Systematic Review and Meta-Analysis

Medicine

OPEN

Visualization analysis of exercise intervention on Alzheimer disease based on bibliometrics

Trends, hotspots and topics

Yu Jin, MD[a], Xue Li, PhD[a,*], Qiongjia Yuan, PhD[a,b], Xiaohan Huang, BD[a], Deman Zhang, BD[a]

Abstract

Background: As the challenges of an aging society continue to escalate, Alzheimer disease (AD) has emerged as a significant health, social, and public concern, garnering substantial attention. Exercise, as a safe, effective, and cost-efficient approach with the potential to mitigate brain aging, has garnered considerable interest. Nevertheless, there has been a limited research investigating the current trends, hotspots, and topics of exercise on AD.

Methods: The literature spanning from 2013 to 2022 was obtained from the Web of Science database, and CiteSpace VI was employed to conduct an analysis encompassing fundamental data, keywords, and co-citation analysis.

Results: A total of 9372 publications were included in the analysis. The annual number of publications has exhibited a gradual increase. The United States and China made significant contributions, with England showing higher citation rates and greater academic influence. The *Journal of Alzheimers Disease*, Neurosciences Neurology, Liu-Ambrose, Teresa represents the most published journal, discipline, and author, respectively. The research trends can be summarized as exploring functional changes and potential mechanisms related to exercise impact on AD. The hotspots in the research include the intersection of AD and diabetes mellitus, as well as the underlying effects induced by exercise. The topics of interest revolve around the application of emerging technologies in the context of exercise and AD.

Conclusion: This bibliometric analysis has identified relevant trends, hotspots, and topics within the exercise intervention on AD. It offers a comprehensive overview that can equip researchers with valuable insights for future exploration and assist scholars in charting research trajectories in related domains.

Abbreviation: AD = Alzheimer disease, CRP = C-reactive protein, CTE = chronic traumatic encephalopathy, DM = diabetes mellitus, NDDs = neurodegenerative diseases, NPS = neuropsychiatric symptoms, RCT = randomized controlled trials, TMS = transcranial magnetic stimulation.

Keywords: AD, bibliometric analysis, CiteSpace, cognition, exercise

1. Introduction

As a progressive, unceasing disease that affects wide brain tissue, Alzheimer disease (AD) is the most common, universal, and prevalent neurodegenerative diseases (NDDs) over 65-year-old people around the world. It reported that proximity 6.7 million elderly people in American are suffering from the different stages of the AD process. Over the next 40 years, the population will double, from 6.7 to 13.8 million.[1] The collapse of the structure and function of neural connection and glia dysfunction, resulting in the breakdown in memorizing impairment, cognitive dysfunction, sensory, attention, and executive function.[2]

Although ample previous research has focused on AD, its typical characteristics and molecular mechanisms are complicated and remain nontransparent. Hitherto, countless researchers and pharmaceutical companies are devoted to the development of medicinal breakthroughs to prevent, delay, or even treat AD.[1] Notwithstanding the huge investments in special drug discovery, the results are not optimistic. Therefore, developing new therapies to protect public health is an imminent task. One promising avenue involves proactive lifestyle changes that can potentially intervene in the AD progression.[3–5] Physical exercise, recognized as an effective and healthful approach to combat the effects of aging, is known to induce physiological benefits and extend a robust lifespan.

The Sichuan Provincial Key Laboratory of Sports Medicine and Key Laboratory of General Administration of Sport of China (No. 2023-A064). Innovative Project of Key Laboratory of Sports Medicine of Chengdu Institute of Physical Education (CX21A02). The "14th Five Year Plan" Scientific Research and Innovation Team of Chengdu Sport University (Grant No. 23CXTD02).

The authors have no conflicts of interest to disclose.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

[a] School of Sport medicine and health, Chengdu Sport University, Chengdu, P.R. China, [b] School of Sport and Health, Jili University, Chengdu, Chengdu, P.R. China.

**Correspondence: Xue Li, Chengdu Sport University, No. 2, Tiyuan Road, Wuhou District, Chengdu 610041, P.R. China (e-mail: lixue2078@126.com).*

How to cite this article: Jin Y, Li X, Yuan Q, Huang X, Zhang D. Visualization analysis of exercise intervention on Alzheimer disease based on bibliometrics: Trends, hotspots and topics. Medicine 2023;102:49(e36347).

Received: 17 June 2023 / Received in final form: 9 October 2023 / Accepted: 7 November 2023

http://dx.doi.org/10.1097/MD.0000000000036347

It achieves this by inhibiting the advancement of NDDs and transforming debilitating conditions, ultimately promoting a healthy brain.[6,7]

CiteSpace (Citation Space), a bibliometric analysis software, facilitates multivariate, temporal, and dynamic visualization analysis of citations. Its outcomes aid in comprehending the underlying knowledge structure within published literature, alongside the developmental trajectory and structural relationships within the knowledge map.[8,9] However, there has been a limited focus on investigating the trends, hotspots and topics related to exercise on AD. Consequently, this bibliometric visualization analysis utilizes CiteSpace to explore the research the trends, hotspots and topics within the impact of exercise on AD.

2. Data collection and materials

2.1. Data collection and screening process

The data for this article were gathered from the SCI-E of the Web of Science database. Detailed information regarding the data source and methodology is provided in Table 1. We excluded literatures based on language restrictions, document types, and other criteria. The complete screening process is depicted in the flow-process diagram presented in Figure 1. Ethical committee approval was not required as this study utilized secondary literature sources.

2.2. Analysis tool and platform

We utilized CiteSpace VI (Version 6.2.2, 64-bit), a visualization tool, to analyze the collected data and create a visual knowledge graph. This tool, developed by Dr Chaomei Chen (Drexel University, USA) offers a specialized and interactive visualization platform for processing extensive datasets, employing data mining algorithms, and conducting bibliometric analyses.[8,10] CiteSpace assists researchers in identifying pivotal literature, exploring cutting-edge research frontiers, and pinpointing research trends. Its visual presentation mode offers investigators a panoramic perspective of the developments within the relevant field.

Table 1

Data source and strategy.

Type	Content
Data source	Web of Science (WOS) database, Science Citation Index Expanded (SCI-E)
Time span	2013-01-01 to 2022-12-31
Document types	Article, Review
Retrieved strategy	(TS=("Alzheimer*") OR TS=("Dementia*") OR TS=("Senile Dementia"))AND (TS = (sport*) OR TS= ("exercise") OR TS=("training") OR TS=("physical activity") OR TS=("fitness"))
Language style	English

TS (topic), including title, keywords, abstract.

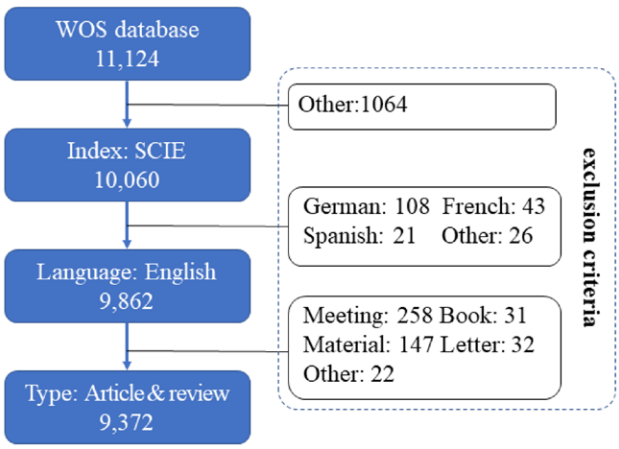

Figure 1. The flow-process diagram of screening process.

2.3. Bibliometric and visualized analysis

We imported the acquired data into CiteSpace VI and selected the following sources: titles, abstracts, author, and keywords. The time period was segmented into 1-year intervals to analyze fundamental information concerning the influence of exercise on AD. This analysis encompassed the trends in annual publications, the geographic distribution, the journals of annual publication, the disciplinary of research, and the prolific authors. Keyword and co-citation analyses were conducted to reflect trends, hotspots and topics.

3. Results

3.1. The trends of annual publication

The number of publications of exercise on AD between 2013 and 2022 is presented in Figure 2. The notable increase in this data indicates a high level of research focus in this field. The data reflects an annual frequency of publications, with the minimum and maximum numbers occurring in 2013 (n = 488) and 2022 (n = 1443), respectively. There has been an increase of nearly one thousand publications over the past decade. Using unary linear regression, we can model this trend with a line that fits the curve: $y = 113.99x + 310.27$. Notably, there has been a significant surge in publications from 2016 to 2021, with over one hundred per year. The substantial volume of publications and citations in recent years has garnered the attention of researchers and scholars in this field.

3.2. The geographic distribution

The purpose of analyzing the geographic distribution by countries/regions is to understand the level of attention given to this field by different regions. Based on the retrieved data, the distribution of countries/regions is primarily concentrated in the USA (2818 publications), the People Republic of China (1117 publications), England (1074 publications), Australia (816 publications), and Canada (672 publications), collectively accounting for half of the total number of publications (Table 2, Fig. 3). While England may not have the highest number of publications, it does boast a higher centrality (value = 0.14), indicating its broader academic influence.

3.3. The journals of publication

We analyzed the journals of publication based on their frequency and compiled the top 5 studies with the highest total citations (Table 3). These findings highlight the journals that have garnered significant attention in the field of exercise intervention for AD. In total, the papers were published across 1570 different journals. Among them, the most prolific journals were the *Journal of Alzheimer Disease* (394 publications), *Frontiers in Aging Neuroscience* (266 publications), *BMC Geriatrics* (222 publications), *PLOS One* (206 publications), and *International Journal of Environmental Research and Public Health* (162 publications), among others. These publications primarily revolved around research themes related to AD, aging, and public health.

In essence, the dual-map overlay of journals was designed to illustrate the foundational knowledge of the published studies

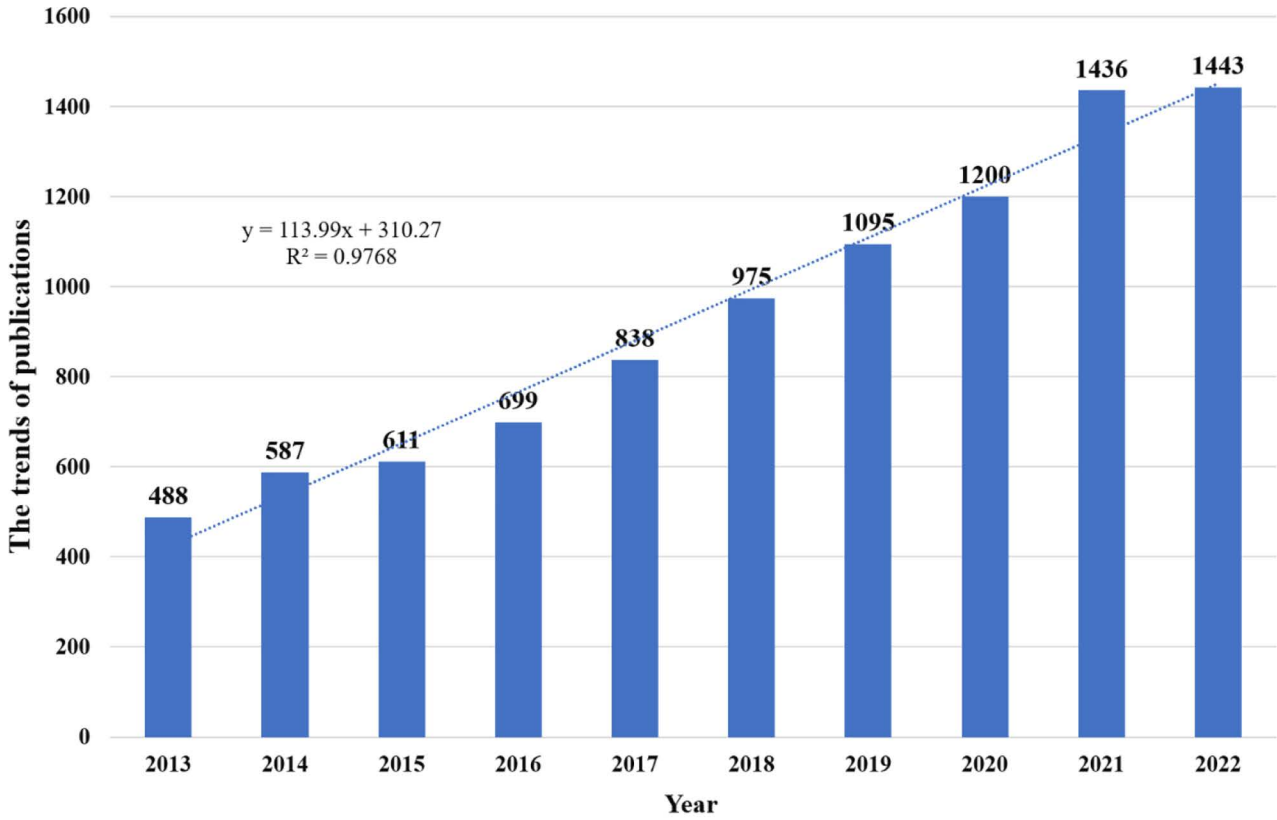

Figure 2. The trends of annual publications in exercise on AD. AD = Alzheimer disease.

Table 2

The Top 5 countries/regions of publication in exercise on AD.

Countries/regions	Frequency	Centrality	Sigma	Burst
USA	2818	0.02	1	0
PEOPLES R CHINA	1117	0	1	0
ENGLAND	1074	0.14	1	0
AUSTRALIA	816	0.08	1	0
CANADA	672	0.01	1	0

AD = Alzheimer disease.

Figure 3. The geographic distribution in exercise on AD. AD = Alzheimer disease.

Table 3

The Top 5 journals of publication in exercise on AD.

Journal name	Frequency	Percentage (%)	IF/Q
Journal of Alzheimers Disease	394	4.204	4.160/Q3
Frontiers in Aging Neuroscience	266	2.838	5.702/Q2
BMC Geriatrics	222	2.369	4.070/Q2
PLOS One	206	2.198	3.752/Q3
International Journal of Environmental Research and Public Health	162	1.729	4.614/Q3

Data from the 2022 edition of Journal Citation Reports.
AD = Alzheimer disease, IF = impact factor, Q = quartile category.

for cited articles and to depict the evolving tracks (Fig. 4). The publication of studies spanned various fields, including molecular biology, immunology (Part I), medicine, medical, clinical (Part II), neurology, sport, ophthalmology (Part II), and psychology, education, and health (Part III). As the published journals form the knowledge base for cited journals, these evolving trajectories indicate that the focal points of these journals transitioned from those in molecular biology and genetics (Part A),

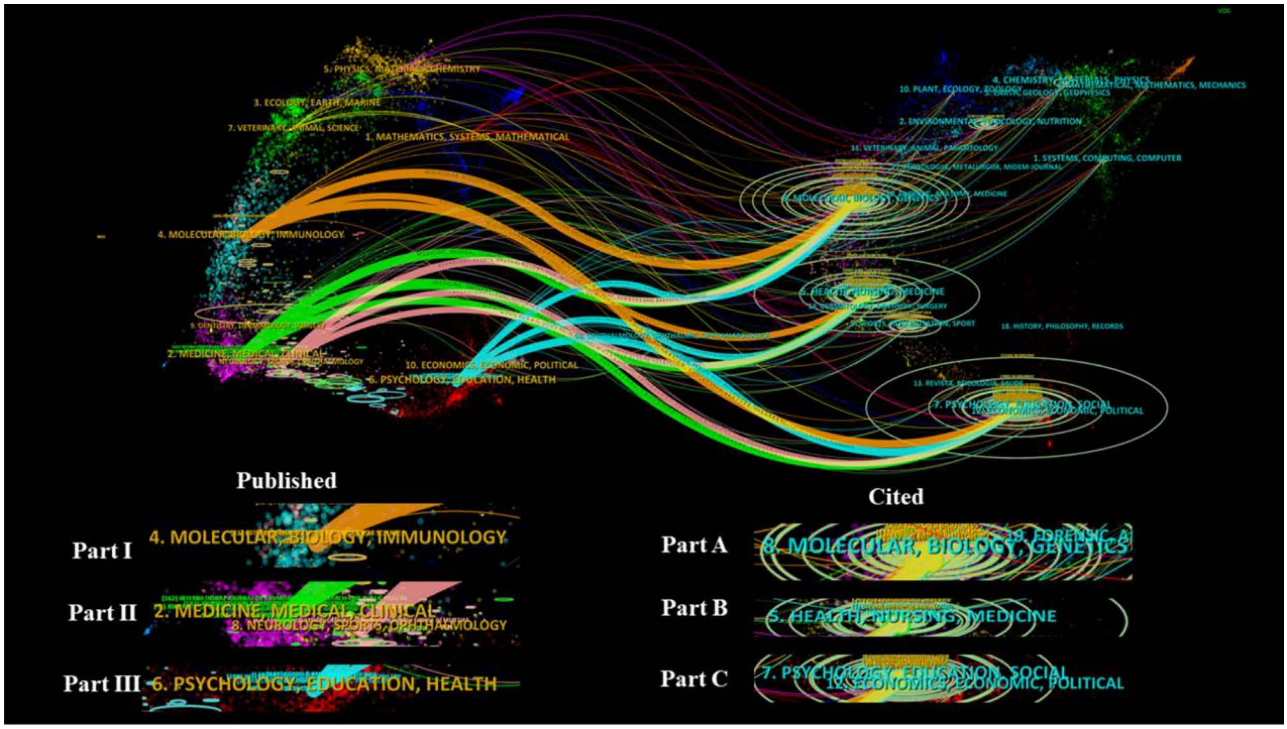

Figure 4. The dual-map overlay of journals in exercise on AD. Left side showed published articles and right side displayed cited articles. AD = Alzheimer disease.

Table 4

The Top 5 disciplines of research in exercise on AD.

Research field	Frequency	Percentage (%)
Neurosciences Neurology	3045	32.49
Geriatrics Gerontology	2399	25.598
Psychiatry	930	9.923
General Internal Medicine	620	6.615
Psychology	495	5.282

AD = Alzheimer disease.

health, nursing, medicine (Part B), to psychology, education, and social (Part C), as well as economics, economic, and political (Part C) studies.

3.4. The disciplines of research

The analysis and integration of research disciplines encompass a total of 106 fields. Among these, the research areas ranked from 1 to 5 are presented in Table 4, which include neurosciences neurology (3045 publications), geriatrics gerontology (2399 publications), psychiatry (930 publications), general internal medicine (620 publications), and psychology (495 publications), among others. The study of the impact of exercise on AD constitutes an interdisciplinary and integrated field, with neurology and geriatrics as the primary research domains. It involves the amalgamation of multiple disciplines, such as medicine and psychology, and offers theoretical and technical support for the role of physical activity in preventing aging and related AD. These diverse perspectives contribute to a comprehensive understanding of the subject.

3.5. The prolific authors

The analysis of prolific authors falls within the domain of cooperative network analysis, with the objective of comprehending

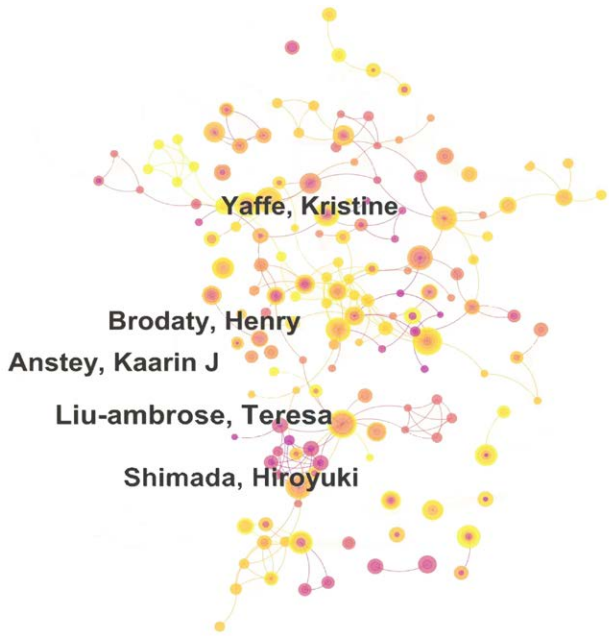

Figure 5. The prolific authors network in exercise on AD. AD = Alzheimer disease.

the fundamental background and collaborative relationships among researchers with a substantial number of publications.[11] In order to gain a deeper insight into the prolific authors within the research topic, we constructed an author network and identified the Top 5 prolific authors using the CiteSpace tool (Fig. 5, Table 5). The visual map reveals that prolific authors are interconnected extensively, indicating a strong and collaborative network among scholars in this field. The Top 5 researchers with the highest number of published

works are Teresa L, Henry B, Kaarin JA, Hiroyuki S, and Kristine Y. They collectively play a pivotal role in advancing this field.

Table 5

Top 5 of the high-yield authors in exercise on AD.

Author	Frequency	Centrality	Sigma	Burst
Liu-Ambrose, Teresa	41	0.05	1.34	5.67
Brodaty, Henry	35	0.03	1	0
Anstey, Kaarin J	34	0.05	1	0
Shimada, Hiroyuki	34	0	1	0
Yaffe, Kristine	33	0.04	1.12	2.77

AD = Alzheimer disease.

3.6. Analysis of keywords

We extracted and sorted the keywords associated with this term and obtained various visual representations, including the keyword co-occurrence knowledge map (Fig. 6A and B), the knowledge map clusters (Fig. 6C), the timeline plot (Fig. 6D), and the burst term map (Fig. 6E). These representations allowed us to rank the keyword intensity and generate a list of keywords with high prominence (Table 6, Fig. 6A). This visualization highlighted keywords that experienced significant short-term growth, underscoring their frequency in the literature. Notable keywords in this regard included AD, dementia, physical activity, older adult, and mild cognitive impairment (MCI). The annual frequency changes of the top 5 keywords are detailed in Figure 6B, illustrating the increasing research focus on these terms. We have organized all the keywords to differentiate between different types of exercise. The human trials consist of various exercises such as strength

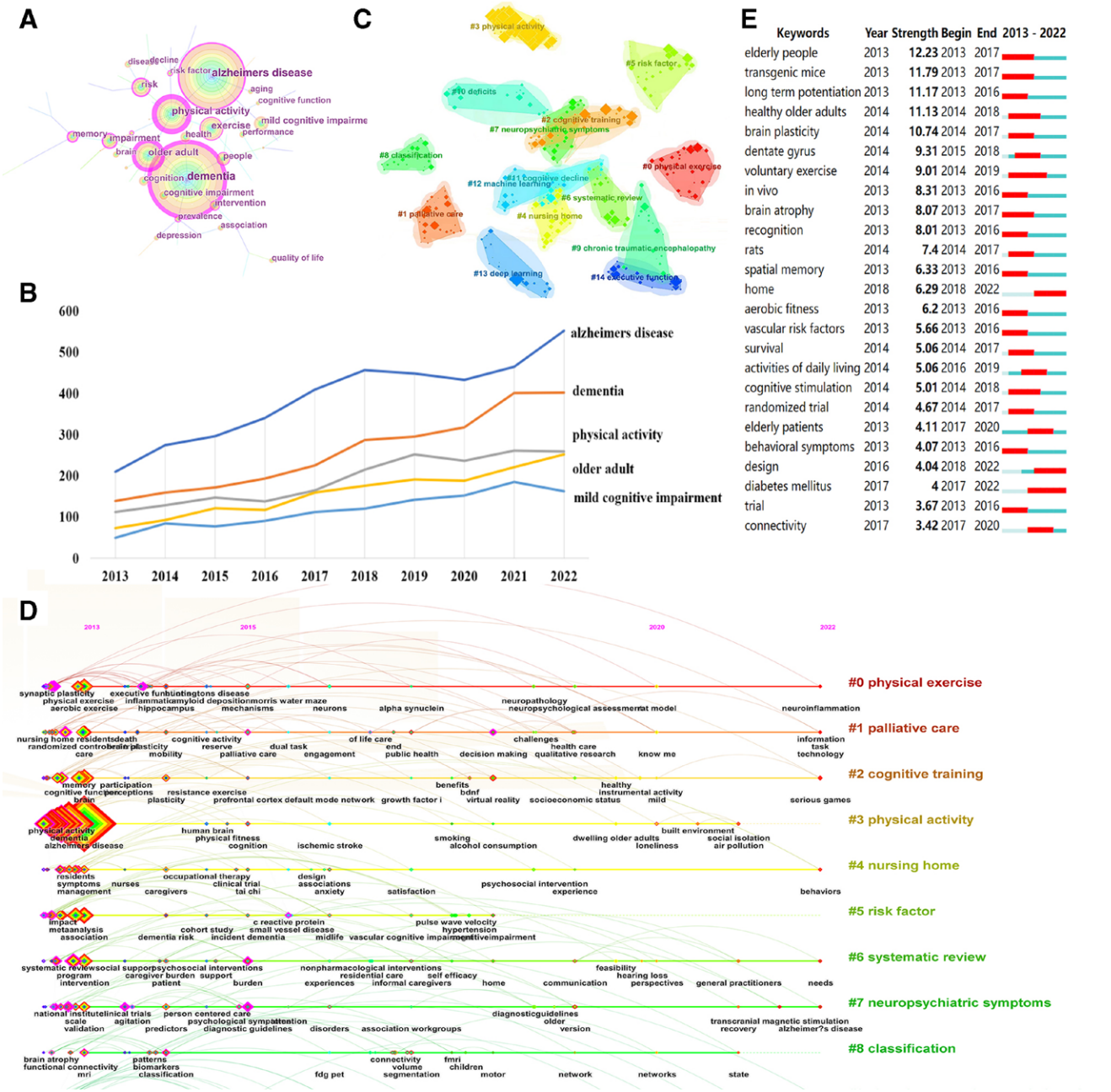

Figure 6. The visualization analysis of keywords. (A) Co-occurrence knowledge map; (B) the annual frequency changes of the top 5 keywords; (C) the cluster of knowledge map; (D) timeline plot burst; (E) term map with the Top 25 strongest citation bursts.

Table 6

The Top 10 frequency and classification of keywords in exercise on AD.

Keywords	Frequency	Centrality	Degree	Sigma
AD	3883	0.02	3	1
Dementia	2588	0.07	6	1
Physical activity	1911	0.16	4	1
Older adult	1589	0.02	3	1
Mild cognitive impairment	1173	0	1	1
Risk	1039	0.12	4	1
Impairment	880	0	1	1
Exercise	853	0	1	1
People	837	0.25	3	1
Cognitive impairment	721	0	1	1

Species	Type of exercise
Human	Physical activity, exercise, aerobic exercise, physical exercise, leisure activity, treadmill exercise, strength, walking, activities of daily living, aerobic fitness, sedentary behavior, tai chi, resistance exercise
Animals	Exercise, aerobic exercise, treadmill exercise, voluntary exercise, resistance exercise

AD = Alzheimer disease.

training, aerobic exercise, walking, physical activity, tai chi, etc. The animal studies include voluntary exercise, treadmill training, and resistance exercise (Table 6).

We also conducted a cluster analysis of the keywords, as shown in Figure 6C, to identify emerging research topics. In accordance with established metrological research methods, we considered 2 values: Modularity Q (Q value) and Silhouette (S value), both of which gauge cluster quality. Generally, $Q > 0.3$ indicates a significant cluster structure, $S > 0.5$ signifies reasonable cluster classes, and $S > 0.7$ suggests a highly convincing cluster.[12,13] Our data revealed $Q = 0.8873$ and $S = 0.9687$, indicating a well-defined cluster structure for this item. The clusters were successfully organized into categories labeled #0-#15. The largest cluster pertains to physical exercise (Cluster 0#, Size = 33, S = 0.946), followed by palliative care (Cluster 1#, Size = 30, S = 0.988), cognitive training (Cluster 2#, Size = 28, S = 1), physical activity (Cluster 3#, Size = 28, S = 1), nursing home (Cluster 4#, Size = 28, S = 1), and others. We categorized these clusters into 3 main categories: intervention (including physical exercise, cognitive training, physical activity), phenotype (including neuropsychiatric symptoms [NPS], chronic traumatic encephalopathy [CTE], deficits, cognitive decline, executive function), and methods (systematic review, machine learning, deep learning).

To gain a deeper understanding of keyword development and to identify research hotspots, we constructed a network timeline, as depicted in Figure 6D. The timeline provides a clear overview of the evolutionary path of research on the impact of exercise on AD over time. In the early stage (2013–2015), attention was primarily directed towards topics such as tai chi, synaptic plasticity, randomized controlled trials (RCT), meta-analysis, systematic review, psychological symptoms, apolipoprotein E (APOE), cognitive function, executive function, and brain injury. The subsequent stage (2016–2019) saw a shift in focus towards C-reactive protein (CRP), alpha-synuclein, brain-derived neurotrophic factor, vascular cognitive impairment, small vessel disease, and ischemic stroke. In recent years (2020–2022), researchers have increasingly explored topics related to neuroinflammation, transcranial magnetic stimulation (TMS), network, gut microbiota, instrumental activity, and other aspects.

Keywords with intensity during specific periods represent research hotspots for those periods. Keywords that have emerged abruptly within a short timeframe signify keyword bursts and become prominent research hotspots.[9] As shown in Figure 6E, keywords like "elderly people," "transgenic mouse," "long-term potentiation," "healthy older people," "brain plasticity" and "dentate gyrus" exhibited the highest burst strength, with numerical values exceeding 10.00. Notably, we demonstrate that aerobic fitness (Strength = 6.2) emerges as the prevailing intervention approach. Furthermore, there exists a slight disparity in the choice of exercise between animal research and human experimentation. Animals exhibit a greater inclination towards voluntary exercise (Strength = 9.01), whereas humans display a stronger preference for activities of daily living (Strength = 5.06). Additionally, "voluntary exercise," "diabetes mellitus" (DM) and "brain atrophy" remained influential for over 5 years between 2013 and 2022. Remarkably, starting from 2017, the link between AD and DM, with the risk of dementia increasing with age and the potential role of insulin resistance in this risk, has emerged as a prominent research focus for neuroscientists.

3.7. Analysis of co-cited reference

Co-citation analysis refers to the simultaneous appearance of 2 articles in the reference list of a third cited reference, establishing a co-citation relationship between the 2 articles.[10] As scientific research continues to advance, it has given rise to an interconnected and continuously expanding system. The mutual citation of scientific literature reflects the inherent laws of scientific development, showcasing the accumulation, continuity, and interdisciplinary nature of disciplines. It enables both forward and backward tracking of development trends. Table 17 displays the top 5 publications with the highest citations in the field of exercise on AD.[14–18] These publications closely examine research topics related to exercise training, prevention, intervention, cognitive decline, and RCTs. The most cited papers, particularly those based on proof-of-concept RCTs, demonstrate that exercise training interventions can either maintain or ameliorate cognitive dysfunction among high-risk elderly individuals or AD patients within the general population. These papers serve as guidelines for the AD population, offering authoritative recommendations for prevention, intervention, and protection. They represent high-quality literature published in reputable journals and hold significant influence (Q1, IF > 10, as indicated in Table 7) within the field of exercise and AD. Table 8 presents a summary of the exercise interventions in the top 5 cited references. Of these high-quality references, 2 were RCT, 2 were reviews, and 1 was a meta-analysis. After excluding the 2 review articles that lacked specific intervention measures, it is evident that all studies were conducted on human subjects, with training programs involving aerobic exercise and strength training. The training frequency was approximately 3 times per week. It should be noted that nearly all training programs employed a long-term training model, indicating that the exercise intervention period is an important and effective training component that requires careful attention.

We then applied cluster analysis to illustrate the term words in co-cited references, which reflect the trends within this field. Our data revealed a Q value of 0.7767 and an S value of 0.9093, indicating a credible and reliable clustering of these items. The cluster network of cited references was divided into 12 distinct clusters, with the largest cluster visualized in Figure 7. We categorized the focal trends into 3 types: Intervention methods: This includes physical activity (Cluster 0#, Size = 53, S = 0.88), cognitive training (Cluster 2#, Size = 46, S = 0.925), prevention (Cluster 7#, Size = 31, S = 0.908), and the Mediterranean diet (Cluster 8#, Size = 19, S = 0.945). Function changes: This category encompasses falls (Cluster 1#, Size = 46, S = 0.932), cognitive reserve (Cluster 3#, Size = 43, S = 0.889), and MCI (Cluster 5#, Size = 38, S = 0.892). Biological mechanisms: Here,

Table 7

Top 5 co-cited references with high frequency.

Ranking	Frequency	Centrality	Cited reference	Author Yr	Journal	IF Q
1	401	0.08	Exercise training increases size of hippocampus and improves memory[14]	Erickson KI 2011[14]	*P Natl Acad Sci USA*	11.1 Q1
2	381	0.06	A 2 yr multidomain intervention of diet, exercise, cognitive training, and vascular risk monitoring versus control to prevent cognitive decline in at-risk elderly people (FINGER): a randomized controlled trial[15]	Ngandu T 2015[15]	*Lancet*	168.9 Q1
3	326	0.01	Potential for primary prevention of Alzheimer disease: an analysis of population-based data[16]	Norton S 2014[16]	*Lancet Neurol*	48 Q1
4	275	0.03	Dementia prevention, intervention, and care[17]	Livingston Gill 2017[17]	*Lancet*	168.9 Q1
5	215	0.15	The diagnosis of mild cognitive impairment due to Alzheimer disease: recommendations from the National Institute on Aging-Alzheimer Association workgroups on diagnostic guidelines for Alzheimer disease[18]	Albert MS 2011[18]	*Alzheimers Dement*	14 Q1

Data from the 2022 edition of Journal Citation Reports.
IF = impact factor, Q = quartile category.

Table 8

Exercise intervention characteristics of co-cited references.

Training	Duration	D/wk	Periods	Effect	References
Aerobic	40 min	3	6 mo	Positive (cognition)	14
Muscle strength training and aerobic exercise	–	1–3 2–5	2 yr	Positive (cognition, executive functioning and processing speed)	15
Vigorous or moderate activity	20 min 30 min	3+ 5+	–	Positive (vascular risk factors)	16

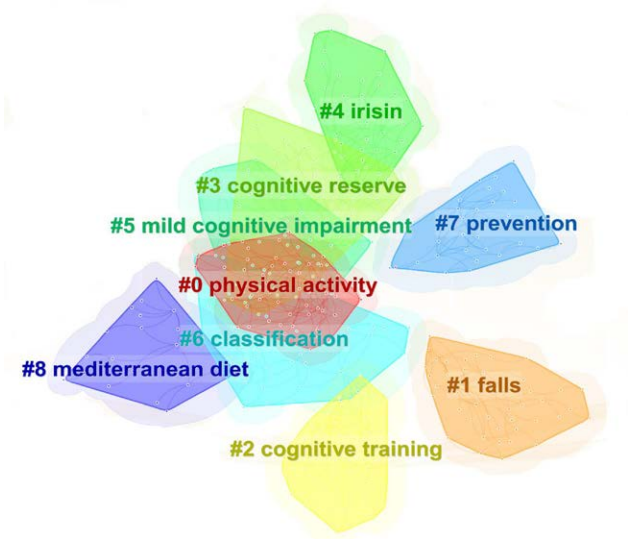

Figure 7. The cluster diagram for the co-cited reference.

it involves irisin (Cluster 4#, Size = 39, S = 0.923), representing different research trends within the field of exercise and AD.

4. Discussion

In this investigation, we present a comprehensive analysis and visualization of the trends, hotspots, and topics in universal research on the impact of exercise on AD using bibliometrics and knowledge mapping. Over the past decade, the number of publications on exercise and AD has steadily increased, yielding fruitful results in this area of study. The distribution of research across countries and regions is prominently led by the USA and China, signifying their central role in this field. Notably, England exhibits higher citation rates and a more expansive academic influence, making remarkable contributions as well. These countries have significantly advanced the field. This research spans multiple disciplines but predominantly revolves around neuroscience and gerontology. The journals where these studies are published primarily relate to neuroscience, aging, and AD. Our analysis of overlay maps reveals a shift from medical mechanisms to clinical applications and from basic theories to social relevance as research transitions from published journals to cited ones. Teresa Liu-Ambrose, a renowned expert specializing in aging, mobility, and cognitive neuroscience, emerges as a central figure with substantial bursts of research activity in the effect of exercise on AD, underscoring firm theoretical foundation and notable scientific research standing and authoritative status in this field.

We employed the cluster of co-cited references analysis to delineate research trends in the field of exercise on AD. Among co-cited references, there is a notable inclination among researchers to design RCTs to delve deeper into the effects of exercise on AD. This disease being a progressive and relentless affliction affecting extensive brain regions, including the cerebral cortex and hippocampus, leads to diminished synaptic density, neural connections, hindered neurogenesis, structural brain changes, and cognitive impairment in both AD-afflicted individuals and mouse models.[19] This neurodegenerative disorder is characterized by the core symptoms of cognitive impairment, primarily affecting older adults. Our study reveals a focus on research trends related to cognitive reversal (Cluster 3#) and MCI (Cluster 5#) within this field. A plethora of publications have elucidated the therapeutic potential of physical exercise, encompassing aerobic and resistance training, in the prevention and treatment of AD, preserving cognitive function in older individuals and animal models alike.[20–22] This could have the potential to delay one-third of dementia cases

globally by mitigating preclinical symptoms.[23] Consequently, robust exercise interventions should be recommended for senior citizens by policymakers, healthcare institutions, and families. Notably, the risk of falls, a primary hazard leading to deleterious consequences in individuals aged over 65, including the loss of independence and a diminished quality of life, imposes a substantial socioeconomic burden.[24] Gait speed and stability are pivotal aspects of physical frailty and sarcopenia, known to be associated with cognitive dysfunction and impairment.[25–27] Statistics indicate that over 30% of elderly individuals fall at least once, with this number rising to 40% to 80% among those with MCI.[28,29] Encouragingly, there is substantial evidence supporting the effectiveness of physical exercise as a strategy for falls prevention.[29,30] Irisin, an exercise-induced myokine released upon cleavage of fibronectin type III domain-containing protein 5 (FNDC5) on the cell membrane, represents a potential molecular mechanism underlying the impact of exercise on AD.[31,32] It stimulates the downstream expression of brain-derived neurotrophic factor, a neurotrophin present in the hippocampus and cortex, thereby enhancing learning and memory capabilities and ameliorating cognitive dysfunction.[33–35] Thus, adopting a healthy lifestyle that includes exercise may constitute a novel therapeutic approach for safeguarding or restoring synaptic function and preventing cognitive decline in AD.

Keywords related to co-occurrence, timeline, and burst analysis can shed light on the developmental trajectory and research hotspots in prior studies. We can categorize these studies into 3 distinct stages based on their predominant features. Broadly speaking, early studies (stages 1–2) have focused on unraveling the underlying mechanisms of AD and investigating the impact of exercise as an intervention. These studies have highlighted the significance of factors like APOE[36] and CRP,[37] which have shown close associations with the pathological processes of AD. Notably, APOE stabilization and the modulation of CRP through exercise have been demonstrated to prevent microglial activation, yielding neuroprotective effects.[38,39] In recent years (stage 3), with the continuous advancement of network technologies, novel intervention approaches have emerged, including TMS and gut microbiota. These approaches have been applied in the realms of classification, prediction, diagnosis, analysis, treatment, and management of AD.[40–44] Furthermore, there is growing interest in exploring the potential of combining noninvasive treatments, such as TMS and exercise, which presents a promising avenue for future research, brightening the prospects for AD prevention and rehabilitation. Recent research hotspots have centered around the interplay between gut microbiota and AD. It has become increasingly evident that alterations in gut microbiota impact not only various gastrointestinal disorders but also central nervous system disorders like AD.[45] Emerging evidence suggests that the beneficial effects of exercise on the brain are associated with multiple underlying mechanisms, including the bidirectional communication between the liver-to-brain,[7] as well as the gut-to-brain crosstalk.[46] These mechanisms exert an influence on the progression of AD. Of particular interest, DM has remained a persistent hotspot from 2017 to the present, fueling experts' enthusiasm to explore the intricate relationship between AD and diabetes. Diabetes and obesity represent modifiable risk factors for AD, the most prevalent form of dementia. Published articles have unveiled a complex web of shared neural mechanisms underlying these conditions, including oxidative stress, mitochondrial dysfunction, inflammation,[47] and insulin resistance.[48] Furthermore, a significant link has been established between advanced glycation end products produced due to chronic hyperglycemia and the advanced glycation end products receptor, further cementing the connection between AD and diabetes.[47]

The keyword clustering in this paper has succinctly summarized the core topics within the related research field. This study has distilled the 15 largest clusters of keywords into 3 distinct categories. Firstly, there are the intervention-related themes, encompassing physical exercise,[49] cognitive training,[50] and physical activity.[51] Multiple interventions have demonstrated their beneficial effects on brain health in aging individuals and those affected by AD. This includes physical exercise, cognitive training, and engagement in physical activities. Furthermore, there growing interest in exploring the synergistic potential of combined approaches, such as integrating cognitive training with aerobic fitness. These combined methods hold promise as advanced prevention strategies for mitigating the progression of AD, warranting further investigation in future research trials. Secondly, we delve into the phenotype-related themes, which encompass NPS, CTE, deficits, cognitive decline, and executive function. NPS constitute central features of AD and dementias, often emerging in the early and intermediate phases of AD. They are characteristic features of MCI as well.[52] Long-term empirical studies have established that CTE can increase the incidence rates of NDDs, including AD and other forms of dementia.[53] These conditions are often associated with tau pathology.[54] Additionally, there is a substantial body of evidence indicating that AD-related brain dysfunction, such as cognitive decline and executive function deficits, can be mitigated by exercise training.[55] Exercise has been shown to help maintain executive function, protect cognitive abilities, and reduce neuronal loss.[21] Lastly, we turn to the methodological aspects, including systemic review, machine learning, and deep learning. Systematic reviews, as a fundamental research method, play a pivotal role in synthesizing findings from various papers and generating credible conclusions. They also aid in the identification of potential biomarkers. Furthermore, the integration of big data with exercise and AD research, driven by advancements in technology, offers a valuable means of monitoring the impact of exercise therapy on cognitive function in older individuals.[56] This, in turn, facilitates more scientific and visually-informed exercise interventions, ultimately enhancing the quality of life for those affected by AD.

5. Limitation

Certainly, this current study has its limitations and calls for further investigation. Firstly, our study exclusively retrieved articles and publications from the Web of Science database, potentially missing out on high-quality articles published in other extensive databases like PubMed and CNKI. Secondly, we restricted our data collection to published studies in English, which may not encompass the entire body of relevant research. Lastly, the absence of official and universally accepted criteria for assessing the quality of the literature we collected underscores the need for a comprehensive evaluation of article quality, including the inclusion of high-quality literature.

6. Conclusion

This article provides a comprehensive overview of exercise on AD, offering insights into general trends, hotspots, and topics within the field through a thorough bibliometric analysis. The general information reveals a rapidly advancing stage that collectively fosters the sustainable growth of this field. Research trends are predominantly centered around the investigation of functional changes and potential mechanisms associated with exercise in AD. Notable hotspots in research emphasize the link between AD and DM, as well as the underlying effects brought about by exercise. Additionally, the research topics delve into the application of emerging technologies in the context of exercise for AD.

Author contributions

Data curation: Yu Jin, Xiaohan Huang, Deman Zhang.
Funding acquisition: Xue Li.
Investigation: Xiaohan Huang, Deman Zhang.
Methodology: Xue Li.
Resources: Yu Jin.
Supervision: Xue Li, Qiongjia Yuan.
Visualization: Yu Jin, Xiaohan Huang, Deman Zhang.
Writing – original draft: Yu Jin.
Writing – review & editing: Yu Jin, Xue Li, Qiongjia Yuan.

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