

Childhood Maltreatment and Internet Addiction: A Moderated Mediation Model of Depression and Physical Activities

Sihong Li*, Leyin Zhang*, Lintong Song, Tianqing Fan, Yanhua Li, Yanmei Shen

Department of Psychiatry, National Clinical Research Center for Mental Disorders, and National Center for Mental Disorders, The second Xiangya Hospital of Central South University, Changsha, Hunan, People's Republic of China

*These authors contributed equally to this work

Correspondence: Yanhua Li; Yanmei Shen, Department of Psychiatry, National Clinical Research Center for Mental Disorders, and National Center for Mental Disorders, The second Xiangya Hospital of Central South University, Changsha, Hunan, People's Republic of China, Email liyanhua2188139@163.com; ymshen@csu.edu.cn

Background: Internet addiction is a growing concern among adolescents, with childhood maltreatment recognized as a significant risk factor. According to the Interaction of Person-Affect-Cognition-Execution model, childhood maltreatment can lead to affective responses, such as depression, which in turn heighten vulnerability to internet addiction. However, the potential protective role of external factors, such as physical activity, in this pathway remains underexplored. This study investigates the mediating role of depression and the moderating role of physical activity in the relationship between childhood maltreatment and adolescent internet addiction.

Methods: Data from 1610 Chinese middle school students were analyzed using statistical software: Mplus 8.3 was used for SEM, while SPSS 26.0 and Hayes' PROCESS Macro were used for correlation analyses, hierarchical regression, and moderated mediation model.

Results: Results showed that emotional abuse was significantly positively associated with internet addiction and the association was mediated by depression. In addition, physical activity moderates the first stage of mediating the effect of depression between emotional abuse and internet addiction. Furthermore, adolescents with lower levels of physical activity exhibited a stronger indirect effect of emotional abuse on internet addiction compared to those in the higher physical activity group. SEM also demonstrated that the model exhibited good fit, reliability, and discriminant validity.

Conclusion: The results show that depression mediated the relationship between emotional abuse and adolescent internet addiction. In addition, the association of emotional abuse and depression is weaker for adolescents who participate more in physical activity. This study emphasizes the necessity of addressing physical activity and provides theoretical guidance for prevention of internet addiction.

Keywords: childhood maltreatment, internet addiction, depression, physical activity, Chinese adolescents

Introduction

Internet addiction (IA) in adolescents refers to the inability of youngsters to control their internet use.¹ In research published in 2013, internet addiction was reclassified by the American Psychiatric Association as an internet gaming disorder within Section III of the DSM-5 criteria.² Moreover, the World Health Organization (WHO) has included Internet Gaming Disorder as a type of substance use and addictive disorder in the draft of ICD-11.³ IA has been a major concern nowadays due to its adverse consequences on social functioning, mental health as well as academic performance for students.¹ A survey conducted in 2020 indicated that 97.6% of middle school students in China had access to the internet, and 74% of children and adolescents owned personal devices such as smartphones.⁴ With the popularity of the internet, the prevalence of internet addiction in mainland China is also increasing, ranging from 10.4% to 26.5%.⁵⁻⁷

Improved prevention and intervention necessitate a deeper exploration of the underlying mechanisms contributing to adolescent internet addiction.

Childhood maltreatment (CM) which includes physical and emotional abuse (EA) as well as neglect has been found to be closely associated with internet addiction.⁸ Furthermore, the “Person-Affect-Cognition-Execution (I-PACE) model” of internet addiction supports this connection, the P-component signifies an individual’s core characteristics processed as predisposing variables.⁹ Among these variables, adverse early childhood experiences have been identified as vulnerability factors for internet addiction.⁹ Specifically, described as “verbal attacks towards a child’s self-esteem or wellbeing, or any behavior that belittles or degrades a child by parents”, emotional abuse has been considered to be most prominently associated with internet addiction.^{10,11} Furthermore, emotionally traumatic childhood events have been proven to be significant factors in the onset and sustainability of addiction, especially the addictive use of the internet.¹² These findings indicate that childhood maltreatment could be significantly involved in adolescent internet addiction. However, there still remain some gaps to fill, although the relationship of childhood maltreatment and internet addiction has been found previously, the mechanism of how different types of childhood maltreatment will influence internet addiction in adolescents has been seldom explored. Moderated mediation analysis proves to be a valuable technique for assessing the connections among different factors. While mediators mediate the relation of two variables, moderators impact the relationship between these variables.¹³ Therefore, to address these gaps, our study employs a moderated mediation design to explore the connection between childhood maltreatment and internet addiction.

There is abundant evidence showing that childhood maltreatment leads to immediate as well as lasting impacts on physical as well as mental health, with depression being one of the most prevalent psychological consequences.^{14–17} Additionally, studies indicate that childhood maltreatment and depression are highly comorbid, with emotional abuse posing a particularly high risk for depression compared to other forms of maltreatment, such as sexual or physical abuse.^{17–19} In accordance with the I-PACE model theory, experiencing trauma in early life (eg, childhood maltreatment) and abnormal affective reactions (eg, depression) are both essential and decisive factors in the development of IA.⁹ This model suggests that individuals with a history of childhood maltreatment may develop dysregulated emotional responses, making them more susceptible to using the internet as a maladaptive coping mechanism.^{9,20} Furthermore, depression and internet addiction interact in a mutually reinforcing cycle.^{21,22} On the one hand, depression may increase the likelihood of developing internet addiction. According to the “Compensatory Internet Use (CIU) model” of internet addiction, internet addiction can serve as a maladaptive coping strategy to fulfill unmet emotional needs and alleviate psychological distress.^{23,24} This suggests that depression can serve as a motivational driver of internet addiction, reinforcing compulsive online behaviors.^{11,23} Conversely, excessive internet use can further exacerbate depressive symptoms. Studies have demonstrated that greater internet addiction severity is associated with increased depression, possibly due to social isolation, neglect of real-world responsibilities, and reduced face-to-face interactions, all of which contribute to emotional distress and depressive symptoms.^{25,26} Both of the I-PACE and CIU models provide support for the hypothesis that depression could serve as a mediator in the relationship between childhood maltreatment and internet addiction. Given the particularly strong association between emotional abuse and depression, we assume that depressive symptoms may form part of the positive pathway through which childhood maltreatment (especially emotional abuse) increases internet addiction.

Even among adolescents who experience childhood maltreatment, vulnerability to this experience varies. Therefore, exploring moderators of different types of childhood maltreatment that influence internet addiction counts. It is well documented that engaging in physical activity (PA) serves as a vital protective measure against depressive symptoms across both clinical and non-clinical groups, as well as individuals vulnerable to depression.^{27–32} Compared to professional cognitive or intelligent activities, engaging in physical activity unlocks a wealth of promising treatment options, as this behavioral intervention is easily accessible to individuals.^{29,33,34} Specifically, the WHO recommends that young individuals between the ages of 5 and 17 participate in at least 60 minutes of physical activity daily, with a focus on moderate to vigorous intensity.^{32,35} In line with this notion, a previous cohort study suggested that engaging in moderate-to-vigorous PA at age 12 was linked to a 9.0% reduction in depression scores by age 18.³⁶ Moreover, physical activity can buffer the negative emotions caused by childhood adversity.^{37,38} Studies showed that a higher frequency of physical activity can improve psychological functioning and reduce depressive symptoms among college students with childhood

maltreatment.³⁹ It has been suggested that physical exercise may indirectly contribute to recovery from maltreatment as it can improve one's capacity to engage in goal-directed behaviors when experiencing depressive emotions.⁴⁰ Thus, it is plausible to hypothesize that appropriate physical activity in adolescents will moderate the relationship between childhood maltreatment and depression.

Collectively, childhood maltreatment and depression contribute significantly to the manifestation of internet addiction. Furthermore, physical activity may moderate the relationship between childhood maltreatment and internet addiction through depression. Nevertheless, the impact of these factors on internet addiction in Chinese middle-school students remains uncertain. Therefore, the objective of this study is to understand how depression mediates the connection between childhood maltreatment and internet addiction in Chinese youth while exploring how physical activity influences this relationship. Drawing from the literature, subsequent hypotheses were posited (seen in [Figure 1](#)):

Hypothesis 1: Childhood maltreatment is positively associated with internet addiction;

Hypothesis 2: Depression will mediate the relation between childhood maltreatment and adolescent internet addiction.

Hypothesis 3: Physical activity will moderate the relation between childhood maltreatment and depression, thereby weakening the risk of internet addiction for childhood maltreated adolescents.

Materials and Methods

Participants

Subjects were enrolled from a middle school in Changsha, Hunan Province, China. The inclusion criteria for subjects in this study were: (a) middle school students aged from 11 to 16 years; (b) the absence of severe physical illness that precluded participation in the study; (c) the ability to comprehend and complete the questionnaire; and (d) willingness to sign a formal consent for participation. A total of 1785 students met the criteria for participation in the study. However, 55 of them declined to take part, and 120 of them were eliminated owing to missing data; thus, 1610 students were ultimately enrolled. In total, 90.2% of respondents responded. The sample's age ranged from 11 to 16 years, with a mean age of 13.11 years ($SD = 0.94$).

Clinical Measures

Childhood Maltreatment

The Childhood Trauma Questionnaire-Short Form (CTQ-SF)⁴¹ ([Supplementary material 3](#)) was used to assess childhood maltreatment. It is a self-administered survey designed to identify various forms of maltreatment experienced during childhood. In this study, we evaluated four subtypes of CM using 23 items of CTQ-SF: physical abuse, physical neglect,

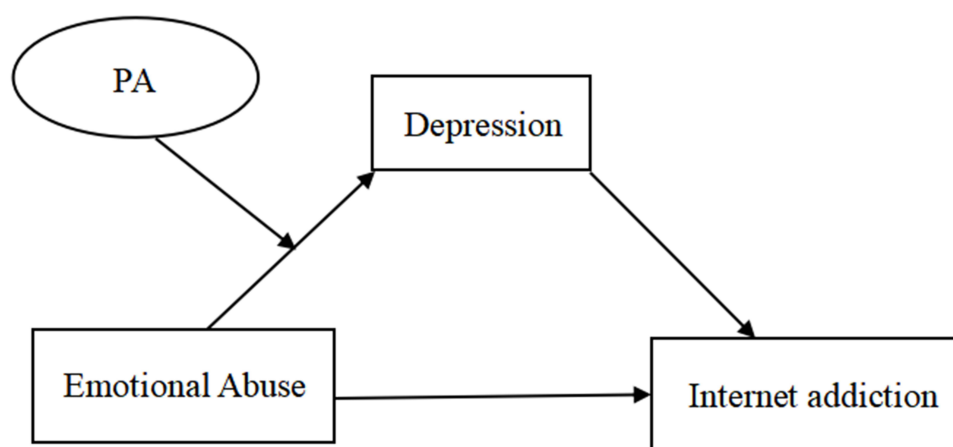


Figure 1 Conceptual model.

Abbreviation: PA, physical activities.

emotional abuse, and emotional neglect. Emotional abuse Subscales consist of five items, including “called stupid, lazy or ugly by family”, “my parents wish they’d never had me”, “insulting or hurtful words from my family”, “someone in my family hated me”, “felt emotionally abused”. Each item was answered on a five-point scale (1 = never, 5 = very often). Cut-off scores of categories of severity were proposed by Bernstein and Fink: moderate and severe (Emotional abuse: ≥ 13 ; Physical abuse: ≥ 10 ; Emotional neglect: ≥ 15 ; Physical neglect: ≥ 10).⁴² In China, the CTQ-SF showed a good level of internal consistency and stability.^{43,44} According to this study, Cronbach’s alpha was 0.81.

Internet Addiction

The 19-item self-reported scale Chinese Internet Addiction Scale’s revision (CIAS-R)⁴⁵ ([Supplementary material 1](#)) was used to measure IA, with participants’ actual conditions over the past year taken into account. Four subscales were included in the IA: compulsive and withdrawal symptoms, tolerance symptoms, interpersonal and health-related issues, and time management issues. The overall score on the comprehensive scale indicated the level of individual IA, with a higher score indicating a stronger inclination towards IA. The CIAS-R has demonstrated high internal consistency across various studies, showing Cronbach’s alpha values between 0.85 and 0.90.^{45–48} In this study, the Cronbach’s alpha for this scale was 0.97.

Depression

The Depression Subscale of Depression Anxiety Stress Scale 21 (DASS-21)⁴⁹ ([Supplementary material 2](#)) was used to assess depression, comprising seven items. Participants were asked to rate how well each item description reflected their personal circumstances over the past week, using a scale from 0 (not at all) to 3 (very much or most of the time). The subscale score was calculated through these seven items, with higher scores suggesting a more intense feeling of depression. The severity rating range of the depression subscale is as follows: 0–9 (Normal), 10–13 (Mild), 14–20 (Moderate), 21–27 (Severe), and 28+ (Extremely severe).⁵⁰ The reliability and validity of the depression subscale have been evaluated within the Chinese population, including adolescents,^{51,52} indicating robust psychometric properties.⁵³ In the present study, the Cronbach’s alpha was calculated to be 0.90.

Physical Activity

The question derived from the Youth Risk Behavior Survey (YRBS) was utilized to evaluate physical activity.⁴⁷ “During the past week, on how many days did you participate in physical activities of moderate to vigorous intensity for at least 60 minutes (which elevated your heart rate and made you breathe heavily at times)? Options range from 0 to 7 days per week. The World Health Organization (WHO) recommends that children and adolescents engage in a cumulative total of 60 minutes of moderate-to-vigorous intensity aerobic physical activity daily to maintain optimal health.⁵⁴ The students were divided into two groups based on their responses: those who reached the standard (7 days) and those who did not (less than 7 days).

Control Variables

Data on age, gender, grade, ethnic group, the presence of siblings, family history, history of physical problems, history of psychological problems, and interpersonal support were obtained in the study. All the important demographic variables were included as control variables. In addition, we included interpersonal support as a control variable to counteract the impact of social isolation. This was assessed using the five items of the Resilience Scale for Chinese Adolescents,⁵⁵ which gauges the extent of interpersonal and social assistance received by adolescents. After reverse-scoring two items, higher scores indicated greater levels of interpersonal support. Responses ranged from “Not at all” to “Completely consistent”. The scale has good reliability and is widely used in China to measure adolescent mental resilience.^{56,57}

Procedure

Wenjuanxing, a professional online survey platform in China, was applied to create the questionnaires. WeChat, a social media platform popular in China, was utilized to disseminate the survey, and all students were invited to fill out the questionnaire on their mobile devices. All scales were administered simultaneously during the survey to ensure consistent measurement timing, with examples provided in the Additional file, and data were collected between November and

December 2020. Before starting to gather the data, informed consent of both the parents and the students was obtained. It was made clear to each student and their parents that their participation in this survey was completely voluntary and that they could withdraw at any time. To ensure that the procedure for collecting data was standardized, the researchers conducted comprehensive training sessions for school teachers involved in data collection. These training sessions were designed to provide teachers with clear instructions and guidelines on how to administer the surveys and gather data consistently across all participating schools. When students encounter difficulties in understanding the survey questions, the teacher can offer timely assistance. The Ethics Committee of Central South University's Second Xiangya Hospital approved this study protocol.

Statistical Analyses

First, the goodness of model fit and factor loading were determined via confirmatory factor analysis (CFA). Using Mplus 8.3, an underlying structural equation model without interaction terms was constructed and compared with the final model with interaction terms. The chi-square test was used to determine whether the model fit with interaction terms better than the base model. Second, to confirm convergent validity, we calculated the average variance extracted (AVE) and composite reliability (CR) and also investigated the significance of reliability and discriminant validity. Third, the correlations of research variables were examined by Pearson correlation analyses. Hierarchical regression analysis was then utilized to validate the hypothesis testing. Finally, we used Models 4 and 7 of the PROCESS macro⁵⁸ to again examine the mediating role of depression as well as to test whether PA moderates the indirect effects of EA on depression. In addition, all models were controlled for covariates (age, gender, grade, ethnic group, the presence of siblings, family history, history of physical problems, history of psychological problems, and interpersonal support). All continuous variables were standardized, and interaction terms were derived from these standardized scores to ensure comparability in the relative strength of various variables. From 5000 random samples of the data, bootstrap confidence intervals (CIs) were calculated to determine whether Model 4 and Model 7 were significant. Non-zero confidence intervals indicate significant effects.

Result

Confirmatory Factor Analysis and Validity Analysis

SEM confirmed that the base measurement model exhibited a good fit ($H_0 = -30,534.155$; $AIC = 61,220.310$; Chi-Square = 1267.596, $df = 275$; $p = 0.000$; $CFI = 0.949$; $TLI = 0.942$; $RMSEA = 0.047$; $SRMR = 0.036$), as CFI and TLI statistics were above 0.90; RMSEA below 0.08, and SRMR below 0.05. Furthermore, it can be inferred that the final model ($H_0 = -30,529.514$, $AIC = 61,213.028$) demonstrates better model fit compared to the baseline model, as indicated by the chi-square test passing with $p = 0.002$ (< 0.05) and the AIC value being higher than that of the baseline model.

Detailed results of the CFA and convergent validity analysis are shown in [Table S1](#). As shown, all depression and IA items had standardized regression weights greater than 0.5, indicating that they were significantly loaded. One of the EAs was slightly below 0.5, but Field⁵⁹ proposed that a factor be considered reliable if it has four or more loadings of 0.6 or higher, irrespective of sample size.

Besides that, to verify convergent validity, the average variance extracted (AVE) and composite reliability (CR) were also calculated. The AVE ranges between 49% and 83%, with one item below 0.5 but above 0.36, which is acceptable.^{60–62} CR for EA, depression and IA were all greater than 0.7. Since the composite reliability of the three constructs exceeds the recommended threshold⁶³ and the AVEs are all above the acceptable levels, the internal reliability of the measurement items is deemed satisfactory.

The results of reliability and discriminant validity are demonstrated in [Table S2](#). In each case, Cronbach's Alpha was greater than the acceptable level of 0.80. To be specific, Cronbach's alpha values were as follows: childhood maltreatment, 0.815; depression, 0.903 and IA, 0.965. And the correlation between the constructs were all smaller than the square root values of the corresponding AVE, indicating ideal discriminant validity of the scale data.

Descriptive Statistics and Correlation Analysis

The participants comprised 847 male and 763 female students. The mean age was 13.11 years (SD = 0.94, range = 11–16 years, one data was missing and in subsequent analyses, we used the mean value of age to fill in that data). Han Chinese accounted for 94.9% and other ethnic minorities for 5.1%. There were 659 individuals (40.9%) with only one child in the family and 951 (59.1%) with siblings. A total of 1599 (99.3%) individuals denied having a family history of mental illness, 1281 (79.6%) denied having previous physical problems, and 1598 (99.3%) denied having previous psychological problems (See Table 1 for details).

As shown in Table 2, all variables are presented as means, standard deviations, and zero-order correlations. According to correlation analysis, IA was positively correlated with EA ($r = 0.21$, $p < 0.001$) and depression ($r = 0.32$,

Table 1 Demographic Characteristics

Variable	Participants (n =1610)
Grade, n (%)	
First year	609(37.8)
Second year	475(29.5)
Third year	526(32.7)
Gender, n (%)	
Male	847(52.6)
Female	763(47.4)
Ethnicity, n (%)	
Han Chinese	1528(94.9)
Other	82(5.1)
Single, n (%)	
Yes	659(40.9)
No	951(59.1)
Age(years), Mean \pm SD	13.11(12.17–14.05)
PH, n (%)	
Yes	329(20.4%)
No	1281(79.6%)
MH, n (%)	
Yes	12(0.7)
No	1598(99.3)
FH, n (%)	
Yes	11(0.7)
No	1599(99.3)

Note: N=1610.

Abbreviations: PH, history of physical problems; MH, history of mental problems; FH, family history.

Table 2 Means, Standard Deviations and Correlations Among Variables

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
Grade	1.95	0.84	–												
Gender	1.47	0.50	0.02	–											
Ethnicity	1.05	0.22	0.00	0.00	–										
Single	1.59	0.49	–0.01	0.064*	0.01	–									
PH	1.20	0.40	0.02	–0.086**	–0.02	–0.070**	–								
MH	1.01	0.09	0.02	0.01	–0.02	0.00	0.03	–							
FH	1.01	0.08	0.01	0.03	0.02	–0.01	0.051*	–0.01	–						

(Continued)

Table 2 (Continued).

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
Age	13.11	0.94	0.856**	-0.055*	0.01	0.01	0.00	0.04	0.02	—	—	—	—	—	—
IS	21.55	2.85	0.02	0.05	0.01	-0.02	0.053*	-0.01	0.01	0.03	—	—	—	—	—
EA	7.47	3.52	-0.060*	0.101**	0.03	0.088**	0.118**	0.066**	0.03	-0.050*	0.00	—	—	—	—
Depression	4.16	4.68	0.00	0.05	0.02	0.079**	0.122**	0.085**	0.03	-0.01	-0.04	0.555**	—	—	—
IA	38.70	14.29	0.092**	-0.055*	0.050*	0.03	0.068**	0.02	-0.01	0.090**	-0.175**	0.210**	0.322**	—	—
PA	1.21	0.40	-0.02	-0.083**	-0.01	-0.05	-0.01	-0.01	-0.01	0.00	0.079**	-0.02	-0.04	-0.064*	—

Notes: * $p < 0.05$, ** $p < 0.01$.

Abbreviations: PH, history of physical problems; MH, history of mental problems; FH, family history; IS, interpersonal support; EA, emotional abuse; IA, internet addiction; PA, physical activities.

$p < 0.001$). Similarly, EA also showed positive correlations with depression ($r = 0.56$, $p < 0.01$). In addition, adolescents who engage in high levels of physical activity are less likely to be addicted to the internet ($r = -0.06$, $p = 0.010$).

Hypotheses Testing

Hypothesis 1 and 2 proposed that CM significantly predicted IA and that depression mediated the relationship. Hierarchical regression analysis was used for hypothesis testing, and the results are presented in Table 3.

We found that, in the first step, controlling for age, gender, nation, the presence of siblings, family history, history of physical problems, history of psychological problems, and interpersonal support as covariates, results showed that IA was significantly predicted by EA ($b = 0.217$, $p < 0.001$) (See Model 6 in Table 3). Therefore, H1 is supported. Moreover, EA exhibited a significant correlation with depression ($b = 0.544$, $p < 0.001$) (See Model 2 in Table 3); As shown in Model 7, depression positively predicted IA ($b = 0.282$, $p < 0.001$) and the relationships between EA and IA was also significant

Table 3 Regression Results

Variables	Depression				IA		
	M1	M2	M3	M4	M5	M6	M7
Step1							
Grade	0.018	0.066	0.064	0.062	0.06	0.079	0.061
Gender	0.05*	-0.009	-0.011	-0.013	-0.041	-0.065	-0.062**
Ethnicity	0.023	0.006	0.006	0.006	0.053*	0.047*	0.045
Single	0.085***	0.036	0.035	0.035	0.03	0.011	0.001
PH	0.131***	0.058**	0.058**	0.062**	0.077**	0.048*	0.031
MH	0.082***	0.047*	0.047*	0.045*	0.009	-0.005	-0.018
FH	0.025	0.012	0.012	0.011	-0.008	-0.013	-0.016
Age	-0.029	-0.044	-0.042	-0.041	0.041	0.035	0.048
IS	-0.045	-0.042*	-0.04	-0.043*	0.179***	-0.178***	-0.166***
Step2							
EA		0.544***	0.544***	0.548***		0.217***	0.064*
PA			-0.026	-0.028			
Step3							
Int				-0.069***			
Step4							
Depression							0.282***
R ²	0.035	0.318	0.319	0.323	0.052	0.097	0.151
Adj. R ²	0.03	0.314	0.314	0.318	0.046	0.091	0.145
Change in R ²	0.035	0.283	0.001	0.005	0.052	0.045	0.054
F	6.478***	74.564***	67.956***	63.61***	9.691***	17.106***	25.782***

Notes: EA*PA, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Abbreviations: PH, history of physical problems; MH, history of mental problems; FH, family history; IS, interpersonal support; PA, physical activities; EA, emotional abuse; IA, internet addiction; Int, interaction effect.

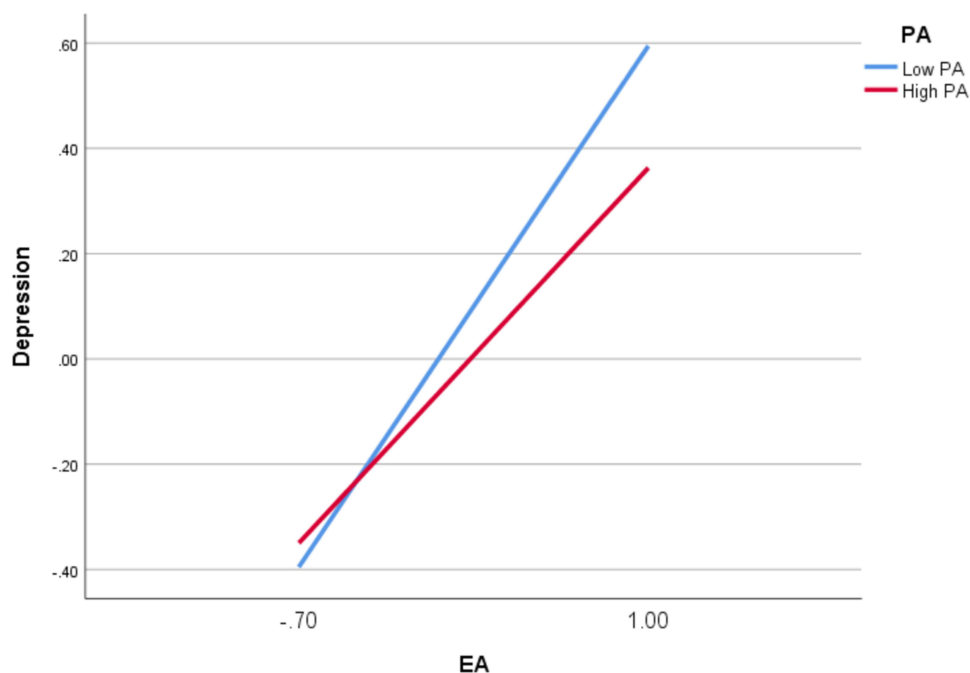


Figure 2 The moderating role of physical activity in the relationship between emotional abuse and depression.

Abbreviations: EA, emotional abuse; Low PA, low levels of physical activity; High PA, high levels of physical activity.

($b = 0.064$, $p = 0.023$), suggesting that depression plays a partial mediating role between EA and IA. Finally, the bias-corrected percentile bootstrap method revealed an indirect effect of 0.15 (95% CI = [0.12, 0.19]) for depression; the empirical 95% confidence interval did not overlap with zero, suggesting a significant mediation effect, which is consistent with the results of the hierarchical regression. Further, the mediation effect accounted for 70.63% of the total effect between EA and IA. Thus, PA and IA are partially mediated by depression, thereby providing support for Hypothesis 2.

Hypothesis 3 assumed that PA acts as a moderator in the relationship between CM and depression, thereby weakening the risk of IA for CM adolescents. As Model 4 showed, the interaction between EA and PA was significantly negative for depression ($b = -0.069$, $p = 0.001$). This study plotted the prediction of EA on depression at two levels of PA for descriptive purposes (Figure 2). Simple slope tests revealed that adolescents engaging in high levels of PA showed a weaker association between EA and depression ($b_{\text{simple}} = 0.42$, $p < 0.001$) compared to those with lower involvement in sports ($b_{\text{simple}} = 0.58$, $p < 0.001$). As depression moderated only the initial stage of the mediation process, this study called it a “first stage moderation model”, representing one variant of moderated models.

In addition, the bias-corrected bootstrap analysis also showed that the PA of adolescent students moderated the indirect effect of EA on IA. As shown in Table 4, among adolescents with high levels of physical activity, the indirect

Table 4 Test of PA as a Moderator in the Mediating Path

	b	SE	BootLLCI	BootULCI
Low_PA	0.16	0.02	0.13	0.20
High_PA	0.12	0.02	0.08	0.16
Contrast	-0.046	0.02	-0.09	-0.01

Notes: N = 1610, Bootstrap = 5000.

Abbreviations: Low_PA, low levels of physical activity; High_PA, high levels of physical activity; BootLLCI, Bootstrapped Lower Confidence Interval; BootULCI, Bootstrapped Upper Confidence Interval.

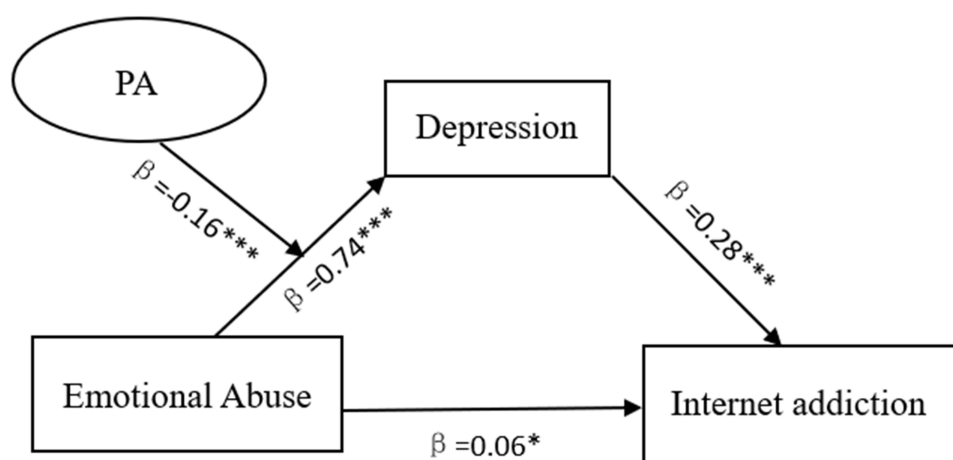


Figure 3 The final conceptual model of Emotional Abuse. β = effect size, * $p < 0.05$, *** $p < 0.001$.

Abbreviation: PA, physical activities.

effect of EA on IA is significant ($\beta = 0.12$, $SE = 0.02$, $CI = 0.08–0.16$). By contrast, for adolescents with lower levels of PA, the indirect effect of EA on IA is stronger ($\beta = 0.16$, $SE = 0.02$, $CI = 0.13–0.20$), aligning with our expectations. A notable contrast emerged in the indirect effect between high and low levels, with a difference of 0.046, 95% $CI = [-0.09, -0.01]$, and thus H3 was supported. The final conceptual model is shown in Figure 3.

As for the other models in the CM, depression fully mediates in physical abuse and IA (Table S3 and Figure S1), and partially mediates in emotional neglect and IA (Table S4 and Figure S2), where the moderating effect of PA was found to be non-significant in both models. Depression partially mediates the relationship between physical neglect and IA, and PA exhibited a negative moderating effect in the latter part of the pathway (Table S5 and Figure S3). However, it is not significant for the overall moderated mediating model as the confidence interval contains 0, $CI = [-0.068, 0.216]$.

Discussion

This study explored a moderated mediation model examining various forms of CM in relation to IA. Our findings revealed that depression mediates the link between EA and adolescent IA. Additionally, we observed that the relation of EA and depression was moderated by WHO-recommended PA, the pathway from EA to depression was weaker in the presence of PA, which highlights the important protective role of PA in IA.

The Mediating Role of Depression

This research showed that the relation between EA and IA was mediated by depression. The findings suggest that higher levels of depression are associated with increased internet addiction among adolescents who have experienced EA.

These findings are in agreement with the interaction of the I-PACE model, suggesting that the IA might result from interactions of factors that are, predisposing factors, moderators and mediators.^{9,64} In this model, childhood EA has been identified as a biopsychosocial risk factor that is associated with a higher likelihood of maladaptive emotional responses. These maladaptive emotional responses are regarded as mediating variables to addictive behavior including IA.

Also worth noting are the associations within the mediation model. There are masses of studies that coincide with the results of the first stage (ie, EA→ depression). As early as in 2012, a meta-analysis showed that children experienced CM were approximately twice as likely to suffer from recurrent or persistent depression compared with children who had not experienced abuse.¹⁶ Furthermore, another meta-analysis pointed out that EA may be more closely linked to the development of depression compared to other forms of CM,^{65,66} and the correlation remained significant even after adjusting for other types.⁶⁷ Regarding the association between depression and IA, several studies have examined their correlation, reporting that IA is strongly and independently associated with a higher prevalence and greater severity of depressive symptoms.^{68–70} One possible explanation for this association is provided by the “Compensatory Internet Use

model” of IA. This model proposes that individuals experiencing psychological distress may engage in excessive internet use as a means of temporary relief or disengagement from overwhelming emotions resulting from early-life adversity.³⁰

Overall, recognizing depression as a mediator in the EA-IA pathway underscores the importance of early intervention strategies for adolescent mental health such as depression. Clinically, comprehensive assessments of childhood experiences and routine depression screening in at-risk adolescents can help identify those vulnerable to IA, enabling timely and targeted interventions to mitigate risk.

The Moderating Role of Sufficient Physical Activity

This present study demonstrates that sufficient PA moderates the pathway between EA and depression, indicating adolescents exhibiting elevated levels of PA demonstrate a reduced likelihood of developing depression, thereby decreasing the likelihood of IA. This fits in with previous studies, recent research has shown that increased PA can modify the onset and progression of depressive symptoms in individuals who experienced childhood abuse.³⁹ For clinical samples, evidence suggests that PA reduces the risk of depressive disorder, reduces symptoms, speeds recovery, reduces relapse rates, and decreases the need for general care.^{71–73} Moreover, for non-clinical samples, the study suggests PA is beneficial for preventing the onset of depressive symptoms.⁷¹ Several theoretical frameworks may explain this moderation effect: First, according to the Cross-Stressor Adaptation Hypothesis, individuals who engage in regular physical activity exhibit reduced physiological and psychological reactivity to stressors beyond exercise itself, such as psychosocial stress. This adaptation may serve as a mechanism for regulating and releasing negative emotions caused by early-life abuse, thereby mitigating emotional distress and reducing the risk of mental health disorders.^{39,74} Second, EA has been shown to impair an individual’s ability to develop trusting and secure relationships, which increases the likelihood of depression.⁷⁵ However, in line with Social Bonding Theory, PA—particularly team-based sports—can foster the development of strong interpersonal connections, providing a sense of belonging, emotional support, and enhanced social competence.^{37,75,76} This social integration may counteract the interpersonal difficulties associated with EA, reducing vulnerability to depression. Lastly, a bevy of works showed that PA has a positive effect on brain health and function.^{77,78} For instance, central levels of brain-derived neurotrophic factor reduction are common in persons with depression, and it could be optimized by PA.⁷⁹ Meanwhile, PA can mitigate the astrocytic dysfunction seen in major depression disorder.⁸⁰ Given PA’s possible role in stress regulation, social bonding, and neurobiological resilience, integrating exercise-based therapy or group sports into treatment plans may help reduce depression and IA risk in adolescents while mitigating the long-term psychological impact of childhood adversity. This approach supports a more holistic and integrative mental health intervention strategy.

Some limitations also should be acknowledged in our study. Initially, the measures are self-report scales, which may introduce recall bias, and subsequent research endeavors should gather data from a greater number of informants to better replicate the results. Second, As a cross-sectional study, a putative causal relationship could not be inferred, and more robust information should be gathered for further hypothesis generation. Third, Cultural factors, such as how society views appropriate child rearing, play a crucial role in defining and comprehending CM. Replication studies using culture-specific CM scales are needed to generalize the findings of this study across different cultural contexts. Finally, certain covariates such as internet accessibility and peer pressure were not included. Future research should incorporate these important control variables to enhance reliability and representativeness.

Conclusion

In summary, a moderated mediation design was used to investigate the relation between CM and IA. The findings indicated that adolescents experiencing EA were at an elevated risk of developing IA. Furthermore, our results extend previous studies by exploring the mediating role of depression and the moderating role of sufficient PA. Specifically, depression was identified as a mediator in the relationship between EA and IA. Additionally, adolescents with sufficient PA demonstrated a reduced likelihood of developing depression, consequently lowering the risk of IA. Theoretically, these findings extend the I-PACE model by identifying PA as a moderator, demonstrating how behavioral factors can mitigate the impact of EA on IA by reducing depression. This underscores the importance of incorporating external protective factors in models of internet addiction. Additionally, our results also suggest that structured PA programs should complement traditional psychological interventions to provide a more effective strategy for reducing IA risk in vulnerable adolescents.

Ethics Approval and Informed Consent

The study protocol was reviewed and approved by the Ethics Committee of Central South University's Second Xiangya Hospital (XSXLJK01) and conformed to the ethical standards for medical research involving human subjects, as laid out in the 1964 Declaration of Helsinki and its later amendments. Before starting to gather the data, informed consent of both the parents and the students was obtained.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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