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Exploring the relationship between physical activity and social media addiction among adolescents through a moderated mediation model

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Physical activity is highly correlated with social media dependence in adolescence, but the underlying mechanisms between these variables require further investigation. This study suggests two potential psychological pathways linking physical activity and social media dependence in adolescence, with depression potentially serving as a mediating factor and difficulty describing feelings acting as a moderating factor. A self-reported survey was conducted with 3,247 Chinese adolescents, including measures of physical activity, social media dependence, depression, and difficulty describing feelings. Descriptive statistics and correlation analyses were performed on these variables, and a mediation-moderation model was developed. Physical activity showed a significant negative correlation with social media dependence, depression, and difficulty describing feelings. Additionally, depression was positively correlated with both social media dependence and difficulty describing feelings, and difficulty describing feelings was positively correlated with social media dependence. Furthermore, difficulty describing feelings moderated the relationship between depression and social media dependence in adolescence. This study provides further insights into the psychological mechanisms underlying the relationship between physical activity and social media dependence in adolescence. Depression serves as a mediating factor, while difficulty describing feelings acts as a moderating factor in the relationship between depression and social media dependence. These findings enhance our understanding of the role of depression and difficulty describing feelings in the relationship between physical activity and social media dependence, offering valuable implications for more comprehensive and targeted interventions aimed at reducing social media dependence among adolescents.

Keywords Physical activity, Social media dependence, Depression, Difficulty describing feelings, Adolescents

With the rapid development of smart electronic devices and social networks, social media has gradually become an integral part of daily life, serving as an important platform for acquiring information and enhancing social interactions[1]. Despite its widespread use bringing convenience to daily activities, excessive use may lead to dependence and addiction[2]. Global data indicates that 62.3% of the population uses social media, with an average daily usage of 2 h and 23 min[3]. Adolescents and young people are the most frequent users, with a usage rate of 93–97%, spending about 3 h daily on social media platforms[4]. Among all studied groups, adolescents exhibit the highest prevalence of social media dependence (35%), compared to university students (23%) and community adults (19%)[5]. The adolescent stage emphasizes the construction of social relationships, and forming close interpersonal bonds is one of its developmental tasks[6]. Adolescents' active use of social media helps in forming close relationships[7]and in China, social media has become a crucial tool for identity formation and socialization among adolescents[8]. However, when social media is not used in moderation, adolescents are more prone to developing social media dependence compared to other age groups[9]. Inspired by the addiction syndrome model[10]social media dependence use is considered a multifaceted and complex behavior, typically resulting from the interaction between distal factors (such as psychosocial vulnerabilities and personality traits)

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and proximal factors (such as negative life events). These interactions may lead to excessive engagement with social media platforms, a pattern that is further reinforced through behavioral and emotional rewards[11]. Social media dependence, as a primary manifestation of internet addiction, is defined as excessive engagement with social media, driven by a strong motivation to log in or use social media, leading to significant time and energy investments at the cost of other social activities, learning/work, relationships, and/or mental health and well-being[12]. This dependence results in excessive, compulsive use of social media platforms, interfering with daily life and causing negative consequences for physical, social, and mental health[11]. Although social media dependence is not officially listed as a disorder in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), related studies indicate that excessive use significantly impairs individual well-being[13]. Given the high prevalence of social media dependence among adolescents and its negative impacts[14]it is crucial to explore its contributing factors in greater depth to develop effective prevention and intervention strategies.

Previous studies have shown a strong correlation between physical activity and social media dependence in adolescence[15]. Physical activity is an indispensable component of daily life, encompassing not only high-intensity exercises such as running and swimming but also low-intensity activities commonly found in learning and work settings, such as sitting, standing, and walking. The American College of Sports Medicine (ACSM) defines physical activity as any voluntary body movement produced by skeletal muscles that requires energy expenditure, ranging from minor daily activities to specific exercises, and can be performed at any time or intensity[16,17]. Regular physical activity is crucial for promoting a healthy lifestyle, having positive effects on cardiovascular, respiratory, nervous, and musculoskeletal systems, while also improving mood and reducing the risk of lifestyle-related diseases[18]. In contrast, insufficient physical activity and excessive dependence on internet use can lead to a sedentary lifestyle, which over time negatively impacts physical health, reduces quality of life, and increases the incidence of mental health issues[19]. An increasing body of research indicates a significant negative correlation between physical activity and social media dependence[15,20];with physical activity also being shown to alleviate symptoms of social media dependence[21]. As a comprehensive intervention, physical activity can address individual behavior from multiple dimensions: physiologically, it alleviates addiction symptoms by improving brain function and regulating neurotransmitters like dopamine; psychologically, it reduces negative emotions such as anxiety[22–26] and depression[27,28], enhancing psychological resilience[29,30]; socially, it provides adolescents with offline social opportunities, helping to replace some online social needs[31]. A meta-analysis concluded that physical activity interventions significantly reduce the incidence of social media dependence, especially in adolescents, where the effect is most pronounced[32]. Based on this literature review, this study hypothesizes that there is a negative correlation between physical activity and social media dependence in adolescence.

Depression may serve as a potential mediator in the relationship between physical activity and social media dependence in adolescence. Depression is a leading cause of the global burden of mental health-related diseases and is the primary cause of disability worldwide, affecting approximately 280 million people[33]. The onset of depression typically occurs during adolescence, marking a critical window for identifying modifiable risk factors and implementing interventions to prevent depression in later life[34]. Depression is a significant public health issue among adolescents. A recent meta-analysis reported that the combined prevalence of mild-to-moderate, moderate-to-severe, and severe depression was 21.3%, 18.9%, and 3.7%, respectively, with the prevalence of depression increasing over time[35]. As a high-risk mental disorder among youth, depression is characterized by symptoms such as lack of energy or sadness. Research indicates that physical activity is an effective method for addressing mental health issues in adolescents[36]. Active participation in physical activity is negatively correlated with the risk of depression[27,28,37–39];and individuals who engage in higher levels of physical activity are 21% less likely to experience depression than those who engage in lower levels[40]. Meta-analyses have also found that low physical activity and poor cardiovascular fitness (CRF) are associated with a higher risk of depression[41]. Physical activity exerts antidepressant effects through various biological and psychosocial pathways, such as stimulating neurotrophic factors, activating the neuroendocrine system, and improving brain function in areas related to depression[42]. Moreover, psychosocial factors (e.g., self-esteem, self-efficacy, social support) may interact with biological changes to mediate the effects of physical activity on depression[43]. Increasing evidence supports the significant role of depression in social media dependence[44]. According to the mood-enhancement hypothesis, individuals experiencing negative emotions are more likely to use leisure activities, such as social media, to alleviate stress[45]. Depressed individuals often turn to social media to regulate their emotions, leading them to spend more time on these platforms[46]. Although depressed adolescents crave social interaction, they tend to avoid face-to-face socializing due to fear of offline interactions[47]. Social media, on the other hand, provides an easier platform for self-presentation[48]. In face-to-face interactions, they anticipate negative evaluations, making them more likely to immerse themselves in social networks to avoid the possibility of rejection[49]. Studies show that depressed adolescents prefer online socializing to compensate for their social skill deficits, a preference that can lead to compulsive social media use and ultimately develop into social media dependence[27,3950–53]. The I-PACE model identifies depression as a key factor in social media dependence[54]and research indicates that depression is positively correlated with the severity of social media dependence[55]significantly increasing the risk of social media dependence among Chinese adolescents[56]. Further meta-analyses confirm the positive correlation between depression and social media dependence, showing that depressed adolescents are at higher risk of developing social media dependence[57]. Based on this review, we hypothesize that depression mediates the relationship between physical activity and social media dependence in adolescence.

When individuals possess certain personality traits, the relationships among the aforementioned variables may be amplified, thus exacerbating the development of maladaptive behaviors. One such critical variable is difficulty describing feelings[58]. Difficulty describing feelings is one of the key dimensions of alexithymia[59]which refers to a deficiency in self-awareness of emotional states. This condition is characterized by difficulties in identifying and describing emotions and the bodily sensations triggered by emotions, along with a reduction

in imaginative activities and tendencies toward externally oriented thinking[60]. Alexithymia is often associated with an externally focused cognitive style, where individuals are more attuned to external events than to their internal emotional experiences[61]. This disorder is considered a manifestation of impaired emotional cognition, processing, and regulation. Research indicates that the prevalence of alexithymia among Chinese students is as high as 37.7%[62], which may be attributed to cultural differences that influence emotional expression and recognition. This higher prevalence suggests that Chinese university students may experience alexithymia at rates greater than students from other countries[63]. Alexithymia has been identified as a transdiagnostic risk factor for various emotion-related psychopathologies, particularly in the fields of behavioral addiction and substance abuse[64]. Studies have also shown that various dimensions of alexithymia are significantly associated with social media dependence, with difficulty describing feelings being particularly closely related to social media dependence[65]. Difficulty describing feelings is considered a potential risk factor for multiple psychological issues and maladaptive behaviors[66]. Specifically, it weakens an individual's ability to accurately label emotional experiences, which hampers emotional expression and adversely impacts interpersonal relationships, ultimately increasing psychological distress[28,53,67–69]. When individuals are unable to effectively process negative emotions, many tend to turn to social media as an emotion regulation tool, seeking temporary emotional relief[70]. Additionally, impaired emotional description abilities may affect an individual's emotional regulation and social support systems, significantly increasing the risk of social media dependence[71]. Therefore, based on the existing research, we hypothesize that difficulty describing feelings moderates the relationship between depression and social media dependence in adolescence.

In summary, previous research has explored the relationship between physical activity and social media dependence, as well as their predictive roles, but the underlying mechanisms remain underexplored. To further contribute to this field and investigate the underlying psychological mechanisms, this study introduces depression as a mediator and difficulty describing feelings as a moderator. Therefore, we propose a hypothetical path model (see Fig. 1) to investigate the interplay between these variables and their effect on social media dependence in adolescence.

Methods

Participants

The survey was conducted in October 2024 using a convenience sampling method. A total of 3,375 adolescents from four secondary schools in Hunan and Sichuan provinces, China, participated in the cross-sectional study. The survey was conducted using paper-based questionnaires distributed in group sessions. The participants were informed about the survey's purpose, the anonymity and confidentiality of their responses, and the data usage. Informed consent was obtained from both the participants and their guardians. On average, it took participants approximately 10 min to complete the questionnaire. The study received approval from the Medical Ethics Committee of the institution to which the authors are affiliated, ensuring that the research design and data collection process adhered to ethical and legal standards. All procedures complied with the standards and guidelines set by the ethics committee, which further enhanced the reliability of the study and participants' trust. The collected data were screened, and questionnaires were excluded if they contained identical answers for consecutive items, incomplete responses, or exhibited patterns such as waves. After excluding invalid questionnaires, 3,247 valid responses were retained (1,617 boys and 1,633 girls), with a mean age of 14.82 years (SD = 1.404).

Measures

Physical activity

Physical activity was assessed using the Physical Activity Scale developed by Liang Deqing[72]. This scale consists of three items, which include intensity, duration, and frequency. Each item has five levels, with intensity and frequency scored from 1 to 5, and duration scored from 0 to 4. The physical activity score is derived by multiplying the scores for each item. Higher scores indicate higher levels of physical activity. In the current sample, the scale's Cronbach's alpha was 0.638.

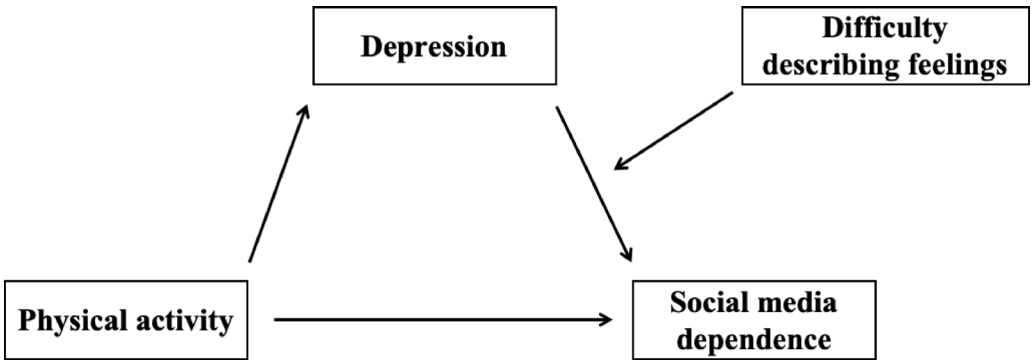

Fig. 1. Hypothesized a mediation model.

Social media dependence
Social media dependence was assessed using the Bergen Social Media Addiction Scale (BSMAS)[73]. The BSMAS contains six items[74]each rated on a five-point Likert scale ranging from 1 (rarely) to 5 (often). A higher total score on the BSMAS indicates a greater level of social media dependence[75]. The Cronbach's alpha for this scale in the current study was 0.800.

Depression
Depression was assessed using the Patient Health Questionnaire-2 (PHQ-2), which evaluates depressive symptoms over the past two weeks. The PHQ-2 is a widely used tool for screening depression, utilizing a four-point Likert scale ranging from 1 (not at all) to 4 (nearly every day). The scale contains two items that assess symptoms of depressed mood and anhedonia, with a total score ranging from 2 to 8 points[76]. Research has shown that the PHQ-2 demonstrates good reliability and validity in both adolescent and adult populations. In this study, the Cronbach's alpha for the PHQ-2 was 0.715.

Difficulty describing feelings
The difficulty describing feelings subscale of the Toronto Alexithymia Scale (TAS), developed by Bagby et al.[77] and revised by Zhu et al.[78]was used to assess the level of difficulty describing feelings among adolescents. The subscale consists of five items, rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with a total score ranging from 5 to 25. Higher scores indicate greater difficulty in describing feelings. The Cronbach's alpha for this scale in the current study was 0.882.

Data processing and analysis
Statistical analysis was performed using SPSS 26.0 software. First, a method bias test was conducted, with a threshold of 40% indicating no significant common method bias[79]. Descriptive statistics and correlation analysis were performed for the participants' demographic characteristics and key variables. Prior to further analysis, the data for the key variables were standardized. To test the hypotheses, we used the PROCESS plugin in SPSS (Models 4 and 14) to examine the relationship between physical activity and social media dependence, exploring the mediating role of depression and the moderating role of difficulty describing feelings[80]. A bootstrap resampling procedure with 5,000 iterations was used to assess model fit and estimate 95% confidence intervals (95% CI), ensuring robustness in data analysis[81]. Demographic variables (age, gender, grade, residence, only-child status, and boarding status) were controlled for in the analyses. A significance level of 0.05 was applied.

Results
Common method Bias test
The results of the common method bias test revealed four factors with eigenvalues greater than 1. The first factor accounted for 20.24% of the total variance, which is below the 40% threshold. This suggests that there is no significant risk of common method bias in this study.

Descriptive analysis
Descriptive statistics for demographic variables are presented in Table 1.

As shown in Table 2, significant gender differences were observed for physical activity ($t = 8.86$, $p < 0.001$), social media dependence ($t = -4.62$, $p < 0.05$), depression ($t = -4.16$, $p < 0.001$), and difficulty describing feelings ($t = -3.50$, $p < 0.001$). Specifically, boys scored higher than girls in physical activity, while girls scored higher than

Items		*N*	Percent
Gender	Boys	1617	49.7%
	Girls	1633	50.3%
Grade	5 th grade of elementary school	36	1.1%
	6 th grade of elementary school	111	3.4%
	1 st year of middle school	384	11.8%
	2nd year of middle school	770	23.7%
	3rd year of middle school	120	3.7%
	1 st year of high school	1220	37.6%
	2nd year of high school	583	18.0%
	3rd year of high school	23	0.7%
Place of Residence	Towns	1581	48.7%
	Village	1666	51.3%
Only child status	Yes	384	11.8%
	No	2863	88.2%
Live on campus or not	Yes	2125	65.4%
	No	1122	34.6%

Table 1. Descriptive statistics of population variables.

Variables		Physical activity		Social media dependence		Depression		Difficulty describing feelings	
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Gender	Boys	20.35	22.66	13.79	5.06	3.95	1.56	14.08	4.10
	Girls	14.21	16.38	14.58	4.74	4.18	1.50	14.57	3.96
	t	8.86***		−4.62***		−4.16***		−3.50***	
Place of Residence	Towns	19.18	21.76	13.96	4.89	4.00	1.56	14.13	4.24
	Village	15.44	17.90	14.41	4.92	4.13	1.50	14.52	3.84
	t	5.36***		−2.62**		−2.32*		−2.77**	
Only child status	Only children	24.57	24.11	13.40	5.07	3.70	1.45	13.39	4.41
	Non-only children	16.28	19.16	14.29	4.89	4.12	1.54	14.45	3.97
	t	7.70***		−3.35**		−5.00***		−4.84***	
Live on campus or not	Live on campus	16.45	18.54	14.23	4.89	4.12	1.54	14.48	3.84
	Not live on campus	18.80	22.38	14.11	4.97	3.96	1.51	14.04	4.38
	t	−3.19**		0.64		2.96**		2.99**	

Table 2. Describes the analysis. *: $p<0.05$;**: $p<0.01$; ***: $p<0.001$

Variables	1	2	3
1 Physical activity	-	-	
2 Social media dependence	−0.112***	-	-
3 Depression	−0.116***	0.363***	-
4 Difficulty describing feelings	−0.128***	0.274***	0.425***

Table 3. Correlation analysis. ***: $p<0.001$

boys in social media dependence and depression. Additionally, girls had higher scores than boys in difficulty describing feelings.

Significant differences were also found between residence location for physical activity ($t = 5.36$, $p < 0.001$), social media dependence ($t = -2.62$, $p < 0.01$), depression ($t = -2.32$, $p < 0.05$), and difficulty describing feelings ($t = -2.77$, $p < 0.01$). Specifically, adolescents living in urban areas scored higher in physical activity, whereas those living in rural areas scored higher in social media dependence, depression, and difficulty describing feelings.

Significant differences were also observed based on the only child status for physical activity ($t = 7.70$, $p < 0.001$), social media dependence ($t = -3.35$, $p < 0.01$), depression ($t = -5.00$, $p < 0.001$), and difficulty describing feelings ($t = -4.84$, $p < 0.01$). Specifically, only children scored higher in physical activity, while non-only children scored higher in social media dependence, depression, and difficulty describing feelings.

Finally, significant differences were found in terms of boarding status for physical activity ($t = -3.19$, $p < 0.001$), depression ($t = 2.96$, $p < 0.01$), and difficulty describing feelings ($t = 2.99$, $p < 0.01$). Adolescents not living in dormitories scored higher in physical activity, while those living in dormitories scored higher in depression and difficulty describing feelings.

Correlation analysis

The results presented in Table 3 indicate significant negative correlations between physical activity and social media dependence ($r = -0.112$, $p < 0.001$), depression ($r = -0.116$, $p < 0.001$), and difficulty describing feelings ($r = -0.128$, $p < 0.001$). Furthermore, social media dependence showed significant positive correlations with both depression ($r = 0.363$, $p < 0.001$) and difficulty describing feelings ($r = 0.367$, $p < 0.001$). Additionally, depression and difficulty describing feelings were positively correlated ($r = 0.500$, $p < 0.001$).

Mediation model testing

After controlling for demographic variables, the results in Table 4 demonstrate that physical activity significantly negatively predicted social media dependence ($\beta = -0.086$, $p < 0.001$). When the mediator variable was included, physical activity remained a significant negative predictor of social media dependence ($\beta = -0.055$, $p < 0.01$). Moreover, when testing the mediation model, physical activity significantly negatively predicted depression ($\beta = -0.089$, $p < 0.001$), and depression significantly positively predicted social media dependence ($\beta = 0.348$, $p < 0.001$). The specific mediation pathways are presented in Table 5. The detailed effect model and paths are shown in Fig. 2.

Moderated mediation analysis

The results from Table 6; Fig. 3, and Fig. 4 indicate that after introducing the moderating variables, the predictive effect of depression on social media dependence remained significant ($\beta = 0.285$, $p < 0.001$). Additionally, difficulty describing feelings significantly predicted social media dependence ($\beta = 0.141$, $p < 0.001$), and the

Outcome Variables	Predictor variables	β	SE	t	R^2	F
Social media dependence	Physical activity (total effect)	−0.086	0.018	−4.810***	0.024	11.448***
Depression	Physical activity	−0.089	0.018	−4.987***	0.027	12.879***
Social media dependence	Physical activity (direct effect)	−0.055	0.017	−3.271**	0.142	67.052***
	Depression	0.348	0.017	21.102***		

Table 4. Mediation model test. **: $p<0.01$;***: $p<0.001$

Intermediary Path	Effect size	SE	Bootstrap 95% CI	Mediating effect ratio
Total Effect	−0.086	0.018	−0.121,−0.051	
Direct Effect	−0.055	0.017	−0.088,−0.022	
Indirect effects	−0.031	0.007	−0.044,−0.018	38.889%

Table 5. Path analysis of mediation model.

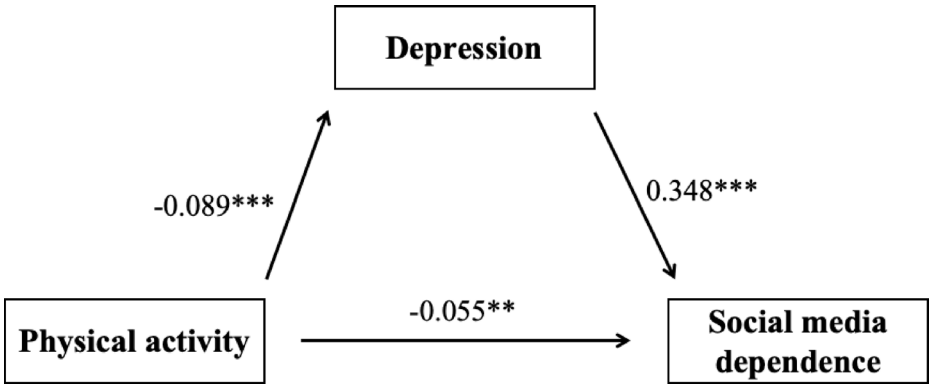

Fig. 2. Mediation model (**: $p < 0.01$; ***: $p < 0.001$).

Variables	Depression			Social media dependence		
	β	SE	t	β	SE	t
Physical activity	−0.089	0.018	−4.978***	−0.047	0.017	−2.807**
Depression (A)				0.285	0.018	15.781***
Difficulty describing feelings (B)				0.141	0.018	7.836***
A × B				0.037	0.015	2.556*
R^2	0.027			0.159		
F	12.879***			61.253***		

Table 6. Tests the mediation model. *: $p<0.05$;**: $p<0.01$; ***: $p<0.001$

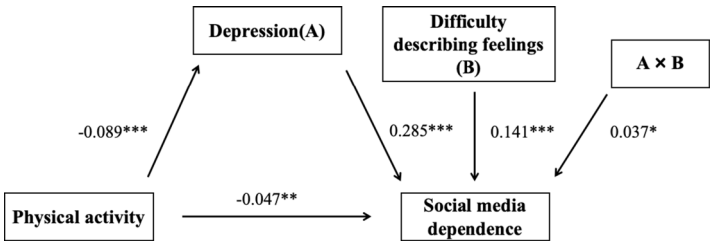

Fig. 3. Moderating mediation model (*: $p < 0.01$; **: $p < 0.01$; ***: $p < 0.001$).

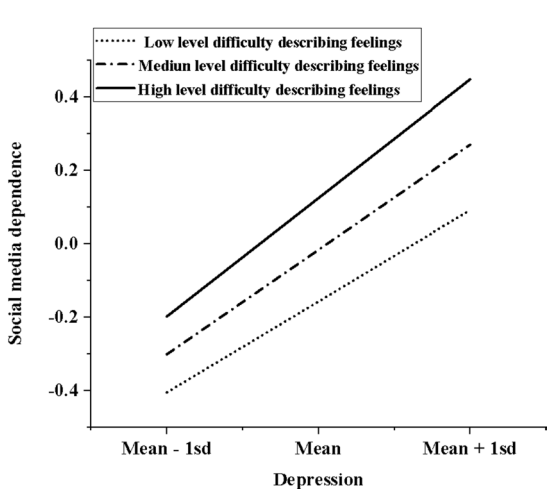

Fig. 4. Simple slope diagram.

DDF Levels	Effect size	SE	t	Lower limit 95%CI	Upper limit 95%CI
Low	0.248	0.025	10.018***	0.200	0.297
Medium	0.285	0.018	15.781***	0.250	0.321
High	0.323	0.022	14.967***	0.280	0.365

Table 7. The moderating effect of different levels of difficulty describing feelings between depression and social media dependence in adolescents. DDF: Difficulty describing feelings; ***: $p<0.001$

interaction term between depression and difficulty describing feelings significantly predicted social media dependence ($\beta = 0.037$, $p < 0.05$). Further analysis revealed that different levels (low, medium, high) of difficulty describing feelings significantly positively moderated the effect of depression on social media dependence (see Table 7).

Discussion

This study examined the relationships among physical activity, social media dependence, depression, and difficulty describing feelings in adolescence. Additionally, we discussed in detail the mediating role of depression and the moderating role of difficulty describing feelings. Our findings reveal that physical activity is significantly negatively correlated with social media dependence, depression, and difficulty describing feelings. Moreover, depression is positively correlated with both social media dependence and difficulty describing feelings, while difficulty describing feelings is positively correlated with social media dependence. After controlling for demographic variables, depression was found to mediate the relationship between physical activity and social media dependence, and difficulty describing feelings significantly moderated this relationship, confirming our initial hypotheses.

This study demonstrates that physical activity has a significant direct negative effect on social media dependence in adolescents, which aligns with findings from similar studies[15,82,83]. The mechanisms underlying the effect of physical activity on social media dependence are complex. Physical activity may influence social media dependence through a series of neurobiological and psychosocial mechanisms. Neurobiological mechanisms may include processes like neuroplasticity and the gut microbiota. Disruption of neuroplasticity pathways could lead to the pathophysiology of social media dependence[84]while physical activity may improve neuroplasticity by enhancing neurogenesis[85] and synaptic plasticity[86]. Emerging evidence in the field of substance addiction suggests that the gut–brain axis may play a role in modulating addictive behaviors through neuroimmune and microbiota-related pathways[87]. While this mechanism is not yet established in the context of behavioral addictions, it is possible that physical activity could indirectly influence social media use patterns by improving neurobiological functioning associated with emotional regulation and reward sensitivity[88]. Furthermore, previous research has suggested that physical activity aligns with the explanatory principles of the social media dependence model and can serve as an effective prevention and intervention method[89]. While not directly examined in this study, previous research suggests that cognitive-behavioral models may help explain how physical activity contributes to reduced problematic social media use. These models highlight the role of maladaptive cognitions and impaired self-regulation in maintaining excessive digital behaviors[90]. Given evidence that physical activity can improve executive function and emotional regulation, it may indirectly reduce vulnerability to problematic social media use[91]. When physical activity involves coordination of cognitive tasks, the structure and function of these tasks are crucial for cognitive operations, and physical activity may enhance cognitive performance[92]. Studies have shown a moderate positive correlation between physical activity

and cognitive functions, particularly executive functions such as attention control, inhibitory control, and decision-making[93]. These capacities are crucial in managing impulses and resisting the urge for excessive social media use[22,26,52,94–101]. When physical activity involves cognitive engagement—such as coordination, planning, or teamwork—it may enhance brain regions involved in self-regulation. These enhancements can, in turn, improve adolescents' ability to manage emotional distress and delay gratification, thereby reducing reliance on social media as a maladaptive coping strategy[102]. In summary, these mechanisms help explain our finding that physical activity is significantly negatively correlated with social media dependence in adolescents. In summary, the evidence presented in this study supports our hypothesis that physical activity is significantly negatively correlated with social media dependence in adolescents.

This study found that depression mediates the relationship between physical activity and social media dependence in adolescence, which aligns with our initial hypothesis. Previous research has established a strong negative correlation between physical activity and depression in adolescents[103]while the relationship between depression and social media dependence has also been well-supported[104]including studies within the Chinese context[105]. The relationship between physical activity and depression can be explained through several mechanisms. Physical activity may influence depression through a range of biological and psychosocial mechanisms, including aspects such as self-esteem, social support, and self-efficacy. Adolescents with depression often exhibit low self-esteem, and the relationship between self-esteem and depression may be cyclical, with low self-esteem exacerbating depressive symptoms[106]. The exercise and self-esteem model[107] suggests that increases in self-esteem are crucial for enhancing the mood-boosting effects of physical activity. Studies using structural equation modeling have found that self-esteem or physical self-concept mediates the relationship between physical activity and depression[108] tasks, leading to feelings of frustration and worsening depressive symptoms[109]. Exercise can help improve self-efficacy, which may extend to other areas and mitigate depressive symptoms[110]. Additionally, individuals with depression frequently report a lack of social support[111]and adequate social support is protective against depression[27,112]. Physical activity may enhance social support by providing social opportunities, thus acting as a buffer in the development of depression[113]. The stress-buffering model[114] conceptualizes the role of social support in mitigating the harmful effects of stress on negative outcomes, suggesting that social support can buffer the impact of stress on negative consequences[114]. The biological mechanisms through which physical activity may prevent or treat depression include neuroplasticity, the gut microbiota, neuroinflammation, and oxidative stress. Disruption of neuroplasticity pathways is considered a key factor in the pathophysiology of depression[115]with the hippocampus being one of the most affected regions in individuals with depression[116]. This area is linked to processes related to depression, such as emotional regulation[117] and stress management[118]. Recent systematic reviews have shown that physical activity can reduce the risk of depression by increasing the volume of the hippocampus and the prefrontal and anterior cingulate cortices in healthy participants[119,120]; as well as by enhancing the circulation of several neurotrophic factors[121]. Dysfunction of the gut-brain axis is considered foundational in depression, and physical activity may alleviate depression by regulating the gut microbiota, increasing short-chain fatty acids (SCFAs) in the gut, and enhancing brain-derived neurotrophic factor (BDNF) and GLP-1 levels[122,123]. Neuroinflammation may also play a role in the pathophysiology of depression[124]and several meta-analyses have shown that physical activity interventions can reduce the risk of depression by lowering the levels of various circulating inflammatory markers (e.g., IL-6, IL-18, CRP, leptin, fibrinogen, and angiotensin II)[125,126]. Oxidative stress pathways are believed to contribute to the pathophysiology of depression and other psychiatric disorders[127]. Research has indicated that long-term physical activity is associated with lower levels of oxidative stress markers, such as serum thiobarbituric acid-reactive substances (TBARS). Furthermore, depression is an unpleasant emotional state, and many adolescents with depression tend to have introverted personalities and are reluctant to communicate with peers. However, social media provides an avenue for these adolescents to escape or even eliminate negative emotions, which may ultimately lead to excessive internet use[128]. According to the social compensation theory[129]individuals experiencing negative emotions are more likely to seek support from the virtual world of social networks, using these platforms to alleviate negative emotions and/or the stress or depression related to dysfunction in their lives[130–132]. Adolescents who experience depression and stress may overuse social media to cope and alter their depressive symptoms, and this overuse can lead to conflicts with real-world obligations and desires. Withdrawal attempts, if unsuccessful, may increase stress. As a result of these conflicts or emotional changes, social media dependence may be further exacerbated. Reduced depression may decrease the likelihood of adolescents engaging in excessive or problematic social media use as a maladaptive coping strategy[133]. This interpretation is consistent with the Compensatory Internet Use Theory (CIUT), which suggests that individuals with negative emotional states often turn to digital platforms for relief[134]. Similarly, the I-PACE model posits that predisposing emotional vulnerabilities like depression influence internet-related addictive behaviors through maladaptive cognitive and affective responses[54]. Together, these models support the pathway whereby physical activity alleviates depression, which then contributes to lower social media dependence. This explanation is supported by previous cross-sectional and longitudinal studies in the field of addiction psychology[135].

This study found that difficulty describing feelings moderates the relationship between depression and social media dependence in adolescence, supporting our initial hypothesis. Individuals with difficulty describing feelings experience significant challenges in understanding both their own and others' emotions. They often struggle to accurately identify others' emotions and have difficulty recognizing or appropriately expressing their own emotions[136]. This limitation in emotional expression tends to lead to the accumulation of negative emotions, which may not be promptly released or processed. Consequently, social media is viewed as an ideal platform for alleviating negative emotions and escaping from reality[137]. According to the general strain theory[138]individuals with difficulty describing feelings are likely to encounter misunderstandings and interpersonal tension due to their struggles in expressing and communicating emotions. This can lead to increased social stress[139]which exacerbates feelings of isolation and loneliness. In such a context, individuals may turn to social media to fulfill

social and emotional needs. The compensatory internet use theory[140] further suggests that negative interpersonal relationships and emotional states may drive individuals toward social media as a coping mechanism to fulfill social needs and alleviate negative emotions. Additionally, the anxiety-avoidance hypothesis[141] posits that for individuals with difficulty describing feelings, social media may serve as a way to escape the challenges of real life, potentially leading to social media dependence. In summary, our findings confirm that difficulty describing feelings plays a significant moderating role in the relationship between depression and social media dependence, further validating our hypothesis.

This study extends previous research by examining the relationships among physical activity, social media dependence, depression, and difficulty describing feelings, with particular attention to how difficulty describing feelings moderates the relationship between depression and social media dependence. The results reveal that physical activity is significantly negatively correlated with social media dependence, depression, and difficulty describing feelings. This suggests that active participation in physical activity can effectively reduce adolescents' engagement in social media dependence, alleviate depressive symptoms, and enhance their ability to describe emotions. Furthermore, a significant positive correlation was found between depression and both social media dependence and difficulty describing feelings, emphasizing that depression may serve as a key psychological mechanism driving social media dependence in adolescence, with difficulty describing feelings intensifying this relationship. Difficulty describing feelings was found to moderate the relationship between depression and social media dependence, indicating that it may exacerbate adolescents' dependence on social media when they face depressive emotions. This finding offers a new perspective on the psychological mechanisms underlying social media dependence and suggests that difficulty describing feelings could be an important risk factor for adolescents' social media dependence. Given these findings, schools and families should pay particular attention to adolescents who have experienced adverse life events such as childhood maltreatment[94,142–145]school bullying[95,96,146–148]and family conflicts, as well as those who frequently experience negative emotions or possess certain personality traits. These factors not only increase the risk of technology addiction but also contribute to poorer sleep quality[149]. In view of the cumulative effects of these risk factors, it is essential to actively implement targeted protective interventions, including providing stable family support to enhance adolescents' sense of security and emotional belonging, encouraging physical activity to promote physical and mental health and improve emotional regulation, and strengthening cognitive training to enhance their ability to cope with negative emotions and stress. Our study not only enriches the theoretical framework on adolescent mental health and social media behavior but also provides practical guidance for future interventions. Promoting physical activity and improving emotion expression abilities, alongside targeted support for vulnerable adolescents, may effectively alleviate depressive symptoms[150] and reduce the risk of social media dependence, offering scientific support for mental health interventions and prevention strategies for adolescents.

However, there are several limitations in this study. First, the data primarily relied on self-reports, which may be influenced by subjective biases, memory errors, or lack of information, potentially affecting the objectivity and accuracy of the data. Second, the sample may lack diversity, limiting the external validity and generalizability of the findings. Lastly, since this study employed a cross-sectional design, causal relationships between variables cannot be definitively established. Future research could use longitudinal studies to further explore the causal mechanisms between physical activity, depression, difficulty describing feelings, and social media dependence.

Conclusion

This study aimed to explore the relationships between physical activity, depression, difficulty describing feelings, and social media dependence in adolescence, and to analyze the mediating and moderating roles of depression and difficulty describing feelings. The results indicate that physical activity is significantly negatively correlated with social media dependence, depression, and difficulty describing feelings, suggesting that higher levels of physical activity help reduce adolescents' social media dependence, alleviate depressive symptoms, and improve emotion description abilities. In addition, depression is significantly positively correlated with both social media dependence and difficulty describing feelings, indicating that depressive emotions play an important role in promoting social media dependence, with difficulty describing feelings further intensifying this relationship. Further analysis revealed that difficulty describing feelings moderates the relationship between depression and social media dependence, confirming that difficulty describing feelings is a crucial factor influencing adolescents' social media dependence. Adolescents with difficulty describing feelings are more likely to accumulate negative emotions and may turn to social media to escape from real-life challenges and emotional issues, thus exacerbating addictive behaviors. In conclusion, physical activity directly influences social media dependence and emotional states, and indirectly reduces the risk of social media dependence by alleviating depressive symptoms and other psychological distress. Difficulty describing feelings, as an important moderating factor, significantly impacts the relationship between depression and social media dependence in adolescents. The findings provide theoretical foundations and practical insights for adolescent mental health interventions and the prevention of social media dependence, suggesting that interventions should focus on promoting physical activity and enhancing emotion expression abilities.

Data availability

The datasets generated and/or analysed during the current study are not publicly available due [our experimental team's policy] but are available from the corresponding author on reasonable request.

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Author contributions

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was approved by the Biomedicine Ethics Committee of Jishou University before the initiation of the project (Grant number: JSDX–2024–0086). And informed consent was obtained from the participants before starting the program.

Additional information

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