

Effects of Physical Activity on Mobile Phone Addiction Among College Students: The Chain-Based Mediating Role of Negative Emotion and E-Health Literacy

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Background: Smartphones have become an important tool for college students' study and life, but mobile phone addiction caused by excessive dependence use of cell phones can have serious negative impacts on college students' mental health, life behaviors, and so on. It is urgent to explore the causes and influence mechanisms of college students' cell phone addiction.

Purpose: The purpose of this study was to investigate the relationship between physical exercise and mobile phone addiction among Chinese college students and the mediating role of negative affect and e-health literacy between the two.

Methods: The stratified sampling method was used to investigate the physical activity, mobile phone addiction, negative emotion and e-health literacy of 4621 university students in Jiangsu Province using the Physical Activity Rating scale, Mobile Phone Addiction scale, Depression-anxiety-stress scale and E-Health Literacy scale, Thus the data were statistically analysed using SPSS 26.0 and AMOS 23.0.

Results: (1) Physical exercise was significantly negatively correlated with mobile phone addiction and negative emotion among college students ($r=-.713$, $P<0.01$; $r=-.571$, $P<0.01$), and physical exercise was significantly positively correlated with e-health literacy ($r=0.616$, $P<0.01$); (2) Negative emotion and e-health literacy played independent mediating roles between physical exercise and mobile phone addiction, respectively; (3) Negative emotion and e-health literacy played chain mediating roles between physical exercise and mobile phone addiction.

Conclusion: This study explored the potential mechanisms of cell phone addiction in college students and found that physical activity can influence Internet addiction through the independent mediating effect including the chain mediating effect of negative emotions and e-health literacy. This study further reveals the mechanism of action of physical exercise affecting college students' cell phone addiction, and provides some reference value for the prevention and intervention of college students cell phone addiction.

Keywords: physical exercise, mobile phone addiction, negative emotion, e-health literacy, chain mediation

Introduction

In this era of advanced development of mobile information technology, cell phone has become an indispensable and important tool in the daily life of the public, which has become a daily habit of the people, excessive dependence on the use of cell phones lead to cell phone addiction and this has become a common phenomenon among college students.¹ Mobile phone addiction is an obsessive state in which an individual's behavior is out of control due to the use of mobile phones, causing significant impairment in physical, psychological, and social functioning.² Excessive use of mobile phones is prone to fatigue, headaches, sleep disorders, memory loss, hallucinations,^{3,4} and certain negative emotions.⁵ Some studies have shown that mobile phone addiction is associated with psychological phenomena such as anxiety and depression,⁶ these negative psychological phenomena can lead college students to reduce the frequency of physical activity.⁷ Moreover, college students are open-minded, have good social adaptability, and are good at accepting new



technologies, but the freedom of time and lack of self-control lead to their addictive behaviors are particularly serious.⁸ Therefore, it is significant to explore the formation mechanism of mobile phone addiction among college students.

Physical exercise has a close relationship with mobile phone addiction.⁹ Physical exercise is the process of physical activity with the purpose of improving health and physical fitness by using various means of sports including combining natural forces to exercise the body.¹⁰ Physical exercise among college students is affected by mobile phone addiction, and prolonged pre-screen behavior has a negative impact on physical activity.¹¹ Physical activity improves negative emotions such as anxiety, depression, frustration and promotes mental health.¹² Some studies have shown that physical exercise can directly affect the frequency of mobile phone use among college students,¹³ which in turn leads to mobile phone addiction distress. In addition, dopamine secreted by the human body during exercise can influence individual addiction status.¹⁴ In view of this, this paper argues that physical exercise can reduce the demand for mobile phone use among college students and improve the problem of mobile phone addiction to a certain extent, also hypothesized that physical exercise among college students is negatively related to mobile phone addiction.

Negative emotions contain anxiety, tension, anger, frustration and other negative psychological effects,¹⁵ when negative emotions cannot be effectively controlled, they are more likely to produce adverse psychological states such as sensitivity and suspicion, depression, and social anxiety.¹⁶ According to related studies, there is a significant positive correlation between negative emotions and mobile phone addiction,¹⁷ and the pain caused by such strong negative emotions can predict the occurrence of mobile phone addiction.¹⁸ Loneliness, as a type of negative emotion is not only an important factor influencing mobile phone addiction,¹⁹ but also one of the elements that determine individuals to adopt different coping styles.²⁰ Some researchers found that stronger feelings of loneliness were associated with stronger desire to use mobile phones²¹ and further reduced physical activity behaviors. In contrast, moderate physical exercise can effectively relieve individuals' psychological stress and reduce the negative effects of negative emotions,²² suggesting that performing physical exercise may reduce individuals' risk of developing mobile phone addiction by reducing the negative effects of negative emotions. Therefore, it is hypothesized that negative emotions mediate the relationship between physical activity and mobile phone addiction.

E-health literacy is the ability to search, discover, understand, and evaluate health information from electronic resources and the application of the knowledge gained to solve health problems.²³ A high level of e-health literacy is an important determinant of the development of a healthy lifestyle.²⁴ Nowadays, the sources of knowledge of university students do not rely solely on textbooks, but various electronic tools have also become a medium of learning, therefore, students must acquire skills to identify, use, and effectively utilize different learning resources available on the Internet.²⁵ Healthy habits are the result of a combination of e-health literacy and online social capital, which is a lifelong learning process.²⁶ Good health habits are based on various sources of self-efficacy such as social observations, social feedback and successful experiences, as well as individual emotions,²⁷ and self-efficacy has a moderating effect on negative emotions.²⁸ Physical exercise can also help college students to improve their self-happiness, maintain a positive mindset, and thus improve their self-efficacy.²⁹ Therefore, it is believed that physical exercise firstly reduces individuals' negative emotional experiences and then enhances their health literacy, which ultimately reduces the possibility of developing mobile phone addiction. Accordingly, it was hypothesized that negative emotions and e-health literacy play a chain mediating role between physical activity and mobile phone addiction.

In summary, physical exercise, negative emotions, and e-health literacy are all important influences of mobile phone addiction. Individual studies have explored the relationship between physical exercise and mobile phone addiction among college students³⁰ and the relationship between negative emotions and mobile phone addiction³¹ respectively, but have not yet revealed the mechanisms of the influence of physical exercise on mobile phone addiction among college students with the role of negative emotions and e-health literacy. Therefore, this study aimed to investigate the separate and chain mediating roles of negative emotions and e-health literacy in the process of physical exercise of college students' influence on mobile phone addiction. The hypotheses of this study include H1: Lack of physical exercises among college students is directly correlated with mobile phone addition; H2: Negative emotion and e-health literacy play separate mediating roles between physical exercise and mobile phone addiction among college students; H3: negative emotion and e-health literacy play chain mediating roles between physical exercise and mobile phone addiction. (The hypothesis model of this study is shown in [Figure 1](#)).

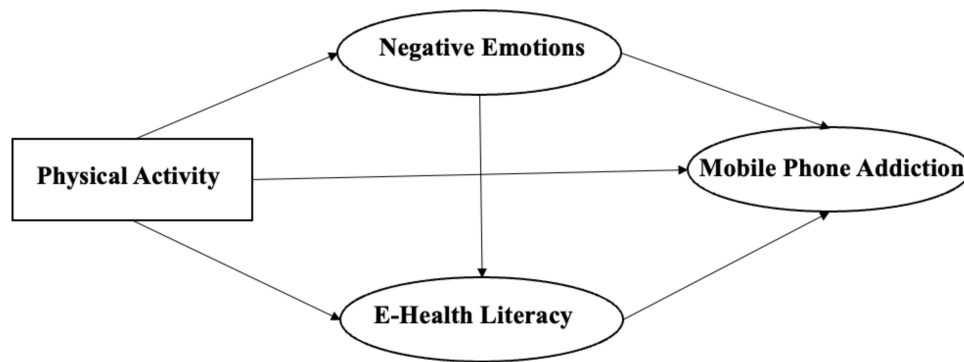


Figure 1 Hypothetical model diagram.

Materials and Methods

Study Design and Setting

On the year 2022, from march 20th to may 20th a cross-sectional study on a survey of college students' mental health in higher education was conducted at Southeast University, Soochow University, Yangzhou University, Yangzhou Vocational and Technical College, and Jiangsu University in Jiangsu Province, China. Data were collected online through the Chinese online questionnaire platform, Questionnaire Star (<http://www.wjx.cn>). The purpose and principles of the questionnaire were detailed at the beginning of the questionnaire, and participants were informed that the survey was anonymous and voluntary. The study was approved by the review committee of Yangzhou University.

Instruments

Participants

The questionnaire was self-reported by online questionnaire users, and 4621 students of freshmen, sophomores and juniors in five colleges and universities in Jiangsu Province were surveyed (at the time of the survey, senior students were facing graduation and career selection and had already left school one after another, so no survey was organized for them). After eliminating invalid questionnaires, 4399 valid questionnaires were obtained, with an effective rate of 95.2%. The main criteria for eliminating invalid questionnaires were: (1) Obvious regularity of answers and excessive number of neutral options; (2) It took too short time to fill in the questionnaire; (3) Conflicting answers to positive and negative questions. There were 2481 male students (56.4%) and 1918 female students (43.6%), with an average age of (19.20 ±2.98) years. The questionnaire was filled out anonymously, the purpose and principles of this survey were explained in detail in the guidance section and other related matters.

Physical Exercise

The Physical Activity Rating Scale (PARS-3),³² woven by the Japanese scholar Kōkuma Hashimoto (1990) and modified by the Chinese scholar Qingde Liang et al, was used to measure the level of physical activity in terms of intensity, frequency and duration of each exercise. The five options of each question were scored from 1 to 5, and the formula was: physical activity = exercise intensity × (exercise time - 1) × exercise frequency, with higher scores indicating greater physical activity of the individual. The Cronbach's α value of the scale in this study is 0.834, which indicates that the scale has a high reliability.

Mobile Phone Addiction Scale

The Tendency to Mobile Phone Addiction Scale for College Students was developed by Xiong Jie et al,³³ a Chinese scholar, with 16 questions containing 4 dimensions of withdrawal symptoms, emergent behaviors, social soothing, and mood change, with a total of 16 items. A 5-point Likert scale was used, with scores ranging from 1 to 5 in the order of not at all, not very much, average, more consistent, and fully consistent; the maximum score was 80 while the minimum score was 16, with higher scores indicating a greater propensity for mobile phone addiction, and vice versa, a lower

propensity for addiction. In this study, the Cronbach's α value of the scale is 0.947, which indicates that the scale has high reliability.

Electronic Health Literacy Scale

The Chinese version of the eHealth Literacy Scale (eHEALS), developed by NORMAN et al³⁴ and translated into Chinese by Shuaijun Guo et al,³⁵ was used. It includes 8 questions with three latitudes: application ability, judgment ability and decision-making ability of online health information and services. The eHealth Literacy Scale (eHEALS) is scored on a 5-point Likert scale, with a score of 1 indicating "very incompatible" and 5 indicating "very compatible", and a total score of 8 to 40. In this study, the Cronbach's alpha value of the eHEALS scale was 0.976.

Depression-Anxiety-Stress Scale

The negative emotions of university students were assessed by the Depression Anxiety Stress Scale (DASS)³⁶ developed by Lovibond (1995), revised by Chinese scholars Gong Xu and Xie Xi Yao,³⁷ and Simplified Chinese version of the Depression Anxiety Stress Scale (21-Item Versions of Depression Anxiety Stress Scale, DASS-21). The questionnaire contains three subscales: depression scale, anxiety scale, and stress scale, with 21 questions, using a four-point scale from 0 to 3 (0: does not meet, 3: always meets), and the higher the score, the more severe the individual's negative emotion. The Cronbach's alpha value for the total DASS-21 scale in this study was 0.969, and the Cronbach's alpha values for the depression, anxiety, and stress subscales were 0.971, 0.894, and 0.923, respectively.

Data Analyses

Data were processed using SPSS 26.0 software, and K-S nonparametric test, reliability analysis, and exploratory factor analysis were used to test the normal distribution of the data and the reliability of the instrument. The standardized data were examined for gender differences on a variable-by-variable basis using the Mann-Whitney *U*-test and for grade differences on a variable-by-variable basis using the Kruskal-Wallis *H*-test. The statistical data were expressed as composition ratio (%) and the measurement data were expressed as $\bar{x} \pm \text{std.dev}$. Spearman correlation analysis was used to analyze the correlations between variables, and Amos 23.0 was used for structural equation modeling. The non-parametric Bootstrap method was used to test the significance of mediating effects. Differences were considered statistically significant at $P < 0.05$.

Common Method Bias Test

Since the study adopted the anonymous self-report method to obtain data, there may be a common method bias effect. According to the study by Hao Zhou et al³⁸ scholars, the data collection procedures should be strictly controlled. Firstly, the psychological questionnaire that makes applicable to our college student population should be selected. Secondly, the confidentiality of personal information and the use of the survey results limited to this study should be emphasized to the respondents. In order to ensure the reliability and accuracy of this research results, this study further used SPSS26.0 to conduct the Harman one-way test for common method deviation, and the results showed that there were 10 factors with eigen values greater than 1, and the variance explained by the first factor was 27.65%, which was less than the critical standard of 40%, indicating that there was no significant common method deviation in this study.

Results

Analysis of Group Differences in Physical Activity, Mobile Phone Addiction, Negative Emotions, and E-Health Literacy

The Mann-Whitney *U*-test for gender showed significant ($P < 0.001$) gender differences and grade differences in physical activity, cell phone addiction, negative emotions, and e-health literacy. Comparison of means revealed that girls had higher physical activity participation (17.56 ± 20.37) and electronic e-health literacy of (29.52 ± 7.15) than boys (14.59 ± 18.36 ; 28.55 ± 7.94), with effect sizes of 0.153 and 0.128, respectively, as measured. Boys had higher levels of cell phone addiction (41.09 ± 14.45) and negative emotions of (16.32 ± 14.23) were higher than those of female students (38.5 ± 13.41 ; 13.48 ± 12.20), with effect sizes of 0, 186 and 0.214, respectively. The results of the Kruskal-Wallis *H*-test for

grade level showed significant grade-level differences in e-health literacy, cell phone addiction, and negative emotions among college students ($P < 0.001$). E-health literacy (28.22 ± 7.27 , 29.26 ± 7.81 , and 30.66 ± 6.87) increased sequentially among freshmen, sophomores, and juniors, and cell phone addiction (41.09 ± 13.31 , 39.58 ± 14.40 , and 36.53 ± 14.04) and negative emotions (15.67 ± 12.71 , 14.96 ± 13.87 , and 11.96 ± 12.19) showed a sequential decrease. The difference between the grades of college students' physical activity was not significant ($P > 0.05$). Detailed results are shown in Table 1.

Relationship Between Physical Activity, Mobile Phone Addiction, Negative Emotions and E-Health Literacy

The statistical results of correlation coefficients (See Table 2) showed that physical exercise, mobile phone addiction and negative emotions were significantly negatively correlated ($r = -.713$, $P < 0.01$; $r = -.571$, $P < 0.01$) and significantly positively correlated with e-health literacy ($r = 0.616$, $P < 0.01$, respectively; e-health literacy was significantly negatively correlated with mobile phone addiction and negative emotions ($r = -.691$, $P < 0.01$; $r = -.729$, $P < 0.01$); mobile phone addiction was significantly positively correlated with negative emotions ($r = 0.794$, $P < 0.01$).

Physical Exercise and Mobile Phone Addiction: Chain Mediating Effect

In order to effectively control the measurement error, including testing the mediating effect of negative affect and e-health literacy between the independent variable physical exercise and the dependent variable mobile phone addiction,

Table 1 Physical Exercise, Mobile Phone Addiction, Negative Emotions, and E-Health Literacy by Mann–Whitney *U*-Test for Gender and Kruskal–Wallis *H*-Test for Grade Level ($M \pm SD$)

Variables	Physical Activity	Mobile Phone Addiction	Negative Emotions	E-Health Literacy
Mann–Whitney <i>U</i>	2133319.000	2,140,384.000	2,128,156.500	2,227,407.000
Wilcoxon <i>W</i>	5212240.000	3,980,705.000	3,968,477.500	5,306,328.000
<i>Z</i>	-5.905	-5.725	-6.023	-3.712
Asymptotic saliency (two-tailed)	0.000	0.000	0.000	0.000
Card Parties	4.63	22.105	22.493	29.315
<i>df</i>	2	2	2	2
Progressive Significance	0.099	0.000	0.000	0.000
Male	14.59 ± 18.36	41.09 ± 14.45	16.32 ± 14.23	28.55 ± 7.94
Female	17.56 ± 20.37	38.5 ± 13.41	13.48 ± 12.20	29.52 ± 7.15
First Year	14.84 ± 17.59	41.09 ± 13.31	15.67 ± 12.71	28.22 ± 7.27
Second Year	16.27 ± 20.04	39.58 ± 14.40	14.96 ± 13.87	29.26 ± 7.81
Third Year	18.45 ± 21.00	36.53 ± 14.04	11.96 ± 12.19	30.66 ± 6.87

Table 2 Spearman Correlation Analysis of Each Variable

Variables	a	b	c	d	e	f	g	h	i	j	k
Physical exercise	I										
Withdrawal symptoms	-0.606**	I									
Protrusive behavior	-0.607**	0.797**	I								
Social soothing	-0.587**	0.731**	0.679**	I							
Mood alteration	-0.589**	0.794**	0.807**	0.703**	I						
Mobile phone addiction	-0.664**	0.939**	0.899**	0.842**	0.900**	I					
Depression	-0.622**	0.746**	0.755**	0.690**	0.739**	0.811**	I				
Anxiety	-0.622**	0.752**	0.749**	0.701**	0.745**	0.814**	0.882**	I			
Stress	-0.616**	0.763**	0.758**	0.707**	0.753**	0.824**	0.891**	0.903**	I		
Negative emotion	-0.646**	0.784**	0.782**	0.727**	0.773**	0.850**	0.953**	0.959**	0.968**	I	
E-health literacy	0.560**	-0.657**	-0.675**	-0.595**	-0.656**	-0.714**	-0.730**	-0.727**	-0.735**	-0.759**	I

Notes: a=physical activity; b=withdrawal symptoms; c=protrusive behavior; d=social soothing; e=mood alteration; f= mobile phone addiction; g=depression; h=anxiety; i=stress; j=negative emotion; k= e-health literacy; ** $P < 0.01$.

this study used structural equation modeling to test the chain mediating effect. According to the process of testing mediating effects proposed by Wen Zhonglin et al,³⁹ AMOS 26.0 was used to analyze the structural equation modeling of the variables physical exercise, mobile phone addiction, negative emotion and e-health literacy. After model correction, the results of the fitted indicators were basically achieved: $X^2/df=4.270<5.000$, $NFI=0.998>0.900$, $GFI=0.995>0.900$, $TLI=0.997>0.900$, $RFI=0.996>0.900$, $CFI=0.998>0.900$, and $RMSEA=0.027<0.080$, indicating that the overall fit of the model is good. As shown in Figure 2, all standardized path coefficients were significant ($P < 0.001$). Physical exercise had a significant negative predictive effect on mobile phone addiction and negative emotion ($\beta=-0.41$, $P < 0.001$; $\beta=-0.58$, $P < 0.001$) and a significant positive predictive effect on e-health literacy ($\beta=0.28$, $P < 0.001$), and the findings confirmed hypothesis H1; negative emotion had a significant positive predictive effect on mobile phone addiction ($\beta=0.55$, $P < 0.001$); e-health literacy had a significant negative predictive effect on mobile phone addiction ($\beta=-0.06$, $P < 0.001$).

To verify the mediating effect of negative affect and e-health literacy, the bias-corrected nonparametric percentile Bootstrap method was used to test the mediating effect between physical exercise and mobile phone addiction,⁴⁰ with a Bootstrap count of 5000, and 95% confidence intervals were calculated; if the 95% CI of the standardized path coefficients did not contain 0, then the intermediate effect was significant. As can be seen from Table 3, the 95% CI of the mediating effect of physical exercise to mobile phone addiction via negative emotion was $[-.090, -.074]$; the 95% CI of the mediating effect of physical exercise to mobile phone addiction via e-health literacy was $[-.008, -.001]$; the 95% CI of the chain mediating effect of physical exercise to mobile phone addiction via negative emotion and e-health literacy was $[-.009, -.001]$, the 95% CI of the above three paths do not contain 0, indicating that the total, direct, and total indirect effects in the model are statistically significant, and the findings confirm hypotheses H2 and H3. Further analysis of the effect sizes of the variables on mobile phone addiction showed that the total effect of physical exercise to mobile phone addiction was -0.199 , the direct effect was -0.107 (effect size 53.8%), the total indirect effect was -0.091 (effect size 45.7%), and the mediated effects of the three paths of physical exercise \rightarrow negative emotion \rightarrow mobile phone addiction, physical exercise \rightarrow e-health literacy \rightarrow mobile phone addiction, and physical exercise \rightarrow negative emotion \rightarrow e-health literacy \rightarrow mobile phone addiction were -0.082 , -0.004 , and -0.005 , respectively, while the effect sizes (ie,

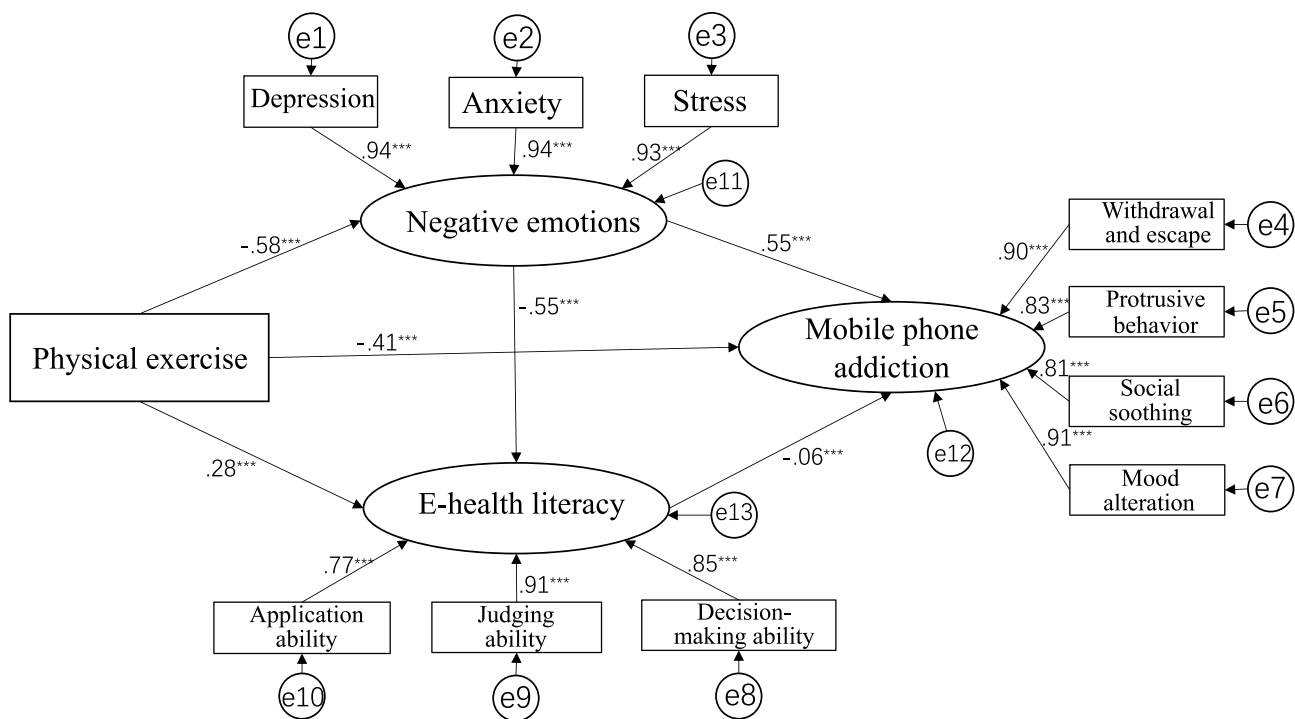


Figure 2 Results of pathway analysis of physical activity, mobile phone addiction, negative emotions, and e-health literacy. Note: *** $P < 0.001$.

Table 3 Mediating Effect Test Between Physical Exercise and Mobile Phone Addiction Among College Students

Path	Effect Value	Bootstrap SE	Bootstrap 95% CI	Relative Intermediary Effect %
Physical exercise→Negative emotion →Mobile phone addiction	-0.082	0.004	[-.090, -0.074]	41.2%
Physical exercise →E-health literacy→Mobile phone addiction	-0.004	0.002	[-.008, -0.001]	2.0%
Physical exercise →Negative emotion →E-health literacy→Mobile phone addiction	-0.005	0.003	[-.009, -0.001]	2.5%
Total indirect effect between physical exercise and mobile phone addiction	-0.091	0.011	[-.373, -0.332]	45.7%
Direct effect	-0.107	0.011	[-.114, -0.101]	53.8%
Total effect	-0.199	0.013	[-.205, -0.193]	100%

relative mediated effects: $ge3$ mediated effect values as a proportion of the total effect) was 41.2%, 2.0%, and 2.5%, respectively, but the 95% confidence intervals of the above indirect effects did not contain 0, indicating that all three pathways were statistically significant.

Discussion

Group Analysis of Physical Activity, Mobile Phone Addiction, Negative Emotions and E-Health Literacy Among College Students

The Mann–Whitney *U*-test for gender showed that the gender differences in physical exercise, mobile phone addiction, negative emotions, and e-health literacy among college students were significant. 1) Physical exercise and e-health literacy were higher among female than male students, the result was consistent with previous national studies.^{41–43} The development of the times promotes the liberation of women’s bodies, and female college students’ physical exercise is no longer influenced by traditional body concepts or macro social gender role perceptions, and they actively participate in the “physical practice” of experiencing sports to improve their perceptions and knowledge of their own bodies and lives,^{44,45} in addition, because female students pay more attention to their health literacy than male students, they are more 2 Girls that have lower levels of mobile phone addiction and negative emotions, which is consistent with previous studies. The Kruskal–Wallis H-test for grades showed that physical activity and e-health literacy increased sequentially in freshman, sophomore, and junior years, while mobile phone addiction and negative affect showed sequential decreases, which is consistent with previous studies.^{41,46,47} Compared to the lower grades, the upper grades are relatively easier in school, while social skills and mental intelligence mature and develop good exercise and lifestyle habits, reducing the frequency of mobile phone use. As they grow older, when faced with negative situations such as neglect or rejection, senior college students are more likely to choose appropriate emotional regulation or cope with everything to get rid of emotional dilemmas.

The Effect of Physical Exercise on College Students’ Mobile Phone Addiction

This study found that physical exercise was significantly and negatively correlated with mobile phone addiction among college students, indicating that the higher the degree of college students’ physical exercise participation the lower the likelihood of mobile phone addiction, (this result is consistent with the results of previous studies).^{10,48,49} Hypothesis H1 holds. Physical exercise indirectly plays a role in treating cell phone addiction by regulating the functions of brain neurotrophic factor, endocrine system and immune system to improve the psychological and mental symptoms of cell phone addicted adolescents. At the immune system level, physical exercise not only inhibits the production of pro-inflammatory cytokines such as tumor necrosis factor (TNF- α), interleukin-1 α (IL-1 α), and interleukin-6 (IL-6) including reduces the activity of peroxidase, but also secretes a large amount of actin IL-6 and other anti-inflammatory factors, which improves the cognitive function of the hippocampus, and exerts a potential function of anti-inflammatory and anti-mobile phone addiction.⁵⁰ Positive thought re-perception theory suggests that individuals with high levels of positive thoughts are better able to focus on present moment activities, improve cognitive functioning, actively reduce

interference from external factors, and enhance control over negative behaviors.⁵¹ Physical exercise can effectively increase the level of trait positivity in college students,⁵² and positivity as a positive personality trait can buffer college students from mobile phone addiction.⁵³ Therefore, college students who regularly participate in physical activity may have higher levels of positive thinking and lower levels of mobile phone addiction. A study by Zhu Fengshu et al stated that the self-control resource model suggests that individuals have limited self-control energy resources and that performing one self-energy control resource requires a certain amount of self-control resources to be consumed.⁵⁴ College students increase their self-control resources through physical exercise, which in turn enhances self-control.⁵⁵ And studies have shown that the higher the self-control ability, the lower the tendency of mobile phone addiction.⁵⁶ This explains that physical exercise among college students can effectively improve the problem of mobile phone addiction, enriching the existing related studies and also providing theoretical and practical insights into intervention initiatives for mobile phone addiction among college students.

Negative Emotions and e-Health Literacy Play Separate Mediating Roles Between Physical Exercise and Mobile Phone Addiction Among College Students

The mediation effect analysis illustrates that there is a mediating role of negative emotion and e-health literacy in the mediation model of physical exercise affecting college students' mobile phone addiction, with the effect size accounting for 42.1% of the total effect; there is also a terminating role of e-health literacy, with the effect size accounting for 2.0% of the total effect. Hypothesis H2 holds, indicating that physical exercise can directly reduce mobile phone addiction, as well as reduce Internet addiction by alleviating negative emotions, and also reduce Internet addiction by improving e-health literacy. The self-control resource model suggests that negative emotions can reduce an individual's resistance to addictive objects by weakening self-control and inhibiting the activity of executive functions, which in turn causes mobile phone addiction.⁵⁷ The Cognitive Theory of Emotion (Cognitive Theory) suggests that emotions stimulate specific goals and cognitions, and that an important function of emotions is to change cognition.³² Cognitive bias is strongly associated with the onset, development and persistence of mobile phone addiction.⁵⁸ Physical exercise can effectively enhance emotion regulation self-control, improve negative emotion cognition, and promote individuals to maintain positive emotions, which in turn reduces the risk of mobile phone addiction.

As the Internet with mobile phones and computers is an important and indispensable part of college students' life and learning, the level of e-health literacy determines the health behavior norms of the college student population in online information search, including a series of abilities to search for electronic resources, understand and evaluate the quality of health information and its applicability in specific situations, with analyzing, understanding, and using health information to make rational decisions.⁵⁸ Studies have shown that exercise is one of the most important factors influencing e-health literacy among college students.⁵⁹ Individuals with high good e-health literacy have healthier lifestyles and help strengthen individual health knowledge and awareness of health responsibilities,^{60,61} so that they can actively obtain appropriate health information to make rational behavioral decisions, which is a decision-making ability to resist mobile phone addiction⁶² and helps to avoid overindulgence in mobile phone behavior.

The Chain Mediating Role of Negative Emotions and e-Health Literacy Between Physical Activity and Mobile Phone Addiction

The study showed that negative emotion and e-health literacy play a chain mediating role between physical exercise and mobile phone addiction, with the effect size accounting for 2.5% of the total effect, ie, college students' physical exercise influences mobile phone addiction by affecting negative emotion, which in turn affects e-health literacy, and finally, hypothesis H4 is verified. Among them, negative emotion can negatively predict e-health literacy, ie, the stronger the negative emotion, the lower the e-health literacy. Studies have shown that rational treatment of online information and reasonable management of individual emotions can effectively avoid being infected by negative information and emotions in cyberspace and promote positive interactions in the online environment.⁶³ Overall, active participation in physical exercise can reduce individuals' negative emotions and thus improve their e-health literacy, enabling them to reasonably controlling themselves to make choices not to indulge in mobile phones and reduce mobile phone addiction in the face of mobile phones.

Conclusion

This study reveals the relationship between physical exercise, cell phone addiction among college students and constructs a chain mediation model, which has important theoretical value for understanding the causes of cell phone addiction among college students and provides insights into the prevention and intervention of cell phone addiction among college students. (1) Physical exercise significantly negatively predicts college students' cell phone addiction and negative emotions, and positively predicts college students' e-health literacy, which means that physical exercise can reduce college students' cell phone addiction and negative emotions, and improve their e-health literacy; (2) Physical exercise not only directly affects cell phone addiction, but also indirectly affects cell phone addiction through the independent mediation of negative emotions and e-health literacy, as well as through the chain mediation of the two; (3) Physical exercise also indirectly affects cell phone addiction.

There are some limitations in this study that need to be improved in future research: first, the cross-sectional design of this study cannot scientifically reveal the causal relationship between variables, and the cross-sectional study has the disadvantage of possible errors in the process of mediation effect testing. Future research will further explore the mechanism of physical activity on Internet addiction through longitudinal perspective or experimental research. Secondly, from an etiological point of view, the cause mechanisms of mental health problems such as negative emotions and cell phone addiction are complex, which may include genetic background, external adverse environment, etc., and it is necessary to carry out research on such psychological problems from a cross-disciplinary perspective in the future. Finally, some family factors (family residence, family income, parents' education level, etc.) may affect the degree of Internet addiction, and the potential factors of Internet addiction will be considered comprehensively from three aspects: individual, social, school and family in future studies.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Requests to access the datasets should be directed to tongwenxia@yzu.edu.cn.

Ethical Approval

The study proposals were reviewed and approved by Yangzhou University, and that it was conducted in accordance with the Declaration of Helsinki. Moreover, before collecting data, the vital information about the study has been introduced to participants and we have obtained the participants' written consent who take part in the research prior to the commencement of the study.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study. All participants' parents and their teachers in charge of the class consent to involve in the study.

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Disclosure

The authors report no conflicts of interest in this work.

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