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Activity Limitation and Risk of Incident Depression Among Middle- Aged and Older Adults in China: Evidence From a Nationally Representative Longitudinal Study

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Research Article

Keywords: Activity Limitation, Incident depression, Middle-aged and older adults in China, Gender differences, Longitudinal cohort

Posted Date: May 14th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9404223/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

With global population aging, depression has become a major public health issue. Although physical inactivity often coexists with depressive symptoms, longitudinal evidence on its impact on depression incidence in low- and middle-income countries remains limited.

Objective

This study aimed to examine the association between baseline activity limitation and incident depression among middle-aged and older adults in China, and to explore moderating effects of demographic and socioeconomic factors.

Methods

Data were from the China Health and Retirement Longitudinal Study (CHARLS). A total of 8,406 participants aged ≥ 45 years without depressive symptoms at baseline were followed from 2018 to 2020. Activity limitation was defined as difficulty in at least one Activities of Daily Living (ADL) or Instrumental Activities of Daily Living (IADL). New-onset depression was identified using CESD-10 cutoff scores. Multivariate logistic regression with sequential adjustments and subgroup analyses were performed.

Results

Over two years, participants with baseline activity limitation had a significantly higher cumulative incidence of depression (22.3%) compared with those without (11.7%, $p < 0.001$). After adjusting for confounders, activity limitation remained an independent risk factor (OR = 1.35, 95% CI: 1.12–1.62). The association was stronger among men (OR = 1.65, 95% CI: 1.17–2.34), older adults (aged ≥ 60), and those with lower education. A significant interaction was found between activity limitation and gender (P = 0.005).

Conclusions

Activity limitation is an independent risk factor for incident depression in Chinese middle-aged and older adults. Men and individuals with lower socioeconomic status warrant particular attention. These findings support integrating functional assessments into geriatric mental health screening.

1 Introduction

The accelerating pace of global population aging is posing increasingly significant challenges to public health systems (1). Among the elderly population, depression has become one of the most prevalent mental health issues. It is estimated that approximately 7% of older adults worldwide suffer from depression, which not only leads to increased disability rates and places a greater burden on healthcare resources but also severely erodes the quality of life for older adults (2). China's demographic transition is particularly rapid: it is projected that by 2050, the population aged 60 and older will exceed 35% of the total population (3). Faced with an increasingly large elderly population, identifying modifiable risk factors for late-life depression holds significant public health implications for the development of precise and effective prevention strategies (4).

Maintaining good functional status is a core element of healthy aging (5), specifically manifested in the ability to perform basic and instrumental activities of daily living(5). However, chronic diseases, cognitive decline, and musculoskeletal disorders associated with aging often lead to a gradual limitation in older adults' ability to perform daily activities(6) Such activity limitations are not only a direct manifestation of physical functional decline but may also trigger far-reaching psychological effects. The loss of self-care abilities resulting from functional impairment may lead to social isolation, damage to self-worth, and increased dependence on caregivers, thereby exacerbating psychological distress (7). It is worth noting that the relationship between physical functional decline and depression may be bidirectional: existing research suggests that a depressive state itself may also accelerate the deterioration of physical function(8).

Although cross-sectional studies have confirmed the association between functional limitations and depressive symptoms across different cultural contexts(9), longitudinal evidence regarding how activity limitations predict the onset of depression—particularly in low- and middle-income countries—remains relatively scarce(10). Existing studies often suffer from methodological limitations, such as a focus on pre-existing depression rather than new cases, inadequate control for confounding factors, or insufficient examination of the potential moderating effects of demographic and socioeconomic factors. Recently, frailty—a geriatric syndrome closely associated with functional decline—has provided a new theoretical perspective for understanding differences in psychological vulnerability among individuals(11).

China's unique sociocultural context provides an ideal setting for exploring this issue. The uneven distribution of medical resources between urban and rural areas(12), changes in social support networks, and traditional gender norms that emphasize male self-reliance and self-sufficiency(13) may all profoundly influence the pathways through which physical limitations lead to psychological distress. At the same time, the unequal distribution of educational attainment and economic resources within the population may, on the one hand, serve as protective resources that cushion the impact of functional decline on mental health; on the other hand, it may also leave vulnerable groups in a more severe predicament when facing functional decline(14) .

To address the aforementioned research gaps, this study utilizes data from the nationally representative China Health and Retirement Longitudinal Study (CHARLS)(15), focusing on middle-aged and older

adults, with the aim of systematically examining the longitudinal association between activity limitations and new-onset depression. Specific research objectives include: (1) evaluating the predictive role of baseline activity limitations on the onset of depression during a two-year follow-up period; (2) examining differences in this association across different genders, age groups, educational levels, and urban and rural populations; and (3) exploring potential mediating mechanisms. These findings offer valuable insights for mental health interventions targeting middle-aged and older adults in China.

2 Methods

2.1. Study Design and Data Source

The data for this study were drawn from the China Health and Retirement Longitudinal Study (CHARLS) (15), a nationally representative longitudinal survey of persons in China 45 years of age or older and their spouses. CHARLS collects comprehensive information on the social, economic, and health circumstances of community-residents(16). The survey employed a multistage stratified probability sampling method, covering 450 villages/communities across 28 provinces (autonomous regions and municipalities) nationwide, with data collected through face-to-face computer-assisted personal interviews(16). This study used the 2018 survey data as the baseline and the 2020 follow-up data as the follow-up outcomes. The original study protocol was approved by the Biomedical Ethics Committee of Peking University, and all participants signed written informed consent forms prior to the survey.

2.2. Study Population

The 2018 CHARLS survey included a total of 19,816 respondents. To identify new cases of depression, this study established the following inclusion criteria: (1) age ≥ 45 years at the time of the baseline survey; (2) Completed both the 2018 and 2020 surveys; (3) Provided complete information on activity limitations and depression symptoms in both surveys; (4) Key exclusion criterion: depression symptom scores below the clinical cutoff at baseline, i.e., no depressive symptoms. After the above screening, a total of 8,406 participants were ultimately included in the statistical analysis (Fig. 1).

2.3. Exposure Assessment: Activity Limitation

This study used a standardized scale to assess functional impairment in participants, covering two dimensions: Activities of Daily Living (ADL)(17)and Instrumental Activities of Daily Living (IADL)(18). The ADL section comprises six core self-care tasks: eating, dressing, bathing, getting in and out of bed, toileting, and controlling bowel and bladder functions. The IADL section comprises five complex tasks necessary for maintaining independent living in the community: cooking, managing finances, shopping, taking medication, and using public transportation. If a participant reported difficulty with any single task in either the ADL or IADL sections, they were defined as having an activity limitation. Previous studies have confirmed that this assessment method possesses good reliability and validity in the CHARLS database(14, 19).

2.4. Outcome Assessment: Incident Depression

This study used the Center for Epidemiological Studies Depression Scale 10-item Short Form (CESD-10) to assess depressive symptoms (20).This scale has been validated and widely used in the CHARLS survey(21). In the survey, respondents were asked about the frequency of various depressive symptoms over the past week, using a four-point scale (0 = rarely or never, 1 = not very often, 2 = sometimes or half the time, 3 = most of the time or constantly), with a total score ranging from 0 to 30. Referring to previous validation studies in Chinese populations (14), this study defined a score of ≥ 10 as indicating clinically significant depressive symptoms. To focus on new cases, participants were classified as having new-onset depression only if their score was < 10 in 2018 (baseline) and ≥ 10 in 2020 (follow-up). By strictly excluding cases of baseline depression, this study minimized bias introduced by reverse causality (i.e., depression leading to a decline in functional status).

2.5. Covariate Assessment

To minimize confounding bias as much as possible, this study comprehensively measured and controlled for a range of potential confounding factors associated with functional decline and mental health outcomes, based on existing theoretical frameworks and empirical evidence(9). Specifically, these covariates encompassed multiple dimensions, including socio-demographics, educational attainment, health status, socioeconomic factors, lifestyle, and social support.

Specifically, sociodemographic factors included age, gender, marital status, place of residence, and retirement status. Among these, age was analyzed both as a continuous variable and, in accordance with the literature, divided into two age groups: 45–59 years and ≥ 60 years; marital status was categorized into married and unmarried/divorced/widowed; and place of residence was classified as urban or rural. To isolate the independent effect of activity limitation on incident depression, we adjusted for a comprehensive set of baseline covariates. These included sociodemographic and socioeconomic status (education [four categories from below elementary to high school or above], log-transformed annual household expenditure, family/social financial support, and health/pension insurance coverage); baseline health (self-rated health, number of physician-diagnosed chronic conditions, physical disability, pain severity [none to very severe], sleep duration, and a 0–21 point cognitive function score); and lifestyle/social factors (smoking [never, former, current], alcohol consumption, regular exercise, living arrangements [alone vs. with others], and frequency of social/family interactions).

2.6. Statistical Analysis

Baseline characteristics were summarized according to the presence or absence of activity limitations. We summed up continuous data by using average values together with standard deviations (SD), while categorical measurement indexes were described by original numbers and percentage values (n, %). Therefore, to examine base-level differences among various groups, we adopted independent t-tests for continuous measurement indexes and Pearson's chi-square tests for categorical measurement indexes.

To evaluate the connection between base-level physical inactivity and newly appeared depression, we employed multivariate logistic regression to compute odds ratios (OR) and their 95% confidence intervals (CI). Our analysis method was built on a step-by-step adjustment of a hierarchical model so that we can control confounding factors. Starting from a rough, non-adjusted analysis (Model 1), we adjusted step by step for different variable groups: Model 2 contained sociodemographic features, Model 3 contained socioeconomic background, then we added health indicators into Model 4, and Model 5 included lifestyle behaviors and social support networks, thus finishing the adjustment process.

To study whether demographic factors had an impact on these connections, we divided the research cohort into different layers according to sex, age group, educational background, and residential area. Moreover, we made formal assessment of these subgroup differences by putting multiplicative interaction terms into fully adjusted models and showing the results via forest plots.

In addition, we carried out a set of strict robustness tests on the main research findings. Instead of only using one modeling method, we did cross-validation of the results by using Cox proportional hazards models and at the same time guaranteed that the proportional hazards assumption was satisfied, and we applied Poisson regression models with robust variance estimators to deal with possible problems of too much data dispersion. To account for missing data, missing covariates were handled using chained equation multiple interpolation (22); Furthermore, we tested whether the core trends remained valid when a stricter depression threshold (≥ 12 points) (23) was applied. After confirming the absence of multicollinearity using the variance inflation factor (24), all statistical calculations were performed using Stata version 18.0 (Stata Corp, TX)

3 Results

3.1. Baseline Characteristics

Table 1 details the baseline characteristics of the 8,406 participants. Among them, 699 people bore mobility limitations, which takes up 8.3 percent of the entire study population. Therefore, when compared with people who have normal physical function, the mobility-limited group is generally more aged, has a higher female proportion, and mainly lives in rural areas, with all $P < 0.001$. Hence, obvious differences are also found in educational attainment. Nearly half of people with activity limitations, which is 47.6 percent, have not finished primary school, while the corresponding proportion in the no-activity-limitation group is 26.6 percent, with $P < 0.001$.

Table 1
Baseline Characteristics of Participants by Activity Limitation Status (N = 8,406)

Variables	Total (N = 8,406)	No Limitation (n = 7,707)	Limitation (n = 699)	P
Socio-demographics				
Age	59.87 ± 9.19	59.45 ± 9.04	64.48 ± 9.51	< 0.001
Gender (Male)	4,527 (53.85%)	4,212 (54.65%)	315 (45.06%)	< 0.001
Residence (Rural)	4,686 (55.75%)	4,233 (54.92%)	453 (64.81%)	< 0.001
Marital status (Married)	7,634 (90.82%)	7,038 (91.32%)	596 (85.26%)	< 0.001
Retired status (Yes)	1,488 (17.81%)	1,382 (18.05%)	106 (15.23%)	0.063
Education				< 0.001
Below primary	2,382 (28.34%)	2,049 (26.59%)	333 (47.64%)	
Primary school	2,804 (33.36%)	2,602 (33.76%)	202 (28.90%)	
Middle school	1,981 (23.57%)	1,881 (24.41%)	100 (14.31%)	
High school and above	1,239 (14.74%)	1,175 (15.25%)	64 (9.16%)	
Health Status				
Chronic disease counts	0.58 ± 0.90	0.55 ± 0.87	0.90 ± 1.13	< 0.001
Physical disability (Yes)	644 (7.66%)	537 (6.97%)	107 (15.31%)	< 0.001
Body Pain (None)	4,118 (48.99%)	3,910 (50.73%)	208 (29.76%)	< 0.001
Cognitive score	13.42 ± 3.27	13.50 ± 3.25	12.24 ± 3.36	< 0.001
Sleep duration (hours)	6.55 ± 1.67	6.57 ± 1.63	6.26 ± 2.00	< 0.001
Self-rated Health				< 0.001
Very Poor / Poor	1,156 (13.75%)	888 (11.52%)	268 (38.40%)	
Fair	4,400 (52.35%)	4,074 (52.86%)	326 (46.70%)	
Good / Excellent	2,849 (33.90%)	2,745 (35.61%)	104 (14.90%)	

Variables	Total (N = 8,406)	No Limitation (n = 7,707)	Limitation (n = 699)	P
Socio-economics				
Consumption (CNY, median [IQR])	12,433 [6,981, 22,210]	12,550 [7,045, 22,517]	10,282 [5,884, 18,587]	< 0.001
Financial support (CNY, median [IQR])	1,500 [0, 5,500]	1,500 [0, 5,500]	1,950 [280, 5,000]	0.118
Medical Insurance (Yes)	8,215 (97.73%)	7,543 (97.87%)	672 (96.14%)	0.003
Pension Insurance (Yes)	4,456 (57.71%)	4,022 (56.56%)	434 (71.03%)	< 0.001
Lifestyle & Social Support				
Regular exercise (Yes)	7,900 (93.98%)	7,302 (94.75%)	598 (85.55%)	< 0.001
Living alone (Yes)	643 (7.83%)	584 (7.76%)	59 (8.54%)	0.469
Social frequency (Weekly+)	3,624 (72.35%)	3,375 (72.42%)	249 (71.35%)	0.420
Child contact (Weekly+)	1,098 (25.79%)	979 (25.20%)	119 (31.82%)	0.036

Health and economic indicators were generally poorer among those with activity limitations. They reported higher prevalence of chronic diseases and physical disabilities, more severe physical pain, lower cognitive scores, and shorter sleep duration (all $P < 0.001$). The median household expenditure in this group was also significantly lower ($P < 0.001$). Nearly all participants (> 96%) held health insurance. Pension coverage was higher in the mobility-impaired group (71.0% vs. 56.6%, $P < 0.001$), consistent with their older average age. Finally, although the proportion of participants engaging in physical exercise was lower in the mobility-impaired group (85.6% vs. 94.8%, $P < 0.001$), no significant differences were found between the two groups regarding living arrangements or frequency of social interaction.

3.2. Incidence of Depression

During the two-year follow-up period, a total of 1,074 participants (12.8%) developed depression. Compared with participants who had no physical activity limitations (11.7%, $P < 0.001$), those with initial activity limitations had a significantly higher prevalence (22.3%), with an absolute difference of 10.6 percentage points between the two groups.

3.3. Association Between Activity Limitation and Incident Depression

The outcomes of our step-by-step logistic regression analysis are summarized by Table 2. In the crude analysis Model 1, insufficient baseline physical activity had connection with more than double the elevated depression risk (OR = 2.26, 95% CI: 1.92–2.66). After we carry out adjustment of sociodemographic and socioeconomic factors in Models 2 and 3, the odds ratio reduces to around 1.75.

Hence, the most obvious decline appears in Model 4; after health status is included, the odds ratio further drops to 1.30 (95% CI: 1.09–1.56), therefore suggesting that physical health condition itself can largely explain this association. However, the final fully adjusted analysis (Model 5) still confirmed that the core association remained statistically significant (OR = 1.35, 95% CI: 1.12–1.62).

Table 2
Association between activity limitation and incident depression (fully adjusted model, Model 5)

Variable	Adjusted OR	95% CI	P
Activity limitation (Yes)	1.35	(1.12–1.62)	0.002
Age	1.02	(1.01–1.03)	< 0.001
Gender (Male)	0.63	(0.54–0.74)	< 0.001
Residence (Rural)	1.45	(1.28–1.65)	< 0.001
Education (High school+)	0.73	(0.59–0.92)	0.007
Chronic disease count (per disease)	1.06	(1.00–1.13)	0.038
Cognitive function score (per point)	0.93	(0.91–0.95)	< 0.001
Sleep duration (per hour)	0.91	(0.88–0.94)	< 0.001
Body pain (Very much)	2.06	(1.57–2.70)	< 0.001
Self-rated health (Good/Excellent)	0.44	(0.31–0.63)	< 0.001

Note: Model 5 was adjusted for sociodemographic factors, socioeconomic status, baseline health, lifestyle, and social support. Full results of Models 1–5 are presented in Supplementary Table S1.

In addition, advancing age (OR = 1.02 per year), living in a rural area (OR = 1.45), the burden of chronic diseases (OR = 1.06 per disease), severe physical pain, poorer self-rated health, and lack of physical activity (OR = 1.26) were all independent risk factors. Female gender (OR = 0.63), retirement (OR = 0.80), higher educational attainment (secondary school and above; OR = 0.73), better cognitive function (OR = 0.93 per point) and longer sleep duration (OR = 0.91 per hour) were protective factors.

3.4. Visualization of Key Predictors: Forest Plot of the Fully Adjusted Model

Figure 2 illustrates the strength of the association between various variables and the risk of depression in the full model. Forest plot analysis revealed a significant positive association between physical inactivity and the risk of depression (OR = 1.35, 95% CI: 1.12–1.62). Furthermore, the impacts brought by health-associated variables were especially notable: in comparison with persons without body ache, “severe physical pain” could raise the depression risk in a significant way (OR = 2.06, 95% CI: 1.57–2.70; conversely, “self-rated good health” played the role of a protective element, OR = 0.44, 95% CI: 0.31–0.63). These research results, hence, disclose that depression among middle-aged and elderly

population has a multi-factor characteristic, and activity restrictions are an independent predictive indicator thus.

Figure 2. Factors Associated with Depression: Multivariable Logistic Regression

Analysis (Model 5)

3.5. Subgroup and Interaction Analyses

Figure 3 demonstrates the disparities existing in the relational link between physical inactivity state and depressive disorder among various subgroup categories. The results indicate that this association was stronger among men (OR = 1.65, 95% CI: 1.17–2.34) than among women (OR = 1.21, 95% CI: 0.96–1.52), and the interaction between physical inactivity and gender was statistically significant (interaction P = 0.005). Among adults aged 60 and older (OR = 1.42, 95% CI: 1.14–1.77), the strength of this association was higher than among middle-aged adults aged 45–59 (OR = 1.23, 95% CI: 0.92–1.64), but this interaction was not statistically significant (P = 0.18). The strength of the association gradually decreased with increasing educational attainment, being highest among those with a primary school education or lower (OR = 1.48). Urban-rural differences were also significant, with the association being stronger among rural residents (OR = 1.40) than among urban residents (OR = 1.23).

Table 3 presents a multivariate logistic regression model that further includes the interaction term between physical inactivity and gender. In this model, the main effect of functional limitation was no longer significant (OR = 1.09, 95% CI: 0.86–1.38), whereas the interaction term between functional limitation and male gender showed a significant positive association (OR = 1.65, 95% CI: 1.17–2.34, P = 0.005), indicating that functional limitation has a more significant impact on the mental health of men.

Table 3
Multivariable Logistic Regression of Depression on Activity Limitation and Gender (N = 8,406)

Variable	OR	95% CI	P
Activity Limitation			
Yes	1.087	[0.855, 1.381]	0.497
Gender			
Male	0.599	[0.510, 0.705]	< 0.001
Interaction Item			
Activity Limitation × Male	1.65	[1.166, 2.336]	0.005
Age	1.017	[1.007, 1.027]	0.001
Residence			
Rural	1.458	[1.287, 1.651]	< 0.001
Education			
Primary School	0.926	[0.798, 1.074]	0.307
Middle School	0.909	[0.766, 1.078]	0.272
High School and Above	0.733	[0.586, 0.918]	0.007
Marital Status			
Married	0.97	[0.770, 1.224]	0.799
Retired			
Yes	0.792	[0.656, 0.956]	0.015
Physical Disability			
Yes	1.037	[0.854, 1.260]	0.714
Chronic Disease Count	1.066	[1.004, 1.132]	0.038
Cognitive Function Score	0.933	[0.913, 0.954]	< 0.001
Self-Rated Health			
Fair	0.66	[0.475, 0.916]	0.013
Good/Very Good	0.427	[0.298, 0.612]	< 0.001
Sleep Duration	0.913	[0.884, 0.942]	< 0.001
Live Alone			

Variable	OR	95% CI	P
Yes	1.037	[0.811, 1.327]	0.771
Constant	0.561	[0.213, 1.473]	0.239

3.6. Visualization of Interaction Effects: Activity Limitation and Gender

As shown in Fig. 4, the impact of activity limitations upon the risk of depression displays obvious differences between different genders. For male individuals, the experience of such limitations almost makes their depression likelihood double, rising it from approximately 8 percent to 15 percent. Among women, the prevalence increases from 12% to 14%. This suggests that functional limitations have a more severe negative impact on men's mental health.

3.7. Relationships Between Continuous Covariates and Predicted Probability of Depression

Figure 5 shows the connections among the non-discrete variables of age, cognitive test results, and sleep length, as well as depression risk. Overall, along with age increase, the possibility of having depression goes up; therefore, when cognitive ability and sleep length become better, this possibility goes down. Moreover, the trend lines of the two groups—people with activity restrictions and people without activity restrictions—are mostly parallel. Hence, this indicates that the influences of these non-discrete factors on depression risk keep the same among individuals who have different functional conditions.

3.8. Age and Activity Limitation: Joint Effects on Depression Probability

Figure 6 shows the mutual action between age and activity limitations upon the depression risk. In every age group, depression prevalence is higher among the physically restricted people than the non-restricted people. When age goes up, depression increases in both groups; therefore, compared with the non-restricted group, the increase speed becomes gradually steeper in the physically restricted group. Hence, these results indicate that advanced age and physical restriction may worsen the psychological load linked with physical limitations, which reflects a cumulative effect of both two factors on depression risk.

3.9. Sensitivity Analyses

The outcomes of the sensitivity analysis shown in Fig. 7 further carried out validation for the robustness of the main research findings. The Cox proportional hazards model demonstrated that the hazard ratio linking physical inactivity to new-onset depression risk was 1.38 95% CI: 1.15–1.66; thus, results gained

from the Poisson regression model which adopted robust standard errors were highly consistent with those of the main analysis. Hence, after we used multiple imputation methods to fill in missing data, the odds ratio for physical inactivity kept stable within the range of 1.32 to 1.37; even when we lifted the depression diagnostic threshold to a more conservative level of ≥ 12 points, this association still held statistical significance OR = 1.28, 95% CI: 1.05–1.56, with only a small decrease in effect size.

4 Discussion

Based on nation-wide representative long-term data coming from the China Health and Retirement Longitudinal Study (CHARLS), this research investigated the long-term connection between initial activity restrictions and new-occurrence depression among middle-aged and elderly people in China(15). Therefore, our discovered results show that activity restrictions are an independent danger factor for newly starting depression, and this connection is obviously adjusted by gender(25, 26). Hence, these results add to the increasing collection of proof on the disability-depression route in low- and middle-income nations and thus have important meaning for depression prevention tactics under the situation of fast population aging.

4.1. Interpretation of Main Findings

The main discovery of this research was that baseline physical activity absence notably predicted depression onset during the two-year follow-up period, with an adjusted odds ratio of 1.35 (95% CI: 1.12–1.62). Therefore, after we made comprehensive adjustments for socio-demographic traits, socio-economic elements, health condition, lifestyle actions and social support, this effect still existed, thus suggesting that the relation was not only confused by pre-existing health status or demographic factors. Compared with people without activity restrictions, those with activity restrictions had a clearly higher cumulative depression incidence (22.3% versus 11.7%), with an absolute risk difference of 10.6 percentage points. Hence, this finding is in accordance with the “disability process model” that Verbrugge and Jette originally put forward(27), suggesting that functional restrictions may start a series of negative psychological responses, such as decreased self-efficacy, increased reliance on other people, and break of fixed social roles, finally causing or worsening depressive symptoms(28). Our findings extend this theoretical system to China, indicating that this path from functional decrease to depression is also suitable in middle-income countries with unique cultural backgrounds and fast-growing ageing populations. The effect size we observed in this study (OR = 1.35) is comparable to or higher than calculation results from Western populations(29, 30). Therefore, given that the activity-restricted population in this study was mainly gathered among older adults with lower socioeconomic status, who live in rural areas and have functional restrictions.

4.2. Gender Differences in Vulnerability

A very noticeable discovery of this research is the important mutual action between activity limitation and gender, interaction P-value = 0.005. Therefore, thus, men who undergo activity limitation own a clearly higher depression risk, odds ratio = 1.65, when compared with women, odds ratio = 1.21.Though

epidemiological researches generally point out that the occurrence rate of depressive illness is higher in female groups(30). This seemingly conflicting outcome may hide deep-seated socio-cultural as well as psychological operation mechanisms(25).

Men display higher degree of psychological weakness when they confront activity restrictions; this situation may have connection with the tight link between masculine role requirements and functional ability inside traditional social-cultural environments(31). When functional ability gets damaged, men not only suffer from physical function loss but also face a self-identity crisis. By contrast, women's social role identities have more varieties, which may reduce the influence of activity limitations on their self-worth feeling to a certain degree(32). Role accumulation theory, which puts forward that multiple social roles can supply people with extra identity sources and psychological resources, is in agreement with this explanation(33).

4.3. Socioeconomic Gradients

Subgroup analysis discovered that a notable socioeconomic gradient exists in the link between physical inactivity and depression(34). Therefore, this effect showed the most obvious level among people with primary education or less (OR = 1.48), and thus this gradient gradually reduced when people's educational attainment goes up. Hence, this educational gradient probably reflects differences in people's capability to obtain psychosocial resources which can weaken the impacts of functional decline; these resources include health literacy, cognitive flexibility, social capital, and financial savings for buying assistive devices or care services(35). The town-country gap discovered in this research—with a more powerful connection among country residents (OR = 1.40) than town residents (OR = 1.23)—therefore may be ascribed to system-level unbalanced situations in medical treatment and social service construction between town and country regions in China(12). In China's rural regions, there exists a very serious lack of rehabilitation services, mental health working personnel and community support plans, therefore causing middle-aged and elderly people with functional restrictions to become more isolated, weak and without enough supporting resources(36).

4.4. Mechanisms and Pathways

Besides the factors we have already talked about, the route from activity restriction to depression runs via a complicated mechanism network(37). Firstly, the social route: functional restrictions directly limit an individual's capacity to take part in important social roles as well as community activities(38). Bringing about a progressive reduction of social networks and a strengthening of lonely feelings. The loss of individual's professional identity, lowered movement ability for visiting friends and family members, and retreat from community activities take away people's sense of purpose, life goals and emotional support—all are recognized depression risk factors(39). Therefore, this path is consistent with findings of Zhang et al. (regarding the mediating function of social support between chronic illness and depression). Second, the biological path: activity restrictions nearly never happen alone; thus, they are often accompanied by chronic pain, sleep troubles and inflammatory processes. Factors that exert direct influence on the neurobiological systems which carry out mood regulation tasks. Chronic stress that

comes from difficulties in dealing with daily life may cause dysregulation of the hypothalamic-pituitary-adrenal axis and break normal cortisol secretion, therefore raising the level of biological susceptibility of individuals.

4.5. Clinical and Public Health Implications

Our findings offer several actionable insights for the prevention of depression in middle-aged and older adults:

Incorporating functional assessment into mental health screening: Assessments of Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) should be routinely included in primary care and community health screenings for older adults(37). Furthermore, effective prevention requires interventions that address functional, psychological and social domains simultaneously. Compared with single-modality approaches, programmes combining physical rehabilitation, pain management, provision of assistive technology and psychosocial support are more likely to yield better outcomes(40). Furthermore, screening efforts should prioritize men, those with lower levels of education and rural populations. To address the psychological issues arising from functional decline, it is ultimately necessary to tackle the upstream social determinants. Such policies as narrowing education gap, building community care networks and giving subsidies to assistive devices provide structural type of protection for these vulnerable groups at the macro level(40).

4.6. Strengths and Limitations

From a method angle, this study obtained benefit from a large, nation-wide representative long-term data set and strict adjustment for a great number of confounding factors(15). Therefore, by concentrating only on newly appeared depression instead of already existing cases, we thus effectively lowered the reverse causality risk, hence strengthening our causal direction-related inference judgments.

Several limitations exist in this research. Hence, we made dependence on self-report measurement scales for both physical functional restriction conditions and depressive symptom situations; Such scales may have restricted ability in exactly evaluating the real scope of activity limitations and depression degrees among elderly people(41). Therefore, future research can construct on this foundation by combining objective measurement items of physical function with formal clinical interview activities. Moreover, our two-year follow-up duration is relatively short; hence, a longer observation time span will be more capable to capture the prolonged developing path of how physical functional decline transforms into depression state(42). Potential residual confounding factors, for instance genetic susceptibility, early-life hardship or personality characteristics, hence may also exert influence on the outcomes of the study. Finally, because of the huge differences in societal attitudes toward ageing, disability and mental health among different cultures—attitudes that produce deep influence on mental health—therefore, extending the dynamic situations that are observed inside Chinese cultural context to other global environments needs to carry out specific validation work(43) .

5 Conclusion

This longitudinal study confirms that activity limitation is an independent risk factor for the onset of depression among middle-aged and older adults in China. The influence of activity restriction upon depression danger shows obvious subgroup difference. Therefore, this connection is more strong among men, people with lower education level, and country residents; thus, the notable gender interaction emphasizes the heavy health gaps that are existing in the aging population. Therefore, it is suggested that ADL/IADL functional assessments should be merged into regular mental health check-ups for middle-aged and elderly people; that specific intervention plans should be constructed for key groups including men, persons with low education level, and rural inhabitants; that an integrated caring mode which combines rehabilitation training and psychological support should be advanced; and that endeavors should be made to reduce the difference of health resources between city and countryside. For future research, objective functional assessments should be combined with longer follow-up durations to carry out deep exploration on the integrated bio-psycho-social mechanisms. At the same time, nursing models must carry out a shift towards whole-person body-mind interfering measures, Therefore, the actual functional effect of all-round nursing methods must be assessed for preventing depressive conditions inside physically weak elderly persons .

Declarations

Ethics approval and consent to participate

The China Health and Retirement Longitudinal Study (CHARLS) was approved by the Biomedical Ethics Committee of Peking University (IRB00001052-11015) and conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent. This study used publicly available de-identified data and was exempt from additional ethical review.

Clinical trial number

Not applicable.

Competing interests

The authors declare no competing interests.

Funding

The Key Humanities and Social Sciences Fund of Anhui Provincial Department of Education (Grant No. 2025AHGXSK30240)

The Incubation Project of National Social Science Fund of Bengbu Medical University (Grant No. 2023byfy141sk)

Author Contribution

Z.Z. (Zhichen Zhu) conceived the study, designed the methodology, conducted the investigation and formal analysis, and wrote the original draft. X.F. (Xiaoyan Feng) curated the data, created visualizations, and reviewed and edited the manuscript. K.S. (Kexin Sha) validated the results and reviewed the manuscript. Q.H. (Qinglong He) supervised the work and reviewed the manuscript. J.Z. (Juye Zhai) curated the data, validated the results, and reviewed the manuscript. Y.L. (Yuwen Liu) conceived the study, supervised the project, administered the project, and reviewed and edited the manuscript. All authors reviewed the manuscript.

Data Availability

The CHARLS data are publicly available at http://charls.pku.edu.cn/. The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

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Figures

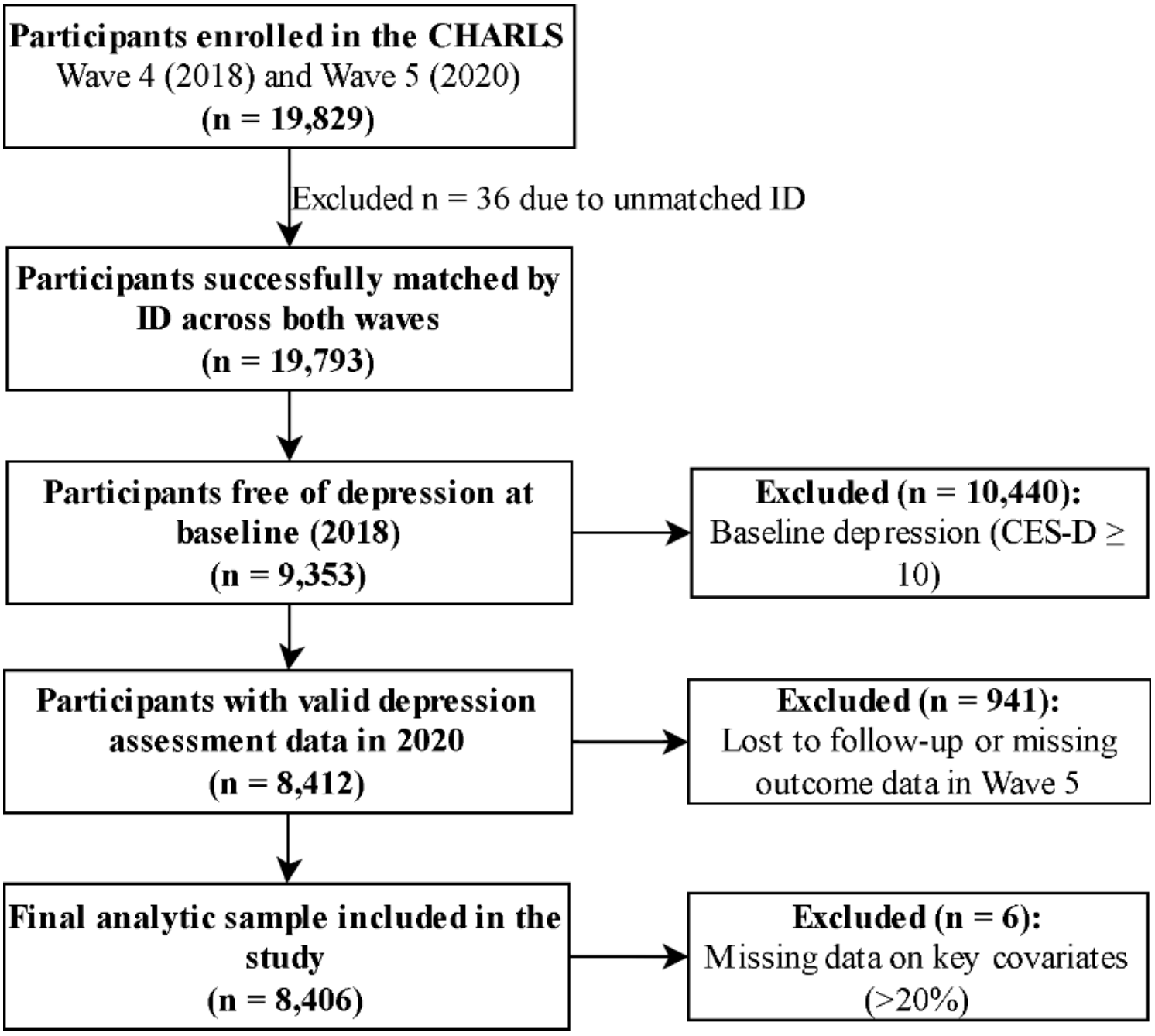


Figure 1

Flowchart of participant selection.

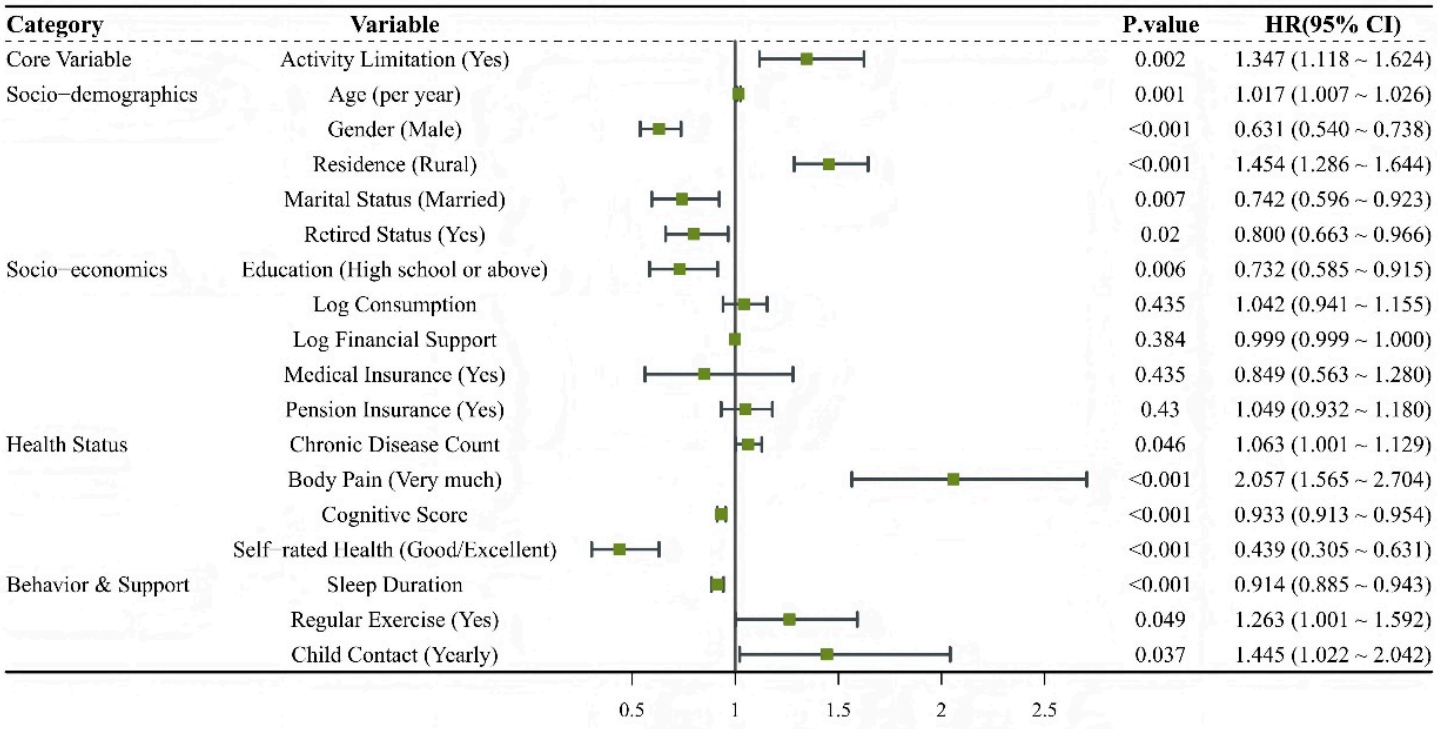


Figure 2

Flowchart of participant selection.

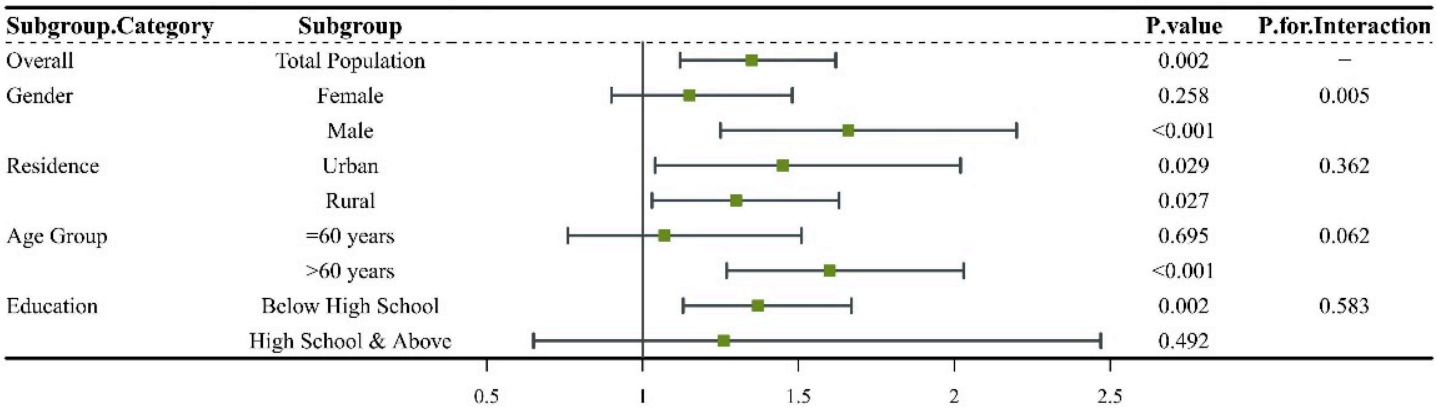


Figure 3

Subgroup Analysis of the Association Between Activity Limitation and Depression Risk.

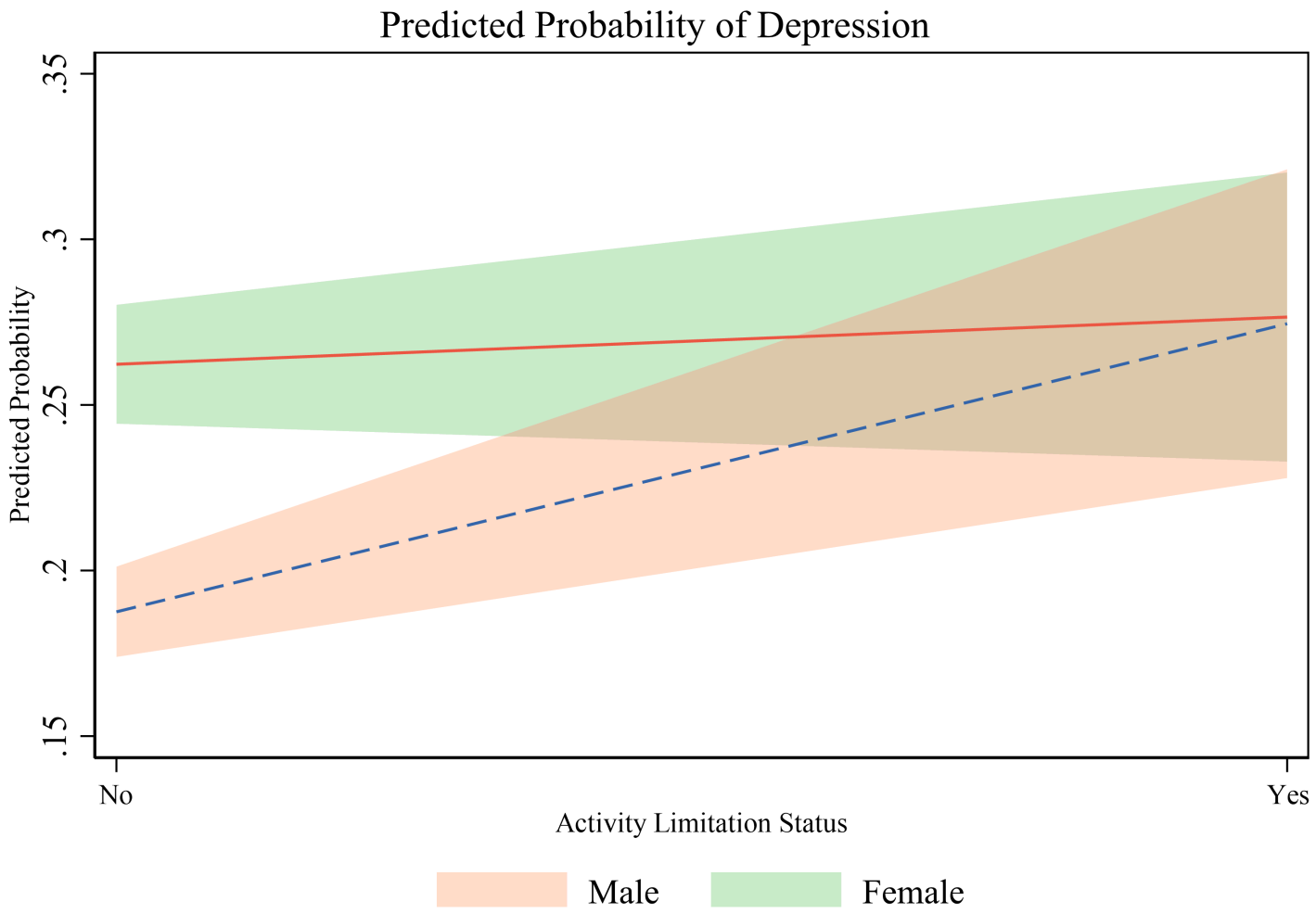


Figure 4

Interaction effect between activity limitation and gender on the predicted probability of depression.

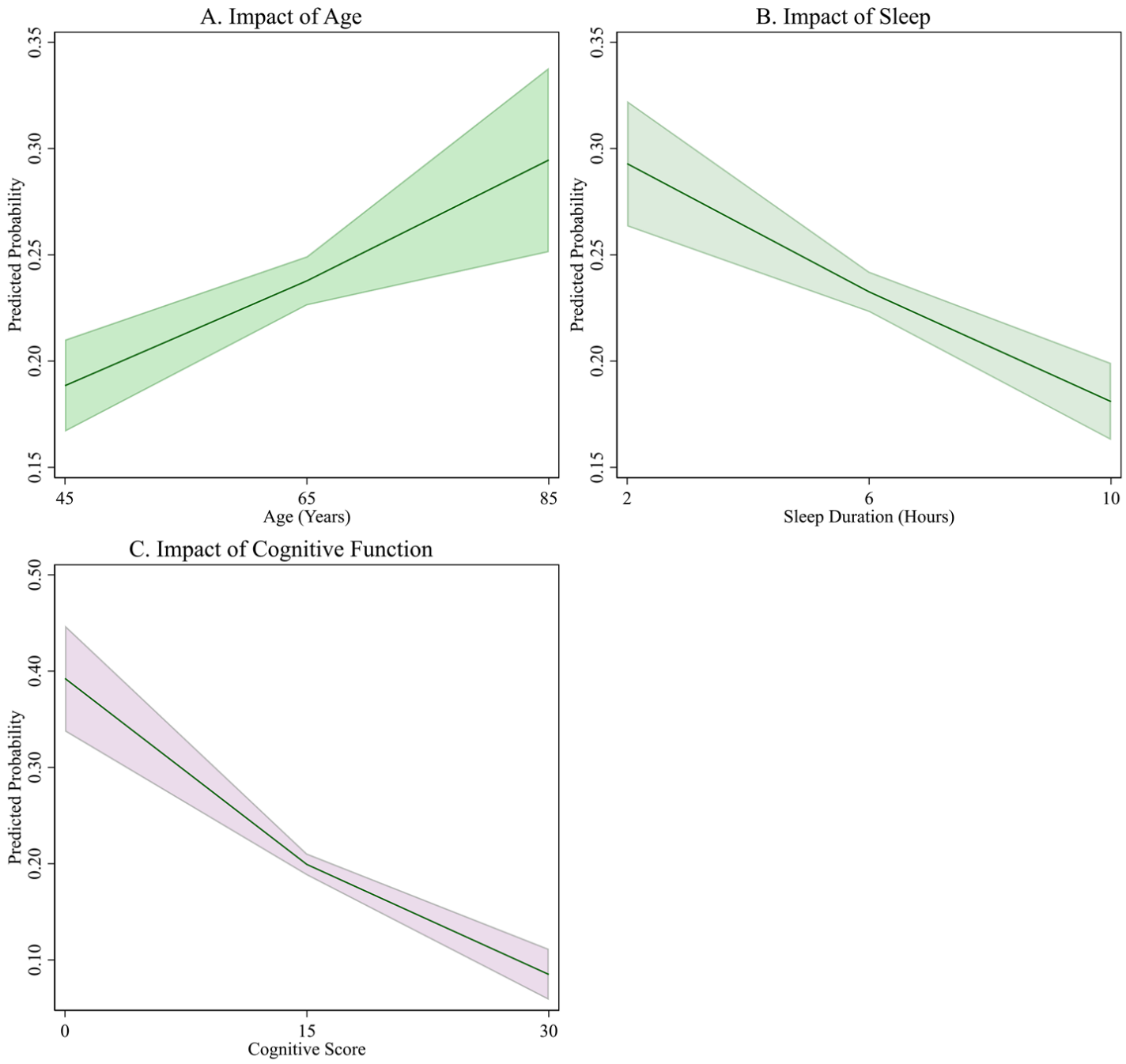


Figure 5

Predicted probabilities of depression across continuous covariates.

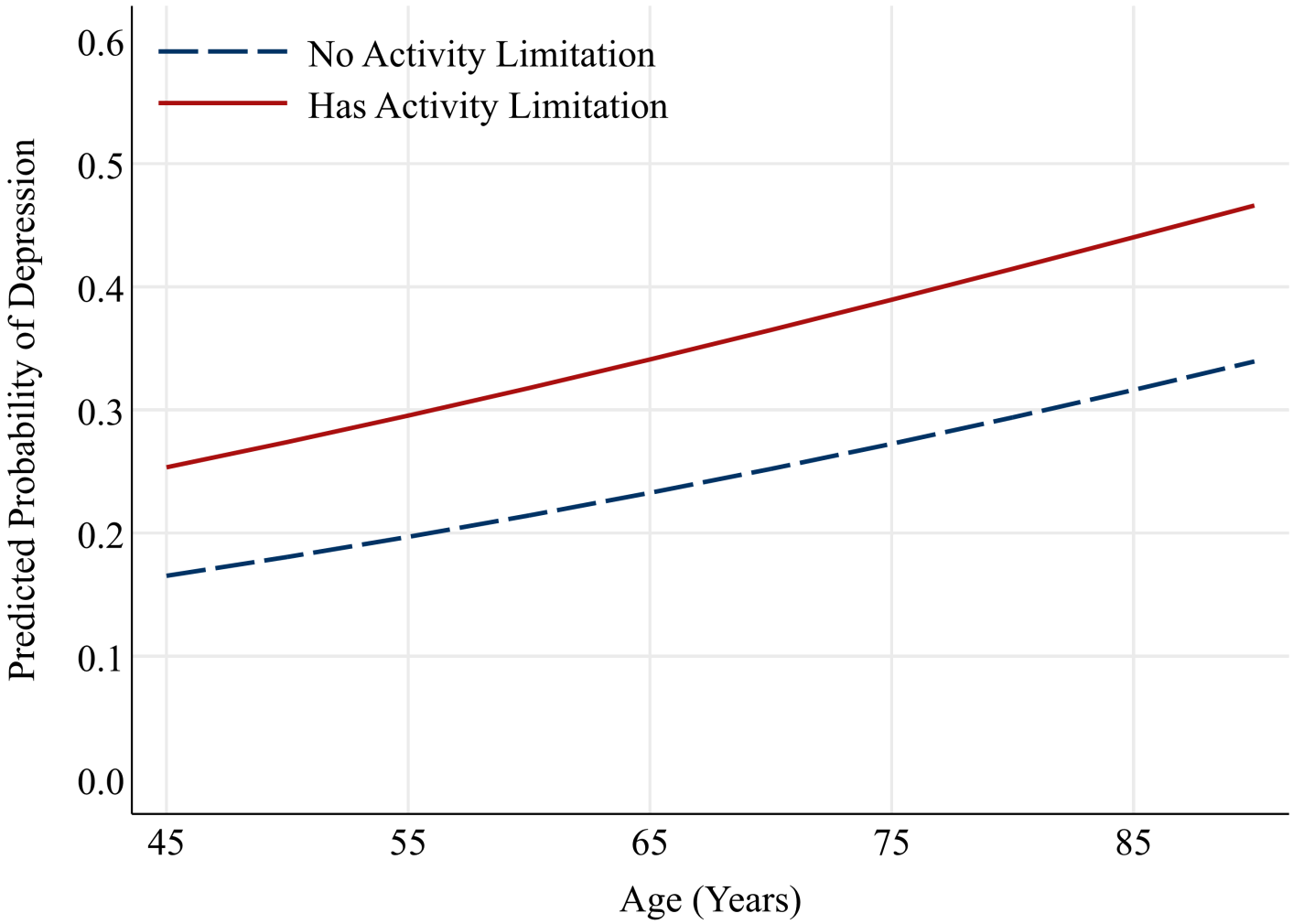
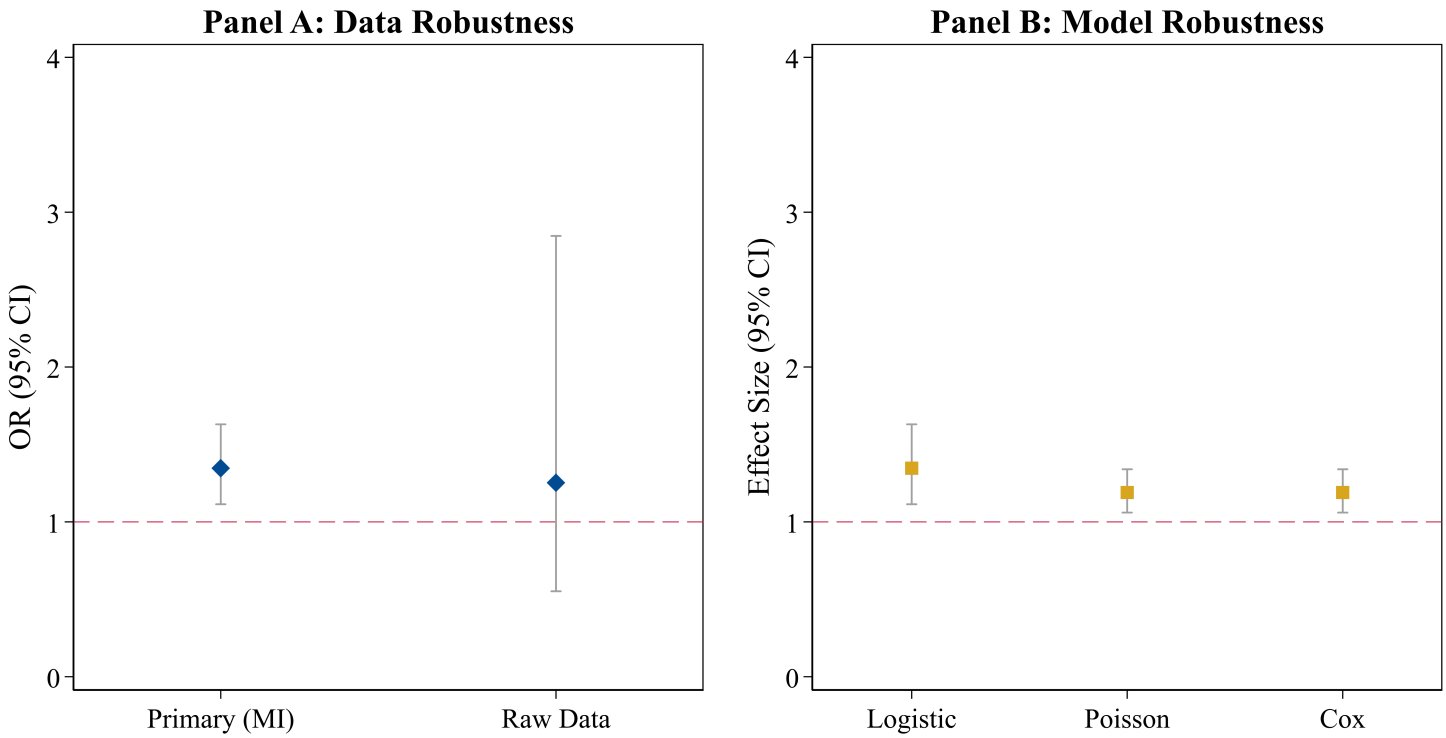


Figure 6

Predicted probability of depression by age and activity limitation status.



Note: Panel A: Comparison of MI vs. Raw data; Panel B: Comparison across algorithms.

Figure 7

Sensitivity Analysis: Robustness of Results Across Data Processing and Model Specifications

Supplementary Files

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- SupplementaryTableS1.docx