

# A bibliometric study of aerobic, resistance, and combined aerobic and resistance exercise research in the elderly: Insights from WoS using citespace



Zhao Changyuan<sup>a</sup>  | Hao Huibin<sup>b</sup> | Roxana Dev Omar Dev<sup>a</sup> 

<sup>a</sup>Department of Sport Studies, Faculty of Educational Studies, Universiti Putra Malaysia, Selangor, Malaysia.

<sup>b</sup>Department of History, Faculty of Arts and Social Sciences, Universiti Malaya, Kuala Lumpur, Malaysia.

**Abstract** As the global population ages, exercise interventions have become increasingly important for promoting health in older adults. Aerobic exercise, resistance exercise, and their combination each offer unique benefits. However, the respective research trends of these exercise modalities have rarely been systematically compared. This study aims to provide a comprehensive bibliometric analysis of these three exercise modalities using Web of Science data and CiteSpace visualization. This study retrieved and analyzed literature from the Web of Science Core Collection (2015–2024) using CiteSpace software. The search targeted articles on aerobic exercise (AE), resistance exercise (RE), and combined aerobic and resistance exercise (CARE) for the elderly. After manual screening, 1,465 articles were included (AE: 616; RE: 746; CARE: 103). CiteSpace was employed to construct country collaboration, institutional, co-authorship, and keyword co-occurrence maps, as well as to identify emerging research fronts. The Results show that RE received the highest research attention, peaking in 2019, while AE maintained a stable output. CARE had lower publication volume but showed notable growth. The United States, Brazil, and China were the leading contributors, though international collaboration in combined exercise studies remains weak. Keyword analysis revealed that AE studies emphasized cardiovascular and cognitive benefits, RE focused on muscle function and nutritional support, and CARE highlighted fall prevention, quality of life, and chronic disease management. The field is shifting from single-modality interventions toward integrated, multidimensional strategies. CARE is emerging as a promising approach due to its comprehensive health benefits. However, gaps remain in research collaboration and knowledge structure in this area. This study provides a macroscopic overview of global trends and may inform interdisciplinary research and policy development aimed at healthy aging.

**Keywords:** physical activity, healthy aging, older adults, bibliometric analysis, research trends, citespace

## 1. Introduction

Population aging is progressing at an increasingly rapid pace. According to a report by the World Health Organization (WHO, 2022), the number of people aged 60 and above is projected to increase from 1 billion in 2020 to 1.4 billion by 2030, accounting for one-sixth of the global population. By 2050, this figure is expected to reach 2.1 billion. With the intensification of population aging, growing attention has been directed toward the physical and mental health and quality of life of older adults. Numerous studies have shown that appropriate physical exercise can not only enhance physical function and life quality among the elderly but also improve their psychological well-being and cognitive performance (Langlois et al., 2013; Ciairano et al., 2010). To be specific, aerobic exercise (AE) can effectively improve cardiovascular health and endurance in older populations (Rismayanthi et al., 2022). Resistance exercise (RE), on the other hand, is widely regarded as a key strategy for preventing age-related sarcopenia and maintaining muscle strength (Westcott, 2012). Combined aerobic and resistance exercise (CARE) appears to offer synergistic benefits in promoting physical function, cognitive ability, and mental health (Liang et al., 2021; Nouchi et al., 2012; Mahmoudi et al., 2022). Consequently, researchers have increasingly focused on the comprehensive impact of different exercise intervention modalities on the health of older adults, and have begun to explore more systematic methods of investigation.

In the past, most studies have relied on experimental intervention designs to assess the effects of physical activity interventions at the individual level. Although such studies provide valuable results, they often lack a comprehensive understanding of the research landscape, particularly in terms of thematic hotspots, structural patterns, and international collaboration networks. In recent years, with the rise of data-driven research, bibliometric analysis has become an important methodological tool for uncovering the development process and research trends within academic fields. Among these tools, CiteSpace is a leading software for constructing scientific knowledge maps and is widely used to identify high-frequency keywords, collaborative networks, and emerging research frontiers (Chen, 2006; Liu et al., 2019). Several studies have recently



explored the use of CiteSpace in the context of elderly exercise research. For instance, Langlois et al. (2013) conducted a systematic evaluation of the effects of physical exercise on cognitive function and quality of life among older adults. Zhang et al. (2025) analyzed research trends on the effects of exercise and nutritional interventions on sarcopenia. Yang et al. (2024) investigated the evolving patterns of research on physical activity, sedentary behavior, and cognitive function in older adults. These studies highlight the analytical capabilities of CiteSpace and demonstrate its value and potential for development within the discipline.

Although previous studies have provided a general overview of exercise interventions for older adults, significant limitations remain in the current literature. First, most bibliometric analyses focus on a single type of exercise, lacking systematic comparison and integration across AE, RE, and CARE. For example, Mi et al. (2023) investigated resistance training, while Zhao et al. (2022) and Zhao et al. (2024) examined the effects of cardiorespiratory and AE on mental health, respectively. Second, in the emerging area of combined exercise, the limited number of studies and scattered distribution of literature have hindered the formation of a systematic knowledge structure. As a result, current research lacks comparative analyses across different types of exercise interventions and an integrated understanding of their distinct effects.

This study aims to fill the above-mentioned research gaps by constructing visualized knowledge maps to identify research hotspots, evolutionary trends, collaboration networks, and core authors and institutions in the field. It not only provides scholars with a comprehensive understanding of the research landscape but also facilitates interdisciplinary and inter-institutional collaboration.

## 2. Materials and Methods

### 2.1. Data sources

The research data were obtained from the Web of Science (WoS), which is recognized as one of the most influential academic literature databases worldwide. It indexes high-quality, high-impact academic resources including journals, conference proceedings, and books across multiple disciplines such as natural sciences, social sciences, and arts & humanities (Pranckutė, 2021). Furthermore, WoS's citation indexing function enables quantitative assessment of paper impact, tracking of disciplinary trends, and identification of key researchers, providing objective evidence for academic evaluation (Dzikowski, 2018).

### 2.2. Literature retrieval

The data collection of this study was conducted in May 2025. In this study, three terms were searched individually. The specific data retrieval method is as follows: Topic = (aerobic exercise AND elderly); Topic = (resistance exercise AND elderly); Topic = (combined aerobic and resistance exercise AND elderly OR combined exercise AND elderly). The retrieval period time was set from January 2015 to December 2024. Then, preliminary screening was conducted using WoS's built-in filters, with the document type restricted to review articles and language limited to English. The document type was restricted to review articles, and the language was limited to English. The initial search yielded 862 articles on aerobic exercise (AE), 1,287 articles on resistance exercise (RE), and 219 articles on combined aerobic and resistance exercise (CARE). Two researchers independently conducted manual screening in three stages: title review, abstract screening, and full-text assessment. A total of 616 AE, 746 RE, and 103 CARE articles met the inclusion criteria and were included in the final analysis. The screening process is illustrated in Figure 1.

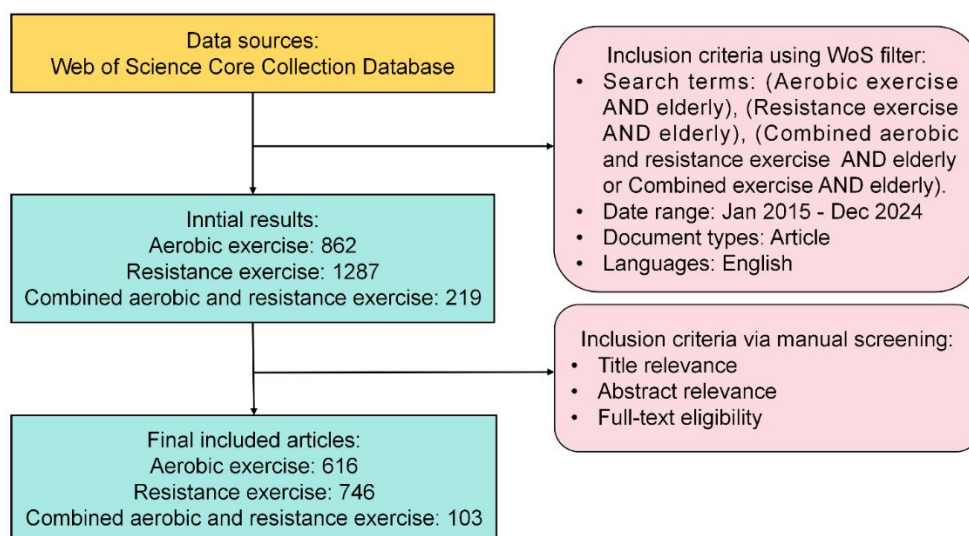


Figure 1 Literature screening process.



### 2.3. Data processing

This study employs CiteSpace, a software developed by Professor Chaomei Chen from the College of Computing and Informatics at Drexel University (Chen, 2016). The research data spans a decade, from January 2015 to December 2024, with a one-year time slice configuration. To ensure both informational richness and visual clarity in the generated maps, only the top 10 highest-frequency nodes from each time period were selected for visualization analysis.

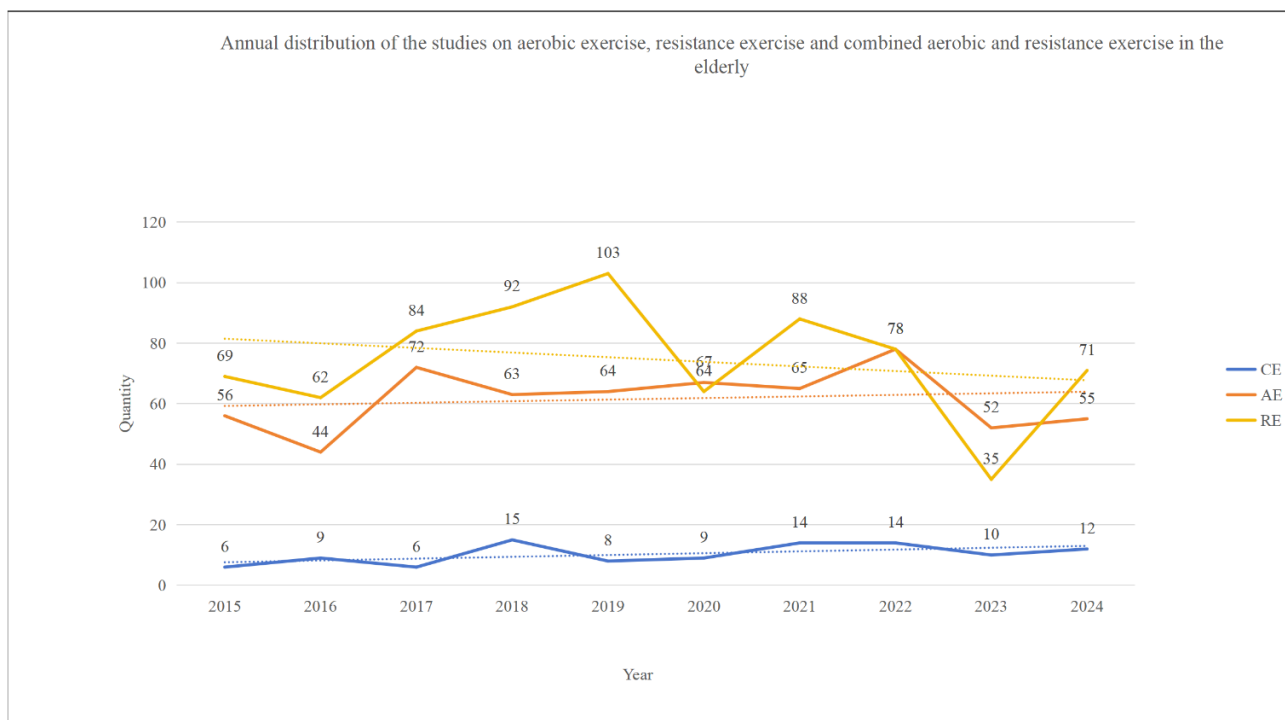
In the quantitative literature analysis, the initially retrieved 1,465 articles (including 616 article on AE, 746 articles on RE, and 103 articles on CARE) were first exported in plain text format, containing publication records and citation data. Subsequently, using the "Data/Import/Export" function of CiteSpace software, these files were converted into executable formats for further analysis.

In this study, CiteSpace was employed to conduct cluster analyses of research institutions, countries, authors, and keywords, generating scientometric knowledge maps through its automated clustering function. The annual publication distribution analysis helps reveal the developmental trajectory of the discipline, while collaboration networks among institutions or countries reflect the geographical distribution and academic influence patterns in research on three different exercise modalities for the elderly. Keyword analysis demonstrates the core research themes and cutting-edge trends in this field (Liu et al., 2019), whereas keyword co-occurrence analysis effectively tracks the temporal evolution of research hotspots, enabling researchers to concisely grasp the developmental trajectory of major topics and deepen their understanding of domain progression (Chen, 2006). Additionally, the identification of "burst terms" can reveal fluctuations in the influence and attention accorded to certain research themes over time (Huibin et al., 2025).

## 3. Results

### 3.1. Publication trend of aerobic, resistance, and combined aerobic and resistance exercise research in older adults

The annual distribution of publications is presented in Figure 2, which illustrates the number of studies related to AE, RE, and CARE in the elderly from 2015 to 2024. To be specific, the volume of publications on AE has remained relatively stable, fluctuating between 56 and 72 articles annually. A peak of 72 publications was recorded in 2017, after which the trend plateaued, indicating consistent academic interest with limited growth. In contrast, RE has been the most studied topic, although publication numbers have varied. After 69 articles in 2015, output dropped slightly before peaking at 103 in 2019. It then declined, reaching a low of 35 in 2023, with a modest rebound to 55 in 2024. These trends suggest RE was a research hotspot from 2017 to 2019, but interest has decreased in recent years. Compared to AE and RE, research on combined exercise (CE) remains limited in volume but has shown a gradual upward trend. The number of related publications increased from 6 in 2015 to 12 in 2024, suggesting that this area is gaining increasing scholarly attention and holds potential for future research development.



**Figure 2** Annual distribution of the studies on aerobic, resistance, and combined aerobic and resistance exercise research in the elderly. *Source:* Web of Science Core Collection Database.



### 3.2. Countries on aerobic, resistance, and combined aerobic and resistance exercise research in older adults

Table 1 lists; presents the top 10 countries in terms of publication volume and centrality in research on AE, RE, and CARE among older adults, reflecting each country's research activity and collaborative influence in these domains. In AE research, the United States ranks first with 104 publications and a centrality score of 0.30, indicating strong international academic influence. It is followed by Brazil (93 publications) and China (65 publications), with China's centrality score of 0.12 suggesting an important role in international collaboration. In the field of RE, Brazil leads with 176 publications, while the United States follows with 134 publications but exhibits the highest centrality across all exercise types (0.46), highlighting its extensive cooperative network. China (52 publications), Spain (49), and Canada (39) also rank among the top contributors, forming a collaborative pattern centered around Brazil and the United States. In contrast, CE research shows significantly lower overall publication volume. Brazil remains the most productive (19 publications), followed by China (17) and Japan (13). Although the United States ranks fifth with only 10 publications, its centrality score of 0.14 indicates a notable influence in international collaboration. These findings collectively demonstrate that while Brazil leads in publication quantity across all three exercise types, the United States consistently plays a central role in global research collaboration, especially in RE and CE domains.

**Table 1** Top 10 countries for frequently published studies on aerobic, resistance, and combined aerobic and resistance exercise research in the elderly.

NO	Quantity (AE)	Countries	Centrality	Quantity (RE)	Countries	Centrality	Quantity (CARE)	Countries	Centrality
1	104	United States	0.3	176	Brazil	0.21	19	Brazil	0.1
2	93	Brazil	0.09	134	United States	0.46	17	China	0.06
3	65	China	0.12	57	South Korea	0	13	Japan	0.04
4	44	Italy	0.11	52	China	0.08	12	South Korea	0
5	44	Japan	0.06	49	Spain	0.07	10	United States	0.14
6	42	South Korea	0	39	Canada	0.11	8	Iran	0
7	40	Spain	0.07	38	Japan	0.01	5	Germany	0
8	32	Canada	0.05	37	Italy	0.18	5	Spain	0.01
9	30	Germany	0.18	37	Denmark	0.02	4	Canada	0.03
10	28	Chinese Taiwan	0.01	35	England	0.19	4	Chinese Taiwan	0

Source: Web of Science Core Collection Database.

Figure 3, 4, 5 presents the national co-occurrence maps in the fields of AE, RE, and CARE for older adults. In these maps, the size of each node represents the number of publications, lines between nodes indicate collaboration between countries, the thickness of the lines reflects the strength of collaboration, and the color gradient illustrates the temporal evolution of the research network.

In AE research (Figure 3), international collaborations appear relatively balanced, with several small to medium-sized collaborative clusters. The United States shows cross-regional cooperation with several Asian countries, including China, Japan, and South Korea, as well as with European countries such as Switzerland, France, England, and Italy. Brazil also maintains cooperative ties with both European and Asian countries. These patterns suggest that AE-related research on older adults is characterized by a relatively broad and diverse international collaboration structure.

In contrast, the RE collaboration network (Figure 4) is more densely connected, indicating a stronger and more structured global research network. The United States and Brazil form a dual-core structure with frequent and stable cooperation between them. The U.S. has established strong ties with European countries (e.g., Denmark, Italy, England) and maintains ongoing collaborations with Asian countries such as South Korea and Japan. Similarly, Brazil engages actively with European nations (e.g., Spain, Germany, England) and collaborates with key Asian countries including China, Japan, and South Korea.

Figure 5 reveals that CE research is still at a relatively early stage of development in terms of international cooperation. The connections between countries are sparse, and two regional clusters can be observed. The first cluster, centered on Brazil, involves collaboration with the United States and Spain. The second cluster is concentrated in East Asia, consisting of China, Japan, and South Korea, where intra-regional cooperation remains steady. Overall, the collaboration network for CE studies is less mature and geographically fragmented compared to AE and RE.



CiteSpace, v. 6.3.R1 (64-bit) Advanced  
May 15, 2025, 11:42:25AM MYT  
WoS: /Users/jizhibinbin/Desktop/AE Cite space/Data  
Timespan: 2015-2024 (Slice Length=1)  
Selection Criteria: g-index (k=25), LRF=2.5, L/N=10, LBY=5, e=1.0  
Network: N=62, E=278 (Density=0.147)  
Largest 5 CCs: 61 (98%)  
Nodes Labeled: 1.0%  
Pruning: None

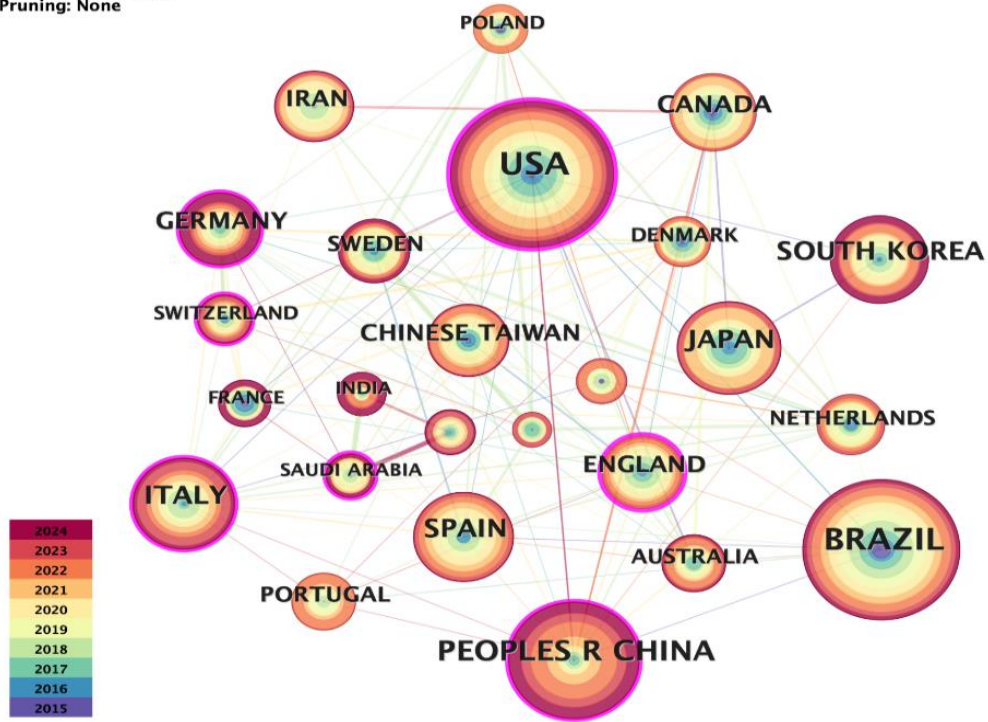


Figure 3 Co-occurrence map of countries conducting research on aerobic exercise research in the elderly.

CiteSpace, v. 6.3.R1 (64-bit) Advanced  
May 16, 2025, 4:06:59PM MYT  
WoS: /Users/jizhibinbin/Desktop/RE Cite space/Data  
Timespan: 2015-2024 (Slice Length=1)  
Selection Criteria: g-index (k=25), LRF=2.5, L/N=10, LBY=5, e=1.0  
Network: N=63, E=210 (Density=0.1075)  
Largest 5 CCs: 61 (96%)  
Nodes Labeled: 1.0%  
Pruning: None  
Modularity Q=0.4524  
Weighted Mean Silhouette S=0.7665  
Harmonic Mean(Q, S)=0.569

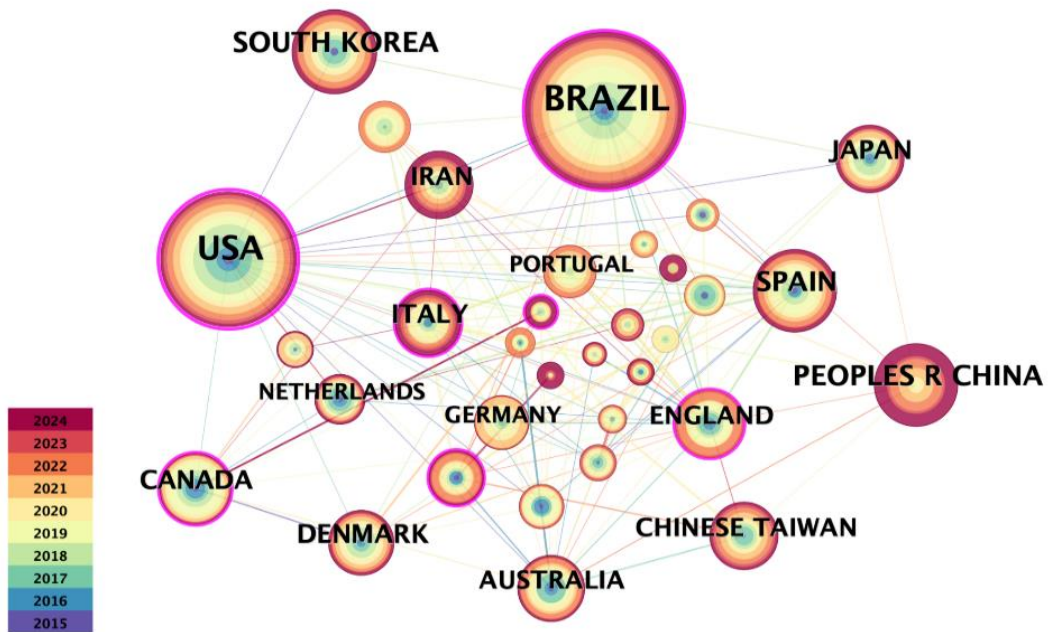
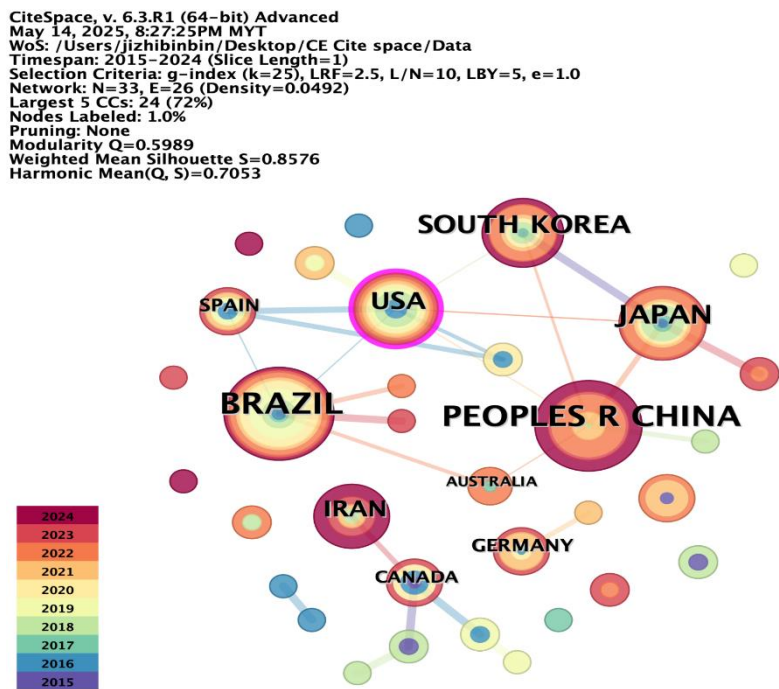


Figure 4 Co-occurrence map of countries conducting research on resistance exercise research in the elderly.





**Figure 5** Co-occurrence map of countries conducting research on combined aerobic and resistance exercise research in the elderly.

3.3. Institutions on aerobic, resistance, and combined aerobic and resistance exercise research in older adults

Table 2 lists the top 10 institutions in terms of publication volume in research on AE, RE, and CARE for older adults. In AE research, the University of São Paulo in Brazil leads with 15 publications, although its centrality score is 0, indicating limited involvement in international collaboration. It is followed by the Federal University of Rio Grande do Sul (14 publications) and Karolinska Institutet in Sweden (13 publications, centrality 0.04). Notably, despite having only 9 publications, the University of Texas System in the United States has a centrality of 0.07, suggesting a moderate bridging role in the academic network.

In RE research, the Federal University of Rio Grande do Sul ranks first with 32 publications and a relatively high centrality score of 0.16. The University of Copenhagen follows with 30 publications and a centrality of 0.04. Other key contributors include Bispebjerg Hospital and Copenhagen University Hospital (25 and 23 publications, respectively), both from Denmark. Several Brazilian institutions also show strong performance, including the University of São Paulo, State University of Londrina, Federal University of Santa Catarina, and State University of Campinas.

In contrast, each of the listed institutions has published only one article, and all centrality scores are 0, indicating the absence of a well-established collaborative network in this emerging field. This suggests that research on combined exercise interventions is still in a preliminary stage, lacking institutional consolidation and cross-institutional cooperation.

Figure 6, 7, and 8 present the institutional co-occurrence maps in the research areas of AE, RE, and CARE for older adults. According to Figure 6, there are notable collaborative relationships among various research institutions, with two primary core collaboration clusters currently formed in this field. The Universidade de São Paulo and the Universidade Federal de São Paulo are core institutions within the Brazilian academic network and maintain a close collaborative relationship with each other. In addition, the University of Texas System plays a leading role in international cooperation, showing strong collaborative links with Universidade Federal do Rio Grande do Sul and Hospital de Clínicas de Porto Alegre.

Figure 7 shows a denser and more complex collaboration network, with three major clusters formed. Brazil demonstrates a high level of institutional cooperation, with major institutions such as Universidade de São Paulo, Universidade Estadual de Campinas, and Universidade Federal de Santa Catarina forming a tightly knit national research network. In Northern Europe, Bispebjerg Hospital acts as a central hub, closely connected with Copenhagen University Hospital and University of Copenhagen, forming a strong Nordic research cluster. Notably, Universidade Federal do Rio Grande do Sul stands out with a particularly high publication volume and wide collaborative reach, serving as an important intermediary between Brazilian institutions and European research networks.

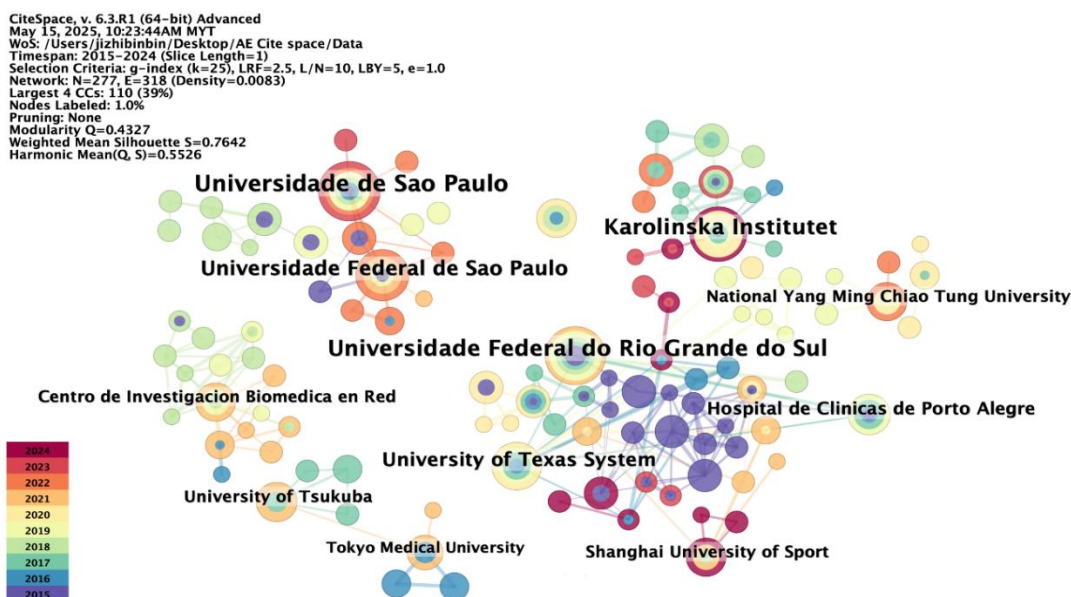
Figure 8 indicates that collaboration among institutions in CE research remains limited, with a sparse and dispersed network structure. Within the existing collaboration map, a university in Porto Alegre, Brazil, plays a central hub role, maintaining cooperative relationships with several institutions, including Sun Yat-sen University and Fujian Normal University in China. Domestically, it collaborates closely with Hospital de Clínicas de Porto Alegre and Universidade Federal de Pelotas, forming a concentrated local network.



**Table 2** Top 10 institutions in terms of publication volume in research on aerobic, resistance, and combined aerobic and resistance exercise in the elderly.

NO	Quantity (AE)	Institution	Centrality	Quantity (RE)	Institution	Centrality	Quantity (CARE)	Institution	Centrality
1	15	Universidade de São Paulo	0	32	Universidade Federal do Rio Grande do Sul	0.16	1	United States Army	0
2	14	Universidade Federal do Rio Grande do Sul	0.01	30	University of Copenhagen	0.04	1	Jieyang Polytech	0
3	13	Karolinska Institutet	0.04	25	Bispebjerg Hospital	0	1	Baylor College Medical Hospital	0
4	11	Universidade Federal de São Paulo	0	23	Copenhagen University Hospital	0.02	1	National Center for Child Health & Development - Japan	0
5	9	University of Texas System	0.07	17	Universidade de São Paulo	0.04	1	Korea University Medicine	0
6	9	Cairo University	0	16	Universidade Estadual de Londrina	0.02	1	Hong Kong Polytechnic University	0
7	8	Egyptian Knowledge Bank (EKB)	0	16	Universidade Federal de Santa Catarina	0.07	1	Rice University	0
8	7	Hospital de Clínicas de Porto Alegre.	0	15	Universidad Publica de Navarra	0.07	1	Baskent University	0
9	6	National Yang Ming Chiao Tung University	0.01	14	Maastricht University	0.02	1	University of Jyvaskyla	0
10	6	Shanghai University of Sport	0.01	13	Universidade Estadual de Campinas	0.06	1	Navarrabiomed	0

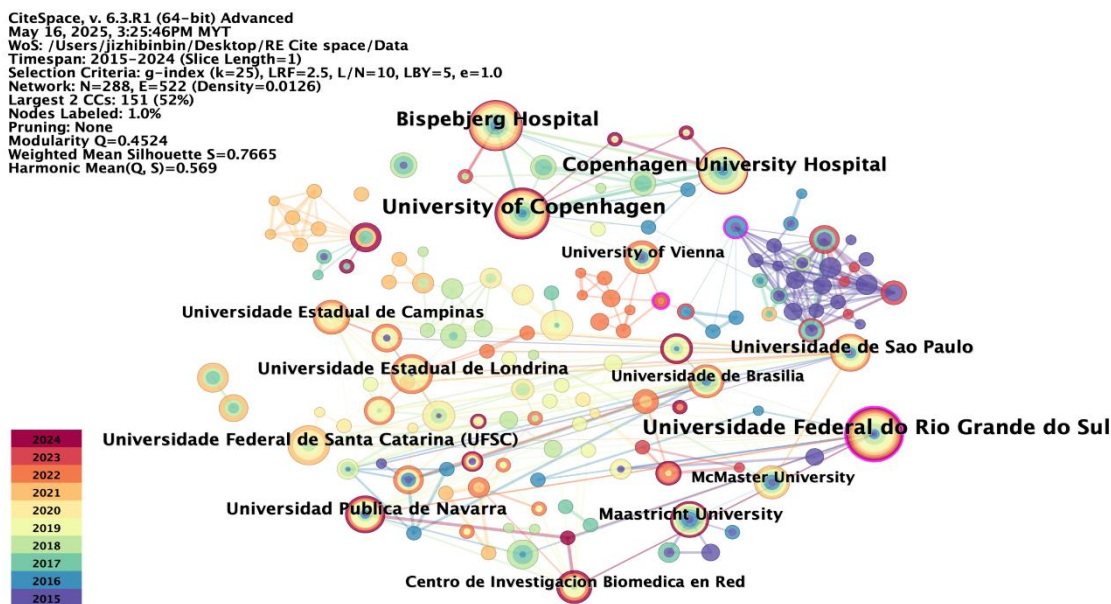
Source: Web of Science Core Collection Database.



Universidade de Sao Paulo (University of São Paulo); Universidade Federal de Sao Paulo (Federal University of São Paulo); Universidade Federal do Rio Grande do Sul (Federal University of Rio Grande do Sul); Centro de Investigacion Biomedica en Red (Center for Networked Biomedical Research).

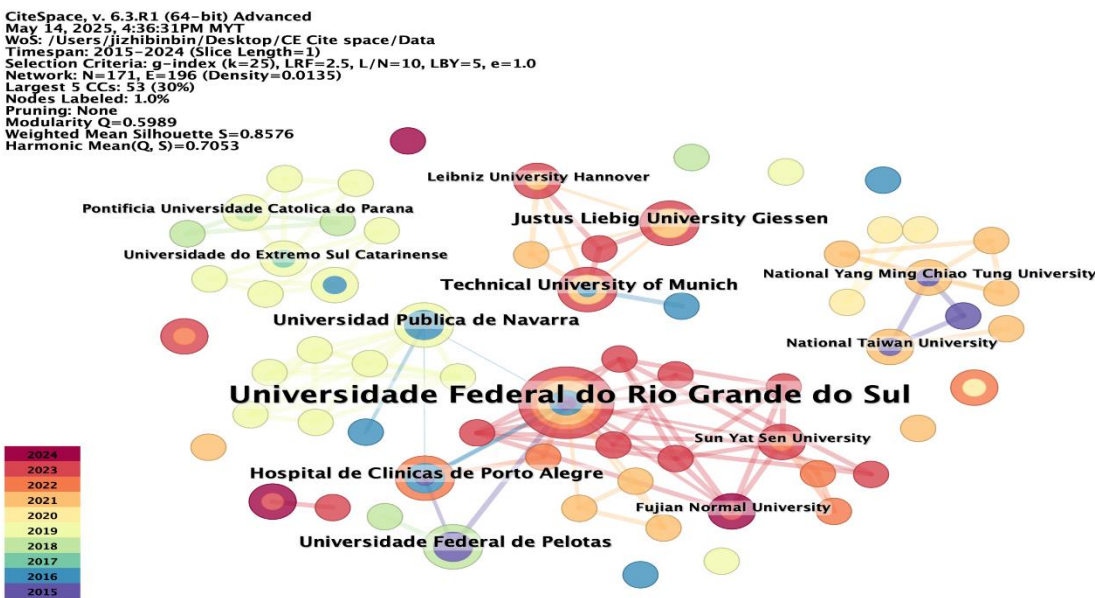
**Figure 6** Cluster view of the research institutions publishing literature on aerobic exercise research in older adults.





Universidade de Sao Paulo (University of São Paulo); Universidade Federal do Rio Grande do Sul (Federal University of Rio Grande do Sul); Centro de Investigacion Biomedica en Red (Center for Networked Biomedical Research); Universidade Estadual de Campinas (University of Campinas); Universidade Estadual de Londrina (State University of Londrina); Universidade de Brasilia (University of Brasilia); Universidade Federal de Santa Catarina (Federal University of Santa Catarina); Universidad Publica de Navarra (Public University of Navarre).

**Figure 7** Cluster view of the research institutions publishing literature on resistance exercise research in older adults.



Universidade Federal do Rio Grande do Sul (Federal University of Rio Grande do Sul); Universidad Publica de Navarra (Public University of Navarre); Pontificia Universidade Catolica do Parana (Pontifical Catholic University of Paraná); Universidade do Extremo Sul Catarinense (University of Southern Santa Catarina); Hospital de Clinicas de Porto Alegre (Porto Alegre Clinical Hospital); Universidade Federal de Pelotas (Federal University of Pelotas).

**Figure 8** Cluster view of the research institutions publishing literature on combined aerobic and resistance exercise research in older adults.

3.4. Author on aerobic, resistance, and combined aerobic and resistance exercise research in the elderly

Figure 9, 10, and 11 illustrate the authorship contributions and collaboration patterns in the fields of AE, RE, and CARE among older adults. Figure 9 shows that Alberton, Cristine Lima is a prolific author and maintains a stable collaborative relationship with Kanitz, Ana Carolina. A notable collaborative cluster has also formed among Marzetti, Emanuele, Calvani, Riccardo, Picca, Anna, and Tosato, Matteo. In contrast, researchers such as Park, Jinkee and Andersson, Eva A appear to work more independently, without forming prominent collaboration networks.

Figure 10 presents a distinct collaboration landscape in the field of RE. The network exhibits a clear multi-centered radial structure, with a significantly higher density of collaboration compared to the aerobic exercise field. Close cooperative ties are observed among Kjaer, Michael, Andersen, Jesper Lovind, Schjerling, Peter, Agergaard, Jakob, and Holm, Lars. Similarly,



Schoenfeld, Brad, Cyrino, Edilson Serpeloni, Ribeiro, Alex Silva, and Prestes, Jonato also form a closely linked group. In addition, Cadore, Eduardo Lusa and Izquierdo, Mikel are connected through collaborative work.

Figure 11 reveals that the author collaboration network in the field of combined exercise is the weakest among the three. Isolated nodes are common, indicating limited collaboration. Although some authors, such as Cadore, Eduardo Lusa, Izquierdo, Mikel, and Alberton, Cristine Lima, remain active as in other exercise domains, the overall scope and intensity of collaboration are noticeably lacking.

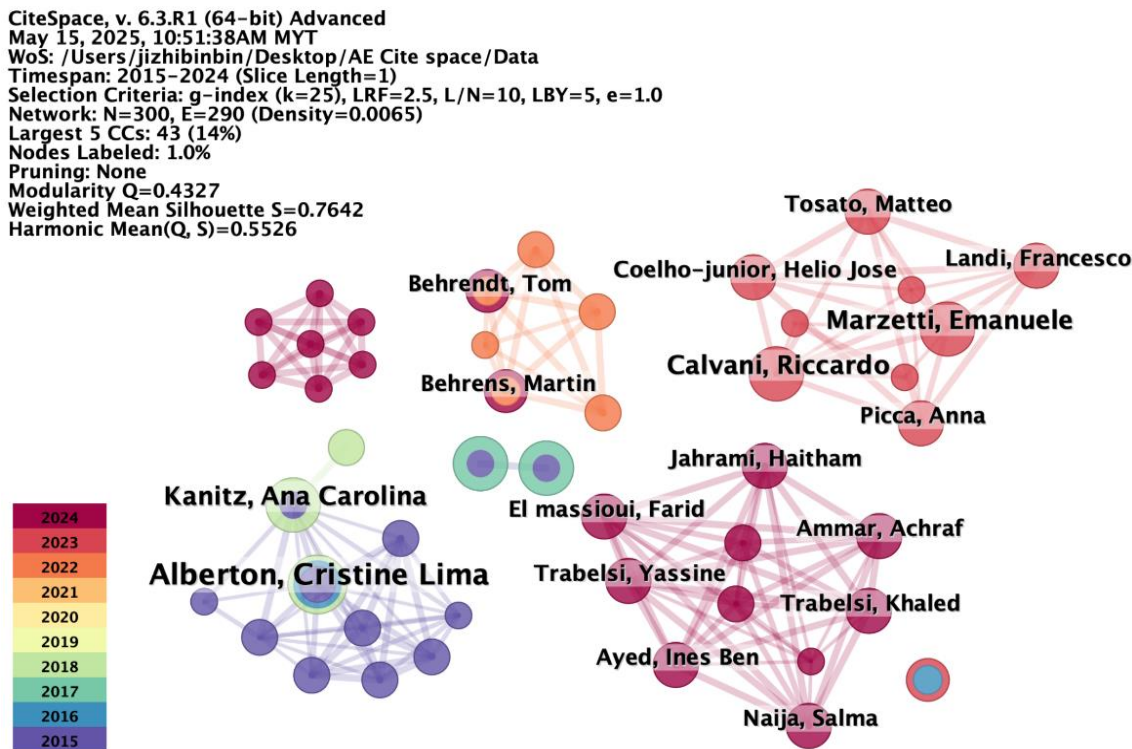


Figure 9 Author collaboration network in the literature on aerobic exercise research in older adults.

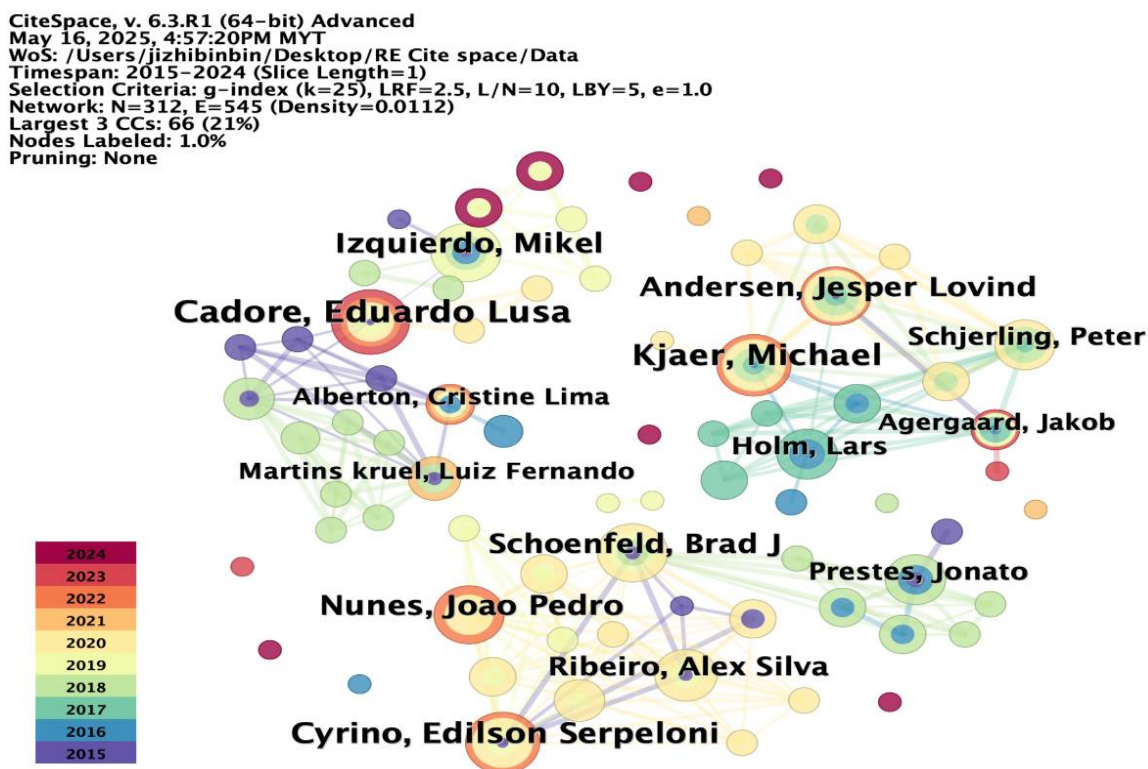


Figure 10 Author collaboration network in the literature on resistance exercise research in older adults.



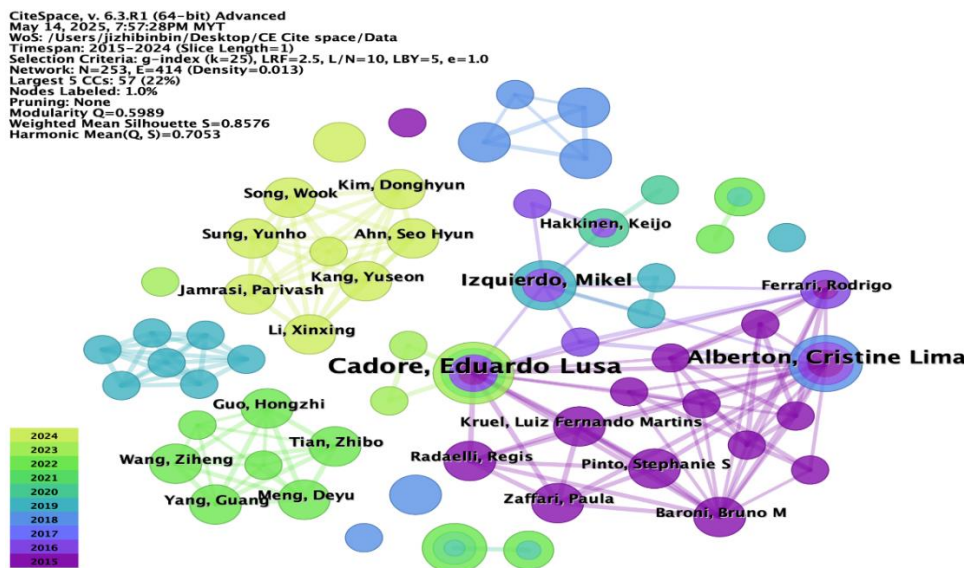


Figure 11 Author collaboration network in the literature on combined aerobic and resistance exercise research in older adults.

### 3.5. Keywords co-occurrence analysis on aerobic, resistance, and combined aerobic and resistance exercise research in older adults

In CiteSpace, keyword co-occurrence analysis generally involves two main steps: first, extracting and classifying keywords to calculate their frequency of occurrence; and second, generating a keyword co-occurrence matrix for further analysis (Chen, 2006). Figure 12, 13, and 14 present the keyword co-occurrence networks for AE, RE and CARE, providing a visual overview of research themes in the field and highlighting both the commonalities and distinctions among different exercise modalities.

Figure 12 displays the keyword co-occurrence network for AE in the elderly, comprising 446 nodes and 1,980 links. In terms of co-occurrence frequency, aside from the keywords "older adults" and "AE," the top five most frequently occurring keywords are: physical fitness, physical activity, organic disease, physical performance, and RE.

Figure 13 presents the keyword co-occurrence network for RE in older adults, containing 536 nodes and 2,224 links. Excluding "older adults" and "RE," the top five keywords by frequency are: physical fitness, organic disease, physical performance, and physical activity.

Figure 14 illustrates the keyword co-occurrence network for CARE. Compared to the networks for AE and RE, this network contains fewer nodes (264) and links (943), reflecting the relatively smaller research base. Beyond the keywords "older adults" and "combined exercise," the top five co-occurring terms are: physical fitness, metabolic disease, quality of life, fall risk, and cardiovascular disease.

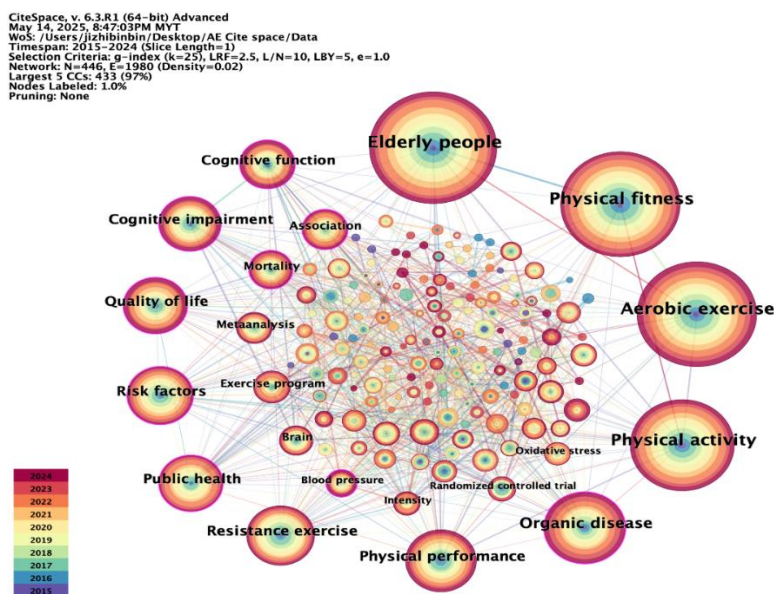


Figure 12 Keyword co-occurrence in the literature on aerobic exercise research in the elderly.



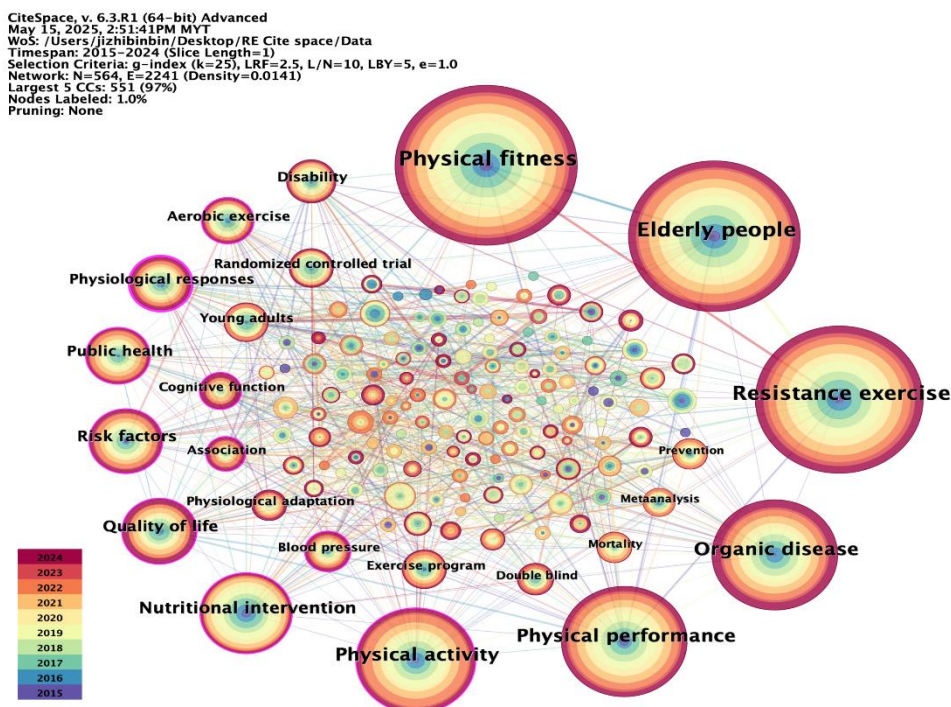


Figure 13 Keyword co-occurrence in the literature on resistance exercise research in the elderly.

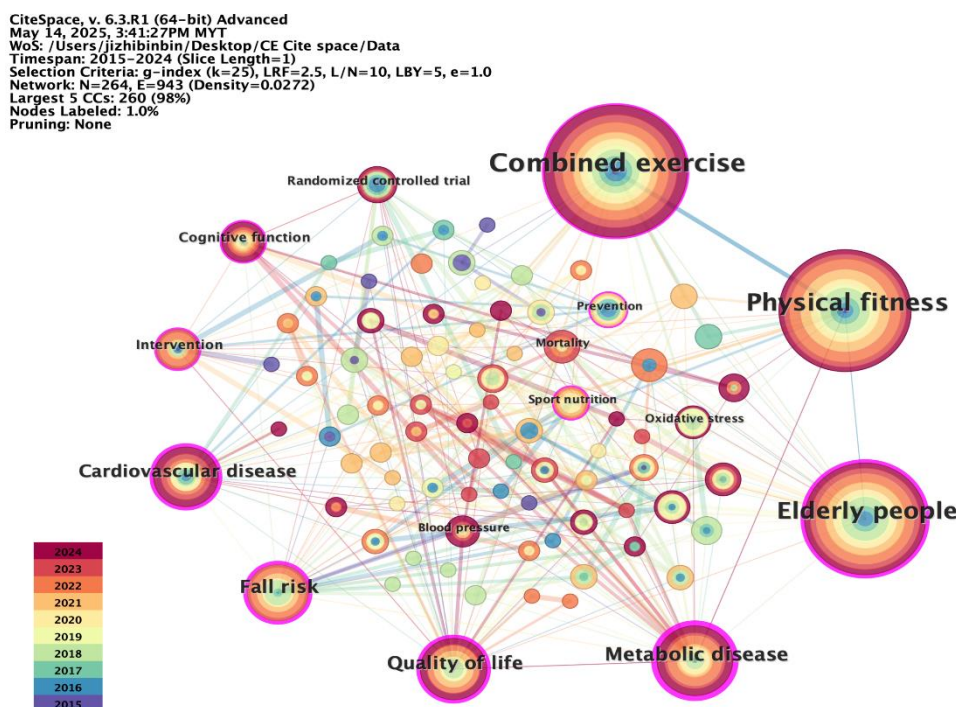


Figure 14 Keyword co-occurrence in the literature on combined aerobic and resistance exercise research in the elderly.

Figure 15 presents the keyword clustering results for AE in older adults, revealing the major research themes within the WoS dataset. A total of eight significant clusters were identified, namely: Neurotrophic factor, physical activity, cardiac rehabilitation, cardiovascular regulation, exercise physiology, metabolic intervention, athletic performance enhancement, and adaptive exercise. These clusters reflect a wide range of topics, including neural and cognitive health, cardiovascular regulation, metabolic and physiological mechanisms, physical performance enhancement, and adaptive exercise strategies.

Figure 16 shows the keyword clusters for RE in older adults. Seven major thematic clusters were identified: nutritional modulation, quality of life, cardiometabolic exercise intervention, cardiometabolic regulation, functional recovery, metabolic regulation, skeletal muscle remodeling, and musculoskeletal function. These clusters indicate that RE research in older adults primarily focuses on health promotion, functional improvement, and chronic disease management.



Figure 17 presents the keyword clusters related to CARE in older adults. Seven significant clusters were identified, including: fall prevention, hormone, physical fitness, elderly people, cognitive function, cardiovascular disease, exercise intensity, and combined exercise. Compared to AE or RE alone, research on combined exercise exhibits a narrower but more refined scope. Its themes are more specific and practical, making it particularly suitable for precision health interventions and the design of clinical exercise prescriptions.

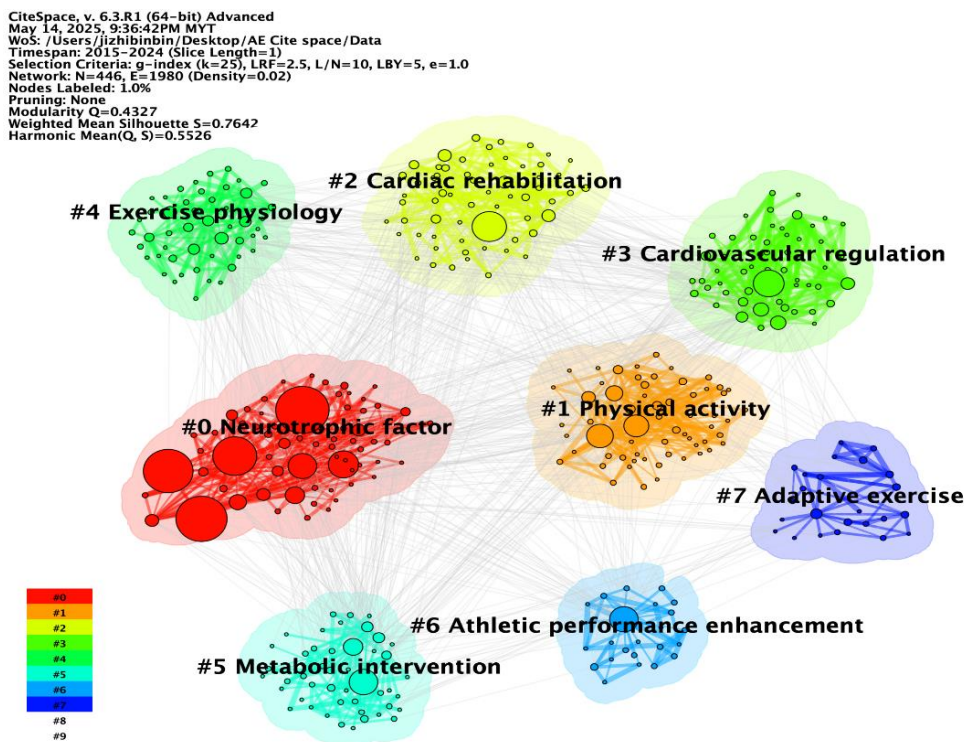


Figure 15 Keyword cluster in the literature on aerobic exercise research in the elderly.

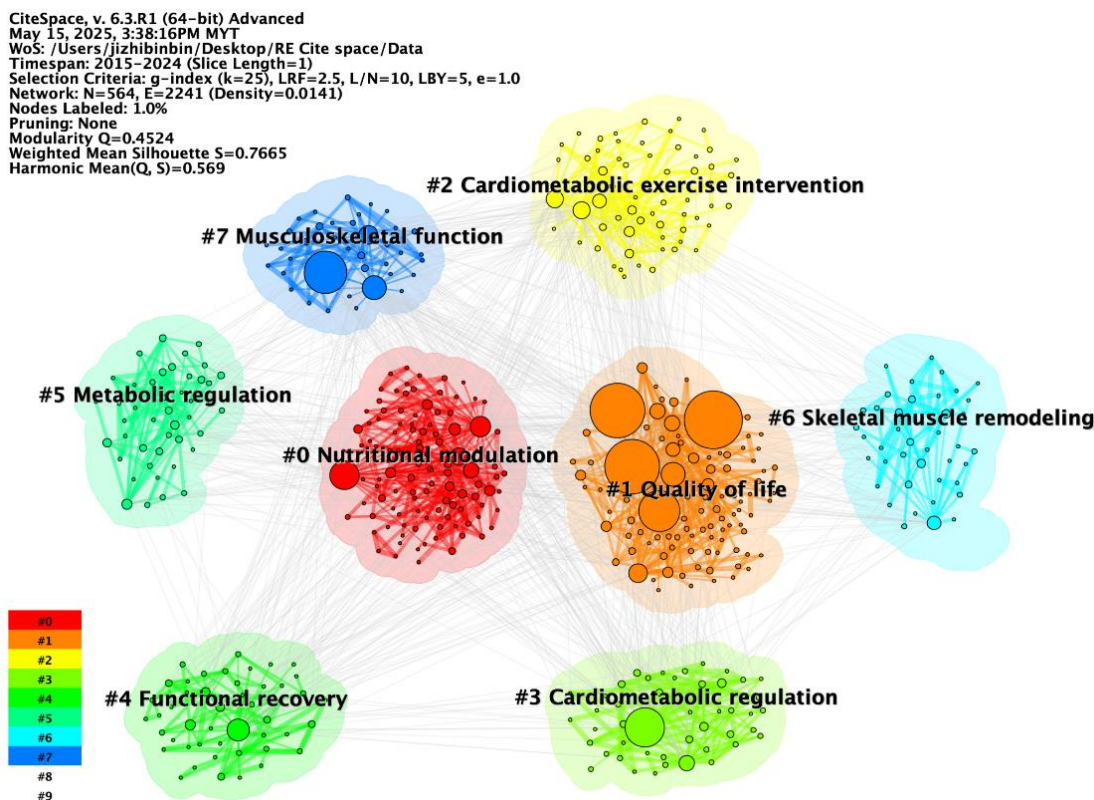


Figure 16 Keyword cluster in the literature on resistance exercise research in the elderly.



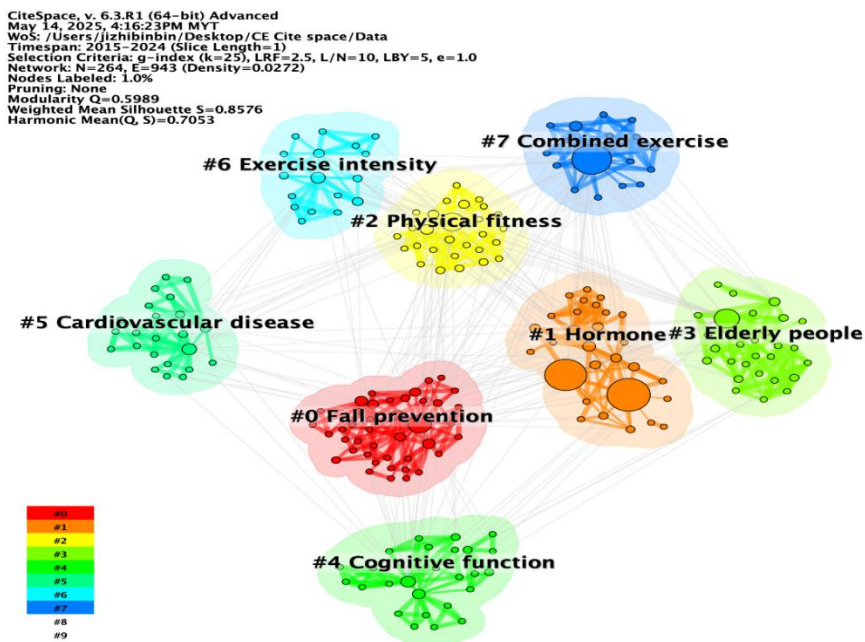


Figure 17 Keyword cluster in the literature on combined aerobic and resistance exercise research in the elderly.

In addition, Figure 18, 19, and 20 present the top ten keywords with the strongest citation bursts and their temporal evolution from 2015 to 2024. Blue lines indicate the start and end years or time spans of the citation bursts, while red segments represent the duration and intensity of the bursts. Figure 18 shows that in the field of AE research for older adults, the earliest citation bursts occurred for the keywords controlled trial and postmenopausal women, both active from 2015 to 2017. The keyword with the highest burst intensity was guidelines in 2021, reaching a burst strength of 2.69. The longest-lasting bursts were observed for guidelines, nutritional interventions, outcome measures, and autonomic nervous system, all of which remained influential from 2021 to 2024. These findings suggest a clear phase-based trend in research focus: in the early stage (2015–2017), studies centered on clinical trials and specific populations; in the middle period (2018–2020), attention shifted to health concerns such as decline and overweight; and in the recent period (2021–2024), the focus turned to nutritional interventions, outcome measures, and autonomic nervous system, several of which continue to gain attention through 2024.

Figure 19 shows that protein synthesis had the strongest citation burst (3.93) between 2016 and 2017, followed by essential amino acids (2.87) and young adults (2.58). Research trends in RE exhibit a clear trajectory: early studies (2015–2017) focused on fundamental mechanisms of amino acid metabolism and protein synthesis; the middle phase (2019–2020) explored gene expression and glycemic control; while recent studies (2021–2024) emphasize clinical applications such as resistance training protocols and the Asian Working Group for Sarcopenia 2021, with resistance training protocols showing a burst strength of 2.73 that continues through 2024.

Figure 20 displays the top ten keywords with the strongest citation bursts in research related to CARE. Among them, oxidative stress had the highest burst strength (1.8), active from 2017 to 2019. Notably, mortality is the only keyword whose burst continues through to 2024 (from 2022), with a burst strength of 1.39, indicating sustained scholarly interest in this topic in recent years.

Keywords	Year	Strength	Begin	End	2015 - 2024
Controlled trial	2015	2.14	2015	2017	[Red segment from 2015-2017]
Postmenopausal women	2015	1.73	2015	2017	[Red segment from 2015-2017]
Randomized controlled trial	2015	2.43	2016	2017	[Red segment from 2016-2017]
Decline	2015	2.2	2018	2019	[Red segment from 2018-2019]
Overweight	2015	1.99	2020	2021	[Red segment from 2020-2021]
Guidelines	2021	2.69	2021	2024	[Red segment from 2021-2024]
Nutritional interventions	2017	2.35	2021	2024	[Red segment from 2021-2024]
Recovery	2016	1.88	2021	2022	[Red segment from 2021-2022]
Outcome measures	2021	1.79	2021	2024	[Red segment from 2021-2024]
Autonomic nervous system	2021	1.79	2021	2024	[Red segment from 2021-2024]

Figure 18 Top 10 Keywords with the Strongest Citation Bursts on aerobic exercise research in the elderly.





Figure 19 Top 10 Keywords with the Strongest Citation Bursts on resistance exercise research in the elderly.



Figure 20 Top 10 Keywords with the Strongest Citation Bursts on combined aerobic and resistance exercise research in the elderly.

#### 4. Discussion

This study still has certain limitations. First, the data collection period was limited to January 2014 through December 2024, excluding earlier relevant research. This may partially restrict a comprehensive understanding of the long-term evolutionary trends and geographical distribution patterns in the field. Second, the observed decline in publications related to resistance training after 2020 may be influenced by disruptions to research progress or delays in publication due to the COVID-19 pandemic. Therefore, the interpretation of these trends requires further validation and supplementation with longer-term and continuously updated data.

##### 4.1. Temporal trends in exercise intervention publications

This study shows that research on AE has maintained a steady output over the past decade, reflecting its foundational role in improving cardiovascular and cognitive health (Chapman et al., 2013). Although its growth rate has been modest, AE remains a core intervention strategy for older adults and continues to receive stable academic attention. In contrast, RE has emerged as the most intensively studied intervention, peaking in 2019. This surge is closely linked to the 2018 release of the revised European consensus on the definition and diagnosis of sarcopenia by the European Working Group on Sarcopenia in Older People (EWGSOP), which not only redefined sarcopenia but also officially classified it as a distinct disease (Cruz-Jentoft et al., 2019). This major shift significantly stimulated research in resistance training. However, a decline in output has been observed since 2020, possibly due to the impact of the COVID-19 pandemic and a saturation of studies in the field.

Notably, although combined exercise (CE) has a relatively low publication volume, it demonstrates the strongest growth momentum. Between 2015 and 2022, the number of CE-related publications increased by 250%, indicating that multi-modal interventions targeting complex health conditions such as frailty and sarcopenia in older adults are becoming an emerging research focus. This exercise modality has been shown to produce synergistic benefits in enhancing physical function, reducing fall risk, and managing multiple chronic diseases (Cadore et al., 2014; Sillanpää et al., 2012). Furthermore, the World Health Organization (WHO) has emphasized the importance of combined exercise in their official guidelines and policy recommendations (Bull et al., 2020), which is expected to further promote research and application in this area.



In summary, research on exercise interventions for older adults is gradually shifting from single-mode approaches toward integrated and multidimensional strategies. While RE continues to lead in research activity and AE maintains its foundational role, combined exercise is steadily emerging as a promising direction.

#### 4.2. Contributions of regions, institutions, and authors

In the field of exercise interventions for older adults, global academic collaboration exhibits a typical pattern of "regional clustering – institution-led – author-centered diffusion," with a distinct multi-level structural characteristic particularly evident across the three themes of AE, RE, and CARE.

From the perspective of regional collaboration networks, the United States, Brazil, and China have formed the core group of countries in the field of exercise interventions for older adults over the past decade. The U.S. and Brazil occupy central positions in the global collaboration networks, particularly in research on AE and RE. Among them, the United States serves as a key intermediary between North America and Europe. Its high regional centrality indicates its leading role in global academic research, a trend likely influenced by the launch of the NIH's "STRIDE" program in 2015 (Ganz et al., 2019). In contrast, Brazil's research is more concentrated within the Latin American region, a pattern that may be related to the strong support provided by the São Paulo Research Foundation (FAPESP) for higher education and research institutions (Fumes-Ghantous et al., 2020). Although Brazil's international collaborations are relatively limited, its domestic research output is active and characterized by a high degree of institutional synergy. In the field of CARE, Brazil continues to lead in publication output. Notably, Asian countries such as China and South Korea have rapidly emerged in CE research. In both countries, national health strategies such as "Healthy China 2030" (Li et al., 2024) and "The National Health Plan 2030" in South Korea (Oh, 2021) have explicitly incorporated physical activity interventions, placing particular emphasis on integrated exercise programs for the elderly. These policies have provided strong institutional and practical support for the development of CE research in these regions.

At the institutional aspect, key research institutions play a central driving role within their respective countries. In both AE and RE research, Universidade Federal do Rio Grande do Sul and Universidade de São Paulo have emerged as leading contributors in Brazil, supported by FAPESP. These institutions not only produce a high volume of publications but also play a guiding role in setting research themes and methodological standards. It is also worth noting the significant contributions from Karolinska Institutet in Sweden, as well as University of Copenhagen and Bispebjerg Hospital in Denmark. Both Sweden and Denmark were among the first countries to integrate the concept of "active aging" into their national health policies, and they have consistently ranked among the top performers in the EU's Active Aging Index (AAI), promoting older adults' employment, social participation, and independent living (Zaidi et al., 2017). However, in the field of combined exercise (CE), although some countries and institutions have started to explore this area, it remains at an early stage overall. The number of publications is relatively limited, and there is still a lack of clearly leading institutions and stable collaborative networks.

At the author level, numerous scholars have demonstrated sustained contributions across various types of exercise intervention research. In the field of AE, authors tend to form several stable but relatively independent research clusters, suggesting the presence of regionally rooted research traditions. In resistance and combined exercise research, scholars such as Cadore, Eduardo Lusa, Alberton, Cristine Lima, and Izquierdo, Mikel show high publication frequencies and occupy central positions within collaboration networks. These researchers are affiliated with highly productive institutions and have played a key role in expanding inter-institutional collaboration. In addition, RE research displays a well-organized, multi-centered collaboration structure, which reflects its strong interdisciplinary character across areas such as physiology, biomechanics, and clinical medicine. In contrast, research on combined exercise shows a fragmented pattern with limited collaboration among authors. Many studies are conducted independently, which may result from the underdeveloped research paradigm or the lack of standardized evaluation systems.

In summary, the United States, Brazil, and China and their representative institutions together form a tripolar structure in the current landscape of exercise research for older adults. The United States stands out for its research leadership and role in international coordination, Brazil is characterized by application-driven efforts and strong domestic collaboration, while China shows high potential and a rapidly growing presence in this field.

#### 4.3. Thematic evolution and research frontiers

Keyword co-occurrence and clustering analyses reveal the thematic distribution and evolutionary trajectory of research on the effects of different exercise interventions in the elderly. Specifically, studies on AE primarily focus on cardiovascular health, neural regulation, and metabolic control, highlighting the importance of AE in managing chronic diseases and improving physical function among the elderly (Juan and Xiany, 2023; Mei and Chang, 2022). Research on RE, by contrast, emphasizes the musculoskeletal system and nutritional interventions, reflecting the field's depth in exploring underlying mechanisms and functional recovery. In comparison, CARE is more oriented toward specific and practical clinical intervention goals, demonstrating a practice-driven approach aimed at functional improvement.

From a temporal perspective, burst keyword analysis further reveals the evolution of research hotspots across different stages. Specifically, in the field of AE, keywords such as autonomic nervous system, nutritional interventions, and functional

assessment have shown continuous bursts since 2021, indicating a shift toward more refined and personalized health promotion strategies. In contrast, early research on RE from 2015 to 2017 focused on fundamental mechanisms such as protein synthesis, while in later stages, attention turned to applied approaches and intervention strategies, including resistance training protocols and essential amino acids. This shift reflects the accelerated translation of basic research findings into practical applications. Additionally, although research on combined exercise (CE) began relatively late, emerging keywords such as fall risk and cognitive function suggest a growing trend toward integrated interventions targeting multiple health challenges. This indicates that CE has the potential to become a key area of focus in future research.

In summary, research on exercise interventions for older adults is gradually evolving from traditional focuses on physical enhancement and disease control toward more comprehensive and multidimensional health promotion strategies. The connection between basic mechanistic research and clinical application is becoming increasingly close, with growing attention to complex health needs such as cognitive function, fall prevention, and quality of life. As a key approach in addressing this shift, combined exercise is steadily leading the development of elderly exercise interventions toward more precise and integrated directions.

## 5. Conclusion

This study conducted a bibliometric analysis of global research on AE, RE, and CARE in the elderly based on data from the Web of Science (2015–2024), using CiteSpace as the core analytical tool.

This study provides a comprehensive overview of the research landscape on exercise interventions for the elderly. First, RE remains the most extensively studied, especially between 2017 and 2019, while AE exhibits consistent scholarly interest. CARE, though still limited in volume, has shown steady growth and is emerging as a promising research frontier. Second, in terms of geographic distribution, the United States, Brazil, and China are the leading contributors. However, collaboration networks in CARE research remain weak and dispersed, indicating the need for stronger international cooperation. Institutional and author analyses revealed several influential actors, though CARE studies lack stable core institutions and collaborative frameworks. Third, thematic evolution analysis suggests that AE research focuses on cardiovascular and cognitive benefits, RE emphasizes muscle function and nutritional support, and CARE centers on fall prevention, quality of life, and cognitive health. Despite its growing relevance, CARE research remains fragmented and underdeveloped.

In conclusion, the research on exercise intervention in the elderly is gradually shifting from a single model to a comprehensive and multidimensional model. This study provides a visualized overview of current knowledge structures and research hotspots, offering valuable guidance for future interdisciplinary collaboration and evidence-based exercise policy for aging populations.

## 6. Limitation

This study still has certain limitations. First, the data collection period was limited to January 2015 through December 2024, excluding earlier relevant research. This may partially restrict a comprehensive understanding of the long-term evolutionary trends and geographical distribution patterns in the field. Second, the observed decline in publications related to resistance training after 2020 may be influenced by disruptions to research progress or delays in publication due to the COVID-19 pandemic. Therefore, the interpretation of these trends requires further validation and supplementation with longer-term and continuously updated data.

## Acknowledgment

I would like to express my sincere gratitude to all contributors for their support throughout the research process. Special thanks are extended to those involved in the literature search, screening, and data visualization using CiteSpace. I also sincerely appreciate those who provided valuable guidance and revisions to the manuscript.

## Ethical Considerations

Not applicable.

## Conflict of Interest

The authors declare no conflicts of interest.

## Funding

This research did not receive any financial support.

## References



- Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J. P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., Lambert, E., ... Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. <https://doi.org/10.1136/bjsports-2020-102955>
- Cadore, E. L., Casas-Herrero, A., Zambom-Ferraresi, F., Idoate, F., Millor, N., Gómez, M., Rodríguez-Mañas, L., & Izquierdo, M. (2014). Multicomponent exercises including muscle power training enhance muscle mass, power output, and functional outcomes in institutionalized frail nonagenarians. *Age (Dordrecht, Netherlands)*, *36*(2), 773–785. <https://doi.org/10.1007/s11357-013-9586-z>
- Chapman, S. B., Aslan, S., Spence, J. S., Defina, L. F., Keebler, M. W., Didehban, N., & Lu, H. (2013). Shorter term aerobic exercise improves brain, cognition, and cardiovascular fitness in aging. *Frontiers in Aging Neuroscience*, *5*, 75. <https://doi.org/10.3389/fnagi.2013.00075>
- Chen, C. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology*, *57*(3), 359–377. <https://doi.org/10.1002/asi.20317>
- Chen, C. (2016). *CiteSpace: A practical guide for mapping scientific literature* (pp. 41–44). Nova Science Publishers.
- Ciairano, S., Liubicich, M. E., & Rabaglietti, E. (2010). The effects of a physical activity programme on the psychological wellbeing of older people in a residential care facility: An experimental study. *Ageing & Society*, *30*(4), 609–626. <https://doi.org/10.1017/S0144686X09990614>
- Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., ... Zamboni, M. (2019). Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. Sarcopenia: Revised European consensus on definition and diagnosis. *Age Ageing*, *48*(1), 16–31. <https://doi.org/10.1093/ageing/afy169>
- Dzikowski, P. (2018). A bibliometric analysis of born global firms. *Journal of Business Research*, *85*, 281–294. <https://doi.org/10.1016/j.jbusres.2017.12.054>
- Fumes-Ghantous, G., Corrente, J. E., & Tatis, A. F. G. (2020). Factors related to functional capacity and quality of life for elderly people in a middle-sized city of São Paulo, Brazil. *Health*, *12*(12), 1562–1574. <https://doi.org/10.4236/health.2020.1212113>
- Ganz, D. A., Siu, A. L., Magaziner, J., Latham, N. K., Trivison, T. G., Lorenze, N. P., Lu, C., Wang, R., Greene, E. J., Stowe, C. L., Harvin, L. N., Araujo, K. L. B., Gurwitz, J. H., Agrawal, Y., Correa-De-Araujo, R., Peduzzi, P., Gill, T. M., & STRIDE Investigators. (2019). Protocol for serious fall injury adjudication in the Strategies to Reduce Injuries and Develop Confidence in Elders (STRIDE) study. *Injury Epidemiology*, *6*, 14. <https://doi.org/10.1186/s40621-019-0190-2>
- Huibin, H., Wenchang, L., Ing, T. M., & Ning, H. (2025). A bibliometric analysis of Hakka studies: Insights from WoS and CSSCI data using CiteSpace. *Multidisciplinary Reviews*, *8*(9), 2025283. <https://doi.org/10.31893/multirev.2025283>
- Juan, P., & Xianyi, Z. (2013). Aerobic exercise effects on the health management of elderly patients with chronic diseases. *Revista Brasileira de Medicina do Esporte*, *29*, e2022\_0787. [https://doi.org/10.1590/1517-8692202329012022\\_0787](https://doi.org/10.1590/1517-8692202329012022_0787)
- Langlois, F., Vu, T. T., Chassé, K., Dupuis, G., Kergoat, M. J., & Bherer, L. (2013). Benefits of physical exercise training on cognition and quality of life in frail older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *68*(3), 400–404. <https://doi.org/10.1093/geronb/gbs069>
- Li, G., Wang, Z., Hao, Y., Qian, J., Hu, B., Wang, Y., Luo, X., Ning, Y., & Lin, F. (2024). Consensus statement of Chinese experts on exercise prescription (2023). *Sports Medicine and Health Science*, *6*(2), 200–203. <https://doi.org/10.1016/j.smhs.2024.02.003>
- Liang, M., Pan, Y., Zhong, T., Zeng, Y., & Cheng, A. S. K. (2021). Effects of aerobic, resistance, and combined exercise on metabolic syndrome parameters and cardiovascular risk factors: A systematic review and network meta-analysis. *Reviews in Cardiovascular Medicine*, *22*(4), 1523–1533. <https://doi.org/10.31083/j.rcm2204156>
- Liu, H., Zhao, S., & Xin, O. (2019). Analysis on the evolution path and hotspot of knowledge innovation study based on knowledge map. *Sustainability*, *11*(19), 5528. <https://doi.org/10.3390/su11195528>
- Mahmoudi, A., Amirshaghghi, F., Aminzadeh, R., & Mohamadi Turkmani, E. (2022). Effect of aerobic, resistance, and combined exercise training on depressive symptoms, quality of life, and muscle strength in healthy older adults: A systematic review and meta-analysis of randomized controlled trials. *Biological Research for Nursing*, *24*(4), 541–559. <https://doi.org/10.1177/10998004221104850>
- Mei, N., & Chang, Y. (2022). Effect of aerobic exercise on physical function indices in the elderly. *Revista Brasileira de Medicina do Esporte*, *29*, e2022\_0236. [https://doi.org/10.1590/1517-8692202329012022\\_0236](https://doi.org/10.1590/1517-8692202329012022_0236)
- Mi, J., Zhang, L., Sun, W., Wang, Z., Yang, P., Zhang, J., & Zhang, Y. (2023). Research hotspots and new trends in the impact of resistance training on aging: Bibliometric and visual analysis based on CiteSpace and VOSviewer. *Frontiers in Public Health*, *11*, 1133972. <https://doi.org/10.3389/fpubh.2023.1133972>
- Nouchi, R., Taki, Y., Takeuchi, H., Hashizume, H., Nozawa, T., Sekiguchi, A., Nouchi, H., & Kawashima, R. (2012). Beneficial effects of short-term combination exercise training on diverse cognitive functions in healthy older people: Study protocol for a randomized controlled trial. *Trials*, *13*(1), 200. <https://doi.org/10.1186/1745-6215-13-200>
- Oh, Y. (2021). The National Health Plan 2030: Its purpose and directions of development. *Journal of Preventive Medicine and Public Health*, *54*(3), 173–181. <https://doi.org/10.3961/jpmph.21.198>
- Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications*, *9*(1), 12. <https://doi.org/10.3390/publications9010012>
- Rismayanthi, C., Zein, M. I., Mulyawan, R., Nurfadhila, R., Prasetyawan, R. R., & Antoni, M. S. (2022). The effect of low impact aerobic exercise on increasing physical fitness for the elderly. *Jurnal Keolahragaan*, *10*(1), 137–146. <https://doi.org/10.21831/jk.v10i1.48743>
- Sillanpää, E., Häkkinen, K., Holviala, J., & Häkkinen, A. (2012). Combined strength and endurance training improves health-related quality of life in healthy middle-aged and older adults. *International Journal of Sports Medicine*, *33*(12), 981–986. <https://doi.org/10.1055/s-0032-1311589>
- Westcott, W. L. (2012). Resistance training is medicine: Effects of strength training on health. *Current Sports Medicine Reports*, *11*(4), 209–216. <https://doi.org/10.1249/JSR.0b013e31825dabb8>
- World Health Organization. (2022). *Ageing and health*. <https://www.who.int/zh/news-room/fact-sheets/detail/ageing-and-health>
- Yang, Z., Hotterbeex, P., Marent, P. J., Cerin, E., Thomis, M., & van Uffelen, J. (2024). Physical activity, sedentary behaviour, and cognitive function among older adults: A bibliometric analysis from 2004 to 2024. *Ageing Research Reviews*, *97*, 102283. <https://doi.org/10.1016/j.arr.2024.102283>
- Zaidi, A., Gasior, K., Zolyomi, E., Schmidt, A., Rodrigues, R., & Marin, B. (2017). Measuring active and healthy ageing in Europe. *Journal of European Social Policy*, *27*(2), 138–157. <https://doi.org/10.1177/0958928716676550>
- Zhang, R., Wang, J., Xi, H., Cheng, Y., & Han, B. (2025). Global research trends in sarcopenia: A bibliometric analysis of exercise and nutrition (2005–2025). *Frontiers in Nutrition*, *12*, 1579572. <https://doi.org/10.3389/fnut.2025.1579572>
- Zhao, J., Bai, Y., Yang, Y., & Li, X. (2024). The impact of aerobics on mental health and stress levels: A visualization analysis of the CiteSpace map. *PLOS ONE*, *19*(3), e0300677. <https://doi.org/10.1371/journal.pone.0300677>
- Zhao, Y., Li, J., Tao, C., & Ding, R. (2022). Research hotspots and trends of cardiopulmonary exercise test: Visualization analysis based on CiteSpace. *Medicine in Novel Technology and Devices*, *16*, 100191. <https://doi.org/10.1016/j.medntd.2022.100191>

