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Investigating the Relationship between Loneliness, Physical Activity, and Internet Addiction: The Mediating Role of Academic Burnout and Self-Control

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Abstract

Objective: Internet addiction (IA) poses significant challenges for university students. Although loneliness, physical activity (PA), self-control (SC), and academic burnout (AB) have been implicated in IA, their distinct contributions and mechanisms require further investigation.
This study aimed to investigate whether loneliness positively predicts IA, while PA and SC serve as protective factors. It further examined the mediating roles of SC and AB in the relationships between loneliness, PA, and IA among university students in Iran.
Method: A cross-sectional study was conducted among 490 university students who were recruited using convenience sampling, as this approach was the most practical and feasible given the ease of online survey distribution and limitations in time and resources. All participants were students from universities located in Tehran, Iran. Validated Persian versions of standardized instruments were used to assess A, loneliness, PA, SC, and AB. Structural equation modeling (SEM) using AMOS was employed to evaluate both direct and indirect associations among the study variables.
Results: Structural equation modeling revealed that loneliness had a moderate positive effect on IA ($\beta = 0.217$, $P = 0.001$), while both PA and SC showed small but significant negative effects (PA: $\beta = -0.207$, $P < 0.001$; SC: $\beta = -0.178$, $P = 0.037$). In contrast, AB did not significantly predict IA ($\beta = 0.055$, $P = 0.425$). Mediation analysis indicated that SC partially mediated the relationship between loneliness and IA (indirect effect: $b = 0.054$, $P < 0.05$), while AB showed no significant mediating role in the model.
Conclusion: These findings support cognitive-behavioral models of IA and suggest that improving self-regulation and promoting social connectedness may help mitigate IA risk. Future studies should employ longitudinal designs to examine causal pathways and explore the moderating role of specific coping styles (e.g., emotion-focused vs. problem-focused).

Key words: *Burnout; Exercise; Internet Addiction; Loneliness; Psychological; Self-Control; Students*

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The Internet is a vital global communication system enabling efficient information exchange, news sharing, and multimedia distribution, while supporting personal connections (1). It is deeply integrated into education, work, entertainment, and daily life, leading to increased usage. However, excessive Internet use can negatively affect physical and mental health, academic performance, cognitive functions, and social relationships (2). When individuals find it difficult to regulate their Internet usage, characterized by persistent obsessive thoughts, withdrawal symptoms, constant focus on remaining online, and neglect of routine daily tasks, this condition is referred to as Internet addiction (IA) (3). IA is increasingly recognized as a psychological and behavioral concern, particularly among university students (4), given its association with numerous negative academic, psychological, and interpersonal consequences (5).

Although extensive research has demonstrated the role of psychological factors such as personality characteristics, attachment patterns, and early life trauma in the development of IA (6-10), it is important to consider that these factors are deeply ingrained and difficult to modify in the short term. Consequently, researchers have turned their attention to situational variables that may exert a more immediate impact on IA.

Physical activity (PA) is one such variable that has been extensively studied. Research indicates that increased PA can help manage IA, with its effectiveness depending on factors such as intensity, duration, and types of activities performed (11). Fan and colleagues demonstrated that participating in moderate-intensity physical activities is effective in preventing IA (12). In addition to individual physical activities, group sports such as soccer and basketball can also effectively prevent IA. These activities fulfill social needs, strengthen interpersonal skills (13). Furthermore, as previously mentioned, many underlying psychological factors, including personality traits, insecure attachment styles, and childhood trauma, tend to converge on common psychological states such as feelings of loneliness (14). Loneliness among university students has a significant predictive impact on their tendency towards IA. Research indicates that both self-loneliness and developmental loneliness can forecast students' tolerance levels and their withdrawal reactions to compulsive internet use (15). As individuals spend more time online seeking relief from loneliness, their real-world social interactions diminish, potentially exacerbating feelings of loneliness and leading to increased Internet use as a coping mechanism (16).

In his cognitive-behavioral model, Davis suggests that individuals experiencing heightened loneliness are more likely to engage in excessive Internet use as a form of psychological compensation (17). Based on this, it can be inferred that the increased tendency to remain in online spaces stems from their isolation. Studies have shown that students who report higher levels of loneliness tend to feel fatigued during their learning processes and exhibit symptoms such as low self-efficacy, social isolation, negative emotions related to learning, and increased emotional exhaustion (18, 19).

Based on Davis's theory, which suggests that individuals turn to internet addiction when facing stress, those with high levels of academic burnout may also exhibit increased Internet use through the mechanism of avoidance (17,18, 20). Research among medical students found that those experiencing higher levels of loneliness also reported significantly higher academic burnout scores (21).The concept of academic burnout (AB) is rooted in Maslach's studies on burnout (22). AB is characterized by a decrease in motivation to complete assignments and engage in academic activities, as well as a growing indifference toward peers, resulting from prolonged pressures associated with curricula and other academic demands (23, 24). This phenomenon often arises when academic expectations and tasks surpass an individual's capabilities and is typically accompanied by symptoms such as emotional exhaustion, negative attitudes, and feelings of inadequacy, all of which can adversely affect one's physical and mental health (25).

Given these negative consequences, identifying effective strategies to mitigate academic burnout is essential. One promising intervention is physical exercise. As a personal resource, regular physical activity can reduce individual pressure and help prevent burnout symptoms (26). Exercise not only enhances mental health and reduces fatigue, but also relieves tension and facilitates emotional resource recovery, thereby minimizing AB and promoting overall well-being (27). Furthermore, Brand's Individual-Emotion-Cognitive-Executive (I-PACE) model of Internet addiction highlights that individual characteristics, influenced by emotional and cognitive factors, impact executive function and inhibitory control, ultimately affecting addictive Internet behaviors. According to this model, it can be inferred that self-control (SC) plays a crucial role in IA. Lower levels of SC may lead to difficulties in regulating online activities, increasing the likelihood of excessive or compulsive Internet use (28). When individuals have difficulty managing their SC regarding Internet use, it often leads to impulsive behaviors and a tendency to seek out risky situations, both of which increase the chances of developing IA (29). Research suggests that individuals with initially high SC typically engage with the Internet in a balanced and healthy manner (30). Additionally, Research consistently demonstrates that self-control plays a significant mediating role in the relationship between physical activity and Internet addiction. From a neurobiological perspective, physical exercise can improve brain areas related to inhibitory control, enhancing individuals' ability to resist impulsive Internet use behaviors (31). For instance, those who engage in regular exercise often exhibit higher levels of SC, as physical activity aids in emotional and stress

management, thereby enhancing the ability to regulate impulsive behaviors (32). Self-control has been identified as another crucial mediating factor in the relationship between loneliness and Internet addiction. Research indicates that loneliness can promote Internet addiction through reduced SC (33).This suggests that the experience of loneliness may diminish an individual's capacity for self-regulation, making them more vulnerable to developing problematic patterns of Internet use.

Despite the growing literature on IA and its correlates, few studies have examined how these variables interact within an integrated model. In particular, the potential mediating roles of SC and AB in the links between loneliness, PA, and IA remain underexplored. While several studies have identified SC and AB as factors associated with IA, few have examined these constructs as mediators within theoretically grounded models. For example, Li *et al*. found that low SC is a robust predictor of IA, but did not assess its mediating role (34). Similarly, Zhang *et al*. demonstrated a link between AB and IA without exploring how burnout may operate between predictors like loneliness or PA and IA outcomes (35). Furthermore, many existing models lack integration with foundational theoretical frameworks. In the present study, we conceptualize SC as a cognitive regulatory process and AB as an affective state within the I-PACE model (28) and Davis's cognitive-behavioral model (17). This integration enables the examination of how personal traits (e.g., loneliness), lifestyle behaviors (e.g., PA), and psychological mechanisms (e.g., SC, AB) interact to influence IA.

Therefore, the present study aimed to examine a theory-driven model in which loneliness and physical activity predict Internet addiction, both directly and indirectly through the mediating roles of self-control and academic burnout. Specifically, the study sought to investigate the direct effects of loneliness, physical activity, self-control, and academic burnout on Internet addiction, while also assessing the mediating roles of self-control and academic burnout in the relationships between loneliness and Internet addiction and between physical activity and Internet addiction.

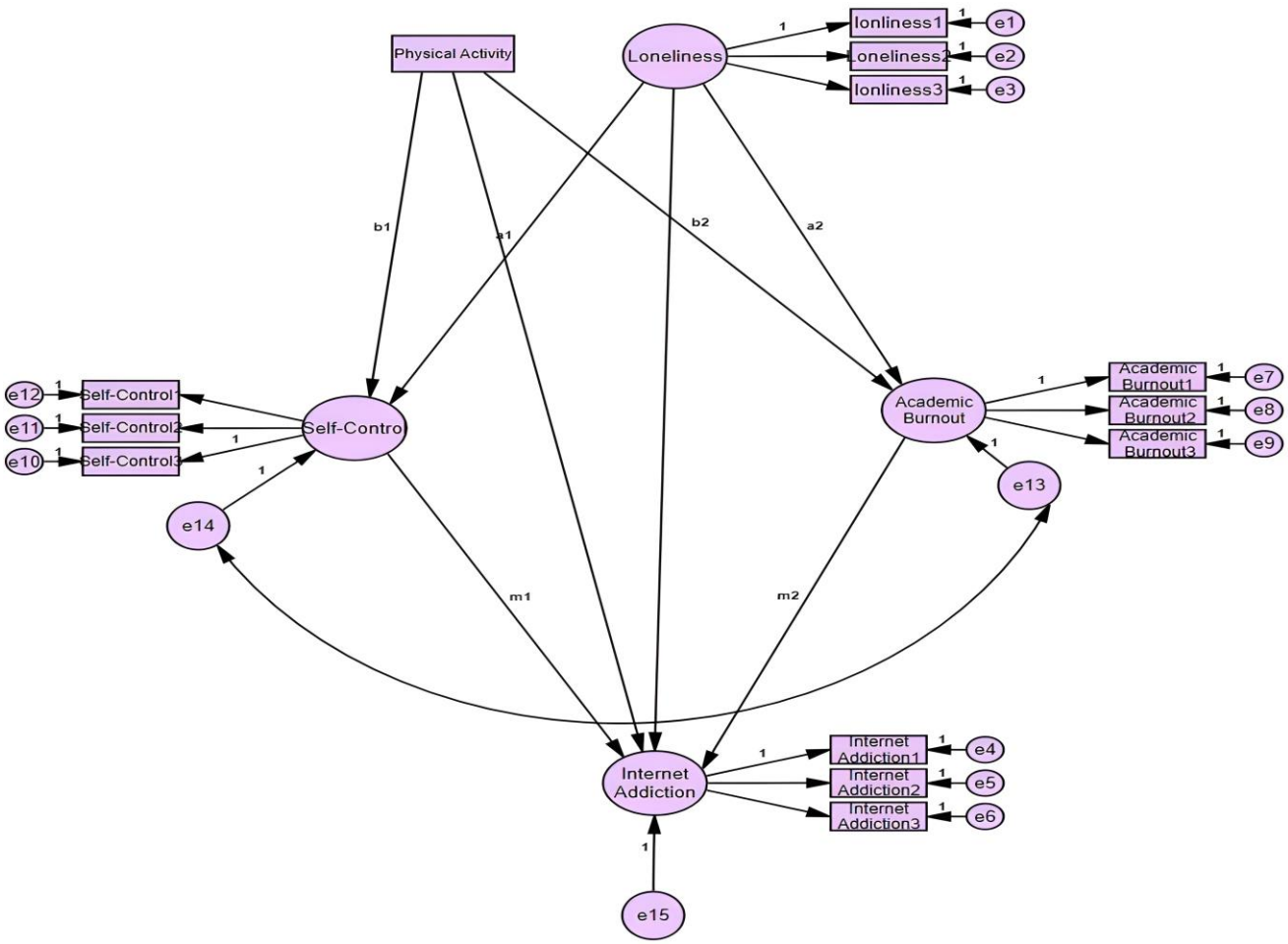

Figure 1. A Conceptual Model of Loneliness, Physical Activity, and Internet Addiction through the Mediating Roles of Academic Burnout, and Self-Control

The conceptual model guiding this study is presented in Figure 1. As shown, loneliness and PA are hypothesized to influence IA via both direct and indirect paths, mediated by SC and AB. This model is informed by the I-PACE framework (28), which emphasizes the interaction of personal characteristics, affective responses, and cognitive processes in the development of problematic internet use. Specifically, loneliness is expected to increase IA directly, as well as indirectly by reducing SC and increasing AB—two pathways associated with poor behavioral regulation and emotional exhaustion (33, 35). PA, on the other hand, is hypothesized to reduce IA directly (36) and indirectly (27, 37), by enhancing SC and reducing AB. SC is expected to negatively predict IA, serving as a protective cognitive factor (38), while AB is hypothesized to increase IA by fostering disengagement and avoidance behaviors (39).Together, this model integrates affective, behavioral, and cognitive mediators to provide a comprehensive view of IA among university students.

Materials and Methods

Methods

This cross-sectional study was conducted among university students in Iran using a non-probability convenience sampling method. Data were collected via an online survey distributed through university-affiliated student groups and academic social media platforms to maximize reach and participation. All respondents were students from universities located in Tehran. Based on estimates from the Free Statistical Calculator for Structural Equation Modeling (SEM) considering the number of variables, the required sample size was between 400 and 500 participants. However, to account for potential exclusions and ensure sufficient statistical power, a total of 1,007 students initially participated.

Eligibility criteria included current university enrollment and age 18 years or older. Exclusion criteria encompassed incomplete or invalid responses and CIAS scores below 64. The CIAS cut-off of 64 is empirically supported in Iranian and Asian samples for its sensitivity and specificity in detecting clinically relevant internet addiction (40, 41), and it indicates a level of use associated with functional impairment.

Ultimately, 490 valid responses (169 male and 321 female students) were included in the analyses. All participants provided online informed consent before completing the questionnaire, and data were fully anonymized to protect participants' privacy. The study protocol was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences.

Measures

The Chen Internet Addiction Scale (CIAS), developed by Chen *et al*., is a self-report questionnaire aimed at assessing symptoms of internet addiction and associated issues within Chinese populations (42). The scale was theoretically grounded in the behavioral addiction framework and designed to identify both the severity and multidimensional nature of problematic Internet use, making it suitable for clinical and research purposes (42, 43). This 26-item instrument evaluates Internet addiction across five dimensions: tolerance, compulsive use, withdrawal symptoms, interpersonal and health-related problems, and time management difficulties. Each item is rated on a four-point Likert scale, where a score of 1 indicates "not at all applicable," and a score of 4 signifies "definitely applicable". The total score ranges from 26 to 104, with higher scores reflecting greater severity of Internet addiction. A score of 64 or above is considered the clinical cutoff for Internet addiction, as established in prior research (44). Obtaining a high score on the CIAS indicates a higher risk and severity of problematic Internet use, including negative impacts on daily functioning (40, 45).

The CIAS exhibits strong internal consistency, with a Cronbach's alpha of 0.949 for the total scale and alphas ranging from 0.87 to 0.92 for its subscales (46). Construct validity of the original scale has been supported through factor analysis, confirming a five-factor structure corresponding to the theoretical domains. The instrument has been widely used and validated in various populations, demonstrating robust psychometric properties and clinical utility (43). The Persian adaptation of this instrument has been validated by Ramezani *et al*. (2012). Their study demonstrated a convergent validity of $r = 0.85$ ($P < 0.001$), and factor analysis using varimax rotation yielded five distinct factors. The Cronbach's alpha for the Persian version was 0.93 for the overall scale, with subscales ranging from 0.67 to 0.85 (47). In the current study, the Cronbach's alpha coefficient for the total CIAS was 0.70. For scoring, individual item scores are summed to yield subscale and total scores, with higher scores indicating more severe Internet addiction.

The Short Form of the International Physical Activity Questionnaire (IPAQ), revised by Qu *et al*., comprises seven questions aimed at assessing the time individuals have spent on various physical activities over the past week. The IPAQ was originally developed by an international group of experts in 1998, with the purpose of providing a standardized and internationally comparable tool for assessing health-related physical activity in adults aged 15–69 years (48). The initial six questions evaluate an individual's physical activity levels, while the final question addresses their sedentary behavior. There are no formal subscales; the questionnaire covers three activity intensity levels (vigorous, moderate, walking) and one item on sitting time. For instance, one of the questions asks, "During the last seven days, on how many days did you engage in vigorous physical activities?" The time allocated to different levels of activity is converted into metabolic equivalents of tasks (METs), which measure the energy cost associated with physical activities. Scoring is based on the sum of MET-minutes per week for each activity

category, calculated according to the official IPAQ guidelines (49). The total possible score theoretically ranges from 0 to several thousand MET-minutes/week, with higher scores indicating greater overall physical activity. A high score reflects a high level of physical activity, while a low score indicates physical inactivity. This questionnaire has demonstrated high reliability and validity, with a test-retest reliability coefficient of 0.87 (50, 51). In the original international validation, test-retest reliability coefficients (Spearman's rho) clustered around 0.8, and criterion validity (compared to accelerometer data) had a median rho of about 0.30. The IPAQ has been validated in diverse populations and languages, showing acceptable measurement properties for use in epidemiological studies (52, 53). Furthermore, the Persian version of the IPAQ has been standardized by Baghani Moghaddam *et al*. (2012). Their study revealed a Cronbach's alpha coefficient of 0.7, indicating good internal consistency, while the Spearman-Brown correlation coefficient of 0.9 reflects strong test-retest reliability (54). The translation and cultural adaptation of the Persian version followed standard forward-backward translation procedures, with review by bilingual experts to ensure cultural relevance; no major adaptation challenges were reported, and the factor structure was consistent with the original version. In the present study, the Cronbach's alpha coefficient for the IPAQ was 0.70. All item responses were converted to minutes per week and aggregated into MET-minutes/week according to the official IPAQ scoring protocol, with higher aggregated scores reflecting greater physical activity.

The University of California at Los Angeles Loneliness Scale Version 3 (UCLA-3), developed and revised by Russell *et al*. (1996), is a tool for assessing individuals' subjective feelings of loneliness. The scale was originally developed in 1978 by Russell, Peplau, and Ferguson, and revised to Version 3 in 1996 to improve clarity and psychometric performance. Its intended purpose is to provide a standardized measure of perceived loneliness in both clinical and research settings across diverse populations (55). This unidimensional scale comprises 20 items and has proven effective in various studies. Participants respond to these 20 questions using a 4-point Likert scale that ranges from 1 ("Never") to 4 ("Always"), with higher scores indicating increased levels of loneliness. Specifically, a score of 45 or above indicates high loneliness, scores between 39 and 44 reflect moderate loneliness, scores from 34 to 38 signify moderate loneliness, scores from 28 to 33 suggest moderate to low loneliness, and scores from 0 to 27 represent low loneliness. The total score thus ranges from 20 to 80, with higher scores reflecting greater perceived loneliness. Original validation studies reported Cronbach's alpha coefficients ranging from 0.89 to 0.94 and test-retest reliability of r = 0.73 over one year, confirming excellent reliability (55). The scale demonstrates good convergent validity, with factor loadings exceeding 0.5, average variance extracted (AVE) above 0.5, and composite reliability (CR) over 0.7. Construct validity is supported by significant correlations with measures of interpersonal relationships, health, and well-being, and confirmatory factor analyses indicate a primary unidimensional structure with some method effects from item wording. Although the scale is most often treated as unidimensional, some studies have identified two underlying dimensions: social loneliness and emotional loneliness (56). It captures two dimensions of loneliness, namely social loneliness and emotional loneliness. The scale's reliability in this study was affirmed by a Cronbach's alpha of 0.895 (57-59). Furthermore, the Persian version of this instrument was standardized by Zarei *et al*. (2015), reporting an overall alpha coefficient of 0.87. The translation and cultural adaptation followed standard forward-backward translation procedures, with reviews by bilingual experts to ensure cultural relevance; no major adaptation challenges were reported, and the factor structure was consistent with the original version (60). The internal correlation coefficient for total loneliness scores was 0.93, $P < 0.009$ (61). In the present study, the Cronbach's alpha coefficient for the scale was 0.72, indicating good internal consistency.

The Maslach Burnout Inventory (MBI) is a self-report scale developed based on the original Maslach Burnout Inventory, prepared by Shaufeil *et al*. (62). The original MBI was created by Christina Maslach and Susan E. Jackson in 1981 to assess occupational burnout, and has since been adapted for various populations, including students, resulting in the Maslach Burnout Inventory–Student Survey (MBI-SS)(63). This scale comprises 15 items, divided into three sub-factors: exhaustion, disinterest, and incompetence. Items are rated on a 5-point Likert scale (from 1 = "never' to 5 = "always"), with items related to incompetence being reverse-scored; higher total scores indicate a greater tendency toward academic burnout. In some versions, a 7-point Likert scale (0–6) is used. In the study conducted by Shin *et al*., Cronbach's α ranged from 0.82 to 0.86 (64). Sepahri Shamloo *et al*. (2017) standardized the Persian version of this instrument, reporting total item correlation and internal consistency (total alpha) values of 0.79, 0.85, and 0.87, respectively. The scale's construct validity was established through exploratory factor analysis, revealing three factors with eigenvalues exceeding 1 (65). The MBI-SS is grounded in the multidimensional model of burnout, conceptualizing burnout as comprising emotional exhaustion, cynicism toward studies, and reduced academic efficacy. Confirmatory factor analyses in various cultural contexts—including Thailand, Spain, Portugal, and the Netherlands—have consistently supported this three-factor structure, with all item factor loadings exceeding recommended thresholds and excellent model fit indices. The instrument has been widely validated and used internationally among university students, demonstrating robust psychometric properties and high internal consistency (63, 66). The

translation and cultural adaptation of the Persian version followed standard forward-backward procedures with expert reviews, and no major adaptation challenges were reported, ensuring the factor structure was consistent with the original version. In the present study, the Cronbach's alpha coefficient for the total scale was 0.68, indicating good internal consistency.

The Tangney Self-Control Scale is a self-report questionnaire developed by Tangney *et al*. the scale was developed to measure individual differences in self-control, based on a broad theoretical foundation encompassing self-discipline, impulse control, healthy habits, work ethic, and reliability(68 ,67) . It consists of 36 items, with a shortened version containing 13 items (69). This scale is designed to evaluate an individual's ability to manage motivation, regulate moods and feelings, curb undesirable habits, maintain discipline, and improve performance. The scale includes two subscales: Inhibitory Self-Control and Primary Self-Control. Respondents rate the items using a 5-point Likert scale, resulting in total scores that range from 13 to 65; higher scores indicate greater self-control. The scale demonstrates good internal consistency (70), with a Cronbach's alpha coefficient of 0.83 (71). Additionally, a domestic version of the instrument was standardized in a study by Asgarian *et al*. (2020), which reported a Cronbach's alpha coefficient of 0.81, further indicating strong internal consistency (72). The original scale was found to have a five-factor structure, but subsequent research has often supported a unidimensional or two-factor structure (such as self-discipline and impulsivity), depending on the population and language adaptation. The Persian version underwent a process of translation and cultural adaptation to ensure conceptual equivalence for Iranian samples, and its validity has been supported through evidence of convergent validity and internal consistency. In the current study, the Cronbach's alpha coefficient for the Persian version was 0.73, confirming reliability in this sample.

Data Analysis

Data were analyzed using SEM with AMOS version 22. A single-step approach was employed in which both measurement and structural models were tested simultaneously. Confirmatory Factor Analysis (CFA) was initially conducted to validate the measurement model for latent variables: Internet Addiction, Academic Burnout, Self-Control, and Loneliness. Given the absence of established sub-dimensions for Internet Addiction, Self-Control, and Loneliness, item parceling was employed to create three indicators per construct (73). Academic Burnout was modeled using its three established dimensions. Physical activity was entered as an observed variable based on the scoring method. The model fit was assessed using multiple indices: The Chi-square/df ratio (2.596), RMSEA (0.057), CFI (0.918), IFI (0.919), GFI (0.955), and SRMR (0.059). These values indicate good model fit, meeting established criteria ($\chi^2/df \leq 3$, RMSEA ≤ 0.08, CFI/TLI/GFI ≥ 0.90, SRMR ≤ 0.08). Full Information Maximum Likelihood (FIML) was used to handle missing data. Path analysis revealed significant direct effects on IA from Loneliness ($\beta = 0.217$, $P < 0.001$), PA ($\beta = -0.207$, $P < 0.001$), and SC ($\beta = -0.178$, $P < 0.05$). AB did not have a significant direct effect on Internet Addiction ($\beta = 0.055$, $P > 0.05$). Loneliness had significant effects on SC ($\beta = -0.294$, $p < 0.001$) and AB ($\beta = 0.206$, $P < 0.001$). Bootstrapping (2000 samples) indicated a significant indirect effect of Loneliness on IA through SC ($b = 0.054$, $P < 0.05$). No other indirect effects were significant ($P > 0.05$).

Ethical Consideration

This study was approved by the Research Ethics Committee of Shahid Beheshti University of Medical Sciences under the ethics code of IR.SBMU.MSP.REC.1403.120. All procedures adhered to the ethical principles outlined in the Declaration of Helsinki as well as international guidelines for online psychological research. Prior to participation, individuals were presented with a detailed informed consent form on the first page of the online survey. Participants could only proceed by checking a consent box, which confirmed their voluntary agreement to participate, acknowledgment of the study's purpose, their right to withdraw at any time without consequence, and understanding of how their data would be used. To ensure anonymity and data protection, no personally identifying information was collected (e.g., names, email addresses, IP addresses). Survey responses were stored in an encrypted and password-protected database, accessible only to the research team. No compensation was provided, and no deception or potentially harmful procedures were used.

Results

The study sample consisted of 490 university students with a mean age of 23.86 years (SD = 4.76). The majority of participants were female, single, and pursuing undergraduate studies. Table 1 presents the detailed demographic characteristics of the sample. Chi-square tests indicated significant heterogeneity in the distribution of gender ($\chi^2 = 47.16$, $P < 0.05$), educational level ($\chi^2 = 654.22$, $P < 0.05$), and marital status ($\chi^2 = 129.6$, $P < 0.05$) across the sample.

Following the description of the sample's demographic characteristics, the subsequent analysis focuses on the key study variables. Table 2 presents the descriptive statistics for these variables, including measures of central tendency, dispersion, and distribution shape. As shown in Table 2, the mean and standard deviation for IA were M = 71.59 and SD = 7.46, respectively. Academic Burnout had a mean of M = 43.00 and a standard deviation of SD = 9.72. SC showed a mean of M = 35.37 and a standard deviation of SD = 4.84. Loneliness was measured with a mean of M = 50.11 and a standard deviation of SD = 7.28. Finally, PA presented a mean of M = 2160.72 and a standard deviation of SD = 2926.04. Assessment of skewness and kurtosis indicated

that the distributions of the variables met the assumptions of normality required for supplementary statistical analyses.

Table 1. Frequency and Percentage of Demographic Characteristics of the University Student Sample (N = 490)

Gender	Frequency	%
Female	231	47.5%
Male	169	34.5%
Total	490	100%
Marital Status		
Single	371	75.7%
Married	119	24.3%
Total	490	100%
Education Level		
Associate degree	6	1.2%
Bachelor's	350	71.4%
Master's	95	19.4%
Professional Doctorate	11	2.2%
Specialized Doctorate	28	5.7%
Total	490	100%

The correlation matrix (Table 3) reveals significant and robust relationships among the study variables. Notably, there is a strong positive correlation between loneliness and IA ($r = 0.226$, $P < 0.01$). Conversely, a similarly strong negative correlation is observed between SC and IA ($r = -0.223$, $P < 0.01$). In contrast, AB does not exhibit a substantial association with IA ($r = 0.039$, $P > 0.05$), while PA shows a weak negative correlation. The measurement model was assessed using CFA. Overall, the model demonstrated acceptable fit, as indicated by the fit indices presented in Table 4. All factor loadings were significant ($P < 0.01$), supporting the construct validity of the latent variables. Based on the structural paths in Table 5 and Figure 2, loneliness had a significant positive effect on IA ($\beta = 0.217$, $P = 0.001$), while self-control ($\beta = –0.178$, $P = 0.037$) and physical activity ($\beta = –0.207$, $P = 0.001$) showed a significant negative effect. Academic burnout was not a significant predictor ($\beta = 0.055$, $P = 0.425$). To examine indirect effects, mediation analyses were conducted using 2,000 bootstrap samples. Results indicated that self-control significantly mediated the relationship between loneliness and IA (indirect effect: $\beta = 0.054$, $P = 0.049$). No significant indirect effects were found for AB or PA (Table 6). Overall, the findings confirm that SC and loneliness are critical factors related to IA. Although no direct correlation was found between AB and PA, both demonstrate a protective effect. These findings underscore the importance of SC strategies in mitigating excessive Internet usage.

Table 2. Results Related to the Descriptive Statistics of Loneliness, Physical Activity, and Internet Addiction, through the Mediating Roles of Self-Control and Academic Burnout

Variable	Mean	Standard Deviation	Kurtosis	Skewness
Internet Addiction	71.59	7.46	1.764	3.165
Academic Burnout	43.00	9.72	0.791	2.698
Self-Control	35.37	4.84	0.180	0.988
Loneliness	50.11	7.28	0.124	2.241
Physical Activity	2160.72	2926.04	1.927	3.527

Table 3. Pearson Correlation Coefficients among Internet Addiction, Academic Burnout, Self-Control, Loneliness, and Physical Activity

Variable	1	2	3	4	5
1.Internet Addiction	1				
2.Academic Burnout	0.039	1			
3.Self-Control	-0.223**	-0.224**	1		
4.Loneliness	0.226**	0.201**	-0.173**	1	
5.Physical Activity	-0.163**	0.073	-0.016	-0.049	1

The association between academic burnout and internet addiction is minimal (0.039), and relationships involving physical activity are generally weak. Stronger relationships were observed between loneliness and both Internet addiction (0.226**) and academic burnout (0.201**).

Table 4. Fit Indices for the Structural Equation Model Examining the Relationships among Loneliness, Physical Activity, Self-Control, Academic Burnout, and Internet Addiction

Fit Index	Calculated Value	Recommended Threshold
RMSEA	0.057	< 0.08 (good fit)
SRMR	0.059	< 0.08 (acceptable)
CFI	0.918	> 0.90 (acceptable)
IFI	0.919	> 0.90 (acceptable)
GFI	0.918	> 0.90 (acceptable)
χ^2/df	2.596	

Table 5. Direct Effects of Loneliness, Physical Activity, Self-Control, and Academic Burnout on Internet Addiction in the Structural Equation Model

Path	Unstandardized Coefficient	Standardized Coefficient	Standard Error	t	P
Loneliness → IA	0.224	0.217	0.069	3.239	0.001
Self-Control → IA	0.001	0.207-	0.001	3.729	0.001
PA→ IA	-0.28	0.178-	0.134	-2.088	0.037
AB→ IA	0.057	0.055	0.071	0.798	0.425
Loneliness → IA	-0.193	0.294	0.048	-4.031	0.001
SC→ IA	0.001	0.029	0.001	0.48	0.631
PA →IA	0.207	0.206	0.062	3.363	0.001
AB→ IA	0.001	0.015	0.285	0.285	0.775

The effects of loneliness, self-control, and physical activity on Internet addiction are small, while the effect of academic burnout on internet addiction is negligible. The presented data show that loneliness, self-control, and physical activity have modest but significant direct effects, whereas academic burnout's direct effect is minimal.

Table 6. Indirect Effects of Loneliness and Physical Activity on Internet Addiction as Mediated by Self-Control and Academic Burnout

Indirect Path	β	Lower Bound	Upper Bound	p
Loneliness → SC → IA	0.054	0.001	0. 16	0.049
Loneliness → AB → IA	0	-0.001	0.001	0.372
Physical Activity → SC → IA	0.012	0.026	0.069	0.422
Physical Activity → AB → IA	0	-0.001	0.001	0.5

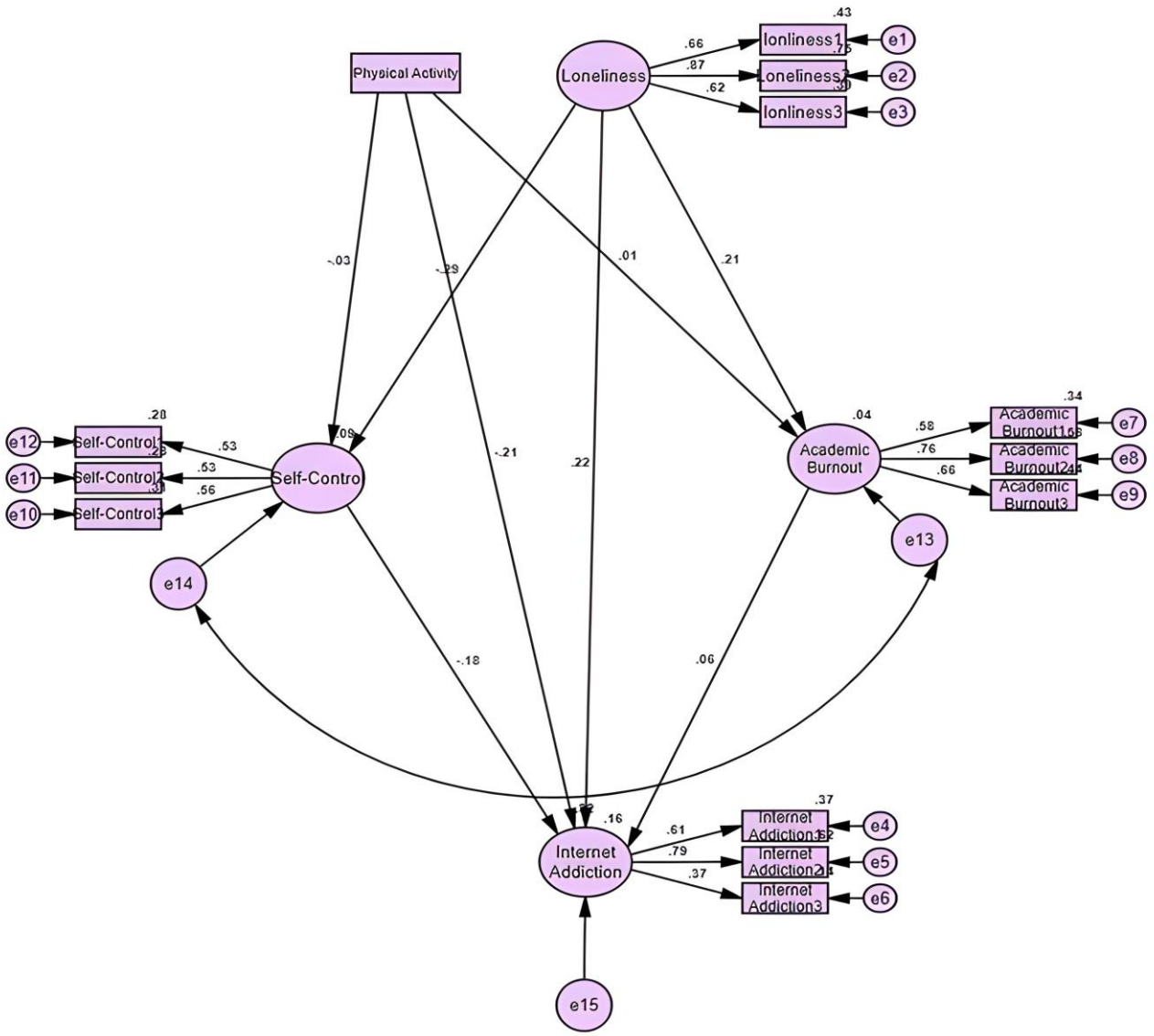

Figure 2. Final Structural Equation Model Showing Standardized Path Coefficients among Loneliness, Physical Activity, Self-Control, Academic Burnout, and Internet Addiction

Discussion

This study aimed to determine the mediating effects of self-control and academic burnout on the relationships between loneliness, physical activity, and Internet addiction among university students. The findings provide important insights into the psychological and behavioral mechanisms underlying problematic Internet use in young adults. The results revealed that loneliness was significantly and positively associated with Internet addiction. This finding supports theoretical perspectives, such as Davis's cognitive-behavioral model, which posit that individuals experiencing heightened loneliness may turn to online environments as a maladaptive coping strategy to fulfill unmet social and emotional needs (17, 73). Such compensatory behaviors, although initially relieving, can reinforce patterns of excessive Internet use and increase the risk of developing addictive tendencies (74).

Notably, our findings offer empirical nuance to Davis's cognitive-behavioral model by illustrating how both cognitive elements—such as beliefs and expectations about the Internet's ability to alleviate loneliness—and behavioral elements—such as the actual engagement in excessive online activity—are present in the student population studied. This dual evidence suggests that interventions should address both maladaptive thought patterns and behavioral habits to effectively reduce problematic Internet use. Self-control emerged as a significant negative predictor of Internet addiction, both directly and as a mediator in the relationship between loneliness and Internet addiction. This is consistent with the I-PACE model, which emphasizes the role of

impaired executive functioning and self-regulation in the development of behavioral addictions (27). The observed mediating effect of self-control further substantiates the I-PACE model's assertion that deficits in executive functioning can heighten vulnerability to Internet addiction, particularly among individuals experiencing loneliness. By demonstrating that self-control bridges the gap between emotional distress and maladaptive online behavior, our results refine the theoretical understanding of how personal regulatory capacities can buffer or exacerbate risk. The mediation analysis suggests that loneliness may not only directly contribute to problematic Internet use but also indirectly increase vulnerability by diminishing individuals' capacity for self-control. These findings highlight the importance of fostering self-regulatory skills as a protective factor against digital dependency. Physical activity was found to have a significant protective effect against Internet addiction. Students who engaged in higher levels of physical activity reported lower levels of problematic Internet use, which may be attributed to benefits such as enhanced mood, better stress management, and more structured daily routines (75-78). Although the indirect effects of physical activity through self-control and academic burnout were not statistically significant, it is possible that physical activity exerts its influence through alternative pathways, such as improving emotional resilience or facilitating social integration (79-81). Interestingly, academic burnout did not demonstrate significant direct or indirect effects on Internet addiction in this sample. While previous research has often linked academic burnout and stress to increased risk of digital escapism (82, 83), the present findings suggest that this relationship may be more context-dependent, potentially moderated by cultural factors or individual differences in coping strategies (84, 85). Moreover, it is important to consider that certain sample characteristics, such as demographic variables or academic disciplines, as well as potential measurement limitations of the burnout scale used, might have influenced the non-significant findings.This divergence from some prior studies indicates that the impact of academic burnout on Internet addiction may depend on whether students primarily use the Internet for academic purposes or as a means of escape, and may also be influenced by contextual factors such as social support and academic self-efficacy. Therefore, future research should systematically examine these moderators and consider specific hypotheses, such as the role of social support as a buffering factor or the differential effects of burnout dimensions on problematic Internet use, to clarify these complex relationships. Recognizing these moderators can help tailor interventions to the specific needs and circumstances of different student populations. Further research is needed to clarify the nuanced role of academic burnout and to determine whether specific dimensions of burnout, such as emotional exhaustion, are more predictive of problematic Internet use. Collectively, these results underscore the central roles of loneliness and self-control in the etiology of Internet addiction among university students. The findings suggest that effective prevention and intervention strategies should prioritize enhancing self-regulation, promoting meaningful offline social connections, and encouraging regular physical activity. Future research should examine whether specific personality traits, such as extraversion or neuroticism, moderate the association between loneliness and Internet addiction (e.g., 'Does extraversion buffer the impact of loneliness on problematic Internet use?'). In addition, randomized controlled trials could test the effectiveness of structured physical activity interventions in reducing Internet addiction among students identified as high-risk based on loneliness or self-control scores, with outcomes including changes in Internet use patterns and psychological well-being. Such targeted studies would clarify for whom and under what conditions interventions are most effective, advancing both theory and practice in the field. Future studies are recommended to explore additional psychological mediators and moderators—such as emotional intelligence, sleep quality, and coping styles—to further elucidate the multifaceted nature of Internet addiction and inform the development of targeted interventions.

Building on these findings, it becomes clear that translating such insights into practical strategies is essential for university settings. Strengthening self-control, particularly in students who experience loneliness, appears to be a key area of impact. For example, universities could implement structured self-control training programs—such as cognitive-behavioral group workshops or mindfulness-based interventions—specifically targeting students identified as experiencing high levels of loneliness through routine psychological screenings. These programs could be delivered through university counseling centers or as part of orientation activities for first-year students, focusing on practical skills like impulse regulation, emotion management, and goal-setting. Evidence from recent studies indicates that emotional self-control training in university settings can effectively reduce maladaptive behaviors and improve emotional well-being in students (86). Offering training in self-regulation skills through counseling services or structured group sessions can be effective, especially when targeted at individuals identified through routine psychological screenings. Rather than general promotion, universities should implement structured, evidence-based physical activity interventions—such as scheduled group exercise classes (e.g., aerobics, yoga, team sports), guided walking programs, or peer-led recreational activities—delivered through university health or counseling services and tailored to students at risk for loneliness or high Internet use. Research shows that such professionally delivered, individually tailored, and frequent interventions are effective in improving

mental health, reducing loneliness, and increasing physical activity among university students (87). For instance, moderate-to-vigorous intensity activities (e.g., group dance, Pilates, sports) have been shown to enhance mood, decrease anxiety and stress, and foster social connection in this population. Incorporating social components and opportunities for peer interaction further increases the effectiveness of these interventions in both reducing loneliness and promoting sustained physical activity engagement (88). The protective role of physical activity also points to the need for accessible and organized opportunities for movement on campus. Integrating activities such as group exercise classes, recreational sports, or walking initiatives into the student life structure can help reduce reliance on digital engagement for emotional relief. Additionally, enhancing emotional coping skills may further support students at risk. Introducing brief training on managing negative affect and building adaptive responses—through orientation programs or online platforms—could reinforce self-regulatory capacity and decrease vulnerability to problematic online behavior.

Overall, these strategies should be implemented selectively and based on data, ensuring that interventions reach students with the highest levels of risk and are adjusted to fit the university context.

Limitation

Although this study provides valuable insights into the relationships among loneliness, self-control, physical activity, and Internet addiction in a university student population, several limitations should be considered when interpreting the findings. The cross-sectional design restricts the ability to draw causal inferences. While a negative association was observed between physical activity and Internet addiction, it cannot be determined whether increased physical activity leads to reduced Internet addiction or vice versa. Additionally, the use of convenience sampling resulted in an overrepresentation of female participants, which may have influenced the results, as previous research suggests that males and females may differ in their experiences of loneliness and patterns of Internet use. As a result, the findings primarily reflect the characteristics of female university students, and caution should be exercised when generalizing to other populations, particularly to male students or non-university groups. Furthermore, although the study focused on key variables based on theoretical and practical considerations, it was not feasible to include all relevant psychological factors, such as depression and social anxiety, due to resource and feasibility constraints. While it is not possible to account for every potential confounder in a single study, the omission of these variables may limit the comprehensiveness of the findings, as unmeasured mental health factors could influence both Internet use and the psychosocial variables examined, potentially confounding the observed associations. Another limitation is that Internet addiction was assessed using self-report instruments rather than neuropsychological tools, as it was not feasible to implement neurocognitive assessments in a large sample. This reliance on self-report may have introduced response bias or reduced the precision of measurement. Similarly, loneliness was measured through self-report questionnaires, whereas in-depth interviews could have provided richer and more nuanced insights into the qualitative aspects of loneliness. To address these limitations, future research is encouraged to employ random sampling methods to obtain more representative samples and to include validated measures of key psychological variables such as depression and social anxiety. Moreover, the use of experimental and longitudinal designs would help clarify the directionality and causality of the observed relationships, while qualitative approaches could provide deeper insights into students' subjective experiences and the mechanisms underlying these associations. In addition, the use of neuropsychological assessments for Internet addiction and qualitative interviews for evaluating loneliness could enhance the accuracy and depth of future findings .

Furthermore, based on our findings, intervention programs that focus on enhancing self-control in students experiencing high levels of loneliness may be particularly beneficial. Future research should also prioritize longitudinal mediation studies to clarify the causal pathways among loneliness, self-control, and Internet addiction. These recommendations are especially relevant for educators, university counselors, and mental health professionals who are in a position to design and implement targeted prevention and intervention strategies.

Despite these limitations, the present study provides important knowledge regarding the interplay of psychosocial and behavioral factors in Internet addiction among university students and highlights directions for future research.

Conclusion

This study demonstrated that self-control plays a significant mediating role in the relationship between loneliness and Internet addiction; specifically, students with higher levels of loneliness and lower self-control are more prone to compulsive Internet use. Additionally, physical activity was directly associated with lower Internet addiction, indicating its potential as an effective protective factor. These findings highlight the importance of strengthening self-control and promoting physical activity in the design of preventive and support interventions for university students. Importantly, the results underscore the need for greater theoretical and empirical attention to the role of self-regulation within the I-PACE model, suggesting that future research should further elaborate on this construct and also incorporate alternative theoretical perspectives to more comprehensively understand the mechanisms underlying

Internet addiction. In practical terms, our findings provide empirical support for the development and implementation of targeted self-control enhancement interventions and structured campus-based physical activity programs, particularly for students exhibiting elevated levels of loneliness or diminished self-control, as these approaches are empirically associated with a reduced risk of Internet addiction in this study.

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Conflict of Interest

None.

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