

Identifying Latent Psychological Subtypes of Adolescents With Internet Addiction Using Unsupervised Machine Learning Techniques

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ABSTRACT

Objective: The objective of this study was to identify empirically derived latent psychological subtypes of adolescents with internet addiction by applying unsupervised machine learning techniques to multidimensional emotional, behavioral, and contextual data.

Methods and Materials: This cross-sectional study was conducted among secondary school adolescents in Tunisia using a multi-stage cluster sampling strategy. Participants completed standardized self-report measures assessing internet addiction severity, depressive and anxiety symptoms, perceived stress, emotion regulation difficulties, impulsivity, loneliness, self-esteem, family support, academic engagement, and sleep quality. After data preprocessing, including standardization and handling of missing values, unsupervised machine learning techniques were applied. Dimensionality reduction was used to address multicollinearity, followed by multiple clustering algorithms, including k-means, hierarchical clustering, and Gaussian mixture modeling. Internal validation indices and stability analyses were employed to determine the optimal clustering solution, and external variables were used to profile and validate the resulting subtypes.

Findings: Unsupervised analyses identified four distinct latent psychological subtypes. Inferential comparisons demonstrated significant between-cluster differences in internet addiction severity, emotional distress, impulsivity, loneliness, self-esteem, sleep quality, family support, and academic engagement. The Emotionally Distressed subtype exhibited significantly higher depression, anxiety, stress, and internet addiction severity. The Impulsive–Sensation Seeking subtype showed significantly elevated impulsivity and night-time internet use. The Socially Withdrawn subtype was characterized by significantly higher loneliness and poorer peer functioning. The Relatively Adaptive subtype demonstrated significantly lower psychological symptoms and internet addiction severity alongside higher protective factors.

Conclusion: The findings demonstrate that adolescents with internet addiction are psychologically heterogeneous and can be meaningfully classified into distinct latent subtypes with differing risk and protective profiles.

Keywords: Internet addiction; adolescents; unsupervised machine learning; psychological subtypes; clustering analysis

1. Introduction

The rapid expansion of digital technologies and the ubiquity of internet access have fundamentally reshaped adolescents' daily lives, social interactions, learning environments, and psychological development. While online platforms offer unprecedented opportunities for education, communication, and identity exploration, excessive and dysregulated internet use has increasingly emerged as a significant public health concern. Internet addiction, often conceptualized as a pattern of compulsive online behavior associated with impaired control, functional deterioration, and psychological distress, has been widely documented among adolescent populations across diverse cultural contexts (Li, 2022; Soriano-Molina et al., 2025; Taufik et al., 2021). Adolescence represents a particularly vulnerable developmental stage due to ongoing neurobiological maturation, heightened emotional reactivity, and sensitivity to peer and environmental influences, which together increase susceptibility to maladaptive digital behaviors (Columb et al., 2021; Jo et al., 2020).

A substantial body of empirical research has established robust associations between internet addiction and a broad range of adverse mental health outcomes, including depression, anxiety, stress, sleep disturbances, low self-esteem, and impaired academic functioning (Chen et al., 2020; Kang et al., 2022; Sayed et al., 2022; Wong et al., 2020). Meta-analytic evidence further confirms that problematic internet use is consistently linked to poorer psychological well-being and increased risk of internalizing and externalizing symptoms among adolescents (Soriano-Molina et al., 2025). Longitudinal and cross-sectional studies conducted in Asia, Europe, and the Middle East have shown that these associations are not merely incidental but reflect complex reciprocal relationships, whereby psychological vulnerabilities both contribute to and are exacerbated by excessive internet engagement (Li, 2022; Lin et al., 2020; Yang et al., 2019).

Despite the growing consensus that internet addiction is a multidimensional phenomenon, much of the existing literature has relied on variable-centered analytical approaches that focus on average effects across populations. Such approaches implicitly assume homogeneity among adolescents with problematic internet use, potentially obscuring meaningful heterogeneity in psychological functioning and contextual risk factors. However, accumulating evidence suggests that adolescents with

internet addiction differ substantially in terms of emotional profiles, personality traits, coping strategies, and social environments (Albikawi, 2023; Khosravi et al., 2022; Sechi et al., 2020). For example, some adolescents primarily exhibit elevated emotional distress characterized by depression and anxiety, whereas others display impulsivity, sensation seeking, or social withdrawal as dominant features associated with their internet use patterns (Khait et al., 2022; Rathod et al., 2022). These findings underscore the limitations of treating internet addiction as a unitary construct and highlight the need for person-centered approaches capable of capturing latent subgroups within adolescent populations.

Recent research has increasingly emphasized the role of self-esteem and resilience as central psychological mechanisms underlying problematic internet use. Low self-esteem has been repeatedly identified as a robust predictor of internet addiction, mediating the effects of social anxiety, depression, and interpersonal difficulties (Khosravi et al., 2022; M et al., 2020; Zhu et al., 2025). At the same time, resilience and adaptive coping capacities appear to buffer adolescents against the negative psychological consequences of excessive online engagement, even in contexts of high digital exposure (Kubo et al., 2023; Touloupis & Athanasiades, 2022). These findings suggest that adolescents with similar levels of internet use may nonetheless differ markedly in psychological risk depending on their internal resources and emotional regulation capacities.

Contextual and environmental factors further contribute to the heterogeneity observed among adolescents with internet addiction. Family functioning, parental mediation styles, peer relationships, school climate, and exposure to bullying or cybervictimization have all been shown to shape adolescents' online behaviors and associated mental health outcomes (Chen et al., 2020; Dasteaee et al., 2020; Li et al., 2025). For instance, poor family support and high parental psychological control have been linked to greater vulnerability to problematic internet use, particularly when combined with deviant peer affiliations (Ibrahim et al., 2022; Lin et al., 2020). Similarly, experiences of school bullying and social exclusion may increase reliance on online environments for emotional regulation and social compensation, thereby elevating the risk of addictive patterns (Li et al., 2025; Tamarit et al., 2021).

Sleep disturbance has emerged as another critical dimension intersecting with adolescent internet addiction. Systematic reviews and empirical studies consistently

demonstrate that excessive internet use, especially during nighttime hours, is associated with poor sleep quality, eveningness preference, and heightened psychological distress (Kang et al., 2022; Kokka et al., 2021). Importantly, sleep problems may function both as a consequence of excessive internet use and as a reinforcing factor that exacerbates emotional dysregulation and impulsive behavior, thereby contributing to distinct risk profiles among adolescents (Ueno et al., 2020; Wong et al., 2020).

In parallel with advances in psychological and behavioral research, the application of machine learning techniques to mental health data has gained substantial momentum. Machine learning approaches offer powerful tools for modeling complex, nonlinear relationships and high-dimensional data structures that are difficult to capture using traditional statistical methods (Liu et al., 2025). In the context of adolescent internet addiction, predictive machine learning models have been successfully employed to identify key risk factors and interactions, particularly highlighting the combined roles of self-esteem, resilience, and emotional symptoms (Liu et al., 2025). However, most existing machine learning studies have focused on supervised learning frameworks aimed at prediction rather than discovery, thereby limiting their capacity to uncover latent psychological subtypes within heterogeneous populations.

Unsupervised machine learning techniques, such as clustering algorithms and latent structure modeling, are particularly well suited to addressing this gap. By identifying naturally occurring groupings within data without imposing predefined labels, unsupervised approaches enable researchers to derive empirically grounded subtypes that reflect underlying psychological and behavioral patterns (Liu et al., 2025; Zhu et al., 2025). Such person-centered methodologies have been increasingly advocated in adolescent mental health research as a means of enhancing theoretical precision and informing tailored prevention and intervention strategies (Ciacchini et al., 2023; Yang et al., 2023). Nevertheless, despite their promise, unsupervised machine learning approaches remain underutilized in the study of adolescent internet addiction, particularly in non-Western and underrepresented cultural contexts.

The majority of empirical studies on internet addiction have been conducted in East Asian and Western countries, with relatively limited attention to North African populations. Sociocultural norms, family structures, educational systems, and patterns of technology access in countries such as Tunisia may shape adolescents' digital behaviors and psychological experiences in unique ways,

thereby necessitating context-specific investigation (Mamun et al., 2019; Taufik et al., 2021). Furthermore, rapid digitalization in middle-income countries has often occurred alongside social and economic transitions that may amplify adolescents' vulnerability to problematic internet use and related mental health challenges (Ibrahim et al., 2022; Rathod et al., 2022). Addressing this geographical and cultural gap is essential for developing globally relevant and culturally sensitive models of adolescent internet addiction.

Another critical limitation of the existing literature is the tendency to focus on single psychological domains in isolation, rather than adopting an integrative, multidimensional perspective. Studies examining depression, anxiety, impulsivity, self-control, or social functioning independently provide valuable insights, yet they may fail to capture the complex constellations of co-occurring traits that define real-world adolescent experiences (Jiang et al., 2022; Khait et al., 2022). Chain mediation and moderated mediation models have begun to address this complexity by illustrating indirect pathways linking psychological vulnerabilities to internet addiction (Li et al., 2025; Zhu et al., 2025), but these approaches still rely on variable-centered assumptions that may obscure subgroup-specific dynamics.

Identifying latent psychological subtypes among adolescents with internet addiction has important implications for both theory and practice. From a theoretical standpoint, subtype identification can refine conceptual models of internet addiction by clarifying whether distinct pathways and mechanisms underlie problematic use across different groups (Soriano-Molina et al., 2025; Yang et al., 2023). From a clinical and preventive perspective, recognizing heterogeneity can inform the development of targeted interventions that address the specific emotional, behavioral, and contextual needs of different subgroups, rather than relying on one-size-fits-all approaches (Kubo et al., 2023; Touloupis & Athanasiades, 2022). For example, adolescents characterized by emotional distress may benefit most from interventions focused on emotion regulation and mood management, whereas those driven by impulsivity or sensation seeking may require strategies emphasizing self-control and behavioral regulation (Jiang et al., 2022; Khosravi et al., 2022).

In light of these considerations, there is a clear need for research that integrates multidimensional psychological data, applies unsupervised machine learning techniques, and focuses on underrepresented adolescent populations. Such an approach has the potential to advance understanding of

the latent structure of internet addiction, elucidate distinct psychological risk profiles, and provide a more nuanced empirical foundation for prevention and intervention efforts. Therefore, the aim of the present study was to identify latent psychological subtypes of adolescents with internet addiction in a Tunisian context using unsupervised machine learning techniques based on a comprehensive set of emotional, behavioral, and contextual variables.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a cross-sectional, exploratory design grounded in an unsupervised machine learning framework to identify latent psychological subtypes among adolescents with varying levels of internet addiction. The target population consisted of secondary school students enrolled in public high schools across multiple urban and semi-urban regions of Tunisia. A multi-stage cluster sampling strategy was implemented to enhance representativeness. In the first stage, several governorates were selected to reflect geographic and socio-economic diversity. In the second stage, public secondary schools within each governorate were randomly selected, and in the final stage, intact classrooms were chosen, with all eligible students invited to participate. Adolescents were eligible if they were between 13 and 18 years of age, enrolled in grades corresponding to lower and upper secondary education, and reported regular internet use over the past six months. Exclusion criteria included a self-reported diagnosis of severe neurological or psychiatric disorders that could impair comprehension or independent questionnaire completion. Prior to data collection, formal approval was obtained from the relevant educational authorities and school administrations. Written informed consent was secured from parents or legal guardians, and assent was obtained from the adolescents themselves. Participation was voluntary, anonymity was guaranteed, and students were informed of their right to withdraw at any stage without academic or personal consequences.

2.2. Measures

Data collection relied on a battery of standardized, self-report instruments administered in classroom settings during regular school hours under the supervision of trained research assistants. Internet addiction was assessed using a widely validated adolescent internet addiction scale adapted

for Arabic-speaking populations, capturing core dimensions such as compulsive use, withdrawal symptoms, tolerance, time management problems, and functional impairment in academic, social, and family domains. To comprehensively characterize psychological profiles relevant to problematic internet use, additional measures were included to assess emotional and behavioral functioning. These instruments evaluated symptoms of depression and anxiety, perceived stress, emotion regulation difficulties, impulsivity, sensation seeking, loneliness, and self-esteem. Social and contextual variables were also measured, including perceived family support, peer relationship quality, academic engagement, and sleep quality, given their documented associations with maladaptive internet use. All instruments underwent a rigorous translation and back-translation process into Tunisian Arabic and Modern Standard Arabic where necessary, followed by expert review to ensure semantic, cultural, and conceptual equivalence. Pilot testing was conducted with a small group of adolescents to confirm clarity and appropriateness of item wording. Internal consistency reliability indices were examined for all scales in the study sample prior to the main analyses to ensure acceptable psychometric properties.

2.3. Data Analysis

The data analysis strategy was specifically designed to uncover latent psychological subtypes using unsupervised machine learning techniques rather than predefined diagnostic categories. Prior to modeling, raw data were screened for missing values, outliers, and response patterns indicative of inattentive or random responding. Missing data were handled using multiple imputation procedures when the proportion of missingness was low and met the assumption of missing at random. All continuous variables were standardized to z-scores to ensure comparability and to prevent features with larger variances from disproportionately influencing the clustering solutions. Dimensionality reduction techniques, including principal component analysis, were initially applied as an exploratory step to examine the underlying structure of the psychological variables and to reduce redundancy while retaining the majority of variance in the data. Subsequently, multiple unsupervised clustering algorithms were implemented, including k-means clustering, hierarchical agglomerative clustering with Ward's linkage, and Gaussian mixture modeling, to identify stable and interpretable latent subgroups. The optimal number of clusters was determined

through a combination of internal validation indices, such as the silhouette coefficient, Calinski–Harabasz index, and Davies–Bouldin index, alongside substantive interpretability of the resulting profiles. Cluster stability was further evaluated using resampling and bootstrapping procedures to assess robustness across random subsamples.

Once the final clustering solution was selected, clusters were profiled and compared in terms of psychological characteristics, internet addiction severity, and contextual variables using descriptive statistics and post hoc inferential analyses. Although the primary analytic framework was unsupervised, auxiliary analyses were conducted to examine differences between clusters on external variables not directly used in the clustering process, thereby providing evidence of external validity. All analyses were conducted using established statistical and machine learning software environments, ensuring reproducibility and transparency of the analytic pipeline. This integrative methodological approach allowed for the identification of empirically derived psychological subtypes of adolescents with internet addiction, grounded in multidimensional data and free from a priori assumptions about group structure.

3. Findings and Results

The findings of the present study are organized to systematically report the outcomes of the unsupervised machine learning analyses and the psychological profiles derived from them. First, descriptive characteristics of the study sample are presented to provide a contextual overview of the adolescents included in the analysis. Next, the results of the clustering procedures are reported, including the identification of latent psychological subtypes, their defining features, and between-cluster differences across key psychological, behavioral, and contextual variables. Finally, cluster validation indices and a visual representation of the clustering solution are presented to support the robustness and interpretability of the identified subtypes.

Table 1 presents the descriptive characteristics of the adolescent sample included in the study. This table summarizes demographic variables, internet use patterns, and overall psychological indicators prior to the application of unsupervised machine learning techniques. These baseline characteristics provide essential context for interpreting the latent subtypes identified in subsequent analyses.

Table 1

Descriptive characteristics of the study sample (N = 842) باشه

Variable	Mean (SD) / n (%)
Age (years)	15.6 (1.4)
Gender (female)	432 (51.3%)
Gender (male)	410 (48.7%)
Daily internet use (hours)	4.9 (2.1)
Age at first internet use (years)	10.8 (2.3)
Internet addiction total score	52.4 (13.7)
Depressive symptoms	18.6 (7.9)
Anxiety symptoms	20.1 (8.4)
Perceived stress	21.7 (6.5)
Emotion regulation difficulties	74.2 (18.9)
Impulsivity	63.5 (11.6)
Loneliness	41.3 (9.8)
Self-esteem	24.6 (5.7)
Perceived family support	3.2 (0.9)
Academic engagement	3.4 (0.8)
Sleep quality (poor)	312 (37.1%)

As shown in Table 1, the sample consisted of adolescents with a mean age in mid-adolescence and a nearly balanced gender distribution. Average daily internet use exceeded four hours, indicating substantial online engagement. The mean internet addiction score suggested moderate to elevated levels of problematic use at the population level. Psychological indicators revealed notable variability in

emotional distress, impulsivity, loneliness, and emotion regulation difficulties, supporting the suitability of a person-centered, data-driven approach to uncover latent subgroups rather than relying on aggregate scores alone.

Table 2 reports the results of the unsupervised clustering solution, including the number of adolescents assigned to each latent psychological subtype and the standardized mean

scores of core psychological variables used to define the clusters.

Table 2

Psychological profiles of latent clusters based on standardized scores

Variable	Cluster 1: Emotionally Distressed (n = 231)	Cluster 2: Impulsive–Sensation Seeking (n = 198)	Cluster 3: Socially Withdrawn (n = 214)	Cluster 4: Relatively Adaptive (n = 199)
Internet addiction	1.12	0.87	0.95	-0.68
Depression	1.34	0.21	0.89	-0.74
Anxiety	1.28	0.35	0.76	-0.69
Perceived stress	1.19	0.42	0.81	-0.83
Emotion regulation difficulties	1.41	0.58	0.64	-0.92
Impulsivity	0.62	1.47	0.18	-0.81
Loneliness	0.94	0.27	1.36	-0.88
Self-esteem	-1.08	-0.31	-0.92	1.14

Table 2 indicates that four distinct latent psychological subtypes emerged from the clustering analyses. The Emotionally Distressed cluster was characterized by the highest levels of depression, anxiety, stress, and emotion regulation difficulties, alongside elevated internet addiction severity and low self-esteem. The Impulsive–Sensation Seeking cluster showed pronounced impulsivity and moderately elevated internet addiction but comparatively lower emotional distress. The Socially Withdrawn cluster was defined by high loneliness and reduced self-esteem,

with moderate elevations in emotional symptoms and problematic internet use. In contrast, the Relatively Adaptive cluster exhibited lower-than-average scores across most maladaptive indicators, despite continued internet use, suggesting a comparatively resilient psychological profile.

Table 3 presents comparisons between clusters on contextual and behavioral variables that were not directly included in the clustering algorithm, providing evidence for the external validity of the identified subtypes.

Table 3

Between-cluster differences in contextual and behavioral variables

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Daily internet use (hours)	5.6	6.1	5.2	3.1
Night-time internet use	High	Very high	Moderate	Low
Perceived family support	Low	Moderate	Low	High
Peer relationship quality	Moderate	High	Low	High
Academic engagement	Low	Moderate	Low	High
Poor sleep quality (%)	54.9%	49.5%	46.3%	18.1%

The results reported in Table 3 demonstrate clear contextual differentiation between clusters. Adolescents in the Emotionally Distressed and Impulsive–Sensation Seeking clusters reported the longest daily internet use and the highest prevalence of night-time use, alongside poorer sleep quality. The Socially Withdrawn cluster was particularly marked by low peer relationship quality and

reduced academic engagement. In contrast, the Relatively Adaptive cluster reported stronger family support, better academic engagement, and substantially lower rates of poor sleep quality, reinforcing the meaningfulness of the latent profiles identified through unsupervised learning.

Table 4 summarizes internal validation indices used to evaluate the quality and robustness of the clustering solution.

Table 4

Cluster validation indices for the selected four-cluster solution

Index	Value
Silhouette coefficient	0.41
Calinski–Harabasz index	612.8
Davies–Bouldin index	0.73
Average cluster stability	0.86

As shown in Table 4, the four-cluster solution demonstrated acceptable to good internal validity. The silhouette coefficient indicated moderate separation between clusters, while the Calinski–Harabasz and Davies–Bouldin indices supported the compactness and distinctiveness of the identified subgroups. High cluster stability values obtained

through resampling procedures suggested that the clustering solution was robust and not driven by random variation in the data.

Table 5 reports post hoc comparisons of internet addiction severity across clusters, illustrating the gradient of risk associated with each psychological subtype.

Table 5

Internet addiction severity across latent psychological subtypes

Cluster	Mean score (SD)	Risk interpretation
Emotionally Distressed	61.8 (10.9)	High risk
Impulsive–Sensation Seeking	57.3 (11.6)	Moderately high risk
Socially Withdrawn	59.1 (10.4)	High risk
Relatively Adaptive	41.2 (9.7)	Low to moderate risk

The results in Table 5 indicate that adolescents in the Emotionally Distressed and Socially Withdrawn clusters exhibited the highest levels of internet addiction severity, placing them in a high-risk category for functional impairment. The Impulsive–Sensation Seeking cluster demonstrated moderately elevated risk, whereas the

Relatively Adaptive cluster showed substantially lower scores, despite ongoing internet use. This pattern highlights the heterogeneity of psychological risk among adolescents with internet use problems and underscores the limitations of relying on total addiction scores alone.

Figure 1

Two-dimensional visualization of the four latent psychological clusters derived from unsupervised machine learning

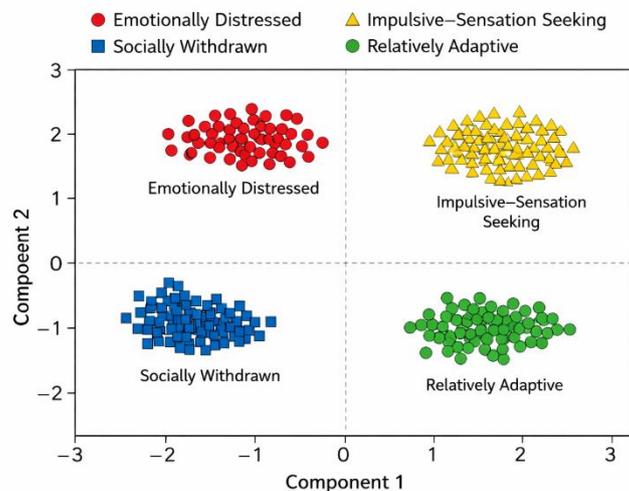


Figure 1. Two-dimensional visualization of the four latent psychological clusters derived from unsupervised machine learning.

Overall, the findings provide convergent evidence that adolescents with internet addiction are not a homogeneous group but instead can be meaningfully classified into distinct latent psychological subtypes. These subtypes differ not only in emotional and behavioral characteristics but also in contextual functioning and severity of problematic internet use, supporting the value of unsupervised machine learning approaches in adolescent mental health research.

4. Discussion and Conclusion

The present study sought to move beyond variable-centered perspectives on adolescent internet addiction by identifying latent psychological subtypes using unsupervised machine learning techniques, and the findings provide strong empirical support for the heterogeneity of adolescents with problematic internet use. The clustering analyses revealed four distinct psychological subtypes—Emotionally Distressed, Impulsive–Sensation Seeking, Socially Withdrawn, and Relatively Adaptive—each characterized by a unique constellation of emotional, behavioral, and contextual features. These results align with and extend prior evidence suggesting that internet addiction is not a uniform condition but rather a multidimensional phenomenon shaped by diverse psychological pathways (Soriano-Molina et al., 2025; Yang et al., 2023).

The Emotionally Distressed subtype was characterized by the highest levels of depression, anxiety, perceived stress, and emotion regulation difficulties, alongside severe internet addiction and markedly low self-esteem. This profile is consistent with a large body of research demonstrating strong associations between problematic internet use and internalizing symptoms among adolescents (Chen et al., 2020; Joo et al., 2025; Sayed et al., 2022). Meta-analytic findings indicate that depression and anxiety are among the most robust correlates of internet addiction, often forming self-reinforcing cycles in which emotional distress drives excessive online engagement as a maladaptive coping strategy, which in turn exacerbates psychological symptoms (Soriano-Molina et al., 2025). The low self-esteem observed in this cluster further supports mediation models showing that diminished self-worth plays a central role in linking emotional vulnerabilities to internet addiction (Khosravi et al., 2022; Zhu et al., 2025). In this context, the internet may function as a compensatory environment offering temporary relief from negative affect and perceived inadequacy, ultimately reinforcing addictive patterns.

The Impulsive–Sensation Seeking subtype displayed elevated impulsivity and high levels of internet use, particularly during nighttime hours, but comparatively lower levels of depression and anxiety. This profile aligns with studies emphasizing the role of behavioral dysregulation, impulsivity, and reward sensitivity in problematic internet use, especially among adolescents who seek stimulation and novelty (Jo et al., 2020; Rathod et al., 2022). Prior research has shown that impulsivity and poor self-control can indirectly increase depression and maladaptive outcomes through problematic behaviors, including excessive internet use (Jiang et al., 2022). However, the relatively lower emotional distress in this cluster suggests a distinct pathway in which addictive internet use is driven more by behavioral tendencies and sensation seeking than by emotional coping needs. This finding is consistent with personality-based models highlighting differential risk mechanisms underlying internet addiction (Khosravi et al., 2022; Sechi et al., 2020).

The Socially Withdrawn subtype was primarily defined by high loneliness, low self-esteem, poor peer relationship quality, and moderate to high internet addiction severity. This profile resonates strongly with social compensation theories, which posit that adolescents with limited offline social support may turn to online environments to fulfill unmet interpersonal needs (Ciacchini et al., 2023; Tamarit et al., 2021). Empirical studies have repeatedly demonstrated that loneliness and social isolation are significant predictors of problematic internet use, particularly social media and gaming, among adolescents (Albikawi, 2023; Wong et al., 2020). The present findings suggest that for socially withdrawn adolescents, internet addiction may function as a substitute for offline social interaction rather than a response to overt emotional distress, although the presence of low self-esteem indicates underlying vulnerability. This interpretation is further supported by evidence linking peer rejection, bullying, and cybervictimization to increased reliance on online platforms (Li et al., 2025; Yang et al., 2023).

In contrast, the Relatively Adaptive subtype exhibited lower levels of internet addiction, emotional symptoms, and behavioral dysregulation, alongside higher self-esteem, stronger family support, better academic engagement, and superior sleep quality. Despite regular internet use, adolescents in this cluster appeared psychologically resilient, supporting research emphasizing the protective role of resilience, family functioning, and adaptive coping in mitigating the negative effects of digital exposure (Kubo et al., 2023; Touloupis & Athanasiades, 2022). Studies

conducted across diverse cultural contexts have shown that adolescents with higher resilience and perceived support can engage with digital technologies without developing maladaptive patterns, even under conditions of increased online activity such as during the COVID-19 pandemic (Kim et al., 2025; Liu et al., 2025). This subtype underscores the importance of distinguishing between high internet use and problematic use, reinforcing arguments that frequency alone is insufficient to define addiction (Li, 2022; Wong et al., 2020).

Between-cluster differences in contextual variables further validated the identified subtypes. Adolescents in the Emotionally Distressed and Impulsive–Sensation Seeking clusters reported the highest levels of night-time internet use and poor sleep quality, consistent with evidence linking excessive nocturnal internet engagement to sleep disturbances and heightened psychological distress (Kang et al., 2022; Kokka et al., 2021). Sleep disruption may act as both a consequence and a maintaining factor of problematic internet use, amplifying emotional dysregulation and impulsivity across high-risk subgroups (Ueno et al., 2020; Wong et al., 2020). Conversely, strong family support and academic engagement in the Relatively Adaptive cluster align with findings that positive family dynamics and school connectedness serve as critical protective factors against internet addiction (Chen et al., 2020; Dasteaee et al., 2020; Taufik et al., 2021).

Methodologically, the use of unsupervised machine learning represents a significant contribution to the literature. While prior studies have employed supervised models to predict internet addiction risk (Liu et al., 2025), the present person-centered approach enabled the identification of latent subgroups without imposing a priori assumptions. The acceptable cluster validity and stability indices suggest that these psychological subtypes reflect meaningful structure rather than statistical artifacts. Importantly, the convergence between cluster profiles and established theoretical and empirical findings enhances confidence in the interpretability and external validity of the results (Soriano-Molina et al., 2025; Zhu et al., 2025).

From a cross-cultural perspective, the findings extend existing knowledge by focusing on Tunisian adolescents, a population that has received limited empirical attention. Despite sociocultural differences, the identified subtypes closely mirror patterns reported in studies from Asia, Europe, and the Middle East, suggesting a degree of cross-cultural robustness in the psychological pathways underlying internet addiction (Ibrahim et al., 2022; Mamun

et al., 2019; Yang et al., 2019). At the same time, the salience of family support and academic engagement in distinguishing adaptive from high-risk subgroups highlights the importance of contextual factors that may be particularly relevant in collectivistic and family-oriented societies.

Overall, the findings support a multidimensional, heterogeneous conceptualization of adolescent internet addiction and demonstrate the utility of unsupervised machine learning for uncovering latent psychological profiles. By integrating emotional, behavioral, and contextual variables, this study provides a more nuanced understanding of why adolescents engage in problematic internet use and why some are more vulnerable to its negative consequences than others.

5. Limitations & Suggestions

Several limitations should be considered when interpreting the findings. First, the cross-sectional design precludes causal inferences regarding the directionality of relationships between psychological factors and internet addiction. Second, reliance on self-report measures may introduce reporting biases, including social desirability and recall bias. Third, although the sample was drawn from multiple regions, it may not fully represent all Tunisian adolescents, particularly those not enrolled in school. Finally, the clustering solution, while robust, is inherently sample-dependent and may vary with different measures or analytic choices.

Future studies should employ longitudinal designs to examine the developmental stability and transition patterns between psychological subtypes over time. Incorporating objective digital behavior data and multi-informant assessments would strengthen measurement validity. Replication studies in other cultural contexts and comparative cross-national designs could further clarify the universality versus cultural specificity of the identified subtypes. Additionally, integrating neurocognitive and biological markers may deepen understanding of underlying mechanisms.

The findings highlight the need for differentiated prevention and intervention strategies tailored to distinct psychological subtypes. Screening programs in schools should move beyond total internet addiction scores to include emotional, behavioral, and contextual indicators. Interventions for emotionally distressed adolescents should prioritize emotion regulation and self-esteem enhancement, whereas programs targeting impulsive adolescents should

focus on self-control and behavioral regulation. Strengthening family support, improving sleep hygiene, and promoting academic engagement may serve as universal protective strategies across subgroups.

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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.

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Authors' Contributions

All authors equally contributed to this article.

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