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How to Improve Mental Health in the Older Adults Through AI-Enhanced Physical Activity: An Emerging Research Topic

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Abstract: Introduction: With the global rise in elderly populations, the demand for healthcare and long-term care services has grown, particularly for addressing mental health. While AI has shown promise for health management of older adults, its effects on physical activity, mental health, and their associations remain largely unexamined. **Objective:** This study aimed to investigate the role of AI in improving mental health among older adults through the promotion of physical activity and elucidating the underlying mechanisms. **Methods:** Bibliometric methods, including CiteSpace and VOSviewer, were employed to analyze 1,831 publications, identifying trends, collaborations, hotspots, and potential applications in this domain. **Results:** AI interventions significantly enhanced mental health in older adults by promoting physical activity. Prominent mechanisms included tailored psychological support, cognitive rehabilitation, and targeted cardiovascular and musculoskeletal interventions. These mechanisms drove better cognitive function, emotional regulation, and physical resilience. These interventions were supported in their effectiveness by biomarkers of BDNF, serotonin, and increased physical activity levels. **Conclusion:** The present study combines insights on AI, physical activity, and mental health to facilitate emerging research opportunities and practical applications. It highlights the importance of AI for individualized exercise interventions, smart health monitoring, and cognitive and emotional rehabilitation. The insights provide an important compass for scholars and practitioners to harness the power of AI to meet the mental health needs of aging societies by systematically mapping the global research landscape that jointly features the changing demographic profile of older persons and anticipated solutions through the use of AI technologies, delivering evidence-based measures.

Keywords: Artificial Intelligence; physical activity; mental health; bibliometric analysis; research trends

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1. Introduction

Currently, the world is rapidly aging. Extensive estimation of the global burden of disease has shown that population aging is one of the most important public health threats. By the year 2050, age-related diseases are projected to be amongst the top causes of disease burden globally. Older adults struggle with overlapping complicated health conditions, and mental health is among the most valuable. (Xi et al., 2022; Bloom et al., 2015; Suzman et al., 2015; Hong et al., 2023; Byass, 2008). Chronic depression and anxiety in older adults can negatively impact immune function, cardiovascular health, and metabolic processes, increasing the risk of chronic diseases like heart disease, hypertension, and diabetes (Civieri et al., 2024; Frasca et al., 2017). In recent few years, AI has demonstrated potential in reducing chronic disease prevalence among older people, especially by supporting mental health (Graham et al., 2020; Qian et al., 2021). Physical activity is another effective

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intervention for improving the mental health of older adults, helping to alleviate symptoms of depression and anxiety(Kazeminia et al., 2020; Lok et al., 2017). AI applications have boosted physical activity levels by providing personalized exercise plans and enabling remote monitoring, fostering long-term healthy habits.(Daly et al., 2020; Shaik et al., 2023). Considering the intricate relationship between mental health and physical inactivity, this interplay often forms a vicious cycle, exacerbating depression, diminishing physical strength, and increasing the risk of falls. (Iso-Markku et al., 2022; Militello et al., 2024), the potential for AI to explore these challenges by promoting physical activity is valuable. While AI's impact both on physical activity and mental health in older adults is existence, the intrinsic connection of this relationship demand further study.

It is crucial to explore the relationship between AI, physical activity, and mental health in older adults, especially in the days global aging accelerates. Many senior people face dual challenges of declining physical functioning and mental health issues(Bleijenberg et al., 2017). AI technologies can enhance exercise intensity and frequency among older adults. Understanding whether AI-driven physical activity interventions improve mental health can provide valuable guidance for exercise and wellness strategies tailored to this population. Additionally, as smart wearables and AI tools become more accessible, older adults can exercise more independently, lessening their reliance on family support networks. Exploring how AI enhances exercise safety and effectiveness for mental well-being can benefit healthcare providers, families, and caregivers in supporting seniors' health. Overall, AI-driven innovations in health management improve quality of life for the elderly, reduce chronic disease incidence, and alleviate healthcare system pressures, thereby freeing resources and promoting societal health.

A comprehensive analysis of research on AI, physical activity, and mental health among older adults is lacking (Karim et al., 2022). As the number of studies on these interconnected topics continues to grow, this study seeks to synthesize existing knowledge and provide a panoramic view using econometric and visualization methods. Unlike traditional content analysis, this approach offers an objective and comprehensive overview by revealing spatial and temporal trends, identifying influential scholars, highlighting emerging thematic frontiers, and advancing the field of study. To the extend of our knowledge, no systematic analysis has been conducted on AI-driven interventions through enhancing physical activity to improve mental health in older adults. This study aims to fill this gap by employing bibliometric mapping and visualization techniques to address key questions: i) identify the most influential countries, institutions, categories, and journals in global AI research on older adults' mental health; ii) examine current concerns and emerging areas within the field; and iii) summarize the impact of AI on promoting physical activity to improve mental health, while outlining research frontiers that warrant further exploration.

This thesis is innovative in several key ways. It presents the first knowledge-mapping review of AI applications for mental health in older adults through physical activity research, offering a unique approach to comprehensively review key literature features and identify emerging trends. Drawing on authoritative databases, it systematically examines international collaborations, evolving trends, and multilevel studies in AI and older adults' mental health. Additionally, this paper highlights research directions to further advance knowledge on using AI for physical activity interventions that improve mental health among older adults. The paper is structured as follows: the methodology section outlines the research approach. The results and discussion section characterizes the literature using knowledge mapping and bibliometric strategies. The research hotspots and application areas analysis reviews key themes through reference co-citation and keyword co-occurrence analyses. The Conclusion and Future Perspectives section summarizes findings and suggests avenues for future research.

2. Methodology

2.1. Data Acquisition and Search Strategy

In this paper, the indexes of four Web of Science core ensembles, namely, the Science Citation Index Expanded (SCI-Expanded), the Social Science Citation Index (SSCI), the Arts and Humanities

Citation Index (A&HCI), and the Emerging Sources Citation Index (ESCI), were selected as the data source. The WoS database was chosen for a number of reasons. Firstly, WoSCC, as a standard database based on knowledge graph analysis(Meho & Yang, 2007), has been widely used in bibliometric studies(Cabeza et al., 2020; Cascajares et al., 2021; Pradhan & Zala, 2021; Pranckutė, 2021). Second, WoSCC, as a multidisciplinary database covering the literature of more than 20,000 journals in the fields of environmental sciences, public health, etc., avoids the bias of the search strategy towards the medical field compared to specialized databases such as, e.g., PubMed. While interdisciplinary databases similar to Scopus also have broad coverage, its metadata categorization, WoS has an advantage over Scopus in that it not only provides categorization by author, year, discipline, and type of literature (as provided by Scopus), but also supports categorization by institution and country(Chadegani et al., 2013; Y. Wang et al., 2024), which makes it easier for scholars to analyze the distribution of organizations. Taking all these factors into account, we finally selected the four indexes of WoSCC for further analysis.

The literature was searched as follows:[TS = ("artificial intelligence" OR "AI" OR "companion AI " OR "socially assistive AI" OR "companion robot" OR "social robot " OR "elderly assistive AI" OR "wearable technology" OR "smart wearable" OR "AI companion wearable" OR "AI companion" OR "assistive device" OR "digital OR "robotic assistant" OR "intelligent personal assistant" OR "care robot" OR "cognitive robot" OR "robotic robot "care robot" OR "cognitive assistant" OR "smart speaker" OR "AI-driven technology" OR "virtual assistant" OR "health technology " OR "digital health tool" OR "assistive robotics" OR "smart home device" OR "voice assistant" OR "intelligent agent" OR "AI system " OR "virtual care" OR "telehealth" OR "telemedicine" OR "ambient assisted living" OR "healthcare robot" OR "personal healthcare healthcare robot" OR "personal healthcare" OR "personal healthcare device" OR "AI health assistant" OR "smart caregiving" OR "elder care technology" OR "intelligent health monitoring")AND TS = ("cognitive function " OR "cognitive health" OR "cognitive decline" OR "memory enhancement" OR "cognitive support" OR "cognitive ability" OR " cognitive performance" OR "mental health" OR "memory training" OR " neurocognitive" OR "cognitive rehabilitation" OR "brain health" OR "cognitive stimulation" OR "memory function" OR "executive function " OR "cognitive aging" OR "cognitive skills" OR "mental function " OR "cognitive engagement" OR "cognitive intervention" OR " neuroplasticity" OR "learning ability" OR "mental acuity" OR " cognitive fitness" OR "brain training" OR "anxiety relief" OR " stress reduction" OR "emotional support" OR "well-being" OR " quality of life" OR "depression". quality of life" OR "depression" OR "emotional well-being" OR " psychosocial health" OR "psychological health" OR "emotional stability" OR "social interaction" OR "social support" OR "life satisfaction") AND TS = ("older adults" OR "elderly" OR "aging population" OR "senior citizens" OR "older people" OR "geriatric" OR "aging individuals" OR "older generation" OR "senior adults" OR "advanced age" OR "late adulthood" OR "older patients" OR "aged patients" OR "older population" OR "aged adults" OR "seniors" OR " older individuals" OR "retired people" OR "aged individuals" OR " gerontology" OR "late-life" OR "aging adults")], spanning 2011–2024 . To avoid bias, all hits were retrieved from the WoSCC as "full record and citation reference" and used on October 7, 2024 for further analysis. With reference to previous studies, only "articles or reviews" were selected for analysis, and the language was limited to "English"(Fei et al., 2023); other literature types and non-English articles were excluded. The reason why we setting the timeframe at 2011 is because most of the research on smart geriatric care started in 2011(X. Liu et al., 2023). The amount of studies then increased significantly after China released the policy document named "Action Plan for the Development of Smart Healthy Aging Industry (2017–2020) "in 2017(Hung, 2023). Basic information about each literature was collected in a text file, such as country, institution, journal source, author, and reference. Initially 2,261 documents were found; then they were filtered by document type and language, resulting in 1,831 documents. The research framework is summarized in **(Figure 1)**

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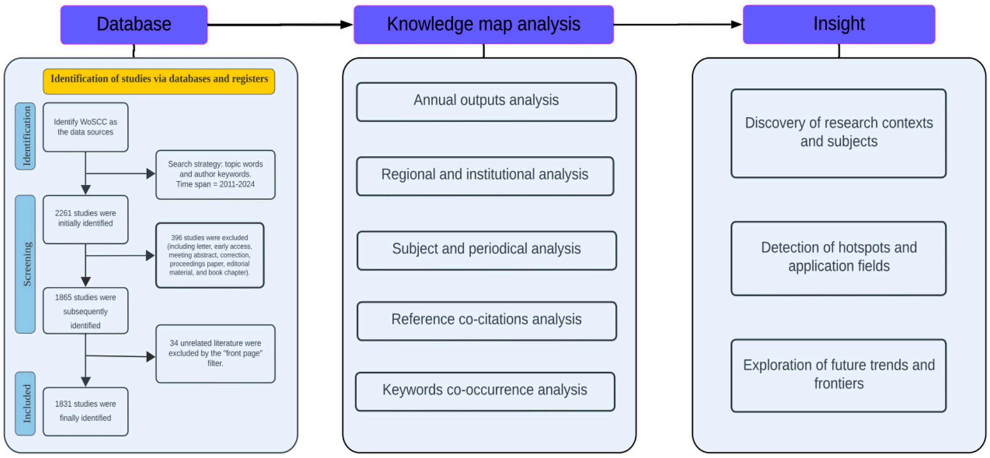

Figure 1. Flow Chart of Study Design for AI-Enhanced Physical Activity Intervention.

2.2. Research Methods and Analysis Tools

The research methodology of knowledge mapping and bibliometrics was used in this study. Knowledge mapping methods enable the visualization and analysis of a specific domain, which mainly involves steps such as data mining, scientometrics, information analysis and graphing. Knowledge mapping is widely used to obtain more granular information related to the content of the study by presenting the distribution of literature and overall research overview(C. Chen, 2006). A bibliometric overview, on the other hand, is a generally recognized means of assessing subject development from a library and information science perspective(Pinto et al., 2019) that can reveal patterns in knowledge flows and domain structure, demonstrate their scientific underpinnings and emergent themes(Li, 2023), and ultimately provide in-depth analyses of knowledge domains. Combining these two strategies can present readers with intuitive illustrations that help understand the current state of the field, its frontiers and hotspots, and provide guidance for future research directions(Jochen Gläser et al., 2017) .

In this study, two Java-based visualization tools, CiteSpace and VOSviewer, were used to describe and present the results of the bibliometric analysis.CiteSpace was developed by Prof. Chaomei Chen of Drexel University and focuses on knowledge graph construction(C. Chen, 2006), and the current version is 6.4.R1.In this paper, CiteSpace is used to visualize and display country and institutional networks, author collaboration networks, cited author relationships, biplot overlays of research categories and journals, and timeline plots of co-cited references. Notably, a co-citation relationship is defined as a situation where two documents are cited by the same third party(Small, 1973).VOSviewer (version 1.6.16) is then used to generate issue-specific keyword co-occurrence maps.

In addition, a knowledge graph usually consists of a set of nodes and connecting lines used to demonstrate collaborative relationships among literature(C. Chen, 2006). Nodes are used to indicate elements such as countries, authors, institutions, journals, references, or keywords, and the size of the node indicates the centrality of the literature, i.e., the larger the node, the higher the frequency of occurrence or citation(Yang et al., 2014). The centrality index in this study is regarded as a bridge from earlier to more recent views, reflecting the extent to which paths in the network pass through the node, and is usually normalized to the interval [0, 1]. Meanwhile, the inter-node connectivity lines indicate the association between nodes; the stronger the connection, the wider the line. The knowledge graph also shows keywords and references with emergent characteristics. Keyword bursting describes the strength of the frequency of topic occurrence, while citation bursting is used to indicate the citation frequency of references(Glenisson et al., 2005). Nodal emergence values are calculated by the Kleinberg algorithm(Mane & Börner, 2004), and with the help of these emergence indices and maps, scholars can identify emerging trends and research hotspots more effectively.

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3. Results and Discussions

3.1. Annual Outputs Analysis

The search of the WoSCC database yielded 1,831 publications related to the dual promotional effects of AI on physical activity and mental health in older adults. Based on statistical analysis, the annual publication trends since 2011 are illustrated in **(Figure 2)**. The changes in the number of publications by year can be indicators of possible research trends. In general, these trends fall into three phases: 2011–2017, 2017–2020, and 2020-present. Although the potential of technology-facilitated exercise to help improve older adults' mental health has been acknowledged, initial studies were limited. In 2011, the potential of novel technologies to address mental health issues in older adults , sparking scholarly interest. Nevertheless, between 2011 and 2017, annual publications remained below 60, reflecting an early stage of research development.

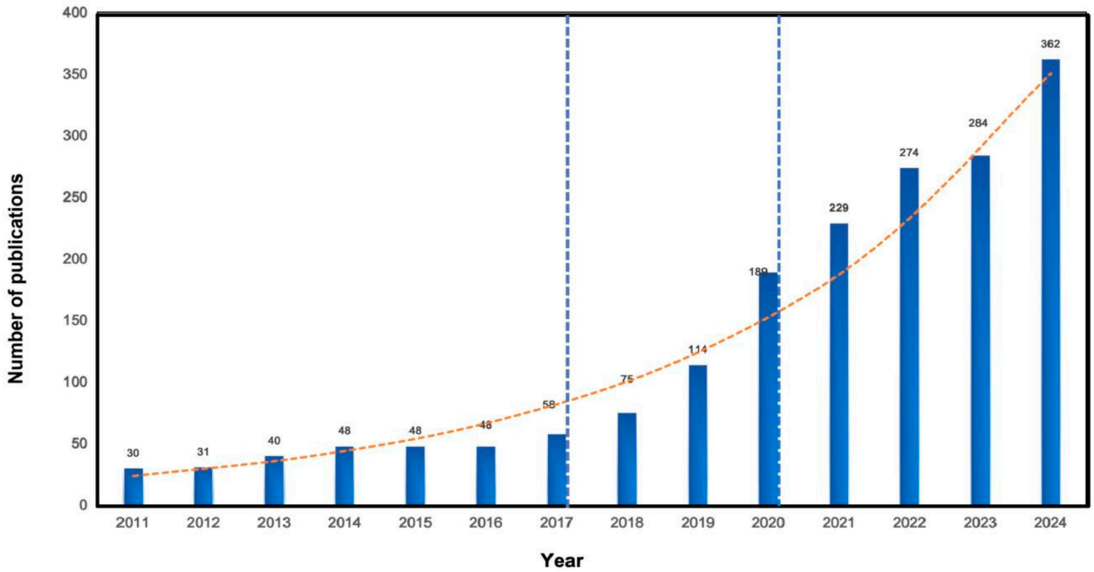

Figure 2. The output of publications and growth trends of pieces of Mental Health in the older adults Through AI-Enhanced Physical Activity research.

With the rapid advancement of AI technology after 2017—particularly in cognitive rehabilitation and intelligent companionship—the number of relevant studies increased significantly. Graham et al. (2020) detailed recent developments in AI-driven cognitive function and mental health support, emphasizing AI's potential benefits in promoting mental health for older adults and boosting confidence in this field. Since 2017, annual publications have grown steadily, reaching 189 in 2020 and continuing an upward trajectory. For example, Liao et al. (2020) demonstrated improvements in older adults' daily activities through a combination of cognitive training and physical activity using virtual reality. Similarly, Jiang et al., (2023) highlighted the importance of multidisciplinary interventions for mental health, while Forberger et al. (2017) promoted healthy aging in Europe through scientific and technological innovations. Using a curve-fitting method, $Y = 2.74x^2 - 11037.96x + 11109369$, where y represents the number of publications and x represents the year, it is estimated that publications on this topic will continue to rise.

3.2. Regional and Institutional Analysis

Scholars from more than 90 regions and 500 institutions have contributed significantly to research on AI's dual facilitation of physical activity and mental health in older adults. **(Table 1)** lists the top 10 contributing countries and institutions, while **(Figure 3A)** illustrates a collaboration

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network across different countries. Each dot in the figure represents a country, with the dot's size corresponding to the volume of publications. The international academic collaboration network, generated via CiteSpace, contains 407 nodes and 929 connections, indicating a global spread of publications across 407 countries or regions and active partnerships among them. The primary collaborations are divided into three groups, led by the US, UK, and China, with the US producing the most literature (623 publications), followed by China (189) and the UK (175). Canada (168) and Italy (150) round out the top five, with each contributing over 150 publications, signifying substantial contributions.

Table 1. Ranking of top 10 countries and institutions of pieces of Mental Health in the older adults Through AI-Enhanced Physical Activity research.

Rank	Country	Publications	Centrality	Rank	Institution	Publications	Centrality
1	USA	623	0.09	1	Harvard University	75	0.03
2	PEOPLES R CHINA	189	0.04	2	US Department of Veterans Affairs	56	0.06
3	ENGLAND	175	0.16	3	Veterans Health Administration (VHA)	55	0.06
4	CANADA	168	0.06	4	Harvard Medical School	52	0.05
5	ITALY	150	0.02	5	University of California System	49	0.13
6	AUSTRALIA	124	0.15	6	University of Toronto	45	0.08
7	SPAIN	108	0.06	7	University of Texas System	45	0.02
8	GERMANY	97	0.02	8	University of London	30	0.1
9	NETHERLANDS	71	0.04	9	Johns Hopkins University	29	0.02
10	SOUTH KOREA	70	0.01	10	Geriatric Research Education & Clinical Center	29	0.02

(Figure 3B) displays institutional collaborations, showing 407 nodes and 929 links among organizations. According to this network, Harvard University leads with 75 publications, followed by the US Department of Veterans Affairs and the Veterans Health Administration (VHA) with 56 and 55 publications, respectively. These institutions, along with others in the top 10, demonstrate strong centrality and influence within the academic community. Notably, universities comprise more than half of the leading institutions, reflecting their significant role in fostering innovation. Nevertheless, non-university institutions oftcen exhibit weaker collaborative ties, while universities maintain extensive networks.

(Figure 3C) highlights the distribution of contributions across countries and regions, with North America, Western Europe, and Australia leading the field in AI-driven physical activity and mental health research for older adults. Western countries dominate the top 10 organizations, which may reflect their greater resource investment in technological and health-related research. AI technologies such as wearables and exercise trackers have enabled Western organizations to make significant progress in enhancing exercise participation, addressing psychological challenges, and preventing disease among older adults. Meanwhile, China, as a developing country facing severe aging challenges, has also made notable contributions to this field. Given its large and diverse population, China faces challenges in improving physical activity levels for older adults nationwide and addressing prevalent chronic diseases and physical decline through exercise interventions.

Investigating the application of AI technologies in managing older adults' exercise and enhancing mental health, particularly through tailored solutions for different regions and economic contexts, remains critical. While Western countries and institutions are key drivers, global collaboration across diverse regions is essential to achieve meaningful advances in this area of research.

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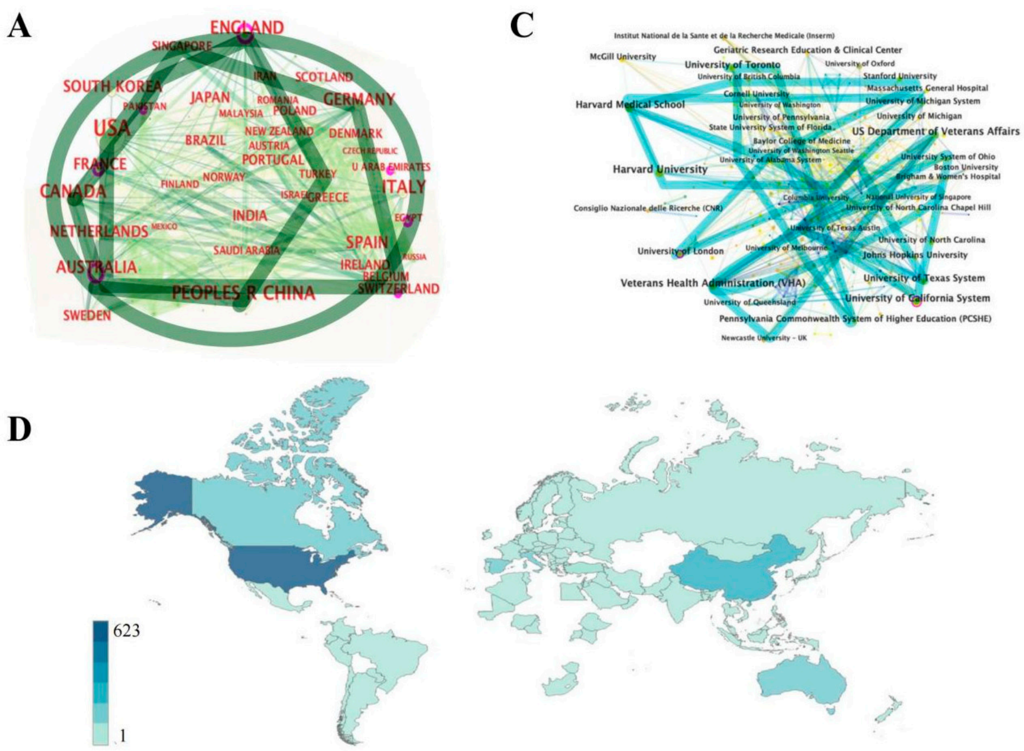

Figure 3. Global Distribution and Institutional Contribution to AI-Enhanced Physical Activity Research for Mental Health in Older Adults. a. The map of countries involved in research on mental health in older adults through AI-enhanced physical activity. b. The institutions contributing to this field of study. c. The world distribution of research publications and collaborations in this emerging domain.

3.3. Subject and Periodical Analysis

(Figure 4A) illustrates the disciplines contributing to research on AI's dual impact on physical activity and mental health in older adults. Disciplines such as 'Gerontology,' 'Neuroscience,' and 'Psychology' are highlighted with purple circles, indicating their central roles in this research area. The network contains 138 nodes and 294 connections, representing 138 subdisciplines involved and 294 collaborative pathways across these fields. Compared to previous literature focused solely on physical activity for mental health in older adults(Forberger et al., 2017; Smith et al., 2017), this network demonstrates greater complexity and comprehensiveness. Exercise science and rehabilitation medicine serve as core disciplines, while collaborations with fields like electrical engineering, neuroscience, and psychology broaden research perspectives. The increasing diversity of disciplines has fostered interdisciplinary collaborations, deepening our understanding of AI's role in enhancing older adults' mental health through increased physical activity.

Following the analysis of disciplines, we examined the cited journals relevant to AI's dual facilitation of physical activity and mental health in older adults. Cited journals refer to those where papers in the field are published, while citing journals are those containing references cited in these works.**(Figure 4B)** offers an overview of cited journals, featuring 731 nodes and 5,601 connections. These journals span a wide array of disciplines, including environmental sciences, with key publications such as the Journal of the American Geriatrics Society and the International Journal of Environmental Research and Public Health. These sources offer valuable insights into the environmental factors affecting AI-driven mental health interventions for older adults. Leading medical journals like The Lancet and the New England Journal of Medicine provide cutting-edge medical perspectives on the effects of physical activity on mental health. Core publications in nursing and gerontology, such as The Gerontologist and BMC Geriatrics, also play a crucial role, while generalist journals like PLOS ONE and iScience enrich the breadth of research. The diverse range of cited journals indicates a shift from single-discipline focus to multidisciplinary clusters, providing a robust theoretical basis for ongoing research.

(Figure 4C) presents a visual analysis of journal evolution related to AI, physical activity, and mental health in older adults from 2011 to 2024, capturing the dynamics of academic trends through publication patterns. The timezone view reveals that from 2011 to 2015, research predominantly focused on geriatrics and neuroscience. Since 2018, there has been a notable shift toward healthcare data analytics and computerized care, underscoring the growing importance of interdisciplinary and international collaboration. The emerging and interdisciplinary nature of AI-driven physical activity to improve mental health in older adults calls for in-depth exploration and increased multidimensional communication and collaboration.

3.4. Analysis of Co-Cited References

Co-cited reference analysis refers to the fact that when two scientific documents are simultaneously cited by the same article, the more co-citations the two documents have, the stronger the relationship between them(C. Chen, 2006). By analyzing this co-citation relationship, researchers can construct a complex citation network. In this study, we used CiteSpace software to concretely demonstrate the citation network structure of AI's dual promotion of physical activity and mental health in older adults through a scientific knowledge map. By analyzing clusters of co-cited literature, we were able to trace the roots of scientific developments in the field and mine them for major research themes and future trends.

There are three options that can be used to create clusters of tags: log-likelihood ratio (LLR), latent semantic indexing (LSI) and mutual information (MI). We used the LLR algorithm because this strategy can cover the "uniqueness and coverage" of all tags. Research topics were divided into clusters, labeled with "#", and then their temporal trajectory was described, as shown in **(Figure 4D)**. The darker the cluster color, the later the literature appeared. Here, we have grouped several noteworthy themes into three categories: "Research Context", "Impacts and Patterns", and "Hot Topics". Modal (Q-value) and weighted average profile (S-value) values were used to assess the plausibility of the clusters, with clusters with $Q > 0.5$ and $S > 0.7$ generally considered compelling. In this analysis, the Q-value was 0.88 and the S-value was 0.95, further validating the validity of the cluster delineation.

The context of this study can be categorized into four main sub-clusters: the mental health of older adults, the positive effects of physical activity, AI-assisted health interventions, and multidisciplinary collaborative networks. In recent years, 'AI-assisted health' has emerged as a novel research topic, especially in personalized physical activity and mental health support. AI provides personalized exercise plan for older adults, enhancing their physical and mental well-being through real-time monitoring and feedback. (Beauchamp et al., 2021; Cortellessa et al., 2021; Delle Fave et al., 2018; Korhonen et al., 2022). Nevertheless, the debate about the effectiveness and sustainability of AI's role in linking physical activity with mental health in older adults remains unsolved. In the meanwhile current research broadly agrees that maintaining physical activity can improve mental health and whole body health in older adults(Battaglia et al., 2016; Delle Fave et al., 2018; Hou et al., 2024), A well-established correlation exists between physical activity, mental health, and quality of life. Previous studies indicate that adequate physical activity improves mental health outcomes, reducing senior depression and anxiety(de Oliveira et al., 2019; Figueira et al., 2023; Lok et al., 2017). Consequently, AI has gained traction as a health management and mental health assessment tool for older adults. Despite technological limitations, researchers are actively exploring how AI can systematically support older adults' physical and mental health, with findings suggesting that the positive effects of physical activity often outweigh potential technological barriers(Graham et al., 2020; Li, 2023; Rutkowski et al., 2019.; Seifert et al., 2019). Additionally, recent studies are refining frameworks to better quantify AI intervention effects, advancing the field of geriatric health(Knowles et al., 2016; Li, 2023).

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Research effects and models in this domain fall into three main areas: personalized health interventions, short- and long-term impacts, and intelligent monitoring and feedback mechanisms. AI-assisted personalized health interventions are among the primary models for improving older adults' mental health. Growing evidence indicates that AI can support health management through real-time monitoring and dynamic feedback(Al-khafajiy et al., 2019; Debauche et al., 2022). Specifically, AI technologies help older adults monitor their emotional states, track physical activity, and provide immediate feedback and motivation, significantly reducing depression and anxiety(Lucia et al., 2024; Vankipuram et al., 2012). Most studies focus on short-term interventions due to the ethical and technical challenges of long-term health interventions. Current evidence suggests that short-term interventions can trigger positive psychological responses, while sustained interventions may lead to deeper health benefits, such as reducing long-term depression risk(Gilbody et al., 2022; Ng et al., 2017). Intelligent monitoring and feedback mechanisms further enhance AI interventions by adjusting health intervention content in real time based on the evolving health status of older adults. The most widely used model combines moderate aerobic exercise with intelligent feedback systems, significantly enhancing mental health and quality of life in older adults(El-Kader & Al-Jiffri, 2017; Song & Yu, 2019).

Several emerging themes in this research area include smart companion robots, personalized psychological support, cognitive rehabilitation, and health support for rural populations. Mental health issues such as loneliness and anxiety are prevalent among older adults, and smart companion robots offer effective emotional support and companionship(Malle et al., 2023). Personalized psychological support services use AI to identify and address the emotional state of older adults, providing tailored guidance to alleviate depression and anxiety(Fulmer et al., 2018). AI-augmented cognitive rehabilitation, often combined with physical activity, helps mitigate memory and cognitive decline in older adults(Cyarto et al., 2012; Liao et al., 2020). In rural areas, where older adults often face limited healthcare resources, AI fills critical health support gaps through remote monitoring and personalized health programs(Al-khafajiy et al., 2019; Bourouis et al., 2011). In summary, smart companionship, personalized psychological support, cognitive rehabilitation, and rural health support represent crucial themes in the application of AI to enhance physical activity and mental health among older adults, meriting focused attention and continued research.

3.5. Analysis of Co-Occurrence Keywords

Keyword co-occurrence graphs can effectively highlight the main research interests and emerging hotspots within a particular field. In this study, we conducted a keyword co-occurrence analysis on research related to AI applications for physical activity and the health of older adults using CiteSpace software. The resulting merged network consists of 489 nodes and 2,146 connections. Among the 400 analyzed keywords, 'older adults,' 'quality of life,' and 'care' were the most frequent, appearing 569, 302, and 224 times, respectively. These keywords indicate the central themes of the field. Other frequently occurring terms include 'artificial intelligence,' 'physical activity,' and 'depression,' all of which draw significant attention.

To further understand the research hotspots in AI-driven physical activity and health for older adults, we categorized the keywords into four clusters: 'Psychic Health,' 'Cognitive Health,' 'Cardiovascular Health,' and 'Bone Health,' as shown in **(Figure 4E)**. The 'Psychic Health' cluster explores how AI-assisted physical activity can help improve psychological issues, like smaller episodes of depression and anxiety common with older adults, enhancing overall life satisfaction and emotional stability. The cluster, 'Cognitive Health', aims to slow cognitive decline with supported physical activities based on artificial intelligence, especially through processes like BDNF (Brain-Derived Neurotrophic Factor). BDNF improves (brain) memory, attention, and blocks the development of degenerative cognitive diseases like Alzheimer's. The Cardiovascular Health cluster focuses on the potential of AI to enhance cardiovascular health by delivering individualized exercise regimens and real-time monitoring to older adults, reducing the likelihood of psychological distress caused by cardiovascular ailments. Last but not least, the 'Bone Health' cluster explores how AI-aided

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exercise can improve bone density, prevent fractures, and promote well-being in older adults by increasing independent living.

The results of this analysis provide a detailed understanding of the research hotspots where AI can improve mental health through promoting physical activity in older adults. This in-depth exploration will be further discussed in the Research Hotspots and Application Areas Analysis section. **(Figure 4F)** highlights the application areas and key research focuses of the study.

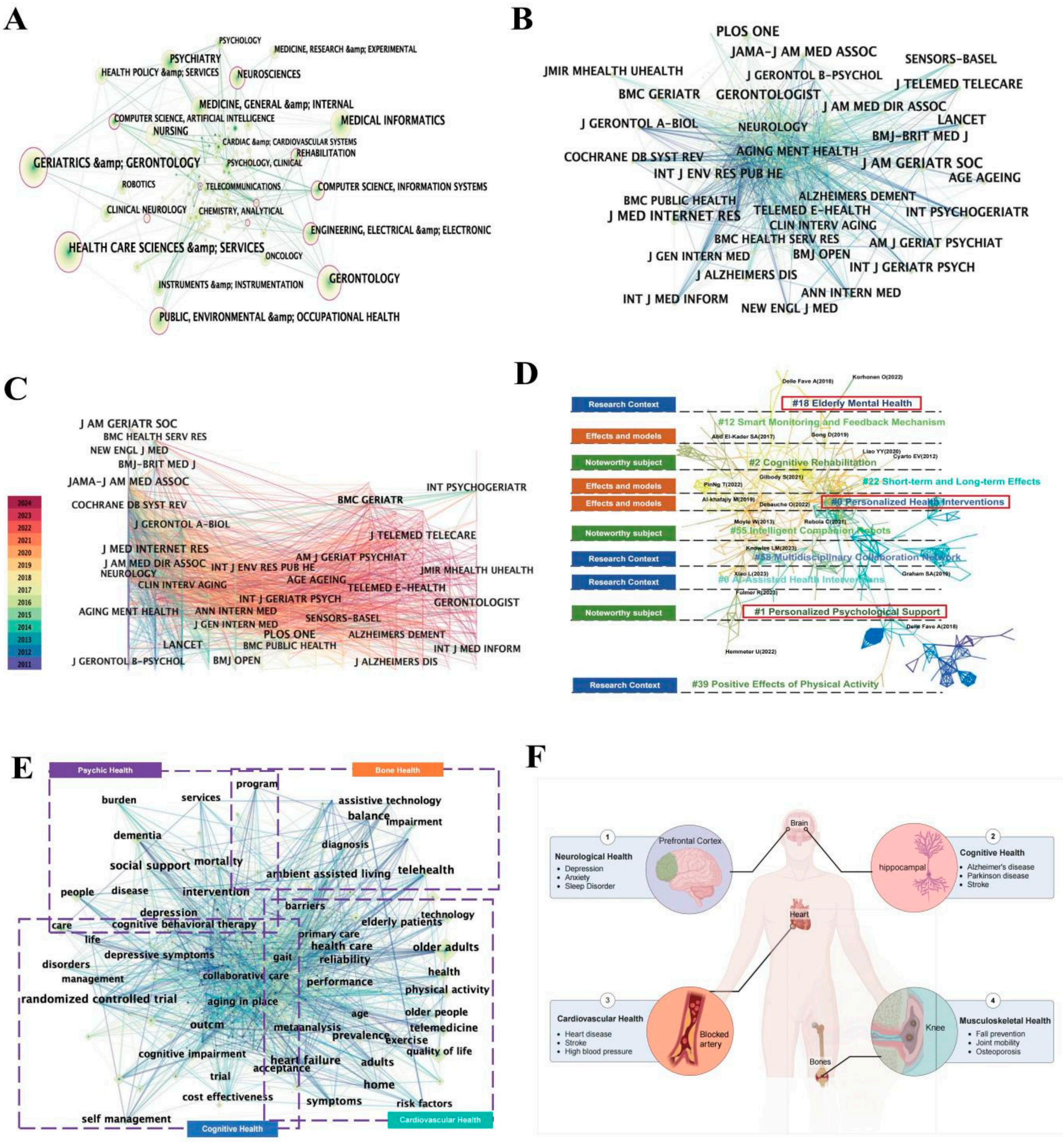

Figure 4. The interdisciplinary landscape and Global collaboration in AI-enhanced physical activity research aimed at improving mental health in older adults. a. Clustered categories of research disciplines involved, highlighting key areas such as geriatrics, computer science, and public health. b. Major contributing journals and their interconnections, illustrating the primary sources of knowledge dissemination. c. Timeline and trends in prominent journal publications over the years, showcasing evolving research focus areas. d. Specific research contexts categorized into key themes, such as personalized psychosocial interventions, effects and models, and neurocognitive impacts. e. Core research themes divided into mental, bone, cognitive, and cardiovascular health, emphasizing the multifaceted nature of the studies. f. Visualization of the physiological and psychological areas impacted by AI-enhanced physical activity, such as neurological, cognitive, cardiovascular, and musculoskeletal health systems.

4. Research Hot Spots and Application Fields Analyses

4.1. Psychic Health

The direct impact of AI-assisted physical activity on older adults' mental health is first observed within the mental health domain. In this context, AI-assisted physical activity can facilitate behavior change, self-determination, and psychological resilience among older adults, ultimately influencing their mental health(Ávila et al., 2022). Firstly, AI-assisted physical activity supports older adults in gradually developing healthy exercise habits. By leveraging AI devices for monitoring and feedback, correct exercise methods are established, making older adults more likely to adhere to exercise routines and generating positive behavioral feedback loops (Dell'Acqua et al., 2013; Ehn et al., 2018). This reinforced behavior can alleviate difficulties in emotion regulation, thereby reducing symptoms of depression and anxiety (Alexandrino-Silva et al., 2019). Secondly, intrinsic motivation, behavioral autonomy, and self-efficacy are critical components in the pursuit of mental health (Ryan & Deci, 2000). Individualized exercise programs designed with AI assistance enhance older adults' self-efficacy by setting achievable exercise goals, providing real-time feedback, and offering encouragement, fostering greater ownership over their health management (Lee et al., 2021). Studies have shown that increased intrinsic motivation significantly improves life satisfaction and emotional stability among older adults(Rodrigues et al., 2023). Ongoing AI assistance during exercise helps older adults achieve accomplishment, overcome feelings of helplessness and improving self-worth, causing significant improvement in mental health. Finally, psychological resilience is at play in older adults' mental well-being. AI-driven physical exercise increases their ability to handle stress and adversity, Hence strengthening their resilience.(Liu, 2023, Lok et al., 2017). AI devices can monitor physiological states and provide psychological feedback, suggesting strategies to help older adults better manage mood swings and stress(Goumopoulos & Menti, 2019). This feedback mechanism enables quicker recovery from negative emotions and increases adaptability to life's challenges for the elderly (Benitez-Lugo et al., 2022). According to positive psychology's theory of well-being, human fulfillment feelings derives from positive emotions, engagement, relationships, meaning, and accomplishment(Gander et al., 2016). (Figure 5A) summarizes the mechanisms by which AI-assisted physical activity impacts mental health.

In conclusion, AI empowers older adults to engage more actively in physical activity, fostering a sense of accomplishment and enhancing their quality of life(Lauzé et al., 2017). The AI-assisted health management system provides not only physical support for exercise but also a positive psychological experience, offering older adults inner fulfillment(Wilmink et al., 2020). In conclusion, AI-assisted physical activity offers all dimensions of support for improving older adults' mental health, effectively alleviating mental health issues and enhancing their overall well-being.

4.2. Cognitive Health

Epidemiologic evidence indicates that the elderly population is particularly susceptible to cognitive decline and neurological disorders due to physiological aging. These conditions include Alzheimer's disease (AD), Parkinson's disease (PD), and stroke (CVA)(Aarsland et al., 2021; Acharya et al., 2021; Bangen et al., 2010; Breteler, 2000; Lo Coco et al., 2016). Such disorders largely impact the physical functioning and quality of life of elderly people. Research has shown that cognitive decline can affect the brain through multiple pathways(Green et al., 2013; Wirth et al., 2014).

First aging causes progressive structural changes in the brain: the number of neurons and the strength of synaptic connections decrease. These changes hurt the brain's ability to process information, showing up as declines in memory, attention, and ability to learn. Second, a close relationship has been observed between changes in cognitive performance and declines in various aspects of brain function, in particular, executive functions and decision-making control, in which performance gradually diminishes among older people. Recent studies indicate that cognitive problems are associated with central nervous system (CNS) inflammatory responses as well.(Walker et al., 2019; Wang et al., 2019). Although the inflammatory response is a defense mechanism,

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prolonged inflammation can lead to neuronal damage and disrupt normal brain function. Neuroinflammation not only worsens the deterioration of brain structures but also related to further cognitive decline.

Nevertheless, it is well-established that exercise not only enhances brain function in healthy individuals but also offers protective and preventive benefits for those with neurological diseases, such as Alzheimer's and Parkinson's (Paillard et al., 2015; Thomas et al., 2020). The main effects of exercise on the brain can be categorized into three areas: neural structure remodeling, neurotrophic factor production, and improved synaptic plasticity(Mashhadi et al., 2021; Rothman & Mattson, 2013; van Praag & Christie, 2015). Notably, brain-derived neurotrophic factor (BDNF) is an important element in improving cognitive and mental health through exercise. Previous studies have shown that impaired cognitive function and psychiatric disorders are strongly correlated with decreased BDNF levels(Teng et al., 2021; Y. Wang et al., 2016). Exercise significantly upregulates BDNF and glial cell-derived neurotrophic factor (GDNF) production (Coelho et al., 2013; Sleiman et al., 2016). Additionally, exercise promotes mitochondrial adaptations, enhancing the brain's oxidative stress environment and helping to prevent or rehabilitate neuropsychiatric disorders (Marques-Aleixo et al., 2015; O'Reilly et al., 2023).

A short-term study using AI-powered personalized exercise programs and virtual health assistants, combined with aerobic and resistance training, assessed cognitive status in older adults. The results demonstrated that AI technology can optimize exercise intensity and frequency, thereby improving cognitive performance, particularly in memory and attention. Based on these findings, several studies are integrating AI algorithms with brain imaging techniques to better understand these effects(Hassandra et al., 2021; Prabha et al., 2024; Rutkowski et al., 2023.). **(Figure 5B)** summarizes the mechanisms by which physical activity contributes to cardiovascular health. In summary, AI technology is emerging as a critical research direction for promoting exercise and improving mental health in older adults. Its applications in cognitive health are particularly significant, with BDNF serving as a key mediator linking AI-assisted exercise to cognitive function enhancement.

4.3. Cardiovascular Health

Cardiovascular disease (CVD) is closely linked to the mental health of older adults, with its prevalence increasing significantly with age and exerting profound effects on physical health and daily living. CVD is one of the leading causes of death and disability among older adults. Studies indicate that cardiovascular problems simultaneously impact older adults' mental health, independence in daily living, and social participation (Babić et al., 2022; Rodrigues et al., 2023). A meta-analysis found that older adults with cardiovascular disease experience reduced independence in daily activities, particularly following severe cardiovascular events such as myocardial infarction and heart failure, which often necessitate long-term care and rehabilitation support (Kitamura et al., 2017, 2021). Additional studies show that CVD triggers symptoms such as chronic fatigue, dyspnea, and decreased exercise capacity, all of which limit daily activity participation and adversely affect the mental health of older adults (Kochovska et al., 2022; Vigorito & Giallauria, 2014). Complications of CVD, including hypertension, diabetes, and atherosclerosis, further worsen the challenges and distress faced by older adults.

Biologically, CVD contributes to increased oxidative stress and inflammatory responses, damaging the vascular endothelium and impairing circulation and cardiac function (Guzik & Touyz, 2017; Senoner & Dichtl, 2019). These pathological changes not only compromise mental health and mobility but also elevate the risk of severe outcomes such as stroke and heart failure.Exercise training is widely used as an adjunctive therapy for cardiovascular disease (Downing & Balady, 2011; Parker, 2012). Regular exercise and physical activity have been shown to improve cardiorespiratory fitness and reduce cardiovascular mortality risk in a safe, feasible, and effective manner (Lavie et al., 2019; N. N. Wu et al., 2019). Exercise positively impacts the cardiovascular system through mechanisms such as remodeling cardiac structure (physiological hypertrophy of the heart), improving vascular

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structure (increasing arteriolar diameters and thinning vessel walls), enhancing vascular endothelial growth factor (VEGF) expression in skeletal and cardiac muscle, and promoting vascular endothelial function (Leung et al., 2008; Tao et al., 2023). **(Figure 5C)** highlights the contribution of physical activity to cardiovascular health.

A key question is whether AI-assisted exercise can significantly improve cardiovascular and mental health in older adults. A lot of studies shows that AI technology can help older adults effectively regulate exercise intensity through real-time monitoring, optimizing their cardiovascular health. For example, one study found that an AI-monitored personalized exercise program improved heart rate variability and reduced cardiovascular event risk in older adults(Eggenberger et al., 2020). AI technologies also monitor respiratory and cardiorespiratory function during exercise, ensuring that the cardiovascular load remains within the safe limits(Meza et al., 2017). Recent research shows that AI-assisted maximal-intensity exercise leads to significant improvements in cardiorespiratory fitness, with AI playing a crucial role in managing respiratory rhythm and exercise intensity(Simonsson et al., 2023). AI-integrated exercise interventions for older adults with CVD have also been effective in reducing cardiovascular inflammatory markers and improving anti-inflammatory responses(Ahn & Kim, 2020). This indicates that AI-assisted exercise not only enhances cardiovascular function but also prevents further disease happening. For older adults with weaker cardiovascular function or chronic inactivity, AI-monitored moderate exercise plans can gradually restore their exercise capacity, thereby enhancing mental health.

In sum, AI offers an effective management tool for older adults' cardiovascular health through personalized exercise plans and real-time monitoring. AI-assisted exercise optimizes cardiovascular health, reduces CVD risk, and ensures safe and effective during exercise practices, ultimately empowering older adults to lead more active lives and improving their mental well-being.

4.4. Musculoskeletal Health

The skeletal system plays a crucial role in research related to the mental health of older adults. Maintaining musculoskeletal health is not only a key factor for ensuring the quality of life but also profoundly impacts their mental health(McLeod et al., 2016; Tieland et al., 2017). Recently, AI-assisted physical activity has increasingly focused on promoting bone health and enhancing musculoskeletal conditions to support mental health and emotional regulation in older adults. Epidemiologic evidence suggests a strong link between physical activity and increased bone density, as well as a reduced risk of fractures(Haxhi et al., 2022; J. Wu et al., 2024). Using AI for custom-tailored workout plans results in a marked increase in older adults' bone density, leading to better emotional stability and reducing psychological complaints like anxiety and depression. In particular, AI-assisted exercise programs tailor the amount and intensity of exercise to minimize the risk of injury and strengthen bones, thereby improving older adults' self-confidence and overall satisfaction in life.

Bone health is mainly dependent on the bone remodeling mechanism, a process that naturally slows with age. Studies have shown that regular weight-bearing exercise promotes bone remodeling and improves bone quality by increasing osteoblast activity(Dibello et al., 2024; Pasqualini et al., 2019). AI devices can monitor exercise intensity in real-time, ensuring older adults bone receive adequate weight-bearing stimulation within safe limits. This boosts bone density and slows the progression of osteoporosis (Watson et al., 2019). Furthermore, studies indicate that the protective effects of AI-assisted exercise interventions on musculoskeletal may be associated with anti-inflammatory mechanisms. For instance, AI-guided aerobic exercise regimens not only promote osteoblast activity but also protect bone health by reducing chronic inflammation in bone tissue(Benedetti et al., 2018). Chronic inflammation in bone tissue is closely linked to osteoporosis, and AI-assisted exercise plays a critical role in modulating the inflammatory response to better protect the skeletal system(Ramachandran et al., 2024). Reduced inflammation levels also ease physical discomfort and help older adults maintain a positive appearance, further improving mental health. Moreover, exercise interventions positively impact bone health by activating the bone morphogenetic protein (BMP) signaling pathway and promoting the release of osteogenic factors

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(Chen et al., 2024; Sánchez-Duffhues et al., 2015). AI devices provide personalized exercise regimens by monitoring the skeletal status and exercise responses of older adults, activating relevant bone growth factors, and supporting continued bone health. Through these mechanisms, AI-assisted exercise programs help older adults maintain skeletal integrity, reduce fracture risk, and alleviate related anxiety (Daly et al., 2020), thus positively impacting their mental well-being.

In summary, bone health has emerged as a key theme in research on AI-assisted physical activity for improving mental health in older adults. With the support of AI technology, personalized exercise programs and scientific monitoring tools can significantly enhance both the skeletal and mental health of older adults. **(Figure 5D)** summarizes the AI-assisted physical activity processes related to bone remodeling in older adults.

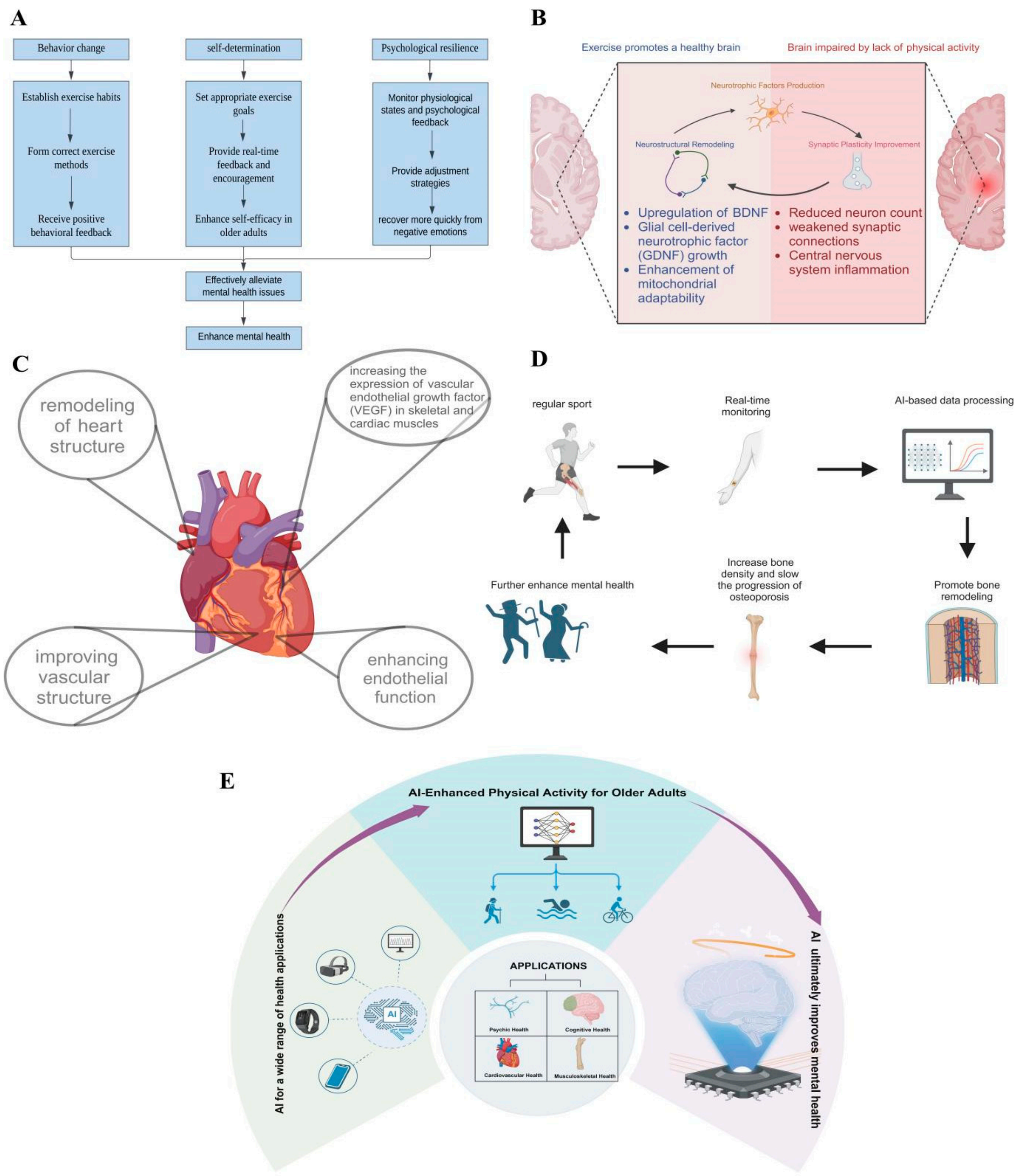

Figure 5. Mechanisms and Applications of AI-enhanced physical activity interventions for improving mental health in older adults. a. Behavioral and psychological pathways, showcasing behavior change, self-determination, and psychological resilience as interconnected processes leading to enhanced mental health in older adults. b. Neural mechanisms illustrating the dual effects of exercise on brain health, including

neurotrophic factor production, synaptic plasticity improvement, and mitigation of central nervous system inflammation. c. Cardiovascular benefits, emphasizing heart remodeling, vascular structure improvements, and enhanced endothelial function via increased expression of growth factors. d. A procedural framework integrating regular physical activity with real-time monitoring and AI-based data processing to promote mental health, bone remodeling, and overall well-being. e. The broader applications of AI-enhanced physical activity, demonstrating its impact across cardiovascular, musculoskeletal, cognitive, and mental health, supported by real-time monitoring and tailored interventions.

5. Conclusion and Future Perspective

5.1. Conclusion

This study is the first to use a knowledge map strategy to describe the distribution of research, major themes, and related research hotspots in the field of AI-facilitated physical activity aimed at improving the mental health of older adults. While previous studies have explored the dual facilitating effects of AI on physical activity and mental health among older adults, a comprehensive understanding of AI's role in enhancing mental health through physical activity remains limited. One reason for this gap is that AI technology, as a relatively new digital tool, has only recently gained widespread use in health-related applications, and the issue of older adults' mental health has gained increasing attention in response to global aging trends. Another reason may be the relatively brief history of interdisciplinary development concerning the impact of AI and its benefits on the relationship between physical activity and mental health in older adults. Nevertheless, annual literature publication volumes and disciplinary analyses indicate that this field is currently experiencing rapid growth.

An analysis of 1,831 relevant publications from the WoSCC database reveals significant growth in AI research within the context of exercise health for older adults since 2011. The United States, the United Kingdom, and China are leading contributors, with key organizations such as Harvard University, the U.S. Department of Veterans Affairs, and the Veterans Health Administration (VHA) playing vital roles in examining the impact and benefits of AI on physical activity and mental health in older adults. The research context mainly involves themes such as older adults' mental health, the positive effects of physical activity, AI-assisted health interventions, and multidisciplinary collaborative networks. Research models focus on personalized health interventions, short- versus long-term effects, and intelligent monitoring and feedback mechanisms. Key topics of interest include intelligent companion robots, personalized psychological support, cognitive rehabilitation, and health support in rural areas.

Additionally, this paper explores four application areas of AI in older adults' motor health. Mental health is a vital area of the health of older adults and is also supported by numerous studies. Research shows artificial intelligence can reduce anxiety and depression among older adults who exercise and may vie to encourage them by offering virtual companionship or providing psychological support that improves their mental health. When it comes to cognitive health, AI-enabled cognitive training and exercise monitoring have proven useful in assisting older adults with Alzheimer's disease, Parkinson's disease, stroke, and other conditions, especially through early intervention for cognitive disorders. Another area where AI and ML will help is cardiovascular health, where machine learning can enhance cardiorespiratory fitness and lower the risk of cardiovascular diseases using both personalized exercise regimens and real-time monitoring. Finally, a review of studies describes the application of artificial intelligence-based physical activity interventions, which have improved bone density, fracture risk, and quality of life in older subjects. The interplay among these four domains provides multidimensional support for AI-assisted physical activity to enhance the mental health of older adults. **Figure 5**E summarizes the flow of this paper, though further research is needed to fully elucidate the specific mechanisms and effects.

5.2. Future Perspectives

Future research on AI-facilitated physical activity for improving older adults' mental health must address the field's early-stage challenges by establishing standardized frameworks, core health indicators, and systematic approaches to ensure consistency across paradigms, interventions, and outcome measures. Key strategies include long-term tracking of personalized exercise plans, short-term AI interventions with real-time feedback, AI-assisted rehabilitation to enhance physical and mental health, tailored solutions for managing chronic diseases, and comprehensive systems integrating personalized exercise and health monitoring. Despite significant progress, limited research explores AI's interaction with biological mechanisms or its integrated effects on physical, mental, and cognitive health. By leveraging advancements in AI technology and multidimensional data analysis, future studies should prioritize interdisciplinary collaboration and optimize the dose-effect relationship between AI and physical activity to maximize health outcomes and uncover novel pathways for improving older adults' overall well-being.

5.3. Strength and Limitations

The primary strength of this study lies in its comprehensive analysis of global literature on how Artificial Intelligence (AI) can enhance physical activity to improve the mental health of older adults, approached from an interdisciplinary perspective using innovative strategies. By integrating knowledge mapping and visualization analysis, this study reveals the current state of research and practical applications, highlighting global collaborations and key trends across different countries, regions, and disciplines. The structured data analysis, including cluster and keyword co-citation analyses, offers valuable insights into how AI-driven interventions impact physical activity and mental health. Nevertheless, limitations such as the restricted use of unstructured knowledge and qualitative methods must be addressed to provide a more complete understanding of AI's potential.

Future research should expand the scope by incorporating a broader range of AI technologies and leveraging multi-database analyses to uncover nuanced pathways and innovative applications. This would enable a deeper exploration of how AI can be optimized to create personalized, data-driven exercise interventions that promote mental well-being, reduce anxiety and depression, and enhance overall quality of life for older adults. Further interdisciplinary collaboration and standardization of key health indicators will help establish more effective AI-based health management systems, paving the way for transformative solutions to support the mental and physical health of the aging population.

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