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Associations between sensory impairment and functional limitations among older Chinese adults: mediating roles of social isolation and cognition

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Abstract

Background The high prevalence of sensory impairment and functional limitations in older adults is a significant concern, yet there is limited understanding of the relationship between these two conditions. Therefore, the objective of this study was to investigate the pathways connecting sensory impairment and functional limitations by examining serial multiple mediating effects of social isolation and cognition in older adults.

Methods Using the China Health and Retirement Longitudinal Study dataset, a sample of 4871 older adults was selected. The study variables included sensory impairment, functional limitations, social isolation and cognition, and other covariates. A hierarchical multiple linear regression model was used to assess the association between sensory impairment and functional limitations. Mediation analysis was conducted to explore the sequential multiple mediating effects of social isolation and cognitive function in the relationship between sensory impairment and functional limitations.

Results Our findings revealed a significant and positive association between sensory impairment and functional limitations ($B=0.615$, 95% CI: 0.397, 0.834). After adjusting for social isolation and cognitive function, the impact of sensory impairment on functional limitations accounted for 87.19% of the total effect. Additionally, approximately 12.81% of the significant relationship between dual sensory impairment and functional limitations was mediated by social isolation and cognitive function. A serial multiple mediating pathway (sensory impairment → social isolation → cognition → functional limitations) was identified, with a coefficient of 0.013 (95% CI: 0.006, 0.020).

Conclusions Our study provides evidence for the mediating effects of social isolation and cognition in the relationship between sensory impairment and functional limitations. Given the prevalence of functional limitations among older adults with sensory impairment, it is crucial to consider social isolation and cognitive function in efforts to reduce the burden of disability care. Future validation of these findings through longitudinal studies is necessary.

Keywords Sensory impairment, Functional limitations, Social isolation, Cognition, Mediation, China Health and Retirement Longitudinal Study (CHARLS)

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Introduction

As the older population grows rapidly, functional limitations are increasingly common in later life and have become a major public health concern [1]. It is estimated that the population of functionally limited older adults in China will increase to 23.9 million by 2060 [2]. Functional limitations are severe impairments in an individual's ability to perform major daily tasks efficiently and are commonly measured using activities of daily living (ADLs) and instrumental activities of daily living (IADLs) [3–5]. Functional limitations are associated with injuries, hospitalization [6], long-term care [7], and increased mortality [8], leading to a decreased quality of life for older adults and an increased burden on families and the health care system. Several studies have identified risk factors for functional limitations, including biological, psychological, social and health-related behaviour factors such as chronic condition, pain, cognitive impairment, demographical factors, family and social relationships, drinking and smoking [9–11]. Therefore, it is important to understand the mechanisms associated with functional limitations fully and to explore modifiable risk factors to prevent or delay their development.

Sensory impairment is a common chronic condition, which includes vision impairment (VI), hearing impairment (HI), and dual sensory impairment (DSI) [12], which is highly prevalent in older adults [13]. Many studies have confirmed that sensory impairment is a risk factor for the development of functional limitations in older adults and can directly affect their ability to perform daily activities [12, 14–16]. Approximately 60% of patients with sensory impairment need assistance in at least one function (e.g., personal care and hygiene, mobility, eating, shopping, household chores, heavy chores, personal finances, and personal care) [16]. However, while most previous studies were conducted to explore the impact of VI or HI on functional limitations [17–19], in recent years, some attention has been given to DSI [15]. Additionally, despite the interest in the nexus between sensory impairment and functional limitations, there is still limited understanding of the underlying mechanisms driving this relationship. Current factors underlying the possible pathways involved in the association between sensory impairment and functional limitations include biological and psychological factors such as chronic conditions [14] and depressive symptoms [20]; however, the role of underlying social and cognitive mechanisms is still unclear and has been underexplored.

The effect of sensory impairment on an individual's social and cognitive health should not be overlooked. Many studies have demonstrated that sensory impairment not only affects the functional capacity of older adults but also leads to markedly worse psychosocial conditions (e.g., social isolation) [21–23] and cognitive

impairment [24, 25]. Previous studies have shown that the social isolation incidence, cognitive impairment incidence, and dementia prevalence are greater among older adults with sensory impairment than among those without sensory impairment [22, 25]. Communication difficulties and decreased social participation due to sensory impairment may lead to impoverished social relationships—i.e., social isolation [23, 26, 27]. Social isolation is defined as an objective deficiency in the quantity of relationships and the frequency of interactions with family, friends, and the broader community [28]. Moreover, sensory impairment may be associated with cognitive impairment through age-related neurological changes (e.g., neurodegeneration of the central nervous system, neuronal atrophy) [29] and vascular changes (e.g., atherosclerosis, microvascular changes) [30, 31].

Social isolation is a recognized risk factor for cognitive decline [32–34]. According to the cognitive reserve hypothesis, social isolation reduces cognitive stimulation, potentially decreasing lower cognitive reserve and increasing the risk of cognitive decline [35]. Neurobiological evidences shows that social isolation is associated with smaller hippocampal volumes and reduced cortical thickness, leading to brain shrinkage and cognitive decline [36]. However, some studies indicated a bidirectional association between social isolation and cognitive function [37, 38]. Additionally, both social isolation and cognitive decline are associated with functional limitations among older adults and a greater burden of disability [32, 39]. Therefore, we hypothesized that social isolation and cognition play mediating roles in the relationship between sensory impairment and functional limitations, insights into the complex relationship.

The biopsychosocial model of the disablement process describes the process of progressive change in which disease and injury lead to limitations (organ function or personal function) and ultimately to functional limitations and disability [40–42]. The disablement process is characterized by personal and environmental factors (risk factors, interventions, and aggravating factors) that accelerate or mitigate functional limitations. To our knowledge, there is a strong correlation between sensory impairment, psychosocial indicators, cognition and functional limitations [43]. Recent studies highlight the crucial role of the social environment in functional limitations, emphasizing a bio-socio-psycho-physical nature model [44, 45]. Considering the above theory and existing research, social isolation and cognition may constitute serial multiple mediating factors influencing the association between sensory impairment and functional limitations; however, this hypothesis requires further research and validation.

In summary, previous studies have demonstrated an association between sensory impairment and functional

limitations in older adults to some extent; however, the mediating effects of social and cognitive mechanisms remain unclear. Consequently, based on the above mentioned theoretical and empirical background, this study proposes a research hypothesis (Fig. 1) to link these variables with functional limitations. This study aims to use nationally representative data to explore the relationship between sensory impairment and functional limitations in older adults, examining the serial mediating effects of social isolation and cognition. Identifying the pathway is essential for interventions and public health policy aimed at mitigating functional limitations among older adults.

Method

Participants

The China Health and Retirement Longitudinal Study (CHARLS) is a nationally representative study of Chinese residents aged 45 years and older. The CHARLS were drawn from a sample of 150 counties in 28 provinces in China by using multistage stratified probability-proportionate-to-size sampling, through one-on-one interviews using a structured questionnaire. The CHARLS began in 2011 (wave 1) with follow-up every 2 years and included information on demographic characteristics, physical health status, mental health status, and socioeconomic status.

The present study was a cross-sectional analysis utilizing data from a population of 19,816 respondents from 2018. This study screened participants and key variables according to previous researches [7, 46]. First, we excluded participants aged 60 years or younger ($n=8912$). Second, we excluded participants with missing functional limitations data ($n=2349$). Third, we excluded individuals with missing values for the main variables (sensory

impairment, social isolation, cognitive scores, and covariates) to acquire complete data ($n=3684$). All covariates, exposures, and outcome data for all participants in the final study sample need to be complete without any missing values. A total of 4871 participants were included in this study.

Dependent variables

The ADL and IADL scales were used to assess functional limitations in older adults. These evaluation tools have widely demonstrated good reliability and validity [4, 5]. The ADL scale comprises six items (dressing, eating, bathing or showering, getting into and out of bed, toileting, and controlling urination and defecation) [3], and the IADL scale includes five items (doing housework, cooking, shopping for groceries, managing money, and taking medication). The four response options were as follows: 1 = ‘No, I do not have any difficulty’; 2 = ‘I have difficulty but can still manage’; 3 = ‘Yes, I have difficulty and need help’; and 4 = ‘I cannot do it’ [47]. The total ADL and IADL scale scores range from 11 to 44, with higher scores indicating greater functional limitations [48]. For example, for an older adult who does not have any difficulty dressing, eating, bathing or showering, or getting into and out of bed (4 points); who has difficulty but can still manage toileting and controlling urination and defecation (4 points); who has difficulty and needs help with doing household chores and needs help with cooking (6 points); and who cannot shop for groceries, manage money, or take medication (12 points), the total functional limitations score is 26.

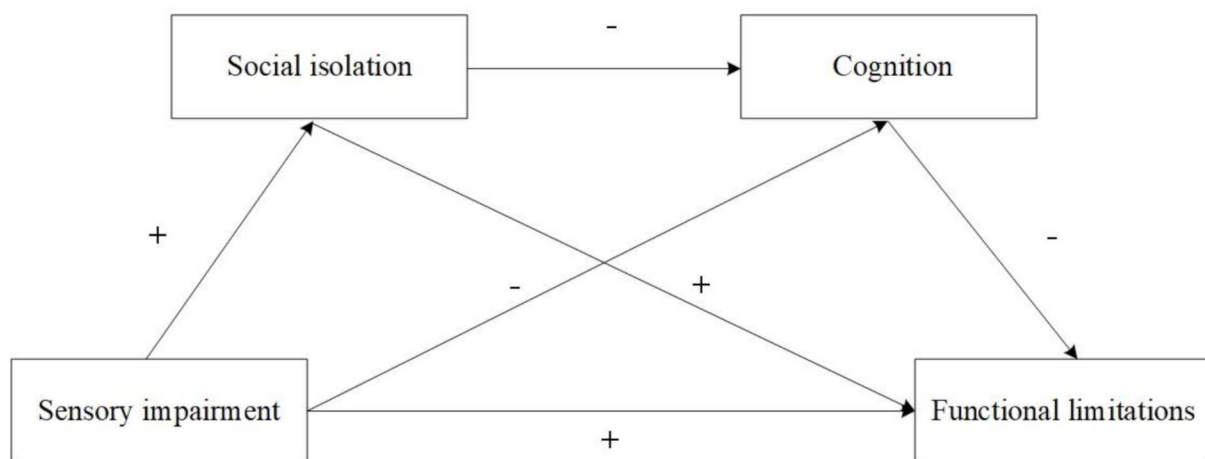


Fig. 1 Model of the serial multiple mediating effects of social isolation and cognition on the association between sensory impairment and functional limitations

Independent variables

Sensory impairment was the independent variable determined through self-reported assessments of vision and hearing function [24]. Similar to the Survey of Health, Aging and Retirement in Europe, CHARLS collected self-reported data on VI included two questions: (1) “How good is your eyesight for seeing things at a distance?” and (2) “How good is your eyesight for seeing things up close?”. Each question was rated on a five-point scale: excellent=1, very good=2, good=3, fair=4, and poor=5. A response of either of the two questions as “fair” or “poor” was classified as having VI. HI was evaluated with the following question: “Is your hearing very good, good, fair, poor, or very poor?”. Respondents reporting “fair” or “poor” hearing were categorized as having HI. DSI was defined as the co-occurrence of VI and HI [23]. According to previous literature [24, 49, 50], this study classified sensory impairment into four groups: no SI, HI only, VI only, and DSI (both HI and VI).

Mediators

The index of social isolation used in the present study was consistent with those used in prior research, and the included items were marital status (currently unmarried), contact with adult children (in person, telephone, or email), residence in a rural area, living alone, and engagement in social activities (e.g., interactions with friends, involvement in community-related organizations, participation in voluntary or charitable work) less than once a month [51]. Scores for this index ranged from 0 to 5, with higher scores indicating a greater degree of social isolation [52].

The Mini-Mental State Examination (MMSE) is a classic tool used to assess cognition, screen for cognitive impairment and dementia and includes items on orientation, memory, attention and computation, and language [53]. The MMSE has good reliability and validity among older Chinese adults [54], and in the CHARLS study, it was administered to subjects using their preferred dialect [55]. Scores for all items range from 0 to 30, with higher scores indicating better cognition [55].

Covariates

Potential confounding variables, including demographic and lifestyle characteristics and health-related factors, were collected via face-to-face self-reports and used in this study [1]. Based on theoretical considerations and empirical findings, covariates were selected [12, 15, 16]. The demographic characteristics included age (≤ 70 , >70), sex (male, female), and educational attainment (≤ 6 years, 6 to <12 years, ≥ 12 years). Lifestyle factors included smoking status (no, yes), alcohol consumption (no, yes), sleep duration (≤ 6 h, 6 to <8 h, ≥ 8 h), and sleep quality (good, bad). Health factors included self-reported

chronic conditions (no chronic condition, one chronic condition, multimorbidity) diagnosed by a doctor, disability (no, yes) and pain status (no, yes).

Statistical analysis

All the statistical analyses were performed using SPSS 25.0 (IBM, Chicago, IL, USA) and Stata 17.0 (StataCorp, College Station, Texas, USA). First, descriptive analysis was used to describe the demographic characteristics of the study population. Second, we tested differences in demographic characteristics by using one-way ANOVAs, χ^2 tests, and Student's t-tests. Third, we investigated the relationship between sensory impairment and functional limitations using multivariate linear regression and a sequential block entry approach. Fourth, due to the non-normal distribution of the data, Spearman correlation analysis was employed to assess the correlations between sensory impairment, functional limitations, social isolation, and cognition. Finally, we used the nonparametric bootstrapping method to test for serial multiple mediating roles of social isolation and cognition between sensory impairment and functional limitations by the SPSS macro PROCESS program in SPSS (Hayes) [56]. Both the causal step and the Sobel test approach have major flaws in testing for mediating effects [57]. Bootstrapping has more power than either of these approaches and provides better control of Type I errors [56]. We conducted adjusted regression models, including the mediation model, by controlling for age, sex, education, chronic condition, sleep duration, sleep quality, disability status, and pain status. All indirect effects were analyzed using 5000 bootstrap samples and 95% confidence intervals (CIs), and significance was indicated when zero was not included in the interval. Subgroup and sensitivity analysis were performed to confirm the results' robustness. $P < 0.05$ (two-tailed) was considered to be statistically significant.

Results

Characteristics of the samples

Table 1 showed that the mean age of the participants was 68.36 years ($SD=6.15$), and 68.12% of whom were less than 70 years. Nearly 50.22% of participants were males, and 49.91% had educational attainment (6 to <12 years). Univariate analysis showed that age, sex, educational attainment, sleep duration, sleep quality, chronic condition, disability status, pain status, sensory impairment, social isolation, and cognition had a statistically significant effect on functional limitations ($P < 0.05$). Notably, the prevalence of VI only, HI only, and DSI was 17.92%, 4.29%, and 70.01%, respectively. Additionally, the prevalence of VI only, HI only, and DSI before addressing missing data was 21.15%, 4.65%, and 59.34%, respectively.

Table 1 Characteristics of the samples (N=4871)

Variables	Mean (SD), or N (%)	Sensory impairment, N (%)				P-value	Functional limitations, mean (SD)	P-value
		No SI	VI only	HI only	DSI			
Sensory impairment								<0.001
No SI	379(7.78)	-	-	-	-		11.87(2.84)	
VI only	873(17.92)	-	-	-	-		12.44(3.38)	
HI only	209(4.29)	-	-	-	-		11.91(2.40)	
DSI	3410(70.01)	-	-	-	-		13.24(3.95)	
Functional limitations, mean (SD)	12.93(3.76)	-	-	-	-	-	-	
Age	68.36(6.15)							
≤70	3318(68.12)	272(8.20)	622(18.75)	137(4.13)	2287(68.93)		12.67(3.45)	
>70	1553(31.88)	107(6.89)	251(16.16)	72(4.64)	1123(72.31)		13.49(4.29)	
Sex						0.001		0.023
Male	2446(50.22)	199(8.14)	391(15.99)	132(5.40)	1724(70.48)		12.81(3.85)	
Female	2425(49.78)	180(7.42)	482(19.88)	77(3.18)	1686(69.53)		13.06(3.65)	
Educational attainment						<0.001		<0.001
≤6 years	917(18.83)	71(7.74)	160(17.45)	30(3.27)	656(71.54)		13.43(3.87)	
6 to < 12 years	2431(49.91)	160(6.58)	410(16.87)	91(3.74)	1770(72.81)		13.06(3.86)	
≥12years	1523(31.27)	148(9.72)	303(19.89)	88(5.78)	984(64.61)		12.44(3.45)	
Sleep duration						0.001		<0.001
≤6 h	2864(58.80)	190(6.63)	489(17.07)	122(4.26)	2063(72.03)		13.06(3.94)	
6 to < 8 h	1586(32.56)	145(9.14)	315(19.86)	72(4.54)	1054(66.46)		12.40(3.12)	
≥8 h	421(8.64)	44(10.45)	69(16.39)	15(3.56)	293(69.60)		13.40(4.40)	
Sleep quality						<0.001		<0.001
Good	2935(60.25)	276(9.40)	530(18.06)	139(4.74)	1990(67.80)		12.48(3.30)	
Bad	1936(39.75)	103(5.32)	343(17.72)	70(3.62)	1420(73.35)		13.61(4.27)	
Chronic condition						<0.001		<0.001
No chronic condition	426(8.75)	44(10.33)	93(21.83)	24(5.63)	265(62.21)		11.69(2.40)	
One chronic condition	904(18.56)	93(10.29)	166(18.36)	46(5.09)	599(66.26)		12.05(2.65)	
Multimorbidity	3541(72.70)	242(6.83)	614(17.34)	139(3.93)	2546(71.90)		13.31(4.05)	
Disability status								
No	4119(84.56)	354(8.59)	788(19.13)	170(4.13)	2807(68.15)	<0.001	12.68(3.44)	<0.001
Yes	752(15.44)	25(3.32)	85(11.30)	39(5.19)	603(80.19)		14.35(4.92)	
Pain status						<0.001		<0.001
No	3744(76.86)	333(8.89)	708(18.91)	177(4.73)	2526(67.47)		12.41(3.15)	
Yes	1127(23.14)	46(4.08)	165(14.64)	32(2.84)	884(78.44)		14.68(4.90)	
Smoking						<0.001		0.450
No	2593(53.23)	197(7.59)	517(19.94)	92(3.55)	1787(68.92)		12.97(3.66)	
Yes	2278(46.77)	182(7.99)	356(15.63)	117(5.14)	1623(71.25)		12.89(3.85)	
Alcohol drinking						<0.001		0.807
No	2519(51.71)	185(7.34)	488(19.37)	85(3.37)	1761(69.91)		12.95(3.64)	
Yes	2352(48.29)	194(8.25)	385(16.37)	124(5.27)	1649(70.11)		12.92(3.88)	
Social isolation, mean (SD)	1.67 (1.10)	1.50(1.13)	1.54(1.10)	1.67(1.45)	1.72(1.09)	<0.001	-	<0.001
Cognition, mean (SD)	22.63(4.55)	23.16(4.51)	23.38(4.43)	22.88(4.41)	22.36(4.57)	<0.001	-	<0.001

Note: -, Not available; Bold type denotes statistical significance (P<0.05)

Abbreviation: N, number; M, mean; SD, standard deviation; SI, sensory impairment; VI only, vision impairment only; HI only, hearing impairment only; DSI, dual sensory impairment.

Correlations among the main variables

As shown in Table 2, the correlation analysis suggested that the main variables were significantly correlated (P<0.001). Sensory impairment was positively associated with functional limitations (P<0.001) and social isolation (P<0.001) and negatively associated with cognition

(P<0.001). Functional limitations were positively associated with social isolation (P<0.001) and negatively associated with cognition (P<0.001). Furthermore, there was a negative correlation between social isolation and cognition (P<0.001).

Table 2 Correlations among sensory impairment, functional limitations, social isolation, and cognition (N=4871)

Variables	Sensory impairment	Functional limitations	Social isolation	Cognition
Sensory impairment	1.000			
Functional limitations	0.121***	1.000		
Social isolation	0.077***	0.116***	1.000	
Cognition	-0.086***	-0.221***	-0.294***	1.000

Note: * $P < 0.05$ (two-tailed); ** $P < 0.01$ (two-tailed); *** $P < 0.001$ (two-tailed)

The association between sensory impairment and functional limitations

As shown in Table 3, Model 1 revealed that older adults with DSI had a significantly greater functional limitations level than did those without sensory impairment ($P < 0.001$). Model 2 showed the association between the DSI and functional limitations when adjusting for confounding variables ($P < 0.001$). The results showed that from Model 1 to Model 2, the direction in which the DSI correlated with functional limitations did not change and was significant, indicating that the DSI was a significant factor influencing functional limitations in older Chinese adults.

Mediation analysis of sensory impairment and functional limitations

Sensory impairment had a significant and positive association with functional limitations ($B = 0.615$, BCa 95% CI: 0.397, 0.834) (Fig. 2a). The coefficient of sensory impairment and functional limitations decreased when controlling for social isolation and cognition ($B = 0.537$, BCa 95% CI: 0.321, 0.752) (Fig. 2b), which accounted for 87.19% of the total effect. According to Table 4, when social isolation and cognition were modeled as mediators, the path coefficients of sensory impairment on functional limitations showed that social isolation and cognition had a significant mediating effect.

In the first indirect pathway ($a_1 \times b_1$), social isolation significantly mediated the effect of sensory impairment on functional limitations, accounting for 2.52% of the total effect. The second indirect pathway ($a_2 \times b_2$) indicated that the impact of sensory impairment on functional limitations was significantly mediated by cognition, with an effect value of 0.051, constituting 8.21% of the total effect. In the third indirect pathway ($a_1 \times a_3 \times b_2$), the effect of sensory impairment on functional limitations was significantly mediated by social isolation and cognition, with an effect value of 0.013. The above results indicated that social isolation and cognition play multiple mediating roles in the association between sensory impairment and functional limitations.

Subgroup analysis based on age is presented in Table S1. The serial multiple mediating of social isolation and cognition on sensory impairment and functional limitations still holds in the ≤ 70 years subgroup. Furthermore, analysis of the model before handling the main missing data also produced comparable results. The total indirect effect of DSI on functional limitations was 0.093 ($P < 0.001$) or 16.03% of the total effect (Table S2 and Fig. S1).

Discussion

In this study, we examined the underlying processes that influence the relationship between sensory impairment and functional limitations in older Chinese adults, and we observed that social isolation and cognition mediated this relationship. It's important to note that mediation analysis in cross-sectional studies is exploratory in nature, and causality cannot be inferred [58]. Exploring the effects of social isolation and cognition on sensory impairment and functional limitations can provide valuable insights for preventive interventions targeting functional limitations.

This study revealed a significant positive correlation between sensory impairment and functional limitations among older adults in China, which is consistent with the findings of previous studies [14, 59]. After controlling for covariates, regression analysis demonstrated that DSI had a significant and positive association with functional limitations, while VI and HI had no significant association with functional limitations, which was similar to results reported in previous studies [15, 60]. The combination of HI and VI has a more significant positive role in functional limitations [61, 62]. For example, a study of the Longitudinal Study on Aging (LSOA) demonstrated that high levels of DSI were shown to increase the risk of difficulty in preparing meals, shopping, and using the telephone than single sensory impairment [59]. Therefore, outreach should be expanded on the prevention, identification, and comprehensive health programs for older adults with sensory impairment, which will likely contribute to the maintenance of good health in older adults.

We found that social isolation significantly mediated the relationship between DSI and functional limitations, which was consistent with previous work [14, 15, 21]. The disablement process model emphasizes that social factors such as social isolation may mediate the pathway from disease accumulation to functional limitations [63]. These findings support that associating sensory impairment with functional limitations through social isolation is a reasonable pathway, which is consistent with previous research [21]. The World Health Organization (WHO) designated the period 2020–2030 as the Decade of Healthy Aging, stating that the ability to maintain optimal activities of daily living and environments conducive

Table 3 Association between sensory impairment and functional limitations (N=4871)

Variables	Model 1					Model 2					
	B	SE	β	t	ULCI	B	SE	β	t	LLCI	ULCI
Sensory impairment											
No SI											
VI only	0.282	0.217	0.029	1.303	-0.142	0.349	0.213	0.036	1.639	-0.068	0.767
HI only	-0.256	0.303	-0.014	-0.845	-0.851	-0.345	0.298	-0.019	-1.158	-0.930	0.239
DSI	0.722***	0.192	0.088	3.755	0.345	0.664***	0.189	0.081	3.510	0.293	1.034
Age											
≤70											
>70	0.722***	0.109	0.090	6.639	0.509	0.540***	0.108	0.067	4.989	0.328	0.752
Sex											
Male											
Female	-0.077	0.106	-0.010	-0.722	-0.285	-0.186	0.105	-0.025	-1.769	-0.391	0.020
Educational attainment											
≤6 years											
6 to <12 years	0.157	0.126	0.019	1.249	-0.090	0.672***	0.130	0.080	5.173	0.418	0.927
≥12years	-0.369**	0.124	-0.046	-2.964	-0.612	0.476**	0.139	0.059	3.431	0.204	0.747
Sleep duration											
≤6 h											
6 to <8 h	-0.224	0.116	-0.028	-1.934	-0.450	-0.247*	0.114	-0.031	-2.176	-0.470	-0.025
≥8 h	0.646**	0.188	0.048	3.433	0.277	0.394*	0.186	0.029	2.117	0.029	0.758
Sleep quality											
Good											
Bad	0.649***	0.111	0.085	5.826	0.431	0.531***	0.110	0.069	4.832	0.316	0.747
Chronic condition											
No chronic condition											
One chronic condition	0.171	0.207	0.018	0.829	-0.234	0.163	0.203	0.017	0.802	-0.236	0.562
Multimorbidity	1.010***	0.182	0.120	5.536	0.652	1.097***	0.180	0.130	6.099	0.744	1.449
Disability											
No											
Yes	1.256***	0.141	0.121	8.902	0.979	1.147***	0.139	0.110	8.253	0.874	1.419
Pain status											
No											
Yes	1.788***	0.125	0.201	14.348	1.544	1.668***	0.123	0.187	13.561	1.427	1.909
Social isolation											
Cognition											
						0.114*	0.052	0.031	2.193	0.012	0.216
						-0.161***	0.013	-0.195	-12.335	-0.186	-0.135

Table 3 (continued)

Variables	Model 1				Model 2							
	B	SE	β	t	LLCI	ULCI	B	SE	β	t	LLCI	ULCI
F	51.35***						57.19***					
Adjusted R ²	0.129						0.159					

Note: Model 1 investigated the association between sensory impairment and functional limitations when adjusting for covariates and mediators limitations when adjusting for covariates and mediators

Abbreviation: B, unstandardized coefficient; SE, standard error; β , standardized coefficient; LLCI=low limit confidence interval; ULCI=upper limit confidence interval; Adj=adjusted; SI, sensory impairment; VI only, vision impairment only; HI only, hearing impairment only; DSI, dual sensory impairment. * $P < 0.05$ (two-tailed); ** $P < 0.01$ (two-tailed); *** $P < 0.001$ (two-tailed)

to better social connectedness are both important components of healthy aging [64]. Therefore, older adults with sensory impairment could be encouraged to promote social integration through greater social networks and social participation and improve their functional abilities. Additionally, recent attention has focused on left-behind older adults, who are at higher risk of physical, psychological, and social function limitations [65, 66]. As urbanization accelerates, addressing social isolation and the left-behind phenomenon is crucial to reducing functional limitations among older adults.

We also found that cognition mediates the relationship between DSI and functional limitations. The present findings concur with previous studies demonstrating associations between DSI and cognition [61] and between cognition and functional limitations [67]; however, these studies have not taken into account the mediating role of cognition. Thus, this finding added new knowledge to the existing literature that DSI indirectly affects functional limitations through cognition in older adults. A possible explanation is that sensory impairment could be associated with a higher risk of functional limitations through mechanistic pathways involving their effects on cognitive load [68]. The sensory impairment may cause an increase in the cognitive resources required for processing the degraded auditory signals, which may lead to a higher burden on cognition [69]. Moreover, if an older adult is unable to bathe independently (ADL), it might be because of a cognitive deficit that limits their ability to perform this task in a sequential manner [67]. Thus, these findings provided new insights into the moderation of cognition on sensory impairment and functional limitations; namely, promoting early cognitive health maintenance in older adults with sensory impairment may help prevent the onset of functional limitations.

This study revealed serial multiple mediating effects of social isolation and cognition in the pathway between DSI and functional limitations, either alone or in combination. Studies have suggested that the relationship between social isolation and cognitive function is complex and bidirectional [37, 70]. Social isolation can lead to reduced cognitive reserve and brain function atrophy [71, 72], while cognitive impairment can cause social withdrawal and barriers to interaction, resulting in social isolation [73]. Given these overlaps, it is plausible that social isolation and cognition might mediate the relationship between sensory impairment and functional limitations among older adults. Specifically, patients with DSI perceived higher levels of social isolation, followed by lower levels of cognition and, as a result, higher levels of functional limitations. According to the sensory loss consequence theory [74], sensory impairment reduces the ability to engage in activities, which may reduce brain stimulation and neural reorganization, increase

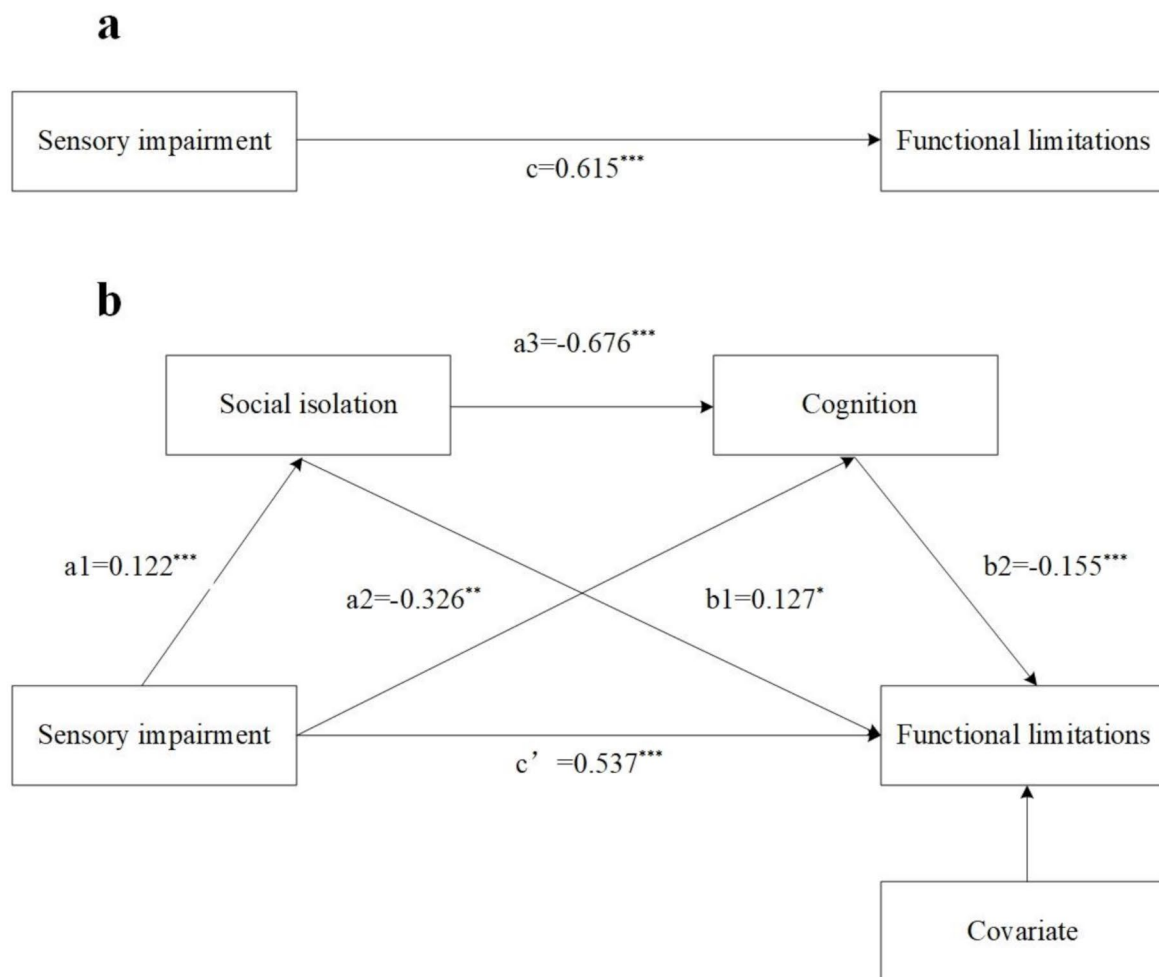


Fig. 2 Serial mediation models for sensory impairment, functional limitations, social isolation, and cognition. Note: Path coefficients were expressed as the standardized regression coefficient. * $P < 0.05$ (two-tailed); ** $P < 0.01$ (two-tailed); *** $P < 0.001$ (two-tailed)

Table 4 Hypothesized serial mediation model of social isolation and cognition between sensory impairment and functional limitations

Pathway	Effect	SE	BootLLCI	BootULCI	p-value	Proportion of effect (%)
Total effect (c)	0.615***	0.112	0.397	0.834	<0.001	100.00%
Direct effect (c')	0.537***	0.110	0.321	0.752	<0.001	87.19%
a1	0.122***	0.031	0.062	0.183	<0.001	-
a2	-0.326**	0.122	-0.565	-0.088	0.007	-
a3	-0.676***	0.057	-0.788	-0.565	<0.001	-
b1	0.127*	0.052	0.025	0.229	0.015	-
b2	-0.155***	0.013	-0.180	-0.129	<0.001	-
Total indirect effects	0.079	0.022	0.039	0.124	-	12.81%
Indirect 1 (a1×b1)	0.016	0.007	0.004	0.032	-	2.52%
Indirect 2(a2×b2)	0.051	0.019	0.014	0.089	-	8.21%
Indirect 3 (a1×a3×b2)	0.013	0.004	0.006	0.020	-	2.08%

Note: Model control for age, education, chronic condition, sleep duration, sleep quality, disability and pain status

Abbreviation: SE, standard error; Effect, standardized regression coefficient; BootLLCI, bootstrapping lowerlimitconfidence interval; BootULCI, bootstrapping upperlimitconfidence interval. * $P < 0.05$ (two-tailed); ** $P < 0.01$ (two-tailed); *** $P < 0.001$ (two-tailed)

perceived social isolation, and subsequently be associated with cognitive decline, finally affecting functional limitations [26, 75]. The present study demonstrated that the disablement process as a framework theory for exploring sensory impairment affecting functional limitations in older adults is reasonable, with social isolation and cognition as key links in this relationship [76]. Recent studies have integrated social environmental factors into disability model, exploring associations between individual, social interactions, cognitive function, and socio-cultural and socio-structural environments [44, 77]. For older adults with sensory impairment, physical and social barriers such as lack of assistive products and rehabilitation services must be considered [44, 45]. Multimodal interventions addressing biological, psychological, social, and physical environments are recommended to mitigate the effects of sensory impairment on functional limitations.

The findings of this study have important implications for public health. First, although sensory impairment is common in older adults, encouraging older adults to prevent, reduce, and correct sensory impairment by auxiliary equipment (eyeglasses, hearing aids) and changes in home and social environments to enhance their social relationships and cognitive abilities, ultimately reducing functional limitations. Second, older adults are encouraged to maintain contact with family members and friends to prevent social isolation and cognitive decline, which can delay or prevent functional limitations and improve their quality of life. Finally, health promotion activities should be developed to increase awareness among older adults regarding functional limitations and promote healthy aging.

This study has several limitations. Firstly, the use of cross-sectional data restricts the ability to establish causality during the mediation analysis, and the conclusion may only be explained by statistics [78]. The cross-sectional nature of this study also limits the ability to identify the causality or directionality of the relationships mentioned above despite the theoretical grounding of the mediated pathways. Therefore, further exploration of the temporal mechanism and causal relationships underlying sensory impairment and functional limitations is necessary through longitudinal or experimental studies in the future. Secondly, although some research supports the reliability of self-reported sensory impairment [21, 22], there are differences in assessments between self-reported and clinical data. Hence, in future research, it is advisable for investigators to consider using objective measurement methods, which could provide a valuable area for further investigation. Fourthly, this study lacks data on physical and social environmental correlates, limiting our exploration of their relationship with functional limitations. Future research should include correlates such as public health policies, infrastructure, and

healthcare models. Fifthly, MMSE scores may not distinguish whether task failure is due to sensory impairment or cognitive impairment, potentially misestimating cognitive function. In clinical practice, using cognitive test tools suitable for patients with sensory impairment can provide a more accurate assessment. Sixthly, the exclusion of participants lacking data on the main variables may have introduced selection bias. Therefore, additional studies with better data are needed to test the scientific validity of the results obtained in this study. Lastly, it is important to note that this study was limited to the older Chinese population, and the generalizability of the findings needs to be verified in other ethnic populations in the future.

Conclusion

This study explored the mechanism of the effects of sensory impairment, social isolation, and cognition on functional limitations in older adults. Social isolation and cognition partially mediated the association between sensory impairment and functional limitations. Future intervention programs should focus on mitigating social isolation and maintaining cognitive health to prevent functional limitations among older adults with sensory impairment. Additionally, longitudinal research is needed to assess the impact of such integrated interventions on the prevention of functional limitations.

Supplementary Information

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Supplementary Material 1

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Author contributions

This study was conceived by B X. and W-h J. Project administration and data curation were completed by B X., Y-x W., Y-x H., J-x L., S Y., and P-p S. Formal analysis was completed by B X., Y-x W., D Z. and H S. B X., Y-x H. and W-h J. wrote the initial draft. All authors participated in reviewing and editing the manuscript. The author(s) read and approved the final manuscript.

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Data availability

The data underlying this article are available in a public, open access repository, and can be accessed at China Health and Retirement Longitudinal Study (CHARLS) <http://charls.pku.edu.cn/index/en.html>.

Declarations

Ethics approval and consent to participate

The ethical review committee of Peking University approved CHARLS and informed consents are signed by participants before their participation (No. IRB00001052-11015).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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