

Mediating Mechanisms and Intervention Strategies of the Bidirectional Relationship Between Mobile Phone Addiction and College Students' Depression

Xiaohong Wei, Jinjiang Xu, En Zhao, Meifen Song, Li Wu*

The First Affiliated Hospital of Guangxi University of Chinese Medicine, Guangxi University of Chinese Medicine, Nanning 530200, China

* Corresponding author

Abstract

With the widespread popularity of smartphones among college students, smartphone addiction (SA) has become increasingly prominent and evolved into a critical public health issue threatening college students' mental health. Existing studies have confirmed a significant bidirectional correlation between smartphone addiction and college students' depression. The two interact through multiple mediating pathways including neurobiology, sleep quality, cognitive function, individual psychological factors and external support, thus forming a vicious cycle. This cycle not only impairs students' academic performance and social functioning, but also poses long-term risks to their physical and mental health. This paper systematically summarizes the bidirectional correlation characteristics between smartphone addiction and college students' depression, analyzes group differences caused by gender, region and major background, and elaborates on five core mediating mechanisms: neurobiology, sleep quality, cognitive function, individual psychology and external support. By integrating available evidence-based interventions, it proposes two categories of intervention strategies oriented by cognition-emotion regulation and behavioral remodeling, so as to provide theoretical basis and practical guidance for mental health education and targeted intervention in colleges and universities.

Keywords

Smartphone addiction; college students; depression; bidirectional effect; mediating mechanism; intervention strategy.

1. Introduction

As digital natives, contemporary college students have smartphones deeply integrated into their daily study, social interaction and entertainment. However, smartphone addiction is increasingly prominent among this group, and its incidence increases year by year 133[1]. Depression is a common emotional disorder among college students. A meta-analysis of 560 studies shows that the detection rates of depression (20.8%) and anxiety (13.7%) rank the second and fourth among college students' mental health problems respectively [2].

There is a complex bidirectional relationship between smartphone addiction and depression, which forms a vicious cycle through multiple mediating mechanisms. This cycle not only affects academic performance and social functioning, but also poses a long-term threat to physical and mental health [3]. Although current relevant studies have made some progress, the systematic sorting of the mechanism network and the integration of intervention strategies still need to be improved. Therefore, this paper reviews concept definition, basis of bidirectional effects, mediating mechanisms and intervention strategies, aiming to provide references for in-depth research and the optimization of mental health services in colleges and universities.

2. Concept Definition and Assessment Tools

2.1. Concept and Assessment Tools of Depression

Depression is a type of mental disorder centered on emotional dysregulation. It is mainly characterized by persistent low mood, loss of interest and pleasure, and mental fatigue. It is often accompanied by varying degrees of cognitive impairment and behavioral changes, with prominent features of high morbidity, high recurrence rate and high disability rate [4]. At the physiological level, it is usually manifested as sleep disorders (difficulty falling asleep, early awakening, excessive sleep), appetite disorders (decreased or increased appetite) and physical discomfort. Its pathogenesis is associated with multiple factors, including genetic factors, neurotransmitter imbalance and psychosocial stress [5]. Classic scales for depression assessment are divided into self-rating scales and observer-rating scales. Among them, the Hamilton Depression Rating Scale serves as a classic tool for clinical diagnosis and therapeutic effect evaluation. There are also specialized classic scales for specific populations such as children, adolescents and the elderly.

2.2. Concept, Core Manifestations and Assessment Tools of Smartphone Addiction

Smartphone addiction is a major type of behavioral addiction, which manifests as individuals' loss of control over smartphone use. Such excessive use impairs daily functions including learning, social interaction and work, accompanied by core features such as withdrawal symptoms, tolerance and impulse control disorders [6]. The core of smartphone addiction lies in psychological dependence rather than simple usage duration. For instance, some students use smartphones for more than six hours a day only for study and necessary social communication without physical and mental impairment, which should not be defined as addiction. On the contrary, functional impairments such as social avoidance and academic failure caused by smartphone use can meet the diagnostic criteria of addiction even with a relatively short usage time [1].

At present, there is no unified diagnostic standard for smartphone addiction in academic circles. However, a variety of assessment tools with good reliability and validity have been developed, including the Mobile Phone Addiction Index (MPAI), Smartphone Addiction Scale (SAS), and College Student Smartphone Addiction Scale (CSAS). These tools mainly conduct quantitative evaluation from the dimensions of loss of control, withdrawal symptoms, tolerance and functional impairment [1][7].

3. Empirical Evidence and Group Differences of the Bidirectional Effect Between Smartphone Addiction and College Students' Depression

Smartphone addiction is significantly positively correlated with college students' depression. The two factors induce and reinforce each other in a bidirectional manner, and such correlation presents obvious differences among groups with distinct gender, regional and professional backgrounds.

3.1. Empirical Evidence: Cross-sectional and Longitudinal Research Evidence

A number of cross-sectional and longitudinal studies have shown that smartphone addiction is significantly positively correlated with depression among college students [8][9]. Xie Fei et al. [10] found that the severity of smartphone addiction was positively correlated with the severity of depressive symptoms. Logistic regression analysis indicated that the risk of moderate and above depression among smartphone addicts was 3.7 times higher than that of non-addicts (OR=3.7, 95%CI=2.9-4.6, P<0.001). A study conducted by Qing Zaihua et al. [1] in southern universities further confirmed that the detection rate of depression among severe smartphone

addicts (CSAS total score ≥ 80) was 58.2%, which was significantly higher than that of mild addicts (21.3%). This correlation remained statistically significant after adjusting for confounding factors such as gender, major and family economic status ($P < 0.05$).

Studies have confirmed a bidirectional relationship between the two. Smartphone addiction may induce or aggravate depression by reducing real-life social interaction, disrupting sleep rhythms and increasing cognitive burden [11][12]. Meanwhile, individuals with depression tend to lose interest in real life. They may seek instant gratification via mobile phones to escape negative emotions, which further strengthens their dependence and eventually develops into addiction [13]. The study by Qing Zaihua et al. [1] verified that depression is an important risk factor for smartphone addiction, which supports this reverse influencing pathway.

3.2. Group Difference Characteristics: Differences in Gender, Region and Major Background

There are significant group differences in the correlation strength and action pathways between smartphone addiction and depression, which are mainly reflected in three aspects: gender, region and major background.

3.2.1. Gender Differences

In terms of addiction susceptibility, the smartphone addiction rate of female college students is significantly higher than that of males, which is related to women's introverted and sensitive personality traits. Such traits make them more vulnerable to frustration in daily life. They tend to relieve real-life pressure through indirect interpersonal interaction via mobile phones, thereby increasing the risk of addiction [14]. In terms of depressive effects, Song Chenxia et al. [15] found that female depressive patients scored higher on anxiety and somatization factors than males. However, other studies have indicated that smartphone addiction exerts a stronger impact on male anxiety. Such differences may be associated with the living environment, major distribution and regional characteristics of research samples [15].

3.2.2. Regional Differences

Differences in the distribution of regional economic and educational resources lead to a pattern that the impact of smartphone addiction on depression is stronger in central and western regions than in eastern regions. Gao Lei et al. [16] investigated college students in Xizang universities and found that the smartphone addiction rate of students in border areas was higher than that in non-ethnic areas. The main reasons lie in inconvenient transportation, as well as differences in language and living customs in border areas. These factors make college students more prone to loneliness. They tend to relieve negative emotions by contacting relatives and friends or seeking entertainment through mobile phones, which ultimately strengthens their addiction tendency.

3.2.3. Major Differences

There are significant differences in mobile phone usage scenarios and addiction risks among college students of different majors, which further affect the correlation strength between smartphone addiction and depression. A study conducted by Zhu Lingling et al. [7] on vocational colleges showed that the smartphone addiction rate of science and engineering students was significantly lower than that of economics, management and art students. The main reasons are as follows. Science and engineering students pay more attention to the functional features of electronic products and use them mainly for practical purposes. In contrast, liberal arts students have more spare time and are prone to negative emotions such as boredom. In addition, liberal arts students are more dependent on mobile phones. When lacking social support, they tend to seek psychological satisfaction through mobile phones, which raises the risk of addiction and depression.

In conclusion, there is a significant bidirectional relationship between smartphone addiction and depression among college students with obvious group differences. In terms of gender, female students show a higher rate of smartphone addiction and differ from males in depression-related somatization symptoms. In terms of region, college students in central, western and border areas present higher smartphone addiction rates and stronger correlation with depression than those in eastern regions. In terms of majors, the smartphone addiction rate of science and engineering students is lower than that of economics, management and art students. Therefore, formulating targeted intervention strategies based on group differences, standardizing college students' smartphone use, and strengthening early depression screening and psychological support are of great significance for promoting the physical and mental health of college students.

4. Mediating Mechanisms of the Bidirectional Relationship Between Smartphone Addiction and College Students' Depression

The bidirectional association between smartphone addiction and college students' depression forms a relational network constructed through multiple mediating mechanisms, which cover multiple dimensions including neurobiology, sleep quality, cognitive function, individual psychology and external support.

4.1. Neurobiological Mediating Mechanism: Coordinated Imbalance of Emotion Regulation and Reward System

Functional abnormalities in the emotion regulation and reward systems constitute the neurobiological basis for their bidirectional relationship. As a key brain region for emotional processing, the amygdala undergoes structural and functional changes that directly affect the onset of depression. Studies have shown that patients with major depressive disorder have reduced amygdala volume. Their structural connectivity is positively correlated with emotional lability of depression, while functional connectivity in resting and task states is negatively correlated with depression [5][17]. Serotonin (5-HT) is a key neurotransmitter regulating amygdala activity, and its decline exacerbates emotion regulation disorders. Smartphone addiction may further impair amygdala function by disrupting the 5-HTergic system [5].

Smartphone addiction is essentially an abnormal remodeling of the reward system, mainly involving the dopaminergic pathways in the limbic system. Dopaminergic neurons in the ventral tegmental area project to the nucleus accumbens. Immediate feedback brought by smartphone use stimulates dopamine release in the nucleus accumbens and reinforces addictive behaviors [18]. In addition, the cingulate cortex is an important component of the limbic system. Its anterior part (ACC) participates in the regulation of reward signals, and its functional abnormalities are closely associated with smartphone addiction. The posterior part (PCC) is involved in visuospatial processing and sensorimotor integration. Abnormal activity in these regions may lead to decreased attention and impaired executive function among smartphone addicts, thereby indirectly aggravating depression [18].

4.2. Sleep Quality Mediating Mechanism: Cyclic Chain Reaction of Disturbed Sleep Structure

Sleep quality serves as a key mediating variable between smartphone addiction and depression. The three factors form a cyclic chain reaction: smartphone addiction → disturbed sleep structure → aggravated depressive symptoms → intensified smartphone addiction [19]. Studies have demonstrated that smartphone addiction is significantly negatively correlated with sleep quality; the higher the level of addiction, the poorer the sleep quality [11][20]. The specific mechanism is as follows: excessive smartphone use before bedtime inhibits melatonin secretion through blue light exposure, curtails effective sleep duration, prolongs sleep onset

latency, and ultimately leads to disrupted sleep structure, which is manifested as reduced deep sleep and sleep fragmentation [11].

Poor sleep quality not only impairs physical health, but also activates the hypothalamic-pituitary-adrenal (HPA) axis to promote the secretion of stress hormones, weaken emotional regulation ability, and elevate the risk of depression [19]. Meanwhile, depressive states further exacerbate sleep disturbances, driving individuals to escape negative emotions by using mobile phones at night, which in turn reinforces addictive behaviors and forms a vicious cycle [10].

4.3. Cognitive Function Mediating Mechanism: Bidirectional Effects of Cognitive Resource Competition and Cognitive Failure

Cognitive resource competition and cognitive failure constitute the cognitive mechanism underlying this bidirectional relationship. Cognitive failure refers to errors in memory, attention and behavioral execution in daily life, which essentially stems from the limitation of psychological resources [21]. According to the cognitive overload theory, simultaneous processing of multiple cognitive tasks leads to the depletion of psychological resources and increases the risk of cognitive failure [22].

Excessive smartphone use among college students occupies substantial cognitive resources, resulting in insufficient cognitive resources required for daily activities such as learning and social interaction. This further triggers cognitive problems including distracted attention, impaired memory and deficient executive function [23]. Persistent cognitive impairments reduce self-evaluation and learning efficiency, induce negative emotions, and raise the risk of depression [24]. In turn, cognitive dysfunction under depressive conditions aggravates such cognitive deficits, driving individuals to escape real-life stress through smartphone use and forming a vicious cycle of cognition, emotion and behavior [10].

4.4. Individual Psychological Mediating Mechanism: Interactive Effects of Multiple Psychological Factors

Psychological factors such as rumination, social anxiety, loneliness and self-esteem play mediating roles in the bidirectional relationship between smartphone addiction and depression, forming a complex psychological mediation network.

4.4.1. Mediating Effect of Rumination

Rumination is defined as an individual's repetitive contemplation of negative emotions, as well as the causes and consequences of stressful events. It can be classified into two categories: normal rumination and pathological rumination [25]. Normal rumination serves as a positive adaptive behavior and assists individuals in achieving their goals. Pathological rumination, by contrast, is negative and maladaptive. It arouses negative emotions, prompts individuals to escape emotional predicaments via smartphone use, and elevates the risk of addiction [26]. High rumination levels among smartphone addicts lead to persistent preoccupation with addictive behaviors, reinforce negative cognition, aggravate depressive symptoms, and ultimately create a bidirectional reinforcement cycle.

4.4.2. Mediating Effect of Social Anxiety

Smartphone addiction and social anxiety promote each other and jointly increase the risk of depression [27]. Excessive smartphone use reduces opportunities for face-to-face interaction, leads to the degradation of social skills, and makes it difficult to establish and maintain real interpersonal relationships, thereby triggering social anxiety [28]. Individuals with social anxiety tend to avoid the discomfort of real social interaction through virtual socialization. Although such behavior can relieve anxiety in the short term, it hinders the development of social skills and self-confidence in the long run, and strengthens smartphone dependence. This vicious cycle ultimately impairs psychological adjustment ability and may even induce or exacerbate depression [27].

4.4.3. Mediating Effect of Loneliness

Loneliness refers to a negative subjective experience arising from an individual's perceived deficiency in the quantity or quality of social relationships. Studies have indicated that smartphone addiction positively predicts loneliness [29]. Excessive immersion in the online world reduces real social engagement among addicts, aggravates interpersonal alienation, and further intensifies feelings of loneliness. Individuals with high loneliness have lower tolerance for negative emotions, are more inclined to escape from reality, and face an elevated risk of depression. Meanwhile, individuals with depression struggle to meet their psychological needs and are more susceptible to loneliness. They therefore seek interpersonal support via smartphones, forming a vicious cycle of addictive behaviors [30].

4.4.4. Mediating Effect of Self-Esteem

Self-esteem is an individual's overall evaluation of self-worth. It is positively correlated with positive cognition and negatively correlated with negative cognition [31]. Individuals with high self-esteem can cope with negative events more effectively and alleviate depression. Their strong self-regulation ability also reduces the risk of smartphone addiction. People with low self-esteem are more sensitive to others' evaluations and prone to the emotional dilemma of self-denial, with a significantly higher risk of depression. To escape real setbacks and negative emotions, low self-esteem individuals tend to seek satisfaction in the virtual world via mobile phones, gradually forming dependence and developing addictive behaviors. Functional impairments caused by addiction further reduce self-esteem and aggravate depressive symptoms [32].

4.5. External Support Mediating Mechanism: The Vital Role of Family Environment and Social Support

4.5.1. Mediating Effect of Family Environment

Family environment is a crucial external factor affecting college students' smartphone addiction and depression. The demonstration effect of parents' phubbing behavior is particularly vital. Studies have shown that paternal phubbing is significantly positively correlated with college students' smartphone addiction. Excessive smartphone use by parents not only sets a bad example but also neglects their children's psychological needs. College students with long-term lack of emotional support are prone to negative emotions. They thus relieve stress and meet emotional needs through mobile phone use, ultimately forming a vicious cycle of addiction and depression [33].

4.5.2. Mediating Effect of Social Support

As an essential resource obtained from the social network, social support plays a vital role in maintaining emotional health and buffering the risk of addiction. Studies have confirmed that smartphone addiction not only affects depressive symptoms directly, but also indirectly exacerbates depression by reducing the level of social support [34]. As a core element of social support, positive peer acceptance can significantly alleviate loneliness, anxiety and depression [35]. On the contrary, individuals with poor peer relationships are more inclined to release emotions and conduct interpersonal communication through mobile phones, thereby increasing the risk of addiction. Studies on adolescents from disadvantaged families in urban and rural areas indicate that smartphone addiction impairs mental health through insufficient peer acceptance as well as fear and inferiority, leading to a vicious cycle [36].

Smartphone addiction and college students' depression interact through mediating mechanisms covering five dimensions: neurobiology, sleep quality, cognitive function, individual psychology and external support. Each mediating mechanism is relatively independent yet interrelated, jointly forming an integrated mediation network for their bidirectional interaction. This provides precise targets for the formulation of subsequent

intervention strategies. Breaking the bidirectional relationship between smartphone addiction and depression from physiological, psychological and environmental dimensions can effectively safeguard college students' physical and mental health.

5. Intervention Strategies for the Bidirectional Relationship Between Smartphone Addiction and College Students' Depression

Based on the above mediating mechanisms of their bidirectional interaction, the development of targeted intervention strategies to break the negative cycle is a key measure to alleviate college students' smartphone addiction, relieve depressive symptoms, and protect their physical and mental health.

5.1. Cognitive-Emotion-Oriented Intervention: Cognitive Bias Correction and Improvement of Emotion Regulation Ability

This type of intervention aims to improve individuals' cognitive bias and emotion regulation capacity. By reshaping cognition related to mobile phone use and enhancing emotional management skills, it can simultaneously alleviate addictive behaviors and depressive symptoms.

5.1.1. Attentional Bias Training

Attentional bias refers to an individual's selective allocation of attention to specific stimuli. Individuals with smartphone addiction generally show attentional preference for mobile phone-related stimuli and attentional bias toward negative emotional information [37]. Attentional bias training corrects cognitive biases by guiding individuals to shift their attention away from phone-related cues and negative information toward positive stimuli. A randomized controlled trial conducted by Chen et al. [38] demonstrated that such training can effectively reduce addictive tendencies as well as anxiety and depressive symptoms among smartphone addicts, with stable effects maintained at the 3-month follow-up. Mechanistic research by Hou et al. [39] further verified that attentional bias training can block the chain reaction of "smartphone addiction → social anxiety → negative attentional bias → depression", providing theoretical support for its clinical effectiveness.

5.1.2. Mindfulness Training

Mindfulness is a psychological state of focusing attention on the present moment in a conscious and non-judgmental manner. As a positive personality trait, mindfulness can buffer the negative impacts of risk factors on psychological adaptation [40]. Individuals with high mindfulness traits are more likely to accept their physical and mental conditions, avoid escaping or suppressing negative emotions, and effectively disengage from negative experiences. For college students with smartphone addiction, mindfulness training enhances their present-moment awareness, reduces impulsive phone use, and improves emotion regulation, thereby alleviating depressive symptoms. Relevant studies have shown that mindfulness training can significantly reduce the level of smartphone dependence and depression scores among addicts. Its core mechanism lies in the improvement of self-control and emotional acceptance.

5.1.3. Behavior Management Training

Behavior management training improves addictive behaviors by formulating rules for smartphone use and strengthening healthy daily habits. Studies have shown that establishing "phone-free zones" in universities and arranging fixed time periods for entertainment application use (e.g., 19:00–21:00 every day) can reduce the smartphone addiction rate of college students by 15.3% ($P < 0.01$) and decrease anxiety and depression scores by 12.7% ($P < 0.05$) [13]. The underlying mechanism is that environmental restrictions and time planning

reduce aimless phone use, improve academic performance and real-life social interaction, and alleviate procrastination and negative emotions, thereby breaking the vicious cycle between addiction and depression.

5.1.4. Combined Exercise Intervention

Exercise intervention alleviates anxiety and depression by promoting endorphin release and regulating neurotransmitter balance, while reducing smartphone usage time. The combination of exercise and psychological counseling can achieve dual improvements in behavior and emotion, with better effects than single intervention. Studies have confirmed that combined exercise and group psychological counseling is significantly superior to monotherapy in reducing psychological craving, lowering addiction severity, and relieving depression and anxiety [41]. On the one hand, exercise optimizes physical condition and emotional regulation ability; on the other hand, group counseling strengthens social support and improves social skills. The synergistic effect of the two measures can target the core pathogenic factors of both addictive behaviors and depression simultaneously, so as to achieve long-term intervention effects.

In conclusion, targeting the bidirectional relationship between smartphone addiction and college students' depression and combining their interactive mediating mechanisms, this study constructs targeted intervention measures oriented to cognitive-emotional regulation and behavioral reshaping from two dimensions: internal cognitive and emotional adjustment as well as external behavioral norms. These two types of interventions have respective emphases and complement each other, forming a comprehensive and operable intervention system. It provides practical support for breaking the negative vicious cycle of the bidirectional interaction between smartphone addiction and depression.

6. Research Summary, Limitations and Future Research Directions

This study confirms a bidirectional relationship between smartphone addiction and college students' depression. Their correlation network involves multiple mediating mechanisms, including neurobiology, sleep quality, cognitive function, individual psychology and social support, which can predict the risk of smartphone addiction and depression among college students. In addition, group differences in gender, region, major and other dimensions exist in the co-occurrence of smartphone addiction and depression. Mechanism-based intervention strategies, such as attentional bias training, mindfulness training, behavior management and group counseling, can effectively alleviate their vicious cycle, and provide practical evidence for mental health education in colleges and universities.

However, most existing studies adopt a cross-sectional design and lack longitudinal follow-up and randomized controlled trials, making it difficult to determine causal relationships and the long-term effects of interventions. Current mechanism researches mainly focus on single mediating pathways, with insufficient discussion on the interaction of multiple mechanisms. Meanwhile, there is selection bias in the samples, and insufficient attention is paid to special groups such as ethnic minority students and students from economically disadvantaged families. In addition, intervention programs lack targeted design and personalized strategies based on group differences. Most studies merely focus on smartphone use duration, while ignoring the differential impacts of different usage scenarios (e.g., short videos and social software) on mental health.

Future research can be further explored in the following directions. First, long-term longitudinal follow-up and causal inference analysis should be adopted to clarify the bidirectional causal relationship and key influencing factors between smartphone addiction and depression. Meanwhile, multimodal neuroimaging techniques (such as fMRI and PET) combined with molecular biological methods should be applied to systematically reveal the

neurobiological mechanisms underlying their interaction [42]. Second, it is necessary to focus on exploring addiction characteristics and depression-related mechanisms among special groups, so as to provide evidence for personalized intervention. Third, new intervention technologies should be developed and verified, including virtual reality-based attentional bias training and artificial intelligence-driven behavior management systems. Furthermore, in-depth analysis of smartphone use content and quality is required to clarify the influencing mechanisms of different usage patterns on mental health, and to provide precise guidance for healthy mobile phone use behaviors.

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