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Relationship between different physical activity parameters and cognitive impairment in middle-aged and older adults: insights from a 4-year longitudinal study

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Abstract

Background Physical activity (PA) is crucial for the prevention and management of chronic diseases and may be associated with cognitive impairment. This study investigated the longitudinal relationship between PA from different parameters (e.g., frequency, duration, intensity, and volume) and the incidence of cognitive impairment in middle-aged and older adults.

Methods Data were derived from the China Health and Retirement Longitudinal Study (2011–2015). A total of 891 adults aged 45 and older were included in this study. Cognitive function was assessed using the Telephone Interview for Cognitive Status criteria, focused on episodic memory and executive function. We categorized participants into normal cognition and cognitive impairment groups. Self-reported PA information including frequency, duration, intensity, and volume was collected through a representative survey. Poisson regression analysis was employed to explore the relationship between PA parameters and the incidence of cognitive impairment over four years.

Results Engaging in moderate or light PA (MPA or LPA) at least three days per week, and vigorous PA (VPA) one to two days per week, was associated with a reduced incidence of cognitive impairment. Additionally, spending 30–119 min per day or 150 min per week or more on any PA intensity was linked to lower cognitive impairment prevalence. Sensitivity analysis, excluding individuals with neurological, mental, or memory impairments, confirmed these findings.

Conclusions The findings highlight that the frequency, duration, and volume of VPA, MPA, or LPA are linked to the incidence of cognitive impairment. Regular PA may reduce the risk of cognitive impairment in middle-aged and older adults.

Keywords Cognitive function, Cognitive impairment, Physical activity, Physical performance

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Introduction

Cognitive impairment is a significant and common health issue that impacts many older adults [1]. Research indicates a high prevalence of cognitive impairment among older adults worldwide, with longevity raising the risk of age-related illnesses like dementia and cognitive impairment [2]. It was estimated that by 2015, approximately 50 million people worldwide were living with dementia

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[3]. Dementia cases are projected to reach 65.7 million within the next decade and 115.4 million by mid-century, doubling every 20 years [4]. Each year, 10.0% to 15.0% of adults with mild cognitive impairment (MCI) progress to dementia, with this percentage rising [5]. In China, 22.9% of older adults have MCI [6]. The normal cognitive aging process is associated with declines in cognitive function, which impacts daily decision-making in later life [7]. Moreover, cognitive impairment can also contribute to various health complications, such as type 2 diabetes [8], heart disease [9], and suicide [10]. Therefore, maintaining cognitive competence is crucial for older adults to care for themselves and enhance their physical and mental health, so as to improve their quality of life.

The determinants of cognitive impairment or function can be classified into non-modifiable and modifiable categories. Non-modifiable variables including age, sex, and heredity (particularly Apolipoprotein E genes), are linked to cognitive decline and dementia and cannot be changed through personal behavior or medical interventions [11]. However, there are several modifiable factors that can help prevent cognitive impairment and dementia. Cardiovascular risk factors – including smoking, obesity, diabetes, metabolic syndrome, and cardiovascular disease such as hypertension – are linked to a higher risk of dementia and cognitive deterioration [11, 12]. Although it is important to be aware of these risk factors, the focus should be on preventive strategies that target modifiable factors. Evidence suggests that lifestyle factors can either contribute to or protect against cognitive decline and dementia, with physical activity (PA) being a significant protective factor [13].

PA refers to meeting established guidelines, typically characterized by reaching a specified threshold of moderate to vigorous physical activity (MVPA) minutes per day [14]. In contrast, physical inactivity is defined as the lack of PA, generally measured by the amount or proportion of time not engaged in activity of a predetermined intensity [14]. PA plays a crucial role in preventing chronic diseases, enhancing mental health, improving physical fitness and mobility, fostering social interactions, and delaying cognitive decline [15]. These comprehensive benefits make it essential for both primary prevention and effective management of disease, beyond merely addressing energy expenditure and obesity issues [16]. Research indicates that physical inactivity is linked to about one-third of Alzheimer disease (AD) cases worldwide, totaling approximately 9.6 million cases [17], and a higher incidence of mental illness was seen in those with the highest sedentary index levels [18]. Moreover, although conditions like depression, diabetes, coronary heart disease, and stroke are known as high-risk factors for cognitive decline, these risks may be mitigated through regular PA [19, 20]. Sedentary behaviour is characterized by activities with an energy expenditure of ≤ 1.5 METs such as sitting, lying down, and watching television [21]. It may impair cognitive function—particularly executive functions—thereby negatively affecting prefrontal cortex functioning. Evidence from bed rest studies has shown significant declines in decision-making performance and slower reaction times in tasks such as the Iowa Gambling Task, underscoring the potential cognitive risks associated with prolonged inactivity [22, 23]. Additionally, individuals who engaged in moderate PA (MPA) were slightly more likely to experience cognitive impairment than those who engaged in vigorous PA (VPA), whereas those with light PA (LPA) were considerably more prone to experiencing cognitive impairment [24].

According to the World Health Organization (WHO, 2022) [25], older adults are advised to engage in a minimum of 75 min of VPA or 150 min of MPA weekly, or a combination of both that provides an equivalent effort. Similarly, the American College of Sports Medicine (2022) [26] reveals that healthy adults are recommended to engage in 20-min sessions of VPA three times weekly or 30-min sessions of MPA five times a week. Although numerous studies have explored the relationship between PA, cognitive impairment, and potential cognitive impairment in middle-aged and older adults [24, 27], the majority of these studies have utilized a cross-sectional design. Furthermore, no study has examined the relationship while accounting for the four PA parameters including frequency, duration, intensity, and volume. Therefore, this prospective research aimed to explore the relationship between PA considering factors such as frequency, duration, intensity, and volume and the incidence of cognitive impairment in middle-aged and older adults.

Materials and methods

Study setting and participants

The China Health and Retirement Longitudinal Study (CHARLS) was conducted in four waves (2011, 2013, 2015, and 2018). A total of 17,708 participants were recruited from 150 counties and districts across 28 provinces in China using multi-stage stratified probability sampling proportional to size. Participants were followed biennially with standardized interviews to collect data on demographics, health, social and economic conditions, and retirement status. This study utilized data from the 2011–2015 waves, as the PA data was not included in the 2018 wave. Further details about the study, including its methodology, are available on the official CHARLS website (http://charls.pku.edu.cn/).

A total of 3,195 participants took part in PA data collection both in 2011 and 2015. We removed 2,304 individuals for the following reasons: (a) 378 individuals aged less than 45 years at baseline in 2011; (b) 536 individuals did not have complete data to define cognitive impairment; and (c) 674 individuals had cognitive impairment at baseline. Among the participants in the final research group, 1,606 individuals did not have cognitive impairment. About four years after the completion of first wave, the third wave was conducted in 2015. The exclusion criterion was the absence of follow-up data ($n = 715$). Finally, participants aged 45 to 94 were included in the analysis (Fig. 1). We compared the data set with the missing data using characteristics like gender, age, education level, smoking status, and hypertension. The objective was to assess if the missing information, as detailed in Supplementary Table S1, could contribute to selection bias.

Assessment of PA

The researchers used a revised version of the International Physical Activity Questionnaire (IPAQ) Short Form, as detailed in Supplementary Table S2, to evaluate participants' PA levels. Previous studies have established the accuracy and consistency of the IPAQ [28, 29]. In our study, we assessed PA by first asking participants, "Did you engage in any PA at a continuous intensity for at least 10 min during an average week?" CHARLS categorized PA intensity into three levels: (a) VPA: Intense activities that cause heavy breathing, including weightlifting, digging, aerobic exercises, fast cycling, and carrying heavy loads; (b) MPA: Activities that cause slightly harder breathing including cleaning the floor, cycling at a steady pace, and carrying light weights; (c) LPA: Activities such as walking within the home or workplace, commuting on foot, and walking for fitness, athletic activities, leisure, or recreational purposes. If participants answered

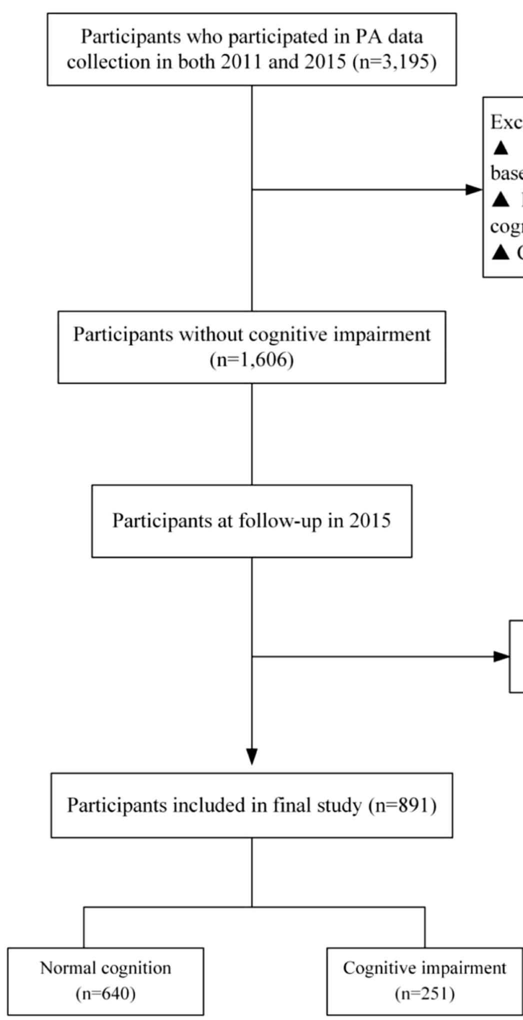

Fig. 1 Flowchart of study participants in this study

"yes," they were then asked about the frequency (days per week) and duration (minutes per day) of their PA. PA frequency was categorized into three groups, ranging from 0 to 7 days per week: inactive, 1–2 days per week, and at least 3 days per week. The duration was classified into three categories: inactive, 10–29 min per day, and 30–119 min per day or more. The weekly volume of VPA/MPA/LPA was calculated by multiplying the frequency (days per week) by the duration (minutes per day). Participants were then grouped based on their weekly volume into inactive, less than 150 min per week, and 150 min per week or more [30].

Diagnosis of cognitive function

The assessment of cognitive function was conducted using two dimensions. The first dimension, focusing on memory, included two tasks: immediate recall, scored from 0 to 10 points, and delayed recall, also scored from 0 to 10 points. The second aspect, executive function, was assessed using the Telephone Interview for Cognitive Status battery. Executive function included three components: visuo-construction (0–1) for redrawing a figure, orientation (0–5) for naming the day and date, and attention (0–5) was evaluated by having participants subtract 7 from 100 five times [31].

Diagnosis of cognitive impairment

There were two broad categories into which the participants were divided: normal cognition and cognitive impairment. Cognitive impairment is categorized according to an individual's level of education. Cognitive impairment is defined as scoring below 17 points for individuals with less than one year of schooling, below 20 points for those with one to six years of schooling, and below 24 points for those with more than six years of schooling based on a previous publication [32, 33].

Potential covariates

In our analysis, we controlled for lifestyle, health, and sociodemographic characteristics as confounders. The study considered several sociodemographic factors: gender classified as male or female, age divided into groups of 40–49, 50–59, 60–69, and 70 and above, marital status categorized as single or married/partnered, and educational attainment including no formal schooling, elementary school or below, and middle school or higher. The lifestyle-related variables included smoking status (categorized as current smokers, former smokers, or individuals who have never smoked) and drinking frequency (>1/month, ≤ 1/month, and never drink). The health-related factors encompassed chronic conditions such as hypertension and dyslipidemia, as well as nervous, psychiatric, and memory-related disorders (yes or no).

Statistical analysis

Characteristics of the research participants were reported using numbers and percentages. To investigate the differences between groups with and without cognitive impairment for categorical data, Chi-square tests were used. The association between PA parameters and the incidence of cognitive impairment was analyzed using Poisson regression models, adjusted for age, gender, education, marital status, alcohol consumption, smoking, hypertension, dyslipidemia, as well as neurological, psychiatric, and memory-related disorders. The reference group for VPA, MPA, and LPA was defined as "inactive". Calculation of the relative risk (RR) and 95% confidence intervals (95% CI) was performed. We conducted sensitivity analyses by excluding patients with mental, neurological, and memory-related impairments to ensure the robustness of our results. The study employed SPSS Statistics version 26.0 to conduct Poisson regression models and Chi-square test, with the level of statistical significance set at $p < 0.05$.

Results

In the final analysis, 251 out of 891 patients were classified with cognitive impairment. Table 1 presents a comparison of cognitive characteristics, lifestyle factors, and health conditions between individuals with normal cognition and those with cognitive impairment during the first phase. Participants with new-onset cognitive impairment were more likely to be female (49.1% vs. 61.4%, $p < 0.05$), older (21.7% vs. 31.5% aged ≥ 70 years, $p < 0.05$), and have lower educational attainment (illiterate: 51.2% vs. 74.1%, $p < 0.001$) compared to those without cognitive impairment at baseline. However, there were no significant differences in smoking status, frequency of alcohol use, or prevalence of major illnesses between the normal cognition and cognitive impairment groups.

Regarding PA frequency, the study found that engaging in LPA for at least 3 days per week (RR: 0.63, 95% CI: 0.47 – 0.84), MPA for at least 3 days per week (RR:0.67, 95% CI: 0.51 –0.90), or VPA for at least 3 days per week (RR: 0.64, 95% CI: 0.46 – 0.89 for >3 days per week) was linked to a reduced risk of cognitive impairment, even after controlling for covariates (Table 2). When it comes to PA duration, engaging in LPA for 10–29 min per day or more (RR: 0.55, 95% CI: 0.36 – 0.84) for 10–29 min per day; RR: 0.66, 95% CI: 0.48 – 0.90 for 30–119 min per day), MPA for 30–119 min per day (RR: 0.61, 95% CI: 0.43 – 0.87), or VPA for 30–119 min per day (RR: 0.45, 95% CI: 0.22 – 0.91) was associated with a lower probability of cognitive impairment after adjustments (Table 3). In terms of PA volume, engaging in LPA for at least 150 min per week (RR: 0.61, 95% CI: 0.46 – 0.82), MPA for at least

Table 1 Baseline characteristics of participants according to the presence of cognitive impairment

Variables	Cognitive impairment (*n* = 251)	Normal cognition (*n* = 640)	*p* value
Gender (*n* = 891)			0.001
Male	97 (38.6%)	326 (50.9%)	
Female	154 (61.4%)	314 (49.1%)	
Age (n = 891)			0.018
40–49 years	30 (12.0%)	85 (13.3%)	
50–59 years	68 (27.1%)	218 (34.1%)	
60–69 years	74 (29.5%)	198 (30.9%)	
≥ 70 years	79 (31.5%)	139 (21.7%)	
Education levels (*n* = 891)			
Illiterate	186 (74.1%)	328 (51.2%)	< 0.001
≤ Middle school	65 (25.9%)	272 (42.5%)	
≥ high school	0 (0.0%)	40 (6.3%)	
Marital status (*n* = 891)			0.615
Married and living with spouse	195 (77.7%)	507 (79.2%)	
Others	56 (22.3%)	133 (20.8%)	
Smoking status (*n* = 891)			0.265
Current smokers	87 (34.7%)	205 (32.0%)	
Former smokers	16 (6.4%)	62 (9.7%)	
Never smoked	148 (59.0%)	373 (58.3%)	
Alcohol drinking frequency (*n* = 891)			0.507
> 1/month	76 (30.3%)	169 (26.4%)	
≤ 1/month	21 (8.4%)	56 (8.8%)	
Never drank	154 (61.4%)	415 (64.8%)	
Hypertension (*n* = 888)			0.807
Yes	52 (21.0%)	139 (21.7%)	
No	196 (79.0%)	501 (78.3%)	
Dyslipidemia (*n* = 877)			0.890
Yes	32 (12.9%)	79 (12.6%)	
No	216 (87.1%)	550 (87.4%)	
Psychiatric problems (*n* = 890)			0.411
Yes	1 (0.4%)	6 (0.9%)	
No	250 (99.6%)	633 (99.1%)	
Memory-related disease (*n* = 891)			0.409
Yes	1 (0.4%)	6 (0.9%)	
No	250 (99.6%)	634 (99.1%)	

150 min per week (RR: 0.63, 95% CI: 0.47 – 0.86), or VPA for at least 150 min per week (RR: 0.63, 95% CI: 0.45 – 0.88) was associated with a lower incidence of cognitive impairment after adjustments (Table 4).

Excluding participants with mental, neurological, and memory-related impairments, we conducted sensitivity analyses (Supplementary Table S3). The results were consistent with those in Table 4, demonstrating an association between PA volume and the incidence of cognitive impairment.

Discussion

This research aimed to investigate the relationship between PA and the onset of cognitive impairment. Adults who engage in at least 150 min of LPA per week, spread over 3 or more days, or at least 30 min per session, exhibit a lower risk of cognitive impairment compared to inactive individuals. Similarly, those who participate in MPA for a minimum of 150 min per week, spread over 3 days or more, also show a reduced incidence of cognitive impairment. Furthermore, individuals who engage in VPA for 150 min or more per week, across 3 or more

Table 2 Relationship between PA frequency and occurrence of cognitive impairment in middle-aged and older adults

PA frequency	Event/participants	Cognitive impairment	
		RR (95% CI)	Adjusted RR[a] (95% CI)
LPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
1–2 d/w	9/24	0.79 (0.52 – 1.66)	0.98 (0.57 – 1.68)
≥ 3 d/w	184/714	0.64 (0.47 – 0.86)*	0.63 (0.47 – 0.84)*
MPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
1–2 d/w	10/42	0.59 (0.32 – 1.08)	0.61 (0.32 – 1.13)
≥ 3 d/w	134/487	0.68 (0.50 – 0.92)*	0.67 (0.51 – 0.90)*
VPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
1–2 d/w	9/37	0.60 (0.32 – 1.13)	0.53 (0.27 – 1.05)
≥ 3 d/w	64/235	0.67 (0.48 – 0.94) *	0.64 (0.46 – 0.89)*

Abbreviations: *VPA* vigorous physical activity, *MPA* moderate physical activity, *LPA* light physical activity, *RR* relative risk, *95% CI* 95% confidential intervals; min/w, minutes/week

* $p < 0.05$

[a] Adjusted for gender, age, marital status, education levels, smoking status, alcohol drinking frequency, hypertension, dyslipidemia, nervous, or psychiatric problems and memory-related disease

Table 3 Relationship between PA duration and occurrence of cognitive impairment in middle-aged and older adults

PA duration	Event/participants	Cognitive impairment	
		RR (95% CI)	Adjusted RR[a] (95% CI)
LPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–29 min/d	26/118	0.55 (0.35 – 0.84)*	0.55 (0.36 – 0.84)*
30–119 min/d	101/373	0.67 (0.49—0.91)*	0.66 (0.48 – 0.90)*
MPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–29 min/d	23/60	0.95 (0.62 – 1.44)	0.99 (0.65 – 1.49)
30–119 min/d	47/190	0.61 (0.42 – 0.88)*	0.61 (0.43 – 0.87)*
VPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–29 min/d	5/17	0.73 (0.33 – 1.59)	0.83 (0.37 – 1.88)
30–119 min/d	8/41	0.48 (0.25 – 0.94)*	0.45 (0.22 – 0.91)*

Abbreviations: *VPA* vigorous physical activity, *MPA* moderate physical activity, *LPA* light physical activity, *RR* relative risk, *95% CI* 95% confidential intervals; min/d, minutes/day

* $p < 0.05$

[a] Adjusted for gender, age, marital status, education levels, smoking status, alcohol drinking frequency, hypertension, dyslipidemia, nervous, or psychiatric problems and memory-related disease

days, exhibit a reduced incidence of cognitive impairment relative to their inactive counterparts.

A sedentary lifestyle and lack of PA are modifiable risk factors that increase the risk of developing AD and dementia. Studies have shown that regular PA helps prevent the onset of neurodegenerative diseases like Alzheimer's and preserves mental and cognitive health as we age. At follow-up, the physically active group significantly outperformed the physically inactive group on cognitive tests, demonstrating the benefits of an active lifestyle [24]. Given the positive association between PA and cognition, engaging in regular PA can help prevent age-related cognitive decline and provide numerous other health benefits. PA at both high and low intensities has

Table 4 Relationship between PA volume and occurrence of cognitive impairment in middle-aged and older adults

PA volume	Event/participants	Cognitive impairment	
		RR (95% CI)	Adjusted RR[a] (95% CI)
LPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–149 min/w	13/40	0.79 (0.74 – 1.33)	0.89 (0.53 – 1.50)
≥ 150 min/w	178/692	0.63 (0.47 – 0.84)*	0.61 (0.46 – 0.82)*
MPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–149 min/w	17/35	0.98 (0.78 – 1.67)	0.99 (0.85 – 2.04)
≥ 150 min/w	125/484	0.64 (0.47 – 0.87)*	0.63 (0.47 – 0.86)*
VPA			
Inactive	32/79	1.00 (ref.)	1.00 (ref.)
10–149 min/w	6/20	0.75 (0.36 – 1.54)	0.70 (0.32 – 1.49)
≥ 150 min/w	67/248	0.67 (0.48 – 0.94)*	0.63 (0.45 – 0.88)*

Abbreviations: *VPA* vigorous physical activity, *MPA* moderate physical activity, *LPA* light physical activity, *RR* relative risk, *95% CI* 95% confidential intervals; min/w, minutes/week

* $p < 0.05$

[a] Adjusted for gender, age, marital status, education levels, smoking status, alcohol drinking frequency, hypertension, dyslipidemia, nervous, or psychiatric problems and memory-related disease

been demonstrated to positively impact cognition and overall health. One study indicated that physically inactive individuals have a higher risk of dementia compared to those who are physically active. Participation in both high and moderate-intensity activities is particularly beneficial in reducing the risk of dementia, with leisure-time PA showing notably positive effects [34].

In addition, our observations indicate that engaging in LPA for 10–29 min per day or more can be beneficial, whereas MPA and VPA do not demonstrate the same benefits. This may be due to the fact that, compared to MPA and VPA, LPA triggers a smaller stress response in the body and causes a less increase in the stress hormone cortisol, potentially providing greater benefits to the brain [35]. Furthermore, the report highlights that LPA, such as walking, is more feasible and sustainable. This is particularly pertinent for older adults and individuals with chronic conditions, as these activities, according to the WHO (2010) [36], are easier to integrate into daily routines, thereby leading to the observed results.

A relationship between PA and cognitive impairment has been shown by earlier studies. The preventive effect of PA on cognitive decline was assessed by finding that compared to women who were less active, the risk of cognitive impairment was lower in those who were more active (>4 h/week) by 88.0% [37]. Additionally, a longitudinal study revealed that individuals who engaged in PA three or more times a week had a lower incidence of dementia compared to those who did so less frequently. The greatest risk reduction was observed in individuals with poor physical functioning at baseline [38]. We identify the key aspects of PA – intensity, frequency, duration, and weekly volume that contribute to lowering the incidence of cognitive impairment in older adults. Regular engagement in LPA or MVPA at least three days per week is linked to a decreased risk of cognitive impairment. Furthermore, spending 30 min or more each day on MVPA is linked to a reduced risk of cognitive decline, while a weekly volume of 150 min or more of LPA, MPA, or VPA is associated with a reduced risk of cognitive impairment. Most previous studies have employed cross-sectional designs, although some longitudinal studies have been conducted, these have generally focused on a single parameter. Compared to studies that focus solely on PA intensity, our research offers more comprehensive guidance for preventing cognitive impairment by providing specific recommendations on PA intensity, frequency, duration, and weekly volume.

The effects of exercise on the brain are complex and multifaceted, involving mechanisms such as neurogenesis, increased capillarization, reduced oxidative damage, and enhanced proteolytic degradation. PA has been shown to increase neurotrophic factors like brain-derived neurotrophic factors, which enhance cognition in AD patients through their neuroprotective effects [39, 40]. Exercise also reduces reactive oxygen species-induced protein damage and regulates the activity of redox-sensitive transcription factors, which are crucial for neuronal development and plasticity [41–43]. Impaired endothelial function in patients with AD may contribute to cognitive impairment. This impairment is possibly linked to beta-amyloid protein-related neuronal cell loss, which occurs through mechanisms such as lipid peroxidation and the generation of reactive oxygen species(ROS) [44]. Frequent PA increases endothelial nitric oxide synthase production, improves endothelium-dependent vasorelaxation, enhances blood flow, and reduces the risk of brain injury [45]. This enhancement in vascular function may mitigate beta-amyloid protein-related neuronal cell loss associated with lipid peroxidation and ROS. In addition, exercise stimulates the release of myokines, proteins produced in skeletal muscle with autocrine, paracrine, or endocrine functions. Myokines play a role in regulating body weight, reducing low-grade inflammation, enhancing insulin sensitivity, suppressing tumor growth, and improving cognitive function [46]. Exercise also accelerates the breakdown of brain glycogen, facilitating the transfer of lactate from astrocytes to neurons, a process linked to the formation of long-term memory [47]. These multifaceted benefits underscore the importance of regular PA as a non-pharmacological intervention to support brain health and mitigate cognitive decline in aging populations, particularly those at risk for or living with AD.

The current study had some disadvantages. Initially, rather than using objective instruments to collect data on PA, a modified version of IPAQ was employed. Prior research has demonstrated that the subjective IPAQ overrates PA levels in comparison to objective PA measurement devices such as accelerometers [48]. Furthermore, walking for sport, exercise, enjoyment, or leisure, along with walking to and from work and home and other activities were included in the new IPAQ definition of LPA. The concept of MVPA may lead participants to mistakenly categorize brisk walking during sports and other activities as LPA. Third, even though we adjusted for a number of pertinent covariates, we neglected to account for additional variables that might have an impact on the link between PA and cognitive impairment, like medication and nutritional status. Fourth, the relatively short 4-year follow-up period of our study may have resulted in minimal changes in health status being observed. Ultimately, the absence of baseline data led to the exclusion of more than half of the participants (2,034 out of 3,195), potentially introducing selection bias. Nevertheless, after excluding individuals with mental, neurological, and memory-related deficits, sensitivity analyses confirmed the validity of the findings.

Conclusions

In summary, it was observed that individuals who engaged in LPA or MPA for 3 or more days per week, and VPA for 3 or more days per week are associated with a significantly lower incidence of cognitive decline compared to those maintaining an inactive lifestyle and LPA are modifiable risk factors that increase the risk of developing AD and dementia. Additionally, engaging in LPA for 10–29 min per day or at least 30 min per day, MPA for at least 30 min per day, and VPA for at least 30 min per day was inversely associated with the prevalence of cognitive impairment. Furthermore, participation in LPA for at least 150 min per week, MPA for at least 150 min per week, and VPA for at least 150 min per week was linked to a lower incidence of cognitive impairment.

These findings highlight the inverse relationship between the frequency, duration, and volume of LPA, MPA and VPA and the incidence of cognitive impairment. The results suggest that consistent participation in PA, particularly at higher frequencies and longer durations, may significantly reduce the risk of cognitive impairment in older adults. This study offers specific recommendations regarding the intensity, frequency, and duration of PA to mitigate the risk of cognitive decline in middle-aged and older adults. Meanwhile, our findings offer guidance to healthcare professionals and public health practitioners in developing prevention strategies about cognitive decline on the ground.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40359-025-02586-3.

Supplementary Material 1: Supplementary Table S1. The characteristics of study participants at baseline in 2011 according to the missing data. Supplementary Table S2. The Modified IPAQ Short Form. Supplementary Table S3. Association between PA volume and the presence of cognitive impairment in psychiatric problems free and memory-related disease- free people.

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Authors' contributions
D. L. Conceptualization; writing – original draft preparation. Y. P. Formal analysis; methodology. J. W. Formal analysis; resources. S. S. Investigation; methodology; resources. X. Z. Formal analysis; investigation; methodology; writing – review & editing. All Authors have read and approved the final manuscript.

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Data availability
The study's supporting data are accessible at http://charls.pku.edu.cn/en/index.htm, through Peking University Open Research Data.

Declarations

Ethics approval and consent to participate
The Peking University Ethical Review Committee granted approval for the study (registration number: IRB00001052-11015), which was carried out in

compliance with the Declaration of Helsinki. Prior to the commencement of the study, the participants gave their written, informed consent. Additionally, every author attested to the fact that every procedure was carried out in compliance with relevant regulations and guidelines.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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