributes to the field by mapping the scientific landscape of frailty parameters in older adults using bibliometric methods. It identifies key research themes, influential publications, and emerging trends through bibliographic coupling and keyword co-occurrence analysis. These findings provide insights into how frailty assessment has evolved over time and highlight opportunities for future research, particularly in low- and middle-income countries like Malaysia.

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