

Exercise modalities in older adults with hypertension: a bibliometric mapping of research on strength, endurance, and balance for cardiovascular health

Modalidades de ejercicio en adultos mayores con hipertensión: un mapeo bibliométrico de la investigación sobre fuerza, resistencia y equilibrio para la salud cardiovascular

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Abstract

The confluence of global population aging and the high prevalence of hypertension necessitates effective strategies to preserve physical function and cardiovascular health in older adults. This bibliometric study maps the research landscape on exercise modalities for improving strength, endurance, and balance in this population, with a specific focus on implications for hypertension management. A comprehensive search of the Scopus database on June 18, 2025, identified 579 relevant publications. Using bibliometrix and VOSviewer, we analyzed publication trends, citation networks, and thematic clusters. Results show substantial growth in scientific output since 1990, accelerating after 2008, with foundational works emphasizing protein-exercise synergy, gait, and fall prevention. Thematic analysis revealed five core domains: aging health, rehabilitation, frailty management, fall prevention training, and fitness

assessment. Emerging trends highlight aqua fitness, multimodal exercise, and mobility. Critically, the analysis identifies significant gaps, including the underrepresentation of hypertension-specific outcomes, agility training, home-based programs, and psychological factors within the dominant research themes. This study concludes that while the field is robust and evolving, future research must explicitly bridge the gap between exercise science for physical function and cardiovascular health outcomes. The findings provide a strategic roadmap for researchers, clinicians, and policymakers to develop integrated exercise prescriptions that concurrently combat physical decline and manage cardiovascular risk in the aging population.

Keywords: Balance, bibliometrics, elderly, exercise, endurance, strength, hypertension, cardiovascular health

La confluencia del envejecimiento poblacional global y la alta prevalencia de hipertensión requiere estrategias efectivas para preservar la función física y la salud cardiovascular en adultos mayores. Este estudio bibliométrico mapea el panorama de la investigación sobre modalidades de ejercicio para mejorar la fuerza, la resistencia y el equilibrio en esta población, con un enfoque específico en las implicaciones para el manejo de la hipertensión. Una búsqueda exhaustiva en la base de datos Scopus el 18 de junio de 2025 identificó 579 publicaciones relevantes. Utilizando Bibliometrix y VOSviewer, analizamos las tendencias de publicación, las redes de citas y los grupos temáticos. Los resultados muestran un crecimiento sustancial en la producción científica desde 1990, que se aceleró después de 2008, con trabajos fundamentales que enfatizan la sinergia proteína-ejercicio, la marcha y la prevención de caídas. El análisis temático reveló cinco dominios principales: salud en el envejecimiento, rehabilitación, manejo de la fragilidad, entrenamiento para la prevención de caídas y evaluación de la condición física. Las tendencias emergentes destacan el aquafitness, el ejercicio multimodal y la movilidad. El análisis identifica brechas significativas, como la escasa representación de los resultados específicos de la hipertensión, el entrenamiento de agilidad, los programas domiciliarios y los factores psicológicos en los temas de investigación dominantes. Este estudio concluye que, si bien el campo es sólido y está en constante evolución, la investigación futura debe abordar explícitamente la brecha entre la ciencia del ejercicio para la función física y los resultados de salud cardiovascular. Los hallazgos proporcionan una hoja de ruta estratégica para que investigadores, médicos y legisladores desarrollen prescripciones integradas de ejercicio que combatan simultáneamente el deterioro físico y gestionen el riesgo cardiovascular en la población envejeciente.

Palabras clave: Equilibrio, bibliometría, personas mayores, ejercicio, resistencia, fuerza, hipertensión, salud cardiovascular

The global population is aging at an unprecedented rate, a demographic shift that presents both opportunities and complex public health challenges¹. Among the most pressing concerns is the age-related decline in fundamental physical capacities—namely strength, endurance, and balance². This decline is not merely a matter of reduced mobility; it is intrinsically linked to the development and progression of chronic conditions, most notably hypertension and cardiovascular disease (CVD). The loss of physical function contributes to a cycle of inactivity, which can exacerbate hypertension, while hypertension itself can accelerate frailty and functional impairment, creating a significant burden on healthcare systems^{3,4}.

Physical decline in older adults is driven by a confluence of biological and lifestyle factors. Key biological alterations include hormonal changes, chronic low-grade inflammation, and diminished neuromuscular function, which collectively contribute to sarcopenia and reduced vascular compliance^{5,6}. These internal processes are often compounded by modifiable external factors such as physical inactivity, poor nutrition, and social isolation^{7,8}. The resultant frailty and functional loss profoundly impact the ability to perform activities of daily living, increasing dependence on caregivers and elevating the risk of adverse health events, including hypertensive crises and stroke^{9,10}. This nexus underscores the urgent need for early, effective interventions to preserve independence and mitigate care demands, with a particular focus on strategies that address both physical function and cardiovascular risk profiles.

Exercise is a cornerstone of non-pharmacological management for both aging and hypertension. A range of modalities has demonstrated efficacy in countering physical decline. Resistance training, utilizing bands or light weights, is paramount for increasing muscle mass and strength, which are critical for metabolic health and blood pressure regulation through improved vascular function^{11,12}. Aerobic exercises, such as walking, cycling, or aquatic activities, are foundational for enhancing cardiorespiratory endurance and have well-established antihypertensive effects through mechanisms like reduced peripheral resistance and improved autonomic balance^{13,14}. Furthermore, modalities targeting balance and neuromuscular control, including sensorimotor training, Tai Chi, and specific gymnastics, improve postural stability and lower-limb strength, thereby reducing fall risk—a major concern for older adults, especially those on antihypertensive medications who may be susceptible to orthostatic hypotension^{15,16}.

Given the vast and continuously expanding array of exercise modalities, there is a need to systematically

synthesize the research landscape at the intersection of geriatric exercise science and cardiovascular health. Bibliometric analysis provides a powerful, quantitative methodology to map this intellectual territory¹⁷. This approach allows for the identification of core research trends, influential authors and institutions, collaborative networks, and thematic evolution over time, offering insights that traditional narrative reviews may overlook¹⁸. It is particularly valuable for pinpointing research gaps and emerging frontiers in a field.

This bibliometric study is designed to provide a comprehensive and nuanced mapping of research on exercise modalities aimed at improving strength, endurance, and balance in older adults, with a dedicated focus on implications for cardiovascular health and hypertension management. We will systematically analyze key bibliometric indicators to delineate the field's intellectual structure and growth trajectory. This includes tracing publication trends to identify growth patterns, highlighting seminal works through citation analysis, and revealing the conceptual architecture via keyword and thematic cluster analysis. The ultimate goal is to furnish researchers, clinicians specializing in hypertension and geriatrics, and policymakers with an evidence-based overview to refine exercise prescriptions, promote integrated care models, and advance healthy aging strategies that concurrently address functional decline and cardiovascular risk.

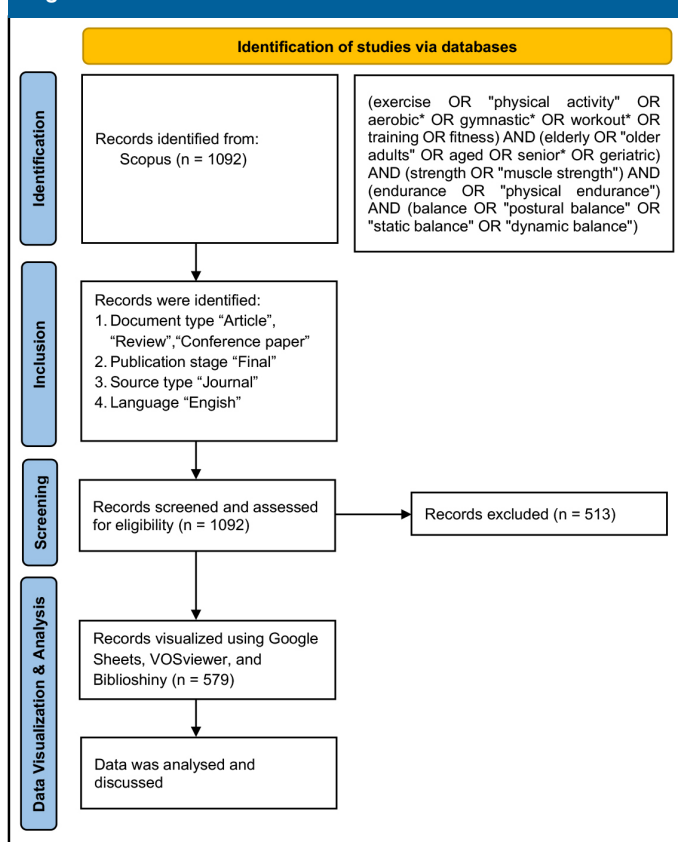
Search Strategy and Data Collection

Data for this bibliometric analysis were retrieved from the Scopus database, selected for its extensive coverage of global scientific literature and robust indexing capabilities, particularly in the biomedical and health sciences¹⁹. To capture the breadth of research at the intersection of exercise, aging, and cardiovascular health, a comprehensive search query was formulated and executed on June 18, 2025. The search string was designed to identify publications focusing on exercise interventions for core physical capabilities in older adults, while being broad enough to encompass studies where cardiovascular or hypertensive outcomes might be reported alongside measures of strength, endurance, or balance. The exact string used was: (exercise OR "physical activity" OR aerobic OR gymnastic OR workout* OR training OR fitness) AND (elderly OR "older adults" OR aged OR senior* OR geriatric) AND (strength OR "muscle strength") AND (endurance OR "physical endurance") AND (balance OR "postural balance" OR "static balance" OR "dynamic balance"). No date restrictions were applied to ensure a complete historical mapping of the field.

Data Screening and Refinement

The initial search yielded 1,092 records. A systematic, two-stage screening process was then implemented to refine the dataset for relevance and quality. First, all records were screened based on their titles and abstracts to eliminate publications clearly outside the study's scope (e.g., studies on young athletes, animal models, or unrelated medical conditions). Subsequently, formal inclusion and exclusion criteria were applied using Scopus's built-in filters. Inclusion criteria were: document type limited to "Article," "Review," and "Conference Paper"; publication stage "Final"; source type "Journal"; and language "English." Exclusion criteria removed "Articles in Press," non-journal sources (e.g., book chapters, editorials), and documents in languages other than English. This stringent screening process resulted in the exclusion of 513 records, yielding a final, refined dataset of 579 publications for in-depth bibliometric analysis. As the data were sourced from a single database with integrated deduplication, no additional duplicate removal was necessary. The complete workflow, from search to final dataset, is illustrated in Figure 1 (Flow chart).

Figure 1. Flow chart



Data Extraction, Visualization, and Analysis

The metadata for the 579 eligible publications were extracted and organized using Google Sheets for initial preparation. The primary bibliometric analysis and visualization were conducted using two specialized software tools: the bibliometrix R-package (version 4.5.0, accessed through its web interface, Biblioshiny) and VOSviewer (version 1.6.20). This analytical procedure aligns with established bibliometric methodologies²⁰.

Biblioshiny was employed for comprehensive descriptive and quantitative scientometric analyses²¹. It enabled the calculation of key metrics related to publication trends, source and author productivity, citation impact, and collaboration networks. VOSviewer was specifically used for constructing and visualizing bibliometric networks based on co-occurrence data, which is essential for mapping the conceptual structure of the research field²².

The analysis was structured to answer the study's objectives:

1. **Temporal and Impact Analysis:** The annual growth of literature was analyzed to identify research trends and phases. The most influential works within the dataset were identified based on total global citation count, providing insight into foundational research contributions²³.

2. **Conceptual Structure Mapping:** To uncover the main research themes and their connections—particularly those linking exercise modalities to cardiovascular and hypertensive health—a keyword co-occurrence analysis was performed. This analysis incorporated both author keywords and the broader “Keywords Plus” (indexer-supplied terms)²⁴. A network was created where nodes represent keywords and links represent their co-occurrence in publications. By analyzing the clusters, frequency, and centrality of keywords within this network, we identified dominant research domains, trending topics, and underdeveloped or niche areas²⁵. Special attention was paid to the presence and connectivity of terms related to hypertension, blood pressure, cardiovascular risk, and related outcomes.

All findings, including publication evolution, citation landscapes, and thematic clusters, are presented through visualizations generated by Biblioshiny and VOSviewer. These visuals are designed to provide an accessible and insightful synthesis of the complex bibliometric data, highlighting patterns relevant to researchers and clinicians in geriatrics and cardiovascular health.

Results

Overview of Dataset and Publication Characteristics

The initial search and screening process resulted in a final dataset of 579 documents published between 1990 and 2025. These documents originated from 277 different sources, collectively accumulating 24,564 references. The research output in this field has demonstrated notable growth, with an annual growth rate of 8.61%. The average age of the documents in the dataset is 9.16 years, indicating a relatively active and evolving area of study. On average, each document in the dataset received 46.1 citations. In terms of document types, articles constituted the majority (489) of the publications, followed by review papers (75) and conference papers (14). The dataset includes contributions from 2,715 authors, with 17 authors contributing to single-authored documents, which account for 19 of the total publications. The collaborative nature of research in this domain is evident, with an average of 5.47 co-authors per document and 23.18% of publications involving international co-authorships. The intellectual structure, as reflected by keywords, includes 2,638 Keywords Plus (ID) and 1,066 Author's Keywords (DE).

Temporal Evolution of Publications

Figure 2. Annual Scientific Production and Average Citation

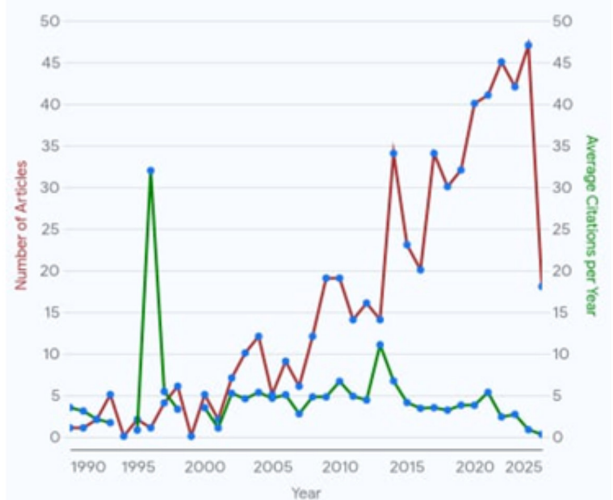


Figure 2. Annual Scientific Production and Average Citation

Figure 2 illustrates the annual scientific production concerning exercise modalities for improving strength, endurance, and balance in older adults from 1990 to 2025. The field has experienced a consistent upward trend in research output over the years. Initially, publication activity was relatively low, with only a few articles published per year in the early 1990s (e.g., 1 article in 1990 and 1991, 2 in 1992). A period of slow but steady growth was observed through the late 1990s and early 2000s, with a gradual increase in annual output. A notable acceleration in research interest became apparent around 2008, with annual publications consistently reaching double digits.

This growth phase continued, showing significant increases in output, particularly from 2014 onwards, where the number of articles consistently exceeded 30 per year. The highest annual publication output was recorded in 2024 with 47 articles, indicating a robust and continually expanding research domain. While 2025 shows 18 articles, this figure likely represents an incomplete year of data at the time of analysis. This trajectory suggests that research on exercise modalities for older adults has moved from a nascent stage into a mature and highly active field, reflecting growing academic and clinical interest in the topic, including its relevance to comorbid conditions like hypertension, over the last two decades.

Most Highly Cited Articles

Table 1 presents the top 10 most highly cited articles within the retrieved dataset, indicating the most influential contributions to the field of exercise modalities for improving strength, endurance, and balance in older adults. These publications represent foundational works that have significantly shaped subsequent research. It is noteworthy that while the core focus is physical function, highly cited works also address nutrition (Rank 1), cognitive function (Rank 5), and cardiovascular conditions (Rank 9), hinting at the interdisciplinary nature of the field and its overlap with cardiovascular health.

Most Relevant Authors, Institutions, Countries, and Sources

The analysis of key contributors reveals a diverse landscape of researchers and organizations driving the field. Donath L. stands out as the most prolific author with 10 articles, followed closely by Buchner D.M. (9 articles) and Cress M.E (8 articles). Other significant contributors include Van Heuvelen M.J.G., Brown M., Morat M., Perra S., Bean J.F., Carvalho J., and Evenhuis H.M., each contributing between 5 to 7 articles.

Regarding institutional output, the University of Jyväskylä and the University of Pittsburgh lead the research landscape, contributing 30 articles each. Other highly productive institutions include the University of Porto (26 articles), German Sport University Cologne (25 articles), University of Maryland (23 articles), The University of Sydney (22 articles), University of Zaragoza (20 articles), University of Basel (19 articles), Harvard Medical School (18 articles), and University of Guelph (18 articles). Geographically, the USA is the dominant country with 677 publications, underscoring its significant role in this research area. Following the USA are Spain (189 publications), China (186 publications), Brazil (181 publications), Australia (143 publications), Canada (134 publications), South Korea (134 publications), Portugal (125 publications), Germany (113 publications), and Italy (106 publications).

The most frequently published sources indicate the core journals in this field. Archives of Gerontology and Geriatrics is the top journal with 21 articles, followed by the International Journal of Environmental Research and Public Health (18 articles), and the Journal of Aging and Physical Activity (15 articles). Other prominent journals include Journals of Gerontology - Series A Biological Sciences and Medical Sciences (13 articles), Aging Clinical and Experimental Research (12 articles), Archives of Physical Medicine and Rehabilitation (11 articles), BMC Geriatrics (11 articles), Journal of Geriatric Physical Therapy (11 articles), European Review of Aging and Physical Activity (10 articles), and Gerontology (10 articles). This global distribution highlights widespread international interest and collaborative efforts in this specialized domain.

Table 1. Top 10 Most Highly Cited Articles

Rank	Title	Journal	Year	Citations
1	Protein intake and exercise for optimal muscle function with aging: Recommendations from the ESPEN Expert Group	Clinical Nutrition	2014	1201
2	The effect of therapeutic exercise on gait velocity in older adults	Journal of the American Geriatrics Society	1996	958
3	Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years	The Gerontologist	2013	751
4	Effects of Different Exercise Interventions on Risk of Falls, Gait Ability, and Balance in Physically Frail Older Adults: A Systematic Review	Rejuvenation Research	2013	673
5	Resistance training and executive functions: a 12-month randomized controlled trial	Archives of Internal Medicine	2010	584
6	Low serum micronutrient concentrations predict frailty among older women living in the community	The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences	1997	506
7	A Randomized Clinical Trial of Therapeutic Exercise in Subacute Stroke	Stroke	2003	450
8	Interventions to prevent disability in frail community-dwelling elderly: a systematic review	Journal of the American Geriatrics Society	2002	447
9	Physical Rehabilitation for Older Patients with Acute Decompensated Heart Failure	New England Journal of Medicine	2021	370
10	The effect of an exercise program on gait and balance in older fallers	Archives of Physical Medicine and Rehabilitation	1998	361

Table 2. Prominent Research Clusters and Associated Keywords

Cluster (Theme)	Core Keywords (Occurrence)	Other Keywords (Occurrence)
1 (Aging Health)	Aging (93), Physical fitness (79), Functional capacities (53), Physical activity (52)	Quality of life (29), Aerobic exercise (21), Physical performance (17), Cognitive (15), Activities of daily living (13), Health (13), Cognitive function (11), Dementia (9), Nursing home (9), Disability (8), Obesity (6), Community dwelling (5), Agility (5)
2 (Rehabilitation)	Exercise (93), Muscular strength (68), Balance (53), Rehabilitation (33)	Gait (24), Exercise therapy (21), Postural balance (17), Flexibility (16), Endurance (9), Accidental falls (8), Tai chi (7), Stroke (7), Reaction time (5), Self-efficacy (5)
3 (Frailty Management)	Frailty (30), Fall (25), Sarcopenia (17), Body composition (13)	Accident prevention (10), Diet (9), BMD (7), Physical therapy (7), Hip fracture (6), Osteoporosis (5), Home exercise (5), Primary care (5)
4 (Fall Prevention Training)	Resistance training (34), Strength training (18), Multimodal exercise (17)	Exercise training (14), Fall prevention (11), Physical exercise (10), Endurance training (8), Postural control (7), Risk of fall (5), Muscle endurance (5)
5 (Fitness Assessment)	Functional fitness (29), Mobility (19), Aerobic capacity (16)	Senior fitness test (11), Aqua fitness (8), Physical health (8), Assessment (5)

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(5)

A Note on Hypertension and Cardiovascular Keywords: A dedicated scan of the keyword network for direct terms like “hypertension,” “blood pressure,” “cardiovascular,” or “vascular health” revealed their notable absence from the high-frequency core keywords within these clusters. This absence is a significant finding in itself, suggesting that while the foundational research on physical function is robust, its explicit and formal linkage to hypertension outcomes in the literature’s keyword taxonomy is not yet prominent.

Trending Research Topics

An analysis of the average publication year for keywords (Figure 6) reveals several emerging topics. Keywords with a more recent average publication year include ‘aqua fitness’ and ‘physical therapy’, suggesting growing interest in aquatic exercise and clinical interventions. Other recently prominent terms include ‘multimodal exercise’, ‘endurance training’, ‘physical exercise’, ‘body composition’, ‘senior fitness test’, ‘community dwelling’, and ‘mobility’. This indicates a shift towards integrated training approaches, specific assessment tools, and community-based interventions.

Underdeveloped Areas/Knowledge Gaps

Keywords with relatively lower occurrences or fewer strong links include specific functional assessments like ‘agility’ (5 occurrences), and particular interventions such as ‘home exercise’ (5 occurrences). While topics like ‘osteoporosis’ (5 occurrences) and ‘hip fracture’ (6 occurrences) appear, they represent areas where further research could strengthen their connections to exercise interventions. Similarly, topics like ‘self-efficacy’ (5 occurrences) and ‘reaction time’ (5 occurrences) could benefit from more robust integration. Crucially, as indicated earlier, the thematic network analysis confirms a clear gap regarding the explicit and systematic inclusion of hypertension-specific outcomes, cardiovascular risk markers, or blood pressure monitoring as central keywords in the existing research landscape on exercise for physical function in older adults.

Figure 6. Overlay visualization of co-occurrence keywords

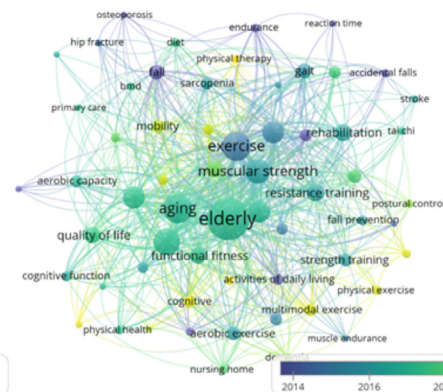
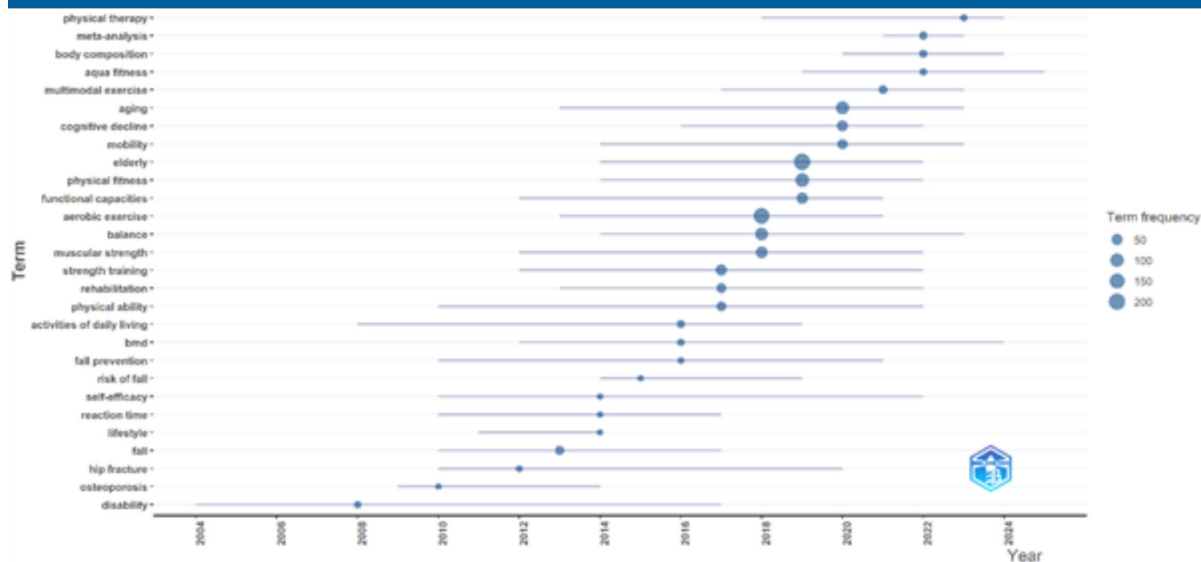


Figure 7. Trend Topics



Discussion

Our bibliometric analysis reveals a clear and dynamic growth in research on exercise modalities for older adults, with a marked acceleration since 2008. This trajectory mirrors global demographic aging and a paradigm shift towards preventive health strategies aimed at preserving functional independence^{26, 27, 28}. The rising life expectancy underscores the urgency for effective, evidence-based interventions, a drive reflected in parallel bibliometric surges in related fields like sarcopenia research²⁹. The sustained growth signals that optimizing physical function in later life is a mature and globally recognized scientific priority.

The landscape is shaped by a network of prolific authors, leading institutions, and influential nations. Consistent output from researchers like Donath L., Buchner D.M., and Cress M.E., and institutions such as the University of Jyväskylä and the University of Pittsburgh, indicates established hubs of expertise. The dominance of the United States in publication volume is likely fueled by its significant aging population and the consequent strain on healthcare systems, necessitating research into independence-preserving strategies³⁰. Similarly, nations like Australia, facing comparable demographic shifts, have integrated healthy aging into national policy, further stimulating research output³¹. The robust international co-authorship network visualizes a collective response to aging as a shared public health challenge, with collaboration facilitating the exchange of expertise needed to address its multifaceted nature.

The thematic analysis via keyword co-occurrence yielded five robust clusters, effectively mapping the intellec-

tual structure. Cluster 1 (Aging Health) establishes the foundational link between physical fitness, functional capacity, and quality of life in aging. Within this cluster, the synergy of endurance, strength, and balance training—often structured via the FITT principle—is recognized as critical for combating physiological decline^{32, 33, 34}. However, our analysis identified a pivotal gap: terms directly related to hypertension, blood pressure, or cardiovascular risk are conspicuously absent from the high-frequency core keywords. This suggests that while the general benefits of exercise for aging are well-established, the literature’s conceptual mapping has not yet fully and formally integrated cardiovascular health outcomes as a central pillar.

Cluster 2 (Rehabilitation) and Cluster 3 (Frailty Management) highlight the translational focus on clinical and syndromic populations. Research here emphasizes restoring mobility and mitigating frailty—a known independent predictor of falls and disability^{35, 36}. Cluster 4 (Fall Prevention Training) specifically underscores the efficacy of resistance and multimodal training, which are also fundamental for improving metabolic and vascular health³⁷. Cluster 5 (Fitness Assessment) reflects the critical need for validated tools like the Senior Fitness Test to evaluate interventions³⁸. The trending topics, including ‘aqua fitness,’ ‘multimodal exercise,’ and ‘physical therapy,’ indicate an evolution towards more accessible, integrated, and clinically applicable exercise solutions³⁹.

Crucially, this map reveals significant underdeveloped areas at the intersection of exercise science and cardiovascular medicine. The low frequency of keywords like ‘agility’ (5), ‘home exercise’ (5), ‘osteoporosis’ (5), ‘self-

efficacy' (5), and 'reaction time' (5) points to research gaps. These are not merely niche topics; they represent critical components for a holistic approach to aging with hypertension. Agility training may benefit dynamic blood pressure control during postural changes; home-based protocols are essential for long-term adherence and hypertension management; exercise for bone health is vital for hypertensive patients often concerned with fracture risk; and self-efficacy is a key determinant of sustainable lifestyle change^{40, 41, 42, 43, 44}. The most striking gap, as noted, is the lack of explicit connection between this extensive physical function literature and hypertension-specific outcomes. Future research must bridge this divide by intentionally incorporating blood pressure metrics, arterial stiffness measures, and other cardiovascular endpoints into studies of strength, endurance, and balance training in older adults.

Limitations of Study

This study has several limitations. Relying solely on Scopus may exclude relevant publications from journals not indexed in this database. Bibliometric indicators measure impact and connectivity but do not directly assess the clinical quality or practical applicability of research⁴⁵. The search strategy, while comprehensive, may have missed some studies due to inconsistencies in keyword indexing. Furthermore, the interpretation of network clusters, though systematic, involves a degree of subjective judgment.

Conclusions

This bibliometric study provides a comprehensive mapping of the evolving research landscape on exercise modalities for strength, endurance, and balance in older adults. It confirms the field's robust growth and global collaborative nature, structured around core themes of aging health, rehabilitation, frailty, fall prevention, and fitness assessment. The analysis identifies a critical, underdeveloped nexus: the need for greater integration between this well-established body of research on physical function and targeted outcomes in cardiovascular health and hypertension management. While trends point towards more practical and multimodal interventions, significant gaps remain in agility training, home-based program efficacy, bone health integration, and psychological determinants of adherence—all of which are highly relevant for the holistic care of older adults with or at risk for hypertension.

Therefore, the findings direct future research, clinical practice, and policy towards developing and evaluating multidimensional exercise prescriptions that explicitly aim to concurrently improve physical function and manage cardiovascular risk factors. Such an integrated approach is essential for advancing evidence-based, non-pharmacological strategies that promote true healthy aging, safeguarding both independence and vascular health.

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