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The relationship between smartphone addiction and sleep quality in older adults: the mediating role of loneliness and depression

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Abstract

Background This study explores the relationship between smartphone addiction and sleep quality, and to further assess the mediating role of loneliness and depression.

Methods A survey of 200 older adults individuals was conducted using the Smartphone Addiction Scale-Short Version (SAS-SV) for smartphone addiction, Pittsburgh Sleep Quality Index (PSQI) for sleep quality, Geriatric Depression Scale-15 (GDS-15) for depression, and DeJong Gierveld Loneliness Scale (DGLS) for loneliness. Linear regression and mediation analysis were performed for statistical analysis.

Results A negative causal relationship was observed between smartphone addiction and sleep quality in the older adults ($p < 0.05$). Depression and loneliness in the older adults may potentially exacerbate the effect of smartphone addiction on sleep quality ($p < 0.05$).

Conclusion Individuals with smartphone addiction appeared to have poorer sleep quality, psychological factors play a mediating role in the association between smartphone addiction and sleep quality in the older adults. This emphasizes the importance of care for the mental health of the older adults and recognizes the negative impact of smartphone addiction on their quality of life.

Keywords Older adults, Smartphone addiction, Sleep quality, Depression, Loneliness, Social support, Nursing strategies, Mental health

Background

In the digital age, mobile phones have become an indispensable part of our daily lives, as per the 49th China Internet Development Status Statistics Report, as of December 2021, China's internet user base reached 1.032 billion, with a 99.7% proportion using mobile internet [1]. Among them, internet users aged 60 and above accounted for a high proportion of 11.5%, with 99.5% of older adults internet users using mobile internet [2]. Smartphone addiction is a disorder that involves compulsive overuse of mobile devices, often quantified as the number of times a user accesses their device and/or the total time they spend online during a specified period of

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time [3, 4]. Although smartphone addiction use is not currently recognized as a formal clinical disorder in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) or the International Classification of Diseases (ICD-10), many aspects of the behavior appear to share similarities with other recognized behavioral addictions [5]. Smartphone addiction is a form of behavior characterized by compulsive use of a device that results in various forms of physical, psychological, or social harm [6, 7].

However, this significant technological advancement also causes certain medical issues [8]. Excessive use of mobile phones may potentially harm sleep quality, a particularly important issue when considering the older adults population [9]. Sleep quality is a crucial component of overall health. It plays a vital role in an individual's physical, psychological, and emotional well-being [10]. Currently, the older adults face unique challenges, including issues related to sleep and health [11]. The use of smartphones, especially before bedtime, has been considered a potential disruptor of sleep patterns and a contributing factor to sleep-related issues [12]. Previous studies have indicated that dependent use of smartphones can lead to varying degrees of sleep disturbances in different countries, age groups, professions, and even among different student populations, resulting in declines in memory, cognition, motor function, and daily social skills, significantly compromising learning and work quality [13, 14]. With the popularity of mobile phones in older adults, the behavior addiction of physical and psychological damage caused by excessive dependence and use of mobile phones will also receive attention [15]. However, the domestic research on loneliness and smartphone addiction mostly focuses on teenagers or students, and there are few reports on loneliness and smartphone addiction in middle-aged and older adults groups. In addition, there is a lack of unified degree division and evaluation criteria for loneliness and smartphone addiction, which makes the results of different studies less comparable [16]. The link between smartphone addiction and sleep quality is complex, with psychological factors like depression and loneliness playing crucial roles. Various theoretical frameworks can inform this mediation model. The cognitive-behavioral model of addiction [17] posits that such behaviors, including smartphone addiction, stem from cognitive distortions and ineffective coping strategies, which may heighten negative emotional states like depression and loneliness. These emotional challenges can then disrupt sleep by triggering rumination, anxiety, and intrusive thoughts prior to bedtime, ultimately leading to diminished sleep quality.

Additionally, the social and emotional loneliness model [18] suggests that loneliness arises not only from social isolation but also from emotional distress, which can be exacerbated by excessive technology use. The sense

of disconnection or feeling “out of touch” due to smartphone overuse may intensify feelings of loneliness, further deteriorating mental health and negatively affecting sleep.

Both depression and emotional loneliness have been established as mediators in the relationship between digital addiction (such as smartphone addiction) and adverse health outcomes [19]. Often, addiction results in depression, as individuals might resort to smartphones to escape negative emotions or avoid real-life social interactions. This withdrawal from healthy engagements can contribute to the emergence or worsening of depressive symptoms, which, in turn, hinder relaxation and sleep, leading to poor sleep quality. Numerous studies have consistently linked depression to sleep issues, particularly in older adults.

Emotional loneliness specifically is a significant factor in how smartphone addiction affects sleep quality. It is well recognized as a risk factor for sleep disturbances, especially among older individuals. As people increasingly depend on smartphones for emotional connections, they may still experience feelings of isolation due to the superficiality of digital interactions. This emotional loneliness can elevate stress and anxiety levels, disrupting sleep patterns. Research indicates a strong connection between loneliness and sleep disturbances, particularly in older populations [20].

Incorporating both depression and loneliness as mediators enriches the understanding of the mechanisms involved. Smartphone addiction appears to impact sleep quality through both emotional distress (loneliness) and cognitive/affective disturbances (depression). Examining these two mediators concurrently allows for a deeper exploration of their independent and interactive influences on sleep quality. Depression and loneliness may function through distinct but complementary pathways: loneliness primarily influences social and emotional well-being, while depression affects cognitive and behavioral aspects of sleep, such as rumination and avoidance. This combined mediation model captures the intricate ways smartphone addiction affects sleep quality.

The rationale for investigating both mediators—depression and emotional loneliness—is rooted in both theoretical models and empirical findings. Each factor uniquely contributes to the detrimental effects of smartphone addiction on sleep quality. By assessing both mediators simultaneously, the study aims to elucidate the psychological mechanisms involved, potentially guiding more targeted interventions to enhance sleep quality for individuals grappling with smartphone addiction.

This research aims to analyze the effect of smartphone addiction on sleep quality in the older adults from an individual-centered perspective, providing a reference for further scientific research on the association between

smartphone addiction and sleep quality. This research is also to provide theoretical support for reducing the negative effects of smartphones and other electronic products on the older adults, and safeguarding their physical and mental health.

Methods

Study design

This study is a cross-sectional study. This study was conducted in the Foshan area from August 2022 to August 2023. Based on information from the Civil Affairs Bureau website, three medical institutions with over 1000 beds and three older adults care institutions with over 300 beds were selected. Additionally, 50 households of elderly people in the community were the research objects were recruited as the study subjects.

Setting

The sample size was calculated by Monte Carlo power analysis of indirect effects [21]. In this study, a total of 2 parallel mediators were set, with an expected power of 0.8, an expected minimum sample size of 200, a maximum sample size of 300, and a sample size increment of 10 for the power estimate. In our pre-experiment, the correlation between Smartphone addiction (independent variable, X), sleep quality (dependent variable, Y), Depression (mediator 1, M1), and emotional loneliness (mediator 2, M2) was evaluated, where the correlation coefficient between X and Y was about -0.2, the correlation coefficient between X and M1 was about 0.2, and the correlation coefficient between X and M2 was about 0.3. The correlation coefficient between M1 and Y is about -0.2, the correlation coefficient between M2 and Y is about -0.3, and the correlation coefficient between M1 and M2 is about 0.1. The minimum sample size to ensure 0.8 potency was calculated to be 180.

1. Hypothesis 1 (Depression as a Mediator):

Smartphone addiction will be positively associated with depression, which in turn will be negatively associated with sleep quality.

Specifically, it is hypothesized that individuals who exhibit higher levels of smartphone addiction will experience more depressive symptoms. In turn, depression is expected to negatively impact sleep quality by exacerbating cognitive and emotional disturbances, such as rumination and difficulty relaxing. Therefore, depression is hypothesized to serve as a negative mediator between smartphone addiction and sleep quality.

Expected Mediating Path: Smartphone Addiction (X) → Depression (M1) → Sleep Quality (Y).

Predicted Effect: The indirect effect of smartphone addiction on sleep quality through depression is expected to be negative.

2. Hypothesis 2 (Loneliness as a Mediator):

Smartphone addiction will be positively associated with loneliness, which in turn will be negatively associated with sleep quality.

It is hypothesized that individuals with higher levels of smartphone addiction are more likely to experience emotional loneliness. This loneliness, especially in older adults, is expected to exacerbate sleep problems by increasing feelings of anxiety and stress, which disrupt sleep patterns. Therefore, loneliness is hypothesized to serve as a negative mediator between smartphone addiction and sleep quality.

Expected Mediating Path: Smartphone Addiction (X) → Loneliness (M2) → Sleep Quality (Y).

Predicted Effect: The indirect effect of smartphone addiction on sleep quality through loneliness is expected to be negative.

Complementary Mediation: The mediators of depression and loneliness are expected to operate in a complementary manner rather than a competing one. While both factors independently mediate the relationship between smartphone addiction and sleep quality, they represent different psychological processes:

Depression: Reflects a more internalized, cognitive-affective response to smartphone addiction, where individuals may experience pervasive sadness, hopelessness, and an inability to engage in normal activities, including sleep.

Loneliness: Represents a social-emotional response, where the individual may feel disconnected or emotionally isolated despite the constant use of their smartphone, leading to heightened anxiety, stress, and sleep disturbances.

Although both depression and loneliness negatively impact sleep quality, they may do so via distinct mechanisms. Depression might cause sleep disruptions through negative mood states and cognitive rumination, while loneliness might increase sleep disturbances by increasing emotional stress and anxiety about social isolation.

The two mediators may complement each other in explaining the effects of smartphone addiction on sleep quality. Specifically, smartphone addiction may lead to both depressive symptoms and feelings of loneliness, and each of these emotional states may further compound the negative impact on sleep quality. Hence, the pathways are complementary in that they each address different emotional and psychological consequences of smartphone addiction.

Inclusion and exclusion criteria

Inclusion criteria

- (1) Age 60 to 70 years old;
- (2) Residing in an older adults care institution or current community residence for ≥ 6 months;
- (3) Clear consciousness, fluent language expression, and ability to understand the questions stated by the investigator correctly;
- (4) Ownership of a smartphone for ≥ 6 months.
- (5) Activities of daily living (ADL) assessment [22] was conducted on older adults individuals included in the study. The Barthel index was used to assess the self-care ability of the elderly, and patients were judged to use the toilet and enter the bathroom.

Whether actions such as eating and dressing can be completed well, including the average age of 60 older adults' individuals with scores above indicates that the patient's ability to live is relatively good.

Exclusion criteria

- (1) Older adults individuals with acute illnesses during the survey period;
- (2) Those suffering from severe physical or mental illnesses;
- (3) Chronic illnesses that may cause pain;
- (4) Failure to complete the survey questionnaire.

Variables

Conduct Smartphone Addiction Questionnaire Short-Version (SAS-SV) [23], Pittsburgh Sleep Quality Index Questionnaire (PSQI) [24], 15 Items Geriatric Depression Scale (GDS-15) [25], DeJong Gierveld Loneliness Scale assessments (DGLS) [26] on older adults individuals included in the study. According to previous studies, obtaining a score of 21 or higher of SAS-SV may indicate a higher degree of smartphone addiction [27]. This questionnaire has been translated into multiple languages and has demonstrated satisfactory Cronbach's alpha scores. The internal consistency test of the SAS-SV (Cronbach's alpha) was found to be 0.916. For PSQI, a total PSQI score of ≤ 5 indicates good sleep quality, while > 5 indicates poorer sleep quality. The internal consistency for PSQI was found to be 0.840, indicating good reliability and validity. For GDS-15, higher total scores indicate more severe depressive symptoms. The internal consistency test of the GDS-15 (Cronbach's alpha) was found to be 0.768. For DGLS, the Cronbach's alpha values for both the overall scale and its subscales ranged from 0.69 to 0.76.

Measurement

Smartphone addiction scale

The Smartphone Addiction Scale - Short Version (SAS-SV) is an assessment tool derived from Kwon et al.(2013) [15] Smartphone Addiction Scale (SAS) with modifications and streamlining, including 10 validated questions selected from the original 33 items [10]. Participants are required to rate statements related to their smartphone usage, using a 6-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (6) for statements such as "Using a smartphone more than expected." Based on the total score, the range of scores falls between 10 and 60, with higher scores indicating a higher level of risk for smartphone addiction.

18-items Pittsburgh sleep quality index questionnaire

The 18-items Pittsburgh Sleep Quality Index (PSQI) is a self-rated sleep quality questionnaire developed by Buysse et al. in 1989 with high reliability ($\alpha = 0.83$) [28]. The Chinese version was translated by Cai and Wang [29]. The questionnaire consists of seven factors: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. The total score ranges from 0 to 21, with higher scores indicating poorer sleep quality.

15-Items geriatric depression scale

A shortened version of the standard 30-item Geriatric Depression Scale (GDS-15) was developed, comprising 15 items [30]. This scale consists of 15 questions, each requiring a "yes" or "no" response. A score of 1 is assigned for each "yes" response, while 0 is assigned for each "no" response. It is important to note that the scores for questions 1, 5, 7, 11, and 13 need to be reverse-calculated (e.g., "Are you in good spirits most of the time?"). Higher total scores indicate more severe depressive symptoms. In this study, the internal consistency test of the GDS-15 (Cronbach's alpha) was found to be 0.768.

DeJong Gierveld loneliness scale

The DeJong Gierveld Loneliness Scale (DGLS) was used to measure the loneliness of the older adults in the study [31]. This scale consists of two subscales: emotional loneliness (EL) and social loneliness (SL). The total score of the DGLS is the sum of the scores from these two subscales, each of which is assessed by three questions with response options including "yes," "more or less," and "no." In this study, the Cronbach's alpha values for both the overall scale and its subscales ranged from 0.69 to 0.76.

Statistical analysis

Statistical analysis was conducted using GraphPad Prism 9.5 and SPSS 29.0. The Process Macro v4.3 plugin was employed to explore potential relationships between

Table 1 General data

Characteristics	Value
n	200
Age (years old)	64.72 ± 3.21
Gender	
Male	126
Female	74
SAS-SV (Smartphone Addiction)	21.11 ± 4.21
PSQI (Sleep quality)	15.36 ± 3.29
GDS-15 (Depression)	6.35 ± 1.28
DGLS (Emotional loneliness)	4.40 ± 1.32

study variables. Descriptive statistics and linear regression analysis were performed using GraphPad Prism 9.5 software for all variables. Process software was used to investigate potential relationships between study variables, particularly in Process Macro v4.3, where Bootstrap sampling was employed to test for mediating effects [32].

The justification for using Bootstrap lies in its ability to provide robust estimates and confidence intervals for complex statistical models, particularly in mediation analysis where indirect effects are of interest. In addition, bootstrap doesn't have strict requirements for data distribution [33].

The research data are all normally distributed, we conducted a mediation analysis using the mediation effect program [34], employing a bias-corrected Bootstrap method with 5000 resamples and a 95% confidence interval. If the interval estimate contains 0, it indicates that the mediating effect is not significant. If the interval estimate does not contain 0, it indicates that the mediating effect is significant, indicating that psychological resilience has a significant mediating effect between sleep disorders and smartphone addiction, with $p < 0.05$ considered statistically significant.

Results

General data of all enrollments

Among the 200 included participants, ages 64.72 ± 3.21 years, 126 males and 74 females, the mean SAS-SV score was (21.11 ± 4.21), the mean PSQI score was (15.36 ± 3.29), the mean GDS-15 score was (6.35 ± 1.28), and the mean DGLS score was (4.40 ± 1.32). The general data was shown in Table 1.

Linear regression analysis

Linear regression analysis found a significant negative causal relationship between smartphone addiction and sleep quality ($p = 0.003$, $R^2 = 0.044$). Additionally, there was a significant correlation between smartphone addiction and depression in the older adults ($p < 0.01$, $R^2 = 0.520$). We also observed a direct significant relationship between smartphone addiction and emotional loneliness ($p < 0.01$, $R^2 = 0.287$). However, it is worth noting that no significant association was identified between smartphone addiction and social loneliness ($p = 0.369$, $R^2 = 0.004$), as shown in Table 2.

Mediation analysis

In this analysis, we used smartphone addiction as the independent variable, loneliness and depression as the mediator variables, and sleep quality as the dependent variable. Additionally, we considered age and gender as control variables to comprehensively understand the impact of the mediation effects.

Smartphone Addiction (IV) → Loneliness (M). $\beta = 0.151$ ($p < 0.01$). Indirect Effect via Loneliness: $\beta = 0.147$ (95% CI [0.087, 0.222]). Total Effect: $\beta = 0.719$.

As shown in Fig. 1, the results of the mediation analysis indicated that without introducing the mediator variables, smartphone addiction had a significant negative effect on sleep quality (-0.047 , $p = 0.021$). After introducing the mediator variables, smartphone addiction still yielded a significant negative effect on sleep quality ($p < 0.01$). Additionally, both loneliness (-0.336 , $p < 0.01$) and depression (-0.224 , $p = 0.001$) had significant negative effects on sleep quality. Furthermore, smartphone addiction had a significant positive effect on depression (0.209 , $p < 0.01$) and loneliness (0.151 , $p < 0.01$).

Furthermore, the direct impact of smartphone addiction on sleep quality was found to be 0.473, while the indirect effects of depression and loneliness were 0.099 and 0.147. The study results indicate that smartphone addiction positively influences sleep quality directly, and it also exerts an indirect influence on sleep quality through depression and feelings of loneliness. Specifically, the direct effect accounts for 47.57% of the total influence, while the indirect effects of depression and loneliness account for 20.93% and 31.08%, respectively.

Table 2 The regression analysis of variable relationship

Outcome Variables	Independent Variables	R^2	β	t	p
Sleep quality	Smartphone addiction	0.044	0.473	5.758	0.003
Depression	Smartphone addiction	0.520	0.209	4.398	< 0.01
Loneliness	Smartphone addiction	0.287	0.151	5.893	< 0.01
Sleep quality	Depression		-0.224	2.421	0.002
	Loneliness		-0.336	6.107	< 0.01
	Smartphone addiction		-0.047	4.271	< 0.01

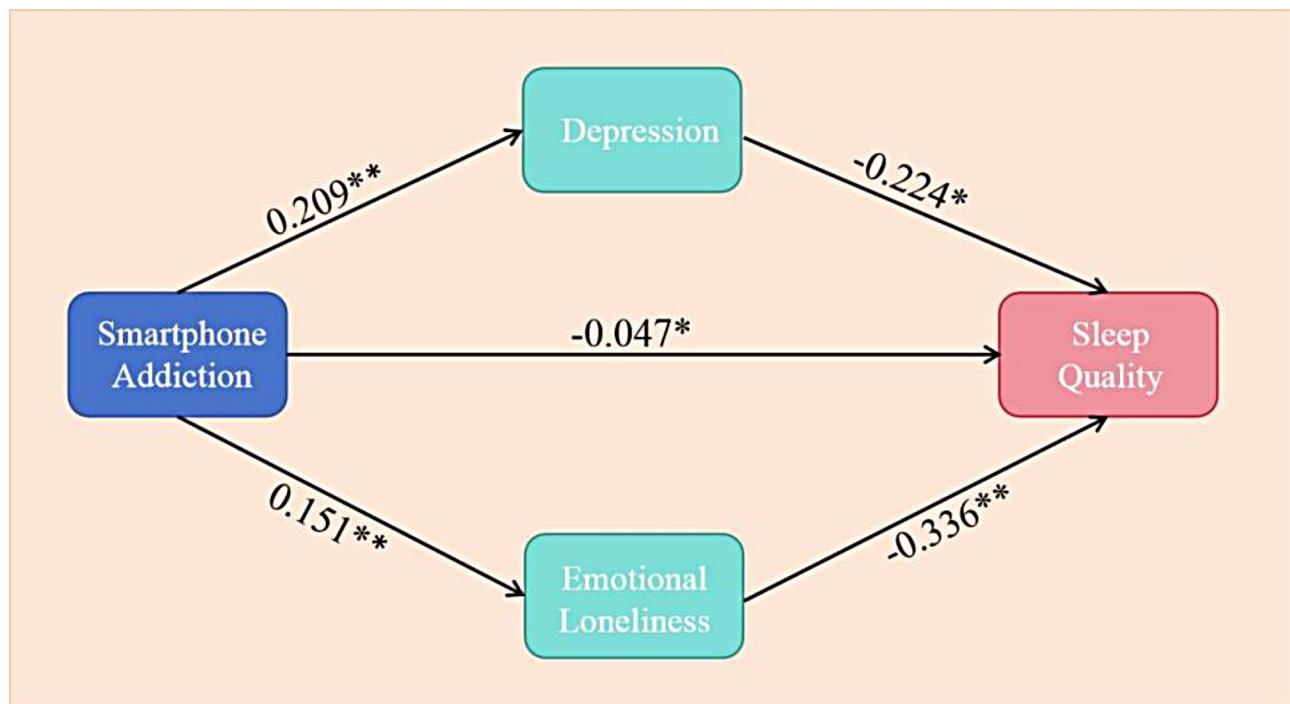


Fig. 1 Mediation analysis of smartphone and sleep quality. * indicates $p < 0.05$; ** indicates $p < 0.01$; Smartphone addiction still has a significant negative impact on sleep quality (-0.047 , $p = 0.021$), while emotional loneliness (-0.336 , $p < 0.01$) and depression (-0.224 , $p = 0.001$) also have a significant negative impact on sleep quality. In addition, mobile phone addiction has a significant positive impact on depression (0.209 , $p < 0.01$), and it also has a significant positive impact on loneliness (0.151 , $p < 0.01$)

Table 3 Influence of smartphone addiction on sleep quality

Model Path	Effect Size	Boot SE	BootLL95% CI	BootUL95% CI	Proportion of Total Effect (%)
Total effect	0.473	0.47	0.143	0.312	
Direct effect	0.225	0.048	0.016	0.198	47.57%
Total indirect effect	0.248	0.021	0.086	0.161	52.43%
MPA-Depression-SQ	0.099	0.014	0.017	0.165	20.93%
MPA-Loneliness-SQ	0.147	0.019	0.041	0.117	31.08%

1. Boot SE - Bootstrapping Standard Error

2. BootLLCI - Bootstrapped Lower Limit Confidence Interval

3. BootULCI - Bootstrapped Upper Limit Confidence Interval

4. MPA-Depression-SQ - Multidimensional Peer Assessment of Depression Scale Questionnaire

5. MPA-Loneliness-SQ - Multidimensional Peer Assessment of Loneliness Scale Questionnaire

The impact of smartphone addiction on sleep quality is summarized in Table 3.

To test the mediation model, we used the PROCESS macro for SPSS (Model 4) with bootstrapping (5,000 iterations) to calculate the 95% bias-corrected confidence intervals (CI) for the indirect effects. The indirect effects of smartphone addiction on sleep quality through depression and loneliness were calculated, and their statistical significance was confirmed by the CI not containing zero.

Mediation results direct effect: The direct effect of smartphone addiction on sleep quality was significant ($\beta = 0.473$, $p < 0.01$), explaining a substantial portion of the relationship.

Indirect effects: depression: The indirect effect of smartphone addiction on sleep quality via depression was significant, with a bootstrapped 95% CI of [0.046, 0.149]. This indicates that the indirect effect was positive and significantly different from zero. **Loneliness:** The indirect effect of smartphone addiction on sleep quality via loneliness was also significant, with a bootstrapped 95% CI of [0.087, 0.222]. This suggests that loneliness partially mediates the relationship between smartphone addiction and poor sleep quality. **Total Effect:** The total effect of smartphone addiction on sleep quality was 0.473 (direct effect) + 0.099 (indirect effect via depression) + 0.147 (indirect effect via loneliness), totaling 0.719. **Interpretation of Confidence Intervals:** The 95% CI for depression's

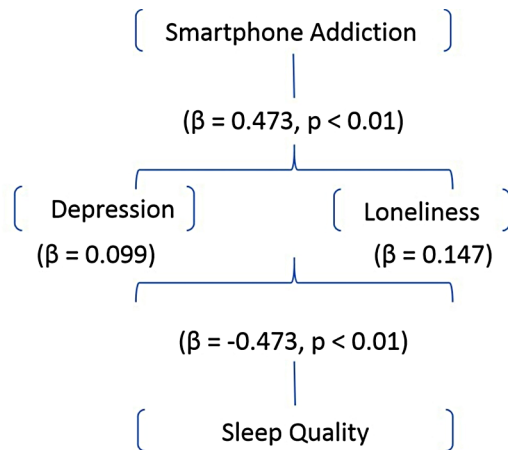


Fig. 2 Parallel mediation diagram. Variables: Independent Variable (IV): Smartphone Addiction; Mediator Variables (M): Depression and Loneliness; Dependent Variable (DV): Sleep Quality. Diagram Structure: Direct Effect (Path a $\rightarrow$ c): Smartphone Addiction (IV) $\rightarrow$ Sleep Quality (DV); Path coefficient: $\beta = -0.473, p < 0.01$; Indirect Effects via Depression (Path a $\rightarrow$ b $\rightarrow$ c): Smartphone Addiction (IV) $\rightarrow$ Depression (M) $\rightarrow$ Sleep Quality (DV). Indirect effect: $\beta = 0.099$, 95% CI [0.046, 0.149], $p < 0.01$. Indirect Effects via Loneliness (Path a $\rightarrow$ b $\rightarrow$ c): Smartphone Addiction (IV) $\rightarrow$ Loneliness (M) $\rightarrow$ Sleep Quality (DV). Indirect effect: $\beta = 0.147$, 95% CI [0.087, 0.222], $p < 0.01$. Total Effect (Sum of Direct and Indirect Effects): Total Effect: $\beta = 0.719$ (Direct + Indirect Effects combined). Diagram Representation: Smartphone Addiction (IV) $\rightarrow$ Direct Path $\rightarrow$ Sleep Quality (DV). Indirect Path 1 (via Depression) $\rightarrow$ Depression (M) $\rightarrow$ Sleep Quality (DV); Indirect Path 2 (via Loneliness) $\rightarrow$ Loneliness (M) $\rightarrow$ Sleep Quality (DV). Include the path coefficients for each effect (Direct and Indirect). Mark significant effects with asterisks or p-values. The indirect effects are broken down into two parts: Depression: Smartphone addiction $\rightarrow$ Depression $\rightarrow$ Sleep quality; Loneliness: Smartphone addiction $\rightarrow$ Loneliness $\rightarrow$ Sleep quality. The total effect is the combined influence of both direct and indirect paths. Smartphone Addiction (IV) $\rightarrow$ Sleep Quality (DV). Direct Effect: $\beta = -0.473$ ($p < 0.01$). Smartphone Addiction (IV) $\rightarrow$ Depression (M). $\beta = 0.209$ ($p < 0.01$). Indirect Effect via Depression: $\beta = 0.099$ (95% CI [0.046, 0.149])

indirect effect ([0.046, 0.149]) does not contain zero, confirming that depression significantly mediates the relationship between smartphone addiction and sleep quality. The 95% CI for loneliness's indirect effect ([0.087, 0.222]) also does not contain zero, indicating that loneliness is a significant mediator in the relationship between smartphone addiction and sleep quality. (Fig. 2)

Discussion

This study demonstrates through structural equation modeling that both loneliness and smartphone addiction directly affect sleep quality. Loneliness directly affects sleep quality, and can also indirectly affect sleep quality through smartphone addiction. Older adults people who feel interpersonal loneliness use smartphones as a medium for self-comfort, reducing sleep time and efficiency. Daytime fatigue, drowsiness, and lack of energy exacerbate sleep disorders, which is consistent with the finding that loneliness increases the tendency to rely on smartphones [30].

In this study, we first conducted a linear regression analysis to analyze the association between smartphone addiction and sleep quality. According to our analysis, we found a significant negative causal relationship between smartphone addiction and sleep quality, indicating that as the level of smartphone addiction increases, the sleep quality of the older adults decreases. This finding aligns with the study by Tian et al. (2022), suggesting that smartphone addiction may compromise the sleep of the older adults [11]. Furthermore, we also observed the effect of smartphone addiction on depression as well as emotional loneliness in the older adults. This implies that smartphone addiction may be associated with the negative mental health status of the older adults. It's worth noting that we did not identify a significant association between smartphone addiction and social loneliness. This may suggest that the impact of smartphone addiction on social loneliness in the older adults is relatively insignificant, or the absence of significance may be attributed to the research methodology [35]. Nonetheless, this outcome serves as a reminder that when investigating the repercussions of smartphone addiction, diverse outcomes may exhibit discrepancies across various psychological and social spheres. Previous research reports have indicated a close association between a decline in sleep quality and an increased risk of cognitive impairment [36, 37]. As sleep quality worsens, cognitive function declines, and anxiety and depression exacerbate. Hence, in clinical interventions or geriatric care, it is crucial to prioritize the sleep quality of older adults [38].

In this study, we further delved into the association between smartphone addiction, depression, loneliness, and sleep quality through mediation analysis. The results of the mediation analysis showed that without introducing the mediator variables, smartphone addiction had a significant positive impact on sleep quality, which is consistent with the results of the linear regression analysis. When depression and loneliness were introduced as mediator variables, we found a significant positive impact of smartphone addiction on sleep quality. Additionally, depression and loneliness also had significant positive effects on sleep quality. This suggests that smartphone addiction may influence the sleep quality of older adults individuals by affecting their psychological states, such as depression and loneliness. This finding is of great importance for formulating nursing strategies and intervention measures.

While both depression and emotional loneliness act as psychological mediators in the relationship between smartphone addiction and sleep quality, it is essential to acknowledge their conceptual differences and clarify how each contributes uniquely to understanding the impact of smartphone addiction on sleep [39]. Although there is some overlap between these constructs—particularly

due to their emotional nature—they are rooted in distinct psychological and social processes, offering unique insights into the effects of smartphone addiction on the well-being of older adults.

Depression as a mediator

Depression is a mood disorder marked by persistent feelings of sadness, hopelessness, and a loss of interest in usual activities. Within the context of smartphone addiction, depression can arise as an emotional reaction to feelings of inadequacy, guilt, or distress associated with excessive smartphone use. It may also develop from cognitive-behavioral patterns in individuals who utilize smartphones as a means to cope with negative emotions or social isolation, only to become overwhelmed by feelings of worthlessness or despair.

Depression predominantly operates as a cognitive-affective process [40]. It encompasses negative thinking patterns (e.g., self-criticism, rumination) and emotional distress that can disrupt physiological functions such as sleep. Individuals experiencing depression may struggle to relax, contend with intrusive thoughts, or exhibit irregular sleep-wake patterns. Additionally, depression impacts motivation and energy levels, making it increasingly challenging for individuals to uphold healthy sleep routines. As a mediator, depression illustrates how smartphone addiction can transition from a behavioral concern to a more deeply internalized emotional issue, disrupting sleep through cognitive processes (e.g., rumination) and emotional withdrawal. The distinct contribution of depression lies in its emphasis on internal emotional disturbances that can significantly impair sleep quality.

Loneliness as a mediator

Loneliness, particularly emotional loneliness, is defined as the perceived gap between the social connections an individual desires and the actual social interactions they experience [41]. Unlike depression, which is predominantly internal and affective, loneliness is characterized as a social-emotional experience. It often arises from feelings of disconnection or insufficient meaningful social support, a situation that can be worsened by an excessive reliance on digital platforms for communication and interaction.

Rooted in social isolation, loneliness reflects the perception of having inadequate emotional support or companionship [35]. Individuals struggling with smartphone addiction may find that their digital interactions lack depth or emotional fulfillment, thereby intensifying their feelings of loneliness. Emotional loneliness can provoke anxiety, stress, and a heightened sense of emotional vulnerability, all of which adversely affect sleep quality. This issue is particularly pertinent for older adults, who may already experience social isolation due to factors such

as physical limitations or a dwindling social network. The social dimension of loneliness differentiates it from depression, as it underscores the emotional pain associated with feeling disconnected, even amidst digital interactions.

Conceptual overlap and justification for both mediators

While depression and loneliness are distinct constructs, they are intricately linked and frequently co-occur, particularly in the context of smartphone addiction [36]. Both can stem from social isolation, emotional distress, or a perceived lack of meaningful relationships, resulting in sleep disturbances. However, the relationship between these two factors justifies their consideration as separate mediators. Depression can serve as both a cause and an effect of loneliness; for instance, feelings of loneliness can trigger sadness and hopelessness (i.e., depression), while depression can exacerbate loneliness through social withdrawal or negative self-perception.

The overlap between the two lies in their shared emotional basis—both depression and loneliness are emotional states that can intensify one another and both contribute to sleep disruption. However, they diverge in their emphasis: depression is primarily internal, cognitive, and affective, while loneliness focuses more on social connectivity and perceived emotional isolation.

Incorporating both depression and loneliness provides a more comprehensive understanding of how smartphone addiction impacts sleep quality. By examining both mediators, the study can shed light on how smartphone addiction disrupts emotional and cognitive well-being, leading to poor sleep quality through distinct psychological pathways (internal vs. social) [37].

This interplay between internal emotional states (depression) and social factors (loneliness) illustrates that smartphone addiction may not only exacerbate depressive symptoms but also worsen feelings of loneliness, creating a cycle that compounds negative sleep outcomes. Including both mediators acknowledges that smartphone addiction affects sleep quality through a synthesis of psychological factors that are experienced both internally (depression) and socially (loneliness).

Although some conceptual overlap exists between the two, it does not undermine their unique roles in the pathway from smartphone addiction to sleep quality [38]. Each mediator addresses a separate yet complementary aspect of the psychological and social ramifications of smartphone use, making their simultaneous inclusion both necessary and valuable.

The mediators of depression and loneliness are conceptually distinct in their focus and origins—depression as an internal emotional reaction and loneliness as a social-emotional experience. While there is some degree of overlap, their inclusion in the mediation model enables

a more nuanced understanding of how smartphone addiction influences sleep quality [25]. Depression and loneliness are not merely alternative explanations; they represent complementary pathways that illuminate the various ways smartphone addiction can undermine sleep among older adults. This comprehensive approach offers a fuller picture of the psychological processes at play, establishing both mediators as essential for understanding the relationship between smartphone addiction and sleep quality.

Specifically, the direct path of smartphone addiction on sleep quality accounted for 47.57% of the total effect, while the indirect paths through depression and loneliness accounted for 20.93% and 31.08% respectively. This indicates that the impact of smartphone addiction on the sleep quality of older adults individuals is not only direct but also involves indirect pathways through influencing their mental health [11]. Therefore, to improve the sleep quality of older adults individuals, nursing measures should emphasize the management of smartphone addiction and negative emotions, such as depression and loneliness. There is a negative causal relationship between smartphone addiction and sleep quality in the older adults, and depression and loneliness in the older adults may exacerbate the impact of smartphone addiction on sleep quality. However, Demirci et al. found that excessive use of smartphones has a direct effect on sleep quality. Excessive use of smartphones directly affects negative emotions such as depression and/or anxiety, indirectly leading to sleep problems [37].

This prompts us that, when providing care for older adults individuals with smartphone addiction, it is essential to focus on psychological care and support for individual psychological well-being and sleep quality. Social support is defined as the degree of emotional satisfaction individuals experience in gaining understanding, respect, and support in social connections [39]. It plays a positive role in enhancing a sense of belonging and positive self-perception, and reducing the occurrence of negative emotions, thereby contributing to improved sleep quality [40, 41]. Furthermore, individual levels of self-confidence have been found to be related to the level of social support [42]. High social support can reduce tendencies towards smartphone addiction and reliance on virtual information, further highlighting the positive impact of social support in addressing smartphone addiction and improving sleep quality [43]. Objective support, including material aid and actual social participation, also has a positive effect on reducing smartphone addiction and improving sleep quality [44]. This suggests that social support plays an important role in reducing reliance on virtual information and increasing support in real-life situations. These research findings provide key insights into the feasibility and multi-level impact of providing care

at the social support level, offering valuable perspectives for improving individual psychological and physiological health [45, 46].

Limitations

There are several limitations that should be acknowledged. Firstly, because of the cross-sectional design of the study, causal relationships should be interpreted with caution. Future research could employ longitudinal designs to further explore these relationships. Secondly, the study was conducted within the cultural context of China and with a limited sample size, which may limit the generalizability of the results. A broader sample is required to validate the universality of the findings. Thirdly, the relationship between smartphone addiction and depression is complex and may involve bidirectional causality, warranting more in-depth research for clarification. Similarly, there may be reverse causal relationships between smartphone addiction, loneliness, and sleep quality, necessitating further longitudinal and experimental studies for investigation. Additionally, aside from depression and loneliness, there may be other variables that potentially mediate the relationship between smartphone addiction and sleep quality, such as social support, which also necessitates further investigation. In the future, we will expand the sample size and conduct multicenter prospective studies to obtain more reliable clinical data to guide future interventions for mobile phone addiction in the older adults.

Conclusion

The findings highlight the dual psychological pathways—depression and emotional loneliness—through which smartphone addiction affects sleep quality. They suggest that mental health interventions focused on reducing depressive symptoms and addressing feelings of loneliness could be effective strategies for enhancing sleep quality among individuals struggling with smartphone addiction. Additionally, this study enhances our understanding of how smartphone addiction can disrupt sleep patterns not only directly but also by exacerbating emotional and social challenges that further impair sleep.

Targeted interventions that address both the psychological and behavioral dimensions of smartphone addiction are crucial for improving sleep quality, especially in vulnerable groups such as older adults. This article contributes to the health field by deepening our understanding of the mechanisms that link smartphone addiction to sleep quality in older adults. By clarifying the mediating roles of depression and loneliness, this study underscores the psychological processes that may contribute to the sleep disturbances frequently experienced by those with smartphone addiction. These insights are vital for designing targeted interventions aimed at improving sleep

quality in this at-risk population, ultimately supporting their overall mental and physical health.

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Author contributions

Hui-Jing Lai: Consulted the literature, designed and completed the research plan, and wrote the manuscript. Zeng-Jie Ye and Shao-Juan Huang: Guide the design of the program. Xiao-Na Wu, Jiang-Yun Liang and Li-Ming Zhou: Data collection and data processing. Xiao-Xiao Mei and Xiao-Na Wu: Statistical analysis of data.

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Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Guangzhou Medical University. This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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