

RESEARCH ARTICLE

Socioeconomic status and mental health-related conditions among Chinese older adults: A national longitudinal cohort study and pathway analysis

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Abstract

Background: Clinically significant depressive symptoms and self-reported mental health-related conditions are increasing among older adults in China. Although socioeconomic status (SES) is an important upstream determinant, nationally representative evidence on its longitudinal association with mental health-related outcomes and related behavioral pathways remains limited.

Objective: To examine the longitudinal association between socioeconomic status and incident mental health-related outcomes among older Chinese adults, and to assess whether social participation and sleep duration partly explain this association.

Methods: Using data from the China Health and Retirement Longitudinal Study (CHARLS, 2011–2018), this study included 5,465 adults without baseline depressive symptoms or self-reported mental health-related conditions. SES was derived from latent class analysis of household income, educational attainment, and employment status, rather than from employment status alone. Incident mental health-related outcomes were identified during follow-up using Center for Epidemiologic Studies Depression Scale-10 screening results and self-reported physician diagnosis. Cox proportional hazards models, subgroup analyses, and pathway analyses were conducted.

Results: Compared with the high-SES class, low SES was associated with a higher risk of incident mental health-related outcomes in the fully adjusted model (hazard ratio: 1.40, 95% confidence interval: 1.15–1.69), with a stronger association among women, while residence- and body mass index-specific patterns were interpreted cautiously. Social activity accounted for 6.1% of the SES–outcome association, whereas sleep duration showed a small suppressor effect (–2.6%).

Conclusion: These findings suggest that socioeconomic disadvantage is associated with elevated mental health-related risk in later life, partly through reduced social participation. The role of sleep requires further investigation using more detailed sleep measures.

Keywords: Aging; China; Depressive symptoms; Sleep; Socioeconomic status; Social activity

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1. Introduction

Late-life mental health contributes substantially to morbidity and service needs in China. Evidence on how socioeconomic status (SES) relates to incident clinically significant depressive symptoms and self-reported mental health-related conditions and the behavioral mechanisms underlying this relationship remains limited in national cohorts. Because the China Health and Retirement Longitudinal Study (CHARLS) is a population-based survey rather than a clinical diagnostic study, Center for Epidemiologic Studies Depression Scale-10 (CES-D-10) scores were not interpreted as evidence of clinically diagnosed mental disorders. In this study, the outcome refers to incident mental health-related outcomes, defined as clinically significant depressive symptoms identified by CES-D-10 screening and self-reported physician-diagnosed emotional, psychiatric, or memory-related conditions. The World Health Organization (WHO) projects that depression will become the leading cause of disease burden worldwide by 2030.¹ Beyond psychological suffering, depressive symptoms and related mental health conditions are linked to elevated risks of cardiovascular disease, diabetes, cognitive decline, and premature mortality.² These conditions also impose high economic costs, with particularly severe consequences in low- and middle-income countries, where access to mental health services remains scarce.³

China exemplifies these global challenges. As the world's most rapidly aging society, China is expected to have over 30% of its population aged 60 or older by 2050.⁴ The prevalence of late-life depression in China has been estimated to range from 20% to 30% among older adults,⁵ representing one of the highest rates globally. Yet access to specialized geriatric psychiatry remains inadequate, especially in rural regions where health resources are constrained.^{6,7} Structural barriers, such as shortages of trained professionals and uneven distribution of health infrastructure, further exacerbate mental health disparities. At the same time, cultural practices including family cohesion, filial piety, and community solidarity may shape how socioeconomic disadvantage translates into mental health outcomes.⁷ However, as rural-to-urban migration accelerates and traditional support systems weaken, these cultural buffers are increasingly strained.

Socioeconomic status has long been recognized as a fundamental determinant of health. Marmot's seminal work on the "social gradient" demonstrated that health outcomes systematically worsen with each step down the socioeconomic ladder.⁸ Life course theory emphasizes that cumulative disadvantage across childhood, adulthood, and later life shapes long-term health trajectories.⁹ Empirical

research supports this framework: meta-analyses show that low SES is consistently associated with higher risks of depression,¹⁰ though effect sizes vary across settings.

International evidence provides strong support for the association between SES and mental health-related outcomes. Cohorts such as the Health and Retirement Study in the United States, the English Longitudinal Study of Ageing, and the Survey of Health, Ageing, and Retirement in Europe have documented robust socioeconomic gradients in depressive symptoms, cognitive decline, and functional impairment.⁹ For instance, lower education and financial strain predict higher risks of depression and earlier onset of disability.¹¹ Nonetheless, welfare systems in high-income countries may buffer some of these adverse effects, raising questions about the extent to which the findings generalize to middle-income contexts such as China.^{3,12}

Research in China has begun to document SES-related health disparities, but limitations remain. Studies using CHARLS and other datasets confirm that lower income and education are associated with worse mental and physical health outcomes.^{6,13} However, three key limitations constrain the literature. First, most Chinese studies rely on single SES indicators, such as income or education, which inadequately capture the multidimensional nature of socioeconomic stratification.^{7,14} Second, much of the evidence is cross-sectional, limiting causal inference. Longitudinal studies are relatively rare, though essential for capturing temporal dynamics in SES and mental health.^{15,16} Third, very few studies have explicitly examined the mechanisms through which SES affects mental health. Social activity, a well-established protective factor embedded in Chinese cultural practices such as Mahjong and square dancing,^{17,18} and sleep, increasingly recognized as a physiological mediator of socioeconomic disparities,¹⁹⁻²¹ have rarely been tested together in a comprehensive analytic framework.

The neglect of subgroup heterogeneity further constrains our understanding. Prior evidence suggests that women may experience stronger SES-depression associations.²² Rural residents may also be disproportionately vulnerable.⁷ Nutritional status is another potential modifier: underweight older adults may experience compounded disadvantage.²³ Yet these dimensions of heterogeneity remain fragmented in the Chinese literature. Consequently, a longitudinal design integrating multidimensional SES and hypothesized pathways is strongly warranted.

From a health psychology perspective, this study is guided by the social determinants of health framework and the biopsychosocial model. These perspectives suggest that socioeconomic disadvantage may influence mental

health through interconnected structural, behavioral, and physiological pathways. Accordingly, social activity and sleep were conceptualized as two theoretically informed pathways linking SES to incident mental health-related outcomes in older adults.

This study seeks to address these gaps in three ways. First, we apply latent class analysis (LCA) to integrate household income, educational attainment, and employment status into a multidimensional SES index, thereby avoiding reliance on any single indicator, such as employment status alone.²⁴ Second, we leverage seven years of longitudinal data from CHARLS (2011–2018) to strengthen causal inference. Third, we explicitly test social activity and sleep as dual mediators while conducting subgroup analyses by sex, body mass index, and rural–urban residence. By combining structural, behavioral, and physiological perspectives, this study advances understanding of the socioeconomic determinants of mental health among older Chinese adults. The findings are expected to inform interventions promoting social participation, improving sleep health, and reducing socioeconomic inequalities, while also contributing to global discussions on healthy aging and health equity.^{1,3}

2. Methods

2.1. Data source and study population

This study used data from CHARLS, a nationally representative survey of Chinese adults aged 45 years and older. Data collection followed four CHARLS waves: baseline in 2011 and follow-up surveys in 2013, 2015, and 2018. Trained CHARLS interviewers administered standardized face-to-face interviews and physical examinations. Questionnaires collected information on demographics, SES, health conditions, sleep, and social activities, while biomarker data were collected where feasible. Data quality was ensured through standardized interviewer training, uniform survey protocols, computer-assisted data collection, field-level consistency checks, and verification of key responses.

After applying predefined eligibility criteria, the analytic cohort comprised 5,465 adults without mental health-related outcomes at baseline. The inclusion criteria were (i) individuals enrolled in the 2011 CHARLS baseline survey, (ii) those aged 45 years or older, and (iii) those with an absence of baseline mental health-related outcomes, valid baseline data, and at least one eligible follow-up assessment after two years. The exclusion criteria were baseline mental health-related outcomes, age younger than 45 years, missing nighttime sleep information, follow-up shorter than two years, and incomplete covariate data. The sample was not limited to participants completing all four

waves. Thus, participants without incident mental health-related outcomes were censored at their last available survey wave. A flowchart of sample selection is provided in [Figure 1](#).

The initial sample included 17,708 respondents in Wave 1. After sequential exclusions, including baseline mental health-related outcomes, age <45 years, missing sleep data, short follow-up, and incomplete covariates, a total of 5,465 participants were retained for analysis.

2.2. Clinically significant depressive symptoms and self-reported mental health-related conditions

The primary outcome was not defined as a clinical diagnosis of a mental disorder. Instead, it was operationalized as an incident of clinically significant depressive symptoms and/or self-reported physician-diagnosed mental health-related conditions. Clinically significant depressive symptoms were assessed using the CES-D-10. Following validated cutoffs in Chinese older populations, participants with CES-D-10 scores greater than 10 were classified as having clinically significant depressive symptoms. In addition, participants who reported a physician diagnosis of emotional, psychiatric, or memory-related disorders were classified as having a self-reported mental health-related condition.

Incident cases were identified during the first follow-up wave if participants met either criterion. Respondents who did not meet either criterion during follow-up were censored at their last available survey wave. The CES-D-10 was used as a screening instrument for depressive symptoms rather than as a diagnostic tool. Therefore, throughout the revised manuscript, the outcome is described as mental health-related outcomes rather than clinically diagnosed mental health disorders.

2.3. Exposure: Socioeconomic status

Socioeconomic status was measured as a multidimensional socioeconomic position using LCA, rather than by employment status alone. Three baseline indicators were included: household income quartile, educational attainment, and employment status. Household income captured material resources, education reflected relatively stable socioeconomic advantage, and employment status was included as one component of labor-force and post-retirement resource conditions.

Employment status was therefore not treated as an independent proxy for SES, but only as one indicator within the LCA model. Covariates used in the analysis are summarized in [Table 1](#). Alternative class solutions with two, three, and four classes were compared using the Akaike Information Criterion, Bayesian Information Criterion,

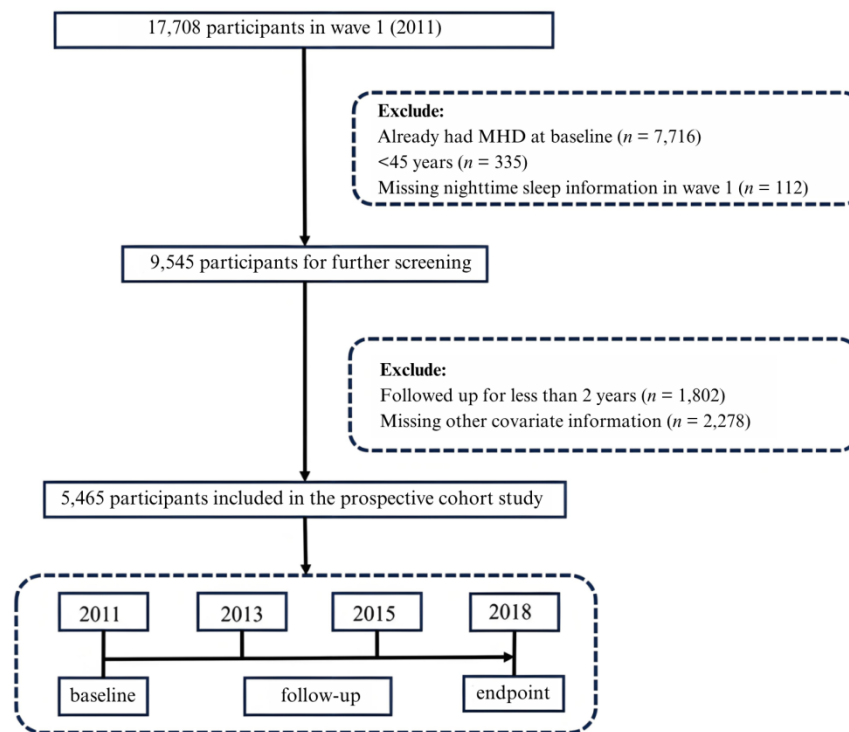


Figure 1. Flowchart of participant inclusion and exclusion in the China Health and Retirement Longitudinal Study, 2011–2018

entropy, the Lo–Mendell–Rubin likelihood ratio test, class size, and substantive interpretability. The distributions of the original SES-related variables are reported in [Table 2](#), and the LCA model fit indices are reported in [Table 3](#) to clarify the construction of the latent SES classes.

2.4. Mediators

Two baseline pathway variables from the 2011 CHARLS wave were examined to capture behavioral and physiological pathways:

- (i) Social participation: Coded as no participation versus any participation in at least one social group. Group activities included community associations, leisure clubs, or cultural/religious gatherings. This variable reflected exposure to social participation but did not capture the frequency, intensity, or quality of engagement.^{15,17,18}
- (ii) Sleep duration: Measured by self-reported nighttime sleep duration in the 2011 baseline survey and dichotomized at the sample median as shorter versus longer sleep duration. This measure reflected sleep duration rather than overall sleep quality. Based on the social determinants of health and biopsychosocial frameworks, sleep was examined as an exploratory pathway through which socioeconomic disadvantage

may influence later mental health-related outcomes.^{19–21}

2.5. Covariates

Analyses adjusted for confounders identified from prior literature, including demographic, behavioral, and health-related factors associated with SES and mental health ([Table 1](#)). Body mass index (BMI) was classified using Asian population-based cutoffs: underweight (<18.5 kg/m²), normal weight (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obesity (≥ 25.0 kg/m²). These cutoffs were used for comparability with prior CHARLS-based studies and to reflect the higher metabolic risk associated with lower BMI levels in Asian populations. Chronic disease status was categorized as none, one, or ≥ 2 chronic conditions.

2.6. Statistical analysis

Baseline characteristics were summarized using means and standard deviations for continuous variables and proportions for categorical variables. Differences between high- and low-SES groups were evaluated using chi-square tests for categorical variables and *t*-tests.

Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between SES and the mental health-related outcomes. Event time was defined as the time at which

Table 1. Operational definitions of key study variables

Variable type	Variable	Definition & coding
Exposure	SES	Derived via LCA (High = 1; Low = 2)
Outcome	Mental-health related outcomes	CES-D-10 >10 or physician-diagnosed disorder (Yes = 1; no = 0)
Pathway variables	Social participation	No participation = 0; any participation in ≥ 1 social group = 1
	Sleep duration group	Shorter sleep duration, < median = 0; longer sleep duration, $\geq$ median = 1
Covariates	Age	45–54 = 1; 55–64 = 2; 65–74 = 3; ≥ 75 = 4
	Sex	Male = 1; female = 2
	BMI	Underweight (<18.5 kg/m ²) = 1; normal weight (18.5–22.9 kg/m ²) = 2; overweight (23.0–24.9 kg/m ²) = 3; obesity (≥ 25.0 kg/m ²) = 4
	Residence	Urban = 0; Rural = 1
	Marital status	Married = 1; partnered/cohabiting = 2; other = 3, including separated, divorced, widowed, or never married
	Smoking	Current = 1; former = 2; never = 3
	Alcohol	Yes = 1; no = 0
	Multimorbidity	None = 0 chronic conditions; one = 1 chronic condition; more = ≥ 2 chronic conditions
	ADL score	0–3 (higher scores indicate greater disability; 0 = no limitation)

Abbreviations: ADL: Activities of daily living; BMI: Body mass index; CES-D-10: 10-item Center for Epidemiologic Studies Depression Scale; LCA: Latent class analysis; SES: Socioeconomic status.

mental health-related outcomes were first observed.

Social participation and sleep duration measured at the 2011 baseline wave were examined as exploratory pathway variables. Because SES and pathway variables were measured at the same baseline wave, these analyses were not interpreted as proving a strict causal mediation sequence. We used a counterfactual-based framework with nonparametric bootstrapping (5,000 resamples) to estimate indirect effects.²⁴ Models adjusted for age, sex, BMI, residence, marital status, smoking, alcohol drinking, chronic disease, and activities of daily living. Bias-corrected 95% CIs and pathway proportions were calculated. A suppressor effect was considered when the indirect effect was opposite in direction to the total effect.

Stratified analyses were performed by sex, BMI category, and urban/rural residence. Within each subgroup, Cox models were adjusted for the same covariates as the fully adjusted model, except for the stratification variable itself. Interaction terms between SES and each subgroup variable were tested in the fully adjusted model to evaluate heterogeneity of SES–mental health-related outcome associations. Prior evidence suggests that SES-related mental health associations may vary by sex, residence, and BMI status.^{7,22,23}

For sensitivity analysis, complete-case analyses were conducted. Results were compared with and without CHARLS survey weights, yielding consistent findings; unweighted results are presented for simplicity. Given the imbalance between the high- and low-SES classes, results were interpreted with caution, and survey-weighted models were used as a robustness check to assess whether the main estimates were sensitive to unequal group distributions.

All analyses were performed using R software version 4.5.0. Statistical significance was defined as a two-sided p -value < 0.05.

2.7. Ethical approval

This study constitutes a secondary analysis of anonymized data from the CHARLS. The CHARLS research protocol received approval from the Institutional Review Board of Peking University (IRB00001052-11015), with all participants providing written informed consent prior to data collection. All procedures involving human participants were conducted in accordance with the Declaration of Helsinki and its subsequent revisions. The CHARLS dataset is publicly accessible (<http://charls.pku.edu.cn>), ensuring compliance with data protection and ethical standards.

3. Results

3.1. Baseline characteristics

The final analytic sample included 5,465 participants (53.1% men; mean age 59.3 ± 8.7 years). Table 2 shows the original SES-related variables used in the LCA. The high-SES class had higher income, higher education, and more stable employment or retirement-related status, indicating that SES was not classified by employment status alone.

Table 3 presents the LCA model fit indices. The two-class model was selected because it had the lowest Bayesian Information Criterion, higher entropy, a significant Lo–Mendell–Rubin likelihood ratio test, and a clearer interpretation as high- and low-SES profiles. The three- and four-class models produced smaller and less interpretable classes.

Table 4 presents baseline characteristics by SES class. Compared with the high-SES group, the low-SES group was more likely to be older, female, and rural, and to be socially inactive, and to show different BMI distributions. The high-SES class was relatively small, which reflects the distribution generated by the LCA rather than an artificially imposed grouping. Therefore, subsequent analyses adjusted for major sociodemographic and health-related covariates, and the findings were interpreted with caution. Most differences were statistically significant ($p < 0.05$).^{6,7,13}

3.2. Socioeconomic status–mental health-related outcome association

Over the seven-year follow-up, participants with low SES exhibited consistently higher cumulative incidence of mental health-related outcomes than those with high SES

Table 2. Distribution of original SES-related variables by latent SES class

Original SES-related variable	Total (N = 5,465)	High SES (N = 391)	Low SES (N = 5,074)	p-value
Household income quartile, n (%)				
Q1, lowest	1,367 (25.0)	10 (2.6)	1,357 (26.7)	<0.001
Q2	1,366 (25.0)	25 (6.4)	1,341 (26.4)	
Q3	1,366 (25.0)	95 (24.3)	1,271 (25.0)	
Q4, highest	1,366 (25.0)	261 (66.8)	1,105 (21.8)	
Educational attainment, n (%)				
Primary or below	3,860 (70.6)	75 (19.2)	3,785 (74.6)	<0.001
Secondary	1,420 (26.0)	190 (48.6)	1,230 (24.2)	
Tertiary or above	185 (3.4)	126 (32.2)	59 (1.2)	
Employment status, n (%)				
Working	3,410 (62.4)	155 (39.6)	3,255 (64.2)	<0.001
Retired	825 (15.1)	210 (53.7)	615 (12.1)	
Not working	1,230 (22.5)	26 (6.6)	1,204 (23.7)	

Notes: SES classes were derived from household income quartile, education, and employment status. *p*-values were calculated using chi-square tests. Abbreviation: SES: Socioeconomic status.

Table 3. Fit indices for latent class models of socioeconomic status

Classes	AIC	BIC	Adjusted BIC	Entropy	LMR-LRT <i>p</i> -value	Smallest class, n (%)
2	18,426.3	18,512.7	18,470.5	0.86	<0.001	391 (7.2)
3	18,391.8	18,524.5	18,459.7	0.79	0.084	116 (2.1)
4	18,376.5	18,555.6	18,468.2	0.74	0.217	48 (0.9)

Notes: Although AIC decreased with additional classes, the two-class model was retained because it showed the lowest BIC, higher entropy, adequate class size, and clearer interpretation as high- and low-SES profiles.

Abbreviations: AIC: Akaike information criterion; BIC: Bayesian information criterion; LCA: Latent class analysis; LMR-LRT: Lo–Mendell–Rubin likelihood ratio test; SES: Socioeconomic status.

Table 4. Baseline characteristics of participants by socioeconomic status

Characteristics	Total (N = 5,465)	High SES (N = 391)	Low SES (N = 5,074)	p-value
Social participation, <i>n</i> (%)				<0.001
No participation	2,691 (49.2)	141 (36.1)	2,550 (50.3)	
Any participation	2,774 (50.8)	250 (63.9)	2,524 (49.7)	
Sleep duration group, <i>n</i> (%)				0.053
Shorter sleep duration	3,592 (65.7)	275 (70.3)	3,317 (65.4)	
Longer sleep duration	1,873 (34.3)	116 (29.7)	1,757 (34.6)	
Age (years), <i>n</i> (%)				<0.001
45–54	2,013 (36.8)	201 (51.4)	1,812 (35.7)	
55–64	2,144 (39.2)	103 (26.3)	2,041 (40.2)	
65–74	1,011 (18.5)	63 (16.1)	948 (18.7)	
≥75	297 (5.4)	24 (6.1)	273 (5.4)	
Sex, <i>n</i> (%)				<0.001
Male	2,904 (53.1)	249 (63.7)	2,655 (52.3)	
Female	2,561 (46.9)	142 (36.3)	2,419 (47.7)	
BMI (kg/m ²), <i>n</i> (%)				0.002
<18.5	276 (5.1)	17 (4.3)	259 (5.1)	
18.5–22.9	2,217 (40.6)	125 (32.0)	2,092 (41.2)	
23.0–24.9	1,148 (21.0)	94 (24.0)	1,054 (20.8)	
≥25.0	1,824 (33.4)	155 (39.6)	1,669 (32.9)	
Residence, <i>n</i> (%)				<0.001
Urban	2,087 (38.2)	294 (75.2)	1,793 (35.3)	
Rural	3,378 (61.8)	97 (24.8)	3,281 (64.7)	
Marital status, <i>n</i> (%)				0.046
Married	4,807 (88.0)	359 (91.8)	4,448 (87.7)	
Partnered/cohabiting	196 (3.6)	8 (2.0)	188 (3.7)	
Other	462 (8.5)	24 (6.1)	438 (8.6)	
Smoking, <i>n</i> (%)				0.002
Current	1,800 (32.9)	110 (28.1)	1,690 (33.3)	
Former	514 (9.4)	55 (14.1)	459 (9.0)	
Never	3,151 (57.7)	226 (57.8)	2,925 (57.6)	
Alcohol drinking, <i>n</i> (%)				0.015
No	3,177 (58.1)	204 (52.2)	2,973 (58.6)	
Yes	2,288 (41.9)	187 (47.8)	2,101 (41.4)	
Chronic disease, <i>n</i> (%)				0.001
None	2,090 (38.2)	115 (29.4)	1,975 (38.9)	
One chronic condition	1,689 (30.9)	134 (34.3)	1,555 (30.6)	
≥2 chronic conditions	1,686 (30.9)	142 (36.3)	1,544 (30.4)	

Notes: The baseline characteristics are grouped by the socioeconomic status of the study samples. Partnered/cohabiting indicates living with a partner without formal marriage; Other includes separated, divorced, widowed, or never married.

Abbreviations: BMI: Body mass index; SES: Socioeconomic status.

(log-rank $p < 0.0001$). Nelson–Aalen cumulative hazard curves (Figure 2) illustrate the divergence between SES groups across follow-up waves.

Cox proportional hazards models further confirmed these associations (Table 5). In unadjusted analyses, low SES was associated with a 67% higher risk of incident mental health-related outcomes (HR: 1.67, 95% CI: 1.37–2.00; $p < 0.001$). After adjusting for demographic and lifestyle factors, the association remained robust (HRs ranging from 1.38 to 1.63 across models, all $p < 0.001$). Even after controlling for multimorbidity, activities of daily living disability, social activity, and sleep, low SES retained an independent effect (adjusted HR: 1.40, 95% CI: 1.15–1.69). Low SES remained associated with higher incident mental health-related outcomes after extensive adjustment, indicating a robust gradient in late-life mental health.^{10,15,16} The association was also examined in survey-weighted sensitivity models, and the direction of the estimate remained unchanged, suggesting that the main finding was not solely driven by unequal SES group sizes.

3.3. Subgroup analyses

Figure 3 displays subgroup analyses by sex, residence, and BMI. The SES–mental health-related outcome association appeared stronger among women than men, with HRs of 1.92 (95% CI: 1.55–2.38) and 1.31 (95% CI: 1.08–1.59), respectively. Residence-specific estimates showed numerical variation, but the interaction test

was not statistically significant; therefore, this pattern was interpreted as descriptive rather than confirmatory evidence of effect modification.

Table 5. Hazard ratios for the association between socioeconomic status and incident mental health-related outcomes

Models	Hazard ratio (95% confidence interval)	p -value
Crude model	1.67 (1.37–2.00)	<0.001
Adjusted model I	1.38 (1.14–1.67)	0.001
Adjusted model II	1.42 (1.17–1.72)	<0.001
Adjusted model III	1.63 (1.35–1.97)	<0.001
Adjusted model IV	1.40 (1.15–1.69)	<0.001

Notes: Crude model: unadjusted; Adjusted model I: adjusted for age, sex, body mass index (BMI), residence, marital status, smoking, and alcohol drinking; Adjusted model II: adjusted for age, sex, BMI, residence, marital status, smoking, alcohol drinking, chronic disease, and activities of daily living; Adjusted model III: adjusted for social participation and sleep duration group; Adjusted model IV: adjusted for all variables.

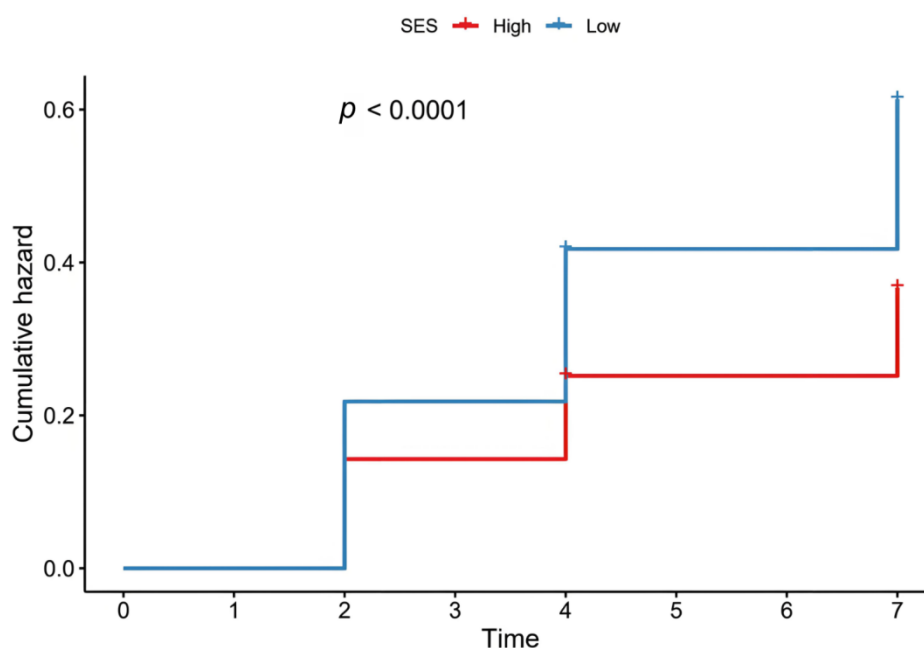


Figure 2. Nelson–Aalen cumulative hazard curves

Body mass index-stratified analyses also showed heterogeneous estimates across categories. Because the direction and magnitude of effects varied across BMI groups, these findings were interpreted with caution and not used to claim a consistent BMI-specific effect. Overall, subgroup results suggest possible heterogeneity, but only statistically supported interaction effects were emphasized.

3.4. Mediation analyses

Figure 4 presents exploratory pathway estimates for social participation and sleep duration. Social participation accounted for 6.1% of the SES–mental health-related

outcome association (bias-corrected 95% CI, $p < 0.05$). By contrast, sleep duration showed a small suppressor effect (-2.6% , $p < 0.05$). Because SES, social participation, and sleep duration were all measured at baseline, these estimates should be interpreted as exploratory evidence of pathways rather than definitive causal mediation. Estimates are reported on the log-hazard scale; positive values indicate an increase in the total effect and negative values indicate attenuation.

These results suggest that reduced social participation may represent one behavioral pathway linking low SES to later mental health-related outcomes, in line with

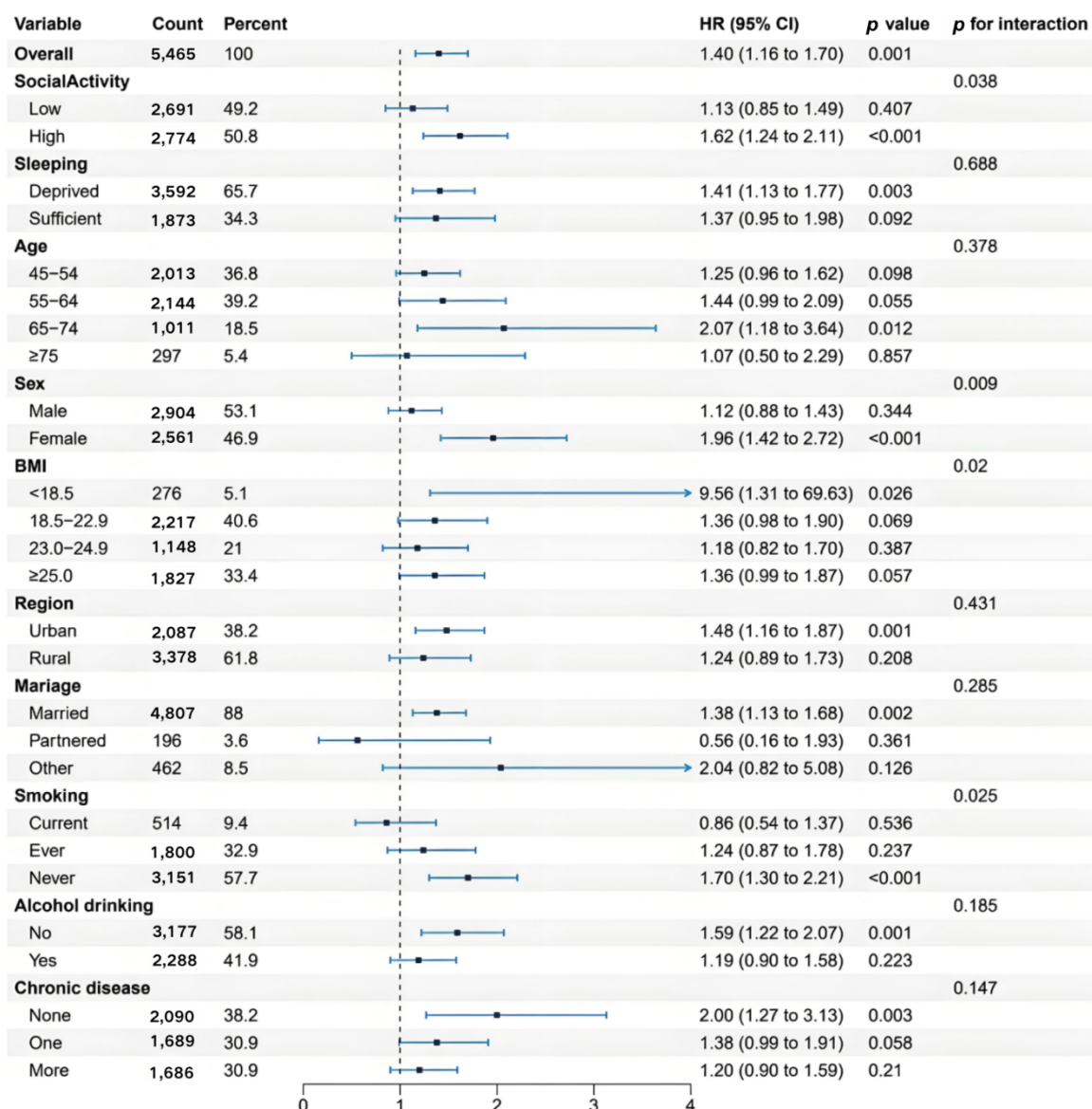


Figure 3. Forest plot of subgroup analyses for the association between socioeconomic status and mental health-related outcomes

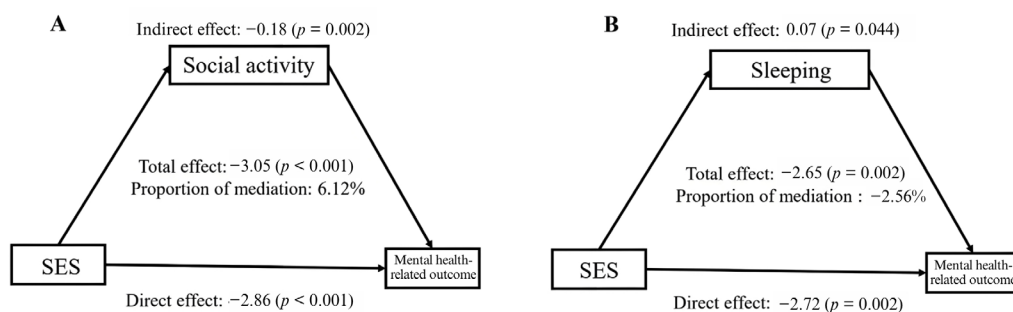


Figure 4. Pathway estimates for social participation and sleep duration in the association between socioeconomic status (SES) and mental health-related outcomes. (A) Social participation and (B) sleep duration were measured at baseline. All exploratory pathway models were adjusted for age, sex, body mass index, residence, marital status, smoking, alcohol drinking, chronic disease, and activities of daily living score.

literature showing the protective role of community engagement.^{15,17,18} However, because SES and social participation were measured at the same baseline wave, this finding should not be interpreted as definitive evidence of temporal mediation. The sleep finding should be interpreted cautiously because sleep was measured only by self-reported duration and dichotomized at the sample median. Therefore, the suppressor effect may reflect measurement limitations, residual confounding, or differences between sleep duration and broader sleep health.^{19–21}

3.5. Sensitivity checks

Sensitivity analyses confirmed the robustness of results. Complete-case analyses yielded estimates consistent with those of the primary models. Results were also stable when applying CHARLS survey weights, supporting the representativeness of the findings.

4. Discussion

4.1. Overall summary

Using 2011–2018 CHARLS data, we found that low SES was associated with a higher incidence of mental health-related outcomes among older Chinese adults. Social participation accounted for a modest part of this association, while sleep duration showed a small suppressor effect. The association was more evident among women, whereas residence- and BMI-specific patterns require cautious interpretation.

4.2. Comparison with prior research and broader context in China

Our findings are consistent with evidence from high-income countries showing socioeconomic gradients in mental health outcomes. Lorant *et al.*¹⁰ reported that individuals in the lowest SES categories were nearly twice as likely to develop depression as those in the highest categories. Similarly, Kivimäki *et al.*¹⁵ documented consistent

associations between low SES and multiple adverse health conditions. These findings are complemented by national evidence from China. A CLHLS-based study found that social participation, including group exercise and organized activities, mediated the association between SES and health outcomes among older adults.^{25,26} This aligns with our mediation results and underscores the relevance of behavioral pathways in the association between SES and the mental health outcome.

Evidence from middle-income contexts remains more limited and inconsistent. A recent study by Xu *et al.*²⁶ also examined the link between SES and depressive symptoms in aging populations. Differences between their findings and ours may be related to differences in cohort composition, SES measurement, and outcome definition. Specifically, our study focused on Chinese older adults in CHARLS, used an LCA-derived baseline SES profile, and defined the outcome as CES-D-10-based clinically significant depressive symptoms plus self-reported mental health-related conditions. For example, Elovainio *et al.*¹⁶ observed an attenuation of the association between socioeconomic disadvantage and depressive symptoms over the life course after behavioral factors were included. Our findings indicate that in China, where welfare protections are weaker and social transformation is rapid, low SES continues to exert a persistent influence on mental health, particularly in rural areas with limited institutional support.⁷ This influence may operate through intertwined pathways involving social participation and sleep. A longitudinal study from South Korea found that depressive symptoms mediated the association between SES and long-term sleep quality patterns.²⁷ This differs from our model, in which sleep was examined as a mediator between SES and incident mental health-related outcomes. Thus, the previous study²⁸ does not provide direct evidence for a sleep-mediated SES–mental health pathway but instead suggests a context-dependent relationship among SES,

psychological distress, and sleep.

The stronger association among rural residents also reflects China's socioeconomic structure. The household registration system and related urban–rural disparities in healthcare access, social safety nets, and community infrastructure may limit both material resources and meaningful social engagement.^{6,7,18} The Healthy China 2030 initiative emphasizes reducing health inequities and promoting mental well-being in later life. Viewed alongside other national studies,²⁶ our findings suggest the need for targeted interventions addressing both socioeconomic disparities and behavioral consequences.

4.3. Mechanistic pathways: Social activity and sleep

Two pathways, social activity and sleep, shed light on how socioeconomic disadvantage translates into mental health disparities.

4.3.1. Social activity as a mediator

Social activity accounted for 6.1% of the SES–mental health-related outcome association, a modest but meaningful proportion. This finding is supported by national evidence showing that social participation, including group exercise and organized activities, mediated the association between SES and physical and mental health among Chinese older adults.²⁶ Specifically, group exercise mediated up to 64.11% of the physical health disparity and 20.44% of the mental health disparity attributable to income inequality.²⁶

In China, social participation is embedded in practices such as Mahjong, square dancing, group exercise, and community mutual-aid networks. These activities provide psychosocial support, a sense of identity, and a sense of purpose. However, socioeconomic disadvantage may restrict access to such resources through financial constraints, geographic isolation, caregiving burdens, or limited community services. This may be especially relevant for women and rural elders.^{7,22} Community-based interventions, such as senior centers and culturally tailored activities, may help buffer the mental health effects of low SES.

4.3.2. Sleep as a suppressor: Unpacking the mechanisms

The observed suppressor effect of sleep adequacy (−2.6%) suggests a more complex relationship than initially hypothesized. In this study, sleep was measured only by self-reported nighttime sleep duration and dichotomized by the sample median. This measure may not fully capture broader aspects of sleep health, including sleep quality, sleep fragmentation, insomnia symptoms, and restorative sleep. A longitudinal study from China showed that depressive symptoms mediated the association between

SES and long-term sleep quality patterns, suggesting that SES, psychological distress, and sleep may interact through context-dependent pathways.²⁸

A likely explanation is measurement mismatch. Low-SES older adults may report sufficient sleep duration but still experience poor sleep quality due to chronic stress, financial strain, neighborhood insecurity, environmental noise, or other socioeconomic stressors.^{29,30} Sleep duration may therefore mask part of the adverse sleep-related consequences of low SES. Objective sleep research also suggests that disadvantaged populations may show poorer sleep continuity and greater sleep variability even when total sleep time does not differ substantially.³¹ Thus, the suppressor effect should not be interpreted as evidence that sleep offsets the mental health risks of low SES. Rather, sleep duration alone may be insufficient to characterize the role of sleep in the SES–mental health-related outcome association pathway.

Future studies should incorporate multidimensional sleep assessments, such as the Pittsburgh Sleep Quality Index, insomnia symptoms, sleep efficiency, sleep fragmentation, and objective sleep indicators. These measures would help clarify whether sleep quality, rather than sleep duration alone, explains part of the socioeconomic gradient in late-life mental health.

4.4. Subgroup heterogeneity

Our subgroup analyses suggested possible heterogeneity in the association between SES and mental health-related outcomes, particularly by sex. The association showed numerical variation across residence and BMI groups, but these patterns should be interpreted cautiously because not all interaction tests were statistically significant. Therefore, subgroup findings should be viewed as exploratory rather than definitive evidence of residence- or BMI-specific effect modification.

First, the stronger association among women may reflect cumulative gender-related disadvantage across the life course. Older women in China are more likely to have experienced lower educational attainment, weaker labor-market participation, limited pension accumulation, and greater caregiving responsibilities. These factors may reduce access to material resources and social support in later life, increasing vulnerability under low-SES conditions.²² Second, the stronger association among rural residents may reflect structural urban–rural inequalities in healthcare access, pension protection, community services, and mental health resources. In rural settings, socioeconomic disadvantage may be compounded by geographic isolation and fewer opportunities for organized social participation.^{6,7}

Third, the underweight group showed a different association pattern, suggesting that nutritional status may be related to SES-linked mental health differences. Underweight status may indicate frailty, inadequate dietary intake, chronic disease burden, or reduced physiological reserve. These conditions may restrict social participation and contribute to psychological distress among older adults with lower SES.²³ Together, these findings suggest an intersectional pattern in which low SES has stronger mental health effects when combined with gender disadvantage, rural residence, or nutritional vulnerability. Because the high-SES subgroup was relatively small, especially in stratified analyses, these results should be interpreted cautiously and confirmed in larger samples.

4.5. Interpretation of effect sizes and model stability

Although the mediation effects of social activity (6.1%) and sleep (−2.6%) were numerically small, they are consistent with typical effect sizes in population-based mediation studies, where multiple pathways often operate in parallel.²⁴ These findings should be interpreted as part of a broader SES-related pathway rather than as isolated behavioral effects. Different forms of social participation may also have different mediating roles. For instance, interacting with friends was found to mediate up to 33.72% of education-related disparities in physical health, highlighting the importance of distinguishing between forms of social engagement.²⁶

The persistence of the SES–mental health-related outcome association across progressively adjusted models indicates that SES exerts a robust influence on mental health that is not fully explained by conventional behavioral or health-related factors. This underscores the importance of structural interventions targeting upstream determinants, such as income security and educational access, in addition to individual-level behavioral interventions.

4.6. Theoretical perspectives

Our findings can be situated within three theoretical frameworks:

- (i) Life course theory: Cumulative disadvantage across the lifespan contributes to long-term health risks.⁹ Our longitudinal analysis shows that SES disparities persist into later life, consistent with this theory.
- (ii) Social gradient in health: Health improves at each step up the socioeconomic hierarchy.⁸ The persistent gradient we observed supports this principle.
- (iii) Social determinants of health framework: SES influences mental health through interconnected structural, behavioral, and biological pathways.¹⁰ Our dual-pathway approach illustrates how disadvantage

is embodied through both social participation and physiological mechanisms.

4.7. Policy implications

Targeted prevention in lower-SES groups, alongside efforts to sustain social participation, could yield incremental gains for mental health. The Healthy China 2030 strategy emphasizes reducing health disparities, promoting mental health, and fostering healthy aging. Our findings support this agenda by identifying concrete pathways for intervention:

- (i) Promoting social participation: Expand community-based programs and social prescribing models, especially in rural and low-income areas. Group exercise and organized social activities may help mitigate SES-related health disparities.²⁶
- (ii) Improving sleep health: Integrate sleep screening into primary care and public health campaigns, with attention to both duration and quality. Addressing depressive symptoms may be important for improving sleep health in low-SES populations.²⁸
- (iii) Targeting vulnerable subgroups: Prioritize women, rural residents, and nutritionally at-risk older adults in mental health promotion and service planning.

These strategies should be integrated into broader socioeconomic reforms, including strengthening old-age insurance and ensuring equitable access to healthcare, to address the root causes of mental health disparities.

4.8. Strengths and limitations

Key strengths include national representativeness, longitudinal design, and integration of behavioral and physiological pathways. Several limitations should also be noted. First, self-reported sleep and social measures are subject to recall and social desirability biases. Second, SES, social participation, and sleep duration were measured at the same baseline wave, which limits the ability to establish a strict temporal sequence of mediation. Third, sleep was measured only by self-reported nighttime duration and did not capture sleep quality, insomnia symptoms, or sleep fragmentation.²⁸ Fourth, sleep was measured only by self-reported nighttime duration and dichotomized at the sample median; therefore, it did not capture sleep quality, insomnia symptoms, sleep fragmentation, sleep efficiency, or daytime dysfunction. Social participation was also measured as participation versus non-participation, without information on the frequency, intensity, or quality of engagement. Therefore, this study could not fully capture the impact of time-varying changes in SES on incident mental health-related outcomes. Fifth, the high-SES subgroup was relatively small compared with the low-SES

subgroup, which may reduce statistical precision and affect the comparability of subgroup and interaction analyses. Although multivariable adjustment and sensitivity analyses were used to reduce this concern, residual imbalance may remain. Finally, unmeasured confounding may persist.

4.9. Future directions

Future research should expand in four directions:

- (i) Biological pathways: Incorporate biomarkers of stress and inflammation to deepen understanding of biological embedding.^{12,13}
- (ii) Cross-national comparisons: To assess universal versus context-specific mechanisms.^{9,15}
- (iii) Advanced methods: Future studies should employ comprehensive sleep assessments, including both sleep quality and duration, using validated instruments such as the Pittsburgh Sleep Quality Index. Furthermore, large-scale cohort data and machine learning methods may help identify complex, non-linear pathways among SES, sleep, and mental health.³²
- (iv) Intervention studies: Develop and evaluate community-based interventions that simultaneously target social participation and mental health, particularly for low-SES older adults.²⁶

By integrating structural, behavioral, and biological perspectives, such studies will advance understanding of socioeconomic determinants of mental health and inform policies to promote resilience and equity in aging societies.

5. Conclusion

In this national longitudinal cohort of older Chinese adults, lower SES was independently associated with an increased risk of incident mental health-related outcomes, suggesting that socioeconomic position is relevant to late-life mental health risk. Social participation accounted for a modest part of this association, while sleep duration showed a small suppressor effect, likely reflecting the distinction between sleep quality and duration. The adverse association between low SES and incident mental health-related outcomes was more evident among women, whereas residence- and BMI-specific differences require cautious interpretation and further confirmation. These findings suggest that reducing socioeconomic disparities should be central to strategies for preventing depressive symptoms and related mental health problems in older Chinese adults, alongside targeted efforts to promote social engagement and support groups with greater observed risk.³³

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Conflict of interest

The author declares no competing interests.

Author contributions

This is a single-authored article.

Ethics approval and consent to participate

This study is a secondary analysis of anonymized, publicly available CHARLS data. Ethical approval for the original CHARLS study was granted by the Institutional Review Board of Peking University (IRB00001052-11015), and all participants provided written informed consent at data collection.

Consent for publication

Not applicable. This study used de-identified, publicly available secondary data and did not include identifiable individual-level information.

Availability of data

The data that support the findings of this study are publicly available from the China Health and Retirement Longitudinal Study (CHARLS) repository: <http://charls.pku.edu.cn>

Further disclosure

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