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Frailty as a mediator between sleep quality and cognitive impairment among the rural older adults: a cross-sectional study

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Abstract

Background Cognitive impairment is a common health problem among older adults. Previous studies have proven the association between sleep quality and cognitive impairment, but the specific underlying mechanisms need to be further explored. This study aimed to examine the relationship between sleep quality and cognitive impairment and the mediating effect of frailty in this relationship among the rural older adults.

Methods Data from a cross-sectional study conducted in rural areas of Shandong Province from September to December in 2023. A total of 695 rural older adults were included. The Pittsburgh Sleep Quality Index (PSQI) was used to measure sleep quality. Frailty was defined using the FRAIL scale. We assessed cognitive impairment using the Dementia Screening Interview (AD8). Logistic regression analyse was used to assess the relationship between sleep quality and cognitive impairment. And the Karlson-Holm-Breen (KHB) method was performed to test the mediating role of frailty in this relationship.

Results After adjusting for all covariates, sleep quality was significantly associated with cognitive impairment (OR = 1.047, 95% CI: 1.005—1.090). Frailty mediated the relationship between sleep quality and cognitive impairment, with a mediation effect value of 0.010 (95% CI: 0.001—0.020), accounting for 17.86% of the total effect.

Conclusions We found there was an association between sleep quality and cognitive impairment, and frailty mediated the above relationship. Comprehensive intervention measures should be taken to reduce the incidence of frailty in the older adults and to improve their sleep quality, thereby preventing and delaying the occurrence and development of cognitive impairment.

Keywords Sleep quality, Frailty, Cognitive impairment

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Background

Currently, population aging has become a major public health problem facing the world [1]. As one of the countries with the most serious aging population, the proportion of older adults aged 65 and above in China has reached 13.50% [2]. Cognitive impairment refers to different degrees of cognitive decline caused by various reasons, ranging from mild cognitive impairment to dementia [3]. In China, up to 19% of older adults suffered from mild cognitive impairment, with higher prevalence in rural than urban areas [4, 5]. Cognitive impairment can impair the physical and mental health of older adults and place a heavy financial and care burden on their families. There was evidence that cognitive impairment can be reversed by effective interventions [6]. Therefore, it is imperative to explore the risk factors and underlying mechanisms that provide a theoretical basis for the prevention and intervention of cognitive impairment.

Sleep quality is a comprehensive indicator that combines subjectivity and objectivity to evaluate how well an individual sleeps [7]. A Meta-analysis showed that the prevalence of sleep disorders among the older adults in rural areas of China was 44%, which was higher than that in urban areas [8]. Long-term sleep disorders can increase the risk of cardiovascular and cerebrovascular diseases, anxiety, depression and other mental disorders [9–11]. Several studies in the United States and Germany found that the older adults with poor sleep quality were more likely to suffer from cognitive impairment [12–14]. A previous cross-sectional study conducted in China also supported this association [15]. Furthermore, sleep problems may have a greater impact on cognitive function than other factors [16]. Although the relationship between sleep quality and cognitive impairment has been widely noted, the underlying mechanisms of this relationship are still unclear.

Frailty is a common age-related clinical syndrome characterized by the loss of physiological reserve and resistance to stressors as a result of the cumulative decline of multiple physiological systems [17]. It can significantly increase the risk of adverse events, such as falls, fractures and even death [18], seriously threatening the health of older adults. A study based on the data from wave 2018 of the China Longitudinal Study of Health and Retirement (CHARLS) showed that the proportion of older adults with frailty in China reached 23.59% [19], which was higher than that in other countries [20]. An increasing body of studies confirmed the association between sleep quality and frailty [21, 22]. Existing research has suggested that sleep disorders as well as some specific adverse sleep problems were related to an increased rate of frailty [23]. Meanwhile, prior literature has demonstrated that frailty may be a risk factor for cognitive function, and the older adults with frailty were more likely to experience cognitive decline [24, 25]. Furthermore, previous results have shown that frailty plays a mediating role between certain factors and cognitive impairment [26, 27]. Therefore, we hypothesized that frailty may be one of the underlying mechanisms between sleep quality and cognitive impairment.

The purposes of this study are as follows: (1) to investigate the association between sleep quality and cognitive impairment among rural older adults; (2) to explore whether frailty is a mediator in the above relationship. 71–75 years old is a sensitive period of cognitive aging [28]. It is significant to intervene and delay the decline of cognitive function.

Methods

Sample selection

The study was conducted in Shandong Province from September to December in 2023. The subjects were selected by a stratified random sampling method. The first stage was to select sample cities according to the low, middle and high levels of economic development. Consequently, Linyi, Zibo, Dezhou were chosen as sample areas. The second stage was to select 3 districts (counties) randomly in each city and exact 4 townships (streets) in each selected district (county), and then choose 6 villages (communities) from each township (street). The third stage was to choose 10–15 residents randomly from each village (community) for the survey. Finally, a total of 2432 questionnaires were distributed, and 2415 valid questionnaires were recovered, with a response rate of 99.3%.

The rural older adults aged ≥ 70 years were selected from the valid questionnaires as our study sample ($N=986$). We excluded patients with severe hearing, visual and communication (i.e., verbal expression) impairments, psychiatric disorders and serious physical illnesses, and participants who withdrew or gave incomplete answers. The size of final sample was 695. Our investigators have undergone unified training (including explaining each item of the questionnaire in detail and giving some examples of items based on the subjects' actual life), and conducted face-to-face interviews with the subjects on the spot. The study was approved by the Medical Ethics Committee of Weifang Medical University (2021YX-066), and performed in accordance with approved guidelines. Written informed consent was obtained from each participant before the survey.

Measures

Cognitive function

Cognitive function was assessed using the Dementia Screening Interview (AD8), developed by the University

of Washington, which contains 8 items. The total scores range from 0 to 8, with higher scores being associated with more severe cognitive impairment. According to the previous literature, a score of ≥ 2 indicates the very early cognitive impairment [29].

Sleep quality

We used the Pittsburgh Sleep Quality Index (PSQI) developed by Buysse et al. [30] to assess the sleep quality of the rural older adults. The questionnaire consists of 7 dimensions, and the score of each dimension ranges from 0 to 3, with a total score of 21. The higher scores reflect the worse sleep quality. A score of ≥ 6 is considered to have a sleep disorder [31].

Frailty

The FRAIL scale was used to assess the frailty status of the participants. The scale consists of 5 items with a full score of 5. The higher the score, the more severe the frailty status. Scores of 0, 1–2 and ≥ 3 indicate nonfrail, prefrail and frail, respectively [32].

Covariates

According to previous relevant literature [33–36], we included several control variables, such as gender (male, female), age (70–74 years, 75–79 years, 80–84 years, ≥ 85 years), marital status (currently married, others), education level (primary school and below, junior high school, senior high school and above) and the number of chronic diseases (0, 1, ≥ 2).

Statistical analysis

First, descriptive analysis was used to describe the socio-demographic characteristics of the participants. Chi-square test and Mann–Whitney U test were used to compare the cognitive impairment status between different subgroups. Then, a causal steps approach proposed by Baron and Kenny [37] was used to analyze the relationship among sleep quality, frailty and cognitive impairment: (1) multiple ordinal logistic regression analysis was employed to test the association between sleep quality and frailty. (2) binary logistic regression analysis was performed to explore the association between sleep quality and cognitive impairment, and (3) binary logistic regression was used to further test the relationship between sleep quality and cognitive impairment when frailty was included as the mediator. At last, based on the Karlson-Holm-Breen (KHB), we examined the mediating effect of frailty. This method allows us to decompose the total and direct effects of sleep quality on cognitive impairment, and the indirect effect through frailty. If 0 was not included in the 95% confidence interval (CI), the mediating effect was considered statistically significant. All statistical analyses were performed by SPSS 26.0 and Stata 17.0. $P < 0.05$ (two-tailed) was defined as the significance level.

Results

Basic information of participants

Table 1 shows that of all the rural older adults surveyed, 63.88% were female, 53.81% were aged 70–74 years, and the majority of the rural older adults were currently married (73.09%). Generally speaking, the education level of the participants was low, with 77.99% of them having the highest education level of primary school and below. 35.40% of the participants had one chronic disease. 53.09% were patients with comorbid chronic diseases. The major chronic diseases were hypertension (71.5%) and diabetes (25.2%). The prevalence of sleep disorders, frailty and cognitive impairment was 40.14%, 26.91% and 61.29%, respectively. Compared with older adults without cognitive impairment, those with cognitive impairment had a higher proportion of female, less education, sleep disorders and frailty. More information was shown in Table 1.

Associations of sleep quality and frailty

As shown in Table 2, after adjusting for gender, age, marital status, education and number of chronic diseases, sleep quality was significantly associated with frailty (OR = 1.036, 95% CI: 1.002—1.071). The odds of reporting frailty increased with the scores of sleep quality. Table 3 shows that frailty mediated the association between sleep quality and cognitive impairment. Model 1 displayed that sleep quality was related to cognitive impairment (OR = 1.054, 95% CI: 1.013—1.096). When frailty was included as a mediator in Model 2, sleep quality was still significantly associated with cognitive impairment (OR = 1.047, 95% CI: 1.005—1.090). Moreover, as shown in Table 4, the results of the mediation analysis based on the KHB method presented that the total effect, direct effect, and indirect effect were statistically significant. The total effect of sleep quality on cognitive impairment was partially explained by frailty, with the indirect effect accounting for 17.86% of the total effect. Figure 1 shows the mediation pathway model.

Discussion

The current study examined the relationship between sleep quality and cognitive impairment in rural older adults, and explored the mediating role of frailty in this relationship for the first time. Our finding revealed that sleep quality was significantly associated with cognitive impairment. The older adults with worse sleep quality had a higher risk of cognitive impairment. In addition,

Table 1 Characteristics of the participants by cognitive impairment ($N=695$)

Variable	N (%)	Cognitive impairment		x^2/Z	*P*-value
		No (%)	Yes (%)		
Observations	695 (100)	269 (38.71)	426 (61.29)		
Gender				48.266	< 0.001
Male	251 (36.12)	140 (55.78)	111 (44.22)		
Female	444 (63.88)	129 (29.05)	315 (70.95)		
Age				2.729	0.435
70–74	374 (53.81)	144 (38.50)	230 (61.50)		
75–79	208 (29.93)	87 (41.83)	121 (58.17)		
80–84	87 (12.52)	31 (35.63)	56 (64.37)		
≥ 85	26 (3.74)	7 (26.92)	19 (73.08)		
Marital status				3.322	0.068
Currently married	508 (73.09)	207 (40.75)	301 (59.25)		
Others[a]	187 (26.91)	62 (33.16)	125 (66.84)		
Education				21.823	< 0.001
Primary school and below	542 (77.99)	185 (34.13)	357 (65.87)		
Middle school	126 (18.13)	70 (55.56)	56 (44.44)		
High school and above	27 (3.88)	14 (51.85)	13 (48.15)		
Number of chronic diseases				4.661	0.097
0	80 (11.51)	34 (42.50)	46 (57.50)		
1	246 (35.40)	106 (43.09)	140 (56.91)		
≥ 2	369 (53.09)	129 (34.96)	240 (65.04)		
Sleep disorders				9.099	0.003
No	416 (59.86)	180 (43.27)	236 (56.73)		
Yes	279 (40.14)	89 (31.90)	190 (68.10)		
Frailty status				55.042	< 0.001
Nonfrail	284 (40.86)	154 (54.23)	130 (45.77)		
Prefrail	224 (32.23)	75 (33.48)	149 (66.52)		
Frail	187 (26.91)	40 (21.39)	147 (78.61)		

[a] Others includes single, divorced and widowed

consistent with our hypotheses, frailty mediated the relationship between sleep quality and cognitive impairment in rural older adults.

The prevalence of cognitive impairment among rural older adults in this study was 61.29%, which was higher than the results of other studies [38]. We consider the possible reasons are as follows: Firstly, age is one of the important risk factors for cognitive impairment. The prevalence of cognitive impairment may increase with age. Our subjects were older adults aged ≥ 70 years. It has been shown that the manifestations of cognitive decline were particularly marked in this phase [39], which may contribute to the high prevalence of cognitive impairment in our study. Secondly, previous studies have demonstrated that rural older adults had a higher prevalence of cognitive impairment than urban older adults [5]. It may be the result of certain environmental factors unique to rural areas. The rural residents are characterized by a generally low level of education. As an important factor affecting cognitive function, the lower the level of education, the higher the risk of cognitive impairment [40]. This connection may be due to the fact that people with low levels of education have poorer learning ability and less knowledge, which can accelerate cognitive decline [41]. Prior research indicated that social participation was a protective factor for cognitive function [42]. The economic status of an individual was closely related to patterns of social participation [43]. Rural residents with lower income levels may be forced to spend more time working, which can reduce their time and opportunities for social engagement, thereby negatively impacting cognitive function. In addition, the type of work can also affect cognitive function to some extent [44]. Most rural older adults are or were engaged in individual, agriculture-based physical labor, which may stimulate the cerebral cortex less and make them more susceptible to cognitive impairment.

Table 2 Analysis of influencing factors of frailty ($N=695$)

Variable	*β*	SE	Wald	*P*-value	OR (95%CI)
Gender					
Male	1.000				
Female	0.609	0.165	13.577	< 0.001	1.389 (1.330, 2.540)
Age					
70–74	1.000				
75–79	0.063	0.165	0.147	0.701	1.065 (0.771, 1.473)
80–84	0.420	0.228	3.409	0.065	1.522 (0.974, 2.377)
≥ 85	0.541	0.388	1.950	0.163	1.718 (0.804, 3.673)
Marital status					
Currently married	1.000				
Others	0.230	0.169	1.835	0.176	1.259 (0.902, 1.754)
Education					
Primary school and below	1.000				
Middle school	-0.253	0.205	1.525	0.217	0.776 (0.519, 1.161)
High school and above	-0.136	0.383	0.126	0.723	0.873 (0.412, 1.848)
Number of chronic diseases					
0	1.000				
1	0.284	0.250	1.290	0.256	1.328 (0.814, 2.166)
≥ 2	0.730	0.241	9.156	0.002	2.075 (1.293, 3.327)
Sleep quality	0.035	0.017	4.308	0.038	1.036 (1.002, 1.071)

The results of this study suggested that poor sleep quality was a risk factor for cognitive impairment after controlling for relevant demographic variables, which was consistent with previous studies [45, 46]. In terms of biological mechanisms, sleep disorders can impede the generation of cortical interstitial space, reduce the clearance rate of Aβ substances from the brain, and then lead to cognitive decline [47]. Moreover, insufficient sleep can lead to increased body secretion of cortisol and day and night rhythm disorders, which may also accelerate cognitive aging [48] and even trigger cognitive impairment. In addition, poor sleep quality can lead to daytime fatigue, difficulty keeping the mind awake, trouble concentrating and memory impairment, affecting overall cognitive function [49].

Our study also investigated that frailty was a mediator in the relationship between sleep quality and cognitive impairment among the rural older adults. This finding provided a new addition to the existing literature. That is to say, sleep quality can affect cognitive function through frailty status. On the one hand, poor sleep quality can lead to frailty of older adults. Poor sleep quality and insufficient sleep can reduce the secretion of growth hormone, IGF-1 and testosterone, promote muscle proteolysis [50], and even lead to sarcopenia [51], accelerating frailty. Meanwhile, sleep disorders can increase the daytime fatigue of older adults, weaken their mobility, lower their immunity and increase their metabolic abnormalities, raising the risk of frailty [52]. On the other hand, frailty was associated with a higher risk of cognitive impairment. One plausible explanation is that frailty can limit older adults' social participation and executive abilities. While social participation, to some extent, plays a protective role in cognitive function [53]. Increasing evidence indicates that that social participation activities can stimulate the nervous system of older adults, promote the metabolism of brain cells and help them maintain a stable state of cognitive function [54]. At the same time, social participation can also help older adults alleviate negative emotions and form a positive attitude and behavioral lifestyle, which is important for cognitive function [55]. In addition, prior studies have found that frailty index was related to atrophy of the temporal and frontal cortices [56], which are both regions of the cerebral cortex associated with cognitive function [57], suggesting that frailty may be a predictor of cognitive decline.

In conclusion, cognitive function can be affected by sleep quality through multiple mechanisms. Adverse sleep problems, such as difficulty falling asleep, sleep deprivation, etc., may lead to functional limitations or disability [58], and further lead to subsequent cognitive impairment. Embodied cognition theory suggests that the body is the basis of cognition. Cognition is formed in the process of interaction between an individual's body and the environment [59]. However, fatigue, resistance,

Table 3 Analysis of the association between sleep quality and cognitive impairment ($N=695$)

Variable	Cognitive impairment			
	Model 1 (without mediator)		Model 2 (with mediator)	
	OR (95%CI)	*P*-value	OR (95%CI)	*P*-value
Gender				
Male	1.000		1.000	
Female	2.656 (1.861, 3.790)	< 0.001	2.390 (1.657, 3.448)	< 0.001
Age				
70–74	1.000		1.000	
75–79	0.826 (0.571, 1.195)	0.310	0.817 (0.559, 1.195)	0.298
80–84	1.089 (0.649, 1.829)	0.747	1.014 (0.592, 1.736)	0.959
≥ 85	1.816 (0.708, 4.661)	0.214	1.620 (0.623, 4.211)	0.322
Marital status				
Currently married	1.000		1.000	
Others	1.054 (0.715, 1.554)	0.790	1.008 (0.676, 1.501)	0.971
Education				
Primary school and below	1.000		1.000	
Middle school	0.635 (0.410, 0.984)	0.042	0.672 (0.429, 1.053)	0.083
High school and above	0.651 (0.286, 1.482)	0.307	0.670 (0.287, 1.563)	0.354
Number of chronic diseases				
0	1.000		1.000	
1	0.992 (0.578, 1.703)	0.976	0.931 (0.537, 1.614)	0.798
≥ 2	1.301 (0.770, 2.198)	0.326	1.099 (0.642, 1.882)	0.731
Sleep quality	1.054 (1.013, 1.096)	0.009	1.047 (1.005, 1.090)	0.027
Frailty status				
Nonfrail			1.000	
Prefrail			2.175 (1.492, 3.172)	< 0.001
Frail			3.397 (2.187, 5.276)	< 0.001

Table 4 Direct and indirect effect of sleep quality and frailty on cognitive impairment

Effect	*β*	SE	Z	*P*-value	95%CI		Mediation (%)
					Lower	Upper	
Sleep quality-Frailty-Cognitive impairment							
Total effect	0.056	0.021	2.74	0.006	0.016	0.097	
Direct effect	0.046	0.021	2.23	0.026	0.006	0.086	
Indirect effect	0.010	0.005	2.14	0.033	0.001	0.020	17.86%

walking and other specific components of frailty may act as substrates to hinder or even interrupt this process, thus negatively affecting individuals' cognitive function. Therefore, frailty may increase the risk of subsequent cognitive impairment among older adults with poor sleep quality.

The proportion of the mediating effect (frailty) in our study was relatively low, accounting for 17.86% of the total effect. It may be attributed to the relatively small size of the sample aged ≥ 80 years, which may weaken the associations between sleep quality, frailty and cognitive impairment, as well as the value of the mediating effect. Frailty may be influenced by variables associated with it but not observed in this study, which may offset a part of its mediating effect. In addition, there may be other potential mechanisms between sleep quality and cognitive impairment. Frailty was only one of several mediating variables between the two variables.

Our study has some implications for the prevention and intervention strategies of cognitive impairment.

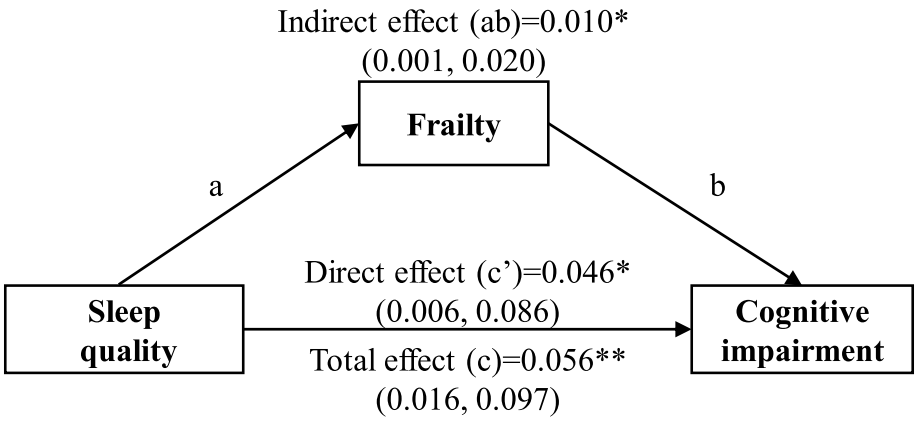

Fig. 1 Path diagram of the association between sleep quality and frailty as a mediator. Notes: ***P*-value < 0.01, **P*-value < 0.05. 95% CIs in the parentheses are shown. Models control for gender, age, marital status, education and number of chronic diseases

Firstly, grass-roots medical personnel should strengthen the monitoring and screening of the sleep quality and frailty status of rural older adults, so that timely intervention measures can be taken to effectively prevent and delay the occurrence and development of sleep disorders and frailty. In addition, older adults should be encouraged to actively participate in social activities, such as playing cards, chess and Mahjong. They should also take proper physical exercises, such as playing Tai Chi and walking slowly. These can help them maintain a healthy physical and mental state, thereby preventing the occurrence of frailty.

There were several limitations in this study. Firstly, this study was a cross-sectional study and the causality cannot be ascertained. A large-scale longitudinal study should be conducted in the future for further validation. Secondly, the proportion of the mediating effect (frailty) in our study was relatively low. Future studies aim to explore additional factors to more systematically explain the relationship between sleep quality and cognitive impairment. Thirdly, using self-reported scales to assess variables may be subject to recall bias and reporting bias. Fourthly, some possible confounders, such as depressive symptoms and social activity in daytime activities, were not included in the statistical models. In the future, they should be fully considered and supplemented for more detailed analysis. Fifthly, the AD8 scale used in the current study was not sufficient to comprehensively assess the cognitive function of an individual. Future research should consider using it in combination with other tools. Sixthly, the influence of the characteristics of rural areas on the residents' cognitive function is complex. The present study is relatively superficial, and relevant mechanisms need to be further clarified. Finally, this study was limited to the rural areas of Shandong Province. In order to verify the validity of the findings, the scope of the study should be further expanded in the future. And a larger sample size should be included to make our conclusions more representative and convincing.

Conclusions

This study is the first time to investigate the relationship between sleep quality and cognitive impairment and the mediating role of frailty in this relationship among rural older adults in China. We found that worse sleep quality was associated with a higher prevalence of cognitive impairment, and that frailty partially mediated the relationship between sleep quality and cognitive impairment in the rural older adults. That is, sleep quality can not only directly affect cognitive function, but also indirectly affect cognitive function through frailty.

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Authors' contributions

PD, CC and WY contributed to the conception and design of the study. ZL and YS contributed to the acquisition of data. MG, XL, DM contributed to the analysis and interpretation of data. PD, CC and WY wrote the original draft of this paper, which was reviewed by HG, YW and ZC. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate

The study was performed in accordance with the Declaration of Helsinki, and approved by the Medical Ethics Committee of Weifang Medical University

(2021YX-066). Written informed consent clarifying the study purposes, significance, methods and risks was obtained from each participant before the survey.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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