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Gender Differences in Physical Activity Patterns and Cognitive Function Among Middle-Aged and Older Adults: Evidence From the CHARLS

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Abstract

While the mental health benefits of physical activity (PA) are well documented, evidence regarding the association between specific PA patterns and the risk of cognitive impairment among middle-aged and older adults in China remains limited, particularly with respect to gender differences. This study aimed to examine the relationships between different dimensions of PA—including intensity, frequency, duration, and total volume and cognitive function among Chinese adults aged 45 years and above. Data were drawn from the 2018 wave of the China Health and Retirement Longitudinal Study (CHARLS), comprising a nationally representative sample of 4,160 participants. Cognitive function was assessed using the Mini-Mental State Examination (MMSE), and binary logistic regression models were employed to estimate the associations between PA patterns and the likelihood of cognitive impairment, stratified by gender. The findings indicated notable gender-specific associations. Among men, engaging in light physical activity (LPA) for 3–5 days per week (OR = 0.42, 95% CI: 0.19–0.92), with daily durations of at least 240 minutes (OR = 0.71, 95% CI: 0.40–1.29) and total weekly activity exceeding 1,260 minutes (OR = 0.69, 95% CI: 0.38–1.25), was associated with a lower risk of cognitive impairment. Among women, LPA performed 6–7 days per week (OR = 0.76, 95% CI: 0.57–1.00), with daily durations of at least 240 minutes (OR = 0.71, 95% CI: 0.50–1.02) and either low (<525 minutes) or high (>1,260 minutes) weekly PA volume (OR = 0.72, 95% CI: 0.51–1.03), was linked to reduced impairment risk. In contrast, excessive vigorous physical activity (VPA), defined as more than 240 minutes per day, was associated with an increased risk of cognitive impairment among women (OR = 1.34, 95% CI: 1.00–1.79). Overall, the study highlights the importance of moderate, light-intensity physical activity for cognitive health in later life and underscores the need to consider gender-specific PA recommendations.

Keywords: *Cognitive Impairment, Middle-Aged, Older Adults, Physical Activity*

A. Introduction

China is experiencing rapid population aging, driven by increased life expectancy and declining fertility rates, with the aging process occurring at a significantly faster rate than in most other countries (Fang et al., 2020). By 2015, the population aged 60 and above had reached 222 million, accounting for 16.1% of the total population, while those aged 65 and above numbered 143.8 million (10.5%)(Shi, 2017). This demographic shift has led to a significant rise in the number of individuals affected by cognitive impairment, posing serious challenges to families, communities, and healthcare systems. Cognitive impairment encompasses a spectrum of conditions ranging from mild cognitive decline to dementia, with dementia representing the most severe form and a leading cause of disability among the elderly worldwide (Cannon et al.,

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2017; Clay et al., 2019). As such, cognitive impairment has become a critical global public health issue(Luo et al., 2022).

According to recent World Health Organization (WHO) data, more than 55 million people globally are living with dementia, a number projected to increase to 78 million by 2030 and reach 150 million by 2050(Luo et al., 2022). In China, the prevalence of dementia is rising in parallel with the aging population. The seventh national census revealed that 18.7% of the population is aged 60 and above, and 13.5% are 65 or older. Dementia, a growing concern among the elderly, currently affects 15.07 million individuals and is projected to rise to 22.2 million by 2030 in China(Xu et al., 2022). In response, the Chinese government has promoted the concept of "healthy aging" as part of the Healthy China 2030 initiative (Xu et al., 2020).

Cognitive impairment is often associated with age-related neurodegenerative diseases and manifests through deficits in memory, orientation, executive function, and language, which can affect daily living to varying degrees (Morley, 2018). Non-pharmacological interventions, such as regular physical activity, a balanced diet, and management of chronic diseases, have been shown to delay or mitigate cognitive decline before it progresses to dementia(Rosenberg et al., 2018).

In recent years, Physical activity (PA) has gained recognition as an effective intervention for cognitive decline due to its accessibility and broad benefits, including improved physical health, sleep, emotional well-being, and social support (Brown & Blanton, 2002). The Lancet Commission on dementia identified 12 modifiable risk factors responsible for 40% of global dementia cases, with PA being key in delaying cognitive decline (Livingston et al., 2020; Prakash et al., 2015). PA not only protects against neurodegenerative diseases like Parkinson's and Alzheimer's (Dauwan et al., 2021), but also enhances neuroplasticity and cognitive function (Hotting & Roder, 2013), particularly executive function and memory in those with mild cognitive impairment, while supporting independence in dementia patients (Nuzum et al., 2020).

Although evidence on PA's impact varies, substantial research confirms its positive effects on cognitive performance in both healthy older adults and those with cognitive impairment(Busse et al., 2009). Studies have shown that moderate and light PA (MPA and LPA) significantly benefit the cognitive and physical functions of older adults with hypertension (Ding et al., 2021).

Cognitive impairment is influenced by demographic factors like age, gender, and education, with older females typically experiencing more severe decline than males (Okura et al., 2019). Gender may moderate the PA-cognition relationship, though findings are mixed. Some studies suggest that females derive slightly greater cognitive benefits from PA(Kumar et al., 2022). These results indicate that regular PA can improve cognitive function across genders. In addition, some studies suggest that prolonged intense physical activity may be moderated by the size of social networks, leading to social isolation in older adults. Furthermore, prolonged physical activity can lead to mental fatigue, which contributes to a decline in physical function and ultimately affects cognitive function and cognitive health (Jedrziewski et al., 2014; Litwin & Shaul, 2019; Yang et al., 2024).

This study aims to explore the relationship between different patterns and levels of PA and cognitive performance. To our knowledge, few studies in China have examined the association between cognitive function and PA across all four key dimensions—intensity, frequency, duration, and volume. Therefore, this study focuses on middle-aged and older adults and seeks to: (1) investigate the patterns of different types of PA; (2) examine the potential impact of PA on cognitive function from multiple perspectives, including intensity, frequency, duration, and volume; and (3) explore gender differences in the potential impact of PA on cognitive function.

B. Methods

Data Source

This study utilized data from CHARLS, a nationally representative longitudinal survey targeting Chinese residents aged 45 and above, along with their spouses. CHARLS covers a wide range of topics, including social, economic, and health-related aspects, offering a valuable dataset for analyzing health and economic issues in China's rapidly aging population. The survey employed a multistage, stratified, probability proportional to size (PPS) sampling method, encompassing 150 counties and 450 communities across 28 provinces, ensuring wide demographic and geographic representation (Wang et al., 2019; Zhao et al., 2014).

Data were collected through computer-assisted personal interviews (CAPI), covering demographics, health status, socioeconomic factors, and community characteristics. Baseline data were collected in 2011, with follow-up surveys conducted biennially through 2018, maintaining a response rate above 80% in each wave. Research involving human subjects in CHARLS was reviewed and approved by the Institutional Review Board of Peking University (IRB00001052-11015).

For this study, data from the 2018 wave were analyzed. Out of the 20,866 participants, 4,160 were selected for cross-sectional analysis based on the following criteria: (1) aged 45 or older; (2) complete data on physical activity (VPA, MPA, LPA); and (3) available individual weights to ensure representativeness. The final sample was obtained after the following exclusions: (1) participants under 45 or missing age information (N=1,604); (2) those missing data on health conditions (e.g., hypertension, diabetes) or health behaviors (e.g., physical activity) (N=8,964); and (3) those missing MMSE scores (N=6,138). Ultimately, 4,160 participants were included, comprising 3,345 classified as cognitively impaired and 815 as cognitively normal. The participant selection process is illustrated in Figure 1.

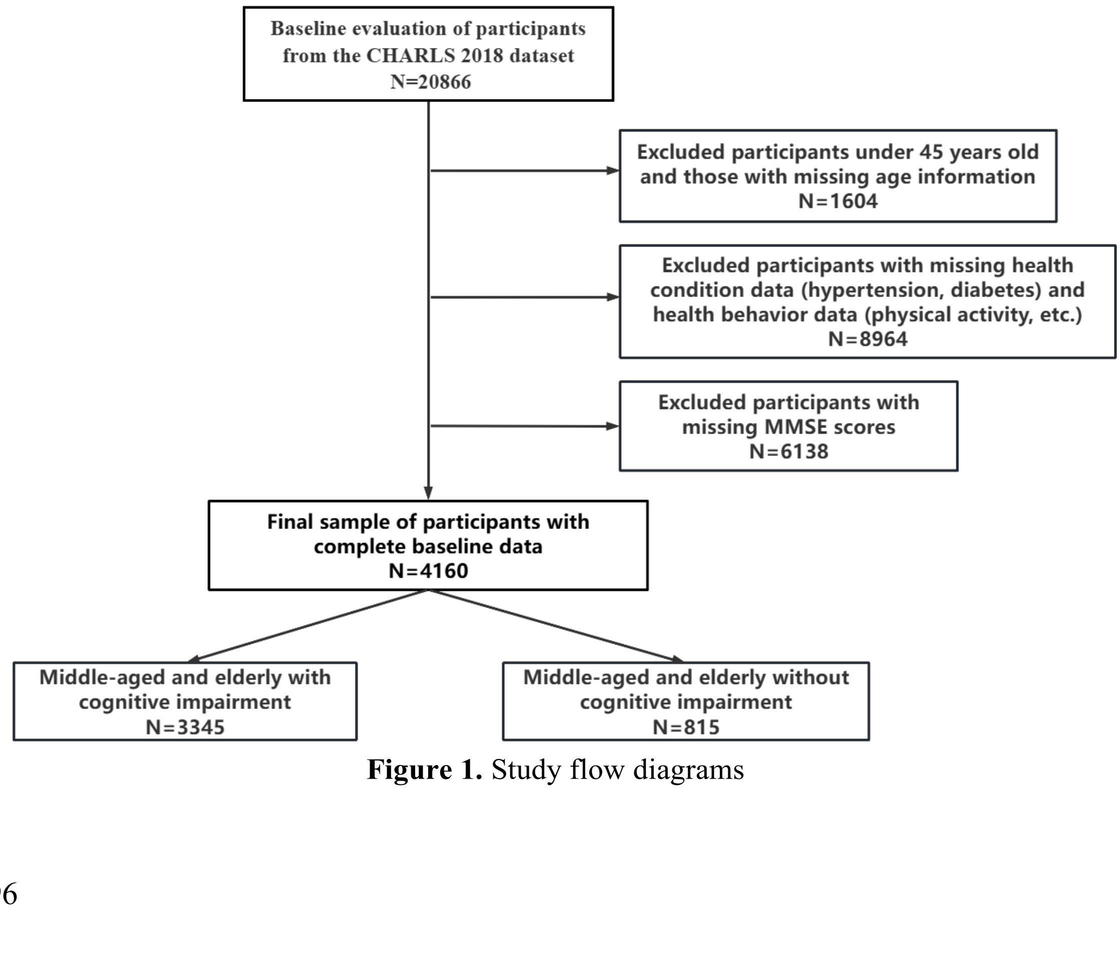

Figure 1. Study flow diagrams

Cognitive Function Assessment

Cognitive function was evaluated using a localized version of the MMSE developed for CHARLS. Since its development in 1975, the MMSE has been widely validated as a reliable tool for cognitive assessment(Folstein et al., 1975). It measures five cognitive domains: immediate memory, delayed memory, temporal orientation, attention and calculation, and visuospatial skills.

In the immediate and delayed memory tests, participants were asked to recall up to 10 words read aloud, with 1 point awarded per correct word (maximum score: 10 for each test). Temporal orientation was assessed by asking participants to identify the current year, month, day of the month, day of the week, and season, scoring 1 point per correct answer (maximum: 5 points). Attention and calculation were evaluated through serial subtraction of 7 from 100, with up to 5 consecutive correct subtractions earning 1 point each (maximum: 5 points). Visuospatial skills were assessed by having participants replicate a drawing, with 1 point awarded for each correct replication.

The total cognitive function score ranged from 0 to 31, with higher scores indicating better cognitive function. Cognitive impairment was classified using education-adjusted MMSE cutoff scores: 18 points for illiterate participants, 21 for those with up to six years of education, and 25 for those with more than six years of education(Liu et al., 2022). Participants scoring below their respective thresholds were classified as having cognitive impairment.

Physical Activity Assessment and Classification

PA was categorized into three intensity levels based on the CHARLS criteria: (1) Vigorous Physical Activity (VPA), this level of activity is characterized by a significant increase in breathing rate and can lead to shortness of breath. Examples of VPA include carrying heavy loads, digging, hoeing, engaging in high-intensity aerobic exercises, cycling at a high speed, and riding a cargo bike or motorcycle; (2) Moderate Physical Activity (MPA), this level results in a noticeable increase in breathing rate, though it is less intense than vigorous activity. Examples of MPA include carrying light loads, cycling at a moderate pace, mopping, practicing Tai Chi, and engaging in brisk walking; and (3) Light Physical Activity (LPA), this level of activity involves minimal exertion and includes activities such as walking (whether for commuting, leisure, or exercise), as well as light household or work-related walking.

Participants were asked if they engaged in VPA, MPA, or LPA for at least 10 consecutive minutes per week. If so, they reported the number of days per week (0-7 days) and the duration per session (<30 minutes, <2 hours, <4 hours, ≥4 hours). PA frequency was classified into four categories: none (0 days), 1-2 days, 3-5 days, and 6-7 days per week. PA duration was categorized into five levels: none, <30 minutes, 30-119 minutes, 120-239 minutes, and ≥240 minutes. Median values were assigned to time intervals based on previous research: 20 minutes for <30 minutes, 75 minutes for 30-119 minutes, 180 minutes for 120-239 minutes, and 240 minutes for ≥240 minutes(Tian & Shi, 2022).

Following World Health Organization (WHO) guidelines, adults are recommended to engage in at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic PA per week, with VPA/MPA exceeding 300 minutes per week potentially posing health risks for older adults. The total duration of VPA, MPA, and LPA was calculated by multiplying the frequency by the duration of each session.

For VPA, responses were categorized into four groups: no VPA, <75 minutes per week, 75-300 minutes per week, and ≥300 minutes per week. MPA duration was divided into four groups: no MPA, <150 minutes per week, 150-300 minutes per week, and ≥300 minutes per week. Due to the lack of international guidelines for LPA, this study adjusted the total duration of LPA into five categories based on quartiles: no LPA, first quartile (≤105 minutes per week), second quartile (≤525 minutes per week), third quartile (≤1260 minutes per week), and fourth quartile (>1260 minutes per week).

For the assessment of moderate-to-vigorous physical activity (MVPA), the score was calculated by multiplying the total duration of VPA and MPA by their respective MET values: MPA=4MET, VPA=7.5MET(Heesch et al., 2011). Given that the lower and upper limits for adequate MVPA are 150 minutes of MPA and 300 minutes of VPA per week, equivalent to 600MET and 2250MET, respectively, the amount of MVPA was subsequently coded as no MVPA, not sufficient MVPA (<600MET), sufficient MVPA (600–2249MET), and overlong MVPA (≥2250MET).

Covariates

In alignment with prior research, this study controlled for potential confounding covariates to ensure the precision and reliability of the results. The covariates included in the analysis spanned multiple dimensions, such as sociodemographics, health behaviors, and health status. For the sake of research clarity and data management, the covariates were categorized as follows:

Sociodemographic Variables included gender (male, female), age groups (45-54, 55-64, 65-74, 75+ years), residency/Hukou (rural, urban, other), educational level (illiterate, primary school, secondary school and above), and marital status (married/cohabiting, divorced/separated/widowed/single).

Based on previous studies, we classified drinking status and smoking status in health behaviors as follows: drinking status(drinker, non-drinker) and smoking status (smoker, Non-smoker)(Yan et al., 2023; Yao et al., 2022). Health Status primarily focused on the presence of hypertension (yes, no) and diabetes (yes, no).

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics 27.0. The dataset was cleaned to remove cases with excessive missing data using listwise deletion, where any participant with missing values on any of the included variables was excluded from the analysis. Normality tests were conducted to validate the analyses. Descriptive statistics, chi-square tests, and binary logistic regression were primarily used due to the categorical nature of the variables. Descriptive statistics summarized participants' sociodemographic characteristics, health behaviors, and health status. Continuous variables are reported as mean ± standard deviation (M±SD), while categorical variables are presented as frequencies and percentages. To examine the relationship between physical activity (PA) and cognitive function, a binary logistic regression analysis was conducted. First, univariate analysis identified variables significantly associated with cognitive function, which were then included in a multivariate binary logistic regression model to control for confounders. The model's goodness of fit was evaluated using the Hosmer-Lemeshow test. The moderating effect of gender on the PA-cognition relationship was assessed by incorporating an interaction term between PA and gender in the regression model. Graphical representations were employed to visually depict the relationship between different PA dimensions and cognitive function. A p-value of less than 0.05 was considered statistically significant in all analyses.

C. Results and Discussion

Participant Characteristics

Table 1 presents the baseline characteristics of the 4,160 middle-aged and older adults included in the analysis, with a mean age of 57.88 ± 8.62 years. Among the participants, 3,345 exhibited cognitive impairment, while 815 had normal cognitive function. Females comprised 72.3% of the sample, and males 27.7%. The majority were aged 45–54 (43.0%), rural residents (60.4%), and nearly half had at least a secondary education (49.5%). Most participants were married or cohabiting (81.9%), non-smokers (90.5%), and non-drinkers (71.2%). Regarding health conditions, 87.3% were free of hypertension, and 95.1% did not have diabetes.

Significant differences between participants with and without cognitive impairment were observed across several variables, including sex, age, residence, education, marital status, smoking, drinking, and the prevalence of hypertension and diabetes. Those with cognitive impairment were predominantly female, aged 45–64, rural residents, with at least secondary education, married or cohabiting, non-drinkers, non-smokers, and largely free of diabetes or hypertension.

Table 1. Basic characteristics of the participant

Baseline characteristics	Total (n=4160)	Cognitive impairment (n=3345)	Cognitive normal (n=815)	P value
Gender, n%				
Male	1154（27.7）	987（29.5）	167（20.5）	＜ 0.001
Female	3006（72.3）	2358（70.5）	648（79.5）	
Age, n%, M±SD, year	57.88±8.62			＜ 0.001
45-54	1788（43.0）	1298（38.8）	490（60.1）	
55-64	1416（34.0）	1219（36.4）	197（24.2）	
65-74	774（18.6）	666（19.9）	108（13.3）	
≥75	182（4.4）	162（4.8）	20（2.5）	
Residency/Hukou, n%				0.232
Urban	1161（27.9）	914（27.3）	247（30.3）	
Rural	2512（60.4）	2035（60.8）	477（58.5）	
Others	487（11.7）	396（11.8）	91（11.2）	
Education level, n%				＜ 0.001
Illiterate	307（7.4）	270（8.1）	37（4.5）	
Primary school	1793（43.1）	1309（39.1）	484（59.5）	
Middle school or above	2060（49.5）	1766（52.8）	294（36.1）	
Marital status, n%				＜ 0.001
Married/Cohabitating	3407（81.9）	2686（80.3）	721（88.5）	

Baseline characteristics	Total (n=4160)	Cognitive impairment (n=3345)	Cognitive normal (n=815)	P value
Divorced/Separated/Widowed/Never married	753（18.1）	659（19.7）	94（11.5）	
Drinking status, n%				0.365
Drinker	1197(28.8)	973(29.1)	224(27.5)	
Non-drinker	2963(71.2)	2372(70.9)	591(72.5)	
Smoking status, n%				0.022
Smoker	394(9.5)	334(10.0)	60(7.4)	
Non-smoker	3766(90.5)	3011(90.0)	755(92.6)	
Hypertension, n%				＜ 0.001
No	3624（87.1）	2881（86.2）	743（91.2）	
Yes	536（12.9）	464（13.9）	72（8.8）	
Diabetes, n%				0.266
No	3955（95.1）	3174（94.9）	781（95.8）	
Yes	205（4.9）	171（5.1）	34（4.2）	

Multidimensional Analysis of Physical Activity Patterns

This section analyzes PA patterns across four dimensions: intensity, frequency, duration, and volume. Overall, the proportion of participants engaging in PA decreased as the intensity increased, with 87% engaging in LPA, 60% in MPA, and 30.6% in VPA. Across all three intensity levels, most participants either did not engage in any PA or participated frequently (6-7 days per week). While the distribution of LPA was similar between males and females, significant gender differences were observed in MPA and VPA: males were more likely to engage in VPA, while females were more likely to engage in MPA, particularly with frequent participation (Figure 2).

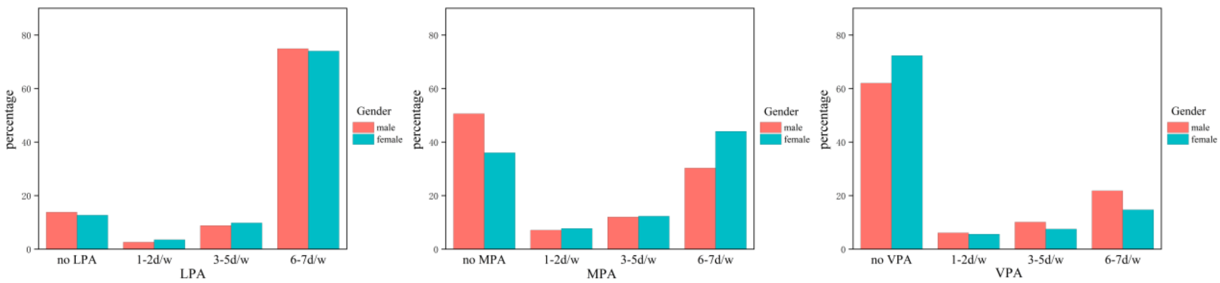

Figure 2. Frequency of males and females participating in LPA, MPA, and VPA

Regarding PA duration, males and females exhibited similar patterns for LPA. However, distinct gender differences emerged in MPA duration: a significant proportion of females (29.2%) spent 30 to 119 minutes per session, while the distribution among males was more evenly spread, with a higher percentage of males not engaging in MPA compared to females. In the VPA group, the majority of both males and females spent more than 4 hours per day on PA (Figure 3).

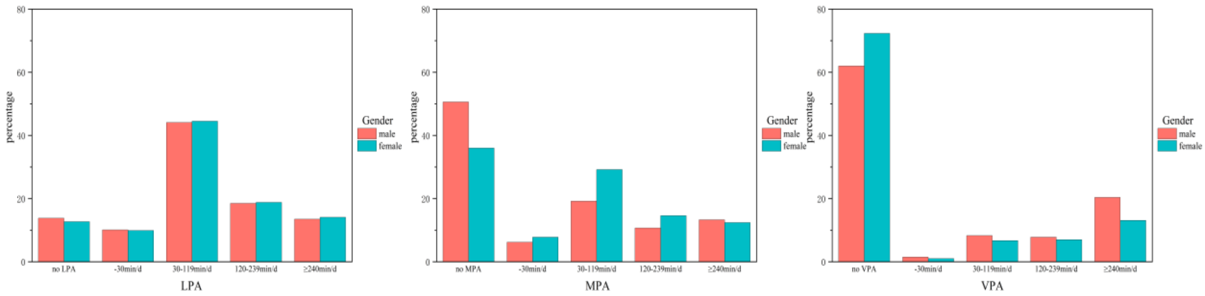

Figure 3. Time per day that males and females participated in LPA, MPA and VPA

Figure 4 summarizes the total weekly time spent on VPA, MPA, LPA, and MVPA. Similar to Figure 2, VPA, MPA, and MVPA distributions showed a clear polarization: a large portion of participants did not engage in any PA, while a substantial proportion exceeded the recommended duration. A significantly higher percentage of males (32.1%) spent more than 300 minutes per week on VPA, whereas a larger proportion of females (48.0%) exceeded 300 minutes per week on MPA. Overall, 61.8% of participants, both male and female, met the recommended levels of MVPA (Figure 4).

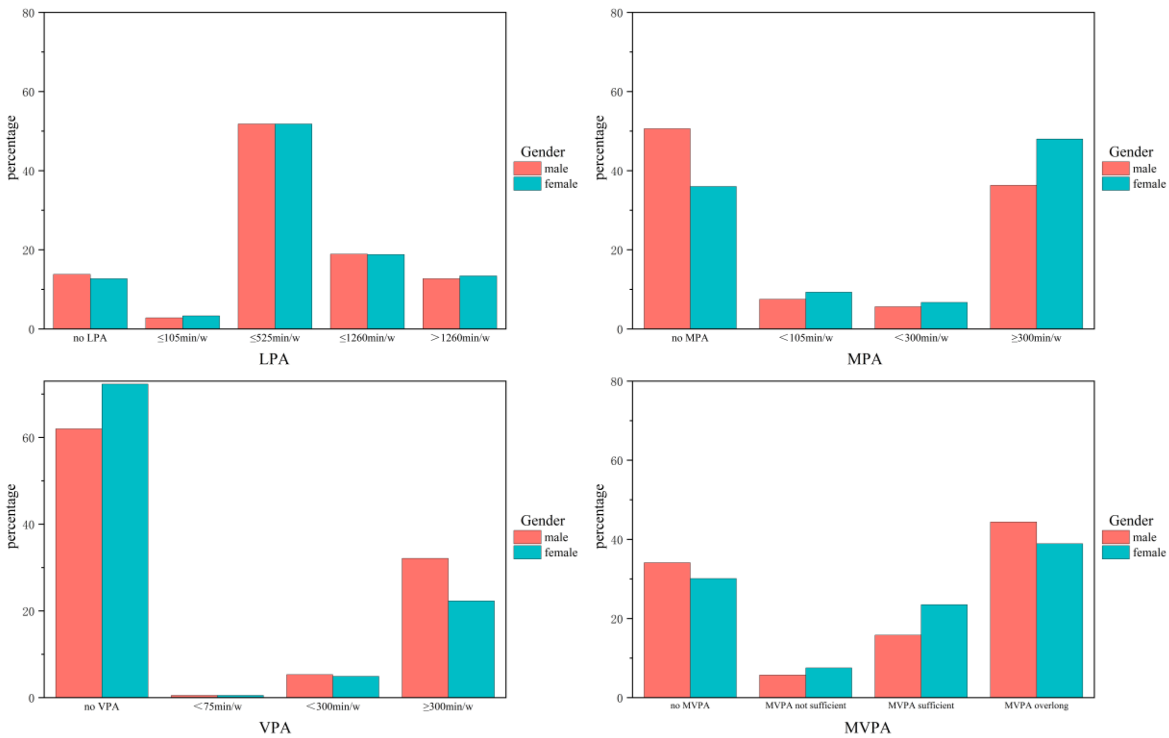

Figure 4 Volume of VPA, MPA, LPA, and MVPA per week in males and females

Relationship Between Physical Activity and Cognitive Risk: Gender Comparison

Table 2 summarizes the association between different dimensions of PA — intensity, frequency, duration, and total activity — and cognitive impairment, with a comparison between males and females. In terms of frequency, engaging in vigorous VPA increased the risk of cognitive impairment compared to those not participating in VPA. However, no significant association was observed between any frequency of VPA and cognitive impairment risk in the overall sample or subgroups. In contrast, engaging in MPA 6–7 days per week was significantly associated with a reduced risk of cognitive impairment in both male and female participants (OR = 0.84, 95% CI: 0.70–1.00, $p < 0.05$). For LPA, participating 3–5 days per week was significantly associated with a lower risk of cognitive impairment, with statistical significance observed among females but not males.

Regarding duration, engaging in more than 4 hours of VPA per session was significantly associated with an increased risk of cognitive impairment (OR = 1.36, 95% CI: 1.07–1.72, $p < 0.05$), particularly in males (OR = 1.34, 95% CI: 1.00–1.79), but not in females (OR = 1.15, 95% CI: 0.74–1.78). For MPA, engaging in 30–119 minutes per day was associated with a significant reduction in the risk of cognitive impairment in the overall sample (OR = 0.77, 95% CI: 0.64–0.93). Similarly, engaging in more than 4 hours of LPA per day was significantly associated with a reduced risk of cognitive impairment (OR = 0.71, 95% CI: 0.53–0.97), although no significant differences were found between males and females for MPA or LPA duration. In terms of total activity, engaging in more than 1,260 minutes of LPA per week was associated with a reduced risk of cognitive impairment (OR = 0.72, 95% CI: 0.53–0.97). Additionally, MVPA of 600–2,249 MET minutes per week was associated with a reduced risk of cognitive impairment (OR = 0.79, 95% CI: 0.53–1.16). For MPA, engaging in less than 150 minutes (OR = 0.96, 95% CI: 0.58–1.60) or more than 300 minutes per week (OR = 0.90, 95% CI: 0.65–1.26) was associated with a reduced risk of cognitive impairment in the overall sample and among females. However, males engaging in more than 300 minutes of MPA per week showed an increased risk of cognitive impairment (OR = 1.33, 95% CI: 0.98–1.81).

Table 2. Relationship between cognitive risk and PA frequency, duration, and volume

	Model 1: Whole sample		**Model 2: Female**		**Model 3: Male**	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
FREQUENCY						
VPA						
No activity	1		1		1	
1-2d/w	1.04	0.74, 1.45	1.10	0.74, 1.62	0.99	0.44, 2.22
3-5d/w	1.10	0.82, 1.47	1.13	0.80, 1.60	1.00	0.54, 1.86
6-7d/w	1.17	0.94, 1.45	1.13	0.88, 1.47	1.19	0.73, 1.95
MPA						
No activity	1		1		1	
1-2d/w	**0.75^{+}**	**0.56, 1.01**	0.79	0.56, 1.10	0.56	0.26, 1.20
3-5d/w	0.95	0.73, 1.23	0.95	0.70, 1.27	0.97	0.48, 1.97
6-7d/w	**0.84***	**0.70, 1.00**	0.92	0.75, 1.13	0.70	0.42, 1.15
LPA						
No activity	1		1		1	

	Model 1: Whole sample		Model 2: Female		Model 3: Male	
	OR	95%CI	OR	95%CI	OR	95%CI
1-2d/w	1.31	0.77, 2.24	1.22	0.67, 2.21	1.10	0.28, 4.24
3-5d/w	0.84	0.60, 1.17	0.87	0.59, 1.28	**0.42***	**0.19, 0.92**
6-7d/w	0.85	0.67, 1.08	**0.76**$^{+}$	**0.57, 1.00**	0.73	0.40, 1.31
DURATION PER TIME						
VPA						
No activity	1		1		1	
＜30min	0.73	0.37, 1.42	0.65	0.29，1.45	0.78	0.22, 2.80
30-119min	0.91	0.68, 1.21	0.83	0.59, 1.16	0.94	0.51, 1.73
120-239min	1.10	0.81, 1.49	1.23	0.85, 1.77	0.71	0.40, 1.26
≥240min	**1.36***	**1.07, 1.72**	**1.34***	**1.00, 1.79**	1.15	0.74, 1.78
MPA						
No activity	1		1		1	
＜30min	0.89	0.65, 1.21	0.91	0.65, 1.28	1.10	0.52，2.31
30-119min	**0.77****	**0.64, 0.93**	**0.82**$^{+}$	**0.66, 1.02**	0.87	0.56, 1.36
120-239min	0.91	0.71, 1.16	0.92	0.69, 1.21	1.28	0.69, 2.38
≥240min	0.97	0.74, 1.25	1.13	0.83, 1.54	0.73	0.45, 1.18
LPA						
No activity	1		1		1	
＜30min	0.88	0.63, 1.23	0.76	0.52, 1.12	1.47	0.71, 3.01
30-119min	0.89	0.69, 1.14	0.80	0.60, 1.07	1.21	0.73, 2.00
120-239min	0.91	0.68, 1.21	0.82	0.59, 1.15	1.22	0.68, 2.19
≥240min	**0.71***	**0.53, 0.97**	**0.71**$^{+}$	**0.50, 1.02**	0.71	0.40, 1.29
VOLUME						
VPA						
No activity	1		1		1	
＜75min/w	0.57	0.23, 1.43	0.63	0.21, 1.85	0.60	0.09, 4.17
＜300min/w	0.94	0.64, 1.37	0.99	0.64, 1.52	0.76	0.34, 1.72
≥300min/w	1.06	0.80, 1.41	1.12	0.81, 1.55	0.74	0.39, 1.41

	Model 1: Whole sample		Model 2: Female		Model 3: Male	
	OR	95%CI	OR	95%CI	OR	95%CI
MPA						
No activity	1		1		1	
＜150min/w	0.96	0.58, 1.60	0.96	0.52, 1.76	1.45	0.50, 4.16
150-299min/w	1.09	0.70, 1.70	1.28	0.75, 2.19	0.91	0.37, 2.25
≥300min/w	0.90	0.65, 1.26	1.10	0.72, 1.69	0.75	0.42, 1.33
LPA						
No activity	1		1		1	
≤105min/w	1.10	0.66, 1.83	1.29	0.70, 2.38	0.66	0.26, 1.71
≤525min/w	0.87	0.68, 1.11	**0.76**$^{+}$	**0.57, 1.02**	1.33	0.81, 2.19
≤1260min/w	0.91	0.68, 1.21	0.82	0.59, 1.14	1.22	0.68, 2.18
＞1260min/w	**0.72***	**0.53, 0.97**	**0.72**$^{+}$	**0.51, 1.03**	0.69	0.38, 1.25
MVPA						
No activity	1		1		1	
＜600 MET	0.79	0.45, 1.40	0.87	0.44, 1.71	0.50	0.15, 1.61
600-2249 MET	0.79	0.53, 1.16	0.69	0.43, 1.12	0.99	0.47, 2.11
≥2250 MET	1.06	0.69, 1.64	0.89	0.53, 1.51	1.48	0.63, 3.46

Note. + indicates $p < 0.1$, * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$; VPA stands for vigorous physical activity, MPA stands for moderate physical activity, and LPA stands for low physical activity. The model is adjusted for age, sex, residency/hukou, educational level, marital status, smoking status, drinking status, hypertension, and diabetes.

This study leveraged data from the 2018 CHARLS to delve into the relationship between PA and cognitive function among middle-aged and older adults, with a particular focus on the moderating role of gender differences. The findings revealed that PA significantly reduces the risk of cognitive impairment in this demographic, suggesting a protective effect on cognitive function independent of other factors.

Gender-specific associations between PA and cognitive function were evident. For males, LPA performed 3-5 days per week (OR = 0.42, 95% CI: 0.19, 0.92, $P < 0.05$) was significantly associated with a reduced risk of cognitive impairment. Each session lasted at least 240 minutes, and the total weekly duration exceeded 1260 minutes. For females, LPA was performed 6-7 days per week, with each session lasting at least 240 minutes and a total weekly duration ranging from 105 to 1260 minutes, similarly showing a protective effect. These benefits are likely due to the positive influence of LPA on cardiovascular health, psychological well-being, and social engagement. However, VPA exceeding 240 minutes per session in females was associated with an increased risk of cognitive impairment (OR = 1.34, 95% CI: 1.00-1.79, $P < 0.05$), potentially due to physical fatigue impairing cognitive performance.

Previous studies have reported a positive association between PA and cognitive function, particularly in middle-aged and older adults, where PA has been shown to independently improve cognitive performance and reduce dementia risk(Buchman et al., 2019). Gender differences in the incidence and prevalence of cognitive impairment have also been well-documented, with research highlighting the gender-specific nature of cognitive aging (Beinhoff et al., 2008). The association between different levels of PA and cognitive risk was observed exclusively in female participants, while no significant effect was found in males (Luo et al., 2022). These findings suggest that gender plays a critical role in the interaction between PA and neurocognition. The results also support a life-course approach to identifying determinants of cognitive aging, emphasizing the importance of considering gender as a moderating factor. Long-term PA has been shown to slow age-related cognitive decline in females, but no such effect has been observed in males (Lopez-Fontana et al., 2018).

Regarding the high prevalence of cognitive impairment in the sample, we observed that most participants exhibited some degree of cognitive decline. This may be linked to the sample selection and the age group, particularly middle-aged and older participants, who are at a higher risk for cognitive decline (Deng et al., 2021; Hu et al., 2022). Furthermore, although the MMSE is widely used for screening cognitive function in older adults, its sensitivity and specificity are limited, potentially missing subtle changes in cognitive impairment (Aaronson et al., 2015). The MMSE is more effective for detecting severe cognitive decline (Zhang et al., 2021) and may overlook mild cognitive impairment. Therefore, more effective methods for cognitive screening are recommended in future studies.

Various explanations have been proposed for gender-specific differences in the impact of PA on cognitive decline. Females, for instance, often outperform males in verbal episodic memory tasks, which are language-related, while males tend to excel in visuospatial tasks(Hyde, 2016). PA is strongly linked to dementia prevention and is vital in managing other health conditions(Dao et al., 2019). Furthermore, the cognitive benefits of PA appear more pronounced in females (Wang et al., 2019).

There is an ongoing debate regarding the dose-response relationship between PA and cognitive function. Different organizations have suggested varying PA guidelines for preventing cognitive decline. A meta-analysis of five prospective studies found that increasing weekly PA by 500 kcal reduced the risk of all-cause dementia and Alzheimer's disease by approximately 10% and 13%, respectively (Xu et al., 2017). Additionally, engaging in PA for 30-45 minutes, 3-4 times per week, over a 12-week period has been shown to improve cognitive function in Alzheimer's disease patients (Zhou et al., 2022).

In this study, gender-specific PA recommendations were identified. For Chinese females aged 45 and above, high-frequency LPA was associated with reduced cognitive risk, while high-frequency VPA and MPA showed an increased cognitive risk compared to lower activity levels. Among males, high-frequency and high-volume MVPA was linked to an elevated cognitive risk. Although PA generally has cognitive benefits, its effects may vary among frail older adults, highlighting the need for further high-quality studies to assess PA interventions in diverse populations.

This study is one of the few to utilize a national dataset to investigate the relationship between PA and cognitive impairment among middle-aged and older Chinese adults, examining multiple dimensions of PA—intensity, frequency, duration, and volume. Previous research, such as studies on hypertensive patients, has explored the multidimensional relationship between PA and cognitive risk(Ding et al., 2021). By leveraging the CHARLS dataset, this study provides new insights into gender-specific differences in the cognitive effects of PA across a broader population.

Despite its strengths, several limitations should be noted. First, the reliance on self-reported PA data may introduce reporting bias. Future studies should incorporate objective measures, such as accelerometers, to better assess the relationship between PA and cognitive impairment. Additionally, the varying effects of PA based on intensity, frequency, and duration complicate the comparison of findings across studies. A more comprehensive approach is needed to fully explore these dimensions. Finally, the MMSE was used to assess cognitive function. While MMSE offers some measurement and screening ability, it has limited capacity for cognitive assessment and may be subject to recall bias. Future studies should utilize more objective and accurate cognitive assessment tools to overcome these limitations. Further high-quality research is also needed to better understand the impact of physical activity on cognitive health.

D. Conclusion

This study highlights the cognitive vulnerability of China's middle-aged and elderly populations, underscoring the need for targeted, cost-effective interventions. Our findings demonstrate a significant association between cognitive risk and physical activity, particularly in terms of intensity and frequency, with notable gender differences. Males engaging in frequent, prolonged MPA were linked to higher cognitive risk, while females showed a reduced cognitive risk with increased frequency and duration of LPA. These findings enhance our understanding of the relationship between physical activity and cognitive function, underscoring the need for gender-specific exercise interventions. Future research should focus on rigorous longitudinal studies to provide more conclusive evidence, ultimately guiding effective public health strategies.

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Authors' contribution

Study concept and design, Ran Yan; methodology, Yawen Yin; statistical analysis, Hongchu Wang; obtained funding, Yi Wang; Supervision, Gang Song; writing—original draft preparation, Ran Yan; writing—review and editing, Ran Yan. All authors have read and agreed to the published version of the manuscript.

Declaration of interests

There are no conflicts of interest to declare regarding the submission of this manuscript, and the manuscript has been approved by all authors for publication.

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Data Availability Statement

(1)The data and analytical methods used in this study are available for replication by other researchers. (2)The data are accessible and can be obtained from the China Health and Retirement Longitudinal Study (CHARLS) website at http://charls.pku.edu.cn/.

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