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How Physical Exercise Reduces Problematic Mobile Phone Use in Adolescents: The Roles of Expression Suppression, Depression, Anxiety, and Resilience

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Background: Problematic mobile phone use has become a pressing concern among adolescents due to its widespread prevalence and associated health risks. Physical exercise has been suggested as a potential intervention, but the psychological mechanisms underlying its effects remain unclear. This study explores how physical exercise impacts problematic mobile phone use through expression suppression, emotional problems (depression and anxiety), and resilience, offering actionable insights for intervention strategies.

Methods: The study involved 2,032 Chinese adolescents who completed standardized self-report questionnaires assessing physical exercise, expression suppression, emotional problems, resilience, and problematic mobile phone use. Statistical analyses were conducted using a moderated serial mediation model.

Results: Among the participants, 25.5% reported problematic mobile phone use, while 37.5% experienced both depression and anxiety. Physical exercise was negatively associated with problematic mobile phone use ($\beta = -0.195$, $p < 0.001$) through its effects on expressive suppression, depression, and anxiety. Indirect effects mediated by expressive suppression and depression/anxiety accounted for 52.0% and 44.4% of the total effect, respectively. Additionally, resilience moderated the pathway linking expressive suppression to depression and anxiety (interaction effect for depression: $\beta = -0.080$, 95% CI: −0.111 to −0.048; for anxiety: $\beta = -0.065$, 95% CI: −0.097 to −0.033), with low resilience amplifying the negative emotional impacts of expressive suppression.

Conclusion: Physical exercise can directly reduce problematic mobile phone use and indirectly alleviate its associated risks by improving emotion regulation and reducing emotional problems. Expressive suppression and depression/anxiety play significant mediating roles, while resilience moderates these pathways, highlighting its protective effect. By targeting both behavioral and psychological factors, interventions that combine physical activity promotion with resilience training show promise in addressing problematic mobile phone use and associated emotional issues in adolescents.

Keywords: physical exercise, expressive suppression, depression/anxiety, resilience, problematic mobile phone use, adolescent

Introduction

Adolescence is not only a crucial developmental period in which prominent changes occur in physical and psychological domains, but also a sensitive time for the formation and consolidation of lifestyle behaviors to promote healthy habit. With the continuous development of technological devices, the mobile phone has become an integral part of adolescents' lives. Problematic mobile phone use, characterized by the inability to control mobile phone usage[1]—also called mobile phone addiction and mobile phone dependence—has emerged as a global public health issue and has become an increasing concern for both researchers and users.[2,3] Its prevalence among adolescents is estimated to be between 15%–40%, with rates continuing to rise.[4] Problematic mobile phone use poses significant risks, potentially leading to severe physical and psychological outcomes, especially among adolescents.[5] While mobile phones are widely acknowledged for meeting

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adolescents' needs, their developmental characteristics make it crucial to address and reduce challenges associated with problematic mobile phone use.[6] Several factors, including emotional problems, expression suppression, and resilience, are believed to play a role in this phenomenon. However, there is a lack of comprehensive studies examining the association between physical exercise and problematic mobile phone use, especially considering these psychological factors.

Depression and anxiety are common, debilitating emotional problems that usually emerge for the first time during adolescence.[7] During adolescence, individuals undergo profound changes in physical, cognitive, emotional, and social aspects, which are more extensive compared to other developmental periods.[8] As a result, they are at greater risks of emotional problems, for example, of depression and anxiety.[9] Depression and anxiety are highly comorbid and share several common etiological processes.[10] It has been demonstrated that approximately 85% of people with depression also experience anxiety, and that 90% of people with anxiety disorders also experience depression.[11] This high comorbidity highlights the need to explore both the shared and distinct factors underlying these emotional problems. Given the widespread prevalence of depression and anxiety among adolescents, this developmental stage is a critical period for identifying and understanding the factors contributing to these symptoms.[12]

Deficits in emotion regulation have been both theoretically proposed and empirically demonstrated to be linked with various affective disorders and addictive behaviors.[13] Depression and anxiety, widely viewed as the result of difficulties with emotion regulation, are intensifying among adolescents,[12,14] and their co-occurrence is characterized by an over-reliance on expression suppression.[15] Expression suppression as a strategy of emotion regulation is defined as inhibiting ongoing emotion expressive behavior.[16] A meta-analysis of 106 empirical studies conducted in China revealed a noteworthy positive correlation between the use of expressive suppression and emotional problems such as depression and anxiety.[17] This strategy of regulating emotions has been linked to adverse effects on social functioning, potentially hindering the ability to obtain social support.[15] Furthermore, individuals who hold the belief that emotions are difficult to regulate often resort to expressive suppression, which might elevate their vulnerability to smartphone addiction. Despite its importance, the link between emotion regulation strategies, particularly expressive suppression, and mobile phone use remains underexplored.[18] Understanding the risk and protective factors that lead to the development of emotional and behavioral problems is essential in preventing them.

As adolescents grow older, their level of physical activity typically declines,[19] with a significant reduction often observed during the transition from junior to senior high school, particularly between the ages of 15 and 16.[20] In contrast, the incidence of psychological challenges, including depression and anxiety, tends to rise with age, becoming especially pronounced during mid-adolescence.[21] Research conducted by Bernstein and McNally suggests that acute bouts of aerobic exercise can address deficits in emotion regulation. Furthermore, incorporating physical activity into psychosocial treatments may enhance interventions aimed at improving emotional control.[22] Tang et al explored the link between physical exercise and negative emotions among 479 university students, serves as a key mediator between physical activity and mental health issues like depression and anxiety.[23] According to the theory of temporal self-regulation of physical activity,[24] various positive outcomes are associated with engaging in physical exercise, potentially influencing behaviors such as problematic mobile phone use. A study by Pereira et al found that adolescents with low levels of physical activity are more prone to experiencing problems with smartphone usage compared to their more active peers.[25] Additionally, a recent meta-analysis confirmed that physical exercise can be an effective approach to prevent or mitigate mobile phone addiction in young people.[26] One narrative review also proposed that physical activity may facilitate resilience to improve emotional and behavioral regulation during adolescence.[27] Adolescence is a critical period characterized by significant changes in physical activity levels and emotional well-being. Gaining deeper insights into the relationship between these factors is essential for providing adolescents with evidence-based strategies to cultivate healthy lifestyle habits. Such strategies can help address emotional and behavioral challenges not only during this developmental stage but also across their lifespan. Although some valuable insights have been made, they are inadequate to address the problem, and the potential effects underlying the association between physical activity and problematic mobile phone use (eg, mediators, moderators) remain largely unknown.[28]

Resilience may also represent a protective factor against emotional and behavioral difficulties for adolescents. Resilience refers to the ability to withstand, recover, and grow in the face of stressors and changing demands.[20] Thus, resilience includes not only recovery but also resistance against mental health problems.[27] Resilience helps to ward off symptoms of depression and anxiety and markedly influences the associations between lifestyle factors and symptoms in adolescents.[29] The diathesis-stress

model suggests that while vulnerable and resilient individuals may not differ during adversity, resilience can modify the impact of adverse events on mental health, particularly depression and anxiety.[30] Resilience has been postulated to be a coping strategy to moderate the progression of negative emotions. Despite increasing research interest in adolescent's emotional problems, there is a lack of information on the underlying mechanisms that influence the development of emotional problems in this population. Furthermore, resilience, as an effective coping strategy, may enable thoughtful insights to help individuals avoid addictive behaviors.[31] We proposed that resilience, as a strategy for coping, might play a role in moderating the development of problematic mobile phone use.

Therefore, this study seeks to provide insights into the potential of physical exercise as an intervention for reducing problematic mobile phone use among adolescents. By investigating the roles of psychological factors such as emotional problems, expression suppression, and resilience, the study aims to contribute to the development of targeted intervention strategies for addressing problematic mobile phone use. Specifically, we hypothesized (1) that physical exercise would be significantly and negatively correlated with problematic mobile phone use in adolescents, and (2) that this relationship would be mediated or moderated by expression suppression, emotional problems, and resilience. While previous research has primarily focused on the direct relationship between physical exercise and problematic mobile phone use, less attention has been paid to the underlying psychological mechanisms. Thus, this study uniquely explores the mediating and moderating roles of these psychological factors, providing a more comprehensive understanding of how physical exercise influences problematic mobile phone use.

Methods

Participants

This study conducted via a convenience sampling administered self-report questionnaires to obtain data from adolescents residing in Shandong Province, China. Participants were recruited through the school's internal network, with data collection occurring via an online survey platform. To qualify for the study, participants had to be between 10 and 19 years old and possess unrestricted access to a mobile phone. Those who completed the questionnaire in under 3 minutes or provided inconsistent responses to certain items (eg, failing to select "strongly agree" for a prompt instructing them to do so) were excluded from the analysis. After a thorough review of our data, we excluded 168 questionnaires from the analysis. This resulted in a final response rate of 92.4%, calculated based on the total number of distributed questionnaires (2,200) and the valid responses included in the analysis (2,032). The participants in our study were adolescents aged 13 to 18 years (mean age = 16.24, SD = 0.98), consisting of 365 males (18.0%) and 1,667 females (82.0%). In terms of residential areas, 1,281 participants (63.0%) resided in rural areas, while 751 participants (37.0%) lived in urban settings. Regarding only-child status, 231 participants (11.4%) were only children, whereas 1,801 participants (88.6%) had siblings. The quality of participants' relationships with their parents was categorized as follows: 1,923 participants (94.6%) reported harmonious relationships with both parents, 59 participants (2.9%) reported harmony with their mother only, 21 participants (1.0%) reported harmony with their father only, and 29 participants (1.4%) reported disharmony. Family income levels, as perceived by participants, were classified into three categories: low income (218 participants, 10.7%), medium income (1,783 participants, 87.7%), and high income (31 participants, 1.5%).

This study adhered to the principles outlined in the Declaration of Helsinki, ensuring compliance with ethical standards for research involving human subjects. Ethical approval was granted by the Ethics Committee of Qingdao University. Written consent was obtained from all participants and their legal guardians after they were informed about the study details. Participants were made aware that their involvement was entirely voluntary, with the freedom to withdraw at any stage of the study.

Measures

Demographic Characteristics

Demographic information, including name, sex, age, residential area, only-child status, relationship with parents, and perceived family income, was collected from the participants.

Physical Exercise

Physical exercise was measured using the Physical Exercise Questionnaire, a tool frequently employed for evaluating physical activity among Chinese adolescents due to its demonstrated reliability and validity.[32] This questionnaire comprises eight items

categorized into two dimensions: exercise commitment and exercise persistence. Participants rated their agreement with each statement on a 5-point Likert scale, where 1 indicated "strongly disagree" and 5 represented "strongly agree". The overall score reflected the participant's level of physical exercise. In this study, the Cronbach's alpha was 0.855.

Expressive Suppression

Expressive suppression was assessed by using the Emotion Regulation Questionnaire, a 10-item self-report tool, was used to evaluate emotion regulation strategies, specifically cognitive reappraisal and expressive suppression, using a 7-point Likert scale where participants rate their agreement from 1 (strongly disagree) to 7 (strongly agree).[33] Higher scores indicated greater habitual use. This study assessed expressive suppression, not cognitive reappraisal, and thus used only that corresponding subscale. The Emotion Regulation Questionnaire, translated into Chinese, has been demonstrated to be a dependable and valid tool for assessing emotion regulation in Chinese student populations.[34] Cronbach's alpha in the present study was 0.782.

Depression and Anxiety

Measures of depression and anxiety were obtained using part of the Depression Anxiety Stress Scale-21(DASS-21).[35] Participants evaluated how much specific experiences were relevant to them over the past week using a 4-point Likert scale, where 0 represented "not at all applicable" and 3 indicated "very much or most of the time". Scores exceeding 9 for depression and 7 for anxiety were used as cut-off points for identifying potential cases. The Chinese version of the DASS-21 has demonstrated strong reliability and validity, making it appropriate for application among Chinese student populations.[36] Cronbach's alpha was 0.879 for the depression scale and 0.849 for the anxiety scale.

Resilience

Resilience was measured using the Connor-Davidson Resilience Scale (CD-RISC).[37] The CD-RISC comprises 25 self-reported items grouped into three subscales: tenacity, strength, and optimism. Responses are recorded on a 5-point Likert scale, ranging from 0 ("never") to 4 ("always"), with a possible total score between 0 and 100. Higher scores reflect greater resilience. The Chinese version of the CD-RISC demonstrated strong reliability, with a coefficient of 0.910.[38] In the present study, Cronbach's alpha was calculated as 0.936.

Problematic Mobile Phone Use

Problematic mobile phone use was assessed using the Self-rating Questionnaire for Adolescent Problematic Mobile Phone Use.[39] This 13-item scale evaluates three aspects: withdrawal symptoms, craving, and physical and mental health. Responses are evaluated using a 5-point Likert scale ranging from 1 (never) to 5 (always), yielding total scores between 13 and 65. A cutoff point based on the 75th percentile was applied to identify problematic use. The questionnaire demonstrates strong psychometric properties and is suitable for evaluating mobile phone dependence among Chinese adolescents.[39] In this study, Cronbach's alpha was 0.927.

Covariates

Age, sex, residential area, only-child status, relationship with parents, and perceived family income were included as control variables based on previous findings. Age, sex, and perceived family income are considered significant factors in understanding associations between physical activity, electronic media use and adolescents' mental health.[40] Relationship with parents play a crucial role in shaping emotional regulation, with positive relationships promoting better coping mechanisms.[41] Residential area and only-child status are key demographic factors known to influence depression, anxiety, and problematic mobile phone use among adolescents.[42] Controlling these variables helps ensure that the effects of physical exercise problematic mobile phone use are not confounded by these external factors.

Statistical Analysis

All statistical analyses were performed using SPSS software, version 25.0. First, Harman's single-factor test confirmed the absence of common method bias in this study. Secondly, we conducted descriptive statistical analyses and Pearson's correlation analyses to explore the relationships among variables. Subsequently, mediation and moderation effects, as well as their combinations, were analyzed using the SPSS PROCESS macro. Specifically, the hypothesized model was examined through models 6 and 91 in the SPSS PROCESS macro. For significant moderating effects, simple slope

analyses were performed, and the results were visualized with slope diagrams. These diagrams were generated using values adjusted by ±1 standard deviation (SD) from the mean of the moderating variable. To address potential discrepancies arising from different data units, all variables were standardized prior to analysis. The bootstrapping method was applied with 5000 resamples, and the 95% confidence interval (CI) was reported. 95% CI is provided to indicate the range within which the true parameter value is likely to fall with 95% certainty. Results were considered statistically significant if the 95% confidence interval excluded zero and the *p*-value was less than 0.05.

Results

Demographic and other basic characteristics of the participants are provided in Table 1. Depression levels among participants were within the normal range for 60.9% of individuals, while 39.1% exhibited symptoms ranging from mild to extremely severe (scores >9). Anxiety levels were normal in 39.2% of participants, with 60.8% experiencing symptoms ranging from mild to extremely severe (scores >7). In total, 37.5% of the participants experienced both depression and anxiety. The estimated prevalence of problematic mobile phone use in the population was 25.5%.

Table 1 Demographic and Other Characteristics of Participants

Characteristic	No. (%) of 2032 Participants
Age, mean ± SD, y	16.24 ± 0.98
Sex	
Male	365 (18.0)
Female	1667 (82.0)
Residential area	
Rural	1281 (63.0)
Urban	751 (37.0)
Only-child status	
Yes	231 (11.4)
No	1801 (88.6)
Relationship with parents	
All in harmony	1923 (94.6)
Harmony with my mother only	59 (2.9)
Harmony with my father only	21 (1.0)
Disharmony	29 (1.4)
Perceived family income	
Low	218 (10.7)
Medium	1783 (87.7)
High	31 (1.5)
Depression	
Normal	1238 (60.9)
Mild	278 (13.7)
Moderate	381 (18.8)
Severe	75 (3.7)
Extremely severe	60 (2.9)
Anxiety	
Normal	797 (39.2)
Mild	179 (8.8)
Moderate	614 (30.2)
Severe	185 (9.1)
Extremely severe	257 (12.7)
Problematic mobile phone use	
Yes	518 (25.5)
No	1514 (74.5)

Table 2 Descriptive Statistics and Correlations Between Variables

Variable	Mean ± SD	1	2	3	4	5	6
1. Physical exercise	27.52 ± 4.90	–					
2. Expressive suppression	14.76 ± 5.32	−0.111***	–				
3. Depression	7.94 ± 7.78	−0.262***	0.259***	–			
4. Anxiety	10.52 ± 7.71	−0.249***	0.270***	0.824***	–		
5. Resilience	50.99 ± 15.70	0.305***	−0.007	−0.277***	−0.219***	–	
6. Problematic mobile phone use	27.75 ± 9.71	−0.195***	0.153***	0.415***	0.382***	−0.114***	–

Note: ***Statistically significant at $p < 0.001$.

Descriptive statistics and correlations of the main variables are shown in Table 2. Physical exercise was negatively correlated with expressive suppression, depression, anxiety, and problematic mobile phone use and was positively correlated with resilience. Expressive suppression was positively correlated with depression, anxiety, and problematic mobile phone use and was negatively correlated with resilience. Depression was positively correlated with anxiety and problematic mobile phone use and was negatively correlated with resilience. Anxiety was negatively correlated with resilience and was positively correlated with problematic mobile phone use.

The moderated serial mediation model was generated using SPSS PROCESS macro Model 91. The serial mediating roles of expressive suppression and depression/anxiety are shown in Figures 1 and 2. Physical exercise demonstrated a negative

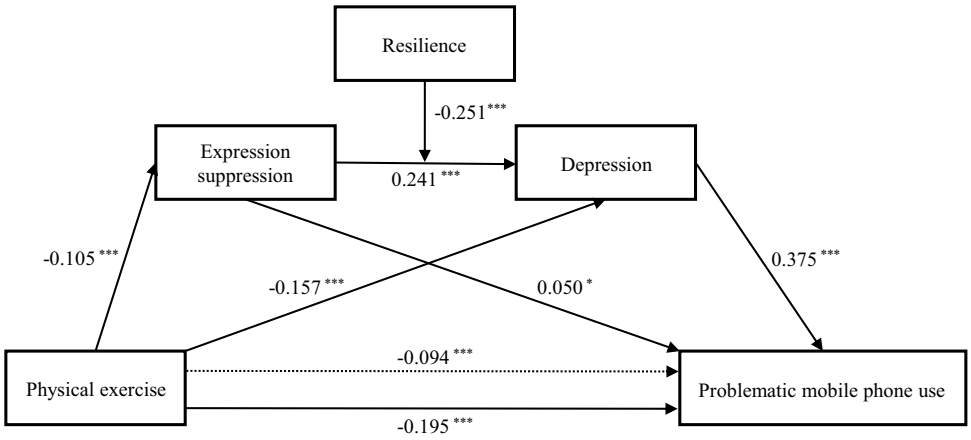

Figure 1 Serial mediating roles of expressive suppression and depression underlie the association between physical exercise and problematic mobile phone use. Numerical values next to each pathway indicate standardized regression coefficients. ***$p < 0.001$, *$p < 0.05$.

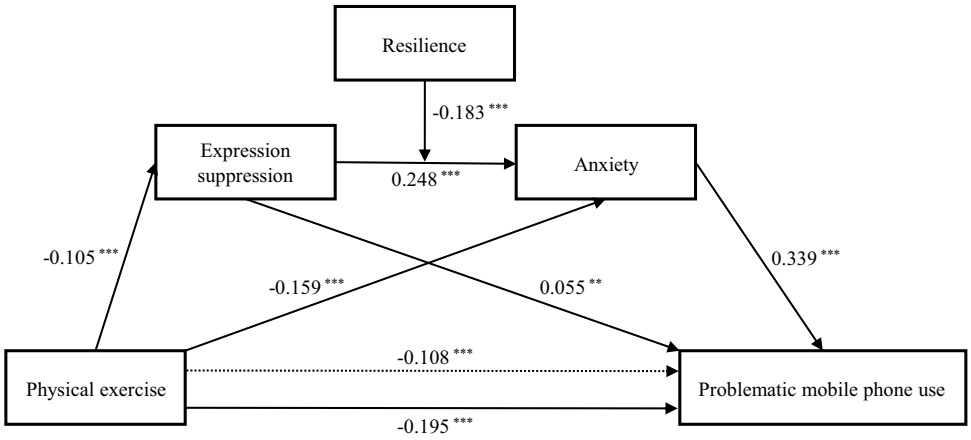

Figure 2 Serial mediating roles of expressive suppression and anxiety underlie the association between physical exercise and problematic mobile phone use. Numerical values next to each pathway indicate standardized regression coefficients. ***$p < 0.001$, **$p < 0.01$.

relationship with expressive suppression, depression, anxiety, and problematic mobile phone use. Conversely, expressive suppression was positively linked to depression, anxiety, and problematic mobile phone use. Depression and anxiety also exhibited positive associations with problematic mobile phone use. The influence of physical exercise on problematic mobile phone use was found to be partially mediated by expressive suppression and depression/anxiety. This indicates that physical exercise not only directly reduces problematic mobile phone use but also influences it indirectly through improved emotional regulation and reduced emotional problems. Mediation analysis, conducted using bootstrapping methods, revealed the serial multiple mediation effects underlying the connection between physical exercise and problematic mobile phone use. The indirect effects mediated by expressive suppression and depression/anxiety accounted for 52.0% and 44.4% of the total effects, respectively. These findings emphasize the importance of addressing both emotion regulation and emotional problems in interventions aimed at reducing problematic mobile phone use. The total indirect effects included three significant pathways. For depression, physical exercise–expressive suppression–problematic mobile phone use, physical exercise–depression–problematic mobile phone use, and physical exercise–expressive suppression–depression–problematic mobile phone use pathways accounted for 2.7%, 44.6%, and 4.7% of the total effect, respectively. For anxiety, physical exercise–expressive suppression–problematic mobile phone use, physical exercise–anxiety–problematic mobile phone use, and physical exercise–expressive suppression–anxiety–problematic mobile phone use pathways accounted for 3.0%, 37.0%, and 4.4% of the total effect, respectively. These results provide actionable insights into the complex mechanisms linking physical exercise and problematic mobile phone use, suggesting that interventions promoting physical activity might effectively reduce problematic mobile phone use by targeting both direct behavioral pathways and underlying emotional and psychological factors.

The moderating effects of resilience are shown in Table 3. The bootstrapping results demonstrated that the interaction effects between expressive suppression and resilience were statistically significant (for depression: $\beta = -0.080$, 95% CI: −0.111 to −0.048; for anxiety $\beta = -0.065$, 95% CI: −0.097 to −0.033). These results indicate that resilience mitigates the adverse effects of expressive suppression on mental health outcomes, highlighting its protective role against emotional dysregulation. To better illustrate the moderating effect of resilience, we conducted a simple slope analysis. Figure 3 shows that for participants with lower resilience (−1 SD), expressive suppression significantly and positively predicted depression/anxiety (depression simple slope = 0.321, $p < 0.001$; anxiety simple slope = 0.312, $p < 0.001$), whereas for participants with higher resilience (+1 SD), expressive suppression also significantly and positively predicted depression/anxiety, but its predictive effect was smaller (depression simple

Table 3 Moderated Mediation Modeling Results Assessing the Effect of Expressive Suppression on Emotional Problems

Outcome Variable	Factor	β	SE	t	LLCI	ULCI	R^2	F
Depression	Expressive suppression	0.241	0.020	12.078	0.202	0.280	0.214	55.080***
	Resilience	−0.251	0.021	−11.731	−0.293	−0.209		
	Expressive suppression ×Resilience	−0.080	0.016	−4.973	−0.111	−0.048		
	Age	0.061	0.020	3.053	0.022	0.099		
	Sex	−0.161	0.054	−2.982	−0.268	−0.055		
	Residential area	0.071	0.043	1.6483	−0.013	0.154		
	Only-child status	−0.128	0.065	−1.957	−0.255	0.000		
	Relationship with parents	0.340	0.046	7.464	0.251	0.429		
	Perceived family income	−0.109	0.060	−1.823	−0.225	0.008		
Anxiety	Expressive suppression	0.248	0.020	12.196	0.208	0.288	0.185	45.855***
	Resilience	−0.183	0.022	−8.416	−0.226	−0.141		
	Expressive suppression ×Resilience	−0.065	0.016	−3.947	−0.097	−0.033		
	Age	0.030	0.020	1.486	−0.010	0.070		
	Sex	−0.071	0.055	−1.285	−0.1789	0.037		
	Residential area	0.074	0.044	1.695	−0.012	0.159		
	Only-child status	−0.004	0.066	−0.053	−0.134	0.127		
	Relationship with parents	0.343	0.046	7.400	0.252	0.434		
	Perceived family income	−0.225	0.061	−3.712	−0.344	−0.106		

Note: ***Statistically significant at $p < 0.001$.

Abbreviations: β, standardized coefficients, represent the strength and direction of these relationships, where positive values indicate a positive association, and negative values indicate a negative association; LLCI, lower limit of the 95% confidence interval; ULCI, upper limit of the 95% confidence interval.

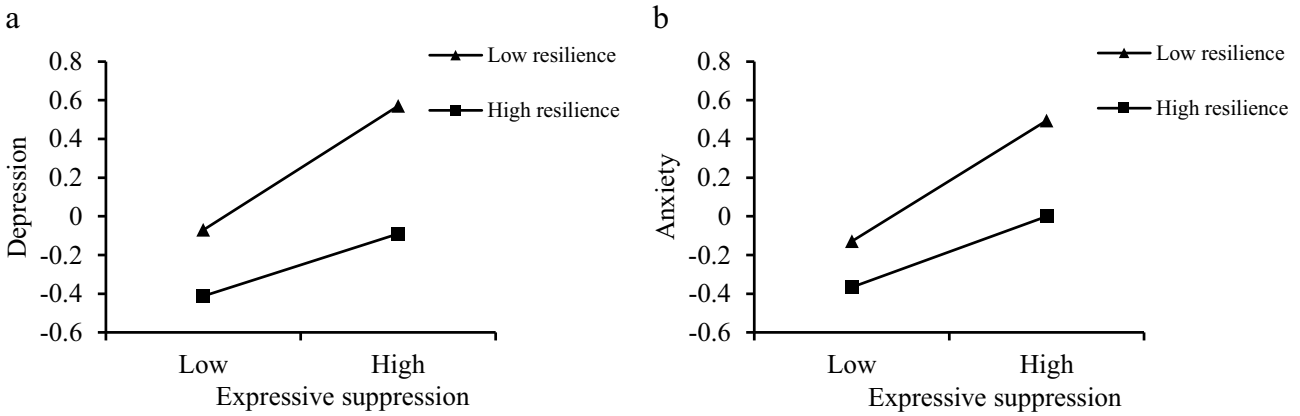

Figure 3 Resilience moderates the effect of expressive suppression on emotional problems. (**a**) A visual representation of the moderation effect of expressive suppression on depression at low and high levels of resilience. (**b**) A visual representation of the moderation effect of expressive suppression on anxiety at low and high levels of resilience.

slope = 0.161, $p < 0.001$; anxiety simple slope = 0.183, $p < 0.001$). These findings suggested that the effect of expressive suppression on depression/anxiety significantly decreased as adolescents' resilience increased. These findings suggest that resilience can buffer adolescents against the negative emotional impacts of expressive suppression. This has important implications for mental health interventions, emphasizing the need to strengthen resilience in adolescents to reduce their vulnerability to maladaptive emotional regulation strategies.

Table 4 gives the moderating effects of resilience underlying serial mediation in the model. The conditional indirect effect results indicated that as the moderator increased, the conditional indirect effect decreased. More specifically, when

Table 4 Moderated Mediation Effect of Physical Exercise on Problematic Mobile Phone Use at Specific Conditional Values of Resilience

Depression	**Specific conditional values of resilience**			
	β	**SE**	**LLCI**	**ULCI**
−1 SD	−0.013	0.003	−0.020	−0.007
Mean	−0.010	0.002	−0.015	−0.005
+1 SD	−0.006	0.002	−0.010	−0.003
	Index of moderated mediation			
	Index	**SE**	**LLCI**	**ULCI**
Resilience	0.031	0.001	0.001	0.006
Anxiety	**Specific conditional values of resilience**			
	β	**SE**	**LLCI**	**ULCI**
−1 SD	−0.011	0.003	−0.017	−0.006
Mean	−0.009	0.002	−0.014	−0.005
+1 SD	−0.007	0.002	−0.010	−0.003
	Index of moderated mediation			
	Index	**SE**	**LLCI**	**ULCI**
Resilience	0.002	0.001	0.001	0.004

Abbreviations: *β*, standardized coefficients, represent the strength and direction of these relationships, where positive values indicate a positive association, and negative values indicate a negative association; LLCI, lower limit of the 95% confidence interval; ULCI, upper limit of the 95% confidence interval; SD, standard deviation; SE, standard error.

resilience was low (−1 SD), the influence of serial mediation was −0.013 for depression and −0.011 for anxiety. When resilience increased to a high level (+1 SD), the influence of serial mediation decreased to −0.006 for depression and −0.007 for anxiety. Thus, resilience played a significant moderating role on the serial mediating effects of expressive suppression and depression/anxiety in the association between physical exercise and problematic mobile phone use. These results underscore resilience as a key target for enhancing the effectiveness of physical exercise in reducing problematic mobile phone use and its associated emotional problems.

Discussion

This study sought to explore the relationship between physical activity and problematic mobile phone use in adolescents, with a focus on the underlying mechanisms. The key findings highlighted two main points: (1) a significant negative correlation exists between physical activity and problematic mobile phone use; and (2) the reduction in problematic mobile phone use associated with physical activity was primarily attributable to a serial mediation effect involving expression suppression and emotional problems (eg, depression and anxiety), along with the moderating role of resilience. The findings from our model suggest that adolescent lifestyle behavior is shaped and affected by multiple contributors at different levels. These findings will be essential to further understanding of potential associations and interventions.

This study found that 25.5% of Chinese adolescents exhibited problematic mobile phone use, a figure of particular concern. According to Liu et al, the rates of depression among adolescents who engage in problematic smartphone use were significantly higher (36.2%) compared to those without such behavior (15.4%). Similarly, the prevalence of anxiety was notably elevated in the problematic smartphone user group (34.8%) versus the non-problematic group (14.6%).[43] In our study, a more detailed analysis revealed that the prevalence of problematic mobile phone use co-occurring with depression and anxiety was 65.8% and 80.9%, respectively. These findings underline the importance of analyzing lifestyle behaviors, such as mobile phone use, from the perspective of emotional factors.

Our findings demonstrated an inverse relationship between physical exercise and problematic mobile phone use during adolescence. While it is crucial to synthesize evidence on the interplay between lifestyle behaviors in adolescents, the precise biological mechanisms underlying this association remain unclear, with multiple plausible explanations. Neurophysiological evidence suggests that the brain regions involved in physical activity and mobile phone use could share common activation pathways. For instance, exercise enhances brain plasticity and activates neural regions associated with reward and addiction processes.[44] Participating in physical activity could also reduce screen exposure and sedentary tendencies, given that mobile phone use is often categorized as a sedentary leisure activity. Consequently, involvement in physical exercise may lower the likelihood of adolescents developing an overreliance on mobile devices. Considering the front-end factors related to emotions and characteristics closely related to lifestyle behaviors among adolescents, our findings inform better understanding of the positive and potential effects of physical activity as an intervention in problematic mobile phone use, and serve as persuasive evidence that actively engaging in physical exercise can affect daily lifestyle behavior through emotional processing in adolescents.

Our findings revealed that expression suppression and emotional problems served as mediating factors in the relationship between physical exercise and problematic mobile phone use in adolescents, with indirect effects accounting for 52.0% (via depression) and 44.4% (via anxiety) of the total effect. These results highlight the significant role of both expression suppression and emotional problems as intermediary mechanisms linking physical activity to mobile phone overuse. Similar to prior research, we observed a strong association between physical exercise and expression suppression. Studies in neuroscience have demonstrated that physical activity can activate brain regions associated with emotion regulation, such as the ventral and dorsal prefrontal cortex.[45,46] Dysfunctional emotional regulation has been suggested as a factor contributing to excessive smartphone use, potentially escalating problematic usage.[18] Liu et al indicated that problematic mobile phone users, compared to a control group, recognized negative emotion expression faster after engaging in emotion regulation strategies, suggesting that their expression suppression was impaired.[47] Our findings reinforce the importance of addressing expression suppression in understanding problematic mobile phone use and underscore its critical role in mediating the effects of physical exercise on such behaviors among adolescents.

In this study, depression (44.6%) and anxiety (37.0%) constituted the largest portions of the total mediating effect of emotional problems on the relationship between physical exercise and problematic mobile phone use among adolescents.

These results highlight the significant role of emotional problems in shaping this relationship. Our findings further demonstrate an inverse association between sports participation during adolescence and symptoms of depression and anxiety. Physical fitness, as a result of regular exercise, has been closely linked to improved mental health in children and adolescents.[48] Existing evidence underscores the importance of exploring this connection; for instance, exercise has been associated with increased diversity in the gut microbiome and higher levels of certain beneficial bacterial genera, which may help alleviate psychological distress.[49] Furthermore, the release of endorphins during exercise can positively influence mood, as suggested by the endorphin hypothesis, potentially leading to reduced pain perception, euphoria, and lower symptoms of depression and anxiety.[50,51] A short-term longitudinal study of adolescents aged 12 to 18 found that symptoms of depression and anxiety significantly predicted increased problematic mobile phone use.[52] Similarly, depression and anxiety, often classified as negative emotions, showed overlapping pathways in our model due to their frequent co-occurrence. The comorbidity rate observed in this study was 37.6%, slightly higher than the 31.6% reported by Wang et al.[53] Collectively, these findings suggest that physical exercise can mitigate excessive mobile phone use by reducing the prevalence of negative emotions, thereby offering protective benefits for adolescents and decreasing the likelihood of problematic behaviors related to mobile phone use.

The serial multiple mediation model employed in this study provides a nuanced perspective on the pathways linking physical exercise to problematic mobile phone use. Our findings revealed that this relationship is partially mediated by expression suppression and emotional problems. Specifically, physical exercise was initially associated with reduced expression suppression, which subsequently influenced emotional problems and ultimately contributed to the risk of problematic mobile phone use. These results highlight a positive sequential association, where increases in one variable corresponded to increases in subsequent variables. Depression has been linked to persistent activation of brain regions involved in top-down emotion regulation.[54] Individuals often rely on expression suppression to manage their emotions; however, this strategy can diminish positive emotional experiences.[55] Consequently, reducing expression suppression, alongside promoting physical exercise, may serve as an effective approach to mitigate negative emotions. Overall, targeting both expression suppression and emotional problems could enhance the effectiveness of interventions using physical exercise to address problematic mobile phone use.

Resilience is an important mechanism underpinning the development of health-related behaviors. Our model adds to the existing literature on the role of resilience in the context of emotional factors by demonstrating its moderating effect on the serial mediation relationship between physical exercise and problematic mobile phone use. A possible interpretation is that individuals with high resilience may exhibit a heightened sense of control over their circumstances. This sense of control might drive them to actively prepare or take precautions to maintain stability and prevent situations where control could be compromised.[56] Thus, adolescents with lower resilience levels might benefit from seeking and utilizing a variety of alternative resources, such as amplifying the effects from physical exercise, to overcome adverse consequences. Ultimately, such a strategy may contribute to lower levels of problematic mobile phone use, perhaps comparable with those from individuals who score higher on resilience. Another important finding from the present study is that resilience also presented as a moderator in the association between expression suppression and emotional problems. Specifically, a buffering effect was observed so that as resilience increased, the negative effect of expression suppression on emotional problems decreased. This finding suggests that resilience plays an important role in shaping the way adolescents' emotions interact with regulation strategies and highlights the need for further research into this concept in other contexts.

While our study provides valuable insights, several limitations should be considered. First, we opted for standardized self-report questionnaires due to their practicality and efficiency in handling a large sample size. These instruments have been extensively validated in previous studies, demonstrating robust psychometric properties such as reliability and validity, making them well-suited for the objectives of our study. However, it is important to note that these instruments may still be influenced by certain biases, such as social desirability and recall bias. Future studies could consider alternative methods of measuring physical activity, such as wearable devices (eg, accelerometers or fitness trackers), which provide more objective data on participants' physical activity levels. Combining self-reports with physiological or behavioral data would enhance the findings and provide a more thorough understanding of the link between physical exercise and problematic mobile phone use. Second, the study utilized a convenience sample from one region in China may restrict the generalizability of its findings. Adolescents in different regions or cultural contexts may experience

varying influences on their emotional regulation and technology use. In Chinese culture, there may be unique societal pressures that affect emotional regulation and mobile phone use, such as academic pressures and family dynamics. These cultural factors could influence the strength and nature of the associations found in this study. Future research should consider examining the role of cultural factors in these relationships, particularly in cross-cultural studies comparing different countries or regions. This would help ensure that the findings are representative and applicable to broader populations. Additionally, employing longitudinal or multi-site designs could provide stronger evidence for causality and help to explore how the relationships between physical exercise, emotional regulation, and problematic mobile phone use evolve over time.

The findings of this study provide valuable insights into practical strategies for addressing problematic mobile phone use among adolescents, with implications for schools, parents, and policymakers. Schools can integrate regular physical exercise programs, such as team sports, yoga, or dance, into the curriculum to reduce problematic mobile phone use and improve emotional regulation, as our study highlights the role of exercise in mitigating emotional dysregulation and psychological distress. Incorporating emotional regulation skills training, such as mindfulness or cognitive-behavioral techniques, into health education programs can further discourage maladaptive strategies like expressive suppression. Parents play a crucial role by fostering an emotionally supportive environment, encouraging open communication, and promoting family-oriented physical activities that reduce reliance on mobile devices. Parenting programs that teach emotional coaching and resilience-building techniques may further empower adolescents to handle stress effectively. Policymakers can amplify these efforts through public health campaigns emphasizing the benefits of physical exercise for emotional well-being, increasing access to community-based sports facilities, and promoting digital literacy to reduce problematic mobile phone use risks. Additionally, resilience-building initiatives should be prioritized in schools and communities to buffer the negative effects of emotional dysregulation. Interdisciplinary collaboration among educators, public health agencies, mental health professionals, and technology companies can facilitate the development of integrated interventions, such as gamified mobile apps that promote physical activity alongside psychoeducational resources. These strategies underscore the importance of addressing behavioral, emotional, and systemic factors to reduce problematic mobile phone use and enhance adolescent mental health and well-being.

This study provides comprehensive insights into the mechanisms linking physical exercise to problematic mobile phone use among adolescents. Our findings reveal that physical exercise not only directly reduces problematic mobile phone use but also indirectly improves emotional regulation and alleviates emotional problems through its effects on expressive suppression, depression, and anxiety. These findings underscore the importance of addressing both behavioral and emotional factors when designing interventions for problematic mobile phone use. Specific action points include integrating structured physical activity programs in schools, encouraging families to create supportive environments that promote regular exercise, and providing adolescents with resources to develop adaptive emotional regulation strategies. Furthermore, resilience-building initiatives could complement these efforts, offering adolescents additional protection against emotional dysregulation. These findings emphasize the need for a multifaceted approach that combines physical activity promotion with psychological interventions to reduce problematic mobile phone use. From a societal perspective, this study underscores the broader relevance of addressing adolescent well-being through integrated interventions targeting both physical and mental health. These findings could inform cross-disciplinary collaborations between public health experts, educators, and psychologists, fostering comprehensive strategies to address problematic mobile phone use and its associated risks.

Data Sharing Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study adhered to the principles outlined in the Declaration of Helsinki, ensuring compliance with ethical standards for research involving human subjects. Ethical approval was granted by the Ethics Committee of Qingdao University. Written consent was obtained from all participants and their legal guardians after they were informed about the study details. Participants were made aware that their involvement was entirely voluntary, with the freedom to withdraw at any stage of the study.

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Disclosure

The authors declare no competing interests.

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