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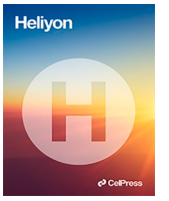

Knowledge mapping of exercise and physical activity research in older adults: Hotspots, bursts, and trends of the last decade

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ABSTRACT

Background and objectives: Global aging has increased the importance of health management in older adults. Exercise is a crucial strategy for healthy aging and has led to numerous scientific advancements due to its impact on age-related illnesses. We aim to investigate the research hotspots, bursts of knowledge base, and trends in the field of exercise and physical activity in older adults over the past decade and present them in a visual manner.

Methods: We searched and retrieved data from the Web of Science database, and performed a bibliometric analysis of publications on exercise and physical activity research in older adults from 2013 to 2022. We evaluated the current status and hotspots through co-occurrence analysis using VOSviewer. The evolution and bursts of knowledge base were assessed through co-citation analysis using CiteSpace. Thematic evolution was analyzed using the bibliometrix package to discover keyword trends. The attribution and collaboration of countries/regions, institutions and authors were also analyzed.

Results: A total of 27,820 publications were included. Publications on exercise and physical activity in older adults increased from 1755 records in 2013–3737 records in 2022 annually. In co-occurrence analysis of keywords, 5 major clusters were revealed: sarcopenia, cognition, frailty, mental health, and rehabilitation. Co-citation analysis reveals that the knowledge base has evolved from references focused on frailty, dementia, and physical activity before 2016 to references focus on sarcopenia, cognition and sedentary behavior after 2020. Among the top 10 high-frequency keywords, sarcopenia demonstrated a consistent and significant upward trend, with its percentage increasing from 8.7 % (82 times) in 2016 to 12.2 % (236 times) in the most recent year, making it the most frequently used keyword. Frailty ranked second, starting at 5.6 % (41 times) in 2013 and gradually rising to 11.7 % (225 times) in 2022. The most productive country, institution and author were the USA (8212 publications), the University of Pittsburgh (501 publications), and Brendon Stubbs(94 publications), respectively.

Discussion: Publications on exercise and physical activity for older adults have surged in the last decade, accompanied by a shift in the knowledge base. Regional disparities in the academic output in this field need to be addressed in the future to promote healthy aging.

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1. Introduction

The global ageing challenge is increasing, with 771 million people aged 65 or over worldwide in 2022 and a projected 1.6 billion by 2050 [1]. With improved medical care and lifestyle changes, global human life expectancy is also gradually increasing [2]. Ageing-related diseases are primary causes of the global disease burden [3]. Delaying ageing process and maintaining a longer healthy life span are viable strategies to reduce the social and economic burden.

Exercise and physical activity are crucial for maintaining the health of older adults, which can improve cognitive and motor function, enhance mental health, reduce risks of age-related diseases, and even extend life expectancy [4,5]. As complex fields involving multidisciplinary intersections, exercise and physical activity have shown beneficial effects on skeletal-muscular, cardiovascular, immunological, and neurological systems [6].

Quickly and accurately focusing on hotspots and challenges can provide directions for breakthroughs in complex fields. Visualizing the hotspots and trends of research fields via bibliometrics and knowledge mapping were defined as "research weaving" framework recently [7,8] with the advantage of allowing for the quantitative analysis of large scale and highly heterogeneous literatures, and the objective and visual presentation of past scholarly research results, thereby reducing artificial bias in the judging process of publications [8]. Bibliometric analysis and knowledge mapping had been used to analyze research status, hotspots, and trends in fields such as obesity [9], neuroscience [10], obstetrics, and gynecology [11].

The field of exercise and physical activities in older adults is gaining importance and relevant publications are increasing dramatically over the past decade, and there is a lack of objective quantitative investigation on current status, hotspots, and trend of research in the face of large-scale scientific findings. This study analyzed the literature published from 2013 to 2022, presenting the research hotspots, bursts of knowledge base, and trends of themes of this field in a visualized manner, aiming to help researchers obtain a comprehensive understanding of this interdisciplinary and multi-system field.

2. Materials and methods

2.1. Searching strategy and data collection

This study was designed as a cross-sectional study in the Web of Science Core Collection (WoSCC) database, the most influential scientific database including journals considered to be of high quality and widely used for bibliometric analysis in the health/medical field [12–14]. The latest literature search was conducted on May 23, 2023, the search and retrieve strategy were shown below: 1. The search terms were TS = ("physical activity" OR "exercise" OR "aerobic exercise" OR "resistance exercise" OR "endurance exercise" OR "high-intensity interval training") AND TS = ("elderly" OR "older adults" OR "geriatric") in the Web of Science database; 2. publication date was from January 1, 2013, to December 31, 2022; literature in 2023 was not included due to ongoing publications; 3. available records in the WoSCC; 4. publication type was article or review, excluding other types of publications including conference, comment, and editorial. All records were downloaded in "Plain text" format to avoid changes due to constant updating. The following publication information was collected: title, abstract, keywords, authors, institution, country, and references.

2.2. Data analysis and mapping

VOSviewer (1.6.18, Leiden University, Netherlands), bibliometrix package (3.2.1) in R (4.0.0, www.r-project.org/) and CiteSpace (6.1.4, Drexel university, Chaomei Chen), were used in the analysis.

Co-occurrence analysis can identify high density keywords to detect research hotspots and was conducted using VOSviewer based on the author's keywords [15]. VOSviewer was developed by Van Eck and Waltman and has been widely used in bibliometric analysis research for knowledge mapping of large-scale documents [16]. In the visual map, the area of the nodes is proportional to the frequency of keywords, and the color of the nodes is determined by their category in cluster analysis. The parameters of keywords co-occurrence included unit of analysis (all keywords), counting method (full counting), Minimum number of occurrences of a keyword (50).

Thematic evolution and thematic maps were generated using the bibliometrix package for reflecting thematic evolution. The bibliometrix package is developed by Aria M and Cuccurullo C for conducting comprehensive scientific mapping analysis [17]. Thematic evolution shows the evolution of themes in different time slices with the Sankey diagram. Thematic maps are based on the density index as the vertical coordinate and the centrality index as the horizontal coordinate. Density represents the strength of internal connections between keywords of a topic, and centrality is the strength of connections between a topic and other topics externally. Thematic maps were divided into four quadrants: I. Motor Themes represent the themes significant and well-developed; II. Niche Themes represent the themes highly developed but less connected with other themes; III. Emerging or Declining Themes represent the possible emerging or declining themes with low internal and external connections; IV. Basic Themes are considered to be the basic and transversal themes of the discipline [18]. Trajectories of change between different time slices were identified to determine emerging or declining trends in themes [17]. The parameters of thematic evolution and thematic maps included weight index (inclusion index weighted by word-occurrences), time slices cutting year (2017), numbers of labels for each cluster (5).

Reference co-citation analysis was used to discover the knowledge base of the domain and its evolution [19]. CiteSpace, an analysis software for bibliometrics developed by Chen Chaomei, was used to display the co-citation relationship in a timeline manner [20,21]. References cited in an article offer valuable insights into the interrelations between scientific base. Co-citation networks establish links between two articles when they are cited together by a third article, thus creating conceptual clusters of interrelated articles. We

generated the evolution of co-citation networks of different time slices, to observe how concepts change over time. Color-coded nodes and edges are used to distinguish the network and colored by year. The thickness and color of the node's rings represent the number of citations an article receives in a particular year. Purple rings represent the node's betweenness centrality. Nodes with high betweenness centrality act as bridges between conceptual clusters in different time frames. The parameters of reference co-citation included time slicing (2013–2022), years per slice (1), node type (cited reference), selection criteria (top N = 50), and no clipping. Co-citation burst detection was used to reflect a sharp increase in attention to a research topic within a time period [15].

We analyzed the contribution of countries/regions, institutions, and authors and calculated the widely used quantitative index of productivity, H-index [22], and G-index [23]. Co-authorship analysis was used to reflect scientific collaborative relationships using VOSviewer, which are considered to exist when different authors, institutions, or countries/regions are present in a publication at the same time [24].

All raw data used in the study were obtained from the public database and ethical approval was waived.

3. Results

3.1. Temporal distribution of publications

As shown in the flowchart of literature searching (Fig. 1), we finally retrieved 27,820 publications, including 23,587 articles (84.8 %) and 4233 reviews (15.2 %). The annual number of publications has seen a significant rise, from 1755 in 2013 to 3737 in 2022 (Fig. 2A).

3.2. Hotspots of keywords

A keyword co-occurrence analysis (Fig. 2B) identified five clusters from keywords occurring more than 50 times: sarcopenia, cognition, frailty, mental health, and rehabilitation. The blue cluster focused on sarcopenia-related studies that promote skeletal muscle strength and physical function through resistance training and nutritional support, with underlying mechanisms including inflammation, oxidative stress, mitochondria, muscle protein synthesis, and leucine. The purple cluster centered on cognition studies primarily through aerobic exercise, promoting executive function as well as cardiorespiratory fitness, with possible mechanisms related to the hippocampus that may ultimately improve dementia diseases such as Alzheimer's disease (AD). The yellow cluster is frailty-related studies, and currently epidemiology remains the focus, with gait speed and grip strength being the key concerns, and diabetes being the most frequently mentioned disease. The green cluster focused on physical activity promoting the mental health of older adults, mainly involving depression, loneliness, stress, social isolation, and sleep problems, using accelerometry as an important research tool. The red cluster showed rehabilitation studies that focused on balance, falls and pain reduction in stroke, osteoarthritis and Parkinson's patients, which involved emerging technologies including virtual reality and exergames and traditional methods including tai chi. After removing keywords of the synonyms of exercise and older adults, the 20 most frequently occurring keywords included sarcopenia, frailty, cognition, rehabilitation, quality of life, dementia, depression, obesity, physical function, and falls

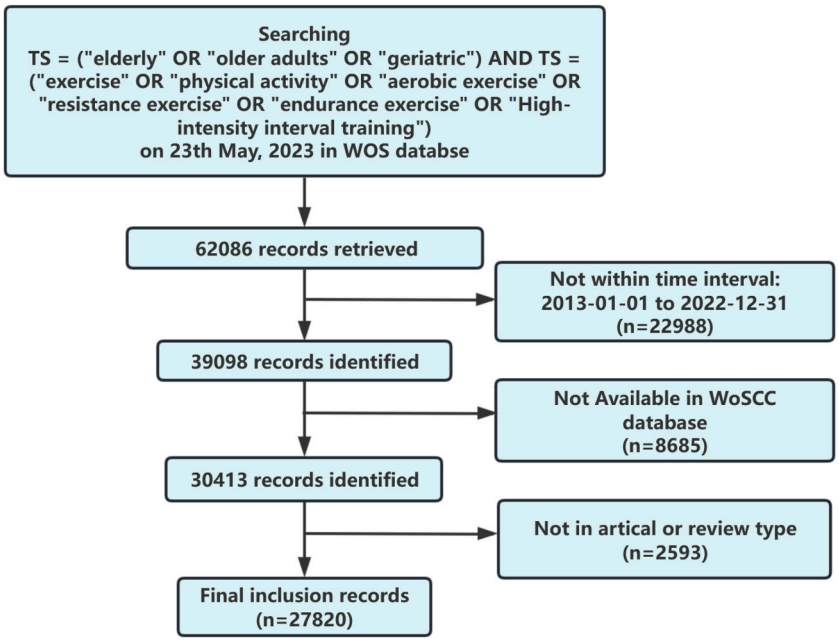


Fig. 1. The flowchart of searching and selection process.

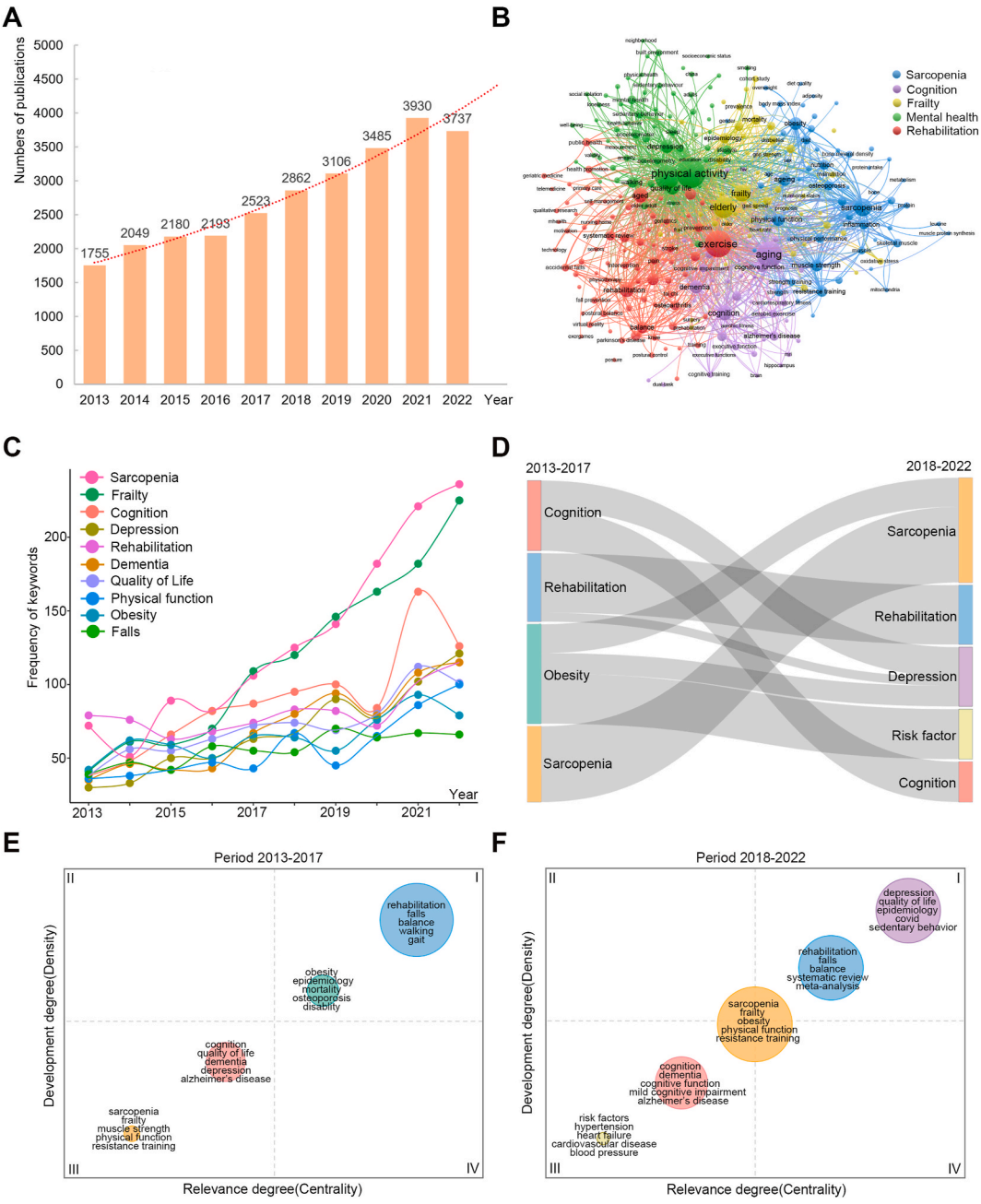


Fig. 2. The hotspots and trends of publications in the field of exercise and physical activity in older adults. (A) The changes in the numbers of global publications over time; (B) The co-occurrence analysis of keywords, nodes are proportional in size to the frequency of keyword occurrence and the color of the nodes is determined by their category in cluster analysis; (C) The changes of high-frequency keywords over time; (D) The thematic evolution of publications in the last decade; (E/F) Thematic maps during 2013–2017 and 2018–2022. Thematic maps were divided into four quadrants: I: Motor Themes with high density and centrality II: Niche Themes with high density but low centrality III: Emerging or Declining Themes with low density and centrality IV: Basic Themes with low density but high centrality.

(Table 1).

Table 2 lists the top 10 cited publications, with the Consensus Report of the Asian Working Group for Sarcopenia published having the highest total citation count of 2389 times [25], and the report by Lancet Commission on Dementia prevention, intervention, and care in 2020 having the highest average citations per year with 725 times [26].

Table 1
Top 20 most frequently occurring keywords in the field of exercise and physical activity in older adults.

Rank	Keywords	Records	Rank	Keywords	Records
1	sarcopenia	1312	11	balance	534
2	frailty	1189	12	muscle strength	528
3	cognition	899	13	resistance training	484
4	rehabilitation	820	14	walking	451
5	quality of life	727	15	epidemiology	424
6	dementia	714	16	nutrition	394
7	depression	692	17	gait	390
8	obesity	650	18	cognitive function	382
9	physical function	572	19	systematic review	382
10	falls	567	20	osteoarthritis	363

Table 2
Top 10 publications with high citations in the field of exercise and physical activity in older adults.

Rank	Title	Publication Year	Total citations	Average citations per year	Source	Type	Ref
1	Sarcopenia in Asia: Consensus Report of the Asian Working Group for Sarcopenia	2014	2389	265.4	Journal of the American Medical Directors Association	Consensus	[25]
2	The Physical Activity Guidelines for Americans	2018	2275	455.0	Journal of the American Medical Association	Guideline	[4]
3	Frailty Consensus: A Call to Action	2013	2183	218.3	Journal of the American Medical Directors Association	Consensus	[41]
4	Dementia prevention, intervention, and care: 2020 report of the Lancet Commission	2020	2175	725.0	Lancet	Review	[26]
5	World Health Organization 2020 guidelines on physical activity and sedentary behaviour	2020	1907	635.7	British Journal of Sports Medicine	Guideline	[36]
6	A 2 year multidomain intervention of diet, exercise, cognitive training, and vascular risk monitoring versus control to prevent cognitive decline in at-risk elderly people (FINGER): a andomized controlled trial	2015	1629	203.6	Lancet	Article	[57]
7	Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment	2020	1627	542.3	Journal of the American Medical Directors Association	Consensus	[25]
8	What low back pain is and why we need to pay attention	2018	1617	323.4	Lancet	Review	[58]
9	Osteoarthritis	2019	1402	280.4	Lancet	Review	[59]
10	Evidence-Based Recommendations for Optimal Dietary Protein Intake in Older People: A Position Paper From the PROT-AGE Study Group	2013	1291	322.8	Journal of the American Medical Directors Association	Consensus	[27]

3.3. Trends of themes

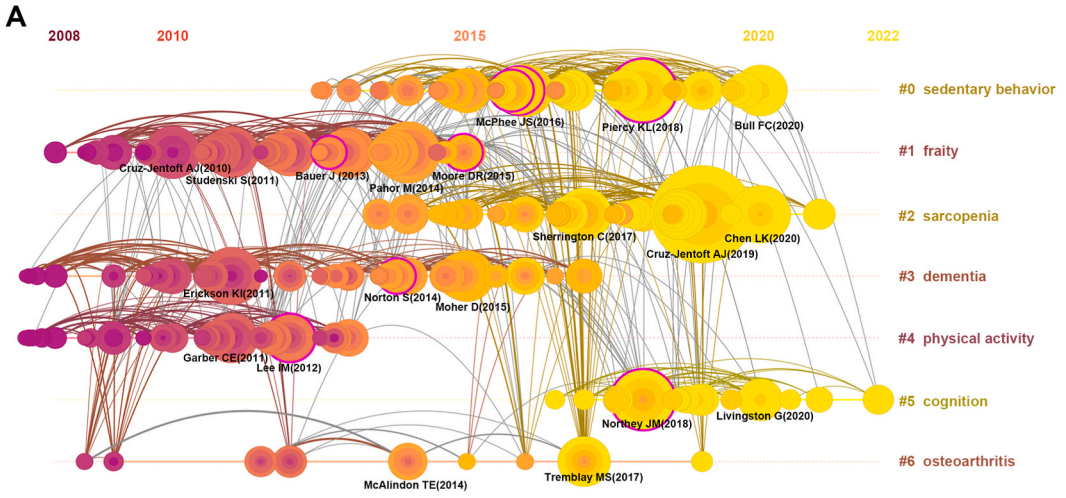
After removing the synonyms of searching terms, Fig. 2C showed the dynamic trends of high-frequency keywords over time. We conducted a statistical analysis of the top 10 high-frequency keywords of included publications, examining their percentages and frequencies for each year. Sarcopenia exhibited a consistent upward trend, increasing sharply from 8.7 % (82 times) in 2016 to 12.2 % (236 times) in the most recent year, making it the most frequent keyword. Frailty ranked second, starting at 5.6 % (41 times) in 2013 and gradually rising to 11.7 % (225 times) in 2022. Cognition was the third most frequent keyword, showing a gradual fluctuating upward trend. Rehabilitation was also an important keyword, although its percentage gradually decreased from 10.8 % (79 times) in 2013 to 6 % (115 times) in 2022. Cognition demonstrated a relatively high frequency in two specific years, with 8.7 % (82 times) in 2016 and 9.0 % (163 times) in 2021. In other years, the frequency fluctuated between 5 % and 8 %. The occurrence of the keyword Depression gradually increased from 4.1 % (30 times) in 2013 to 6.3 % (121 times) in 2022.

Fig. 2D shows the thematic evolution from 2013 to 2017 and 2018–2022, while Fig. 2E/2F represent the evolution of themes in different time periods based on centrality and density. A thematic cluster (orange) mainly including sarcopenia, frailty, muscle strength, physical function, and resistance training in the lower left quadrant in Fig. 2E moved towards the motor theme quadrant with higher density and centrality and a larger node area in the period 2018–2022 (Fig. 2F). Additionally, a new thematic cluster with high density and centrality emerged between 2018 and 2022, including keywords such as depression, quality of life, epidemiology, covid, and sedentary behavior.

3.4. Evolution and burst of knowledge base

We conducted a reference co-citation analysis to reflect the knowledge base in a timeline manner, showing 7 major clusters (Fig. 3A). The co-citation relationships between clusters over time are demonstrated in the Supplemental Video. From 2013 to 2016, most co-citations occurred among frailty, dementia, and physical activity clusters. From 2016, connections between these clusters and sarcopenia, cognition, and sedentary behavior clusters started to emerge. Purple ring nodes serving as bridges between these conceptual clusters. In recent years, research on sedentary behavior, sarcopenia, and cognition has strengthened, resulting in the main clusters of sedentary behavior, sarcopenia, and cognition in 2020 and beyond.

Several key references are highlighted in each cluster. Within frailty cluster, Bauer J et al.'s evidence-based recommendations for optimal dietary protein intake [27], and Moore DR et al.'s study on relationships between protein intake and myogenic fiber protein synthesis in older adults establish links between frailty cluster and sarcopenia cluster [28]. These studies suggest that older adults require more protein intake to maintain skeletal muscle mass than younger adults and protein intake levels should be adjusted based on activity levels and co-morbidities. In sarcopenia cluster, three key references are Sherrington et al.'s meta-analysis on fall prevention in older adults [29], the update on the consensus of sarcopenia by the European Working Group on Sarcopenia in Older People (EWGSOP) in 2019 [30], and Chen et al.'s RCT on multidomain interventions for physical frailty, depression, and cognition [31]. The meta-analysis by Norton S et al. establishes links between the dementia and cognition cluster [32], which suggests that around 1/3 of AD might be caused by modifiable risk factors. By reducing vascular risk factors, like physical inactivity, the incidence of AD could decrease. In the cognition cluster, Northey et al.'s meta-analysis on exercises improving cognitive function in adults aged 50 and above [33], and 2020 Lancet Commission report on dementia prevention, intervention, and care are two notable references [26]. Within physical activity cluster, the study by Lee IM et al. on the impact of physical inactivity on major global non-communicable diseases is an important bridge to the sedentary behavior cluster [34]. The study estimates that physical inactivity contributes to 9 % of premature



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2013 – 2022	Publish	Burst period	Strength	Authors	Source
	2010	2013-2015	99.09	Cruz-Jentoft AJ et al.	Age and Ageing
	2011	2013-2016	91.88	Erickson KI et al.	P NATL ACAD SCI USA
	2011	2013-2016	73.76	Studenski S et al.	JAMA
	2011	2013-2016	72.97	Garber CE et al.	MED SCI SPORT EXER
	2013	2015-2018	56.76	Bauer J et al.	J AM MED DIR ASSOC
	2014	2016-2019	76.08	Pahor M et al.	JAMA
	2016	2019-2022	56.82	McPhee JS et al.	Biogerontology
	2019	2020-2022	145.55	Cruz-Jentoft AJ et al.	Age and Ageing
	2018	2020-2022	66.04	Piercy KL et al.	JAMA
	2019	2020-2022	55.08	Sherrington C et al.	COCHRANE DB SYST REV

Fig. 3. The burst of references co-citation in the field of exercise and physical activity in older adults. (A) The co-citation analysis of references in time-line manner. Nodes are proportional in size to the number of reference co-citations and the thickness and color of the node's rings reflect the number of citations an article receives in a given year. Nodes with purple rings indicate high betweenness centrality, which are essential to connecting conceptual clusters that exist in different time periods. The connections between references are shown by the density of links and a unique color is assigned to each year. (B) The top 10 references with the strong citation bursts. A burst is a surge of the frequency of the citation of an article. The red bar indicates the time interval when the reference co-citation burst started and ended.

deaths and reducing inactivity by 25 % could prevent over 1.3 million deaths annually. In sedentary behavior cluster, McPhee et al.'s review on physical activity among older adults from the perspective of healthy aging and frailty [35], the 2018 physical activity guidelines for Americans [4] and the 2020 WHO guidelines for physical activity and sedentary behavior [36] are three key references.

We analyzed the top 10 references by their citation burst strength (Fig. 3B, Table 3). The EWGSOP consensus on sarcopenia in 2010 [37] and revised version in 2019 [30] had the strongest citation burst, followed by an RCT by Erickson et al. on exercise's cognitive benefits [38]. Four of the top 10 references' citation bursts are ongoing, including a review on physical activity, healthy aging, and frailty in older adults [35], EWGSOP2019 consensus [30], physical activity guideline for Americans [4], and a meta-analysis on exercise for fall prevention [39].

3.5. Attribution and collaboration of countries/regions, institutions and authors

A total of 144 countries/regions contributed to this field. Among the 40 countries/regions with over 100 publications, the United States had the highest number of publications at 8212 and South Africa had the fewest at 102. We identified the top 10 countries/regions based on their publication numbers, and calculated the publication count per million people and per trillion gross domestic product (GDP). Australia, the Netherlands, and Canada have the highest publication numbers per million people and per trillion GDP (Fig. 4A). England, and Australia have the most citations, while the Netherlands, England, and Germany have the highest average citations per publication (Table 4). Fig. 4B displays four co-authorship clusters among countries/regions, with the USA, England, and Australia having the strongest link strength. The largest red clusters mainly encompass North American and Asian countries such as the United States, Canada, China, and Japan due to their closer cooperation. European countries/regions are represented by two clusters, centered around England, Germany, and the Netherlands. Additionally, a yellow cluster is centered around Brazil and Spain.

Table 5 lists the top 10 productive institutions, with the University of Pittsburgh(501 publications) having the largest number of publications and University College London having the highest citations(16515 times) and average citations per publication(48.1 times per publication). Fig. 4C displays the co-authorship relationships of institutions, with the University of Pittsburgh having the highest link strength. Table 6 summarizes information on the top 10 authors with the most publications and Fig. 4D shows co-authorships among scholars and clusters them into 17 clusters. Brendon Stubbs having the largest number of publications (94 publications) and having the highest citations per publication (54 times per publication).

4. Discussion

The field of exercise and physical activities in older adults has become increasingly important, and this study aims to investigate research hotspots, bursts of knowledge base, and trends of themes in this field over past decade. This study analyzed literature focusing on exercise and physical activity in older adults published from 2013 to 2022 and presenting in a visualized manner. The number of global publications in this field has grown rapidly in the past decade, with sarcopenia, frailty, and cognition being major areas of focus. Research on sedentary behavior is also an emerging trend. Given the increasing global aging population, it is important to address regional disparities and promote cooperation to achieve early, effective, and equal physical exercise interventions for older adults.

Research on exercise in older adults is organized into five clusters: sarcopenia, cognition, frailty, mental health, and rehabilitation.

Table 3
Top 10 references with strong citation burst in the field of exercise and physical activity in older adults.

Rank	Title	Publication year	Citation Burst Period	Burst Strength	Source	Type	Ref
1	Sarcopenia: revised European consensus on definition and diagnosis	2019	2020–2022	145.55	Age and Ageing	Consensus	[30]
2	Sarcopenia: European consensus on definition and diagnosis	2010	2013–2015	99.09	Age and Ageing	Consensus	[37]
3	Exercise training increases size of hippocampus and improves memory	2011	2013–2016	91.88	PNAS	Article	[38]
4	Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial	2014	2016–2019	76.08	JAMA	Article	[60]
5	Gait Speed and Survival in Older Adults	2011	2013–2016	73.76	JAMA	Article	[61]
6	Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise	2011	2013–2016	72.97	Medicine & Science in Sports & Exercise	Guideline	[62]
7	The Physical Activity Guidelines for Americans	2018	2020–2022	66.04	JAMA	Guideline	[4]
8	Physical activity in older age: perspectives for healthy ageing and frailty	2016	2019–2022	56.82	Biogerontology	Review	[35]
9	Evidence-Based Recommendations for Optimal Dietary Protein Intake in Older People: A Position Paper From the PROT-AGE Study Group	2013	2015–2018	56.76	Journal of the American Medical Directors Association	Review	[27]
10	Exercise for preventing falls in older people living in the community	2019	2020–2022	55.08	Cochrane Database of Systematic Reviews	Meta-Analysis	[39]

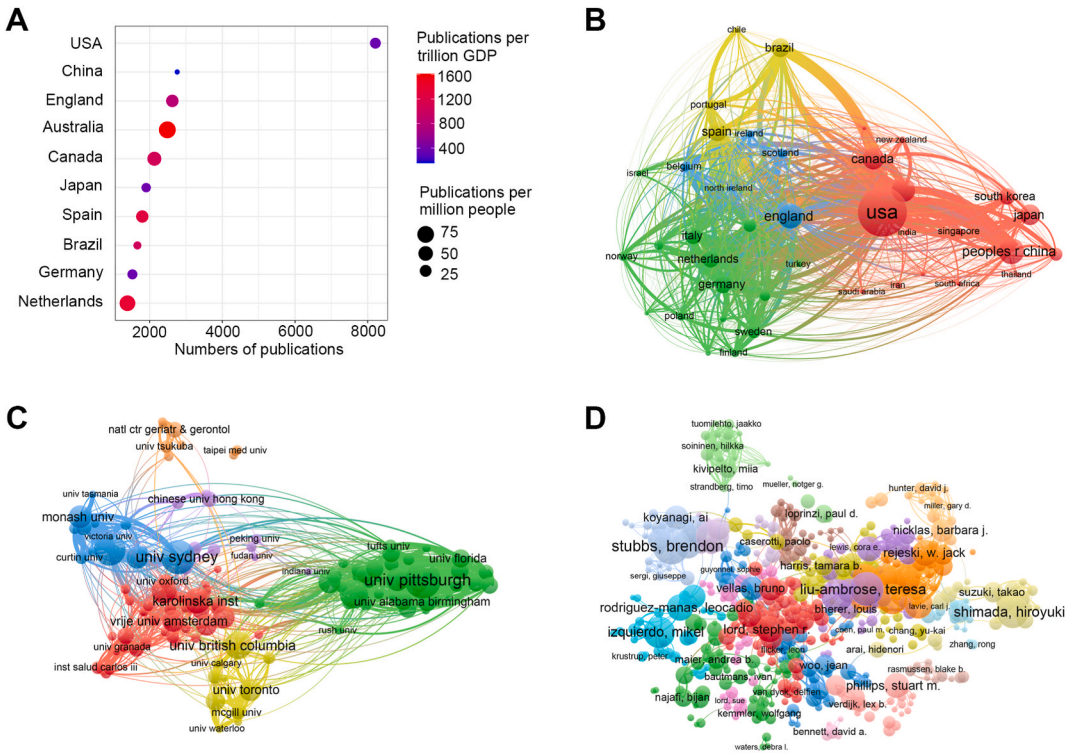

Fig. 4. The attribution sources, collaboration networks on exercise and physical activity in older adults (A) The top 10 productive countries/regions in this field; (B) The co-authorship relationships of countries/regions, the size of the nodes indicates the number of publications, and the thickness and length of the links between the nodes indicate the strength and relevance of the connections between the nodes; (C) The co-authorship relationships of institutions; (D)The co-authorship relationships of authors.

Table 4
The top 10 productive countries/regions in the field of exercise and physical activity in older adults.

Rank	Country/ region	Numbers of Publications	Publications per million people*	Publications per trillion GDP*	Numbers of Citations	Average citations per publication	Co-authorship total link strength
1	USA	8212	24.7	357.1	228972	27.9	5129
2	China	2756	2.0	155.4	46041	16.7	1607
3	England	2622	38.9	822.8	97889	37.3	4147
4	Australia	2485	96.5	1610.9	76773	30.9	2958
5	Canada	2128	55.6	1068.9	63363	29.8	2184
6	Japan	1903	15.1	385.4	34494	18.1	796
7	Spain	1796	37.9	1260.1	47315	26.3	2463
8	Brazil	1662	7.8	1033.0	30281	18.2	1440
9	Germany	1525	18.3	361.1	50497	33.1	2207
10	Netherlands	1388	79.2	1363.4	52531	37.8	2246

*Calculations based on latest population and GDP data from world bank of 2021 (https://databank.worldbank.org/). GDP is calculated using GDP (current US$).

Keyword analysis showed that frailty and sarcopenia are the two most frequent keywords in this field, with their use rapidly increasing after 2016. Sarcopenia is a condition characterized by the progressive loss of muscle mass and strength, which can result in physical disability, poor quality of life, and even death [37,40]. Frailty, on the other hand, is an age-related clinical condition characterized by a decline in physiological capacity and increased susceptibility to functional decline after stressor events, which can lead to a decrease in autonomy and independence in older adults [41,42]. Sarcopenia and frailty are related geriatric syndromes, with overlapping causes. Sarcopenia is often considered a significant contributor to frailty, and tends to develop before frailty [42]. Muscles, as an organ that can be intervened through training, have become a link between sarcopenia and frailty. We found the knowledge base has evolved from references focused on frailty before 2016 to references focused on sarcopenia. Currently, there is insufficient evidence to support individual and health-system interventions to manage frailty [43]. However, resistance exercise has been reported to reverse the loss of muscle strength equivalent to that lost in 20 years for frail older adults in a plan lasting 8–12 weeks, promoting gait speed and strength improvement [44]. Exercise training may currently be the most important preventive measure to reduce the frailty in older adults [43].

Table 5
The top 10 productive institutions in the field of exercise and physical activity in older adults.

Rank	Institution	Country/ region	Numbers of Publications	Numbers of Citations	Average citations per publication	Co-authorship total link strength
1	University of Pittsburgh	USA	501	16958	33.8	1153
2	University of Sydney	Australia	468	20006	42.7	622
3	University of Melbourne	Australia	431	12826	29.8	935
4	University of Illinois	USA	389	10629	27.3	454
5	University of British Columbia	Canada	377	10145	26.9	462
6	Karolinska Institutet	*Sweden*	354	12911	36.5	519
7	University College London	England	343	16515	48.1	390
8	University of California, *San Francisco*	*USA*	314	9687	30.9	650
9	*Monash University*	Australia	309	5485	17.8	581
10	Harvard Medical School	USA	306	7908	25.8	671

Table 6
The top 10 productive authors in the field of exercise and physical activity in older adults.

Rank	Author	Affiliation	Numbers of publications	Numbers of citations	Average citations per publication	Total link strength	H-index	G-index
1	Brendon Stubbs	King's College London/ Anglia Ruskin University	94	5078	54.0	202	39	72
2	Teresa Liu-Ambrose	University of British Columbia	84	2259	26.9	159	26	48
3	Fernando Rodriguez-Artalejo,	Universidad Autónoma de Madrid	82	1898	23.1	171	26	40
4	Luigi Ferrucci	National Institute of Health (USA)	81	3266	40.3	123	35	68
5	Hiroyuki Shimada	National Center for Geriatrics and Gerontology(Japan)	81	1934	23.9	317	24	41
6	Mikel Izquierdo	Universidad Pública de Navarra	78	3446	44.2	157	32	64
7	Abby C King	Stanford University	74	3675	49.7	305	27	60
8	Anne B Newman	University of Pittsburgh	70	2737	39.1	279	27	54
9	Marco Pahor	University of Florida	69	3017	43.7	365	27	65
10	Todd M Manini	University of Florida	68	2216	32.6	281	21	50

Frailty is a complex challenge that involves multiple systems and implementing multi-component intervention packages, evaluating their effectiveness, and controlling heterogeneity is difficult. Therefore, early identification and intervention of sarcopenia as an important antecedent stage in the onset of frailty may be a more accessible and efficient strategy. This may explain the research interest shifting from frailty to sarcopenia.

We found cognition is currently a significant research focus, with a shift from dementia in recent years. Dementia, characterized by ageing-related deterioration of cognitive function, is one of the leading causes of disability and dependence in older adults worldwide and no known cure [45]. Exercise has been studied as a potential treatment for cognitive impairment [46], but it remains a complex and controversial topic. Current evidence suggests that physical activity has a small but positive impact on both normal cognition and mild cognitive impairment, particularly through aerobic exercise [47]. However, in individuals with mild-to-moderate dementia, moderate-to-high intensity aerobic exercise and resistance training may improve physical fitness but do not appear to slow cognitive decline [48]. The meta-analysis by Northey et al. is found to be a key reference in cognition research cluster in our results and reported various types of exercise - aerobic, resistance, multi-component, and tai chi - improved cognition in adults over 50^{33}. These may account for the shift in research interest toward the cognitive domain. However, the benefits of exercise for dementia are still not negligible. The report on dementia by the Lancet Commission, also prominent in the cognitive cluster reference, highlighted physical inactivity as an important modifiable risk factor for dementia [26]. Several large studies have confirmed that moderate-to-vigorous physical activity can reduce the risk of dementia [49,50]. Further research is required to optimize exercise parameters for cognitive improvement in older adults with varying cognitive baselines and to fully understand the benefits of exercise for different age groups and the underlying mechanisms and biomarkers involved.

What needs to be made clear is that sarcopenia, frailty and cognition have a considerable degree of cross-linkage in studies of older adults. Recent evidence suggests that dementia increases the risk of developing sarcopenia and frailty [51], while sarcopenia itself is a potential risk factor for cognitive impairment [52]. Current evidence for improving cognition focuses mainly on aerobic exercise [26], although the evidence for aerobic exercise in cognitive improvement in dementia is insufficient, extended exercise parameters may still be an important direction. Multicomponent exercise programs have been shown to improve both physical and cognitive function in community-dwelling frail/pre-frail older patients with mild cognitive impairment or mild dementia [53].

Studies of sedentary behavior in older adults have also received attention in recent years. Our analysis indicates that sedentary behavior, depression, quality of life, epidemiology, and Covid were grouped together as a theme topic between 2018 and 2022. Given Covid-19 as a major health event during this period, its impact on physical inactivity among the older adults requires attention. Current analysis suggests that reduced physical activity among older adults during the pandemic may be a risk factor for depression [54]. In 2020, WHO issued guidelines on physical activity and sedentary behavior, recommending that older people over 65 years of age should limit the duration of sedentary behavior and use physical activity to replace sedentary behavior [36]. Due to the degradation of physical function and the frequent presence of multiple diseases in older adults, who may have less basic physical activity and time than adults, more evidence is needed to properly define sedentary behavior in older adults and what level of sedentary behavior is associated with the health and development of disease.

At last, we analyzed the contribution and collaboration in this field. In last decade, the USA, Australia, and Europe are major productive countries/regions in this field. Influential institutions and authors are mainly from these regions. China and Japan were the countries with the highest number of publications in the Asian region. According to population data in 2022, Europe and Northern America region has the highest proportion of older adults in the world, with nearly 19 % of the population aged 65 and older, followed by Australia/New Zealand region (16.6 %) [1], which may explain the high level of interest in these regions. In addition, studies have shown that there is a huge disparity in the funding of physical activity research between regions and the lack of funding agencies for physical activity in some regions may also discourage research output [55]. To achieve healthy aging, it is imperative to address regional disparities and promote cooperation in the future.

The limitation of this study is that the WoS database was the only data source for the bibliometric search. Although WoS is by far the predominant source of data for bibliometric analysis due to its consistent and standardized format of bibliographic records and the extensive coverage [13], our retrieved data may be incomplete. Effective integration of large-scale indexed records of publications across databases is currently difficult to achieve, which remains unresolved in studies of bibliometric analysis [11,56]. Suitable tools are needed to address this limitation in the future to reduce selection bias.

5. Conclusion

In the past decade, there has been a surge in publications on exercise and physical activity for older adults. Five interdisciplinary themes revealed in this field, with sarcopenia, frailty and cognition being the hotspots of research. Sedentary behavior is an emerging trend.

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Data will be made available on request.

CRediT authorship contribution statement

Ya-Xi Luo: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization. **Ying-Hai Zhu:** Writing – review & editing, Formal analysis, Data curation. **Xiu-Qing Yao:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e23181.

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