



OPEN Impact of smartphone dependence on depression in Chinese adolescents with a moderated mediation model

Xuehui Li¹, Wenjuan Zhang¹, Wen Li¹, Shengkai Wang¹ & Deng Pan²✉

In the digital age, smartphones have evolved into essential tools in contemporary society, raising significant concerns regarding their influence on daily life, particularly among adolescents. This research, drawing on the social-ecological systems theory, explored how smartphone dependence gradually impacted adolescent mental health under the combined influence of family and school environments. This study collected data from 3,770 high school students in China and analyzed it using SPSS along with the PROCESS. The results showed that smartphone dependence positively affected adolescent depression. Academic burnout and school belonging served as linked mediators in the relationship between smartphone dependence and depression. Moreover, parental involvement, serving as a moderating factor, played a significant role in the relationship between academic burnout and school belonging on adolescent depression. When parental involvement was low, the positive association between academic burnout and depression was substantial, as was the negative association between school belonging and depression. However, with higher levels of parental involvement, the positive effect of academic burnout on depression diminished, while the negative effect of school belonging on depression became more pronounced. These findings illuminated the psychological mechanisms that contributed to smartphone dependence and provided a theoretical framework for formulating interventions designed to alleviate depression in adolescents.

Keywords Smartphone dependence, Depression, Academic burnout, School belonging, Parental involvement, Adolescents

In the digital era, smartphones have become indispensable tools in daily life, particularly among adolescents. While smartphones offer various benefits, such as access to educational resources and enhanced social connectivity, excessive use has raised concerns about potential negative implications for mental well-being, particularly in relation to depression¹. Adolescence is a critical developmental stage characterized by significant physical, emotional, and cognitive changes, making individuals particularly susceptible to the potential negative effects associated with smartphone dependence. Smartphone dependence refers to an excessive reliance on smartphones, which may contribute to behavioral and psychological issues such as procrastination, social withdrawal, and academic burnout².

Previous studies suggest that excessive smartphone use is closely associated with poor sleep quality, lower academic performance, and emotional difficulties, including reduced life satisfaction, anxiety, and depressive symptoms. However, research on the relationship between smartphone dependence and depression has predominantly focused on individual psychological factors, often overlooking the broader environmental context in which adolescents develop, such as family and school settings³. The socio-ecological system theory provides a useful framework for understanding the interactions between individual behaviors and environmental influences, suggesting that school belonging and academic burnout may serve as mediating factors in the association between smartphone dependence and depression. Furthermore, parental involvement may act as a key moderating factor that mitigates the negative effects of smartphone dependence.

This study examines how smartphone dependence is related to adolescent depression through the mediating roles of academic burnout and school belonging, while also investigating the moderating effect of parental involvement. In the Chinese cultural context, family and school expectations for students are typically high,

¹Affiliated School of Education Science, Qingdao University, Qingdao, Shandong 266071, China. ²Department of Clinical Laboratory, The Affiliated Hospital of Qingdao University, Qingdao University, Qingdao, Shandong 266005, China. ✉email: dengpan@qdu.edu.cn

particularly within the framework of exam-oriented education, which places significant academic pressure on students⁴. This pressure often contributes to academic burnout, which in turn may affect psychological well-being. Additionally, China's collectivist culture emphasizes social identity and group relationships, making school belonging crucial for students' social adaptation and emotional stability. Research suggests that students with lower school belonging are more likely to experience loneliness and emotional distress, which may increase the risk of depression⁵. Therefore, the selection of academic burnout and school belonging as mediating variables in this study is grounded in their central role within the cultural and social context.

By investigating a sample of Chinese adolescents, this study aims to provide a deeper understanding of the psychological mechanisms linking smartphone dependence and depression, offering theoretical insights for developing interventions to improve adolescent mental health.

The effect of smartphone dependence on depression

Smartphone dependence refers to an excessive preoccupation with various activities conducted via smartphones, leading to a persistent and intense desire to use them. Li et al. found that adolescents who spend more than four hours per day on their smartphones tend to experience reduced sleep duration, increased daytime drowsiness, and a higher risk of depressive symptoms⁶. Additionally, Kuss and Griffith indicated that smartphone dependence may lead to social isolation by reducing opportunities for face-to-face interactions, which in turn may impact mental well-being⁷. Depression, a common symptom of internalizing problems in adolescents, has been widely acknowledged as a critical indicator for assessing the psychological health status of teenagers⁸. Recent data from the World Health Organization (WHO) indicated that around 14% of adolescents aged 10–19 globally experienced mental health problems. Depression, anxiety, and behavioral disorders ranked as major contributors to illness and disability among individuals in this age group⁹. Therefore, scholars worldwide have conducted numerous studies exploring the link between smartphone dependence and depression in recent years. An investigation among South Korean high school students revealed a significant association between increased smartphone dependence and elevated levels of depression¹⁰. A study on American adolescents indicated that smartphone dependence not only affected brain function but also indirectly exacerbated depressive symptoms through sleep problems¹¹. A Japanese study revealed a close connection between smartphone dependence, reduced sleep quality, and students' depressive symptoms¹². While most studies have substantiated a positive correlation between the two, insufficient attention has been given to the mediating and moderating factors and their underlying mechanisms. The few existing studies have predominantly adopted a psychological perspective, emphasizing individual traits such as attentional control and cognitive failures¹³. However, based on the socio-ecological system theory, adolescent development is largely influenced by their surrounding environment, particularly at the microsystem level, including school and family¹⁴. This theory posits that individual development is closely intertwined with the social environment, highlighting the significant role of family and school contexts in shaping adolescent mental health. Focusing solely on individual characteristics may provide an incomplete understanding of the relationship between smartphone dependence and adolescent well-being. Expanding the research perspective to encompass social systems and environmental factors, such as family and school, allows for a more accurate and comprehensive examination of the complex mechanisms through which smartphone dependence may impact adolescent mental health. Furthermore, studies suggested that adolescents under the age of 20 are particularly vulnerable to smartphone dependence¹⁵. Meanwhile, with the advent of the digital era, adolescents, particularly high school students, have become increasingly reliant on smartphones in their daily lives. Smartphones serve not only as primary tools for social interaction and entertainment but also as essential mediums for accessing information and learning. As a result, high school students exhibit a higher tendency toward smartphone dependence, making them a crucial population for studying the impact of smartphone dependence on mental health. Exploring the impact of smartphone dependence on depression within this specific age group is crucial. Hence, building on the preceding discussion, this study presents **Hypothesis 1**: Smartphone dependence may have a direct impact on adolescent depression.

The chain mediating roles of academic burnout and school belonging

Academic burnout refers to a state in which students experience emotional exhaustion, academic disengagement, and a sense of low achievement in academic activities¹⁶. High levels of academic burnout are associated with declining academic performance, increased absenteeism, and mental health issues such as depression. He proposed that academic burnout includes three dimensions: emotional exhaustion, academic disengagement, and low personal achievement, all of which are closely related to students' mental health¹⁷. Kuss and Griffiths found a significant negative correlation between academic burnout and students' academic performance and mental well-being¹⁸. Multiple studies have shown that academic burnout is highly prevalent among Chinese students, particularly in high school, where academic pressure is closely linked to mental health issues¹⁹.

For high school students, who spend the majority of their time at school, it often becomes a second "home." China's collectivist culture emphasizes social identity and group relationships, and school belonging is crucial for students' social adaptation and emotional stability. Research also suggests that school belonging is closely related to the mental health of Chinese students, with students who have low school belonging being more likely to exhibit depressive symptoms²⁰. Smartphone dependence, as a behavioral pattern, is often accompanied by an imbalance in the allocation of time and attention. Adolescents who excessively rely on smartphones, especially for social media and entertainment, tend to experience reduced study time, distracted attention, and academic procrastination—all common manifestations of academic burnout²¹. Academic burnout essentially represents an imbalance between academic tasks and demands and an individual's investment and psychological resources. Prolonged academic burnout can lead students to lose interest in learning, and experience anxiety and helplessness²². On the other hand, smartphone dependence also reduces opportunities for face-to-face social interaction, affecting students' relationships with peers and teachers, which in turn weakens their sense of school

belonging. School belonging refers to students' emotional connection and integration with their school. When students feel disconnected from their school, they are more likely to experience feelings of isolation and emotional distress, further exacerbating mental health issues²³. Therefore, based on existing literature and China's unique educational environment, we believe that academic burnout and school belonging serve as effective mediators in the relationship between smartphone dependence and depression²⁴. Drawing from the preceding discussion, this study puts forward **Hypothesis 2**: Smartphone dependence could indirectly influence depression among adolescents through the chain – mediated effects of academic burnout and school belonging.

The moderating role of parental involvement

Parental involvement refers to the active participation of parents in their children's academic, emotional, and social development²⁵. It encompasses interactions with schools and teachers, support for children's learning, and emotional care within the family environment. Parental involvement emphasizes the active role of parents in both education and daily life, making it more specific and actionable, with a direct impact on students' academic achievement and emotional well-being. For example, behaviors such as participating in school activities, communicating with teachers, and providing learning resources at home directly affect students' academic performance and emotional support. In the Chinese cultural context, parents are seen as key supporters of their children's education and mental health, with their involvement directly influencing students' psychological adaptation and academic success²⁶. Therefore, parental involvement, as a variable, has strong theoretical grounding and practical value, providing specific directions for educational interventions. As a family factor influencing adolescent development, parental involvement significantly impacts the occurrence of depressive symptoms in adolescents²⁷. Research indicated that parental involvement can moderate the effect of smartphone dependence on adolescent depression. When adolescents perceive increased parental presence and care, they are better equipped to manage the psychological stress associated with smartphone use, thus mitigating the risk of developing depressive symptoms²⁸. Furthermore, parental involvement is linked to greater psychological well-being in adolescents, indicating that active engagement from parents can help buffer the adverse effects of smartphone dependence²⁵. Additionally, parental involvement moderates the relationship between smartphone dependence and academic burnout. Research has demonstrated that when parents actively engage in supporting their kids' learning process offer crucial emotional support and learning resources, which help reduce academic pressure and lessen feelings of academic burnout²⁹. This positive parental engagement can counteract the negative consequences of smartphone dependence, allowing adolescents to maintain focus on their studies and emotional well-being. Moreover, parental involvement is closely related to school belonging. Existing research indicates that the more active the parental involvement, the stronger the adolescents' belonging within school³⁰. A robust sense of belonging can further enhance adolescents' resilience against the detrimental effects of smartphone dependence and academic burnout, thus reducing the chances of developing depressive symptoms. It is evident that parental involvement serves as a key moderating factor in the complex relationships between smartphone dependence, academic burnout, school belonging, and depression. While some research has explored the interaction of these factors, the specific mechanisms by which parental involvement moderates these relationships remain unclear. Given the strong link between smartphone dependence and increased academic burnout, which can further impact mental health and potentially trigger depressive symptoms, it becomes critical to examine the interplay of these factors. Therefore, based on these observations, this study proposes **Hypothesis 3**: Parental involvement may moderate the effects of smartphone dependence, academic burnout, and school belonging on adolescent depression.

The present study

In summary, this study targeted high school students and adopts a social-ecological theoretical perspective to examine the impact of smartphone dependence on adolescent depression. We introduced academic burnout, school belonging, and parental involvement as key environmental variables representing school and family contexts, and developed a moderated chain mediation model to examine the underlying mechanisms. Drawing from prior researches, we developed a theoretical model (Fig. 1) and put forward the subsequent hypotheses: (1) H1: Smartphone dependence positively predicts adolescent depression. (2) H2: Academic burnout and school belonging serve as chain mediators in the relationship between smartphone dependence and depression. (3) H3: Parental involvement moderates the effects of smartphone dependence, academic burnout, and school belonging on depression.

Methods

Participants

This study involved 4,032 senior high school students from 72 different high schools in Eastern China.. The selected schools represented both urban and rural areas, as well as various levels of high schools, ensuring good geographic and educational diversity in the sample. Gender was coded as a binary variable (male = 1, female = 0) and considered as a control variable in the data analysis. Age was included as a continuous variable without special coding. Other covariates, such as family structure and place of residence, were coded according to their original categories or values and included in the multiple regression analysis to ensure the accuracy and completeness of the model. Prior to data collection, researchers clarified the study's objectives, procedures, potential risks, and benefits in detail, and obtained informed consent from both participants and their guardians. The study was approved by the Ethics Committee of the Medical College of Qingdao University (QDU-HEC-2024396) and conducted following ethical guidelines for the protection of human participants. All participants filled out a series of questionnaires, including standardized scales for assessing smartphone dependence, academic burnout, parental involvement, and depression. After excluding incomplete questionnaires (e.g., those with identical answers for all items or those completed in less than 60 s), The research team closely monitored data quality and

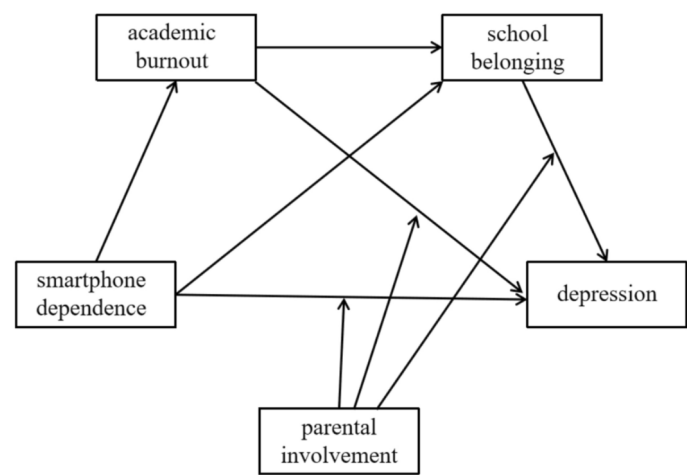


Fig. 1. Hypothetical model of the study.

	characteristics	N(%)
Gender	male	1916 (50.8%)
	female	1854 (49.2%)
Number of siblings	0	1388 (36.8%)
	1	1967 (52.2%)
	2 or more	415 (11%)
Family structure	Intact	3539 (93.9%)
	divorced parents	159 (4.2%)
	deceased father or mother	49 (1.3%)
Place	rural	1822 (48.3%)
	town	208 (5.5%)
	urban	1740 (46.2%)

Table 1. Demographic characteristics of the participants (N= 3770).

conducted a systematic analysis of missing values. Missing data were handled using imputation methods (such as mean imputation, regression imputation, etc.) to ensure the validity and reliability of the data analysis. A total of 3,770 valid responses were collected, yielding an effective response rate of 93.5%. The demographic details of the participants are shown in Table 1.

Measures and instruments

All measurement instruments used in this study have been validated in Chinese samples. For the academic burnout scale, we adopted the version by Wu (2007), which has been validated among Chinese adolescents, with a Cronbach’s α coefficient of 0.91, indicating high internal consistency. The school belonging scale and the depression scale also underwent appropriate validation processes, with the structural validity and reliability of their subfactors meeting standard criteria. Additionally, following standard translation and back-translation procedures, the English versions of these scales were translated into Chinese to ensure cultural adaptation. In this study, all measurement tools were based on validated scales from existing literature, which have been previously tested and adapted for use in Chinese student samples.

Smartphone dependence scale

We utilized the smartphone dependence scale developed by Kwon and revised by Xiang in 2019³¹ to measure smartphone dependence among adolescents. This revised scale eliminates redundant, ambiguous, and irrelevant items from the original version, making it more suitable for assessing smartphone dependence in adolescents. The scale consisted of 10 items distributed across five dimensions: daily disturbance, withdrawal symptoms, cyber relationships, overuse, and tolerance. Participants were presented with statements such as “I cannot tolerate being without a smartphone” and “Others say that I devote an excessive amount of time on my smartphone.” and rated their responses on a scale from 1 to 6. The total score was calculated by summing all item scores, where higher totals signified more severe smartphone dependence. The Cronbach’s α coefficient of the scale was 0.917, indicating a strong level of internal consistency.

Depression scale

We employed the depression scale developed by He et al. in 2003³². This scale was a revised and abbreviated version of the original depression scale, specifically designed to enhance its suitability for screening depression in adolescents by removing items that are not applicable or perform poorly in this age group. The scale measured how frequently depressive symptoms occurred over the past week to evaluate current or potential depression. It consisted of 9 items spanning three dimensions: depressive affect, positive affect, and somatic symptoms along with slowed activity. Participants were presented with statements such as “I feel depressed” and “I find it hard to do everything” and rated their responses on a scale from 1 to 4. Reverse – scored items were recorded, and the total score was calculated by summing all item scores, where higher totals signified a greater likelihood of depression. The Cronbach’s α coefficient of the scale was 0.909, indicating a strong level of internal consistency.

Academic burnout scale

We employed the academic burnout scale developed by Wu in 2007³³. This scale contained 16 items across three dimensions. Participants were presented with statements such as “I’m struggling so much with my studies that I feel like giving up,” and “I don’t feel any sense of achievement in my learning,” and rated their responses on a scale from 1 to 5. Reverse – scored items were recoded, and the total score was calculated by summing all item scores, where higher totals signified greater academic burnout. The Cronbach’s α coefficient of the scale was 0.931, indicating a strong level of internal consistency.

School belonging scale

We employed the school belonging scale from the Program for International Student Assessment (PISA) (OECD, 2018)³⁴, which included two dimensions: positive and negative feelings. The scale included six items, such as “I feel like I belong at my school” and “I feel lonely at school.” Participants rated their responses on a scale from 1 to 4. Reverse – scored items were scored, and the total score was calculated by summing all item scores, where higher totals signified a stronger school belonging. The Cronbach’s α coefficient of the scale was 0.857, indicating a strong level of internal consistency.

Parental involvement scale

We employed the parental involvement scale developed by Chen in 2019³⁵. The scale was completed by students based on their perception of their parents’ involvement. It was categorized into three dimensions to comprehensively assess parental participation in education. The scale contained 14 items, such as “My parents often estimate my potential” and “My parents frequently communicate with my teachers about my situation.” Participants rated their answers on a scale from 1 to 4. The total score was calculated by summing all item scores, where higher totals signified higher parental involvement. The Cronbach’s α coefficient of the scale was 0.921, indicating a strong level of internal consistency.

Data processing

Firstly, we utilized SPSS 27.0 and its related plugins to perform a series of analyses, including descriptive statistical analysis, correlation analysis, mediation effect testing, and moderation effect testing. We employed Pearson correlation analysis to examine the relationships among smartphone dependence, academic burnout, school belonging, parent – child cohesion, and depression. Subsequently, we applied the PROCESS macro in SPSS to test the mediation and moderation effects.

Results

Common method bias test

Common method bias (CMB) may occur when data is gathered from a single source and through the use of a consistent measurement instrument, or based on self – reports, potentially distorting the true relationship between variables³⁶. Harman’s Single – Factor Test was one of the most frequently used methods for assessing CMB³⁷. This method involved conducting a factor analysis, wherein all measurement items were loaded into a single – factor model. If a single factor accounts for a substantial portion of the total variance—typically exceeding 40%—there may be concerns regarding common method bias³⁸. Results from the CMB test in this study revealed that nine factors had eigenvalues greater than 1, with the first factor accounting for just 19.680% of the variance, which is significantly below the 40% threshold. Therefore, the analysis suggests that common method bias was not a significant issue in this study.

Descriptive statistics and correlation analysis of each variable

The relationships between variables were verified through correlation analysis. The results were presented in Table 2. The findings revealed that smartphone dependence was positively correlated with academic burnout and depression, while it was negatively correlated with school belonging and parental involvement. Similarly, academic burnout was negatively correlated with school belonging and parental involvement, while it showed a positive correlation with depression. School belonging showed a positive correlation with parental involvement and a negative correlation with depression. Additionally, parental involvement was negatively correlated with depression.

Testing the mediating effect

We used the Process macro in SPSS to test the main effects, moderating effects, and chained mediation effects among the five variables: smartphone dependence, depression, academic burnout, school belonging, and parental involvement³⁹. To ensure the robustness of the tests, we further employed a variance corrected Bootstrap method, setting 5,000 iterations and selecting a 95% confidence interval to assess significance. Considering that factors

	1	2	3	4	5
1.Smartphone dependence	1				
2.Academic burnout	0.525***	1			
3.School belonging	- 0.449***	- 0.709***	1		
4.Depression	0.480***	0.765***	- 0.720***	1	
5.Parental involvement	- 0.368***	- 0.539***	0.530***	- 0.519***	1
M	20.730	35.813	20.208	15.298	44.910
SD	10.807	12.918	3.470	5.411	8.854

Table 2. Correlation analysis among the variables. Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

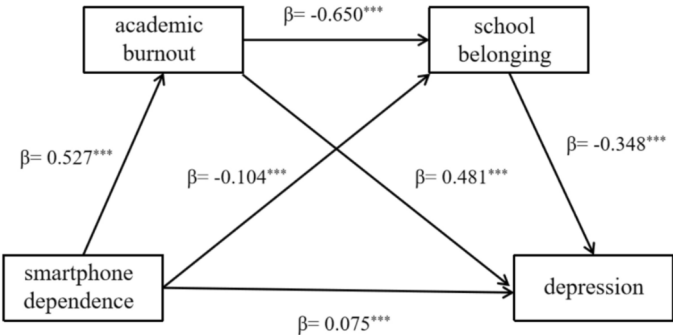


Fig. 2. Results of the chain mediation test.

Path	Effect Size	Boot SE	Boot LLCI	Boot ULCI
Direct effect	0.075	0.011	0.052	0.097
Indirect effect	0.404	0.014	0.377	0.431
Smartphone dependence → academic burnout → depression	0.25	0.012	0.227	0.275
Smartphone dependence → school belonging → depression	0.036	0.006	0.024	0.049
Smartphone dependence → academic burnout → school belonging → depression	0.118	0.008	0.102	0.134
Total effect	0.479	0.014	0.45	0.507

Table 3. Decomposition of total effect, mediated effect and direct effect.

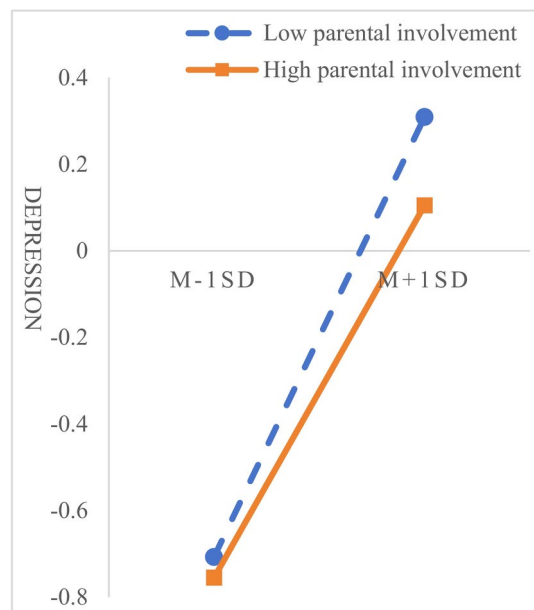
such as gender, number of Siblings, family structure, place of residence were correlated with the variables under study, we incorporated these factors as control variables during data processing. The results were displayed in Fig. 2 and Table 3.

Firstly, smartphone dependence had a positive impact on depression among high school students ($\beta = 0.075^{***}$, $p < 0.001$), providing support for hypothesis H1. Smartphone dependence was found to significantly contribute to academic burnout ($\beta = 0.527^{***}$, $p < 0.001$), and academic burnout, in turn, had a positive effect on depression ($\beta = 0.481^{***}$, $p < 0.001$). This suggests that academic burnout mediates the link between smartphone dependence and depression. In addition, smartphone dependence negatively influenced school belonging ($\beta = -0.104^{***}$, $p < 0.001$), while school belonging had a negative effect on depression ($\beta = -0.348^{***}$, $p < 0.001$). This indicates that school belonging acted as a mediator in the relationship between smartphone dependence and depression. Secondly, the effect size of smartphone dependence on depression was 0.075 (95%CI 0.053 ~ 0.097), with the confidence interval not including 0, indicating a positive impact of smartphone dependence on depression, further reinforcing support for hypothesis H1. In the path "smartphone dependence → academic burnout → depression," the path coefficient was 0.250 (95% CI 0.227 ~ 0.275), with the confidence interval not including 0. In the path "smartphone dependence → school belonging → depression," the path coefficient was 0.036, and the 95% confidence interval did not include 0. Thirdly, in the path "smartphone dependence → academic burnout → school belonging → depression," the path coefficient was 0.118, (95% CI 0.102 ~ 0.134), with confidence interval not including 0, and the chained mediation effect of academic burnout and school belonging was significant, thereby supporting hypothesis H2.

Moderating effect test

To examine the potential moderating effect of parental involvement on the relationship between smartphone dependence and depression, we first standardized the variables and then applied PROCESS model 89 to assess the moderating impact of parental involvement. In this model, the effect size of parental involvement on depression

Variables	β	SE	t	Bootstrap 95%CI	
				Lower	Upper
Parental Involvement	− 0.063	0.012	− 5.192***	− 0.086	− 0.039
Smartphone Dependence	0.077	0.012	6.608***	0.054	0.099
Smartphone Dependence $\times$ Parental Involvement	0.012	0.011	1.125	− 0.009	0.033
Academic Burnout	0.469	0.015	31.582***	0.44	0.498
Academic Burnout $\times$ Parental Involvement	− 0.039	0.014	− 2.812**	− 0.066	− 0.012
School Belonging	− 0.313	0.015	− 21.488***	− 0.342	− 0.285
School Belonging $\times$ Parental Involvement	0.029	0.013	2.324*	0.005	0.054

Table 4. Analysis of Multiple Mediated Paths.**Fig. 3.** The influence of parental involvement in moderating the connection between academic burnout and depression.

was -0.063 (95% CI $-0.086 \sim -0.039$), excluding 0; the effect size of smartphone dependence on depression was 0.077 (95% CI $0.054 \sim 0.099$), also excluding 0; However, the interaction effect between the two variables was 0.012 (95% CI $-0.009 \sim 0.033$), which included 0. The effect size of academic burnout on depression was 0.469 (95% CI $0.440 \sim 0.498$), excluding 0; The interaction effect between academic burnout and smartphone dependence was -0.039 (95% CI $-0.066 \sim -0.012$), also excluding 0. The effect size of school belonging on depression was -0.313 (95% CI $-0.342 \sim -0.285$), excluding 0; The interaction effect between school belonging and depression was 0.029 (95% CI $0.005 \sim 0.054$), also excluding zero. As presented in.

Table 4, this indicated that the moderating role of parental involvement in on academic burnout and the impact of school belonging on depression were significant. Therefore, hypothesis H3 was supported.

To further clarify the nature of these interaction effects, individuals were categorized into high and low parental involvement groups, using one standard deviation above and below the mean score, for a simple slope analysis. As presented in Fig. 3 and Fig. 4, when parental involvement was low, academic burnout had a significant positive predictive effect on depression ($\beta = 0.508$, $p < 0.001$). However, when parental involvement was high, this positive predictive effect of academic burnout on depression was reduced ($\beta = 0.430$, $p < 0.001$). Similarly, when parental involvement was low, the negative predictive effect of school belonging on depression was significant ($\beta = -0.343$, $p < 0.001$). In contrast, when parental involvement was high, this negative predictive effect of school belonging on depression became even stronger ($\beta = -0.284$, $p < 0.001$).

Using the difference analysis method proposed by Edwards et al. (2007) to examine the moderated chain mediation effect, the results were presented in Table 5. When parental involvement was one standard deviation above the mean (i.e., at a higher level), the chain mediation effects for the three paths were 0.223 , 0.03 , and 0.096 , with 95% confidence intervals that did not include 0. When parental involvement was one standard deviation below the mean (i.e., at a lower level), the chain mediation effects for the three paths were 0.264 , 0.036 , and 0.116 , with a 95% confidence interval that also did not contain 0. The chain mediation effects under high parental involvement were lower than those under low parental involvement.

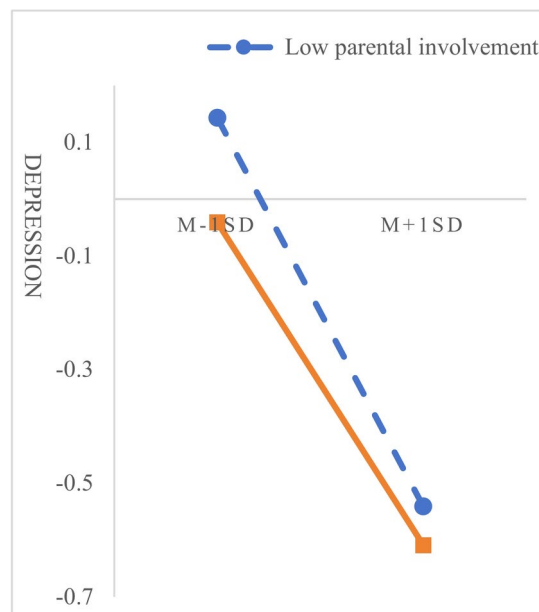


Fig. 4. The influence of parental involvement in moderating the connection between school belonging and depression.

Path	Moderating Variable	Effect Size	Boot SE	Boot LLCI	Boot ULCI
smartphone dependence → academic burnout → depression	high parental involvement	0.223	0.016	0.193	0.255
	low parental involvement	0.264	0.017	0.232	0.297
smartphone dependence → school belonging → depression	high parental involvement	0.03	0.006	0.019	0.042
	low parental involvement	0.036	0.006	0.024	0.048
smartphone dependence → academic burnout → school belonging → depression	high parental involvement	0.096	0.008	0.056	0.089
	low parental involvement	0.116	0.008	0.094	0.127

Table 5. Estimates and confidence intervals of moderated chain mediating effect.

Discussion

This study, based on the social ecological theory, explored the potential mechanisms by which adolescent smartphone dependence affected mental health in school and family environments. Through a chained mediation model, the results revealed a positive correlation between smartphone dependence and depression in adolescents. Specifically, the analysis indicated that academic burnout and school belonging mediated the relationship between smartphone dependence and depression, and they functioned in a chained mediation manner. Additionally, the study observed that parental involvement moderated the relationship between academic burnout and depression, as well as between school belonging and depression. Consequently, the hypotheses H1 to H3 proposed in this study were essentially verified.

This study indicated that there was a positive correlation between adolescent smartphone dependence and depression, consistent with previous research findings. The study revealed a strong association between smartphone dependence and the occurrence of negative emotional states^{40,41}. The antecedent-consequence model of problematic smartphone use suggests a connection between smartphone dependence and emotional health issues, indicating that individuals who excessively rely on their smartphones have a higher likelihood of experiencing emotional problems⁴². According to psychological resource theory, individuals possess limited psychological resources, which encompass various aspects such as emotional, cognitive, and social support. These resources are crucial for managing daily life, learning, work, and social interactions. When individuals excessively use their smartphones, particularly by becoming engrossed in social media, gaming, or other mobile applications, they can deplete a significant portion of these psychological resources. This depletion can render them more vulnerable when facing various pressures in life⁴³. Moreover, excessive smartphone use can distract individuals and reduce opportunities for face-to-face interactions, potentially leading to emotional fatigue and social isolation, thereby adversely affecting mental health⁴⁴. Additionally, an overreliance on smartphones can hinder individuals' ability to effectively cope with academic and work-related stress, as they may lack the necessary coping mechanisms and resources to manage their time and energy. As psychological resources diminish, the feelings of helplessness and anxiety in the face of challenges and difficulties may increase, ultimately leading to the emergence of depressive symptoms⁴⁵. Therefore, it is crucial for adolescents to manage their smartphone usage wisely and maintain a balance in their psychological resources to protect their mental health.

This study explored the potential mediating effects of academic burnout and school belonging on the relationship between smartphone dependence and depression. Research indicated a close relationship between smartphone dependence and decreased academic performance, primarily stemming from the negative impacts associated with excessive smartphone use. Specifically, smartphone dependence often leads to academic procrastination, as students become distracted by social media, videos, and games, which hampers their ability to complete assignments or study on time⁴⁶. This situation not only disrupts their learning progress but also results in the continual postponement of academic goals, creating a vicious cycle. Furthermore, the distraction caused by smartphones makes it difficult for students to concentrate during class, hindering their ability to absorb and understand knowledge, ultimately affecting their academic grades⁴⁷. The decline in academic performance directly contributes to the emergence of academic burnout. Academic burnout is characterized by a prolonged negative psychological state, typically manifested as a loss of interest in learning, feelings of exhaustion, and doubts about one's abilities. When students experience academic burnout, they often feel fatigued and helpless, emotions that not only diminish their motivation to study but may also adversely affect their mental health, increasing the risk of depression⁴⁸. Research has shown that students in a state of academic burnout are more prone to anxiety and depressive symptoms, which further diminishes their coping abilities when faced with academic pressures⁴⁹. Additionally, smartphone dependence indirectly affects adolescent mental health by impacting students' sense of school belonging. Excessive smartphone use leads students to rely more on virtual social platforms, resulting in a reduction of face-to-face interactions with peers⁵⁰. In person communication is crucial for building healthy relationships and enhancing one's sense of belonging, while virtual interactions often fail to meet these needs. Over time, this shift can result in feelings of isolation and detachment, thereby weakening their connection to the school. A diminished sense of belonging makes students feel isolated and misunderstood within the school environment, which can exacerbate depressive symptoms⁵¹. In summary, smartphone dependence impacts adolescents' mental health through multiple pathways. Therefore, understanding this phenomenon and its related factors is essential for implementing effective interventions aimed at improving adolescent mental health. Schools and families should collaborate to help students use smartphones responsibly, promote healthy study habits, and foster interpersonal relationships, thus reducing the adverse impact of smartphone dependence on adolescents' mental health.

Besides exploring the separate mediation effects of academic burnout and school belonging, this study delved into the chained mediating effects between smartphone dependence and depression. The findings indicated that smartphone dependence was initially correlated with an increase in academic burnout, which subsequently led to a decline in school belonging, ultimately raising the risk of depression. This correlation between smartphone dependence and academic burnout aligns with existing research, which consistently showed that excessive smartphone use can detrimentally affect adolescents' academic performance and engagement. Specifically, smartphone dependence often leads to increased procrastination, distraction, and a decrease in motivation for learning, which collectively contribute to academic burnout. As students experience heightened academic burnout, they may feel overwhelmed, powerless, and frustrated regarding their academic responsibilities. This emotional state can result in a significant reduction in their participation in school activities and interactions with peers and teachers⁵². Consequently, this diminished engagement and interaction fosters feelings of disconnection from the school environment, which in turn weakens their sense of school belonging. Furthermore, a decrease in school belonging can exacerbate depressive symptoms. When students feel isolated and disconnected from their school community, their mental health is likely to deteriorate, leading to higher levels of depression⁵³. Therefore, the chained mediation effect suggests that smartphone dependence impacts adolescents' mental health both directly and indirectly, by influencing the interrelated factors of academic burnout and school belonging. Promoting adolescent mental health requires addressing these interconnected issues. It is crucial to implement strategies that not only target smartphone dependence but also combat academic burnout and enhance school belonging. Schools should create supportive environments that help students manage academic pressures effectively and foster a sense of belonging.

This study further revealed that parental involvement played a crucial moderating role in the relationships between smartphone dependence, academic burnout, school belonging, and depression, particularly in the latter halves of Path 1 (academic burnout to depression) and Path 2 (school belonging to depression). Specifically, adolescents who experienced greater parental involvement had a weaker connection between academic burnout, decreased school belonging, and depression. In contrast, those with lower parental involvement exhibited stronger effects of these factors on depression. This indicates that active parental involvement serves as a protective factor, effectively buffering the negative impact of academic pressures and social challenges on mental health⁵⁴. Research suggests that parental involvement provides emotional support, academic assistance, and behavioral guidance, significantly benefiting adolescent development⁵⁵. Through close interactions, parents can detect early signs of psychological distress and offer timely support. In cases of academic burnout, parental involvement helps alleviate feelings of helplessness and pressure, thereby reducing the likelihood of depression. Similarly, when school belonging declines, engaged parents can help rebuild their child's confidence in social settings, fostering a sense of belonging and identity within the school environment. From the perspective of social-ecological systems theory, the family serves as a critical microsystem in adolescent development, with the parent-child relationship at its core. A strong parent-child relationship creates a stable, supportive home environment, enhancing adolescents' sense of security and belonging. This security empowers them to better cope with challenges from academic and social contexts, improving their emotional regulation and resilience. Active communication and engagement between parents and adolescents can significantly reduce behavioral issues, such as emotional outbursts or academic struggles, that might otherwise lead to negative mental health outcomes. Thus, parental involvement not only provides essential support in adolescents' lives but also moderates the effects of academic burnout and reduced school belonging on depression, especially in relation to the negative consequences of smartphone dependence. In other words, higher parental involvement can help mitigate the

detrimental effects of smartphone dependence by reducing academic burnout and enhancing school belonging, thereby lowering the risk of depression. This underscores the need for both schools and families to collaborate in promoting adolescent mental health, emphasizing the critical role parents play in supporting their children as they navigate the challenges of smartphone use and academic pressure.

Limitations and future prospects

This study possesses certain constraints as well. Firstly, the sample is restricted to senior high school students in China and lacks samples from other regions and grade levels, which could impact wider relevance of the results. Future studies should strive to incorporate a more varied sample from various regions and grade levels to confirm the results. Although this study relied on self-reported data from adolescents, we controlled for potential rater bias using a factor model. While this approach cannot entirely eliminate rater bias, it has minimized the potential effects of systematic bias to the greatest extent possible. Future research could further validate our findings by incorporating multi-source data. Secondly, the cross-sectional nature of this study only highlights correlations between variables, making it difficult to determine causality. Future research could implement a longitudinal approach to monitor changes in adolescents' smartphone use, academic burnout, and depressive emotions, thereby further validating causal relationships.

Conclusion

The results of this study underscore the significant impact of smartphone dependence on adolescent depression, with academic burnout and school belonging serving as key mediators in this relationship. As expected, smartphone dependence was positively associated with depression, which is consistent with previous studies that highlight the negative psychological effects of excessive smartphone use. This study also found that academic burnout and school belonging played crucial roles in explaining how smartphone dependence contributes to depression. Specifically, academic burnout was found to mediate the relationship between smartphone dependence and depression, suggesting that the negative effects of smartphone dependence on academic performance and emotional well-being contribute to depressive symptoms. The chain mediation model revealed that smartphone dependence first led to increased academic burnout, which in turn diminished students' sense of school belonging. The reduced sense of school belonging, characterized by feelings of isolation and alienation, further exacerbated depressive symptoms. This finding aligns with the broader literature on the importance of school belonging for adolescent well-being, which suggests that a strong connection to the school environment helps buffer against emotional distress. Conversely, a diminished sense of belonging, as observed in adolescents experiencing high levels of academic burnout, contributes to emotional exhaustion and depressive symptoms. Furthermore, the moderating role of parental involvement was a key finding in this study. The results indicated that parental involvement mitigated the negative effects of academic burnout and school belonging on depression. This suggests that when parents are actively engaged in their children's academic and emotional development, adolescents are better equipped to cope with the psychological challenges posed by smartphone dependence. These findings support previous research that emphasizes the importance of parental involvement in promoting adolescent mental health and resilience.

The practical significance of this study lies in its potential to inform interventions aimed at reducing the negative psychological effects of smartphone dependence on adolescents. By identifying academic burnout and school belonging as key mediators, this research highlights the importance of supporting adolescents' academic engagement and fostering a positive school environment. Interventions targeting academic burnout, such as time management training and stress reduction programs, could help mitigate the adverse effects of smartphone dependence on adolescents' mental health. Additionally, promoting a sense of school belonging through extracurricular activities and peer support programs could help students feel more connected to their school, reducing the risk of depression. Parental involvement also emerged as a critical factor in moderating the effects of smartphone dependence on depression. These findings suggest that parents should be encouraged to take an active role in their children's education and emotional well-being, providing guidance and support to help adolescents navigate the challenges of smartphone use and academic pressures. Schools and communities should collaborate with parents to create environments that foster positive relationships between adolescents and their families, which can buffer against the negative psychological impacts of smartphone dependence. In conclusion, this study provides valuable insights into the complex relationship between smartphone dependence and depression in adolescents. The findings emphasize the importance of addressing both individual and environmental factors in understanding and mitigating the psychological consequences of excessive smartphone use. By focusing on academic burnout, school belonging, and parental involvement, this research contributes to the development of more effective interventions to promote adolescent mental health in the digital age.

Data availability

Due to the involvement of participants' privacy in this study, the data is not publicly available. However, the data can be accessed upon reasonable request by contacting the corresponding author.

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Author contributions

X.L., W.Z., W.L., and S.W. conducted the investigation. X.L. and W.Z. wrote the original draft, and reviewed and edited the manuscript. D.P. acquired funding and supervised the project and handled project administration. All authors reviewed and approved the final version of the manuscript.

Declaration

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to D.P.

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