Effect of Frailty on Cognitive Function in Chinese Older Adults: A Postprint of a Moderated Chain Mediation Study

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Abstract

Background Currently, cognitive impairment has become one of the major risk factors seriously affecting the quality of life in older adults. Studies have identified a correlation between frailty and cognitive function, yet research on the mediating and moderating mechanisms between them remains relatively limited.

Objective To investigate the impact of frailty on cognitive function and to examine the mediating roles of activities of daily living and depressive symptoms, as well as the moderating role of social participation, in the relationship between frailty and cognitive function.

Methods Data from 8,173 older adults aged 65 years and above were obtained from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS), including information on frailty, cognitive function, activities of daily living, depression, social participation, and demographic characteristics. Differences in cognitive function among older adults with various characteristics were analyzed. Pearson correlation analysis was employed to explore correlations among variables; hierarchical regression analysis was used to assess the effect of frailty on cognitive function; and the PROCESS macro was utilized to test the chain mediating effect of activities of daily living and depression between frailty and cognitive function, as well as the moderating effect of social participation.

Results Among the 8,173 participants, 1,769 (21.6%) had cognitive impairment. Hierarchical regression analysis revealed that frailty negatively predicted cognitive function (B=-2.862, P<0.001). Chain mediating effect analysis demonstrated that activities of daily living (B=-1.713, 95%CI=-1.944~-1.498) and depression (B=-0.435, 95%CI=-0.531~-0.345) partially mediated the association between frailty and cognitive function. Social participation moderated the effect of frailty on cognitive function through the frailty-cognitive function pathway

(B=1.140, 95%CI=0.822~1.457), the activities of daily living-cognitive function pathway (B=-0.413, 95%CI=-0.560~-0.266), and the depression-cognitive function pathway (B=0.113, 95%CI=0.015~0.211).

Conclusion Social participation moderates the direct and indirect effects of activities of daily living and depression on the relationship between frailty and cognitive function. The findings suggest that interventions focusing on mental health and improving social relationship quality among older adults may help disrupt the association between frailty and cognitive impairment.

Full Text

Impact of Frailty on Cognitive Function in Chinese Older Adults: A Moderated Chain-Mediated Effect Study

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Abstract

Background: Cognitive impairment has become one of the serious risk factors affecting quality of life among older adults. While studies have identified an association between frailty and cognitive function, research on the mediating and moderating mechanisms between them remains relatively scarce. **Objective:** This study examines the influence of frailty on cognitive function, testing the mediating roles of activities of daily living (ADL) and depressive symptoms, as well as the moderating role of social participation. **Methods:** Data from 8,173 older adults aged 65 and above were selected from the 2018 China Longitudinal Healthy Longevity Survey (CLHLS), including information on frailty, cognitive function, ADL, depression, social participation, and demographic characteristics. Differences in cognitive function across various participant characteristics were analyzed, and Pearson correlation analysis was employed to examine interrelationships among variables. Stratified regression analysis was used to assess the impact of frailty on cognitive function, and the PROCESS macro was utilized to test the chain-mediated effects of ADL and depression between frailty and cognitive function, along with the moderating effect of social participation. **Results:** Among the 8,173 participants, 1,769 (21.6%) had cognitive impairment. Stratified regression analysis revealed that frailty negatively predicted cognitive function (B=-2.862, P<0.001). Chain-mediated effect analysis demonstrated that both ADL (B=-1.713, 95%CI=-1.944~-1.498) and depression (B=-0.435, 95%CI=-0.531~-0.345) partially mediated the relationship between frailty and cognitive function. Social participation moderated the effect of frailty on cognitive function through three pathways: the frailty-cognitive function path

(B=1.140, 95%CI=0.822~1.457), the ADL-cognitive function path (B=-0.413, 95%CI=-0.560~-0.266), and the depression-cognitive function path (B=0.113, 95%CI=0.015~0.211). **Conclusion:** Social participation moderates both the direct and indirect effects of ADL and depressive symptoms on the relationship between frailty and cognitive function. The findings suggest that interventions focusing on mental health and improving social relationship quality may help disrupt the association between frailty and cognitive impairment.

Keywords: Frailty; Cognitive impairment; Activities of daily living; Depressive symptoms; Social participation; Older adults

Introduction

As the aging population continues to grow, China faces an increasingly serious aging challenge [1], and cognitive impairment among older adults has attracted widespread concern. The prevalence of mild cognitive impairment among Chinese older adults is 20.8%, four times that of dementia, with 10%-15% of cognitively impaired patients gradually progressing to dementia annually [2], placing substantial pressure on healthcare systems, social services, and families while posing a major public health challenge. Although cognitive decline is recognized as an objective phenomenon of aging, research indicates that cognitive deterioration can be improved and delayed [3], prompting scholars to investigate influencing factors and underlying mechanisms.

Frailty is a common clinical syndrome among older adults, representing a state of multisystem functional decline that increases vulnerability to stressors [4] and leads to adverse health outcomes including cognitive impairment, depressive symptoms, disability, and premature mortality [5]. Currently, frailty has become a significant public health issue affecting older adult health [6], with prevalence increasing with age. Studies report an overall frailty prevalence of approximately 44.5% [7]. Epidemiological and clinical research demonstrates that frailty is an important predictor of cognitive impairment [8-10], with both conditions sharing underlying mechanisms including neuropathological changes, hormonal dysregulation, malnutrition, chronic inflammation, vascular disease risk, mental health issues, vitamin D deficiency, and decreased albumin levels [11-12]. This study proposes Hypothesis 1: Frailty significantly negatively predicts cognitive function in older adults.

Few studies have examined the mediating and moderating roles of individual activity capacity, psychological factors, and social factors in this relationship. Activities of daily living (ADL), as a key indicator of physical health in older adults, directly affects quality of life. Long-term ADL deficiency further accelerates frailty progression. A cohort study by HAJEK et al. [13] demonstrated that functional decline (including ADL) is consistently associated with cognitive deterioration. This study proposes Hypothesis 2: ADL mediates the relationship between frailty and cognitive function. Mental health among older adults

is receiving increasing attention [14], with a cohort study finding that depression significantly negatively predicts cognitive function in this population [15], possibly because late-life depression-induced hippocampal atrophy leads to cognitive damage [16]. Additionally, important research shows that frailty and comorbidities in older adults are associated with both depression and cognitive impairment [17-18]. This study proposes Hypothesis 3: Depression mediates the relationship between frailty and cognitive function. Previous research has tested the parallel mediating roles of ADL and depression between frailty and cognitive impairment [19]. Given the strong relationship between ADL and depression [20], we posit that ADL and depression may represent a psychological pathway explaining the frailty-cognitive function association, expecting that frailty first affects ADL, which then influences depression, ultimately impacting cognitive function. This study proposes Hypothesis 4: ADL and depression play a chain-mediated role between frailty and cognitive function.

Social participation reflects active living [21] and can regulate emotional states in older adults, with greater social participation associated with lower depression risk [22]. Engaging in social, cultural, entertainment, and volunteer activities helps older adults maintain physical exercise while fostering a sense of belonging, reducing social isolation, and delaying both cognitive decline [23] and physical frailty [24]. MIN et al. [22] revealed that different types of social participation affect cognitive decline risk through distinct mechanisms, with regular informal social interactions exerting beneficial effects on older adults' functional capacity. However, research on whether social participation negatively moderates the relationships among frailty, ADL, depression, and cognitive function remains limited. Therefore, this study proposes Hypothesis 5: Social participation moderates the effects of frailty, ADL, and depression on cognitive function. We constructed a moderated chain-mediated model as shown in Figure 1 [Figure 1: see original paper] to investigate the moderating role of social participation, which holds significance for identifying boundary conditions of risk factors affecting cognitive function, expanding pathway analysis between frailty and cognitive function, and developing targeted intervention strategies.

Methods

1.1 Data Source

The China Longitudinal Healthy Longevity Survey (CLHLS) is a long-term tracking project investigating health status, longevity, and influencing factors among older adults in China. Initiated in 1998 by the Institute of Ethnology and Anthropology at the Chinese Academy of Social Sciences, the CLHLS conducts follow-up surveys every 2-3 years. The survey covers health status, lifestyle, socioeconomic conditions, family support, social support, and healthcare utilization among adults aged 65 and above across urban and rural areas nationwide. The CLHLS has been approved by the Biomedical Ethics Committee of Peking University (IRB00001052-13074), and all participants provided informed consent. This study utilized data from the 2018 wave as the research

sample.

1.2 Study Sample

The 2018 CLHLS included 15,874 participants. This study included adults aged 65 and above, first excluding those with dementia, then excluding participants missing data on frailty, cognitive function, ADL, depression, or social participation, and finally removing cases with missing covariate values, resulting in a final sample of 8,173 older adults, as shown in Figure 2 [Figure 2: see original paper].

1.3 Frailty Assessment

Frailty was defined using the FRAIL Scale, identified by the presence of three or more of the following five components [25-26]: (1) fatigue, defined as inability to lift a ten-pound weight; (2) resistance, defined as inability to perform three consecutive squats and stands; (3) illness, defined as having five or more chronic diseases; (4) exhaustion, defined as answering "no" to the question "Do you feel full of energy?" ; and (5) weight loss, defined as BMI < 18.5 kg/m^2.

1.4 Cognitive Function Assessment

Cognitive function was assessed using the Mini-Mental State Examination (MMSE), comprising five dimensions: orientation, registration, attention and calculation, recall, and language/comprehension/self-coordination, with 24 items total. The maximum score is 30, with higher scores indicating better cognitive function. Based on previous research, participants scoring <24 were identified as having cognitive impairment [26]. The scale' s internal consistency coefficient (Cronbach' s α) was 0.893.

1.5 ADL Assessment

Basic Activities of Daily Living (BADL) were used to evaluate ADL [27], including six items: bathing, dressing, eating, toileting, grooming, and walking. Scoring was assigned as 3 points for independent completion, 2 points for some difficulty, and 1 point for inability, with total scores ranging from 6-18. Higher scores indicate better ADL function. The scale' s Cronbach' s α coefficient was 0.818, demonstrating good internal consistency.

1.6 Depression Assessment

The Center for Epidemiologic Studies Depression Scale (CES-D) was used to assess the frequency of feelings or behaviors in the past week. The scale includes 10 items, with items 5, 7, and 10 measuring positive psychological states and reverse-scored accordingly, while the remaining seven items are positively scored. Responses of "always, often, sometimes, rarely, never" are assigned values from 0-3, with total scores ranging from 0-30. Scores $ $10 were defined as

indicating depressive symptoms [2]. The scale' s Cronbach' s α coefficient was 0.927, indicating high reliability.

1.7 Social Participation

Following BERKMAN et al. [28], social participation encompasses meeting friends, attending activities, volunteering, occupational tasks, and group recreational activities. Based on the CLHLS questionnaire and previous research, we constructed a social participation index comprising three components: social activities, physical activities, and cognitive activities. Social activities included six aspects: spousal interaction, visiting neighbors, participating in social activities, traveling, having confidants, and receiving help. Physical activities included five items: exercising, doing housework, practicing tai chi, dancing in public squares, and outdoor activities. Cognitive activities were measured by three items: reading, playing cards or mahjong, and watching TV or listening to the radio. The 14 items were dichotomously scored (1 for "yes," 0 for "no"), with total scores ranging from 0-14. Higher scores indicate greater social participation capacity. Using SPSS for reliability and validity testing, the scale' s Cronbach' s α coefficient was 0.937 (>0.7 indicates high reliability), demonstrating good psychometric properties.

1.8 Covariates

Covariates included age, gender, current residence, living situation, pre-retirement occupation, education, economic status, smoking, and alcohol consumption. Living with family or in nursing institutions was classified as non-living alone. Occupations were categorized as professional or non-professional. Education was reflected by years of schooling, with >1 year considered as having received education. Economic status was assessed by the question "How does your life compare locally?" with three categories: wealthy, average, or poor.

1.9 Statistical Analysis

SPSS 25.0 was used for statistical analysis. Continuous variables were expressed as ($\bar{x}\pm s$), with independent samples t-tests for between-group comparisons. Categorical data were analyzed using ^{2} tests. Pearson correlation analysis examined relationships among cognitive function, frailty, ADL, depression, and social participation. Stratified regression analysis explored the relationship between cognitive function and frailty in older adults. The SPSS macro PROCESS was used for mediation and moderation analysis. Model 6 (chain multiple mediation model) tested whether the relationship between cognitive impairment and frailty was mediated by ADL and depression, with mediation established when the 95% CI of indirect effects ($a\times b$) excluded zero. Model 89 (where direct and indirect pathways of chain mediation are moderated by one variable) analyzed whether social participation moderated the mediation effects. $P<0.05$ was considered statistically significant.

Results

2.1 Common Method Bias Analysis

Since all variables were self-reported, Harman' s single-factor statistical control method was used to assess common method bias, with the percentage of variance explained by the first factor relative to total explained variance serving as the criterion. Results showed the first factor explained 20.41% of variance, below the 40% threshold, indicating that common method bias was not a significant concern and further analysis was warranted.

2.2 Participant Characteristics

Among the 8,173 participants included in the analysis, 3,826 were male and 4,347 were female, with a mean age of 82.8$\pm$11.2$years.ThemeanCES-Dscorewas7.25\pm$4.41, $ADLscore$17.43$\pm$1.65, $socialparticipationscore$6.11$\pm$2.44, $andMMSEscore$25.86$\pm$\$5.51
A total of 1,769 participants (21.6%) had cognitive impairment, accounting for 14.7% (564/3,826) of males and 27.7% (1,205/4,347) of females. Compared to those with normal cognitive function, individuals with cognitive impairment were older, more likely to be female, live in rural areas, have non-professional occupations, lack formal education, be frail and depressed, and had lower rates of smoking and alcohol consumption. They also exhibited higher CES-D scores and lower ADL, social participation, and MMSE scores (all $P<0.05$). Economic status also differed significantly between groups ($P<0.05$), while living situation showed no significant difference ($P>0.05$), as shown in Table 1 .

2.3 Correlation Analysis

Correlation analysis revealed that ADL and social participation were positively correlated with cognitive function, while frailty and depression were negatively correlated with cognitive function ($P<0.01$), supporting the rationale for further moderated mediation analysis.

2.4 Effect of Frailty on Cognitive Function

To examine the effect of frailty on cognitive function, stratified regression analysis was conducted with cognitive function as the dependent variable. In Step 1, all covariates were entered: age (actual value), gender (male=0, female=1), residence (urban=0, rural=1), living situation (non-living alone=0, living alone=1), occupation (professional=0, non-professional=1), education (no formal education=0, educated=1), economic status (wealthy=0, average=1, poor=2), smoking (no=0, yes=1), and alcohol consumption (no=0, yes=1) as Model 1. In Step 2, frailty (no=0, yes=1) was added as Model 2. Model 1 showed that age, gender, residence, and economic status were negatively associated with cognitive function ($P<0.05$), while education was positively associated ($P<0.05$). Living situation, occupation, smoking, and alcohol consumption showed no significant associations ($P>0.05$). Model 2 results indicated that frailty negatively pre-

dicted cognitive function (P<0.05), supporting Hypothesis 1, as shown in Table 3 .

2.5 Chain Mediation Analysis

Model 6 was used to analyze the chain-mediated effects of ADL and depression between frailty and cognitive function. PROCESS results showed that all path coefficients had 95% CIs excluding zero, indicating significance. Frailty significantly positively predicted depression (B=3.323, 95%CI=3.063~3.583) and significantly negatively predicted ADL (B=-1.453, 95%CI=-1.544~-1.362) and cognitive function (B=-2.970, 95%CI=-3.276~-2.663). ADL significantly positively predicted cognitive function (B=1.179, 95%CI=1.113~1.246) and significantly negatively predicted depression (B=-0.094, 95%CI=-0.153~-0.035). Depression significantly negatively predicted cognitive function (B=-0.131, 95%CI=-0.156~-0.106). Mediation test results are presented in Table 4 and Figure 3 [Figure 3: see original paper], showing that ADL and depression independently mediated the frailty-cognitive function relationship, supporting Hypotheses 2 and 3, and also demonstrated chain mediation, supporting Hypothesis 4.

2.6 Moderated Chain Mediation

Model 89 was used to test the moderating effect of social participation. Results showed that the interaction between frailty and social participation (B=1.140, 95%CI=0.822~1.457) and the interaction between depression and social participation (B=0.113, 95%CI=0.015~0.211) both significantly positively predicted cognitive function, while the interaction between ADL and social participation was negatively associated with cognitive function (B=-0.413, 95%CI=-0.560~-0.266), supporting Hypothesis 5, as shown in Table 5 .

To further validate the moderating effects, simple slope analyses were conducted and plotted (Figure 4 [Figure 4: see original paper]). Under high social participation, the chain-mediated effect of ADL and depression was significant (B=-0.008, 95%CI=-0.015~-0.002), while under low social participation, this effect was more pronounced (B=-0.015, 95%CI=-0.0271~-0.004). Simple slope analysis indicated that under high social participation, depression negatively predicted cognitive function (B=-0.251, 95%CI=-0.401~-0.101) and ADL positively predicted cognitive function (B=0.493, 95%CI=0.169~0.818), while frailty' s prediction of cognitive function was non-significant (B=-0.375, 95%CI=-0.941~0.191). Under low social participation, depression (B=-2.654, 95%CI=-2.979~-2.329) and ADL (B=1.32, 95%CI=1.211~1.428) showed stronger predictive effects on cognitive function, and frailty significantly negatively predicted cognitive function (B=-2.654, 95%CI=-2.979~-2.329), confirming the moderated chain-mediated effect. Any level of social participation negatively moderated the frailty-cognitive function relationship, as shown in Table 6 .

Discussion

This study examined the effect of frailty on cognitive function in older adults, focusing on the chain-mediated roles of ADL and depression and the moderating role of social participation. Results demonstrate that ADL and depression chain-mediate the association between frailty and cognitive impairment. Furthermore, social participation negatively moderates the frailty-cognitive function association, affecting both direct and indirect pathways.

The cognitive impairment prevalence of 21.6% in this study aligns with previous reports [2], with a higher proportion among females. Risk factors for cognitive impairment appear to include older age, female gender, lower education, poorer economic status, ADL limitations, and depressive symptoms. The frailty prevalence of 16.6% is lower than previously reported [26], possibly due to inconsistent assessment methods. Low education, ADL limitations, and depressive symptoms are independent factors associated with frailty, and the shared risk factors between cognitive function and frailty may reflect underlying mechanistic links.

All variable pairs showed significant correlations, supporting our hypotheses. Regarding Hypothesis 1, frailty significantly negatively predicted cognitive function, consistent with Western studies [10]. This may occur because frailty accompanies physiological decline, including nervous system degeneration, and may accelerate age-related brain structural and functional changes, thereby contributing to cognitive decline.

ADL and depression independently mediated the frailty-cognitive function relationship. Frailty typically leads to physical functional decline, affecting ADL such as self-care, mobility, and social interaction. When ADL is limited, older adults may experience social isolation and lack cognitive stimulation, accelerating cognitive decline. Additionally, frailty reduces quality of life, potentially causing depressive symptoms that directly impair attention, memory, and information processing. The chain-mediated effect shows that ADL decline reduces autonomy, increases loneliness and guilt, and elevates depression risk [29]; depression is associated with cognitive impairment [15], creating a dual impact where ADL decline increases depression, which further impairs cognitive function, forming a vicious cycle.

Regarding the final hypothesis, frailty directly and negatively affects cognitive function, with ADL and depression serving as mediators and social participation as a moderator. These findings indicate that for individuals with poor social participation, the risk of cognitive impairment may be more pronounced [30-31]. Social participation provides emotional and practical support, enhances positive emotions, improves cognitive capacity, offers learning opportunities, and fosters belonging, effectively mitigating frailty' s negative impact on ADL and helping older adults maintain independence and quality of life. Social interaction promotes cognitive health by enhancing neuroplasticity and cognitive reserve, while also reducing depression levels, thereby diminishing depression' s negative cognitive effects and indirectly protecting cognitive function. China' s collectivist

culture emphasizes individual-group connectedness, aligning with social participation values and potentially positively influencing cognitive function among older adults in this cultural context.

This study has limitations. First, the cross-sectional design limits ability to establish temporal sequence among frailty, ADL, depression, and cognitive impairment. Given previous reports of potential bidirectional relationships, reverse causation cannot be ruled out (i.e., cognitive impairment may cause frailty). Despite these limitations, the moderated chain-mediated effects provide new insights into mechanisms linking frailty and cognitive function, offering opportunities for early detection, intervention, and monitoring of cognitive impairment. The results provide important evidence for psychosocial pathways between frailty and cognitive impairment, encouraging clinicians and researchers to consider social factor interactions when examining causes and psychological factors contributing to cognitive decline.

Author Contributions: LI Yuling conceptualized and designed the study, focusing on the intersection of geriatric frailty and psychology, and revised the final manuscript. LIU Yuting developed the research framework, designed the analytical approach using mediation and moderation effects, performed data cleaning and statistical analysis, and drafted the manuscript. QIU Lixia conducted statistical analysis.

Conflict of Interest: The authors declare no conflicts of interest.

Note: Figure translations are in progress. See original paper for figures.