KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 05 February 2026
Revised 22 March 2026
Accepted 08 April 2026
Published Online 10 June 2026

Journal of Adolescent and Youth Psychological Studies

Volume 7, Issue 6, pp 1-13

E-ISSN: 2981-2526

K-Nearest Neighbors Classification of High-Risk Internet Addiction Profiles among Adolescents Based on Impulsivity, Loneliness, Sleep Quality, and Parental Monitoring

Dilshod. Karimov[1], Emily. Cartwright[2*], Aigerim. Sadykova[3]

[1] Department of Psychology, National University of Uzbekistan, Tashkent, Uzbekistan
[2] Department of Clinical Psychology, University of Toronto, Toronto, Canada
[3] Department of Applied Psychology, Al-Farabi Kazakh National University, Almaty, Kazakhstan

*** Corresponding author email address**: emily.cartwright@utoronto.ca

A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Karimov, D., Cartwright, E., & Sadykova, A. (2026). K-Nearest Neighbors Classification of High-Risk Internet Addiction Profiles among Adolescents Based on Impulsivity, Loneliness, Sleep Quality, and Parental Monitoring. *Journal of Adolescent and Youth Psychological Studies, 7*(6), 1-13.
http://dx.doi.org/10.61838/kman.jayps.5432

A B S T R A C T

Objective: This study aimed to develop and evaluate a K-Nearest Neighbors classification model for identifying high-risk internet addiction profiles among Canadian adolescents based on impulsivity, loneliness, sleep quality, and parental monitoring.

Methods and Materials: This cross-sectional predictive study was conducted among 1,284 adolescents aged 13 to 18 years from secondary schools in Canada. Participants completed standardized self-report measures, including the Internet Addiction Test, Barratt Impulsiveness Scale–11, UCLA Loneliness Scale Version 3, Pittsburgh Sleep Quality Index, and Parental Monitoring Scale. Internet addiction risk status was defined using established Internet Addiction Test cutoff scores, and adolescents were classified into high-risk and low-risk groups. Data preprocessing included missing-value treatment, outlier screening, and standardization of continuous predictors. The dataset was divided into training and testing subsets using stratified sampling. A K-Nearest Neighbors algorithm was trained to classify internet addiction risk, and hyperparameter optimization was performed using grid search with five-fold cross-validation.

Findings: The optimized KNN model demonstrated strong inferential and predictive performance in classifying adolescent internet addiction risk. The final model achieved an accuracy of 88.72%, precision of 85.91%, recall of 83.47%, specificity of 90.84%, F1-score of 84.67%, AUC-ROC of 0.924, and Cohen's kappa of 0.742. The confusion matrix showed that the model correctly classified 171 low-risk adolescents and 57 high-risk adolescents, with 17 false positives and 12 false negatives. Hyperparameter optimization indicated that the strongest model performance was obtained with k = 11 using the Euclidean distance metric. Permutation importance analysis identified impulsivity as the strongest predictor, followed by parental monitoring, loneliness, and sleep quality.

Conclusion: The findings indicate that K-Nearest Neighbors classification can accurately identify high-risk internet addiction profiles among adolescents using a concise set of psychological, sleep-related, and family-based predictors.

Keywords: *Internet addiction; adolescents; K-Nearest Neighbors; impulsivity; loneliness; sleep quality; parental monitoring; machine learning.*

1. Introduction

Internet use has become an indispensable component of adolescents' daily lives, providing opportunities for communication, education, entertainment, and social engagement. Digital technologies facilitate access to information, support academic learning, and enable adolescents to maintain social connections across geographical boundaries. Despite these benefits, growing concerns have emerged regarding excessive and uncontrolled internet use among young people. Problematic internet use, often referred to as internet addiction, has increasingly been recognized as a significant public health concern due to its association with emotional, behavioral, social, and academic difficulties. Contemporary evidence suggests that problematic internet use is not merely characterized by high levels of online engagement but rather by impaired control, compulsive use patterns, withdrawal symptoms, and significant functional impairment in everyday life (Kuss et al., 2021). The increasing prevalence of internet-connected devices and social media platforms has intensified concerns regarding the vulnerability of adolescents to addictive online behaviors, making the identification of risk factors and vulnerable profiles an important priority for researchers and practitioners.

The significance of problematic internet use among adolescents is reflected in the growing body of international research documenting its prevalence and adverse consequences. Studies conducted across diverse cultural contexts have reported substantial proportions of adolescents exhibiting symptoms of internet addiction and related behavioral addictions (Agrawal et al., 2024; Zeyrek, 2026). Systematic reviews indicate that problematic internet use has become a global phenomenon extending beyond specific regions or cultures, affecting adolescents in both developed and developing countries (Kuss et al., 2021). Research has further demonstrated that problematic internet use frequently co-occurs with a variety of psychiatric and psychological difficulties, including depression, anxiety, emotional dysregulation, and reduced psychosocial functioning (Ghali et al., 2023; Marano et al., 2025). As adolescents increasingly rely on digital technologies for social interaction and entertainment, understanding the factors that differentiate low-risk from high-risk users has become increasingly important.

Recent conceptualizations emphasize that internet addiction should be viewed as a multidimensional phenomenon resulting from the interaction of individual vulnerabilities, environmental influences, and developmental factors. Qualitative investigations have revealed that adolescents often describe problematic internet use as a coping mechanism for emotional distress, social difficulties, boredom, and unmet psychological needs (Özparlak et al., 2023; Rollo et al., 2023). Theoretical models suggest that excessive internet engagement may serve as a maladaptive strategy for emotion regulation and social compensation, particularly among adolescents experiencing psychological vulnerabilities (Chatterjee & Rai, 2023). Longitudinal evidence further indicates that problematic internet use develops over time through complex interactions between individual characteristics and environmental conditions, resulting in heterogeneous developmental trajectories rather than a single uniform pattern (Tóth-Király et al., 2021).

One of the most consistently identified predictors of problematic internet use is impulsivity. Impulsivity refers to a tendency toward rapid, poorly considered actions without adequate evaluation of consequences. Adolescence is a developmental period characterized by ongoing maturation of executive control systems, making impulsive behaviors particularly common. Several studies have demonstrated that adolescents with higher levels of impulsivity are more likely to engage in excessive internet use and exhibit symptoms of addiction (Haddad et al., 2021). Impulsive individuals often seek immediate rewards and may experience difficulties regulating online behaviors, contributing to prolonged engagement with internet-based activities. Emerging evidence suggests that impulsivity may influence problematic internet use through multiple pathways, including impaired self-control, reward sensitivity, and difficulties delaying gratification (Kim et al., 2023). Furthermore, investigations employing mixture modeling approaches have identified impulsivity-related cognitive and behavioral profiles that are strongly associated with internet addiction severity (Eşkısu et al., 2023). These findings suggest that impulsivity represents a critical individual-level risk factor deserving particular attention in predictive models of internet addiction.

Loneliness has also emerged as a prominent psychological correlate of problematic internet use. Adolescence is a period during which peer relationships and social belonging become increasingly important. Feelings of loneliness may motivate adolescents to seek alternative forms of social interaction through digital platforms, potentially increasing vulnerability to excessive internet engagement. A comprehensive meta-analysis demonstrated

a robust relationship between loneliness and internet or smartphone addiction among adolescents, indicating that socially isolated youth are significantly more likely to develop problematic online behaviors (Ge et al., 2023). Similar findings have been reported in studies examining adverse childhood experiences and developmental trajectories of loneliness, suggesting that persistent social isolation contributes substantially to problematic internet use (Lin & Chiao, 2022). Network analytic investigations further indicate that loneliness occupies a central position within broader symptom networks involving psychological distress and digital addiction (Kabadayı, 2024). Consequently, loneliness appears to function both as a risk factor and as a potential consequence of excessive internet use, creating a self-reinforcing cycle that may intensify behavioral addiction over time.

Sleep quality constitutes another important factor associated with adolescent internet addiction. Numerous studies have documented significant associations between excessive internet use and disrupted sleep patterns, including reduced sleep duration, increased sleep latency, and poorer overall sleep quality. The widespread availability of smartphones and internet-enabled devices has increased adolescents' opportunities for nighttime internet use, often interfering with healthy sleep habits. Research has demonstrated that poor sleep quality frequently co-occurs with problematic internet use and may contribute to emotional and cognitive difficulties that further reinforce addictive online behaviors (Çelik et al., 2024). Sleep deprivation has also been identified as a key characteristic within latent profiles of adolescents exhibiting technology-related addictions (Kabadayı, 2024). Given the established importance of sleep for emotional regulation, cognitive functioning, and psychological well-being, investigating its role in internet addiction risk classification may provide valuable insights into mechanisms underlying problematic digital behaviors.

Family-related factors have likewise received considerable attention in the literature on adolescent internet addiction. Among these factors, parental monitoring represents one of the most influential protective mechanisms. Parental monitoring refers to the degree to which parents are aware of and supervise their children's activities, peer relationships, and behavioral choices. Research consistently demonstrates that supportive parental involvement and effective monitoring are associated with lower levels of problematic internet use among adolescents (Nannatt et al., 2022). Family functioning more broadly has been shown to influence internet addiction through pathways involving emotional support, hope, and social adjustment (Li et al., 2021). Studies examining parent–adolescent relationship quality have further revealed that weak parental bonds and reduced monitoring contribute to greater susceptibility to problematic internet behaviors (Koca & Saatçı, 2022). These findings underscore the importance of considering family influences alongside individual psychological characteristics when examining adolescent internet addiction.

The consequences of problematic internet use extend beyond behavioral dependence and encompass a wide range of psychological and psychosocial outcomes. Excessive internet engagement has been linked to depression, anxiety, aggression, anger, and social anxiety among adolescents (Haddad et al., 2021). Systematic reviews have documented associations between problematic internet use and suicidal thoughts and behaviors, highlighting the potentially serious implications of uncontrolled digital engagement (He et al., 2024). Furthermore, problematic internet use has been associated with non-suicidal self-injury, gambling problems, and other maladaptive behaviors, suggesting substantial overlap among various forms of behavioral addiction and psychological distress (Losaberidze et al., 2025). The growing recognition of these adverse outcomes has increased the urgency of identifying adolescents at elevated risk before severe psychological consequences emerge.

Research has also highlighted substantial heterogeneity among adolescents experiencing problematic internet use. Rather than representing a homogeneous population, adolescents exhibit distinct patterns of symptoms, risk factors, and behavioral outcomes. Latent class and profile analyses have identified multiple subgroups characterized by varying combinations of internet use behaviors, emotional difficulties, and psychosocial risks (Moreno et al., 2022; Pontes & Macur, 2021). More recent investigations have demonstrated that different profiles of problematic internet use are associated with distinct psychopathological outcomes over time (Wang et al., 2025). Additionally, network analyses have revealed gender differences in symptom structures and pathways underlying problematic internet use, suggesting that risk factors may interact differently across subgroups of adolescents (Liu et al., 2023). Such findings emphasize the importance of moving beyond traditional variable-centered approaches toward person-centered and predictive methodologies capable of identifying high-risk profiles.

JAYPS Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

In parallel with these developments, machine learning techniques have gained increasing prominence in psychological and behavioral health research. Unlike conventional statistical approaches that primarily focus on explaining relationships among variables, machine learning algorithms are specifically designed to optimize prediction and classification accuracy. These methods are particularly useful when multiple interacting risk factors contribute to complex behavioral outcomes. The K-Nearest Neighbors (KNN) algorithm represents one of the most widely used supervised machine learning techniques due to its simplicity, interpretability, and effectiveness in classification tasks. KNN classifies individuals based on similarity to neighboring observations, making it particularly suitable for identifying high-risk profiles within heterogeneous populations. Given the multifactorial nature of internet addiction, machine learning approaches may provide more accurate and clinically useful predictions than traditional analytical methods.

Although previous studies have identified numerous correlates of problematic internet use, several important gaps remain. First, much of the existing literature has focused on isolated predictors rather than examining how multiple psychological and family-related factors jointly contribute to risk classification. Second, relatively few studies have applied machine learning methods to classify adolescents according to internet addiction risk using theoretically relevant variables. Third, despite strong evidence linking impulsivity, loneliness, sleep quality, and parental monitoring to problematic internet use, limited research has investigated their combined predictive utility within a single classification framework. Addressing these gaps may contribute to more effective screening strategies and targeted prevention programs for adolescents vulnerable to internet addiction.

Therefore, the aim of the present study was to develop and evaluate a K-Nearest Neighbors classification model for identifying high-risk internet addiction profiles among Canadian adolescents based on impulsivity, loneliness, sleep quality, and parental monitoring.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design utilizing a supervised machine learning approach to classify adolescents according to their risk of internet addiction. The primary objective was to develop and evaluate a K-Nearest Neighbors (KNN) classification model capable of identifying high-risk internet addiction profiles based on psychological and familial factors, including impulsivity, loneliness, sleep quality, and parental monitoring. The study was conducted among secondary school students in Canada during the 2025–2026 academic year.

A total of 1,284 adolescents participated in the study. Participants were recruited from public and private secondary schools located in the provinces of Ontario, British Columbia, Alberta, and Quebec using a multistage cluster sampling procedure. Eligible participants were between 13 and 18 years of age, enrolled in full-time secondary education, and able to read and understand English or French. Adolescents with diagnosed severe cognitive impairments or neurological conditions that could interfere with questionnaire completion were excluded from the study. The final sample consisted of 652 males (50.8%) and 632 females (49.2%), with a mean age of 15.74 years (SD = 1.48). Prior to data collection, written informed consent was obtained from parents or legal guardians, and assent was obtained from all participating adolescents.

2.2. Measures

Internet addiction was assessed using the Internet Addiction Test (IAT) developed by Kimberly Young. The IAT is a widely used self-report instrument consisting of 20 items designed to measure problematic internet use and addiction-related behaviors. Participants respond to each item on a five-point Likert scale ranging from 1 (rarely) to 5 (always). Total scores range from 20 to 100, with higher scores indicating greater levels of internet addiction. Previous research has consistently demonstrated strong psychometric properties for the instrument, including satisfactory construct validity and internal consistency reliability across adolescent populations. In the present study, participants scoring 50 or above on the IAT were categorized as belonging to the high-risk internet addiction group, while those scoring below this threshold were classified as low-risk users for machine learning analyses.

Impulsivity was measured using the Barratt Impulsiveness Scale–11 (BIS-11), developed by Ernest S. Barratt. The BIS-11 contains 30 items assessing attentional impulsivity, motor impulsivity, and non-planning impulsivity. Responses are recorded on a four-point Likert scale ranging from 1 (rarely/never) to 4 (almost always/always). Higher scores indicate greater impulsive

tendencies. The BIS-11 has been extensively validated in adolescent and adult populations and has demonstrated acceptable reliability coefficients and stable factor structures across diverse cultural contexts.

Loneliness was assessed using the UCLA Loneliness Scale Version 3, developed by Daniel Russell. The scale consists of 20 items designed to evaluate subjective feelings of social isolation and dissatisfaction with interpersonal relationships. Participants rate each statement on a four-point scale ranging from 1 (never) to 4 (often). Higher total scores reflect greater perceived loneliness. Previous studies have reported excellent internal consistency, convergent validity, and test–retest reliability for the instrument among adolescent populations.

Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI), developed by Daniel J. Buysse and colleagues. The PSQI contains 19 self-report items that generate seven component scores assessing subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. These components are combined to produce a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality. The PSQI has demonstrated strong psychometric characteristics and has been widely used in adolescent health and behavioral research.

Parental monitoring was assessed using the Parental Monitoring Scale developed by Laurence Steinberg and colleagues. The instrument evaluates the extent to which parents are aware of their adolescents' activities, peer relationships, academic behaviors, and daily routines. The scale consists of 14 items rated on a five-point Likert continuum ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicate greater levels of parental supervision and monitoring. Previous research has confirmed the validity and reliability of the scale in studies examining adolescent behavioral adjustment and risk-taking behaviors.

2.3. Data Analysis

Data analysis was conducted using Python version 3.12 and the Scikit-learn machine learning library. Preliminary analyses included data screening, treatment of missing values, identification of outliers, and assessment of descriptive statistics. Missing data accounted for less than 3% of the dataset and were handled using k-nearest neighbor imputation procedures. Continuous variables were standardized using z-score normalization to ensure comparable scaling across predictors.

The target variable consisted of internet addiction risk status, categorized into high-risk and low-risk groups based on established IAT cutoff scores. Predictor variables included total and subscale scores of impulsivity, loneliness, sleep quality, and parental monitoring. The dataset was randomly divided into training (80%) and testing (20%) subsets using stratified sampling to preserve class distributions. Hyperparameter optimization was performed using grid search combined with five-fold cross-validation within the training dataset. Different values of k ranging from 3 to 25 and various distance metrics, including Euclidean and Manhattan distances, were evaluated to determine the optimal classification model.

Model performance was assessed using multiple evaluation metrics, including accuracy, precision, recall, F1-score, specificity, and area under the receiver operating characteristic curve (AUC-ROC). Confusion matrices were generated to evaluate classification performance across risk groups. Feature importance was further explored through permutation importance analysis to identify the relative contribution of impulsivity, loneliness, sleep quality, and parental monitoring to the prediction of internet addiction risk. Statistical analyses and machine learning procedures were conducted at a significance level of $p < .05$, and all findings were interpreted within the framework of predictive classification modeling for adolescent behavioral health research.

3. Findings and Results

The final dataset consisted of 1,284 adolescents from secondary schools across Canada. The sample included 652 males (50.8%) and 632 females (49.2%). Participants ranged in age from 13 to 18 years, with a mean age of 15.74 years (SD = 1.48). Regarding grade level, 22.4% were enrolled in Grade 9, 25.7% in Grade 10, 27.6% in Grade 11, and 24.3% in Grade 12. The average daily internet use reported by participants was 5.63 hours (SD = 2.14). Based on the Internet Addiction Test classification criteria, 347 participants (27.0%) were categorized as belonging to the high-risk internet addiction group, whereas 937 participants (73.0%) were classified as low-risk users. No significant differences were observed between male and female participants regarding age distribution or parental educational attainment. Preliminary screening indicated that all study variables were normally distributed within

acceptable ranges, and no severe multicollinearity was observed among the predictor variables.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variable	Mean	SD	1	2	3	4	5
1. Internet Addiction	46.83	14.57	—				
2. Impulsivity	67.24	11.36	.61**	—			
3. Loneliness	42.71	10.18	.55**	.48**	—		
4. Sleep Quality (PSQI)	8.14	3.27	.49**	.39**	.44**	—	
5. Parental Monitoring	39.58	8.91	-.52**	-.36**	-.41**	-.33**	—

Table 1 presents the descriptive statistics and bivariate correlations among the study variables. The mean Internet Addiction Test score was 46.83 (SD = 14.57), indicating moderate variability in problematic internet use within the sample. Impulsivity demonstrated the strongest positive correlation with internet addiction ($r = .61$, $p < .01$), suggesting that adolescents exhibiting greater impulsive tendencies were substantially more likely to report problematic internet use behaviors. Loneliness was also strongly associated with internet addiction ($r = .55$, $p < .01$), while poor sleep quality demonstrated a moderate positive relationship ($r = .49$, $p < .01$). In contrast, parental monitoring exhibited a significant negative correlation with internet addiction ($r = -.52$, $p < .01$), indicating that higher levels of parental supervision were associated with lower levels of problematic internet use. The intercorrelations among predictor variables were moderate in magnitude, suggesting that each construct contributed unique information to the predictive model.

Table 2

Performance Metrics of the Final K-Nearest Neighbors Classification Model

Metric	Value
Accuracy	88.72%
Precision	85.91%
Recall (Sensitivity)	83.47%
Specificity	90.84%
F1-Score	84.67%
AUC-ROC	0.924
Cohen's Kappa	0.742

The performance evaluation of the optimized K-Nearest Neighbors model is presented in Table 2. The model achieved an overall classification accuracy of 88.72%, indicating that nearly nine out of ten participants were correctly classified into high-risk or low-risk internet addiction categories. Precision reached 85.91%, demonstrating that most adolescents identified as high-risk were correctly classified. Recall, which reflects the model's ability to detect genuinely high-risk individuals, was 83.47%. The specificity value of 90.84% indicated excellent discrimination of low-risk users. The F1-score of 84.67% reflected a balanced combination of precision and recall. Furthermore, the area under the receiver operating characteristic curve reached 0.924, indicating outstanding classification performance and strong discriminatory capability. The Cohen's Kappa coefficient of 0.742 suggested substantial agreement between observed and predicted classifications beyond chance.

Table 3

Confusion Matrix of the Final K-Nearest Neighbors Model

Actual Class	Predicted Low-Risk	Predicted High-Risk
Low-Risk	171	17
High-Risk	12	57

JAYPS Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

The confusion matrix shown in Table 3 provides a detailed overview of the classification outcomes. Among low-risk adolescents, 171 participants were correctly classified, whereas only 17 were incorrectly identified as high-risk. Within the high-risk category, 57 adolescents were correctly identified, while 12 participants were misclassified as low-risk. These findings demonstrate that the model maintained a relatively balanced classification performance across both groups. Importantly, the number of false negatives remained low, indicating that relatively few adolescents with problematic internet use profiles were overlooked by the predictive algorithm. This characteristic is particularly valuable in school-based screening contexts, where the accurate identification of at-risk individuals is a primary objective.

Table 4

Hyperparameter Optimization Results for K-Nearest Neighbors Models

Number of Neighbors (k)	Distance Metric	Cross-Validation Accuracy
3	Euclidean	84.91%
5	Euclidean	86.48%
7	Euclidean	88.15%
9	Euclidean	89.03%
11	Euclidean	89.47%
13	Euclidean	88.72%
15	Euclidean	88.34%
11	Manhattan	87.56%

The hyperparameter optimization procedure demonstrated that model performance improved progressively as the number of neighbors increased from three to eleven. The highest cross-validation accuracy (89.47%) was achieved when k = 11 using the Euclidean distance metric. Beyond this value, classification performance showed a slight decline, suggesting that excessively large neighborhood sizes reduced the model's sensitivity to meaningful local patterns within the data. Comparisons between distance metrics revealed that Euclidean distance consistently outperformed Manhattan distance across equivalent parameter configurations. Consequently, the final classification model was developed using k = 11 and Euclidean distance, providing the most stable and accurate predictive solution.

Figure 1

Receiver Operating Characteristic (ROC) Curve of the Optimized K-Nearest Neighbors Model for Classification of High-Risk Internet Addiction Profiles

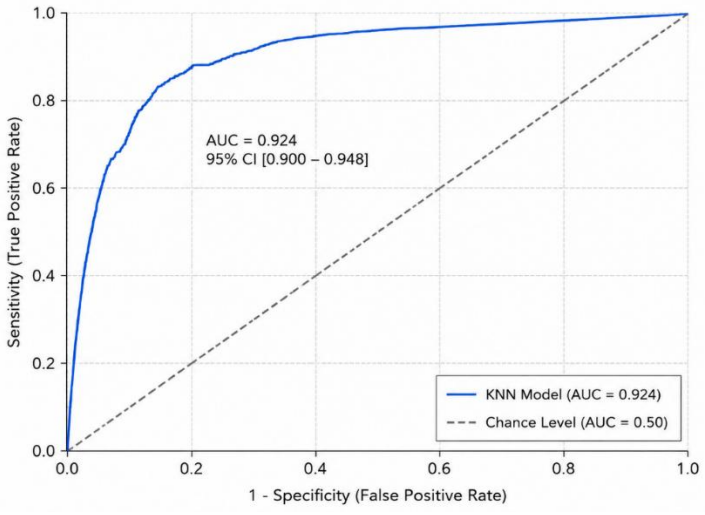

Figure 1 illustrates the receiver operating characteristic curve for the final K-Nearest Neighbors classification model. The ROC curve demonstrated strong separation between high-risk and low-risk internet addiction classes, yielding an area under the curve of 0.924. The steep ascent observed in the early portion of the curve indicates high sensitivity with relatively low false-positive rates. This finding confirms that the predictive model possessed excellent discriminative power and was highly effective in distinguishing adolescents exhibiting high-risk internet addiction characteristics from those demonstrating normative patterns of internet use.

To further investigate the relative contribution of predictor variables, permutation importance analyses were conducted following model optimization. The results indicated that impulsivity emerged as the most influential predictor, accounting for approximately 31.8% of total predictive importance. Parental monitoring represented the second most influential factor (27.4%), followed by loneliness (22.6%) and sleep quality (18.2%). These findings suggest that both individual psychological vulnerabilities and family-related protective factors play critical roles in the development and maintenance of problematic internet use among adolescents. Collectively, the findings demonstrate that the K-Nearest Neighbors algorithm achieved robust classification performance and successfully identified high-risk internet addiction profiles based on a multidimensional combination of behavioral, emotional, sleep-related, and parental factors.

4. Discussion

The present study developed and evaluated a K-Nearest Neighbors classification model for identifying high-risk internet addiction profiles among Canadian adolescents based on impulsivity, loneliness, sleep quality, and parental monitoring. The findings demonstrated that the optimized KNN model had strong classification capacity, with an overall accuracy of 88.72%, precision of 85.91%, recall of 83.47%, specificity of 90.84%, F1-score of 84.67%, AUC-ROC of 0.924, and Cohen's kappa of 0.742. These results indicate that the model was not only accurate in overall classification but also balanced in distinguishing high-risk from low-risk adolescents. The AUC value above 0.90 suggests excellent discriminatory power, meaning that the combination of psychological, behavioral, sleep-related, and familial predictors provided a robust basis for separating adolescents with high-risk internet addiction profiles from those with lower-risk patterns. This finding is consistent with recent research emphasizing that problematic internet use is a multidimensional behavioral health phenomenon rather than a single symptom-based condition, and that high-risk adolescents often present with interacting emotional, cognitive, behavioral, and contextual vulnerabilities (Pontes & Macur, 2021; Wang et al., 2025; Zeyrek, 2026).

The descriptive and correlational findings showed that impulsivity had the strongest positive association with internet addiction, followed by loneliness and poor sleep quality, whereas parental monitoring showed a moderate negative association. This pattern supports the assumption that adolescents with weaker self-regulatory capacity, higher emotional isolation, and poorer sleep functioning are more vulnerable to excessive and uncontrolled internet use, while active parental supervision may operate as a protective factor. The strong correlation between impulsivity and internet addiction is consistent with earlier evidence showing that adolescents with elevated impulsivity are more likely to engage in excessive digital behaviors, experience difficulty controlling online activity, and seek immediate reinforcement through internet-based platforms (Haddad et al., 2021; Kim et al., 2023). In this regard, the current findings support the view that internet addiction is closely connected to deficits in inhibitory control, reward sensitivity, and behavioral regulation. Adolescents high in impulsivity may be less able to interrupt prolonged online engagement, resist gaming or social media cues, or regulate digital routines according to academic, social, or sleep-related responsibilities.

The model's feature importance results further confirmed the central role of impulsivity, which accounted for the largest share of predictive contribution. This finding aligns with mixture modeling studies indicating that problematic internet use is often concentrated among adolescents with specific profiles of cognitive vulnerability, dissociation, behavioral activation, and self-regulatory difficulty (Çelik et al., 2024; Eşkısu et al., 2023). The importance of impulsivity may also explain why internet addiction frequently overlaps with other behavioral addictions, including gaming-related problems, excessive social media use, gambling tendencies, and other reward-driven behaviors. Recent systematic evidence has shown that problematic internet use, problematic gaming, and other addictive behaviors may share common transdiagnostic mechanisms, including impaired control, affective dysregulation, and sensitivity to immediate reinforcement (Ghali et al., 2023; Losaberidze et al., 2025). Therefore, the current model's reliance on

impulsivity as the strongest classifier is theoretically meaningful and clinically relevant, as impulsivity may represent a common pathway through which adolescents become vulnerable to multiple forms of technology-related behavioral addiction.

Loneliness also emerged as a substantial predictor of high-risk internet addiction. This finding is consistent with a systematic review and meta-analysis showing a significant relationship between loneliness and internet or smartphone addiction among adolescents (Ge et al., 2023). Adolescents who experience social disconnection may use the internet to compensate for unmet interpersonal needs, reduce feelings of exclusion, or seek social validation through online platforms. However, excessive reliance on online interaction may intensify loneliness over time when digital engagement replaces face-to-face communication, limits family interaction, or exposes adolescents to negative social comparison. The present findings also align with evidence suggesting that loneliness trajectories and adverse social experiences are associated with later problematic internet use (Lin & Chiao, 2022). From a psychological perspective, loneliness may function both as a precipitating factor and a maintaining factor. Adolescents may initially turn to digital environments to escape isolation, but repeated online engagement may reinforce avoidance of offline relationships, thereby strengthening the cycle of loneliness and problematic use.

The role of loneliness in the KNN model is also consistent with theoretical accounts that conceptualize problematic internet use as a maladaptive attempt to manage unmet relational and emotional needs. Mentalization-based and psychosocial models suggest that problematic digital behavior may emerge when adolescents experience difficulty interpreting interpersonal experiences, regulating emotional distress, or establishing secure social connections (Chatterjee & Rai, 2023). Qualitative studies also show that adolescents often describe problematic internet use in relation to boredom, emotional escape, peer pressure, identity exploration, and difficulty managing offline social realities (Özparlak et al., 2023; Rollo et al., 2023). Therefore, the predictive contribution of loneliness in the present study suggests that high-risk internet addiction profiles should not be understood merely as excessive screen exposure, but as behavioral expressions of broader emotional and relational vulnerabilities.

Poor sleep quality was another meaningful predictor of high-risk classification. The positive association between PSQI scores and internet addiction indicates that adolescents with poorer sleep quality were more likely to belong to the high-risk group. This finding supports previous research identifying insomnia, sleep deprivation, and disrupted sleep patterns as important correlates of problematic internet and smartphone use among adolescents (Çelik et al., 2024; Kabadayı, 2024). There are several possible explanations for this relationship. Excessive evening or nighttime internet use may delay bedtime, increase cognitive and emotional arousal, and expose adolescents to stimulating content that interferes with sleep onset. Conversely, adolescents with sleep difficulties may use the internet during periods of wakefulness, thereby increasing exposure to reinforcing digital activities. Poor sleep may also weaken executive functioning, emotional regulation, and decision-making, which in turn can reduce adolescents' capacity to control internet use. Thus, sleep quality may contribute to internet addiction both directly and indirectly through its effects on self-regulation and emotional vulnerability.

The negative association between parental monitoring and internet addiction, as well as its high feature importance in the classification model, indicates that family context plays a protective role in adolescent digital behavior. Adolescents who reported higher parental monitoring were less likely to be classified as high-risk users. This finding is consistent with family-focused research showing that parental involvement, supervision, communication, and family functioning are associated with lower problematic internet use among children and adolescents (Li et al., 2021; Nannatt et al., 2022). The finding also aligns with research showing that parent–adolescent relationship quality may influence problematic internet use through mechanisms such as fear of missing out, emotional insecurity, and reduced behavioral boundaries (Koca & Saatçı, 2022). In the context of adolescent development, parental monitoring may reduce risk by establishing clear expectations about internet use, encouraging balanced routines, supporting sleep hygiene, and increasing awareness of adolescents' peer and online activities.

The current findings are especially important because parental monitoring was not merely correlated with internet addiction but contributed meaningfully to classification performance. This suggests that protective family factors should be integrated into predictive models rather than treated only as background variables. Adolescents with high impulsivity, loneliness, and poor sleep may be especially vulnerable when parental monitoring is low, because reduced supervision may allow problematic patterns to intensify without timely correction. Conversely, consistent

parental involvement may buffer the effects of psychological vulnerabilities by creating external structure and opportunities for early intervention. These findings are compatible with broader evidence showing that adolescent problematic internet use is shaped by both individual-level and contextual factors (Chen et al., 2021; Tóth-Király et al., 2021).

The strong classification performance of the KNN model also supports the use of person-centered and machine learning approaches in adolescent behavioral health research. Previous latent profile and latent class studies have shown that adolescents can be grouped into distinct digital behavior profiles, with different combinations of psychosocial risks and later outcomes (Moreno et al., 2022; Wang et al., 2025). Similarly, network analysis has demonstrated that symptoms of problematic internet use may be structured differently across gender and risk subgroups, suggesting that variable-centered approaches may overlook important patterns of heterogeneity (Liu et al., 2023). The present study extends this literature by showing that a supervised classification model can use theoretically relevant predictors to identify high-risk adolescents with high accuracy. The optimized model, using k = 11 and Euclidean distance, produced stable performance across cross-validation and testing procedures, indicating that high-risk internet addiction profiles can be detected through similarity-based classification using a relatively concise set of predictors.

The confusion matrix further supports the practical value of the model. Among low-risk adolescents, the majority were correctly classified, and among high-risk adolescents, most were accurately detected. The false negative rate was relatively low, which is especially important in school-based or preventive screening contexts, where failing to identify adolescents at risk may delay intervention. This finding is meaningful in light of evidence linking problematic internet use with serious psychological outcomes, including depression, anxiety, aggression, social anxiety, suicidal behavior, and non-suicidal self-injury (Haddad et al., 2021; He et al., 2024; Losaberidze et al., 2025). Studies on social media exposure, electronic games, and digital engagement further show that excessive digital behavior may be associated with emotional distress, psychiatric symptoms, and impaired psychosocial functioning in youth (Bottaro & Faraci, 2022; Garcia et al., 2024; Marano et al., 2025). Therefore, a model that accurately identifies high-risk adolescents may have important implications for early detection, school counseling, and family-based prevention.

The findings also contribute to the broader literature on digital technology use among adolescents by emphasizing that risk classification should consider quality and context of use rather than internet use time alone. Although greater internet usage time has been associated with poorer mental health outcomes in adolescents, time-based indicators alone may not adequately distinguish normative digital engagement from addiction-like patterns (Kwak et al., 2022). The present study shows that psychological vulnerabilities and family-related conditions can improve classification of high-risk profiles beyond simple exposure measures. This interpretation is consistent with research showing that adolescents' digital media use patterns are heterogeneous and that different subgroups may vary in psychological risk, family context, and functional impairment (Moreno et al., 2022; Petrović et al., 2022). In this sense, problematic internet use should be understood as a multidimensional risk condition involving impulsive control, emotional needs, sleep disruption, and parental regulation rather than simply as high-frequency internet access.

5. Conclusion

Overall, the results support the conclusion that high-risk internet addiction among adolescents can be accurately classified using a KNN model based on impulsivity, loneliness, sleep quality, and parental monitoring. The findings align with previous research showing that problematic internet use is associated with psychological distress, family functioning, sleep-related difficulties, and broader behavioral addiction risks (Agrawal et al., 2024; He et al., 2024; Kuss et al., 2021). The model's high AUC, balanced precision and recall, and meaningful predictor structure indicate that machine learning classification can offer a useful methodological pathway for identifying adolescents who may benefit from preventive support. At the theoretical level, the findings reinforce a biopsychosocial interpretation of internet addiction in which self-regulatory vulnerabilities, emotional isolation, sleep disruption, and family supervision jointly shape risk. At the applied level, the results suggest that adolescent internet addiction screening should move beyond single-variable assessment and incorporate multidimensional risk profiles that reflect the complexity of adolescent digital behavior.

JAYPS
Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

6. Limitations & Suggestions

The present study has several limitations that should be acknowledged. First, the cross-sectional design prevents causal interpretation of the relationships among impulsivity, loneliness, sleep quality, parental monitoring, and internet addiction risk. Although the model demonstrated strong predictive performance, it cannot determine whether these variables cause internet addiction or whether problematic internet use contributes to increased impulsivity, loneliness, sleep problems, or reduced parental involvement. Second, the study relied on self-report instruments, which may be influenced by response bias, social desirability, or inaccurate recall, particularly regarding internet use and sleep behavior. Third, although the sample included adolescents from multiple Canadian provinces, the findings may not fully generalize to all cultural, linguistic, rural, Indigenous, immigrant, or socioeconomically diverse adolescent populations in Canada. Fourth, the KNN model was developed using selected psychological and family-related predictors, but other relevant factors such as peer influence, academic stress, personality traits, psychiatric symptoms, type of online activity, and objective digital usage data were not included.

Future research should use longitudinal designs to examine how impulsivity, loneliness, sleep quality, and parental monitoring interact over time to influence the onset, persistence, or remission of internet addiction symptoms. Future studies should also validate the current KNN model in independent adolescent samples and compare its performance with other machine learning algorithms such as random forest, support vector machine, logistic regression, gradient boosting, and neural networks. Including objective behavioral data from smartphones, app usage logs, wearable sleep trackers, or parental monitoring applications may improve predictive accuracy and reduce reliance on self-report measurement. Future research should also examine whether classification performance differs by gender, age group, province, socioeconomic status, immigration background, family structure, or type of internet activity. In addition, future models may benefit from including mental health variables, academic functioning, peer relationship quality, emotion regulation, fear of missing out, and online gaming or social media patterns to develop more comprehensive risk profiles.

The findings of this study have practical implications for schools, parents, counselors, and adolescent mental health professionals. School-based screening programs may use multidimensional assessment frameworks that include impulsivity, loneliness, sleep quality, and parental monitoring to identify adolescents who are vulnerable to problematic internet use. Interventions should not focus only on reducing screen time, but should also strengthen self-control, emotional regulation, offline social connection, sleep hygiene, and family communication. Parents may benefit from guidance on supportive monitoring practices that combine clear rules, open communication, emotional warmth, and consistent supervision of online activities. Counselors and psychologists working with adolescents should assess whether excessive internet use is functioning as a coping strategy for loneliness, distress, poor sleep, or impulsive reward seeking. Preventive programs should therefore integrate digital literacy, behavioral self-regulation, social skills training, family involvement, and sleep education to reduce the risk of internet addiction and promote healthier patterns of adolescent technology use.

Acknowledgments

We would like to express our appreciation and gratitude to all those who cooperated in carrying out this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

Authors' Contributions

All authors equally contributed to this article.

JAYPS Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

References

Agrawal, M., Rajaram, S., & Kumar, G. R. (2024). Internet Addiction and Psychological Health in Adolescent Indian Medical Students: A Cross-Sectional Study. *Basic and Clinical Neuroscience Journal*, *15*(4), 477-488. https://doi.org/10.32598/bcn.2021.3295.2

Bottaro, R., & Faraci, P. (2022). The Use of Social Networking Sites and Its Impact on Adolescents' Emotional Well-Being: A Scoping Review. *Current Addiction Reports*, *9*(4), 518-539. https://doi.org/10.1007/s40429-022-00445-4

Çelik, O., YalÇIn, R. Ü., & Eşkısu, M. (2024). A Mixture Modeling of the Behavioral Activation System and Problematic Internet Use in Adolescents: The Role of Metacognition, Online Dissociation, and Insomnia. *Scandinavian journal of psychology*, *66*(3), 355-369. https://doi.org/10.1111/sjop.13091

Chatterjee, D., & Rai, R. (2023). Behind the Screens: Proposing a Mentalization-Based Theoretical Model of Problematic Internet Use. *Cyberpsychology Journal of Psychosocial Research on Cyberspace*, *17*(5). https://doi.org/10.5817/cp2023-5-6

Chen, C., Yang, C., & Nie, Q. (2021). Social-Emotional Learning Competencies and Problematic Internet Use Among Chinese Adolescents: A Structural Equation Modeling Analysis. *International journal of environmental research and public health*, *18*(6), 3091. https://doi.org/10.3390/ijerph18063091

Eşkısu, M., Boysan, M., & Çam, Z. (2023). A Mixture Modeling of the Predictors of Internet Addiction: Cognition and Dissociation. *Psychological Reports*, *127*(5), 2262-2286. https://doi.org/10.1177/00332941221149180

Garcia, B. T., Oliveira, D. L. D., Merlotto, A. C., Domingos, F. C., Cavicchioli, S. d. A., Fernandes, A. C. P., & Siqueira, A. C. (2024). The Impact of the Abuse of Electronic Games in Children and Adolescents: Scoping Review. *Brazilian Journal of Health Review*, *7*(1), 111-133. https://doi.org/10.34119/bjhrv7n1-010

Ge, M. W., Hu, F. H., Jia, Y. J., Tang, W., Zhang, W. Q., Zhao, D. Y., Shen, W. Q., & Chen, H. L. (2023). The Relationship Between Loneliness and Internet or Smartphone Addiction Among Adolescents: A Systematic Review and Meta-Analysis. *Psychological Reports*, *128*(3), 1429-1451. https://doi.org/10.1177/00332941231180119

Ghali, S., Afifi, S., Suryadevara, V., Habab, Y., Hutcheson, A., Panjiyar, B. K., Davydov, G. G., Nashat, H., & Nath, T. S. (2023). A Systematic Review of the Association of Internet Gaming Disorder and Excessive Social Media Use With Psychiatric Comorbidities in Children and Adolescents: Is It a Curse or a Blessing? *Cureus*. https://doi.org/10.7759/cureus.43835

Haddad, C., Malaeb, D., Sacre, H., Khalil, J. B., Khansa, W., Hajj, R. A., Kheir, N., Saade, S., Obeïd, S., & Hallit, S. (2021). Association of Problematic Internet Use With Depression, Impulsivity, Anger, Aggression, and Social Anxiety: Results of a National Study Among Lebanese Adolescents. *Pediatric Investigation*, *5*(4), 255-264. https://doi.org/10.1002/ped4.12299

He, X., Chen, S., Yu, Q., Yang, P., & Yang, B. (2024). Correlations Between Problematic Internet Use and Suicidal Behavior Among Chinese Adolescents: A Systematic Review and Meta-Analysis. *Frontiers in Psychiatry*, *15*. https://doi.org/10.3389/fpsyt.2024.1484809

Kabadayı, F. (2024). Smartphone Addiction, Depression, Distress, Eustress, Loneliness, and Sleep Deprivation in Adolescents: A Latent Profile and Network Analysis Approach. *BMC psychology*, *12*(1). https://doi.org/10.1186/s40359-024-02117-6

Kim, E. L., Gentile, D. A., Choo, H., Liau, A. K., Li, D., & Khoo, A. (2023). Differential Predictors of Problematic Internet Use and Problematic Video Gaming Among School Children: A 2-Year Longitudinal Study. *Technology Mind and Behavior*, *4*(2), 195-207. https://doi.org/10.1037/tmb0000109

Koca, F., & Saatçı, F. (2022). The Mediator Role of Fear of Missing Out in the Parent-Adolescent Relationship Quality and Problematic Internet Use. *International journal of mental health and addiction*, *20*(3), 1897-1912. https://doi.org/10.1007/s11469-022-00822-0

Kuss, D. J., Kristensen, A. M., & López-Fernández, O. (2021). Internet Addictions Outside of Europe: A Systematic Literature Review. *Computers in human Behavior*, *115*, 106621. https://doi.org/10.1016/j.chb.2020.106621

Kwak, Y., Kim, H., & Ahn, J. W. (2022). Impact of Internet Usage Time on Mental Health in Adolescents: Using the 14th Korea Youth Risk Behavior Web-Based Survey 2018. *PLoS One*, *17*(3), e0264948. https://doi.org/10.1371/journal.pone.0264948

Li, X.-K., Zhan, P.-S., Chen, S.-D., & Ren, J. (2021). The Relationship Between Family Functioning and Pathological Internet Use Among Chinese Adolescents: The Mediating Role of Hope and the Moderating Role of Social Withdrawal. *International journal of environmental research and public health*, *18*(14), 7700. https://doi.org/10.3390/ijerph18147700

Lin, W. H., & Chiao, C. (2022). Relationship Between Adverse Childhood Experiences and Problematic Internet Use Among Young Adults: The Role of the Feeling of Loneliness Trajectory. *Journal of Behavioral Addictions*, *11*(4), 1080-1091. https://doi.org/10.1556/2006.2022.00074

Liu, S., Zhang, D., Tian, Y., Xu, B., & Wu, X. (2023). Gender Differences in Symptom Structure of Adolescent Problematic Internet Use: A Network Analysis. *Child and adolescent psychiatry and mental health*, *17*(1). https://doi.org/10.1186/s13034-023-00590-2

Losaberidze, M., Mallorquí-Bagué, N., Demetrovics, Z., Jiménez-Múrcia, S., Potenza, M. N., Soborun, Y., Romero, P., Reinhardt, M., Kökönyei, G., Mestre-Bach, G., & Czakó, A. (2025). Scars, Screens, and Stakes: Link Between Non-Suicidal Self-Injury and Problem Gambling, Problem Gaming, and Problematic Internet Use – A Systematic Review. *Journal of Behavioral Addictions*, *14*(4), 1481-1502. https://doi.org/10.1556/2006.2025.00079

Marano, G., Lisci, F. M., Rossi, S., Marzo, E. M., Boggio, G., Brisi, C., Traversi, G., Mazza, O., Pola, R., Gaetani, E., & Mazza, M. (2025). Connected but at Risk: Social Media Exposure and Psychiatric and Psychological Outcomes in Youth. *Children*, *12*(10), 1322. https://doi.org/10.3390/children12101322

Moreno, M. A., Binger, K., Zhao, Q., Eickhoff, J. C., Minich, M., & Uhls, Y. T. (2022). Digital Technology and Media Use by Adolescents: Latent Class Analysis. *Jmir Pediatrics and Parenting*, *5*(2), e35540. https://doi.org/10.2196/35540

Nannatt, A., Tariang, N. M., Gowda, M., & Devassy, S. M. (2022). Family Factors Associated With Problematic Use of the Internet in Children: A Scoping Review. *Indian Journal of Psychological Medicine*, *44*(4), 341-348. https://doi.org/10.1177/02537176221090862

Özparlak, A., Karakaya, D., Önder, A., & Günbayı, İ. (2023). Problematic Internet Use in Adolescents: A Phenomenological Study. *Journal of Psychiatric and Mental Health Nursing*, *30*(4), 731-742. https://doi.org/10.1111/jpm.12900

Petrović, Z. K., Peraica, T., Kozarić-Kovačić, D., & Palavra, I. R. (2022). Internet Use and Internet-Based Addictive Behaviours

During Coronavirus Pandemic. *Current Opinion in Psychiatry*, *35*(5), 324-331. https://doi.org/10.1097/yco.0000000000000804

Pontes, H. M., & Macur, M. (2021). Problematic Internet Use Profiles and Psychosocial Risk Among Adolescents. *PLoS One*, *16*(9), e0257329. https://doi.org/10.1371/journal.pone.0257329

Rollo, S., Venuleo, C., Ferrante, L., & Picione, R. D. L. (2023). What Adolescents Have to Say About Problematic Internet Use: A Qualitative Study Based on Focus Groups. *International journal of environmental research and public health*, *20*(21), 7013. https://doi.org/10.3390/ijerph20217013

Tóth-Király, I., Morin, A. J. S., Hietajärvi, L., & Salmela-Aro, K. (2021). Longitudinal Trajectories, Social and Individual Antecedents, and Outcomes of Problematic Internet Use Among Late Adolescents. *Child development*, *92*(4), e653-e673. https://doi.org/10.1111/cdev.13525

Wang, Y., Hall, B. J., Chen, Y., & Chen, C. (2025). Latent Profiles of Problematic Internet Use and Their Six-Month Subsequent Psychopathology Outcomes. *Addictive Behaviors Reports*, *21*, 100607. https://doi.org/10.1016/j.abrep.2025.100607

Zeyrek, İ. (2026). Behavioural Addiction and Associated Risk Factors Among High School Students. *Acta Neuropsychiatrica*, *38*. https://doi.org/10.1017/neu.2026.10054

JAYPS
Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526