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Original Research

From social isolation to frailty: the chain mediating roles of depression and cognitive decline among Chinese older adults

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ABSTRACT

Background: As global aging accelerates, frailty has emerged as a critical public health challenge. Although social isolation is recognized as a prevalent psychosocial risk factor among older adults, the longitudinal mechanisms linking it to frailty—specifically via the chain mediating pathways of depression and cognitive decline—remain underexplored.

Objective: This study aimed to investigate the presence and magnitude of the "social isolation → depression → cognitive function → frailty" chain mediation pathway in the Chinese elderly population.

Methods: Using four waves of data (2011–2018) over 7 years from the China Health and Retirement Longitudinal Study (CHARLS), we analyzed a final sample of 3316 participants aged ≥60 years who were non-frail at baseline. The chain mediation pathways were tested by integrating logistic regression analyses within a structural equation modeling framework. The significance of direct and indirect effects was examined using the bias-corrected bootstrap method with 5000 resamples.

Results: Among the 3316 participants (mean age: 68.9 ± 5.9 years; 60.5% female), 1947 (58.7%) developed frailty during follow-up. After full adjustment for covariates, social isolation exhibited no significant direct effect on frailty. Instead, its impact was exclusively indirect through three distinct pathways: (1) the independent mediating route of depression (effect value = 0.976; 95% CI: 0.200–1.735); (2) the independent mediating route of cognitive function (effect value = 0.490; 95% CI: 0.003–0.985); and (3) the chain mediating route from depression to cognitive function (effect value = 0.173; 95% CI: 0.035–0.311). The total indirect effect value was 1.638 (95% CI: 0.637–2.611), confirming a full mediation mechanism.

Conclusion: Social isolation functions as a distal determinant that indirectly escalates the risk of frailty by potentially inducing depression, which subsequently accelerates cognitive decline. These findings highlight the need for integrated interventions targeting social engagement, mental health, and cognitive function to prevent or delay frailty in older populations.

1. Introduction

Global aging is a prevailing demographic trend, presenting substantial public health challenges. Among these, understanding the determinants of frailty and related geriatric syndromes remains a critical yet complex task. Frailty is a state in which a person is vulnerable to stressors because their physiological reserves have declined significantly across multiple systems, making the likelihood of adverse health events such as falls, hospitalization, functional dependence and death significantly higher [1]. However, frailty is not an inevitable consequence of aging, but rather a dynamic and potentially reversible state [2].

Social isolation is a critical psychosocial determinant of health in later life. It is characterized by an objective lack of both close personal ties and broader social connections, rather than merely subjective feelings of loneliness [3]. In China, these concerns are particularly salient due to demographic shifts, declining household size, increasing nuclear family structures, and large-scale rural-to-urban migration, all of which may exacerbate social isolation among older adults [4]. Prospective studies have linked social isolation to a range of adverse health outcomes, including cardiovascular disease, cognitive decline, and all-cause mortality [5]. A longitudinal study utilizing data from the English Longitudinal Study of Ageing (ELSA) revealed that individuals experiencing social isolation had a significantly higher risk of frailty during the follow-up period. This association has been corroborated across

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different cultures and cohorts [6]. In the older population in China, Wang et al. also found that social isolation could independently predict cognitive decline [7]. Numerous studies have found a significant association between social isolation and frailty, but the underlying etiological pathways remain poorly understood [8].

Depression and cognitive impairment are considered major pathways linking social disconnection to physical frailty [9,10]. Social isolation may promote depressive symptoms through chronic stress dysregulation and diminished emotional support [11]. Depression, in turn, may accelerate the development of frailty via behavioral changes (e.g., reduced physical activity, poor dietary intake) and physiological cascades (e.g., systemic inflammation) [12]. Concurrently, social isolation is associated with accelerated cognitive decline. The deprivation of cognitive stimulation and complex social interactions may deplete cognitive reserves and induce cognitive impairment, which can further aggravate frailty by impairing executive function, hindering health self-management, and reducing the ability to perform complex daily activities [13]. Moreover, studies have confirmed that depression accounts for 36.85% of the total effect on cognitive function among older adults [14]. This suggests a potential chain mediating pathway: social isolation may directly deplete cognitive reserves and induce cognitive impairment, while also promoting depressive symptoms that, in turn, accelerate cognitive decline, ultimately resulting in an increased risk of frailty.

Although previous studies have explored the associations between social isolation, depression, cognitive function, and frailty, these factors are often viewed independently or as confounders rather than as elements in a continuous causal chain. Therefore, existing research remains insufficient in understanding the complex psychological pathways through which social isolation exerts deleterious effects on physical frailty. To address this gap, this study aims to: (1) prospectively investigate the associations between social isolation, depression, cognitive function, and the incidence of frailty in a nationally representative large cohort of middle-aged and older adults in China; (2) examine the potential mediating roles of depression and cognitive function in this association, both independently and sequentially (social isolation → depression → cognitive function → frailty). Elucidating these pathways will contribute to understanding the psychosocial etiology of frailty and provide information for developing comprehensive interventions targeting social engagement, mental health, and cognitive vitality to prevent or delay the onset of frailty in older populations.

2. Methods

Data sources This was a prospective cohort study using secondary data from the China Health and Retirement Longitudinal Study (CHARLS). Starting in 2011, there were additional rounds in 2013, 2015, and 2018, and this large-scale interdisciplinary project uses multistage stratified sampling to select a representative sample of Chinese residents aged 45 and over. The total number of all 150 counties and 450 village-level units in the country is included in the sampling frame.The CHARLS project has been approved by the Peking University Ethics Review Committee (Approval No.: IRB00001052–11,015) [15]. All participants were followed for a minimum of 7 years, from the 2011 baseline survey through the 2018 follow-up wave. The inclusion criteria for this study were: age ≥60 years; non-frail at the baseline survey (2011). Exclusion criteria included: missing frailty assessment at the baseline survey; diagnosed as frail at the baseline survey; incomplete baseline data; loss to follow-up regarding frailty status; and missing covariates such as social isolation, depression, and cognitive function. Participants with any missing FI component were excluded (N = 565) using complete-case analysis, as the FI requires all items and imputation could misclassify frailty status. Ultimately, 3316 participants were included in the sample. Baseline characteristics were generally comparable between completers and those lost to follow-up. A detailed flowchart of participant screening is shown in Fig. 1.

Social Isolation Referring to existing research, the social isolation index is constructed based on objective social networks and participation in social activities, encompassing four dimensions: marital status, living conditions, frequency of contact with children, and social activities [16]. We used cumulative scoring to quantify isolation, with each of the following being one point: (1) no spouse (spouse deceased, divorced, or single), (2) living alone, (3) contact with children less than once a week through any medium, (4) no participation in any leisure or social activities in the past month. The final index was between 0 and 4, and the higher the value, the more isolated the individual was. In accordance with the protocols set out in advance, scores 2 and above are defined as socially isolated [17].

Cognitive function Cognitive function was assessed using the cognition test module in the CHARLS questionnaire, which primarily evaluates three cognitive domains: executive function, language function, and memory function. The Mental Intactness status comprises 11 items evaluating temporal cognition, arithmetic ability, and visuospatial abilities, with 1 point awarded for correct responses and 0 points for errors, yielding a score range of 0–11. Memory capacity is assessed through immediate and delayed word recall tests. The immediate recall test involves interviewers orally presenting 10 common words at a steady pace, followed by immediate recall and repetition by respondents, with 1 point awarded for each correct recall, resulting in a score range of 0–10. The delayed recall test is conducted 5–10 min after the immediate test, requiring respondents to recall and repeat the same 10 words, with scoring rules identical to the immediate test, producing a score range of 0–10. Memory capacity is calculated as the average of both immediate and delayed recall scores, with a final score range of 0–10. The total cognitive function score is the sum of the "mental status score" and "memory capacity score," ranging from 0 to 21, where higher scores indicate better cognitive function [18]. This cognitive assessment battery has been well-validated in multiple CHARLS-based investigations as a reliable measure of global cognitive function in Chinese older adults [19,20].

Depression The assessment was carried out using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10). There are 10 items on this scale: 3 items evaluate depressive symptoms, 5 items assess somatic symptoms, and 2 items evaluate positive affect (with reverse scoring). Each item is scored based on the frequency of symptom occurrence, ranging from 0 points ("never or rarely") to 3 points ("most of the time"). The total score ranges from 0 to 30 points, with higher scores indicating more severe depressive symptoms [21].

Frailty Index (FI) According to the standard procedure for FI construction, 34 variables reflecting health deficits including physiological, social, and functional aspects were included. The FI was built by adding 34 health factors from physical, functional and psychosocial domains in the deficit-accumulation principle. Comorbidities were ten chronic conditions such as cardiovascular disease, diabetes, and malignancy, and sensory deficit in vision and hearing. Functional capacity measured by the six basic activities of ADLs, and five activities from the IADLs, e.g., feeding and dressing, and handling financial matters, respectively. And further on in terms of this index incorporating physical performance indicators (such as grip strength, chair stand test), mobility measures (100 m walk), as well as self-reported recollection, fall history and general well-being. The scoring adhered to the standard operating procedure: binary variables: binary variables received 1 or 0 points depending on presence, while four-category and five-category variables received 1 or 0 points according to severity. FI score was computed by dividing the number of items indicating deficits present by the total possible deficits (34) in this study (range 0–1). The higher the value, the greater the accumulation of health deficits and the more severe the functional impairment. According to the literature report, this study defined individuals with FI ≥0.25 as frail [22].

Covariates Demographic characteristics comprised age group (60–69 years, 70–79 years, ≥80 years), gender (male, female), education level (primary school or less, junior high school, high school or

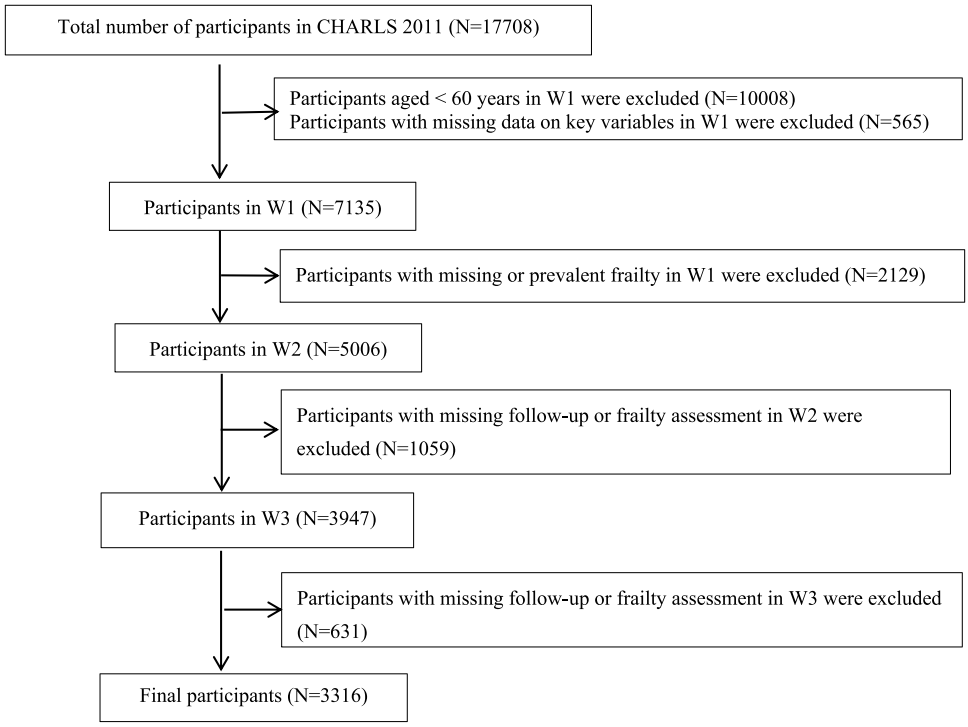


Fig. 1. Flowchart for participant screening.

above), and place of residence (urban, rural). Lifestyle variables included smoking, drinking and sleeping duration. Smoking status was defined as self-reported current smoking (yes, no). Alcohol drinking was defined as consuming alcoholic beverages more than once per month in the past year (yes, no). Following the previous studies, sleep duration was divided into three groups: short sleep (≤6 h per night), normal sleep (7 - 9 h per night) and long sleep (≥10 h per night) [23].

Statistical analysis Statistical analyses were performed using IBM SPSS 26.0 and AMOS 28.0 software. Continuous variables were presented as median (interquartile range, IQR), and categorical variables were reported as frequency and percentage. Categorical variables were compared using the chi-square test, while continuous variables were compared using the Mann-Whitney U test. Logistic regression was used to explore the associations of social isolation, depression, cognitive function, and frailty, with results presented as odds ratios (OR) and 95% confidence intervals (CI). Three hierarchical models were constructed: the original model (Model 1), the model adjusted for demographic characteristics (Model 2), and the fully adjusted model incorporating both demographic and lifestyle covariates (Model 3). To examine the nonlinear dose-response relationships among depression, cognitive function, and frailty risk, restricted cubic spline (RCS) analysis was performed. Spearman's rank correlation coefficients were calculated to examine bivariate correlations among key variables, and chain mediation analysis was carried out using a structural equation modeling (SEM) framework. Confirmatory factor analysis (CFA) was used to evaluate the measurement model. Based on Kline's guidelines, acceptable fit was defined as $\chi^2/df \langle 3$, CFI $\rangle 0.90$, GFI > 0.90, AGFI > 0.90, RMSEA < 0.08, and SRMR < 0.08 [24]. The PROCESS macro (SPSS Model 6) was used with 5000 bootstrap resamples, and the bias-corrected bootstrap method was applied to test the significance of direct and indirect effects in the chain mediation model. Indirect effects were considered statistically significant if their 95% confidence interval did not contain zero. All statistical tests were two-tailed, and a *P*-value < 0.05 was considered statistically significant.

3. Results

Baseline characteristics Baseline characteristics Among the 3316 participants (mean age: 68.9 ± 5.9 years), 1947 (58.7%) developed frailty during follow-up (391 at W2, 574 at W3, and 982 at W4), whereas 1369 (41.3%) remained non-frail. The sample comprised 1309 males (39.5%) and 2007 females (60.5%). Age distribution showed 2182 participants (65.8%) aged 60–69 years; 2598 (78.3%) had primary school education or less, 2566 (77.4%) were married, and 2044 (61.6%) resided in rural areas, as detailed in Table 1.

3.1. Multivariable logistic regression of social isolation, depression, and cognitive function with frailty

Table 2 presents the logistic regression associations of social isolation, depression, and cognitive function with frailty risk in each model. In the unadjusted model (Model 1), social isolation (OR=1.280, $P = 0.023$), depression (OR=1.141, $P < 0.001$), and cognitive function (OR=0.853, $P < 0.001$) were all significantly associated with frailty risk. However, after adjusting for demographic characteristics and lifestyle factors, no significant association was found between social isolation and frailty risk. Depression and cognitive function remained significantly associated with frailty across all three models. We also used restricted cubic spline (RCS) model to investigate the depression-cognitive function- frailty dosage relationship. The restricted cubic spline analysis revealed a significant linear association between depression and frailty (overall association $P < 0.001$; nonlinear association $P > 0.05$), indicating that the risk of frailty increased progressively with greater severity of depressive symptoms. In contrast, the association between cognitive function and frailty exhibited a non-linear pattern (overall association $P < 0.001$, nonlinear association $P < 0.001$), as shown in Fig. 2.

3.2. Correlation analysis of social isolation, depression, cognitive function and frailty

Spearman correlation analysis was conducted among social

Table 1
Baseline characteristics of participants stratified by incident frailty status during follow-up.

Characteristics	Total ($N = 3316$) n (%)	Non-frail group (n = 1369, 41.3%) n (%)	Frail group (n = 1947, 58.7%) n (%)	*P*
Main variables				
Classification of social isolation				
Non-Social isolation	2631(79.3)	1165(44.3)	1466(55.7)	<0.001
Social isolation	685(20.7)	204(29.8)	481(70.2)	
Depression score, median (IQR)	10(5, 15)	6(3, 10)	13(8, 18)	<0.001
Cognitive function, median(IQR)	11(4, 14)	13(10, 15)	7(2, 12)	<0.001
Covariates				
Demographic characteristics				
Age group (years)				
60~69	2182(65.8)	1074(49.2)	1108(50.8)	<0.001
70~79	961(29.0)	275(28.6)	686(71.4)	
≥80	173(5.2)	20(11.6)	153(88.4)	
Sex				
Male	1309(39.5)	601(45.9)	708(54.1)	<0.001
Female	2007(60.5)	768(38.3)	1239(61.7)	
Educational level				
Primary school or less	2598(78.3)	1042(40.1)	1556(59.9)	0.032
Middle school	476(14.4)	216(45.4)	260(54.6)	
High school or above	242(7.3)	111(45.9)	131(54.1)	
Residence				
Urban	1272(38.4)	589(46.3)	683(53.7)	<0.001
Rural	2044(61.6)	780(38.2)	1264(61.8)	
Lifestyle characteristics				
Smoking				
No	2687(81.0)	1122(41.8)	1565(58.2)	0.261
Yes	629(19.0)	247(39.3)	382(60.7)	
Alcohol drinking				
No	2500(75.4)	995(39.8)	1505(60.2)	0.002
Yes	816(24.6)	374(45.8)	442(54.2)	
Sleep duration				
Short sleep	2063(62.2)	726(35.2)	1337(64.8)	<0.001
Normal sleep	1109(33.4)	602(54.3)	507(45.7)	
Long sleep	144(4.3)	41(28.5)	103(71.5)	

Note: Categorical variables are reported as n (%), continuous variables as median (IQR). Social isolation: cumulative score ≥2; Depression: 10-item CES-D (0–30); Cognitive function: CHARLS cognitive battery (0–21); Frailty: FI ≥ 0.25.

isolation, depression, cognitive function, and frailty. Social isolation was positively correlated with depression and frailty, and negatively correlated with cognitive function; depression was positively correlated with frailty and negatively correlated with cognitive function; cognitive function and frailty were negatively correlated. The correlations among social isolation, depression, cognitive function, and frailty were all statistically significant (Table 3), meeting the statistical requirements for conducting mediation effect testing.

3.3. A chain mediation model of social isolation, depression and cognitive function on frailty

A chain mediation model was constructed with social isolation as the independent variable, depression and cognitive function as mediators, and frailty as the outcome variable, adjusting for age group, gender, education, residence, alcohol consumption, and sleep duration. The CFA demonstrated good model fit ($\chi^2/df = 2.539$; CFI = 0.913; GFI = 0.928; AGFI = 0.882; RMSEA = 0.071; SRMR = 0.047), as shown in Table 4. The results of the mediation model showed that social isolation positively predicted depression ($\beta = 1.017$, $P < 0.01$) and negatively predicted cognitive function ($\beta = -0.542$, $P < 0.05$). Depression negatively predicted cognitive function ($\beta = -0.188$, $P < 0.01$) and positively predicted frailty ($\beta = 0.960$, $P < 0.001$). Cognitive function negatively predicted frailty ($\beta = -0.903$, $P < 0.001$). The direct effect of social isolation on frailty was not statistically significant ($\beta = 1.281$, $P > 0.05$), but its indirect effects through depression and cognitive function were significant, indicating full mediation, as shown in Fig. 3.

Table 2
Multivariable logistic regression associations between social isolation, depression, cognitive function, and frailty.

Variables	Model 1		Model 2		Model 3	
	OR(95% CI)	*P* value	OR(95% CI)	*P* value	OR(95% CI)	*P* value
Social isolation	1.280 (1.035, 1.583)	0.023	1.116 (0.893, 1.394)	0.335	1.114 (0.891, 1.393)	0.344
Depression	1.141 (1.124, 1.157)	<0.001	1.152 (1.135, 1.169)	<0.001	1.149 (1.132, 1.166)	<0.001
Cognitive function	0.853 (0.839, 0.868)	<0.001	0.843 (0.827, 0.860)	<0.001	0.842 (0.826, 0.859)	<0.001

Note: OR, Odds Ratio; CI, Confidence Interval.
Model 1 was unadjusted.
Model 2 was adjusted for demographic characteristics (age group, gender, education, residence).
Model 3 was further adjusted for lifestyle characteristics (smoking, alcohol drinking, sleep duration) based on Model 2.

3.4. Test of the chain mediation effect of social isolation, depression and cognitive function on frailty

The chain mediation model was tested using PROCESS macro Model 6 with 5000 bootstrap resamples. The total effect value was 2.919 (95% CI: 1.204–4.635). The direct effect value was 1.281 (95% CI: −0.143–2.705), and the total indirect effect value was 1.638 (95% CI: 0.637–2.611). Since the 95% CI for the direct effect included zero, depression and cognitive function fully mediated the relationship between social isolation and frailty. Three significant indirect pathways were identified: ① social isolation → depression → frailty (effect value = 0.976; 95% CI: 0.200–1.735); ② social isolation → cognitive function → frailty (effect value = 0.490; 95% CI: 0.003–0.985); ③ social isolation → depression → cognitive function → frailty (effect value = 0.173; 95% CI: 0.035–0.311), as shown in Table 5.

4. Discussion

Over a 7-year follow-up period, this study found that social isolation was associated with an increased risk of frailty among older adults, and confirmed the chain mediating role of depression and cognitive function in this relationship among the Chinese older population. The results indicate that social isolation does not directly predict the incidence of frailty, but rather exerts an indirect effect through a chain pathway of depression → cognitive function → frailty. This finding provides new empirical evidence for understanding how psychosocial factors influence physical health via affective and cognitive mechanisms, and offers important insights for the prevention and intervention of frailty in later life.

This study found that after fully controlling for demographic and lifestyle variables, the direct association between social isolation and frailty was no longer statistically significant. This result diverges from some international findings, such as Davies et al., who reported that social isolation could independently predict frailty [25]. Discrepant findings between our study and those international cohorts are likely attributable to methodological distinctions. That study tracked frailty

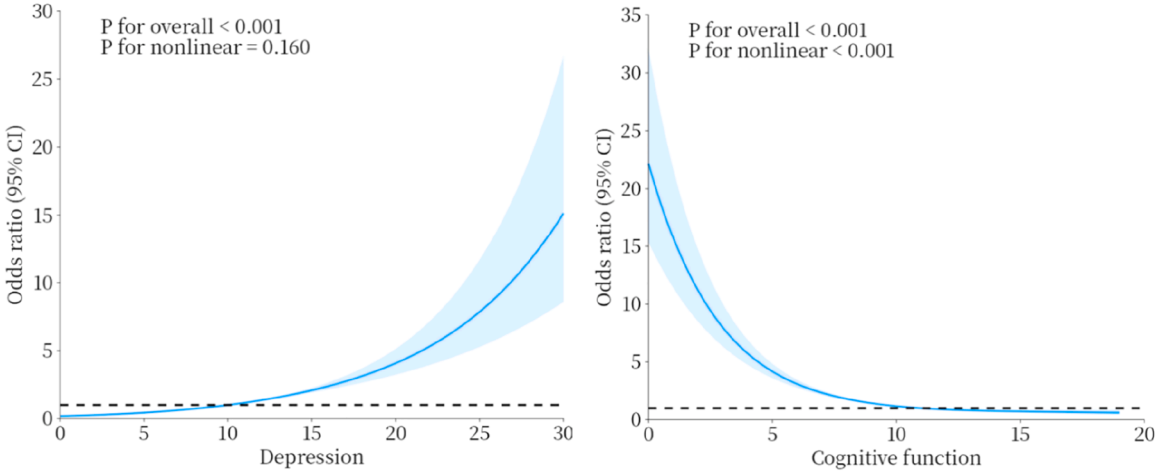


Fig. 2. Restricted Cubic Spline Graph of Depression, Cognitive Function, and Frailty.
Note: The spline plot was generated using three knots (10th, 50th, and 90th percentiles). The model was adjusted for demographic characteristics (age group, gender, education, residence) and lifestyle factors (smoking, alcohol drinking, sleep duration).

Table 3
Correlation analysis of social isolation, depression, cognitive function, and frailty.

Variables	Social isolation	Depression	Cognitive function	Frailty
Social isolation	1			
Depression	0.120***	1		
Cognitive function	−0.155***	−0.324***	1	
Frailty	0.142***	0.515***	−0.458***	1

**: P < 0.01; ***: P < 0.001.

Table 4
Fit indices of chain mediation model.

Fit Indices	χ2/df	CFI	GFI	AGFI	RMSEA	SRMR
Reference Values	≤3	>0.90	>0.90	>0.90	<0.08	<0.08
Test Values	2.539	0.913	0.928	0.882	0.071	0.047

Note: x^2/df: Ratio of chi-square to degrees of freedom; CFI: Comparison fit index; GFI: Goodness of fit index; AGFI: Adjusted goodness of fit index; RMSEA: Root mean square error; SRMR: Standardized root mean square residual.

trajectories in a sample including participants with baseline prevalent frailty and omitted cognitive function as a key intermediate confounder. In contrast, we restricted analyses to initially non-frail adults to examine incident frailty, using a four-domain social isolation index covering both structural and functional social deficits, while Davies' team relied on a condensed 3-item scale. Mehrabi and Béland also utilized separate assessment batteries for social participation, networks and support, hindering direct cross-study comparisons [26]. Beyond these methodological differences, cross-national variations in welfare regimes, family structures, policy environments, cultural differences, and other factors may also account for the observed discrepancies [27]. Nevertheless, our study design cannot empirically verify such explanations.

Furthermore, depressive symptoms exerted a robust mediating effect linking social isolation to incident frailty (β=0.976), supporting the hypothesized emotional pathway: social isolation → depression → frailty. Rather than merely a mood disturbance, depression manifests as a multisystem pathophysiological state modulated by neuroimmune processes and may further exacerbate frailty through behavioral pathways involving apathy and reduced physical activity [28]. Accumulating neuroimmunological evidence indicates that sustained social isolation acts as a key precursor to chronic low-grade inflammation, triggering persistent elevations in pro-inflammatory cytokines including

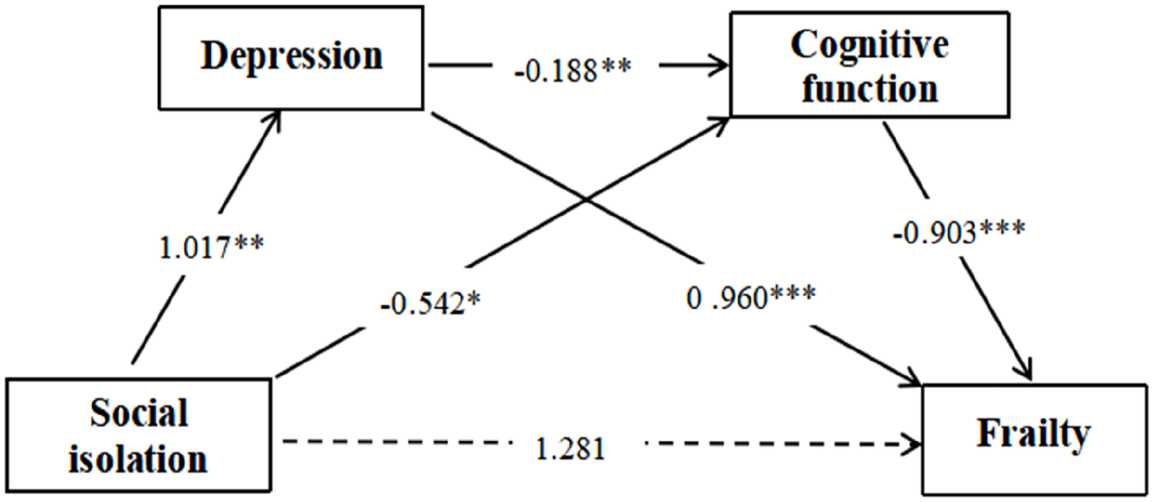


Fig. 3. Mediating Role of Depression and Cognitive Function Between Social Isolation and Frailty.
Note: Dashed line indicates that the pathway is not significant. *: P < 0.05; **: P < 0.01; ***: P < 0.001.

Table 5
Testing of chain mediation effects on depression and cognitive function.

Project		Effect	Standard Error	*t*	*P*	95% CI	
Total effect		2.919	0.875	3.337	0.001	1.204	4.635
Direct effect		1.281	0.726	1.764	0.078	−0.143	2.705
Indirect effect	TOTAL	1.638	0.506			0.637	2.611
	Ind 1	0.976	0.385			0.200	1.735
	Ind 2	0.490	0.246			0.003	0.985
	Ind 3	0.173	0.069			0.035	0.311

Note: Ind 1: Social isolation → depression → frailty; Ind 2: Social isolation → cognitive function → frailty; Ind 3: Social isolation → depression → cognitive function → frailty.

interleukin-6 (IL-6) and C-reactive protein (CRP) [29]. This chronic inflammatory cascade represents a shared core biological mechanism underlying both depression and frailty; such inflammatory burden may disrupt skeletal muscle metabolism and deplete bodily physiological reserves, thereby facilitating the emergence of the frailty phenotype [30].

A major novel contribution of the present analysis lies in the empirical validation of the serial chain mediation pathway: social isolation → depressive symptoms → cognitive dysfunction → frailty. This theoretical model suggests a unified mechanistic framework explaining how adverse social exposures translate sequentially into affective and cognitive impairments, which ultimately progress to physical frailty in older age. This sequential adverse cascade stems largely from depression-related cognitive deterioration, which may present as slowed information processing and impaired executive function. The plausible biological underpinnings include fronto-limbic circuit dysregulation secondary to depressive symptoms, diminished hippocampal neuroplasticity, and systemic inflammation-mediated damage to the blood-brain barrier and cerebral neurons [31]. Taken together, this chain mediating pathway suggests an integrated framework to characterize the progressive trajectory from social isolation to physical frailty among community-dwelling older adults.

The study also has several limitations: First, the sample had an overrepresentation of rural residents (61.6%), and a generally low education level (78.3% had primary school education or less), which to some extent limits the generalizability of our findings to urban or highly educated older cohorts; Second, although longitudinal data were used, the observational nature of the study precludes fully establishing causal relationships; Third, the lack of biological markers made it difficult to reveal physiological mechanisms; Fourth, social isolation, depressive symptoms and cognition were measured solely at baseline, lacking repeated assessments to unpack their dynamic temporal relationships. Future research should further integrate multi-biomarker and neuroimaging technologies to elucidate the specific biological mechanisms of this pathway, and validate the efficacy of comprehensive interventions through rigorous randomized controlled trials, thereby providing more actionable scientific evidence to promote healthy aging.

5. Conclusion

This study reveals that social isolation does not have a direct relationship with frailty, but indirectly increases the risk of incident frailty through a chain pathway that triggers depressive symptoms and subsequently impairs cognitive function. This suggests that, in the context of an aging society, promoting social engagement among older adults and paying attention to their mental health and cognitive vitality may be a vital holistic strategy to prevent or delay the onset of frailty. Future health interventions for older adults should integrate multidimensional approaches such as social, psychological, and cognitive aspects to achieve more effective early prevention and health management of frailty.

Ethics approval and consent to participate

The study was reviewed and passed with Protocol-NO. IRB00001052–11,015 at Peking University (Chars). All the participants gave written informed consent. This secondary data analysis was done following the ethical standards of the institutional and national research committees as well as the Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent for publication

Not applicable.

Availability of data and materials

This study used public datasets. Data of the China Health and Retirement Longitudinal Study (CHARLS) can be obtained from the following URL: https://charls.pku.edu.cn/.

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Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not employ any AI tools in this work.

CRediT authorship contribution statement

Hujia Yang: Writing – original draft, Formal analysis, Conceptualization. **Chunduo Liang:** Visualization, Software, Formal analysis. **Junqian Ma:** Methodology, Investigation. **Ning Ma:** Investigation, Data curation. **Rui Guo:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Shusong Deng:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Competing interests

The authors declare that they have no competing interests.

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