

## Physical Activity and Frailty in Aging: A Bibliometric Investigation

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### ABSTRACT

**Background:** Frailty poses a significant risk to the functional abilities and overall health of older adults, often leading to a decline in physical function. There was a positive impact of regular physical activity on muscle strength, aerobic capacity, and balance in older adults, including those with frailty. However, many of these studies have not precisely defined or measured frailty in their populations. **Objective:** This study seeks to examine the publishing patterns related to physical activity and frailty and rank the most frequently used author keywords in the Web of Science (WoS) and Scopus databases. **Methods:** This study utilizes the renowned software tools ScientoPy, VOSviewer, and Biblioshiny to analyze and process the relevant publication data. **Results:** The results reveal an encouraging trend in the growth of literature on physical activity and frailty in the databases since 1991. The country analysis indicates that the United States has emerged as an active publisher in this field, followed by Japan and Spain. These trends provide valuable insights for researchers, aiding them in identifying key areas of focus, proactive institutions, and core source titles that have contributed to the existing knowledge on physical activity and frailty. **Conclusion:** This knowledge can guide researchers in exploring new avenues of investigation and understanding the evolving landscape of physical activity and frailty research.

## **Introduction**

Frailty, a crucial concern in gerontology and public health, serves as an essential conduit to connect healthy aging with disability (1). Immediate attention needs to be directed towards this issue, as healthcare systems lacking adequate resources to cater to the aging population must make adjustments. The decline in physiological reserves and heightened vulnerability to stressors that accompany frailty expose older adults to unfavorable health outcomes, including an increased risk of disability, morbidity, and mortality (2). The aging of the global population has emerged as a pressing concern, with frailty being a critical matter that has profound implications for individuals' quality of life and presents substantial obstacles for healthcare systems on a global scale.

The implications of frailty go beyond individual health, encompassing negative outcomes such as falls, fractures, disability, hospitalization, and mortality among the elderly (3). Failing to address and prevent frailty not only compromises the well-being of older individuals but also places a substantial burden on healthcare costs for individuals and nations. The involvement in physical activity is of utmost importance for the preservation of general health and well-being, as it assumes a central role in the regulation of body systems. It plays a crucial role in regulating bodily systems. The World Health Organization (WHO) defines PA as any bodily movement that requires increased energy expenditure beyond resting requirements, including household tasks, leisure activities, and structured exercises (4). PA holds promise in influencing the trajectory of frailty among older adults. Nevertheless, the correlation between physical activity (PA) and frailty continues to be a subject of continuing research. Previous systematic reviews and meta-analyses have shed light on the association between physical fitness components and frailty syndrome in the elderly, with usual walking speed emerging as a strongly correlated fitness test (5-7).

Existing research on exercise training interventions for older adults needs an updated synthesis of evidence to improve our understanding. Moreover, the current literature examining the association between PA and frailty displays inconsistencies in research design, population features, and techniques for evaluating frailty. The nonattendance of a standardized system for weakness evaluation hampers the capacity to reach clear-cut conclusions about the correlation between physical activity and the commencement of frailty. Therefore, the main objective of this study is to conduct a comprehensive bibliometric analysis that explores and evaluates the convergence of physical activity and frailty from a bibliometric standpoint. Through co-occurrence analysis of author keywords, this research aims to visually analyze trends, contributions from journals and countries, sources, and the intellectual framework of the field. These findings will enhance our understanding and foster the development of the physical activity and frailty research landscape.

### **Research Questions (RQs):**

1. How has the overall publication growth evolved over the past decade in the chosen research field?
2. Which countries have contributed the most to the research output in the field, and how has their contribution changed over time?
3. Which academic institutions have been most productive in terms of publications and citations, and what characteristics set them apart from others?
4. What are the most highly cited papers in the field, and what characteristics do they share?
5. How does the collaboration network between authors, countries, and keywords influence the publication output and impact within the chosen research field?

## **Materials & Methodology**

This study used a strict bibliometric analysis to explore scientific publications on physical activity and frailty from 1951 to June 2023. The data were obtained from the Web of Science and Scopus databases, and the ScientoPy and VOSviewer software tools were employed for data preparation and visualization purposes (8, 9). Meanwhile, another

tool, a Biblioshiny (10), was employed for thematic mapping to gain deeper insights into the emerging clusters within the field.

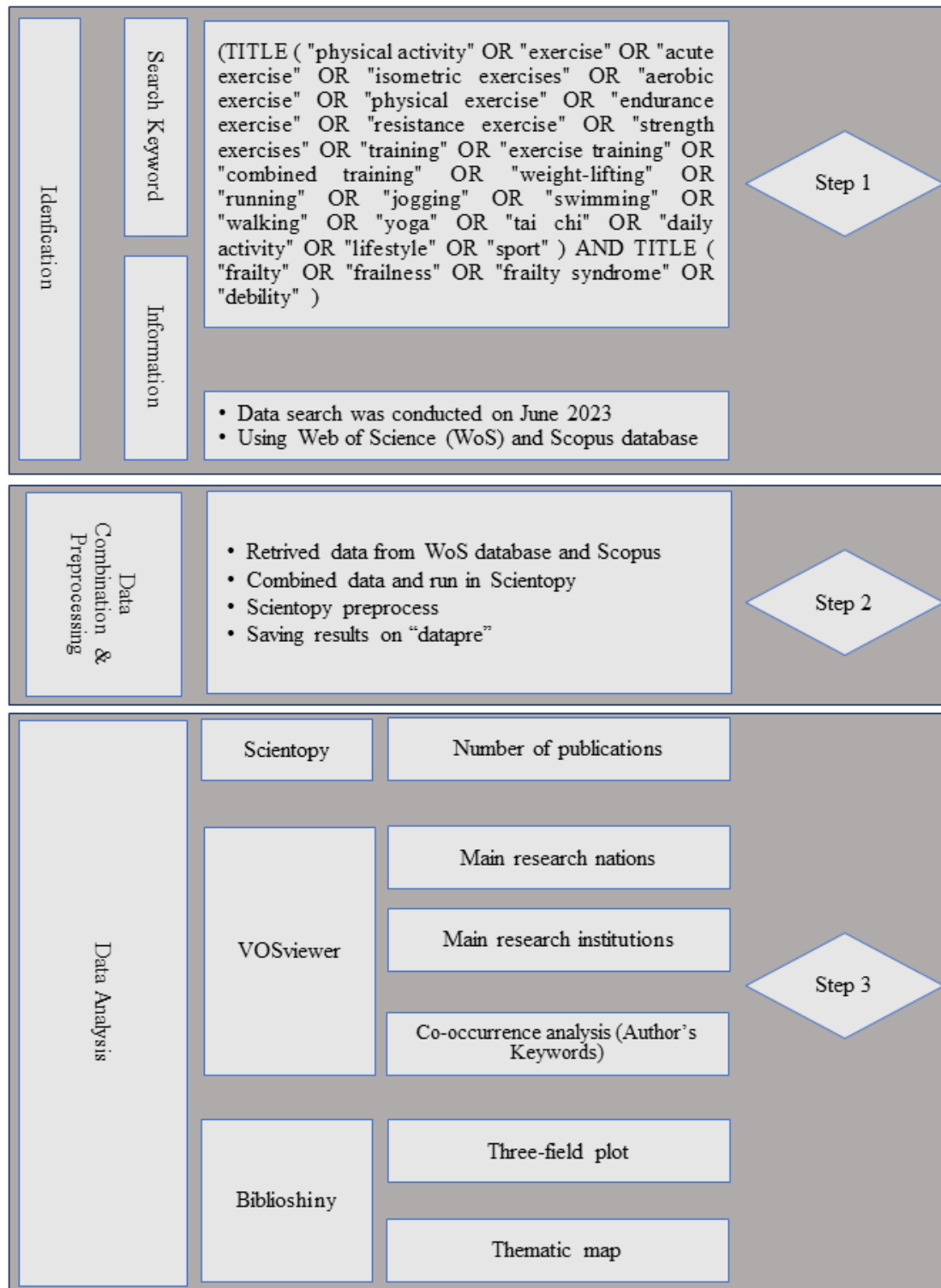


Figure 1: The research framework

### ***Bibliometric Assessment and Procedures***

Bibliometric analysis is an intricate and innovative technique that allows for detailed scientific investigation. It can reveal the history of a discipline and highlight new areas of study. This method uses statistics to assess research impact and quality by examining key components within a specific field. (11).

On June 21st, 2023, a search for data was performed and publications were obtained from the WoS and Scopus databases. The search was conducted based on the article title, using the following keywords: "physical activity," "exercise," "acute exercise," "isometric exercises," "aerobic exercise," "physical exercise," "endurance exercise," "resistance exercise," "strength exercises," "training," "exercise training," "combined training," "weight-lifting," "running," "jogging," "swimming," "walking," "yoga," "tai chi," "daily activity," "lifestyle," and "sport," combined with keywords related to frailty such as "frailty," "frailness," "frailty syndrome," and "debility." The study was carried out in three stages based on established literature databases (Refer Figure 1: The research framework). The research landscape was comprehensively understood through the utilization of bibliometric analysis and an extensive search strategy. The study endeavors to enhance the existing literature and provide crucial insights in this research area.

### ***Pre-processing data***

ScientoPy's bibliometric analysis used 1032 papers from WoS and Scopus. During pre-processing, 19.00% of the original data—196 papers—were removed from the dataset due to their document type. These publications were removed, leaving 836 for analysis.

**Table 1: Pre-process data from the ScientoPy**

Info	Number	Percentage
Loaded papers	1032	
Omitted papers by document type	196	19.00%
Total papers after omitted papers removed	836	
Loaded papers from WoS	404	48.30%
Loaded papers from Scopus	432	51.70%
Duplicated removal results:		
Duplicated papers found	381	45.60%
Removed duplicated papers from WoS	4	1.00%
Removed duplicated papers from Scopus	377	87.30%
Duplicated documents with different cited by	232	60.90%
Total papers after rem. dupl.	<b>455</b>	
Papers from WoS	400	87.90%
Papers from Scopus	55	12.10%

48.30% of the papers (404) were from Web of Science, while 51.70% (432) were from Scopus. This allocation of publications from the two databases permitted a complete literature review on the issue. Duplicate paper detection and removal were crucial pre-processing steps. 381 papers (45.60%) were duplicates. Duplicates were carefully deleted to sanitize and maintain data integrity. 4 duplicates (1.00%) were deleted from Web of Science, whereas 377 (87.30%) were removed from Scopus.

Some duplicated papers had different "cited by" values, showing the complexity of handling duplicates and the significance of removing them for proper analysis. 232 papers (60.90% duplicates) had different citation counts. After removing duplicates, the dataset had 455 publications. These included 400 Web of Science papers and 55 Scopus papers. This final dataset provides a solid foundation for bibliometric analysis and gives researchers a clean and reliable set of publications to study research field trends and patterns. Table 1 shows pre-processing data.

## Results and Discussions

### *The publication growths and research trends*

Figure 2 illustrates the publication growth trends of the Web of Science (WoS) and Scopus databases from 1990 to 2023. The figure exhibits various crucial metrics for each database, such as the Total number of publications, Annual Growth Rate (AGR), Average Daily Yield (ADY), Percentage Daily Yield (PDLY), and h-Index.

For Web of Science (WoS), the total number of publications began at zero in 1990 and steadily increased over the years with some fluctuations, ultimately reaching 400 publications by 2023. The AGR for WoS indicates a negative growth rate of -16.5%, signifying an average annual decrease in the number of publications by 16.5% throughout the entire period. The ADY for WoS stands at 61.5, indicating an average of 61.5 papers published daily within the database during the entire period. Moreover, the PDLY value of 30.8% reveals that WoS contributed to approximately 30.8% of the daily publications in the analyzed field during the entire period. The h-Index of 52 reflects WoS's impact based on the number of highly cited papers, offering valuable insights into the database's influence.

Regarding Scopus, there were no recorded publications in the database in 1990, but the number gradually increased, reaching 55 publications by 2023. The AGR for Scopus displays a minor negative growth rate of -0.5%, suggesting a slight average annual decrease in the number of publications during the entire period. The ADY value for Scopus is 7.5, indicating that, on average, 7.5 papers were published daily within the database throughout the entire period. Scopus contributed to around 27.3% of the daily publications in the research field during the entire period, as demonstrated by the PDLY value. The h-Index of 10 represents Scopus's impact based on the number of highly cited papers, offering insights into the database's influence within the scholarly community.

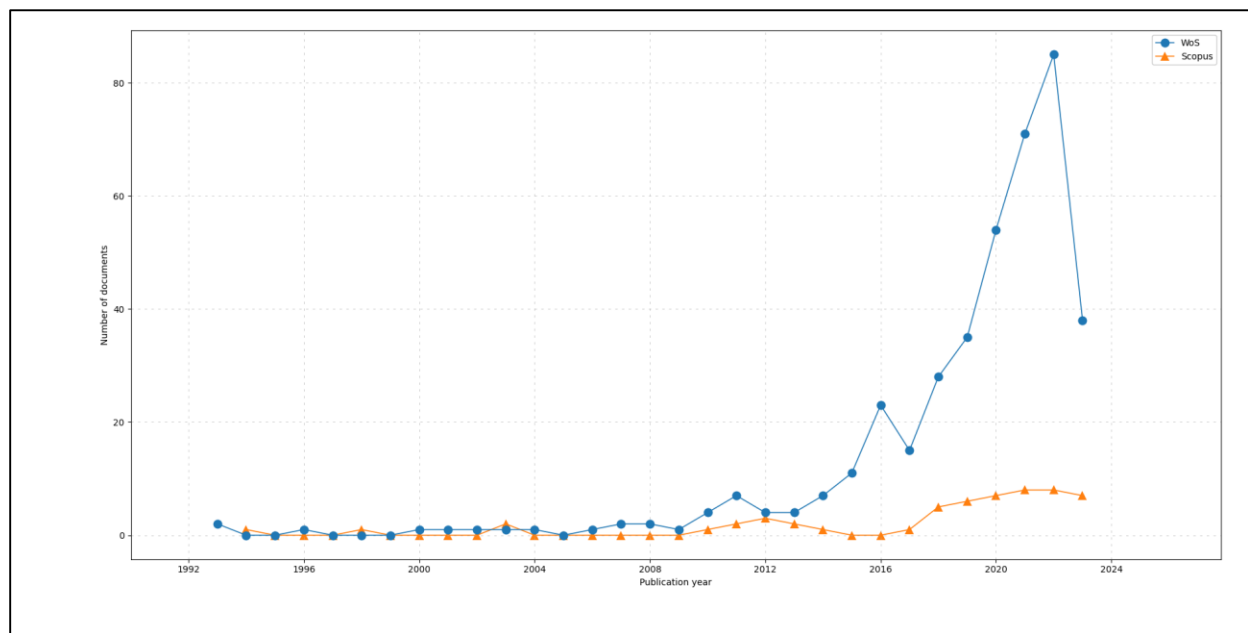


Figure 2. The publication growths from 1993-2023

***The Top 10 Countries contributed to the publications.***

Figure 3 displays the research output of the top countries in the field over the years from 1990 to 2023. This figure shows each country's publications by year, allowing us to track their contributions. With 97 contributions, the US leads. It shows a consistent growth in publications, starting with a single publication in 1993, gradually increasing, and peaking at 17 publications in 2022. However, there is a drop to 10 publications in 2023. Japan is ranked second with a total of 58 publications. The contribution of the subject under consideration has exhibited a consistent level of stability throughout the years, with a marginal escalation from two articles in 1994 to sixteen publications in 2019. Nevertheless, it is worth mentioning that there has been a significant decrease in the number of publications, namely to a total of five in the year 2020 and a complete absence of recorded publications in the year 2023. Spain ranks third with 56 publications. Its publication output remained low until 2008, but it has shown consistent growth since then, reaching its peak of 11 publications in 2017. There is a decline to two publications in 2023. China follows with 47 publications. China's contribution has significantly increased over the years, with notable growth in recent times. It reached its highest point of 16 publications in 2021, but there is a slight decrease to 12 publications in 2023. The United Kingdom holds the fifth position with 44 publications. Its publication output has been relatively steady, with a consistent number of publications each year, but there is a decline to 6 publications in 2022 and no publications in 2023. Canada is in sixth place with 36 publications. Its publication output has been consistent, with minor fluctuations, and it reached its peak of 12 publications in 2019. However, there is a decline to two publications in 2023. Brazil ranks seventh with 24 publications. Its contribution has been steadily increasing over the years, with a significant rise to eight publications in 2022. However, there will be a decrease to one publication in 2023. Taiwan holds the eighth position with 23 publications. Its publication output has been relatively stable, with some variations, but there is a slight increase to 7 publications in 2022, followed by a decline to 3 publications in 2023. Italy follows with 22 publications. Its publication output remained low until 2016 but has been steadily increasing since then. It reached its peak of 4 publications in 2022, followed by a decline to 0 publications in 2023. Australia is in the tenth position with 21 publications. Its contribution has shown steady growth, with a peak of 7 publications in 2020, but there is a decrease to 3 publications in 2023. In summary, Figure 3 provides valuable insights into the publication contributions of the top countries in the field over the years. It highlights trends of growth, stability, and decline in their research outputs, allowing researchers to analyze the changing landscape of research contributions from these countries within the chosen research field.

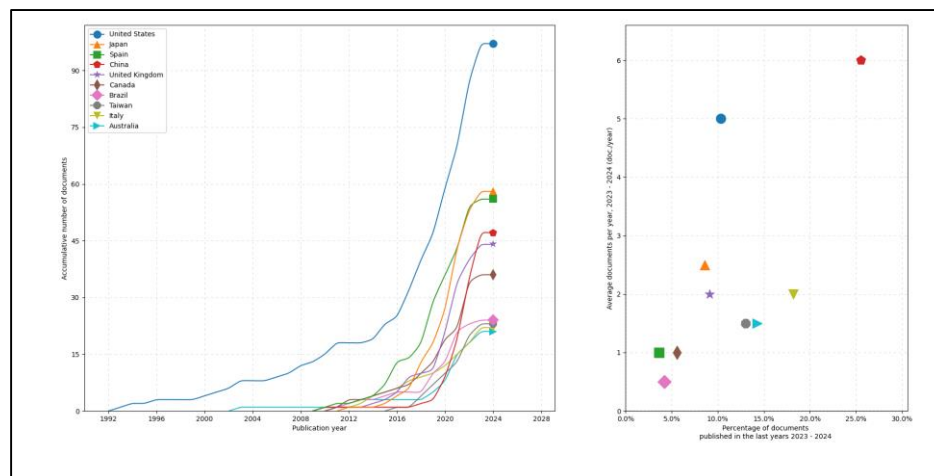


Figure 3. Top countries contributed to the publications from 1993-2023

***The Top 10 Active Institutions to the publications***

Figure 4 presents a list of the top 10 most active institutions based on their research output in the selected research field. Leading the list is Dalhousie University in Canada, with an impressive total of 12 publications, showcasing its significant involvement and productivity in producing research within the domain. Following closely behind in second place is the National Center for Geriatrics and Gerontology in Japan, which contributed 11 publications, indicating its active and prominent role in the field.

The third position is shared by two institutions: the Tokyo Metropolitan Institute of Gerontology in Japan and the Universidad Autónoma de Madrid in Spain, both contributing nine publications each. These institutions have demonstrated their dedication to research and scholarly endeavors, making significant contributions to the advancement of knowledge in their chosen areas. Taipei Medical University in Taiwan, Universidad Castilla-La Mancha in Spain, and the University of Helsinki in Finland are tied for the fourth position, with each institution having produced eight publications. This demonstrates their active and meaningful involvement in research activities, contributing to the wealth of scholarly knowledge in the field.

The eighth position is shared by two institutions: Hospital Universitario Getafe in Spain and University College London (UCL) in the United Kingdom, both contributing seven publications each. These institutions have contributed to field research via their dedication to excellence. Rounding off the top 10 list is the Universidad de Valencia in Spain, with seven publications, solidifying its position as an actively engaged institution in research activities.

Figure 4 provides valuable insights into the productivity and contribution of these top institutions in the selected research field. Their substantial publication counts reflect their dedication to research and scholarly pursuits, making them important players in advancing knowledge and understanding within the domain. Policymakers, researchers, and stakeholders can utilize this information to identify key institutions leading in research productivity and collaboration within the field, facilitating opportunities for potential partnerships and knowledge exchange.

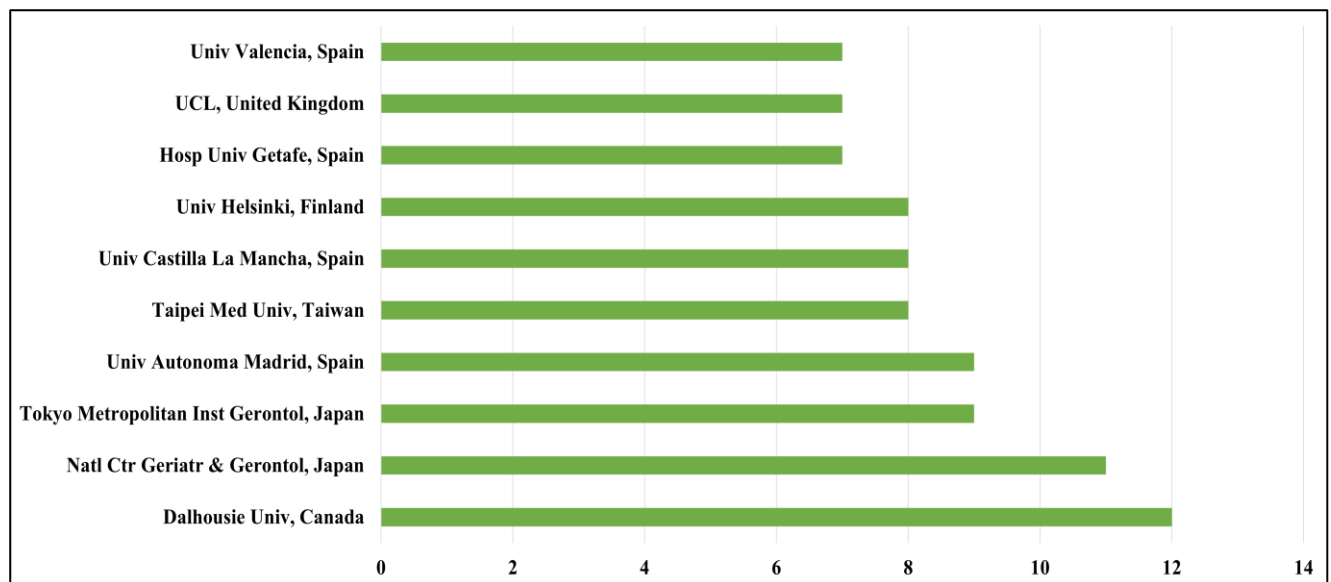


Figure 4. Top 10 active institutions contributed to the publications from 1993-2023

***Highly cited articles***

In Table 2, in the field of research focused on physical frailty in elderly individuals, several top authors have made significant contributions with their studies. These authors have explored various interventions and approaches aimed at managing frailty and improving the overall health and well-being of the elderly population.

Fiatarone et al. conducted one of the groundbreaking studies in 1994 (12), and they published their findings in the New England Journal of Medicine. Their research investigated the efficacy of exercise training and nutritional supplementation for physical frailty in very elderly people. The study demonstrated that such interventions can have a positive impact on frailty and physical function, with significant improvements observed in the study participants. Another noteworthy study, conducted by Wolf et al. (13) and published in the Journal of the American Geriatrics Society in 1996, explored the effects of Tai Chi and computerized balance training on reducing frailty and falls in older people. The research indicated that these interventions could be beneficial in reducing frailty and improving balance in older individuals, which can subsequently contribute to a reduction in falls and related injuries.

In a more recent study published in 2016 in the journal Biogerontology, McPhee et al. (14) discussed physical activity in older age and its potential perspectives for healthy aging and frailty. This study provides valuable insights into the role of physical activity in promoting healthy aging and reducing frailty risks among the elderly population. Theou et al. (15), in their systematic review published in the Journal of Aging Research in 2011, examined the effectiveness of exercise interventions for managing frailty. Their comprehensive review of existing research provides a valuable resource for understanding the impact of exercise in managing frailty and highlights the potential benefits of exercise interventions in improving the health and well-being of frail individuals. Binder et al.'s (16) research, published in the Journal of the American Geriatrics Society in 2002, investigated the effects of exercise training on frailty in community-dwelling older adults. Their randomized, controlled trial demonstrated the potential of exercise as an effective intervention for addressing frailty in older adults.

Latham et al. (17) conducted yet another significant study, which they then published in the Journal of the American Geriatrics Society in 2003. This randomized, controlled trial examined the effects of quadriceps resistance exercise and vitamin D supplementation in frail older people. The results highlighted the potential benefits of exercise and vitamin D in improving frailty outcomes in older individuals. Finally, Tarazona-Santabalbina et al.'s study (18), published in the Journal of the American Medical Directors Association in 2016, explored a multicomponent exercise intervention that not only reversed frailty but also improved cognition, emotion, and social networking in the community-dwelling frail elderly. Their findings underscore the importance of multicomponent interventions in addressing frailty holistically and promoting overall well-being in the elderly population.

In conclusion, these top authors have significantly contributed to the understanding of physical frailty in elderly individuals and have shed light on effective interventions for managing and reversing frailty in this population. Their research has the potential to impact the way healthcare professionals approach frailty management and improve the quality of life for elderly individuals worldwide.

**Table 2.** Top cited papers in physical activity and frailty in aging

Top cited paper	Author(s)	Year	Sources	Total citations
Exercise training and nutritional supplementation for physical frailty in very elderly people	Fiatarone M.A., O'Neill E.F., Ryan N.D., Clements K.M., Solares G.R., Nelson M.E., Roberts S.B., Kehayias J.J., Lipsitz L.A., Evans W.J.	1994	New England Journal of Medicine	2156
Reducing frailty and falls in older persons: An investigation of Tai Chi and computerized balance training	Wolf, S.L., Barnhart, H.X., Kutner, N.G., McNeely, E., Coogler, C., Xu, T.S., Clements, S.D., Connell, B.R., Fletcher, R.J., Green, R., Kutner, M., Rusin, M., Snider, A., Schorr, R.	1996	Journal Of the American Geriatrics Society	831
Physical activity in older age: perspectives for healthy ageing and frailty	McPhee, J.S., French, D.P., Jackson, D., Nazroo, J., Pendleton, N., Degens, H.	2016	Biogerontology	594
The effectiveness of exercise interventions for the management of frailty: A systematic review	Theou O., Stathokostas L., Roland K.P., Jakobi J.M., Patterson C., Vandervoort A.A., Jones G.R.	2011	Journal Of Aging Research	420
Effects of exercise training on frailty in community-dwelling older adults: Results of a randomized, controlled trial	Binder, E.F., Schechtman, K.B., Ehsani, A.A., Steger-May, K., Brown, M., Sinacore, D.R., Yarasheski, K.E., Holloszy, J.O.	2002	Journal Of the American Geriatrics Society	397
A randomized, controlled trial of quadriceps resistance exercise and vitamin D in frail older people: The Frailty Interventions Trial in Elderly Subjects (FITNESS)	Latham, N.K., Anderson, C.S., Lee, A., Bennett, D.A., Moseley, A., Cameron, I.D.	2003	Journal Of the American Geriatrics Society	329
A Multicomponent Exercise Intervention that Reverses Frailty and Improves Cognition, Emotion, and Social Networking in the Community-Dwelling Frail Elderly: A Randomized Clinical Trial	Tarazona-Santabalbina, F.J., Gomez-Cabrera, M.C., Perez-Ros, P., Martinez-Arnau, F.M., Cabo, H., Tsaparas, K., Salvador-Pascual, A., Rodriguez-Manas, L., Vina, J.	2016	Journal Of the American Medical Directors Association	305

### *Thematic map*

The thematic map (Refer to Figure 5(a)) was created via the network approach and reveals the emerging clusters and provides insights into the centrality, density, and frequency of each cluster. The cluster "frailty" is the most frequent theme in the research literature, with a high cluster frequency of 651 occurrences. It has a relatively lower centrality, indicating that it is not as closely connected to other clusters. However, it exhibits the highest density among all

clusters, suggesting that there is a strong interconnectedness among keywords within the "frailty" cluster. This cluster's prominence indicates that frailty is a focal point in the research, with numerous studies exploring different aspects of frailty in the context of aging and healthcare. In addition, frailty is a complex issue in elderly care. Research has identified six distinct frailty profiles based on physical, psychological, social, and cognitive domains of functioning, providing an empirical base for meaningful frailty profiles that can help tailor care interventions to the specific needs of each profile (19).

The "aging" cluster is the second most frequent theme, with 152 occurrences. It ranks relatively lower in centrality but demonstrates a moderate density, indicating that it is connected to other clusters, although not as densely as the "frailty" cluster. Research on aging is a vital area of investigation, and its moderate density suggests that it has relationships with other research themes, possibly overlapping with other clusters in the thematic map. Next, the cluster "physical function" is closely related to frailty research, ranking higher in density and centrality. It has a cluster frequency of 150, indicating a significant number of occurrences in the literature. The high density implies that "physical function" is interlinked with other clusters and may play a crucial role in the context of frailty and aging research. As further supported by the fact that there are multiple dimensions of frailty and similarly reduced physical capacity, frailty might affect selective components of cognition and quality of life (20).

The "cognitive frailty" cluster has a relatively high frequency of 147, suggesting it is an important research area. It ranks moderately in both centrality and density, indicating that it is moderately interconnected with other themes in the research landscape. Cognitive frailty, which explores the intersection of cognitive impairment and frailty in older adults, is an emerging topic of interest in the field. The "sarcopenia" cluster has a lower frequency compared to the previously mentioned clusters. However, it ranks higher in centrality and density, suggesting that it is relatively more interconnected with other themes in the research. Sarcopenia, the age-related loss of muscle mass and function, is gaining attention due to its association with frailty and physical decline in older adults. Previous meta-analyses also agreed that sarcopenia was independently associated with cognitive impairment (21).

The "elderly" cluster, with a frequency of 64, ranks high in centrality, indicating its strong connections with other themes in the research. However, it exhibits a lower density, suggesting that although it is interconnected, it may not form dense relationships with other clusters. "Elderly" is a general keyword encompassing various aspects of research related to older adults. The "physical frailty" cluster is closely related to the overall concept of frailty and has a moderate frequency of 64. It ranks relatively high in both centrality and density, indicating its interconnectedness and importance in the research landscape.

The "cognition" cluster focuses on cognitive aspects and ranks relatively high in centrality, suggesting its significance in the research network. However, it has a lower density, indicating it may not be as densely interconnected with other clusters. This cluster likely explores the cognitive aspects of aging, frailty, and related health conditions. The "cardiopulmonary exercise capacity" cluster is the least frequent theme, with only six occurrences. However, it ranks highest in centrality, indicating its strong connectivity to other research themes. Its lower density suggests it may not have dense relationships with other clusters, but its centrality suggests it plays a crucial role in the overall research network. Frailty among older adults contributes to reduced exercise capacity among lung transplant candidates independent of disease severity (22).

In summary, the thematic map using the network approach highlights the key research clusters in frailty, aging, and related topics. The most prominent cluster is "frailty," reflecting its central importance in research with high density and frequency. Other clusters, such as "aging," "physical function," "cognitive frailty," and "sarcopenia," also hold significance in the research landscape. The centrality, density, and frequency of these clusters provide valuable insights into the relationships and importance of different research themes in the field of frailty and aging research.

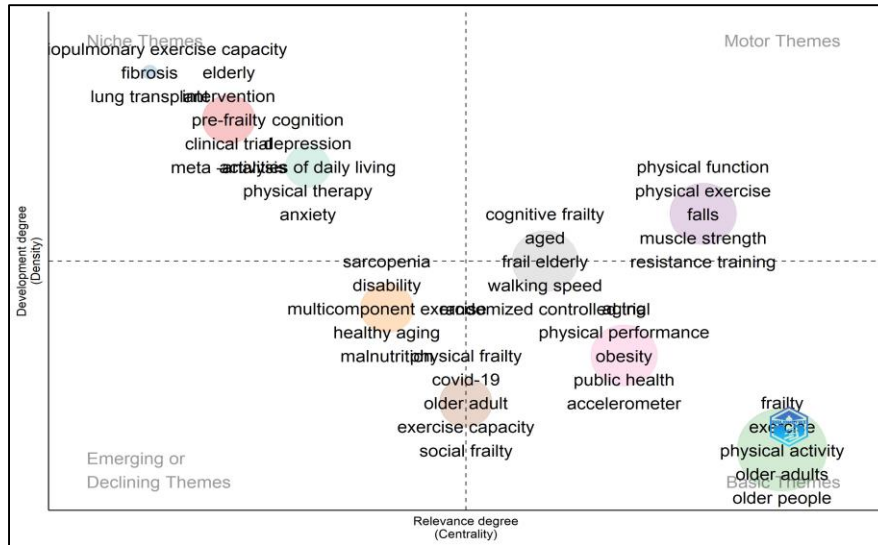


Figure 5(a): Thematic Map from the Network Approach

Figure 5(b), as generated by via the co-occurrences analysis, presented the occurrences of keywords used by authors in the selected research field. The size of each label corresponds to the weight or frequency of the keyword's occurrence in the literature. Analyzing the high occurrences of these keywords provides valuable insights into the focus areas and key themes that authors are emphasizing in their research related to frailty and aging.

Frailty, aging, and associated research literature contains many keywords for numerous reasons. First, the growing aging population and its health issues have piqued researchers and healthcare professionals' interest in frailty and its effects on older persons (23). Thus, frailty and aging research are crucial. Frailty and aging-related health conditions are major public health challenges. Governments, legislators, and healthcare organizations are progressively addressing the healthcare demands of the aging population. Public health has pushed researchers to study frailty and aging to improve older individuals' quality of life.

Researchers and politicians have also studied frailty and its effects on healthcare systems, including hospitalization rates and costs. Frailty research is significant because it can reduce healthcare system strain. Physical activity and exercise are vital for health promotion and illness prevention, especially for older persons (24). Exercise is being studied for its effects on physical function, frailty, and healthy aging. Researchers are focusing on these subjects to promote healthy lives and prevent frailty-related health concerns. Frailty and aging research is interdisciplinary, which increases keyword occurrences. Frailty and aging affect gerontology, medicine, physical therapy, and public health. This attracts scholars from various fields, resulting in multiple-term appearances. Due to their social and economic impacts, funding agencies promote research on aging and frailty. To get funding, researchers may study these topics.

Frailty and aging researchers may utilize certain keywords to identify knowledge gaps and develop trends. These keywords can help researchers find regions that need further study, focusing on certain themes. Scientific journal publication trends may affect keyword importance. Frailty and aging research may increase keyword usage in certain publications and platforms. In conclusion, the high frequency of terms linked to frailty, exercise, physical activity, and aging in the study literature indicates their importance to the scientific community. These keywords are frequently used in research publications due to the field's multidisciplinary nature and increased interest in frailty, healthy aging, and older individuals' well-being. Researchers are also investigating these crucial areas due to public health concerns and healthcare system impacts.

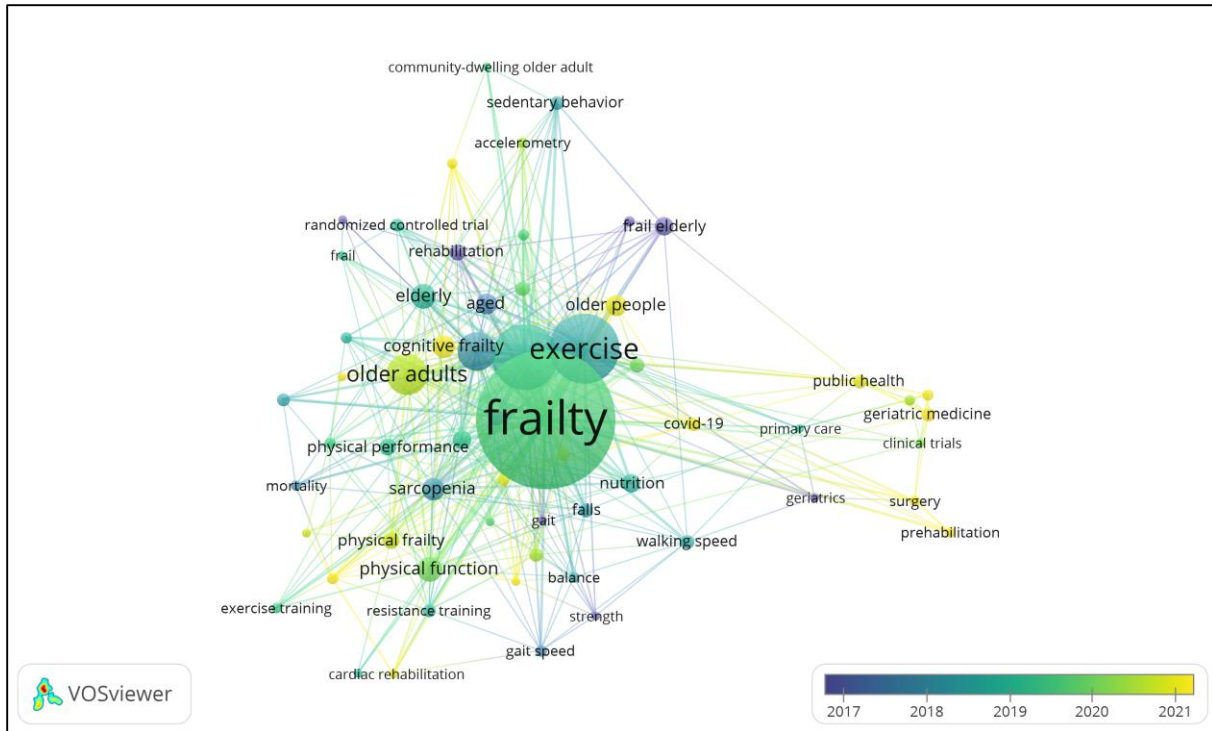


Figure 6(b): Overlay visualisation map of the author keywords

## Conclusion

In conclusion, the publications in the table demonstrate how physical activity programs might reduce frailty in older persons. These studies show that exercise training, balance training, and multicomponent therapies reduce frailty and promote healthy aging. These works have received many citations, demonstrating their scholarly impact and importance to geriatrics and public health.

The table also shows the rigorous research methods used to study physical exercise and frailty. This research shed light on frailty's causes, exercise's benefits, and physical activity's ability to manage and prevent it. These papers emphasize the importance of physical activity in promoting healthy aging, enhancing functional abilities, and improving the overall well-being of older adults, which has major implications for gerontology healthcare professionals, policymakers, and researchers. The mentioned studies lay the groundwork for further study, targeted interventions, and evidence-based policies on physical activity and frailty. They inform clinical practice and frailty strategies for the elderly. These studies promote physical activity's preventative and therapeutic benefits, improving older individuals' health and quality of life.

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