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The association between social media addiction and psychological well-being in adolescents with sequential mediation by physical activity and loneliness

Ahmet Yavuz Mallı[1], Abdullah Düğenci[2], Cihan Ayhan[2], Emrah Seçer[1], Zülbiye Kaçay[3], Yunus Şahinler[4] & Özkan Işık[5]✉

Social media addiction is a phenomenon that may adversely affect adolescent mental health and is increasingly recognized as a public health concern by international authorities such as the World Health Organization. Understanding the potential mechanisms underlying the association between social media addiction and psychological well-being is important for informing effective intervention strategies. This study aimed to examine the sequential mediating role of physical activity and loneliness in the association between social media addiction and adolescents' psychological well-being. This cross-sectional study included 290 high school students (mean age = 15.73; 59% female, 41% male) enrolled in high schools in Türkiye. Data were collected using the Bergen Social Media Addiction Scale, the International Physical Activity Questionnaire, the UCLA Loneliness Scale (Short Form), and the Psychological Well-Being Scale. Data were analyzed using SPSS. Normality assumptions were first examined, followed by descriptive statistics and Pearson correlation analyses to assess the relationships among the study variables. Subsequently, Hayes' PROCESS Macro Model 6, a bootstrap-based sequential mediation analysis, was employed to examine the hypothesized indirect associations. Social media addiction was significantly and negatively associated with psychological well-being. The sequential mediation analysis indicated that social media addiction is associated with lower levels of physical activity, which in turn is associated with higher levels of loneliness, and that the proposed sequential indirect association with psychological well-being was statistically significant (indirect effect = -0.0259, 95% CI [-0.0488, -0.0072]). Conclusion The results indicate that physical activity and loneliness may represent an important sequential pathway in the association between social media addiction and adolescents' psychological well-being. Accordingly, public health interventions targeting adolescent mental health may benefit from addressing social media use while also promoting physical activity as a potential component of strategies to support psychological well-being.

Keywords Adolescents, Loneliness, Serial mediation, Social media, Physical activity, Psychological well-being

In the modern digital age, social media has become an integral part of students' lives, serving as a fundamental platform for communication and information dissemination[1,2]. However, the aimless and uncontrolled use of social media can lead to social media addiction, which is a behavioral addiction[3]. Social media addiction (SMA) is defined as a communicative addiction or behavioral intention on social media, driven by an uncontrollable urge to use social media and characterized by devoting excessive time and effort to it, which can weaken other vital areas of life[4]. Due to its prevalence among adolescents and its adverse effects on mental health, this condition is now recognized by authorities as an urgent public health issue[5,6]. During adolescence, a critical period for the construction of identity and self-esteem[7], increased social media use has been associated with

[1]Faculty of Sport Sciences, Erzincan Binali Yıldırım University, Erzincan, Turkey. [2]Faculty of Sport Sciences, Sakarya University of Applied Sciences, Sakarya, Turkey. [3]Faculty of Sport Sciences, Çanakkale Onsekiz Mart University, Çanakkale, Turkey. [4]Faculty of Sport Sciences, İstanbul Gelişim University, İstanbul, Turkey. [5]Faculty of Sport Sciences, Balıkesir University, Balıkesir, Turkey. ✉email: ozkan.isik@balikesir.edu.tr

the emergence of various health and psychosocial difficulties among adolescents, a vulnerable group[8]. In recent years, the association between social media addiction and poorer mental health outcomes has been widely documented by researchers[9,10] and has been reported across multiple studies[11–13]. In this context, psychological well-being[14], which refers to an individual's positive mental and emotional state, has become one of the most studied concepts in relation to social media addiction. Research generally indicates a negative relationship between social media use and adolescent psychological well-being[15–17]. However, some studies suggest that this relationship may also have positive aspects[18]. Similarly, adolescents in Türkiye are under intense influence from digital technologies and social media. Recent studies conducted in Türkiye have reported associations between greater use of technological devices and various adverse mental and physical health outcomes among young people[19]. This intense digital interaction is associated with psychosocial difficulties in adolescents, such as increased social appearance anxiety[20] and eating disorders[21]. However, the excessive and uncontrolled use of these technological developments that make human life easier can be associated with adverse psychosocial outcomes in individuals. Furthermore, increased screen time has been associated with more sedentary behavior and lower levels of physical activity[22]. Therefore, understanding how social media addiction is associated with the well-being of adolescents in Türkiye, as well as the potential pathways involving physical activity and loneliness, is critical for developing evidence-based intervention programs. Physical inactivity is associated with adverse effects on human health, and adolescence is a formative period during which individuals develop behaviors that can influence their health in adulthood[23]. Based on this premise, this study examines the role of two critical mediating variables: physical activity and loneliness.

Physical activity is essential for the physical and psychological well-being of school-aged children and adolescents[24–26], and it is considered fundamental for supporting mental health[27]. Schools are ideal settings for promoting this activity[28,29]. The literature consistently demonstrates that physical activity is associated with better mood and psychological well-being[30–36] and that it may function as a protective factor when performed in natural settings[37]. However, excessive use of internet games and social media[38–40] has been associated with decreased levels of physical activity[41,42]. The second important mechanism, loneliness, is a feeling of inconsistency between the social relationships a person desires and their current relationships[43]. Loneliness has a strong negative relationship with psychological well-being[44–46] and has been associated with adverse physical and mental health outcomes[47]. Some researchers hypothesize that the increase in loneliness among adolescents is potentially related to increased screen time[48,49]. Indeed, problematic use of social media has been associated with loneliness[50–53] and has been linked to social isolation[54,55].

Although the literature has primarily examined the bilateral relationships between these variables separately, less is known about whether these factors may operate as part of a sequential pathway and how they may be interconnected within such a process. Considering that physical activity has the potential to be associated with lower levels of loneliness[56,57], it can be argued that social media addiction may be associated with poorer psychological well-being through a potential pathway involving lower physical activity and higher levels of loneliness. Understanding this possible sequential mediating mechanism is crucial, particularly in terms of identifying potential intervention targets. This is because it proposes that a digital behavior (social media use) may be associated with changes in physical activity, which may in turn be associated with an emotional outcome (loneliness). Within this framework, the present study aims to address this gap in the literature by examining the association between social media addiction and adolescents' psychological well-being through the sequential mediating role of physical activity and loneliness.

Within this framework, the primary objective of this study, conducted on a sample of high school students in Türkiye, is to examine the sequential mediating role of physical activity and loneliness in the relationship between social media addiction and psychological well-being. The study's original contribution to the literature is that it tests a potential process linking these variables. This model provides a more comprehensive theoretical basis than studies examining dual relationships in the field by elucidating how a digital behavior (social media addiction) may be related to lower physical activity, which in turn may be linked to higher levels of loneliness.

The conceptual model of the study is presented in Fig. 1, and the hypotheses are outlined below.

H_1: There is a significant association between adolescents' levels of social media addiction and their levels of psychological well-being.

H_2: Adolescents' levels of physical activity mediate the association between social media addiction and psychological well-being.

H_3: Adolescents' loneliness levels mediate the association between social media addiction and psychological well-being.

H_4: Adolescents' physical activity and loneliness levels sequentially mediate the association between social media addiction and psychological well-being.

Theoretical framework

In this study, a multi-layered theoretical framework has been adopted to conceptualize the complex associations between social media addiction, physical activity, loneliness, and psychological well-being. Rather than treating these four theoretical perspectives as independent explanations, the present study conceptualizes them as complementary perspectives that address different components of the proposed association pattern. Specifically, Compensatory Internet Use Theory (CIUT) helps explain the potential psychological and social motivations underlying problematic social media use; the Displacement Hypothesis provides a behavioral explanation for how excessive social media engagement may be associated with reduced participation in offline activities such as physical activity; Self-Determination Theory (SDT) provides a psychological framework for understanding the relevance of relatedness, competence, and autonomy to loneliness and psychological well-being; and Social Cognitive Theory (SCT) provides an overarching perspective emphasizing the reciprocal interactions among personal factors, behavior, and environmental influences. Taken together, these perspectives provide a coherent

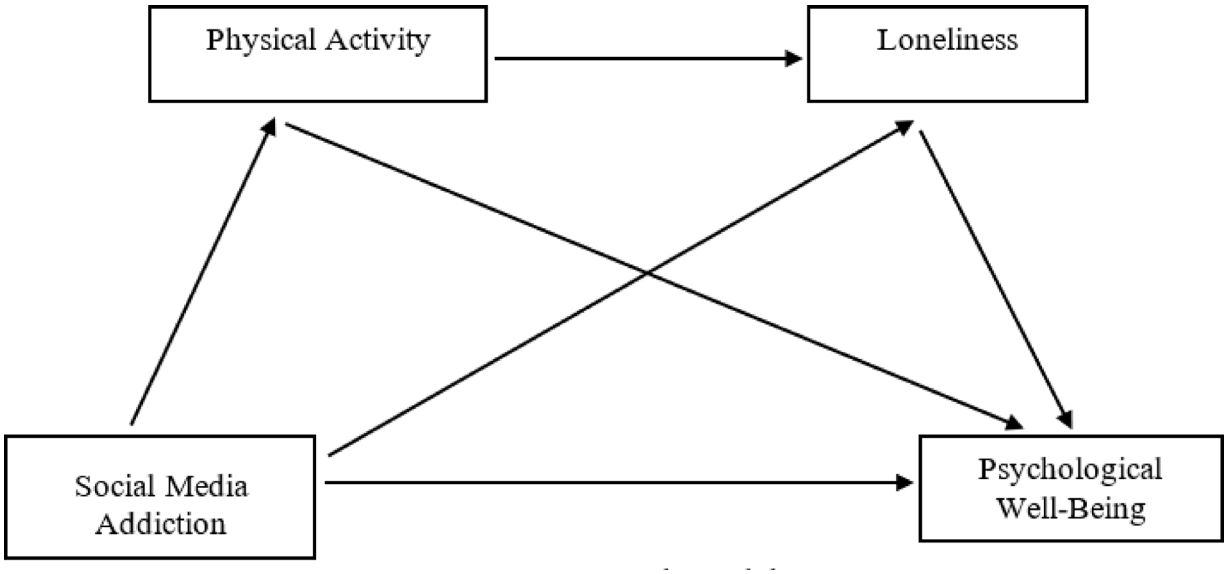


Fig. 1. Research model.

theoretical rationale for examining the potential associations among social media addiction, physical activity, loneliness, and psychological well-being while acknowledging that these relationships may be reciprocal rather than strictly unidirectional. Fundamentally, the Compensatory Internet Use Theory (CIUT)[58] provides a framework for understanding how individuals may use social media in response to stress, negative emotions, or unmet social needs. This framework emphasizes that social media use is not merely a behavior but also a tool for meeting psychological needs. In this respect, CIUT addresses the potential motivation underlying problematic social media engagement, whereas SDT provides a broader account of the psychological needs that may be relevant to such compensatory behavior. Self-Determination Theory (SDT)[59] provides a complementary perspective by highlighting how satisfaction or frustration of the basic psychological needs for autonomy, competence, and relatedness may be relevant to adolescents' engagement with social media and physical activity. Thus, CIUT and SDT are complementary: CIUT helps explain why adolescents may increasingly engage with social media in the context of unmet needs, whereas SDT helps explain how the satisfaction or frustration of basic psychological needs may be associated with psychological well-being. The Displacement Hypothesis[60] extends this framework from psychological motivation to behavioral engagement. According to this perspective, time and attention devoted to social media may displace participation in important offline activities. Accordingly, excessive social media engagement may be associated with reduced involvement in physical activity, which represents an important behavioral context for adolescent development and well-being. In this way, the Displacement Hypothesis provides the theoretical bridge between social media addiction and physical activity, complementing CIUT by explaining a potential behavioral pathway through which intensive social media engagement may be associated with broader psychosocial outcomes. SDT further helps explain the potential connection between physical activity, loneliness, and psychological well-being. Physical activity may provide opportunities for social interaction, competence experiences, and the development of interpersonal connections, whereas lower participation in such activities may be associated with fewer opportunities to satisfy these needs. In particular, the need for relatedness is relevant to understanding loneliness, as insufficient or unsatisfactory social connections may be associated with greater feelings of loneliness. In turn, loneliness may be associated with lower psychological well-being. Thus, SDT provides a theoretical basis not only for the association between social media addiction and psychological well-being but also for the latter stages of the proposed sequential pathway involving physical activity, loneliness, and psychological well-being. The Social Cognitive Theory (SCT)[61] provides an overarching perspective that complements these theories by emphasizing reciprocal and dynamic interactions among personal factors, behavior, and environmental influences. From this perspective, social media use, physical activity, loneliness, and psychological well-being may influence and be influenced by one another within a broader social and behavioral context. This reciprocal perspective is particularly relevant to the present study because it recognizes that the proposed relationships need not be strictly unidirectional. Accordingly, SCT provides an important theoretical basis for interpreting the proposed statistical pathway as one possible pattern of associations within a dynamic system rather than as evidence of a predetermined causal process. These complementary theoretical perspectives collectively provide the basis for the study's hypotheses. The negative relationship between social media addiction and psychological well-being (H_1) is conceptualized based on the Compensatory Internet Use Theory (CIUT) and Self-Determination Theory (SDT). CIUT suggests that adolescents may turn to social media to compensate for unmet social needs. At the same time, SDT states that psychological well-being depends on the satisfaction of basic needs such as relatedness, competence, and autonomy. Problematic social media use may not necessarily satisfy the need for relatedness, particularly when online interactions are perceived as less meaningful or supportive, and it may also

be associated with lower perceptions of competence in the context of social comparison. Therefore, unmet basic psychological needs may be associated with lower levels of psychological well-being.

The Displacement Hypothesis provides a theoretical basis for H2 by explaining how excessive engagement with social media may be associated with reduced participation in offline activities. According to this hypothesis, greater time spent on social media may be associated with less time available for important developmental activities, such as physical activity. In addition, the displacement of offline social and recreational activities may reduce opportunities for interpersonal interaction, which provides a complementary rationale for the potential association between problematic social media use and loneliness examined in H3. Similarly, digital communication, which may serve as an alternative to some forms of face-to-face interaction, may be associated with weaker social bonds and greater feelings of loneliness, forming the basis of H_3.

The sequential mediation model (H_4), the final and most comprehensive hypothesis of the study, represents the point at which these theoretical perspectives converge rather than operate independently. This potential process begins, according to the Displacement Hypothesis, with social media addiction being associated with lower levels of physical activity. Lower participation in offline activities may be associated with fewer opportunities for social interaction and relatedness, providing a theoretical basis for the potential association between lower physical activity and greater loneliness. Lower physical activity may, in turn, be associated with greater feelings of loneliness, potentially reflecting fewer opportunities for offline social interaction. In the final stage, greater loneliness may be associated with lower psychological well-being, consistent with the importance of relatedness emphasized by Self-Determination Theory. Accordingly, CIUT provides a basis for understanding the potential compensatory functions of social media use, the Displacement Hypothesis explains the potential link between social media engagement and physical activity, SDT explains the relevance of relatedness and psychological needs to loneliness and well-being, and SCT provides a broader framework for recognizing the reciprocal nature of these associations. Taken together, these theories provide the conceptual rationale for examining the proposed sequential association between social media addiction, physical activity, loneliness, and psychological well-being. Importantly, this theoretical ordering represents a hypothesized pattern of associations rather than an established temporal or causal sequence. Given the cross-sectional design of the present study, alternative and bidirectional relationships among the variables cannot be ruled out (Fig. 2).

Method

Research model

This study investigates the association between social media addiction and psychological well-being in adolescents. Additionally, the mediating roles of physical activity and loneliness in this association are examined. To achieve this objective, the correlational survey model, a quantitative research method, was employed in the study. A correlational survey is defined as a model aimed at determining the relationships between two or more variables[62,63]. In research conducted in social fields, identifying direct relationships may be insufficient due to the complexity of the relationships between variables. Understanding the potential mechanisms underlying the association between two variables is essential for understanding social reality. It is stated that increasing the current body of knowledge and adding unique value to the relationship pattern with the relevant theory can be achieved by testing mediating effects[64].

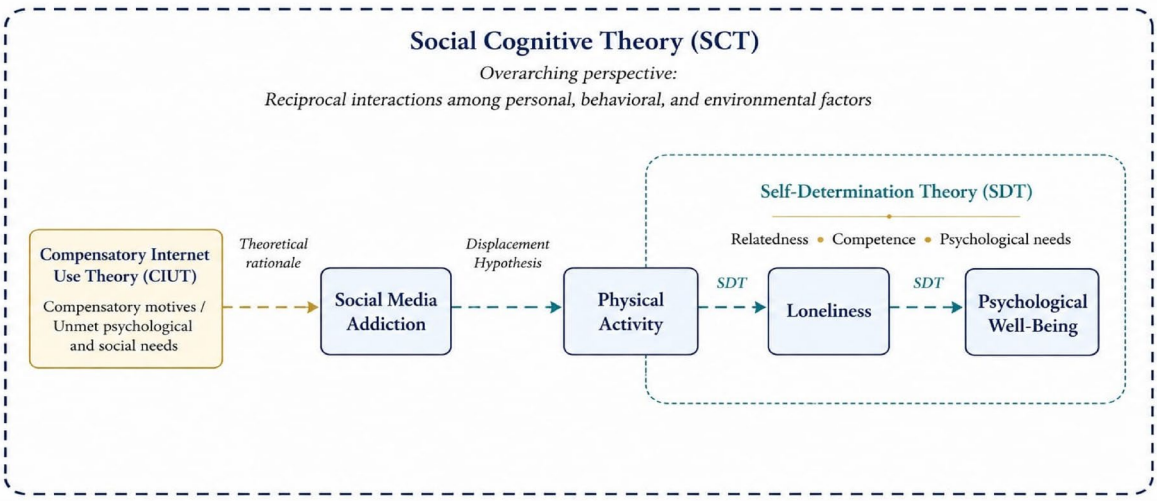


Fig. 2. Integrated theoretical framework linking social media addiction, physical activity, loneliness, and psychological well-being. The arrows represent theoretically hypothesized associations and do not imply temporal or causal relationships.

Procedure and participants

A cross-sectional design was used, with all study variables assessed during a single data-collection period. The participants were high school students recruited from different schools located in different provinces across Türkiye, and data collection was conducted between February and June 2025. The sample was selected using convenience sampling, a non-probability sampling method, based on practical reasons such as the researcher's ease of access and the schools' willingness to participate in the research[65]. Because participants were recruited from a limited number of accessible schools using convenience sampling, the sample may not be fully representative of the broader population of high school students in Türkiye, and the generalizability of the findings should therefore be interpreted with caution.

Of the 447 students approached and invited to participate, 322 (72.0%) agreed to participate, whereas 125 (28.0%) declined or did not provide parental consent. Among the 322 students who agreed to participate, 32 were excluded because of incomplete questionnaire data, including missing responses and failure to complete one or more study scales. Consequently, the final analytic sample consisted of 290 high school students, representing 64.9% of the students initially approached. Completing the surveys took approximately 20 to 25 min. Details of the ethical approval and the informed consent procedures are provided in the Ethical Approval and Data Collection Procedures section.

An a priori power analysis was conducted using the G*Power program[66]. The analysis was based on a two-tailed bivariate correlation, assuming an effect size of r =.20, α = 0.05, and statistical power of 0.80. This analysis indicated that a minimum of 193 participants was required, and the final sample of 290 participants substantially exceeded this minimum requirement under the specified assumptions. However, because this calculation was based on a bivariate correlation, it was not specifically designed to estimate the statistical power of the sequential mediation model tested using PROCESS Model 6. Therefore, the G*Power result was considered a general sample-size benchmark rather than a model-specific power estimate for the sequential indirect effect. Increasing the sample size can enhance the reliability of findings, reduce the likelihood of sampling error, and improve the precision of effect size estimates[67], and the importance of appropriate sample-size determination in planning and interpreting research findings has also been emphasized in the literature[68]. Nevertheless, the absence of a model-specific power analysis for the sequential mediation model is acknowledged as a methodological limitation, and future studies should consider Monte Carlo simulation or other model-specific power approaches when determining sample sizes for complex mediation models.

Data collection tools

Bergen social media addiction scale

Social media addiction was measured using the Bergen Social Media Addiction Scale[69]. The scale consists of six items rated on a 5-point Likert scale ranging from 1 = "very rarely" to 5 = "very often." A higher score on the scale indicates a stronger addiction to social media. The Turkish psychometric analyses of the scale were conducted by Demirci (2019)[70], who provided good evidence of reliability and validity. The scale's internal consistency coefficient was found to be 0.80 (Demirci, 2019). The Cronbach's Alpha reliability coefficient of the scale in this study was calculated to be 0.74. A Cronbach's Alpha coefficient above 0.70 generally indicates that the measurements are reliable[71]. The threshold values proposed by Byrne (2016)[72] and Gürbüz (2021)[64] were used as the basis for the fit indices. The model fit indices: including the Chi-square (χ^2) and Chi-square/degrees of freedom ratio (χ^2/df < 3), Comparative Fit Index (CFI > 0.90–0.95), Standardized Root Mean Square Residual (SRMR < 0.08–0.05), Tucker-Lewis Index (TLI > 0.90–0.95), Root Mean Square Error of Approximation (RMSEA < 0.08–0.05) (Table 1). The initial one-factor model was first tested without correlated residuals and showed inadequate model fit (χ^2/df = 6.394, TLI = 0.771, CFI = 0.862, RMSEA = 0.137 and SRMR = 0.063). The modification indices were subsequently examined together with the substantive similarity of item content, rather than being used solely as a statistical basis for improving model fit. Based on this evaluation, two residual covariances were specified: Item 1 with Item 3 and Item 4 with Item 6. The covariance between Items 1 and 3 was considered theoretically defensible because both items reflect the prominent role of social media in individuals' psychological and daily functioning. Specifically, Item 1 assesses excessive mental preoccupation with social media, whereas Item 3 assesses the use of social media to cope with or forget personal problems. The covariance

Index	Good Fit	Acceptable	SMA	PA	LS	PWB
X^2/df	< 3	< 3(X^2/df) < 5	2.517	-	1.350	1.807
TLI	> 0.95	> 0.90	0.935	-	0.987	0.908
CFI	> 0.95	> 0.90	0.970	-	0.992	0.916
RMSEA	< 0.05	< 0.08	0.072	-	0.035	0.053
SRMR	< 0.05	< 0.08	0.041	-	0.027	0.040
Cronbach alpha	0.90	0.60–0.80	0.74	-	0.80	0.80
Skewness	-	−3/+3	−0.021	1.626	0.552	−0.474
Kurtosis	-	−3/+3	−0.358	2.449	−0.525	−0.347

Table 1. Goodness of fit indices and threshold values used in SEM, Cronbach's alpha, normality analyses. SMA = Social Media Addiction; PA = Physical Activity; LS = Loneliness; PWB = Psychological Well-Being; χ^2/df = Chi-square/Degrees of Freedom; TLI = Tucker-Lewis Index; CFI = Comparative Fit Index; SRMR = Standardized Root Mean Square Residual; RMSEA = Root Mean Square Error of Approximation.

between Items 4 and 6 was considered theoretically plausible because both items reflect impaired control over social media use and its interference with everyday responsibilities. Item 4 concerns unsuccessful attempts to reduce or stop social media use, whereas Item 6 concerns the negative consequences of excessive use for work or studies. Thus, these residual covariances were specified to account for plausible item-specific shared variance arising from conceptual overlap rather than solely to improve statistical fit. Following these two theoretically justified modifications, the one-factor model demonstrated acceptable overall fit (χ^2/df = 2.517, TLI = 0.935, CFI = 0.970, RMSEA = 0.072, SRMR = 0.041). The resulting model retained the intended unidimensional structure, and no items were removed. These findings, together with the acceptable internal consistency coefficient (α = 0.74), provide support for the adequacy of the scale's measurement structure in the present sample.

Psychological well-being scale

The scale was developed by Diener and colleagues (2010) to assess an individual's existing socio-psychological well-being[73]. Items on the Psychological Well-being Scale are rated on a 1–7 scale, ranging from "strongly disagree" (1) to "strongly agree" (7). All items are phrased positively. Scores range from 8 (if the respondent answers "strongly disagree" to all items) to 56 (if the respondent answers "strongly agree" to all items). A high score indicates that the person has many psychological resources and strengths. The scale was adapted into Turkish by Telef (2013), and the Cronbach's alpha coefficient was calculated as 0.80[74]. The Cronbach's Alpha Reliability coefficient of the scale in this study was calculated as 0.80. A Cronbach's Alpha coefficient above 0.70 generally indicates that the measurements are reliable (Nunnally & Bernstein, 1994). The threshold values proposed by Byrne (2016)[72] and Gürbüz (2021)[64] were used as the basis for the fit indices. The model fit indices: including the Chi-square (χ^2) and Chi-square/degrees of freedom ratio (χ^2/df < 3), Comparative Fit Index (CFI > 0.90–0.95), Standardized Root Mean Square Residual (SRMR < 0.08–0.05), Tucker-Lewis Index (TLI > 0.90–0.95), Root Mean Square Error of Approximation (RMSEA < 0.08–0.05) (Table 1). The initial one-factor model was first tested without correlated residuals and yielded inadequate fit (χ^2/df = 2.944, TLI = 0.587, CFI = 0.705, RMSEA = 0.082 and SRMR = 0.061). The modification indices were subsequently examined together with the substantive similarity and conceptual relatedness of the item content, rather than being used solely as a statistical basis for improving model fit. Based on this evaluation, three theoretically defensible residual covariances were specified: Item 1 with Item 5, Item 6 with Item 7, and Item 1 with Item 4. These residual covariances were considered theoretically plausible because the respective item pairs share conceptually related content concerning personal meaning and purpose, positive self-evaluation and future orientation, and meaningful engagement with the well-being of others. Thus, the specified residual covariances were intended to account for plausible item-specific shared variance arising from conceptual overlap among the items rather than being introduced solely to obtain improved statistical fit. Importantly, all items remained indicators of the same underlying psychological well-being construct, with no items removed, additional latent factors specified, or cross-loadings introduced. Following these theoretically justified modifications, the final one-factor model demonstrated acceptable overall fit (χ^2/df = 1.807, TLI = 0.908, CFI = 0.916, RMSEA = 0.053, and SRMR = 0.040). The resulting model therefore retained the intended unidimensional structure while demonstrating improved empirical fit. Together with the acceptable internal consistency coefficient (α = 0.80), these findings provide support for the adequacy of the measurement structure of the Psychological Well-Being Scale in the present sample.

UCLA loneliness scale - short form

It was developed by Hays and DiMatteo (1987)[75] and adapted into Turkish by Yıldız and Duy (2014), consists of seven items[76]. The UCLA-SF response format is organized into a four-point scale: (1) Never, (2) Rarely, (3) Sometimes, and (4) Always. Item 5 of the scale, "I can find friends whenever I want," is reverse-scored. The lowest possible score on this unidimensional scale is 7, and the highest possible score is 28. A low scale score indicates a low level of loneliness, while a high score indicates a high level of loneliness. The Cronbach's Alpha reliability coefficient was determined to be 0.74. The Cronbach's Alpha reliability coefficient for the scale in this study was calculated to be 0.80. A Cronbach's Alpha coefficient above 0.70 generally indicates that the measurements are reliable[71]. The threshold values proposed by Byrne (2016)[72] and Gürbüz (2021)[64] were used as the basis for the fit indices. The model fit indices: including the Chi-square (χ^2) and Chi-square/degrees of freedom ratio (χ^2/df < 3), Comparative Fit Index (CFI > 0.90–0.95), Standardized Root Mean Square Residual (SRMR < 0.08–0.05), Tucker-Lewis Index (TLI > 0.90–0.95), Root Mean Square Error of Approximation (RMSEA < 0.08–0.05) (Table 1). The initial one-factor model was first tested without correlated residuals and showed inadequate model fit (χ^2/df = 4.508, TLI = 0.867, CFI = 0.912, RMSEA = 0.110, SRMR = 0.058). The modification indices were subsequently examined together with the substantive similarity and conceptual relatedness of the item content, rather than being used solely as a statistical basis for improving model fit. Based on this evaluation, two theoretically defensible residual covariances were specified between Items 1 and 2 and between Items 5 and 6. These residual covariances were considered theoretically plausible because the respective item pairs reflect closely related aspects of interpersonal connectedness and perceived social withdrawal, thereby potentially sharing item-specific variance beyond that explained by the general loneliness factor. Thus, the residual covariances were specified to account for plausible shared variance arising from conceptual overlap in item content rather than being introduced solely to improve statistical model fit. Importantly, all seven items were retained, and the intended unidimensional structure of the scale was preserved without introducing additional latent factors or cross-loadings. Following these theoretically justified modifications, the final one-factor model demonstrated good overall fit (χ^2/df = 1.350, TLI = 0.987, CFI = 0.992, RMSEA = 0.035 and SRMR = 0.027). The chi-square test was also nonsignificant (χ^2 = 16.196, df = 12, p =.182), further indicating that the hypothesized measurement model was consistent with the observed data. The resulting model retained the intended unidimensional structure while demonstrating substantial improvement in model fit. Together with

the acceptable internal consistency coefficient (α = 0.80), these findings provide support for the adequacy of the measurement structure of the UCLA Loneliness Scale–Short Form in the present sample.

International Physical Activity Questionnaire (IPAQ) short form

The International Physical Activity Questionnaire (IPAQ) is a standardized measurement tool developed to determine the physical activity levels of individuals aged 15–65[77]. A validity and reliability study on the Turkish sample was conducted by Öztürk (2005)[78]. The total score of the short form is calculated based on the sum of the duration (in minutes) and frequency (in days) of activities. The IPAQ uses a minimum of 10 min of physical activity at a time as a criterion[79]. Physical activity level was assessed based on the total MET minutes/count calculated using the International Physical Activity Questionnaire short form (IPAQ-SF). Since this variable is calculation-based, the reliability coefficient (e.g., Cronbach's alpha) was not reported.

This study was conducted in accordance with the 1964 Declaration of Helsinki and relevant ethical standards. Ethical approval was obtained from the Ethics Committee for Human Research in Health and Sports Sciences at Erzincan Binali Yıldırım University (date: January 31, 2025; reference number: E-88012460-050.04-427952; protocol number: 01/11). Data were collected during class hours in a face-to-face setting with the support of school teachers. Prior to data collection, students were given a parental informed consent form to take home so that written consent could be obtained from their parents (or legal guardians), and students who returned the signed parental consent form were included in the study. In addition, informed consent was obtained from the participating students. Participants were informed that participation in the study was voluntary and that they could withdraw from the study at any time. Finally, prior to administering the survey, participants were provided with an information sheet explaining the purpose of the study and its confidentiality principles.

Statistical analysis

Research data were analyzed using SPSS 22.0 software. Before analysis, outliers, missing data, and the assumptions of normality and multicollinearity were examined. Participants with incomplete questionnaire data were excluded from the analyses using listwise deletion. In total, 32 participants were excluded because they did not provide complete responses to the study measures, resulting in a final analytic sample of 290 participants. Normality was assessed based on skewness and kurtosis coefficients, as well as Z-values and Mahalanobis distance. Following Kalaycı (2018), skewness and kurtosis coefficients falling within the range of − 3 to + 3 were considered indicative of an acceptable approximation to normality and sufficient to support the use of parametric statistical procedures[80]. Accordingly, the distributional characteristics of the study variables were evaluated based on these criteria. Multicollinearity was assessed using tolerance and variance inflation factor (VIF) statistics. The VIF values were 1.091 for social media addiction, 1.068 for loneliness, and 1.080 for physical activity, while the corresponding tolerance values were 0.917, 0.937, and 0.926, respectively. These results indicated no evidence of problematic multicollinearity among the predictor variables.

The factor structures of the scales were tested using confirmatory factor analysis with AMOS 26. The Hayes PROCESS macro for SPSS was used to examine the proposed serial mediation model in this study. The Hayes PROCESS macro enables the isolation of the indirect effect of each mediator. It allows for the examination of the indirect association transmitted through both mediators in sequence[81]. PROCESS Model 6 and a nonparametric percentile bootstrap procedure with 5,000 resamples were applied to estimate the direct and indirect associations and their corresponding 95% confidence intervals.

Results

Table 2 shows the demographic findings of adolescents. It was found that 59% of participants were female and 41% were male. The age distribution was as follows: 13.1% were 14 years old, 36.9% were 15 years old, 19% were 16 years old, 25.9% were 17 years old, and 5.2% were 18 years old. Additionally, the average age of the

***n*: 290**	***n***	**%**
Gender		
Female	171	59
Male	119	41
Age (year)		
14	38	13.1
15	107	36.9
16	55	19
17	75	25.9
18	15	5.2
Average age (year)	15.73	
Grade		
9 10 11 12	116 56 67 52	39.7 19.3 23.1 17.9

Table 2. Demographic results for participants.

Variables	SMA	PA	LS	PWB	M	SD
SMA	1	−0.233**	0.209**	−0.292**	17.85	5.28
PA		1	−0.185**	0.256**	2743.97	2758.48
LS			1	−0.500**	12.73	4.45
PWB				1	38.93	9.24

Table 3. Correlations between variables and descriptive analyses. $N = 290$; SMA= Social Media Addiction; PA= Physical Activity; LS= Loneliness; PWB= Psychological Well-Being; M= Mean; SD= Standard Deviation; $^{*}p < .05$; $^{**}p < .01$.

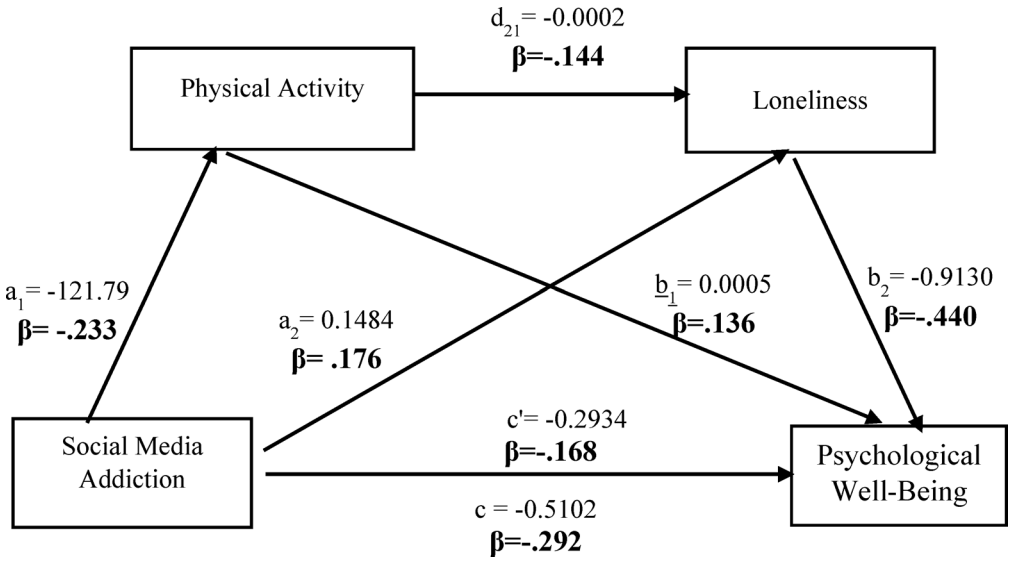


Fig. 3. Results of serial mediation analysis.

participants was 15.73. Furthermore, 39.7% of the participants were in the 9th grade, 19.3% were in the 10th grade, 23.1% were in the 11th grade, and 17.9% were in the 12th grade.

Table 3 shows the descriptive statistics (M = mean, SD = standard deviation) and Pearson correlation coefficients for social media addiction (SMA), physical activity (PA), loneliness (LS), and psychological well-being (PWB). A significant negative correlation was found between SMA and PA ($r = -.233$, $p < .01$), whereas SMA was positively correlated with LS ($r = .209$, $p < .01$) and negatively correlated with PWB ($r = -.292$, $p < .01$). PA was negatively associated with LS ($r = -.185$, $p < .01$) and positively associated with PWB ($r = .256$, $p < .01$). In addition, LS was negatively correlated with PWB ($r = -.500$, $p < .01$).

Figure 3 illustrates that social media addiction (SMA) was negatively associated with physical activity (PA) (B= −121.79, $p<.001$). In contrast, SMA was positively associated with loneliness (LS) (B = 0.1484, $p=.003$), whereas PA was negatively associated with LS (B= −0.0002, $p=.015$). PA was positively associated with psychological well-being (PWB) (B = 0.0005, $p=.009$), whereas LS was negatively associated with PWB (B= −0.9130, $p<.001$). Table 4 further shows that the total association of SMA with PWB was negative and statistically significant (B= −0.5102, 95% CI [−0.7043, −0.3160]), supporting H1. The indirect association of SMA with PWB through PA was statistically significant (B= −0.0555, 95% CI [−0.1157, −0.0080]), supporting H2. Similarly, the indirect association of SMA with PWB through LS was statistically significant (B= −0.1355, 95% CI [−0.2411, −0.0440]), supporting H3. For H4, the sequential indirect association of SMA with PWB through PA and LS was statistically significant (B= −0.0259, 95% CI [−0.0488, −0.0072]), supporting the hypothesis. The total indirect association of SMA with PWB was also negative and statistically significant (B= −0.2168, 95% CI [−0.3369, −0.1120]). Finally, the direct association of SMA with PWB remained negative and statistically significant (B= −0.2934, 95% CI[−0.4708, −0.1159]).

Discussion

This study examined the association between social media addiction and psychological well-being in adolescents, with particular attention to the sequential mediating roles of physical activity and loneliness. The findings indicate that social media addiction was negatively associated with adolescents' psychological well-being, suggesting that this process operates through a multi-layered psychosocial mechanism. The study supported a negative association between social media addiction and psychological well-being, revealing that the variables of physical activity and loneliness may represent important mediating pathways within this association.

	B	β	BootSE	BootLLCI	BootULCI
SMA → PA	−121.79	−0.233	29.923	−180.69	−62.902
SMA → LS	0.1484	0.176	0.0496	0.0508	0.2459
PA → LS	−0.0002	−0.144	0.0001	−0.0004	−0.0001
PA→ PWB	0.0005	0.136	0.0002	0.0001	0.0008
LS → PWB	−0.9130	−0.440	0.1057	−1.1211	−0.7049
SMA➔ PA ➔ PWB	−0.0555	−0.032	0.0276	−0.1157	−0.0080
SMA ➔ LS ➔ PWB	−0.1355	−0.077	0.0500	−0.2411	−0.0440
SMA ➔ PA ➔ LS ➔ PWB	−0.0259	−0.015	0.0105	−0.0488	−0.0072
Direct effect	−0.2934	−0.168	0.0901	−0.4708	−0.1159
Total indirect effect	−0.2168	−0.124	0.0574	−0.3369	−0.1120
Total effect	−0.5102	−0.292	0.0986	−0.7043	−0.3160

Table 4. Model 6 serial mediation test analysis results. B = unstandardized regression coefficient; β = standardized regression coefficient; BootSE = bootstrap standard error; BootLLCI = bootstrap lower-level confidence interval; BootULCI = bootstrap upper-level confidence interval. SMA = Social Media Addiction; PA = Physical Activity; LS = Loneliness; PWB = Psychological Well-Being. The relatively large unstandardized coefficient for the SMA → PA pathway reflects the original MET-min/week metric of the IPAQ; therefore, the magnitude of this coefficient should be interpreted in relation to the measurement unit of physical activity.

Social media addiction and psychological well-being

The main finding of the study is that there is a significant and negative relationship between social media addiction (SMA) and psychological well-being. This finding contributes a digital-age perspective to the broader understanding of adolescent mental health, which has also been shown to be significantly influenced by traditional socio-environmental factors such as parenting practices and material conditions[82]. This result supports the first hypothesis (H_1) and is consistent with a broad literature documenting the association between social media use and poorer mental health outcomes[83–86]. This finding can be explained within the framework of the Compensatory Internet Use Theory (CIUT) and Self-Determination Theory (SDT). Adolescence is a time, between childhood and young adulthood marked by changes in physical, cognitive and emotional aspects[87]. Adolescents may turn to social media to compensate for unmet psychological needs (e.g., forming relationships, feeling a sense of belonging); however, problematic engagement with these platforms may not provide sufficient fulfillment of these needs and may consequently be associated with lower psychological well-being. This may contribute to a cycle that reinforces feelings of social isolation due to the superficial nature of virtual interactions[88].

Physical activity as a behavioral pathway

One of the key findings of the study is that physical activity may function as a meaningful behavioral mechanism in the relationship between social media addiction and psychological well-being. The results indicate that the association between social media addiction and psychological well-being may be partially accounted for by lower levels of physical activity. This finding is consistent with the possibility that patterns of digital engagement may be associated with differences in individuals' daily routines and health-related behaviors. The analyses support the H_2 hypothesis by revealing that physical activity was negatively associated with social media addiction and that lower levels of physical activity were associated with lower levels of psychological well-being.

The importance of physical activity in this process can be explained by its psychological and social benefits. The literature consistently shows that physical activity is associated with lower levels of depressive symptoms and higher levels of overall life satisfaction[89,90]. From the perspective of Self-Determination Theory (SDT), physical activity may support life satisfaction and psychological resilience by fulfilling basic psychological needs, such as autonomy, competence, and relatedness[91,92]. Studies have shown that students who regularly participate in sports tend to have lower levels of internet addiction[93]. Furthermore, recent research shows that physical activity is associated with social benefits, such as lower levels of negative interpersonal behaviors, including cyberbullying[94]. This suggests that physical activity may be relevant to both internal psychological states and positive external social behaviors. More importantly, the benefits of physical activity are not limited to adolescence; consistent participation has also been shown to be associated with a reduced risk of neurodegenerative diseases, such as dementia, in later life[95]. This finding highlights the critical importance of physical activity for lifelong cognitive and mental health. These findings are also consistent with the Displacement Hypothesis, which provides a theoretical explanation for the observed association between social media engagement and physical activity. Indeed, the literature has demonstrated that increasing social media addiction is associated with lower levels of physical activity among adolescents[96]. This situation suggests that greater engagement with social media may be associated with more sedentary behavior and less time allocated to physical activity and offline social interactions[97,98]. Consequently, lower levels of physical activity may be one pathway through which social media addiction is associated with poorer psychological well-being; however, the cross-sectional design does not establish that increased social media use temporally precedes or causes reductions in physical activity.

The mediating role of loneliness

Loneliness has emerged as an important psychosocial pathway in the relationship between social media addiction and psychological well-being in this study. The positive association between social media addiction and loneliness, together with the negative association between loneliness and psychological well-being, is consistent with previous research[99]. Loneliness is a negative emotional experience stemming from the discrepancy between desired and actual social relationships and has adverse effects on both physical and mental health[51,100–102]. From the CIUT perspective, adolescents may turn to social media to alleviate their feelings of loneliness may experience short-term emotional relief; however, problematic social media engagement may also coexist with or contribute to greater perceived social disconnection.

Serial mediation mechanism: from digital behavior to emotional outcome

The most original contribution of this study is the identification of a statistically significant sequential indirect association involving physical activity and loneliness in the relationship between social media addiction and psychological well-being. When these findings are considered together, the results suggest that the association between social media addiction and psychological well-being may be characterized by a sequential pattern involving physical activity and loneliness. According to our findings, increasing social media addiction was associated with decreasing physical activity; decreasing physical activity, in turn, was associated with growing loneliness. Higher loneliness was subsequently associated with lower psychological well-being within the statistical model. In particular, the statistical significance of this pathway from physical activity level to loneliness (p =.015) is consistent with the possibility that physical activity may be relevant to adolescents' social connectedness[103]. This sequential association is important because it suggests a theoretically plausible linkage among digital behavior, physical behavior, and emotional well-being. However, these findings should not be interpreted as evidence that excessive social media use first causes inactivity, which subsequently causes loneliness and reduced psychological well-being. Because all variables were measured at a single time point, the temporal ordering implied by the sequential mediation model cannot be empirically established. Alternative explanations are therefore plausible. For example, adolescents experiencing lower psychological well-being or greater loneliness may be more likely to engage in social media as a means of coping, social compensation, or distraction. Similarly, lower physical activity may be a consequence rather than an antecedent of poorer psychological well-being or greater loneliness. Reciprocal relationships among these variables are also theoretically plausible, consistent with the reciprocal determinism proposed by Bandura's Social Cognitive Theory. Thus, the sequential model tested in this study should be understood as a theory-informed pattern of statistical associations rather than a demonstrated causal chain. Longitudinal and prospective studies are needed to determine whether social media addiction precedes changes in physical activity and loneliness over time and whether these changes subsequently predict psychological well-being. Cross-lagged panel models, longitudinal mediation analyses, or other designs capable of establishing temporal precedence would be particularly valuable for testing the directionality of these relationships. Consequently, rather than establishing a unidirectional causal process, the present findings highlight a potentially meaningful set of interrelated behavioral and psychosocial factors that may warrant consideration in interventions targeting adolescent mental health. The findings should also be interpreted within the cultural and educational context of Türkiye. Adolescents' social media use and psychological well-being may be shaped by their family relationships, peer interactions, and school environments, as well as by culturally specific patterns of digital engagement. These contextual factors may influence how adolescents use social media, participate in offline activities, and experience social connectedness. Regional evidence provides a relevant comparison. For example, Kheirey et al. (2024), in a cross-sectional study of 431 secondary school students in Tabriz, Iran, found that psychological distress mediated the associations of moral intelligence and communication skills with internet addiction[104]. Although their study examined different psychological and interpersonal variables from those investigated in the present study, it provides relevant evidence from a geographically and culturally comparable setting that problematic internet use may be associated with broader psychological and interpersonal characteristics among adolescents. This regional evidence should be viewed as complementary rather than directly confirmatory of the present findings, given the differences in study variables and proposed models. Accordingly, the sequential association identified in the present study should not be assumed to operate identically across countries. Cross-cultural and multinational studies are needed to determine whether the associations among social media addiction, physical activity, loneliness, and psychological well-being are consistent across different cultural, family, peer, and educational contexts.

Practical implications

Low levels of physical activity among adolescents necessitate effective interventions, as current literature suggests that peer relationships play a crucial role in adopting and maintaining positive health behaviors during adolescence[105]. In this context, our findings suggest that intervention and prevention programs addressing social media addiction in adolescents may benefit from going beyond digital media regulation alone and from considering physical activity and social connectedness as potentially relevant components.

Promoting physical activity may support psychological well-being and social connectedness, particularly when activities provide opportunities for meaningful peer interaction. In this regard, organizing physical education programs that include group exercises that strengthen peer interaction and social bonds in schools could be considered. Furthermore, including the assessment of physical activity habits in school-based psychological counseling services could offer a comprehensive approach.

The findings suggest that considering the supportive role of physical activity in both physical and mental development when developing educational policies could contribute to the health and well-being of young people. However, such interventions should be evaluated longitudinally to determine whether changes in physical activity or social connectedness lead to subsequent improvements in psychological well-being.

Limitations and future directions

When evaluating the findings of this study, the following limitations should be taken into consideration. First and most importantly, the cross-sectional design of the study prevents the establishment of temporal precedence or causal relationships among social media addiction, physical activity, loneliness, and psychological well-being. Although the sequential mediation model was theoretically grounded and statistically supported, the significant indirect effects should be interpreted as a theoretically specified statistical pathway rather than evidence of causal or temporal ordering among the variables. Accordingly, the mediation findings should be understood as evidence of an indirect statistical association consistent with the proposed theoretical framework, rather than as evidence of a causal mechanism. For example, lower psychological well-being or greater loneliness may also contribute to increased social media use as a form of coping or social compensation, while lower physical activity may reflect pre-existing differences in psychological well-being or social connectedness. Thus, bidirectional and alternative explanations cannot be ruled out. Future studies could use longitudinal, prospective, or cross-lagged designs to better examine the temporal ordering and potential causal pathways among these variables.

Second, the use of convenience sampling and recruitment from a limited number of schools may have reduced the representativeness of the sample and limited the generalizability of the findings to the broader population of high school students in Türkiye. Because the sampling process relied on school accessibility and willingness to participate, selection bias cannot be ruled out. In addition, data were collected through teachers in the participating schools, and school-level identifiers were not recorded during data collection; therefore, the exact number of participating schools could not be reported, and clustering at the school level could not be examined. In addition, 125 of the 447 students initially approached did not participate because they declined or did not provide parental consent. Therefore, non-response bias cannot be excluded, as students who did not participate may have differed systematically from those who participated in ways that were not assessed in the present study. Although the study provides evidence regarding the associations among the variables within the sampled population, the findings should not be assumed to be representative of adolescents across different geographical, educational, or sociodemographic contexts. Accordingly, the findings should be generalized beyond the participating schools and sampled population with caution. In addition, the findings should be interpreted within the cultural and educational context of Türkiye. Cultural orientations, family and peer relationships, school environments, and culturally specific patterns of social media use may shape adolescents' experiences of social media, physical activity, loneliness, and psychological well-being. Accordingly, the sequential association identified in the present study may not operate in exactly the same way across different cultural contexts. Although the findings may have relevance for adolescents in other settings, their applicability to populations with different cultural, family, educational, and social environments remains uncertain. Future cross-cultural and comparative studies should examine whether the observed associations and the proposed sequential mediation pattern are replicated across countries and cultural contexts. Future studies should employ probability-based sampling strategies and recruit participants from a larger and more diverse range of schools and regions to enhance the generalizability and external validity of the findings, and should document school-level information so that clustering and site-related variability can be assessed.

Third, although the final sample of 290 participants exceeded the minimum sample size indicated by the a priori G*Power analysis, this calculation was based on a two-tailed bivariate correlation rather than on the complete sequential mediation model tested using PROCESS Model 6. Therefore, the G*Power estimate should be interpreted as a general sample-size benchmark rather than as a model-specific power analysis for the sequential indirect effects. The absence of a model-specific power analysis represents an additional methodological limitation of the present study. Future research should consider Monte Carlo simulation or other model-specific power approaches when determining sample sizes for complex mediation models.

Fourth, the confirmatory factor analyses involved theoretically justified residual covariances during model refinement. Although these modifications were evaluated not only on the basis of modification indices but also with reference to the substantive similarity and conceptual relatedness of the corresponding items, the possibility of sample-specific model fit or overfitting cannot be completely excluded. Therefore, the modified measurement models should be interpreted with consideration of the fact that the residual covariances were examined within the present sample. Future studies should replicate the measurement models in independent samples and, where feasible, use cross-validation to evaluate the stability and replicability of the observed factor structures and model fit.

Fifth, data were collected solely using self-report scales; this may introduce common method bias and measurement error risks. This limitation is particularly relevant to physical activity, which was assessed using the self-reported International Physical Activity Questionnaire–Short Form (IPAQ-SF). Self-reported physical activity may be subject to recall bias and social desirability bias and may therefore result in inaccurate reporting or overestimation of actual physical activity levels. Such measurement error may have attenuated or distorted the observed associations involving physical activity and, consequently, may have influenced the estimated indirect effects in the sequential mediation model. In addition, the IPAQ-SF was originally developed for individuals aged 15–65 years[77], whereas 38 participants (13.1%) in the present sample were aged 14 years, the sample otherwise ranging from 14 to 18 years (M = 15.73). Therefore, the age-related considerations and the self-report nature of the measure may limit the precision of the physical activity estimates in younger participants, and this should be taken into account when interpreting the physical activity findings. In future studies, the use of qualitative methods such as semi-structured interviews or focus group discussions alongside quantitative tools could increase the depth of the data. Future studies should also consider using physical activity instruments specifically designed or validated for adolescents and, where feasible, objective measures such as accelerometers to reduce measurement error and provide a more robust assessment of physical activity. In addition, incorporating behavioral indicators of social media use could reduce reliance on self-report measures and provide a more comprehensive assessment of these associations.

Conclusion

In conclusion, this study revealed that the negative association between social media addiction and psychological well-being in adolescents was accompanied by a sequential indirect pathway involving lower physical activity and higher loneliness. This finding suggests that behaviors in the digital realm may be associated with adolescents' levels of physical activity, which may in turn be related to psychosocial outcomes such as loneliness and psychological well-being.

The study's fundamental contribution to the literature is its modeling of this process as an integrated psychosocial pathway and its emphasis on the potential role of physical activity in this process, both as an individual health behavior and as a facilitator of social interaction. However, this pathway should be interpreted as a theory-informed pattern of statistical associations rather than as evidence of a temporal or causal sequence. Elucidating the interrelationships among these factors has important implications for interventions targeting adolescent mental health. Our findings suggest that interventions focusing solely on limiting screen time may not be sufficient and that a multifaceted approach that considers digital habits, physical activity, and face-to-face social connectedness may be warranted.

In summary, this study indicates that efforts to support adolescent mental health in the digital age may benefit from going beyond technology use alone and from creating environments and opportunities that enable young people to be physically and socially active. Future longitudinal research with larger, more diverse, and appropriately powered samples is needed to determine whether the proposed temporal ordering is supported and whether changes in social media use, physical activity, and loneliness are followed by subsequent changes in psychological well-being.

Data availability

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions
AYM, AD, CA, ES, YŞ, and OI conceptualized the study, collected data, analyzed the data, prepared the figures, and wrote the manuscript. OI and ZK elaborated the methodology in depth and performed the final check of the manuscript. All authors have read and approved the final manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
This research was approved by the Erzincan Binali Yıldırım University Human Research Health and Sports Sciences Ethics Committee (E-88012460-050.04-427952), and the research was conducted in accordance with the Declaration of Helsinki. In addition, informed consent was obtained from all participants and their legal guardians before the study.

Additional information
Correspondence and requests for materials should be addressed to Ö.I.

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