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The mediating effects of sleep quality in the relationship between loneliness and depression among middle-aged and older adults

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Loneliness has long been recognized as a key predictor of depression in older adults, and both are related to sleep quality. However, to this day, less is known about whether sleep quality mediates their relationship. This study aimed to examine the relationship between loneliness, sleep quality, and depressive symptoms, and to further explore whether sleep quality mediates the relationship between loneliness and depressive symptoms. Using the random cluster sampling method, 1016 permanent residents aged 45 and above in Ankang City, Shaanxi Province were selected. The relationship between loneliness, sleep quality, and depressive symptoms was analyzed using binary logistic regression, and the mediating role of sleep quality between loneliness and depressive symptoms was analyzed using the PROCESS macro in SPSS 25.0 software. The average age of the participants in this study was 60.39 ± 8.50. Regression analyses showed that individuals with loneliness (OR 7.161, 95%CI: 4.889–10.490, P < 0.001) and those with poor sleep quality (OR 4.777, 95%CI: 3.301–6.913, P < 0.001) were more likely to experience depressive symptoms than individuals without loneliness and with good sleep quality. This study also found a significant mediating effect of sleep quality between loneliness and depressive symptoms [effect value = 0.066, bootstrap 95% CI: (0.037, 0.093)] with an effect size of 13.31%. Loneliness may lead to reduced sleep quality in individuals, which in turn may lead to or exacerbate depressive symptoms. Therefore, this study highlights the importance of assessing and improving sleep quality in lonely people.

Keywords Depression, Loneliness, Sleep quality, Mediating effect, Middle and old adults

The Global Burden of Disease (GBD) Study 2021 report has highlighted that as of 2021, the number of individuals with depression worldwide has reached 332 million cases[1]. Projections suggest that by 2030, depression is poised to become the leading cause of the global disease burden[2]. Depression not only impairs cognitive function, increases the risk of dementia, and leads to disability but also poses the extreme consequences of suicide and death[3,4]. Against the backdrop of an aging population, depression poses a severe threat to the health, quality of life and survival of the elderly[4]. Studies indicate that over one-third of the global elderly population experiences depressive symptoms[5]. In China, the combined estimated prevalence of depression among the elderly is 20.0%[6]. Additionally, middle-aged individuals face increasing risks of depression due to parenting responsibilities, eldercare burdens, work-related stress, and anxiety regarding social status changes associated with aging and retirement[7,8]. Therefore, exploring the risk factors and underlying mechanisms of depressive symptoms in middle-aged and older adults is of urgent necessity.

With advancing age, the natural decline in physical function, increased disability, reduced social participation, and experiences of major life events such as widowhood significantly increase older adults' susceptibility to loneliness[9,10]. Loneliness is a complex subjective emotional experience that occurs when an individual perceives

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that their social needs remain unmet in terms of either the quantity or quality of social relationships[11,12]. It can be categorized into emotional loneliness (resulting from a lack of emotional connection due to insufficient intimate relationships) and social loneliness (stemming from difficulties in achieving the desired sense of social belonging during actual social interactions)[13]. Longitudinal studies have demonstrated a significant positive correlation between loneliness and subsequent depression in older adults[14]. A study from Japan showed that both social and emotional loneliness have a significant positive predictive effect on depressive symptoms among participants[15]. The loneliness model proposed by Hawkley et al. may elucidate the underlying mechanism of this association: when an individual perceives social isolation, the subconscious becomes overly vigilant to social threats or dangers. In this state, individuals are prone to cognitive biases, excessive focus on negative social information, and subsequent social withdrawal. This withdrawal behavior further exacerbates the individual's isolated state, triggering a series of negative emotions such as pessimism, stress, anxiety, and hostility, thereby affecting mental health[16]. From the perspective of brain functional connectivity and neural networks, loneliness and depression share a unique link in the processing of negative emotions[17]. Individuals with experiences of loneliness often struggle to effectively regulate negative emotions, easily falling into pessimistic states characterized by decreased self-esteem, diminished self-worth, self-mockery, and self-loathing, which in turn promote the development of depressive symptoms[18].

Sleep is a critical process for physiological restoration in the body and is closely related to emotional regulation, cognitive function, and mental health[19]. High-quality sleep is essential for the process of sleep recovery [16]. Studies have shown that loneliness can impair sleep quality, leading to daytime dysfunction such as fatigue and low energy. Poor sleep quality, in turn, further exacerbates loneliness, creating a vicious cycle[16]. A study from Sweden demonstrated that individuals who experience loneliness repeatedly face a higher risk of sleep disorders, with loneliness serving as a predictor of sleep disorder onset[20]. Meanwhile, sleep disorders interact with depression and are among the strongest predictors of depression onset[21–23]. Therefore, we hypothesize that sleep quality may mediate the transition from loneliness to depression.

Existing studies have shown that sleep quality plays a mediating role between perceived stress and depression as well as between loneliness and cognitive function[24,25]. However, most studies have focused only on the relationships between two of these factors, with few exploring the associations among all three. Moreover, these studies often have small sample sizes and lack consistent conclusions[26,27]. Therefore, this study aims to investigate the impact of loneliness on depressive symptoms and to validate the mediating role of sleep quality. This will help elucidate the underlying mechanisms through which loneliness leads to depression and provide a scientific basis for healthcare providers, eldercare service workers, and social workers to design effective preventive measures against loneliness and depression in middle-aged and older adults.

Methods

Sample and data collection

This cross-sectional study was conducted in Shaanxi Province, China, from July to August 2023. We employed a random cluster sampling method to obtain a representative sample. Ankang City was randomly selected within Shaanxi Province, followed by the random selection of two counties, Zhenping and Hanbin. Community service centers in these counties were designated as survey sites and residents meeting inclusion/exclusion criteria were surveyed. The survey team, consisting of physicians and medical students, conducted the study; physicians used the Inbody body composition analyzer to determine participants' Body Mass Index (BMI), while medical students, working in groups, administered the questionnaire survey. All team members underwent standardized training one week before the survey's commencement.

The questionnaire was administered through face-to-face interviews, with informed consent obtained from all participants. Interviewers guided participants through the questionnaire using a standardized script and assisted as needed. Each questionnaire took approximately 30 min to complete. It was collected immediately after completion. Individuals were included when they were aged 45 years and over, had lived in the area for over six months, and could cooperate with a comprehensive assessment. Participants were excluded if they had severe cognitive dysfunction or communication barriers that prevented participation, or a refusal to participate by them or their families.

From 1265 respondents, duplicates and cases with incomplete data on depression, loneliness, and sleep quality were excluded. Multiple imputation (n = 20) was used for covariates with missing data. 1016 individuals were included, resulting in an efficacy rate of 80.3%. Figure 1 details the process of participant recruitment.

The study was conducted following the ethical principles of the Declaration of Helsinki, and pre-survey approval was obtained from the Medical Ethics Review Committee of Xi'an Medical University (approval number: XYLS2023090).

Survey instruments

Center for Epidemiologic Studies Depression Scale—10-item version (CESD-10)

This study utilized the 10-item Center for Epidemiologic Studies Depression (CESD-10) scale[28] to evaluate the severity of depressive symptoms. Participants rated the frequency of specific feelings and behaviors experienced within the last week on a four-point Likert scale: 0 (rarely/never), 1 (sometimes), 2 (often), and 3 (most of the time/all of the time). The items "I feel hopeful about the future" and "I am happy" were reverse-scored, with higher scores reflecting fewer depressive symptoms. The remaining items were scored conventionally. The total scale score ranges from 0 to 30. A cutoff of ≥ 10 on the CESD-10 was applied to identify participants with clinically significant depressive symptoms, a threshold with adequate predictive validity for diagnosing clinical depression[28]. This scale has demonstrated robust reliability and validity in Chinese adult populations, as confirmed by previous research[29]. In this study, the Cronbach's α for the CESD-10 was 0.768.

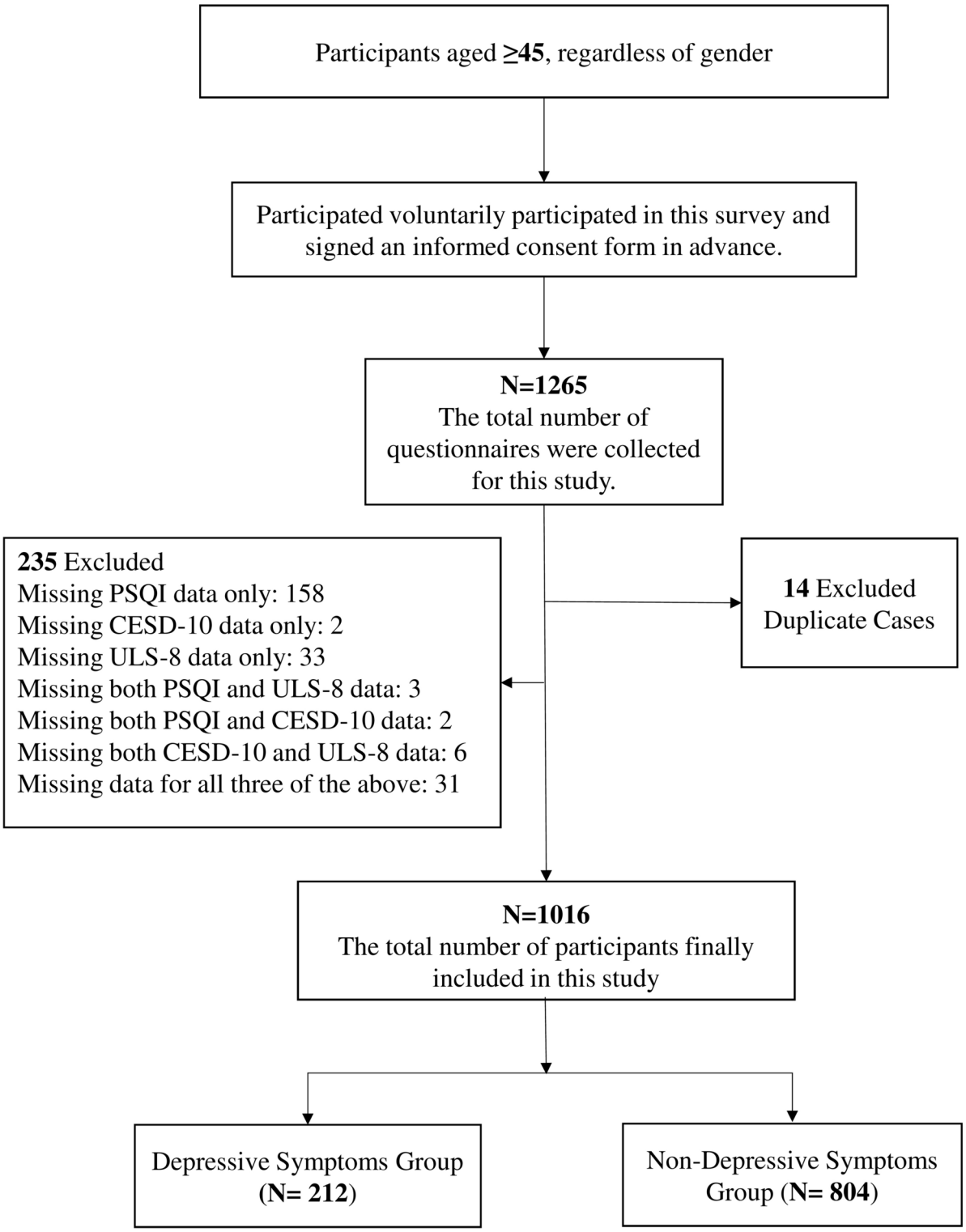

Fig. 1. Flowchart of participant inclusion in this study.

The University of California, Los Angeles Loneliness Scale (ULS-8)

The ULS-8 scale[30], comprised of items 2, 3, 9, 11, 14, 15, 17, and 18 from the revised University of California, Los Angeles Loneliness Scale (ULS-20), assesses loneliness with responses rated on a four-point scale: 1 (never), 2 (rarely), 3 (sometimes), and 4 (always). Items 3 "I am a person who enjoys making friends" and 18 "When I need to, I can find companionship" are reverse-scored. Scores range from 8 to 32, with higher scores reflecting increased loneliness; scores of 8 to 15 suggest no loneliness, while scores of 16 and above indicate its presence[31]. The ULS-8 has shown satisfactory discriminant validity and internal consistency, offering a reduced respondent

burden compared to the ULS-20 without substantial loss of information. In this study, the Cronbach's α for the ULS-8 was 0.714.

Pittsburgh Sleep Quality Index (PSQI)

The Pittsburgh Sleep Quality Index (PSQI)[32] is an 18-item instrument to assess an individual's sleep quality over the previous month. It assesses seven dimensions: subjective sleep quality, sleep latency, sleep duration, efficiency, disturbances, use of sleep medication, and daytime functional disturbances. Scores for each dimension range from 0 to 3, and total scores for all dimensions range from 0 to 21. The lower the total score of the PSQI, the better the sleep quality. A score of 7 or below indicates good sleep quality, while a score above 7 implies poor sleep quality. The reliability and validity of the PSQI have been well-established in Chinese populations.[33] In this study, the Cronbach's alpha for the PSQI was 0.736.

Covariates

The questionnaire collected the following covariates, including sociodemographic factors, lifestyle factors, and chronic disease conditions.

Sociodemographic factors

Age (years), gender, education level, occupation, marital status, family type, living situation, family adversities (whether experienced in the past year), hospitalization experience (whether had in the past year), and family per capita monthly income (in the past year).

Lifestyle and chronic disease conditions

Lifestyle: smoking, drinking status, and BMI. BMI is measured by a body composition analyzer (Inbody). Participants are measured while wearing light clothing and taking off their shoes. According to the results, it is defined as underweight (BMI < 18.5 kg/m^2), normal weight group (18.5–23.9 kg/m^2), overweight (BMI 24–27.9 kg/m^2), and obesity (BMI ≥ 28 kg/m^2).

Chronic disease conditions: Whether there has been a history of hypertension, diabetes, and coronary heart disease diagnosed by a doctor.

Statistical analysis

The statistical analysis software employed in this study is IBM SPSS version 25.0. Categorical data were described using frequencies and percentages, while continuous data, including CESD-10 scores, ULS-8 scores, PSQI scores, and age, which were skewed in distribution, were described using medians and quartiles (M [P25, P75]). Group comparisons regarding the presence of depressive symptoms were performed using Pearson's chi-squared test and Mann–Whitney U test. Binary logistic regression analysis was used to assess the association between loneliness, poor sleep quality, and depressive symptoms, with the absence of loneliness and good sleep quality as references, and odds ratios (OR) and 95% confidence intervals (CI) were provided as estimates. Four regression models were established: Model 1 was a single-factor model. Model 2 was adjusted for age and gender. Model 3 was further adjusted for other demographic factors significant in univariate analysis (education level, occupation, marital status, living situation, average monthly household income, hospitalization history) and chronic disease conditions (hypertension, diabetes, coronary heart disease). Model 4 included adjustments for sleep quality or loneliness based on Model 3. Spearman's correlation analysis was used to test the correlations among loneliness, sleep quality, and depression. Finally, the mediation effect of sleep quality was tested using Model 4 in the SPSS 25.0 macro program PROCESS version 4.0[34], with bias-corrected percentile Bootstrap method for mediation effect testing, and the Bootstrap resampling number was set to 5,000. A P-value of less than 0.05 was considered statistically significant.

Results

Participant characteristics

The supplementary table shows the baseline characteristics of participants according to the existence of depressive symptoms. A total of 1016 people were included in the study. Age ranged from 45 to 92 years with a median age of 60 (54, 67). There were 485 middle-aged people (47.7%) and 531 older people (52.3%). Of these, 675 were female (66.4%), 274 had no education (27%), and 572 worked in agriculture (56.3%). Depressive symptoms were reported by 212 participants (20.9%), 238 (23.4%) felt lonely and 346 (34.1%) reported poor sleep quality. See the supplementary table for more details.

Univariate analysis of depressive status in participants

Univariate analysis in the supplementary table indicates that loneliness, sleep quality are significantly correlated with the detection rate of depressive symptoms (P < 0.001). Among participants with feelings of loneliness, the detection rate of depressive symptoms is 49.2%, much higher than that of those without (12.2%). In participants with poor sleep quality, the detection rate is 39.9%, remarkably higher compared to those with good sleep quality (11.0%).

Among the covariates, family type, family adversities, smoking status, alcohol consumption status, and BMI have no significant association with the detection rate of depressive symptoms (P > 0.05). However, significant differences are observed in other factors. For example, the elderly group (23.7%), females (25.6%), Farmers (23.4%), widowed individuals (31.6%), those living alone (31.3%), as well as participants with low educational levels, low average monthly household income, and those suffering from hypertension, coronary heart disease, or diabetes, all show a higher detection rate of depressive symptoms. Please refer to the supplementary table for detailed information.

Variables	Model	Depressive symptom	
		OR (95%CI)	P
Loneliness	Model1	6.952 (4.985–9.695)	< 0.001
	Model2	6.983 (4.956–9.837)	< 0.001
	Model3	6.714 (4.715–9.562)	< 0.001
	Model4	7.161 (4.889–10.490)	< 0.001
Sleep quality	Model1	5.344 (3.867–7.385)	< 0.001
	Model2	4.778 (3.440–6.636)	< 0.001
	Model3	4.610 (3.294–6.453)	< 0.001
	Model4	4.777 (3.301–6.913)	< 0.001

Table 1. Association of loneliness and sleep disorders with depressive symptoms. Notes: Model 1: Unadjusted model. Model 2: Adjusted for age (continuous variable) and gender. Model 3: Adjusted for education level, occupation, marital status, living situation, average monthly household income, hospitalization history, hypertension, diabetes, and coronary heart disease, in addition to the covariates in Model 2. Model 4: Adjusted for sleep disorders or loneliness, in addition to the covariates in Model 3.

	M [Q1, Q3]	Depression	Loneliness	Sleep quality
Depression	6 [3, 9]	1		
Loneliness	13 [10, 15]	0.449**	1	
Sleep quality	6 [4, 9]	0.486**	0.139**	1

Table 2. Descriptive statistics and Spearman correlation analysis of variables in the mediation model. Notes: **P < 0.01.

Association of loneliness and poor sleep quality with depressive symptoms

The associations among loneliness, poor sleep quality, and depressive symptoms are presented in Table 1. Four binary logistic regression models were constructed. Statistically significant covariates from the univariate analyses were stratified, with whether the participants had depressive symptoms serving as the dependent variable, and loneliness and sleep quality (dichotomous variables) as the independent variables. After adjusting for gender and age, participants with loneliness (OR: 6.983; 95% CI: 4.965–9.837) and those with poor sleep quality (OR: 4.778; 95% CI: 3.440–6.636) had an increased odds of experiencing depressive symptoms (Table 1, Model 2). After further adjusting for factors such as educational level, occupation, marital status, place of residence, monthly per capita household income, hospitalization experience, hypertension, diabetes, coronary heart disease, as well as sleep quality or loneliness, similar associations between loneliness, poor sleep quality, and the occurrence of depressive symptoms were observed (Table 1, Model 4).

Correlations of depression, loneliness, and sleep quality

Table 2 presents the correlations between depression, loneliness, and sleep quality among participants. The median loneliness score was 13 [10, 15], the median depression score was 6 [3, 9], and the median sleep quality score was 6 [4, 9]. Spearman's correlation analysis revealed positive correlations between loneliness and depression scores ($r = 0.449$, $P < 0.01$), sleep quality and depression scores ($r = 0.486$, $P < 0.01$), and between loneliness and sleep quality scores ($r = 0.139$, $P < 0.01$).

The mediating role of sleep quality between loneliness and depressive symptoms among middle-aged and older adults.

Tables 3 and 4, and Fig. 2, show the outcomes of the mediation analysis using model 4 in the PROCESS 4.0 macro. The CESD-10, ULS-8, and PSQI raw continuous scores were standardized and included in the mediation model. The findings indicate that, after controlling for sociodemographic factors, lifestyle, and chronic disease covariates, the total effect of the model was 0.496 ($c = ab + c'$). The direct effect of loneliness on depressive symptoms was significantly 0.430 (c'), accounting for 86.69% of the total effect. To assess the magnitude of the indirect effect, the Bootstrap method was employed for mediation testing, with 5000 resampled datasets from the original data. The results showed that the indirect effect ($a*b$) was 0.066 (Bootstrap 95% CI = [0.037, 0.093]). The 95% CI for the indirect effect of sleep quality did not include 0, indicating a partial mediating role of sleep quality between loneliness and depressive symptoms. The mediation effect was 13.31% ($a*b/c$).

Discussion

In this study, we found that after adjusting for socio-demographic, health status, and lifestyle factors, loneliness and poor sleep quality were independent risk factors for depressive symptoms among participants. Additionally, our findings reveal the mediating role of sleep quality between loneliness and depressive symptoms, offering new insights into the mechanisms by which loneliness may lead to depression.

The overall prevalence of depressive symptoms among middle-aged and older adults in this study was 20.9%, which is lower than the 23.61% reported by NianWei et al.[35] using data from the 2018 CHARLS. Among those

Model	Outcome variable	Independent variables	β	SE	t	P
Model I	Depression	Loneliness	0.496	0.026	18.845	< 0.001
		R	0.593			
		R^2	0.352			
		F	31.831			
		P	< 0.001			
Model II	Sleep quality	Loneliness	0.161	0.031	5.200	< 0.001
		R	0.341			
		R^2	0.116			
		F	7.721			
		P	< 0.001			
Model III	Depression	Loneliness	0.430	0.023	18.373	< 0.001
		Sleep quality	0.408	0.024	17.225	< 0.001
		R	0.707			
		R^2	0.500			
		F	55.452			
		P	< 0.001			

Table 3. The mediating effect of sleep quality between loneliness and depressive symptoms. Notes: Model 1: Loneliness predicts depressive symptoms. Model 2: Loneliness predicts sleep quality. Model 3: Sleep Quality and Loneliness Combined Predict Depressive Symptoms. The mediation model was adjusted for sociodemographic factors (age, gender, education level, occupation, marital status, family type, living situation, per capita monthly household income, family adversities in the last year, hospitalization experience), lifestyle factors (smoking status, drinking status, BMI), and chronic disease conditions (hypertension, diabetes, coronary heart disease).

Pathway	β	SE	LL95%CI	UL95%CI	% Mediated
Total effect	0.496	0.026	0.444	0.547	
Direct effect	0.430	0.023	0.384	0.476	13.306
Indirect effect	0.066	0.014	0.037	0.093	

Table 4. Total, direct, and indirect effects in the mediation model (N = 1016). Notes: LL95% CI stands for the lower 95% confidence interval limit, and UL95% CI stands for the upper 95% confidence interval. The percentage of mediation (% Mediated) is computed as the ratio of the indirect effect to the total effect.

aged 60 and above, the prevalence of depressive symptoms was 23.7%, higher than the rates found by Wang et al.[36] in their surveys of Liaoning Province (18.17%), Henan Province (18.87%), and Guangdong Province (9.93%) in China. The higher prevalence of depressive symptoms among the aged 60 and above in this study, compared to those provinces, in addition to differences in assessment tools. Socioeconomic inequalities often lead to disparities in health and healthcare utilization[37]. Over half of the subjects in this study were farmers, indicating a generally lower economic status among the study population. Consequently, the prevalence of depressive symptoms is relatively high in this particular group.

Furthermore, in the univariate analysis, the elderly compared to the middle-aged, women, those who are widowed, living alone, have a lower level of education, lower household monthly income, and suffer from hypertension, diabetes, and coronary heart disease, were found to be at a higher risk of depression. The potential mechanisms for late-life depression include increased chronic inflammation, HPA-axis dysregulation, reduced neurotrophic factor production, and β-amyloid accumulation[38]. From adolescence to menopause, hormonal fluctuations in women, especially estrogen withdrawal, make them more prone to depression than men[39]. A Japanese study found that living alone and being widowed increases depression risk, and our study concurs[40]. Living alone reduces family interactions, leading to social isolation, loneliness, and thus a higher depression risk[41]. Losing a spouse, key emotional support, breaks an emotional bond, leaving individuals vulnerable to loneliness, pain, and depression[42,43]. Longitudinal research indicates that lower socioeconomic status signals a higher depression risk[44]. Lower education can limit career growth, resulting in low-paying, high-stress, and unstable jobs, lowering living standards, causing stress, and raising depression risk. A Chinese prospective study confirmed a significant link between chronic diseases and depression, with mobility issues, ADL (activities of daily living) limitations, chronic pain, and sleep quality mediating this relationship[45]. Regarding BMI and depression, prior research has inconsistent results. One study has shown that being underweight (BMI < 18.5 kg/m^2) or obese (BMI > 30 kg/m^2) increases the risk of depression, in other words, a U-shaped association between BMI and depression levels[46]. However, other studies only show a link between obesity and depression[47]. In this study, there was no significant association between BMI levels and depressive symptoms, which is consistent

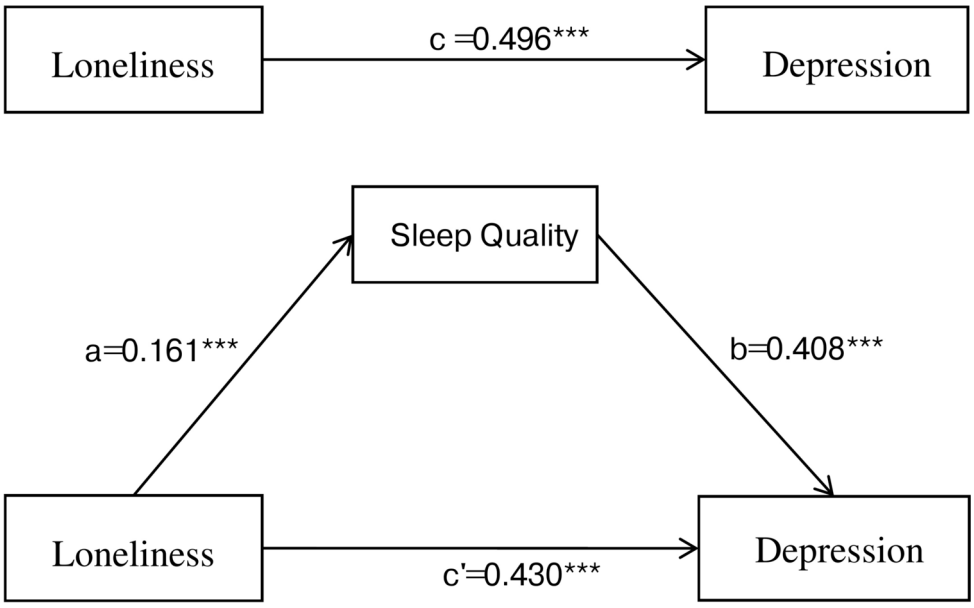

Fig. 2. Mediation path diagram of loneliness, sleep quality, and depression. Note: *** indicates $p < 0.001$. Path c: The total effect of loneliness on depressive symptoms; Path a: The direct association between loneliness and sleep quality; Path b: The association between sleep quality and depressive symptoms; Path c': The direct effect of loneliness on depressive symptoms after accounting for the mediating effect of sleep quality.

with the findings of a previous study[48]. The association between BMI and depression is complex and may be influenced by cultural background differences and psychosocial factors of the study subjects. When societal bias and discrimination against body weight are less significant, it may reduce the link between BMI and depression[49], which could explain the findings of this study.

In this study, a positive correlation was observed between the loneliness score and the sleep quality score. Specifically, the higher the level of loneliness, the poorer the sleep quality, which is in line with the findings of previous meta-analyses exploring the association between loneliness and sleep[50]. Previous research has indicated that stress is one of the key predictors of sleep quality and is closely associated with loneliness[51,52]. Studies have indicated that the stress experienced due to loneliness partially mediates the association between loneliness and sleep quality[53]. Excessively high stress can over-activate the hypothalamic–pituitary–adrenal axis, trigger pre-sleep cognitive arousal, and disrupt sleep[54]. Moreover, at the neurobiological level, loneliness is related to structural and functional alterations in key brain regions, such as the amygdala, prefrontal cortex, insula, and the networks involved in attention and vision. These regions play significant roles in emotional regulation, self-perception, and social cognition, and their dysfunction may be associated with a decline in sleep quality[55].

A study in South Korea involving 176,794 adults indicated that poor sleep quality was significantly associated with depressive symptoms[56], and our study reached the same conclusion. Inflammatory pathways might explain the association between sleep disorders and depression. Specifically, it has been demonstrated that sleep deprivation or disorders can lead to an upregulation of pro-inflammatory cytokines, including interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and C-reactive protein[57,58], which in turn are significantly correlated with the presence of depression[59]. Furthermore, there appears to be a genetic comorbidity between sleep disturbances and depression[60], suggesting that certain genes implicated in sleep regulation may also play a role in depression. Additionally, sleep disturbances may contribute to the progression of depression by disrupting the normal expression of circadian rhythm genes[61].

This study shows that loneliness can significantly and positively predict depressive symptoms, which is consistent with the results of previous studies[14]. Chronic stress is a recognized risk factor for depression[62]. As a social stressor, loneliness[52] can trigger long-term chronic stress. From a physiological perspective, stress can activate the hypothalamic–pituitary–adrenal (HPA) axis, leading to the over-secretion of stress hormones such as cortisol[63,64]. Prolonged exposure to high cortisol levels can disrupt the normal metabolism and regulation of neurotransmitters, thereby increasing an individual's risk of developing depression[65]. Some studies have indicated that exposure to chronic stress can lead to a decline in sleep quality, which in turn indirectly triggers depression[66]. Sleep plays a crucial role in physical recovery and stress response. Good sleep can reduce the levels of stress hormones, thus alleviating the negative physical and psychological impacts of stress[67]. Therefore, improving sleep quality can not only relieve chronic stress but also mitigate the impact of loneliness on depressive symptoms.

Previous studies on the interactions among loneliness, sleep quality, and depressive symptoms have yielded varying results. For example, research on patients with type 2 diabetes has shown that the direct impact of loneliness on sleep quality is not significant, and the relationship between the two is mainly mediated by depressive symptoms[26]. However, studies conducted during the COVID-19 pandemic have indicated that sleep

quality mediates the association between loneliness and overall mental health (including depression, anxiety, and stress), with the mediating effect accounting for 37.58%[27]. The findings of this study are consistent with this, confirming that there is a significant mediating effect of sleep quality between loneliness and depressive symptoms. This discovery provides a new perspective for understanding the mechanism by which loneliness triggers depression: intense feelings of loneliness may indicate poor sleep quality, which in turn can trigger or exacerbate depressive symptoms. Therefore, the results of this study suggest that improving sleep quality may alleviate the negative impact of loneliness on depression. Based on this, in preventive healthcare work, intervention programs for improving sleep quality, such as sleep health education, cognitive-behavioral therapy, and relaxation training, should be provided to individuals experiencing loneliness, so as to prevent or reduce the occurrence of depressive symptoms. In clinical practice, doctors and mental health professionals can adopt a comprehensive treatment approach that combines psychotherapy, pharmacotherapy, and sleep intervention for patients with depression to improve the treatment effect.

This study has limitations. First, it uses cross-sectional data for causal effect inference, limiting our ability to precisely determine causal relationships. Future studies should use a longitudinal design to directly verify the causal links among loneliness, sleep quality, and depressive symptoms, providing a solid theoretical base for early intervention. Second, despite controlling for many potential confounding factors, unmeasured ones may still affect the results. Future research could explore these variable relationships in diverse populations and cultural settings to enhance the generalizability of findings. Third, data collection through questionnaires is prone to recall bias. Additionally, the relationships among sleep quality, loneliness, and depression are complex. This study only verified the mediating effect of sleep quality. Sleep quality may also have a moderating effect, and factors like personality traits and social support may moderate this mediating relationship. Future research can comprehensively consider sleep quality's different roles and incorporate more relevant variables for an in-depth analysis of this complex relationship.

Conclusion

In conclusion, the detection rate of depressive symptoms among participants in this study was 20.9%, with loneliness and poor sleep quality confirmed as independent risk factors for depression. In addition, the relationship between loneliness and depressive symptoms was found to be partially mediated by sleep quality. The results of this study highlight the importance of assessing and improving sleep quality in people experiencing loneliness. Interventions aimed at alleviating loneliness may benefit from incorporating strategies to improve sleep, which could help in reducing the development of depressive symptoms. Implementing interventions that both reduce loneliness and enhance sleep quality simultaneously may be more effective in preventing or alleviating depressive symptoms in this population.

Data availability

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

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Author contributions

Y.L. and D.-l.Z. conceived and designed the study. W.-h.W., L.Z., and M.X. collected and evaluated the data. Y.L., L.-p.S., D.-l.Z., M.-y.W., and D. L. analyzed and interpreted the data, and Y.L. wrote the manuscript. Y.L., M.-j.W., and J.-f.H. revised the manuscript. All authors read and approved the final manuscript. All authors agree to publish this work.

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Competing interests

The authors declare no competing interests.

Ethics declarations

The study complied with the guidelines of the 2013 revised Declaration of Helsinki and was approved by the Medical Ethics Review Committee of Xi'an Medical College (Approval No. XYLS2023090); all participants in this investigation obtained their informed consent before being investigated.

Additional information

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