

The association between trajectories of physical activity and depression among older adults in China: an empirical study based on CHARLS data

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Research Article

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Abstract

Background

Geriatric depression is a growing public health concern.

Methods

Using group-based trajectory models, we analysed data from five waves of the China Health and Retirement Longitudinal Study (CHARLS) from 2011 to 2020 to identify latent clusters and the characteristics of changes in physical activity over time during the follow-up period. Multivariable logistic regression models were employed to analyse the association between different physical activity trajectory types and depression, and sensitivity analyses were conducted. Subgroup analyses were conducted to explore differences in depression among older adults with distinct characteristics across different physical activity trajectories.

Results

A total of 4067 older adults were included in the study, and four physical activity trajectories were identified: the Sustained low group, the Initial low followed by rise group, the Initial high followed by decline group, and the Sustained high group. After adjusting for confounding factors, using the Sustained low group as the reference, the Initial low followed by rise group (OR = 0.585) and the Sustained high group (OR = 0.549) showed a significantly reduced risk of depression, while the Initial high followed by decline group did not demonstrate a significant protective effect; Subgroup analysis indicated that the protective effect was more pronounced among individuals aged ≥ 65 years and women, and the results were validated as robust through sensitivity analysis.

Conclusion

Both the initial low followed by rise and sustained high physical activity groups significantly reduce depression risk, with age and gender differences. Encouraging inactive older adults to increase physical activity may help prevent depression.

1 Introduction

Population aging has become a prominent global public health issue, characterized by a dual increase in both the number of people aged 65 and older and their proportion of the total population. According to data from the United Nations' World Population Prospects 2024 [1], the global elderly population is projected to grow from approximately 830 million in 2024 to over 1.6 billion by 2050—nearly doubling in size. As a country experiencing rapid population aging, China faces particularly acute challenges related

to its aging population. This profound demographic transition is reshaping the global burden of disease, placing immense pressure on traditional healthcare systems—which have historically centered on acute care—to transition toward models focused on chronic diseases and long-term care. Among these, depression is a particularly critical public health issue, affecting over 264 million people worldwide [2]. In China, the prevalence of depression among middle-aged and older adults aged 45 and above exceeds 30% [3]. By 2023, depression is projected to rank first in the global burden of disease [4]. As one of the most common mental health disorders, depression in older adults not only reduces their quality of life and ability to live independently but also serves as a major risk factor for the onset, development, and progression of mild cognitive impairment to dementia. It severely impacts the quality of life and healthy life expectancy of older adults, imposing a heavy economic and caregiving burden on patients, families, and society.

In recent years, a large body of research has confirmed that PA exerts a significant protective effect against depression in older adults [5]. The benefits of PA for mental health are widely recognized; it primarily improves depression in older adults through synergistic mechanisms such as neurobiochemical, neuroendocrine, behavioral-psychological, and social pathways. Based on data from the fifth wave of the CHARLS survey involving 14371 middle-aged and older adults, Wang et al. concluded that PA is associated with a lower risk of depression [6]. Similarly, Byeon analyzed data from 256 older adults living alone in South Korea and found that PA—particularly flexibility-based PA—is one of the protective factors against depression in older adults [7]. A study of 690 community-dwelling older adults in Brazil used the Baecke-Old scale to assess PA levels, and the results showed an association between PA and reduced depression levels [8], further supporting the protective role of PA in the mental health of older adults.

Although previous studies have confirmed the protective effect of PA against depression in older adults, some limitations remain. Most studies have only examined PA at a single, fixed point in time, overlooking the dynamic impact of the trajectory of PA over time on depression. This cross-sectional research method, which focuses on a single point in time, struggles to fully reveal the long-term causal relationship between the two; that is, it cannot investigate the outcome of depression onset in conjunction with subsequent changes in PA. In light of this, this study utilizes longitudinal data from CHARLS (2011–2020) to identify dynamic trajectories of PA and thoroughly explore the dynamic association mechanisms between PA and depression. Dynamic association research can more accurately reveal the causal relationship between PA and depression, providing a new perspective for understanding the mechanisms underlying depression and offering a scientific basis for developing personalized depression prevention and intervention measures for older adults in China.

2 Materials and methods

2.1 Participants

The data for this study were drawn from CHARLS, a project that received ethical approval from the Ethics Review Committee of Peking University (IRB00001052-11015). This survey primarily targeted middle-aged and older adults aged 45 and above in China. The sample covered 28 provinces, 150 districts (counties), and 450 community (village-level) units across China [9]. During the survey period, each respondent who agreed to participate signed an informed consent form. To date, CHARLS has released data from the baseline survey (2011), the first follow-up survey (2013), the second follow-up survey (2015), the third follow-up survey (2018), and the fourth follow-up survey (2020), comprising a total of five waves of data. This study utilized data from all five waves, excluding participants who: (1) were under 60 years of age; (2) had missing baseline data; (3) had missing PA assessments; or (4) had missing depression assessments. A total of 4067 participants were ultimately included in the study. All analyses involving human data in this study comply with the institutional research ethical standards and the ethical principles laid down in the Declaration of Helsinki and all its subsequent revisions. Clinical trial number: not applicable. The participant selection process is shown in Fig. 1.

Table 1 should be placed here

Table 1
Assignment of variables.

Variable	Assignment
Gender	0 = Male, 1 = Female
Age	0 = < 65 years, 1 = ≥ 65 years
Marital status	0 = With partner, 1 = Without partner
Residential area	0 = Urban, 1 = Rural
Educational level	0 = No formal education, 1 = Primary school and below, 2 = Junior high school and above
Smoking	0 = Yes, 1 = No
Alcohol drinking	0 = Yes, 1 = No
Depression	0 = Non-depression, 1 = Depression
PA trajectory group	0 = Sustained low group, 1 = Initial low followed by rise group, 2 = Initial high followed by decline group, 3 = Sustained high group

2.2 Research methods

2.2.1 Assessment of depression

This study used the 10-item Center for Epidemiological Studies Depression Scale (CES-D10) to measure depressive symptoms. This scale consists of 10 items designed to assess respondents' emotional state over the past week. Each item offers four response options: "Rarely or never," "Not very often," "Sometimes or half the time," and "Most of the time," scored as 0, 1, 2, and 3 points, respectively. The items "I am hopeful about the future" and "I feel happy" are reverse-scored. The total score ranges from 0 to 30 points, with a total score of ≥ 10 used as the criterion for determining the presence of depressive symptoms [10]. Depression is classified into two categories: normal and depressed, assigned values of 0 and 1, respectively.

2.2.2 Assessment of PA

This study evaluated PA in older adults using the International Physical Activity Questionnaire (IPAQ). The IPAQ consists of 7 questions that, based on the duration of activities of varying intensity and the frequency of such activities over a week, are used to construct three levels of PA: low, moderate, and high. According to previous research [11], PA duration of 10 min to < 0.5 h is assigned a value of 30 min; duration of 0.5 – <2 h was assigned a value of 60 min; duration of 2 – <4 h was assigned a value of 180 min; and duration of ≥ 4 h was assigned a value of 240 min. Additionally, to avoid grouping errors, in accordance with the data truncation principle, this study recoded individuals who reported more than 3 h of PA at a given intensity per day to 180 min. This principle allows for a maximum of 21 hours (1260 minutes) of PA at each intensity level to be reported per week. PA levels in the IPAQ follow international calculation methods, using metabolic equivalents (METs) instead of total PA volume, calculated as MET value $\times$ weekly frequency $\times$ daily duration. Specifically, the MET value for low PA is 3.3, the moderate PA level has a MET value of 4.0, and the high PA level has a MET value of 8.0. This yields the amount of each of the three types of PA performed by the individual; summing these values gives the individual's weekly MET value. According to the PA level grouping criteria, participants are classified into three PA levels—low, moderate, and high—and assigned values of 1, 2, and 3, respectively.

2.3 Statistical methods

Data were organized using Stata 17.0 statistical software and analyzed using R. Count data were described using proportions and rates, and comparisons between groups were performed using the chi-square test. Group-Based Trajectory Modeling (GBTM) was used to construct four heterogeneous PA dynamic change trajectories. This model utilized the PROC TRAJ procedure in SAS 9.4 to identify subgroups of individuals exhibiting similar patterns over time, classifying these individuals into four "trajectory groups." The criteria for determining the optimal number of trajectories and model evaluation are as follows: the average posterior probability (AvePP) is typically > 0.7 ; the proportion of each trajectory group is generally $\geq 5\%$; the Overclassification Advantage (OCC) is generally > 5 ; the population distribution proportion (π_j) based on group membership probability is close to the population distribution proportion (P_j) based on group membership posterior probability; the Relative Entropy (E_k) is typically > 0.7 ; and the Bayesian Information Criterion (BIC) is closer to 0 [12–13]. The optimal number of groups is determined based on the above principles. A multivariate unconditional logistic regression model is used to analyze the impact of different PA trajectories on depression in older adults and to conduct a stratified

analysis; subgroup forest plots are generated using GraphPad Prism 8. Interaction terms between different PA trajectories and demographic factors are included in a binary logistic regression interaction model to explore their interaction with depression. The significance level is set at $\alpha = 0.05$.

3 Results

3.1 Determination of the optimal number of PA trajectory groups

When the order of the fixed-group trajectories was set to 2, 1–4 GBTMs were constructed. According to the objective fit criteria table, it was found that the BIC for the 4th group was closer to 0 than that of the first 3 groups, and all other indicators met the evaluation criteria. Taking into account both clinical significance and model parsimony, four groups were ultimately determined to be the most appropriate number of trajectory groups, as shown in Table 2. Group 1 comprised 596 individuals (13.99%) and exhibited a consistently low and stable trend throughout the study period; it was defined as the “Sustained low group.” Group 2 comprised 2,155 participants (52.99%), with a low baseline PA level that showed an upward trend later on; it was defined as the “Initial low followed by rise group.” Group 3 comprised 285 participants (7.01%), with a high baseline PA level that showed a downward trend later on; it was defined as the “Initial high followed by decline group.” Group 4 consisted of 1,058 individuals (26.01%), exhibiting a consistently high and stable trend, defined as the “Sustained high group,” as shown in Fig. 2.

Table 2
Objective fitting criteria for determining PA trajectories.

Number of trajectories	Order	Avepp(%)	OCC	Pj(%)	π_j (%)	BIC	Ek
1	2	100		100	100	-11 871.51	0
2	2 2	98.60-92.25	32.9–25.6	66.60–33.40	68.26–31.74	-11 498.73	0.86
3	2 2 2	91.30-80.80-93.78	9.7-21.5-32.5	52.78-14.35-32.87	51.97-16.35-31.68	-11 372.40	0.781
4	2 2 2 2	91.26-75.16-82.91-88.07	9.9-39.1-25.7-21.5	52.57-6.46-13.87-27.10	51.37-7.18-15.89-25.56	-11 331.33	0.786

3.2 Evaluation of model fit

When the number of trajectory groups was set to 4 and the polynomial order within each group was set to 2, Table 3 presents the primary evaluation metrics for the trajectory group fit. The results show that in each PA trajectory group, AvePP(%) was > 70%, the Over-Classification Advantage (OCC) was > 5, and

there was good consistency between the posterior probability (P_j) and the group membership probability (π_j) of group members, indicating that the model fits the data well.

Table 3
Evaluation indicators of model fit for four PA trajectory groups.

Group	OCC	Avepp(%)	P_j (%)	π_j (%)
Sustained low group	62.7	89.28	11.14	11.72
Initial low followed by rise group	10	96.9	76.49	75.78
Initial high followed by decline group	83.3	88.14	8.11	8.19
Sustained high group	161.7	87.95	4.26	4.32

3.3 Baseline characteristics of different PA trajectory groups

The 4067 older adults surveyed had a mean age of (68.76 ± 6.31) years, with 2196 men (54%) and 1870 women (46%). Among them, 3376 (83%) were non-depressed, and 691 (17%) were depressed. There were no significant differences in depression status among the elderly across gender, age, or smoking status; however, statistically significant differences ($P < 0.05$) were observed across residential area, marital status, educational level, and alcohol consumption, as shown in Table 4.

Table 4
Baseline characteristics of the study population.

Variable	Total	Sustained low group	Initial low followed by rise group	Initial high followed by decline group	Sustained high group	X ²	P
	N = 4067	N = 569	N = 2155	N = 285	N = 1058		
Gender						2.758	0.431
Male	2196(54%)	290(51%)	1185(55%)	162(57%)	550(52%)		
Female	1870(46%)	279(49%)	970(45%)	123(43%)	508(48%)		
Age						7.626	0.054
<65 years	1179(29%)	142(25%)	625(29%)	94(33%)	328(31%)		
≥65 years	2888(71%)	427(75%)	1530(71%)	191(67%)	730(69%)		
Residential area						8.943	<0.05
Rural	3091(76%)	421(74%)	1616(75%)	211(74%)	857(81%)		
Urban	976(24%)	148(26%)	539(25%)	74(26%)	201(19%)		
Marital status						22.187	< 0.01
Without partner	732(18%)	137(24%)	366(17%)	40(14%)	190(18%)		
With partner	3335(82%)	432(76%)	1789(83%)	245(86%)	868(82%)		
Educational level						21.535	<0.05
Illiterate	1383(34%)	216(38%)	711(33%)	77(27%)	391(37%)		
Primary school and below	1586(39%)	233(41%)	862(40%)	117(41%)	381(36%)		
Junior high school and above	1098(27%)	119(21%)	582(27%)	91(32%)	286(27%)		
Alcohol drinking						10.269	<0.05
No	2481(61%)	387(68%)	1271(59%)	174(61%)	656(62%)		

Variable	Total	Sustained low group	Initial low followed by rise group	Initial high followed by decline group	Sustained high group	X ²	P
	N = 4067	N = 569	N = 2155	N = 285	N = 1058		
Yes	1586(39%)	182(32%)	884(41%)	111(39%)	402(38%)		
Smoking						3.847	0.278
No	2196(54%)	290(51%)	1142(53%)	154(54%)	603(57%)		
Yes	1871(46%)	279(49%)	1013(47%)	131(46%)	455(43%)		
Depression						31.953	< 0.01
No	3376(83%)	432(76%)	1832(85%)	217(76%)	899(85%)		
YES	691(17%)	137(24%)	323(15%)	68(24%)	159(15%)		

Table 4 should be placed here

3.4 Multivariate logistic regression analysis of the association between PA trajectories and depression in older adults

Using depression status (healthy = 0, depressed = 1) as the dependent variable, we conducted a multivariate logistic regression analysis with the PA trajectory of the Sustained low group as the independent variable. After adjusting for confounding factors, compared with the Sustained low group, the Initial low followed by rise group (OR = 0.585, 95% CI: 0.475–0.720) and the Sustained high group (OR = 0.549, 95% CI: 0.445–0.675) showed a significantly reduced risk of developing depression. See Table 5.

Table 5
Logistic regression analysis of PA trajectory and depression.

Model 1	PA trajectory group	OR(95%CI)	P
	Sustained low group	1(ref)	
	Initial low followed by rise group	0.541(0.440–0.665)	< 0.01
	Initial high followed by decline group	0.963(0.720–1.280)	0.890
	Sustained high group	0.538(0.435–0.665)	< 0.01
Model 2			
	Sustained low group	1(ref)	
	Initial low followed by rise group	0.565(0.458–0.698)	< 0.01
	Initial high followed by decline group	1.045(0.775–1.405)	0.889
	Sustained high group	0.535(0.430–0.665)	< 0.01
Model 3			
	Sustained low group	1(ref)	
	Initial low followed by rise group	0.585(0.475–0.720)	< 0.01
	Initial high followed by decline group	1.087(0.800–1.475)	0.805
	Sustained high group	0.549(0.445–0.675)	< 0.01
^a Model 1 was unadjusted. Model 2 adjusted for age, gender, residence area, education level, and marital status. Model 3 adjusted for age, gender, residence area, education level, marital status, smoking and alcohol drinking.			

Table 5 should be placed here

3.5 Stratified multivariate logistic regression analysis of the impact of PA trajectories on depression in older adults with different characteristics

A stratified multivariate logistic regression analysis was conducted with depression status as the dependent variable and the PA trajectory of the Sustained low group as the independent variable. The results showed that, compared with the Sustained low group, the Initial low followed by rise group had a greater protective effect against the risk of depression among older adults aged ≥ 65 years (OR = 0.512, 95% CI: 0.346–0.757) and men (OR = 0.541, 95% CI: 0.327–0.895). The “Sustained high” group was associated with a greater reduction in the risk of depression among older adults aged ≥ 65 years (OR = 0.436, 95% CI: 0.274–0.694) women (OR = 0.541, 95% CI: 0.329–0.889). See Fig. 3.

3.6 Sensitivity analysis of multivariate logistic regression on the association between PA trajectories and depression in older adults

To assess the robustness of the results, our study excluded participants aged 80 years and older. We then conducted a multivariate logistic regression analysis with depression status (healthy = 0, depressed = 1) as the dependent variable and the “Sustained low” PA trajectory group as the independent variable. After adjusting for confounding factors, compared with the Sustained low group, the Initial low followed by rise group (OR = 0.609, 95% CI: 0.440–0.833) and the Sustained high group (OR = 0.572, 95% CI: 0.402–0.813) showed a significantly reduced risk of developing depression. This indicates that the results are robust and reliable. See Fig. 4.

4 Discussion

In this study, we used GBTM for the first time to systematically evaluate the relationship between PA and depression among older adults in China, and confirmed that maintaining regular PA is negatively associated with the incidence of depression in older adults. We found that, compared to the “Sustained low” PA group, older adults in the “Initial low followed by rise” and “Sustained high” PA groups were associated with a lower risk of depression. Our study also indicated that the association between different PA trajectory groups and depression varied across subgroups: compared to younger older adults and men, older men and women who maintained consistently high levels of PA may have a lower risk of depression. This finding provides new empirical evidence for the development of comprehensive, personalized strategies to prevent depression in older adults.

4.1 Types of PA trajectories in older adults

Based on five waves of follow-up data from CHARLS (2011–2020), this study used the GBTM group trajectory model to construct four heterogeneous PA trajectories for 4,067 participants: the “Sustained low group (13.99%)”, the “Initial low followed by rise group (52.99%)”, the Initial high followed by decline group (7.01%),” and “Sustained high group (26.01%).” The “Initial low followed by rise group” accounted for the largest proportion, followed by the “Sustained high group” and the “Sustained low group,” with the “Initial low followed by rise group” having the smallest proportion. The “Initial low followed by rise group” and the “Sustained high group” accounted for the largest proportions of PA, which may reflect the overall improvement in PA attainment rates among older adults in China in recent years.

As the health benefits of PA for older adults receive increasing attention, research on related PA trajectories has been growing. Consistent with this study, Zhao et al. [14], using data from the China Longitudinal Health and Longevity Study (CLHLS) and the Generalized Bayesian Time-Series Model (GBTM), identified four PA trajectories. Nemoto et al. [15], using data from the Australian Women’s Health Longitudinal Study, identified four PA trajectories that were largely consistent with the four trajectories identified in this study. Hu [16] et al., based on follow-up data from the Chinese Longitudinal aging Study (CHARLS), constructed four PA trajectories: persistently low, initially low then increasing, initially moderate then decreasing, and initially high then decreasing. However, the trajectory trends and

proportions differed slightly from those in this study, which may be related to the trajectory fitting method. that study used a Growth Mixture Model (GMM) for PA trajectory fitting, whereas the GBTM method adopted in this study is a simplified version of GMM, offering higher classification accuracy and more interpretable results [17]. In addition to the aforementioned studies, Wang et al. [18] analyzed data from 8,227 adults aged ≥ 50 years participating in the UK Longitudinal Study of aging and used the GBTM method to construct five PA trajectories. Chen et al. [19] also constructed five PA trajectories in their study. Meanwhile, Wang et al. [20] utilized the extended model of GBTM, the Group-Based Dual-Trajectory Model (GBDTM), based on five-wave follow-up data from CHARLS, to classify the PA of 5,765 participants aged ≥ 55 into three groups: Persistently low PA, Decreasing PA, and Rising PA. Buvarp et al. [21], using a 5-year randomized controlled trial conducted by the Swedish Stroke and Rehabilitation Center, classified participants' PA into two trajectory groups: "increasers" and "decreasers." Many studies on PA trajectories exhibit both homogeneity and heterogeneity: while they categorize PA for analysis, there are differences in the trajectory patterns and proportions across studies. This may be attributed to inconsistencies in trajectory fitting methods, baseline characteristics of the study populations, and the handling of various variables.

4.2 Relationship between PA trajectory types and depression in older adults

After adjusting for confounding factors such as age, the results of this study showed that, compared with the "Sustained low" group, older adults in the "Initial low followed by rise" and "Sustained high" groups had a significantly lower risk of developing depression, whereas the "Initial high followed by decline" group did not exhibit the same effect. Consistent with the findings of this study, a cross-sectional study by de Oliveira et al. examining the association between PA and depression among 200 community-dwelling older adults found that, compared to the sedentary group, older adults who regularly engaged in PA had a 71% lower risk of developing depression [22]. Similarly, in a large-scale study of 18453 adults, Guo et al. found that, compared to the physically inactive group, the risk of depression was reduced by 18% in the physically active group and by 29% in the highly active group [23], further underscoring the importance of maintaining high levels of PA over time. Consistent with the above findings, Kim et al. [24] used the International Physical Activity Questionnaire to divide participants into four groups: persistent sedentary, maintenance, relapse, and adoption groups. They found that, compared to the persistent sedentary group, the maintenance group was associated with a lower incidence of depression. However, this study differs slightly from the present study. It demonstrated an inverted U-shaped relationship between PA and depression incidence, and the adoption group was associated with lower depression incidence only among women. In contrast, the present study showed that consistently maintaining a high level of PA was associated with a lower risk of depression, and the "initial high followed by decline" group exhibited a significant association with lower depression incidence in both male and female participants. This may be due to differences in the participants' nationalities and the methods used to assess variables. Kim et al.'s participants were from South Korea, and they used MET values to assess PA, whereas the participants in this study were from China, and PA was categorized into low, moderate, and high levels, which may have influenced the similarities and differences in the results. These differences do not affect the conclusion that maintaining regular, active

PA is associated with a lower incidence of depression, a finding that has been confirmed by most studies [25–26]. Furthermore, this study further confirms that the PA trajectories of the “Sustained high” group and the “Initial low followed by rise” group offer the greatest benefits for depression intervention in the elderly population. A possible reason is that PA can produce a series of physiological effects, such as altering levels of endorphins and monoamine neurotransmitters and reducing concentrations of the stress hormone cortisol, thereby effectively improving mood [27]. Some studies indicate that exercise can stimulate the growth of new neurons and promote the release of proteins such as brain-derived neurotrophic factor (BDNF), thereby enhancing neuronal survival. PA can, to a certain extent, reverse the aging process of physiological functions and maintain the physiological reserve capacity of older adults. It also serves as a protective factor and intervention strategy for issues such as anxiety, depression, and insomnia. Additionally, social interactions that may occur during PA can further help dispel and alleviate negative emotions [28].

4.3 Population differences in the association between PA trajectories and depression in older adults

To explore differences in the association between various PA trajectories and depression among older adults, this study conducted further subgroup analyses by age and gender. The results revealed that, compared to the Sustained low group, the Initial low followed by rise group and the Sustained high group exhibited protective effects against depression only in individuals aged 65 years or older, whereas no such benefits were observed in those under 65 years of age. This finding may be attributed to the fact that older adults aged ≥ 65 years constitute a high-risk group for depression, with the rate of decline in various physical functions accelerating with age. A certain level of PA can slow this physical decline by enhancing skeletal muscle strength and regulating metabolism [37], thereby helping to prevent depression and prevent its onset [29]. Compared to the Sustained Low group, the Sustained High group offers greater benefits in preventing depression among older women. Research has shown that women may experience more significant improvements than men in areas such as enhanced cardiopulmonary function and reduced cardiovascular disease risk through regular PA [30–32], leading to more favorable neurobiological and hormonal responses and greater improvements in self-efficacy [33]. This may explain why the incidence of depression decreases significantly among women who engage in high-intensity PA. Thus, it is evident that differences in the quality of PA may result in varying benefits for depression prevention and treatment.

In summary, based on the CHARLS data and using the GBTM method, this study identified four distinct PA trajectories. The results indicate that older adults in the “Initial low followed by rise” and “Sustained high” groups exhibited a significantly reduced risk of developing depression. While the benefits of PA for depression prevention and treatment vary across different populations, the underlying mechanisms remain unclear. Overall, the preventive and interventionary role of PA in addressing depression among older adults should be emphasized. Efforts should be made to raise awareness among older adults about the importance of actively participating in PA, encourage them to maintain higher levels of PA, and advocate for older adults with currently low levels of PA to engage in exercise. Older adults should fully recognize the health benefits of regular PA, proactively adjust their lifestyles, select appropriate exercise

methods based on their health status and personal interests, and actively participate in physical activities while maintaining them over the long term. Researchers should continue to monitor the association between PA and depression, actively conduct interdisciplinary research, and integrate knowledge from multiple fields—including medicine, kinesiology, and psychology—to deeply explore the specific mechanisms by which different PA patterns affect older adults' health, thereby providing more robust scientific evidence for developing precise intervention strategies. The government should increase investment in fitness facilities for the elderly, particularly in rural areas, by constructing more senior-friendly fitness venues equipped with professional exercise equipment and instructors. It should also encourage social organizations to participate in senior fitness services, thereby providing older adults with a wider range of fitness options.

This study has certain limitations. On the one hand, the CHARLS data were collected via questionnaires, which may introduce recall bias, leading to imprecise assessments of PA levels and depressive states and thereby affecting the accuracy of the study results. Additionally, as this study employs an observational design, it cannot directly establish a causal relationship between PA trajectories and depression. Although the findings suggest that certain PA trajectories are associated with a reduced risk of depression, the underlying mechanisms linking the two remain unclear. Given these limitations, future research could be improved in the following ways: 1) Employ objective methods to measure PA, accurately assess participants' PA levels, and utilize more precise analytical methods to determine the dose-response relationship between PA levels and depression in older adults. 2) Conduct interventional studies, such as randomized controlled trials, to dissect the mechanisms underlying depression in older adults and thoroughly explore the underlying mechanisms linking different PA trajectories to depression, thereby providing robust scientific support for the development of more effective intervention strategies for depression in older adults.

5 Conclusion

Based on CHARLS 2011–2020 data, four PA trajectories were identified among Chinese older adults. Compared with the sustained low group, the initial low followed by rise group and the sustained high group were significantly associated with lower depression risk, especially among those aged ≥ 65 years and women. These findings indicate that maintaining adequate PA or increasing activity from low levels can effectively reduce the risk of depression in older adults, providing evidence for targeted mental health interventions.

Declarations

Ethics approval and consent to participate

The data for this study were drawn from CHARLS, a project that received ethical approval from the Ethics Review Committee of Peking University (IRB00001052-11015). During the survey period, each respondent who agreed to participate signed an informed consent form.

Consent for publication

All authors approve the manuscript and agree to its publication.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contribution

HXL: Conceptualization, data curation, formal analysis, methodology, visualization, Writing—original draft, Writing—review and editing. ZW: Conceptualization, supervision, validation, Writing—review and editing.

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Data Availability

The datasets supporting the conclusions of this study come from the China Health and Retirement Longitudinal Study (CHARLS). Access to CHARLS data is subject to restrictions. The data used in the current study are not publicly available because they were obtained under official authorization. However, these datasets can be accessed upon request with permission from the CHARLS research team of Peking University.

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Figures

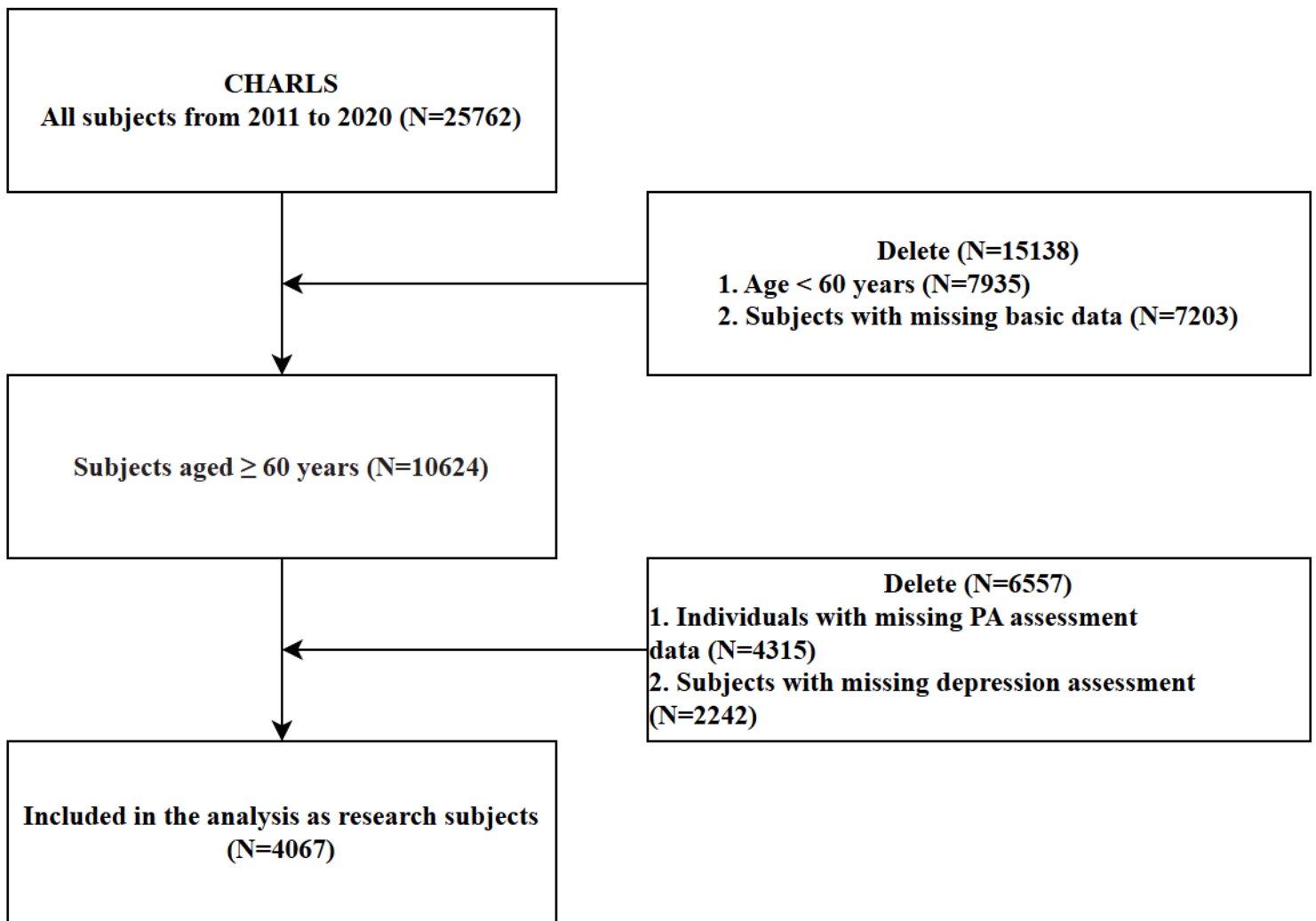


Figure 1

Screening process of the study participants.

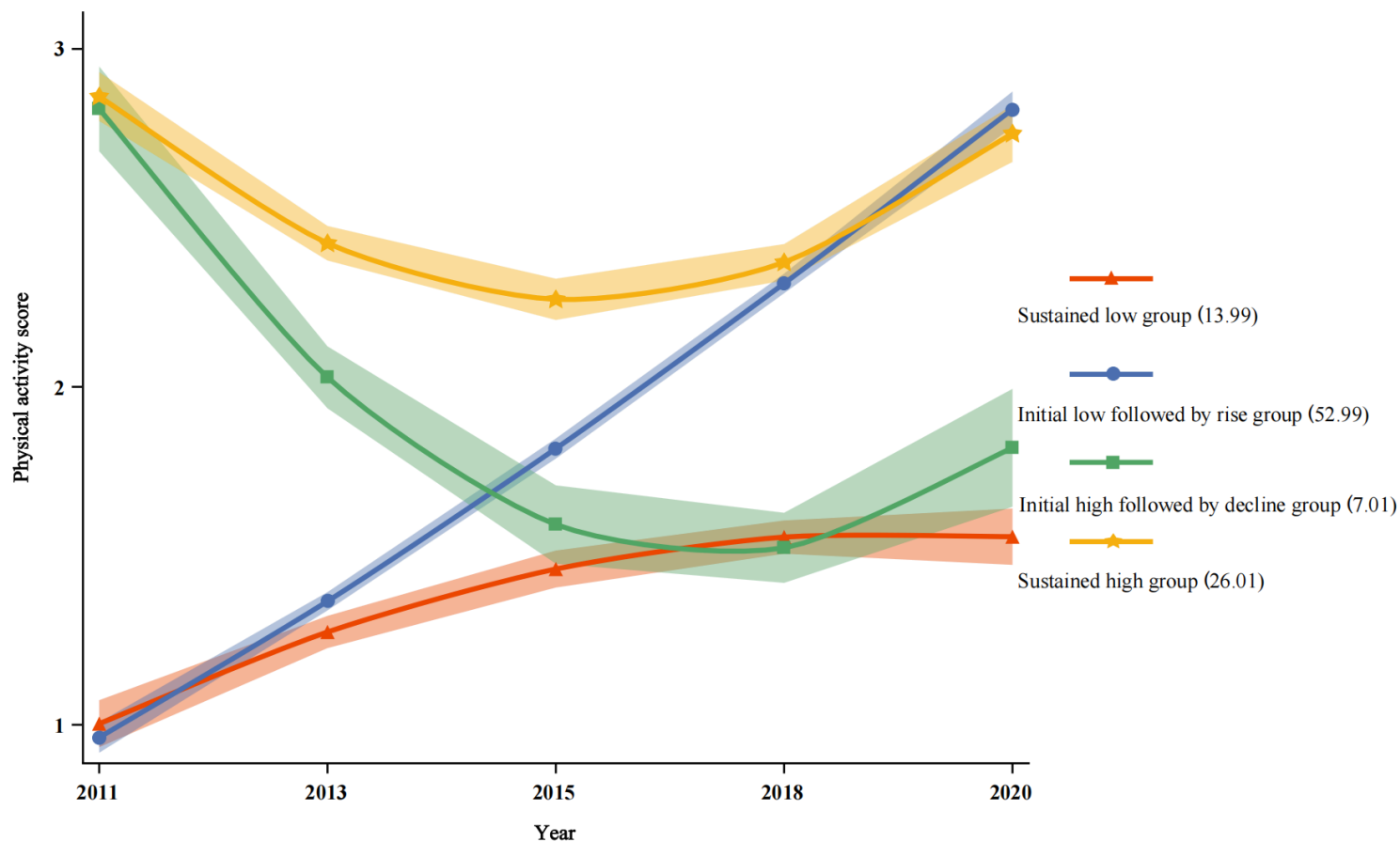


Figure 2

Physical activity trajectories of four groups.

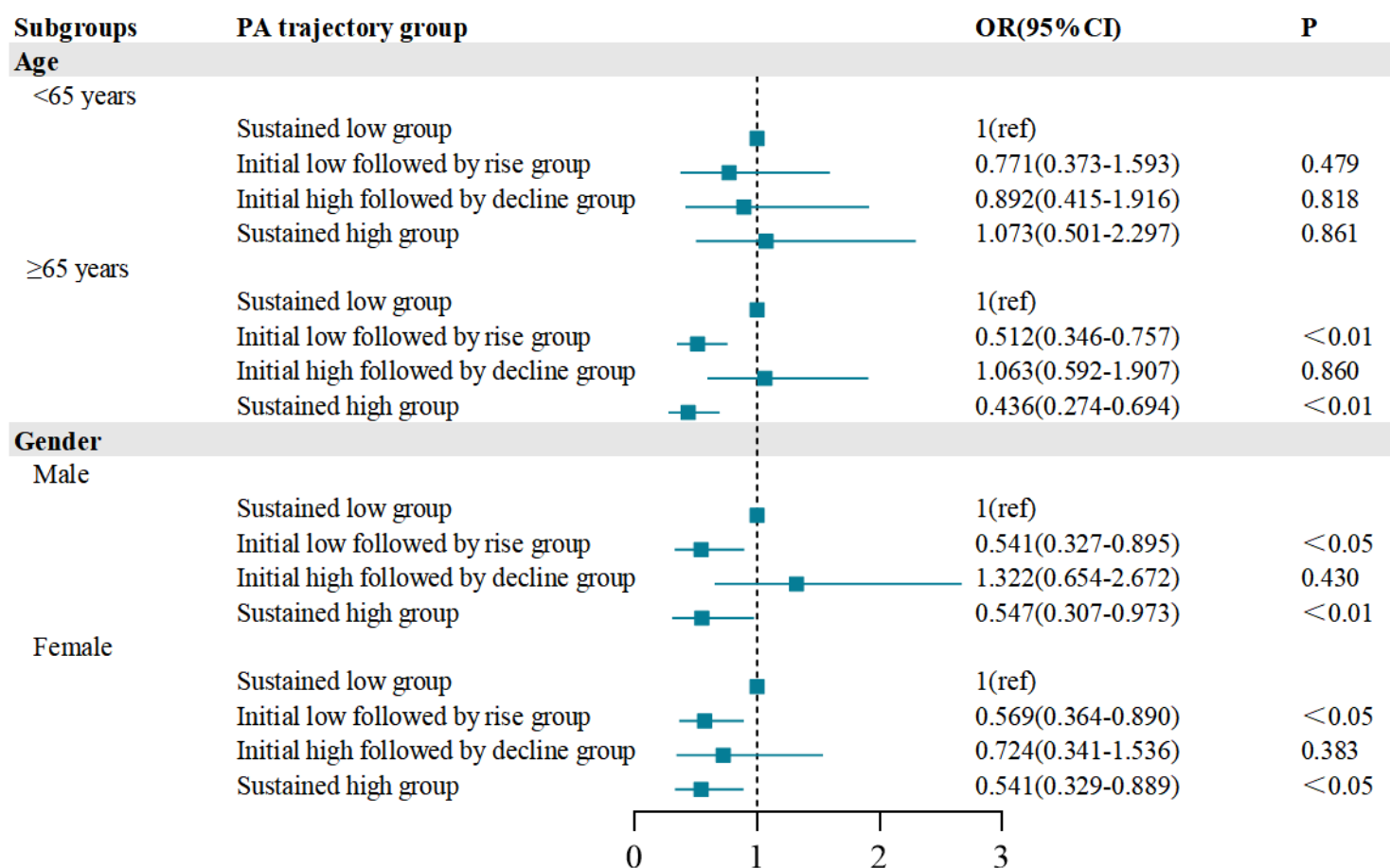


Figure 3

Stratified analyses of PA trajectories and depression across older adult subgroups.

^a Model 1 was unadjusted. Model 2 adjusted for age, gender, residence area, education level, and marital status. Model 3 adjusted for age, gender, residence area, education level, marital status, smoking and alcohol drinking.

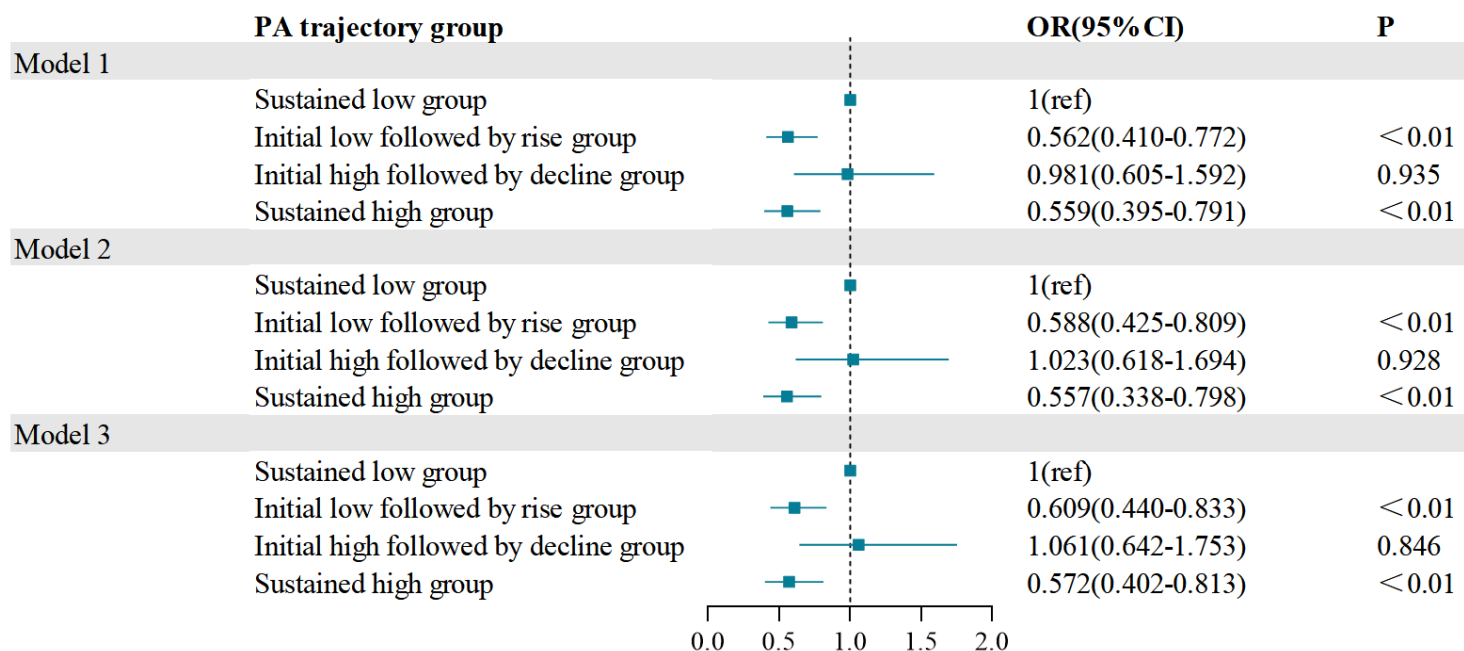


Figure 4

Sensitivity analysis of the association between PA trajectories and depression.

^a Model 1 was unadjusted. Model 2 adjusted for age, gender, residence area, education level, and marital status. Model 3 adjusted for age, gender, residence area, education level, marital status, smoking and alcohol drinking.