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Delineating risk pathways and identifying distinct subgroups for internet gaming disorder: an integrated multi-level analysis

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL

The study was approved by the institutional ethics review committee of Xiangya Hospital, Central South University, for research purposes only (No. 202211690) approved by the Human Investigations Committee of Central South University by The Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from every participant before the investigation.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

W.Q.: Conceptualization, Formal analysis, Visualization, Writing – original draft.

X.Z.: Formal analysis, Methodology, Software, Writing – review & editing.

M.Z.: Investigation, Data curation, Project administration.

M.L.: Investigation, Resources, Validation.

A.G.: Methodology, Writing – review & editing.

K.Y.: Methodology, Supervision.

D.Y.: Resources, Writing – review & editing.

H.D.: Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

X.Y.: Resources, Investigation., Supervision, Writing – review & editing.

B.T.C.: Supervision, Writing – review & editing.

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ABSTRACT

Background and aims: Internet gaming disorder (IGD) is a growing global mental health concern, yet its heterogeneity and the interplay of risk factors remain unclear. This study aimed to delineate interrelationships among psychological risk factors, identify distinct IGD subgroups, and inform personalized intervention strategies.

Methods: This cross-sectional, multicenter study employed a cluster sampling approach to obtain a final sample of 13,512 Chinese adolescents and young adults. We assessed IGD severity and multiple risk/protective factors using standardized scales. Analyses included multivariable logistic regression, network analysis, latent profile analysis (LPA), and random forest modeling with SHAP explanation.

Results: The prevalence of high-risk IGD was 15.9%. Independent risk factors included male gender, depression, anxiety, cognitive failures, social interaction anxiety, and impulsivity, while psychological resilience was protective. Network analysis revealed the Distraction and Resilience facets (Tenacity and Strength) as the most central nodes, with Distraction, Interaction Anxiousness and Sensation Serving as key bridges connecting different symptom clusters. LPA identified four subgroups: "Emotional-Cognitive Dysfunction" (high symptoms, low childhood adversity), "Moderate-Risk with Prevalent Family Dysfunction," "Executive Dyscontrol" (high impulsivity deficits, low reward sensitivity), and "High-Adversity Compensatory" (high childhood adversity, low current psychopathology). Random forest modeling achieved 85.3% accuracy in

classifying subgroups, with family dysfunction as the most discriminative feature.

Conclusions: This study showed that IGD represented a heterogeneous condition with distinct risk pathways. Integrating network and person-centered analysis revealed two primary pathways to severe IGD—emotional-cognitive dysfunction and executive dyscontrol—and resolved paradoxical findings. This typology supported a precision-based approach to assessment and intervention.

Keywords: internet gaming disorder, latent profile analysis, risk factor, network analysis, adolescents

INTRODUCTION

Internet gaming disorder (IGD), recognized in the DSM-5 as a disorder due to addictive behaviors, represents a significant global mental health concern, particularly among adolescents and young adults who exhibit the highest vulnerability [1, 2]. Empirical research consistently demonstrates that IGD is associated with adverse psychosocial and cognitive outcomes, including impaired family relationships, reduced social competence, and diminished academic achievement [3, 4], as well as deficits in executive control and emotional regulation [1]. This risk is further exacerbated by high comorbidity with depression and anxiety [5, 6], consistent with neurobiological overlap in addictive disorders [7, 8]. Despite well-documented associations with various risk factors, understanding of IGD remains limited due to the absence of integrative approaches capable of capturing the dynamic interplay among these emotional, cognitive, and behavioral components. This gap highlights the critical need for multifactorial, system-level analyses to elucidate the heterogeneous pathways underlying IGD.

The etiology and progression of IGD are highly heterogeneous, arising from distinct configurations of interacting psychological [9, 10] and environmental factors (Zhuang et al., 2023), which underscores the need to identify subgroups with predominant risk components. Latent Profile Analysis (LPA) addresses this need by classifying individuals into subtypes based on their distinct profiles across multiple risk factors, providing a person-centered representation of clinical condition [13] and

identifying clinically meaningful subgroups that differ in their emotional, cognitive, and behavioral characteristics.

Building on this rationale, the present study integrates risk factor assessment, network analysis, and latent profile modeling within a unified framework. We hypothesized three core points: first, key psychological risk factors for IGD—depression, anxiety, suicidality, cognitive failures, social interaction anxiety, impulsivity, and the behavioral activation system—form a highly interconnected network, with certain variables acting as central and bridging nodes to link affective, cognitive, and motivational domains; second, IGD is a heterogeneous syndrome, and latent profile analysis (LPA) will identify clinically meaningful subgroups (e.g., emotional–cognitive dysfunction, executive dyscontrol) reflecting divergent etiological pathways; third, these subgroups are empirically distinguishable via random-forest classification with SHAP interpretation, with family dysfunction as the most discriminative feature. Guided by the I-PACE model (which emphasizes affective-cognitive-executive interactions in addiction), this study aims to map risk factor interrelationships, identify IGD subgroups, and lay the groundwork for personalized early detection and intervention—directly addressing the unclear role of distinct dominant pathways in IGD to advance theoretical understanding.

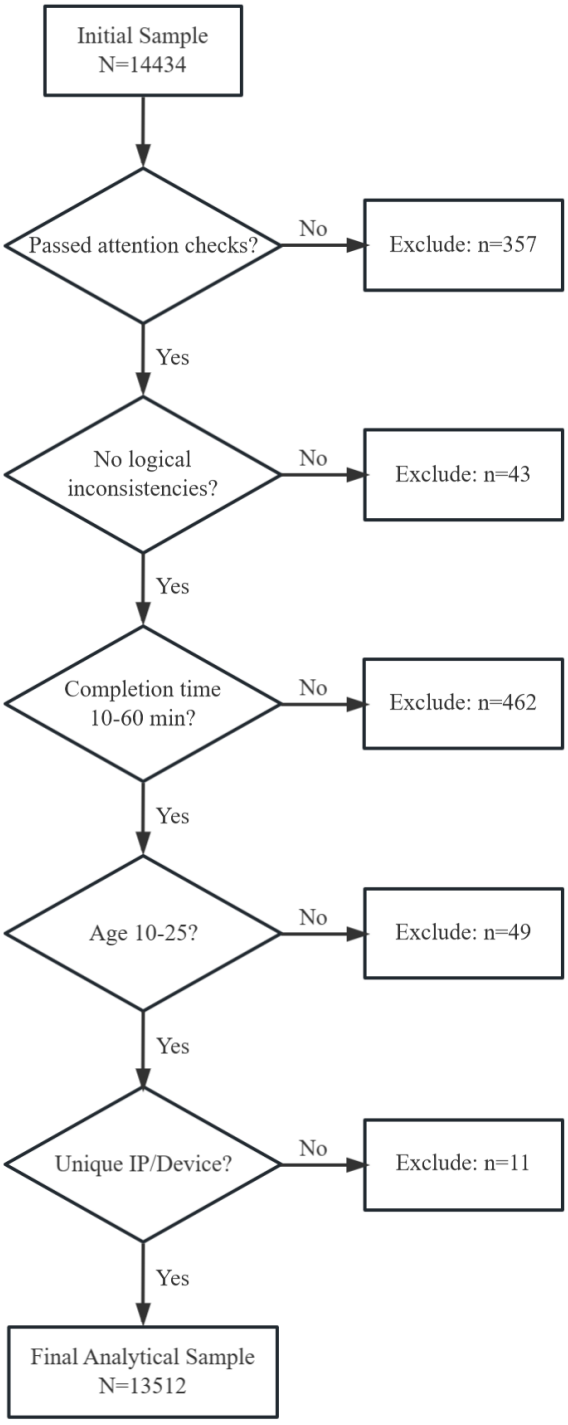
METHOD

Participants and procedure

A multi-stage cluster sampling design was employed to obtain a representative sample of adolescents and young adults. Between June and December 2024, an online questionnaire survey was conducted across universities, secondary schools, and elementary schools in cities with varying economic levels within seven provinces in China (Hunan, Jiangxi, Guangdong, Hainan, Jiangsu, Henan, and Inner Mongolia). Schools were randomly selected from educational authority lists, with entire classes invited; non-participating schools/classes were replaced randomly. After providing informed consent, participants completed a self-administered questionnaire that took approximately 20 minutes to finish. The questionnaire collected demographic data (gender, education level, region) and assessed IGD symptoms, depression, anxiety, stress, self-harm, suicidality, and other psychological/behavioral factors over the past 12 months. Participants were informed of their right to withdraw from the survey at any time without penalty. Following data screening for attention lapses, logical inconsistencies, duplicate entries, non-adolescent respondents, and implausible completion times, a total of 13,512 valid responses were retained for analysis, yielding a response rate of 93.61% (Figure 1).

Insert Figure 1 here

Figure 1. Identification of eligible participants



Measures

A series of standardized scales were administered. These included the internet gaming disorder Scale-Short Form (IGDS9-SF), the Depression-Anxiety-Stress Scale-

21 (DASS-21), the Eating Attitudes Test-26 (EAT-26), the Cognitive Failures Questionnaire (CFQ), the Interaction Anxiousness Scale (IAS), the UPPS-P Impulsive Behavior Scale, the Behavioral Inhibition/Activation System Scale (BIS/BAS), the Connor-Davidson Resilience Scale (CD-RISC), and the Adverse Childhood Experiences-International Questionnaire (ACE-IQ). Detailed information on all measures is provided in the Supplementary Materials S1.

Statistical analysis

First, univariate analyses and multivariable logistic regression (SPSS 26) identified potential risk factors. Second, network analysis (bootnet package in R) visualized interrelationships and characterized the network via strength and bridge centrality indices. Subsequently, LPA was performed using the mclust package in R to identify distinct subgroups based on the configurations of these risk factors. The optimal number of latent profiles was determined by comparing model fit indices, including the Bayesian Information Criterion (BIC), Integrated Completed Likelihood (ICL), Akaike Information Criterion (AIC), and the Lo-Mendell-Rubin Likelihood Ratio Test (LMRT). To further delineate the core risk features distinguishing each identified subgroup from a healthy reference group, random forest classification models were built for each subgroup using the randomForest package. The contribution of each feature to classification was quantified using SHapley Additive exPlanations (SHAP) values, computed via the fastshap package.

RESULTS

Participant characteristics

A total of 13,512 participants were included in the final sample, comprising 2,143 individuals with IGD and 11,369 healthy controls (HC). The overall mean age was 17.34 years, with 42.3% male participants. In the IGD group, the mean age was 17.69 years, 56.6% were male, and the mean IGDS9-SF score was 25.44. In the HC group, the mean age was 17.27 years, 39.6% were male, and the mean IGDS9-SF score was 13.18 (Supplementary Table 1).

Identification of IGD risk factors

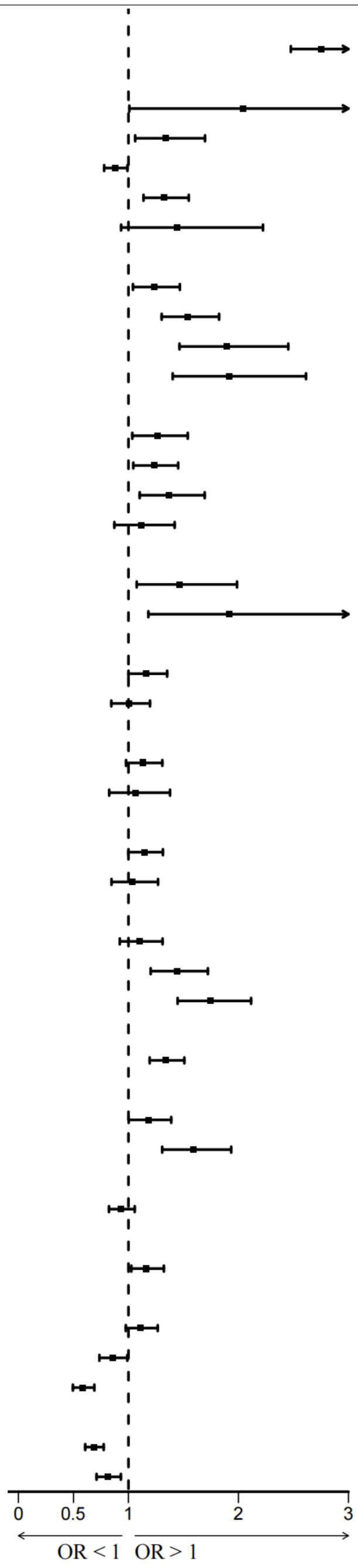
Univariate analysis results

Based on established cutoff values for the respective questionnaires, participants were classified into different levels for each risk factor. Variables with a p-value of less than 0.1 in these initial analyses were selected for subsequent multivariable modeling and network analysis. Detailed sample characteristics and the results of the univariate analyses are summarized in Table 1.

Insert Table 1 here

Table 1. Univariate analysis of Internet Gaming Disorder Severity by Sociodemographic and Clinical Variables

Variable		OR(95%CI)	P value
Gender	Female	Reference	
	Male	2.75 (2.48,3.06)	<0.001
Educational background	Senior high school	Reference	
	Elementary school	2.04 (1.01,4.14)	0.048
	Junior high school	1.34 (1.06,1.70)	0.014
	College degree	0.88 (0.78,0.99)	0.035
	Bachelor's degree	1.33 (1.14,1.55)	<0.001
	Master's degree	1.44 (0.93,2.22)	0.100
DASS-Depression rank	Normal	Reference	
	Mild	1.24 (1.04,1.47)	0.015
	Moderate	1.54 (1.30,1.82)	0.008
	Severe	1.90 (1.46,2.45)	0.014
	Extremely Severe	1.91 (1.40,2.61)	0.021
DASS-Anxiety rank	Normal	Reference	
	Mild	1.26 (1.03,1.54)	0.004
	Moderate	1.23 (1.04,1.45)	0.391
	Severe	1.37 (1.10,1.69)	<0.001
	Extremely Severe	1.11 (0.87,1.42)	0.016
DASS-Stress rank	Normal	Reference	
	Mild	1.46 (1.07,1.99)	<0.001
	Moderate	1.92 (1.18,3.12)	<0.001
Self-mutilation	Never thought	Reference	
	Intended to but didn't	1.16 (1.00,1.35)	0.051
	Have tried	1.00 (0.84,1.20)	0.957
Suicide	Never thought	Reference	
	Intended to but didn't	1.13 (0.98,1.31)	0.096
	Have tried	1.07 (0.82,1.38)	0.625
Eating attitudes test rank	Normal	Reference	
	Tendency	1.15 (1.00,1.31)	0.050
	High tendency	1.04 (0.85,1.27)	0.734
CFQ rank	Low	Reference	
	Moderate-low	1.10 (0.92,1.31)	0.296
	Moderate-high	1.44 (1.20,1.72)	<0.001
	High	1.75 (1.45,2.12)	<0.001
IAS rank	Normal	Reference	
	IAS	1.34 (1.19,1.51)	<0.001
Impulsive rank	Low	Reference	
	Moderate	1.18 (1.00,1.39)	0.047
	High	1.59 (1.31,1.93)	<0.001
BIS rank	Low	Reference	
	High	0.93 (0.82,1.06)	0.273
BAS rank	Low	Reference	
	High	1.16 (1.03,1.32)	0.018
Resilience rank	Low	Reference	
	Moderate-low	1.11 (0.98,1.27)	0.112
	Moderate-high	0.85 (0.74,0.99)	0.036
	High	0.58 (0.49,0.69)	<0.001
ACE rank	Low	Reference	
	Moderate	0.69 (0.61,0.78)	<0.001
	High	0.81 (0.71,0.93)	0.003



Note. DASS: Depression-Anxiety-Stress Scale, CFQ: Cognitive Failures Questionnaire, IAS: Interaction Anxiousness Scale, UPPS: The UPPS-P Impulsive Behavior Scale, BIS: Behavioral Inhibition System, BAS: Behavioral Activation System, ACE: Adverse Childhood Experiences.

As shown in Table 1, male gender (OR=2.75) was a strong demographic risk factor. Educational background showed a non-linear association with IGD risk: relative to high school education, elementary school, junior high school, and bachelor's degree were associated with higher risk, while college degree was protective (Table 1).

A dose-response relationship was observed for depressive symptoms, with odds of IGD increasing from OR=1.24 (Mild) to OR=1.91 (Extremely Severe). Anxiety (Mild: OR=1.26; Severe: OR=1.37) and stress (Mild: OR=1.46; Moderate: OR=1.92) were also positively associated with IGD.

Higher cognitive failures (Moderate-High: OR=1.44; High: OR=1.75), social interaction anxiety (OR=1.34), and impulsivity (High: OR=1.59) were significant risk factors, whereas psychological resilience was protective (High vs. Low: OR=0.58).

An inverse association was found for adverse childhood experiences (Moderate: OR=0.69; High: OR=0.81). Behavioral inhibition system scores were not significant (all $p > 0.10$) and were excluded from further analysis.

Multivariable logistic regression analysis

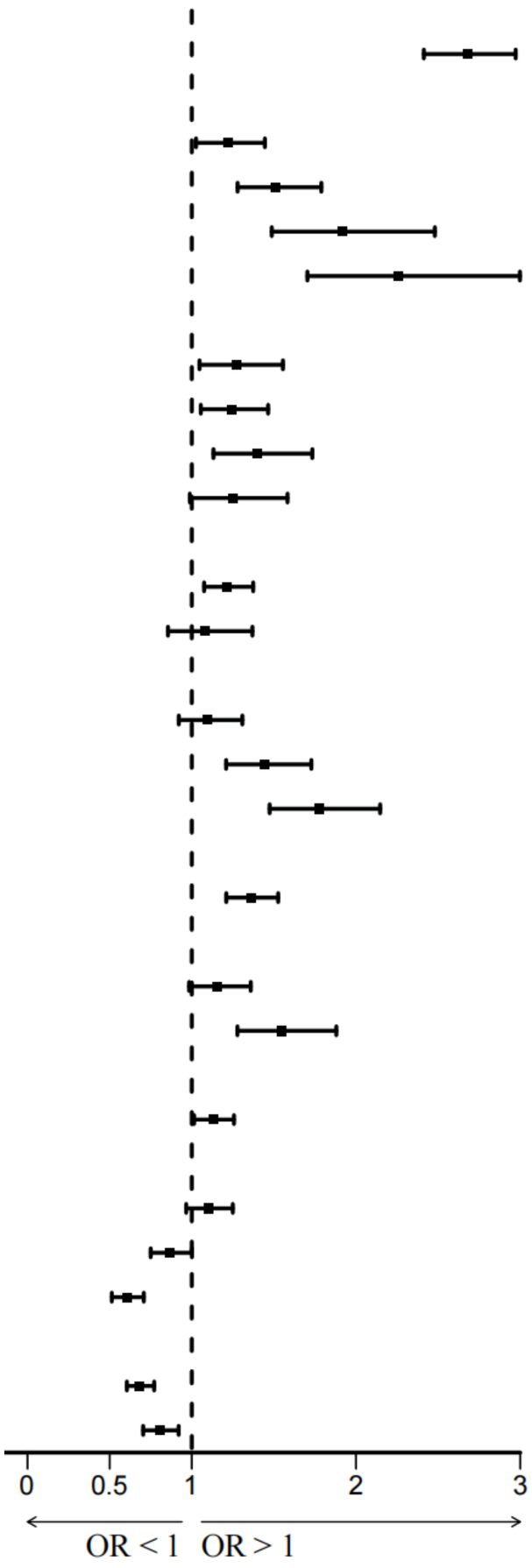
A multivariable logistic regression model was conducted identify factors

independently associated with IGD. All variables that demonstrated significant associations in the univariate analyses were included in the model: gender, educational background, stress, anxiety, depression, self-mutilation, suicidal behavior, eating disorders, cognitive failures, social interaction anxiety, impulsivity, the BA, psychological resilience, and ACEs. The results are presented in Table 2.

Insert Table 2 here

Table 2. Factors associated with IGD in Multivariable Logistic Regression Analysis

Variable		OR(95%CI)	P value
Gender	Femal	Reference	
	Male	2.68 (2.41,2.97)	<0.001
DASS-Depression rank	Normal	Reference	
	Mild	1.22 (1.03,1.45)	0.024
	Moderate	1.51 (1.28,1.79)	<0.001
	Severe	1.92 (1.49,2.48)	<0.001
	Extremely severe	2.26 (1.70,3.00)	<0.001
DASS-Anxiety rank	Normal	Reference	
	Mild	1.28 (1.05,1.55)	0.016
	Moderate	1.24 (1.05,1.47)	0.009
	Severe	1.40 (1.13,1.73)	0.002
	Extremely severe	1.25 (0.99,1.58)	0.063
Suicide	Never thought	Reference	
	Intended to but didn't	1.22 (1.07,1.37)	0.002
	Have tried	1.08 (0.85,1.37)	0.511
CFQ rank	Low	Reference	
	Moderate-low	1.10 (0.92,1.31)	0.297
	Moderate-high	1.45 (1.21,1.73)	<0.001
	High	1.78 (1.47,2.15)	<0.001
IAS rank	Normal	Reference	
	IAS	1.36 (1.21,1.53)	<0.001
Impulsive rank	Low	Reference	
	Moderate	1.16 (0.98,1.36)	0.079
	High	1.55 (1.28,1.88)	<0.001
BAS rank	Low	Reference	
	High	1.13 (1.01,1.26)	0.027
Resilience rank	Low	Reference	
	Moderate-low	1.10 (0.97,1.25)	0.151
	Moderate-high	0.87 (0.75,1.00)	0.052
	High	0.60 (0.51,0.71)	<0.001
ACE rank	Low	Reference	
	Moderate	0.68 (0.60,0.77)	<0.001
	High	0.80 (0.70,0.92)	0.001



Note. DASS: Depression-Anxiety-Stress Scale, UPPS: The UPPS-P Impulsive Behavior Scale, CFQ: Cognitive Failures Questionnaire, ACE: Adverse Childhood Experiences, BAS: Behavioral Activation System, IAS: Interaction Anxiousness Scale

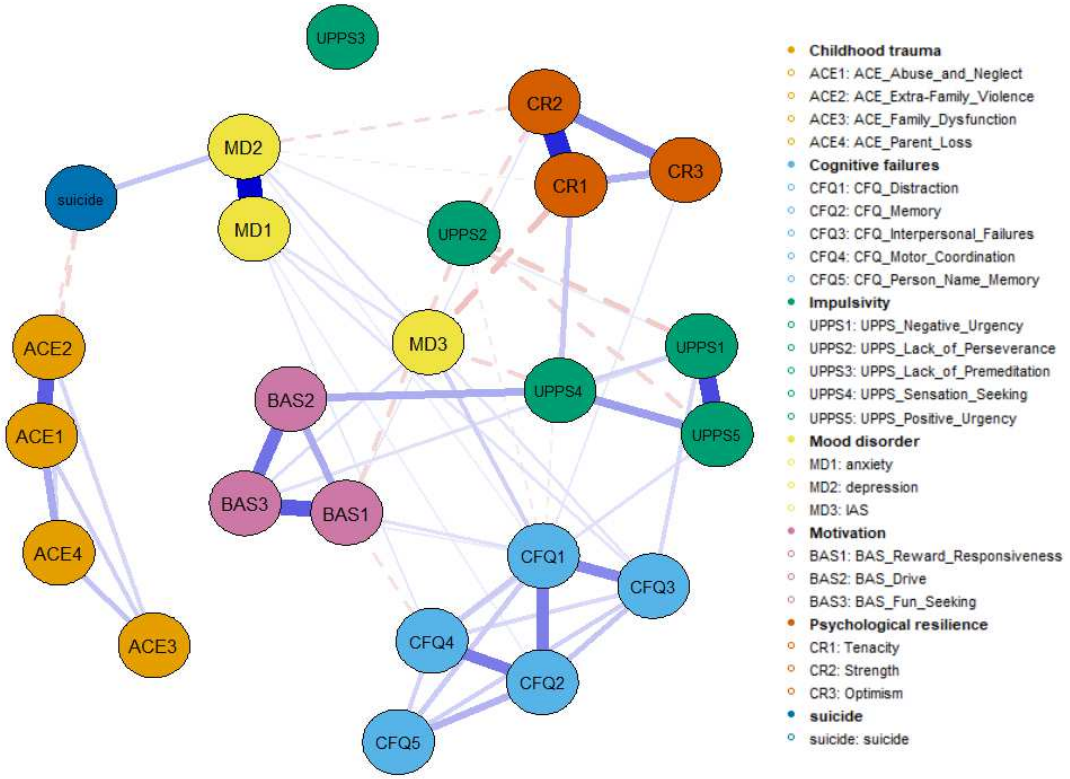
The multivariable model identified several independent predictors of IGD. Male gender was the strongest demographic correlate (OR = 2.68). Both depression and anxiety showed independent dose-response relationships with IGD risk (Depression ORs: 1.22 to 2.26; Anxiety 'Extremely Severe': OR = 1.25). Among cognitive-behavioral traits, cognitive failures ('High': OR = 1.78), social interaction anxiety (OR = 1.36), and high impulsivity (OR = 1.55) were significant risk factors, as was a high behavioral activation system score (OR = 1.13). Psychological resilience was a strong protective factor (OR = 0.60). Conversely, adverse childhood experiences (ACEs) showed an unexpected inverse association with IGD (e.g., 'Moderate' ACE: OR = 0.69). Variables significant in univariate analyses but not in the multivariable model (educational background, stress, self-mutilation, eating attitudes) likely had their effects accounted for by the stronger predictors included.

Interrelationships among IGD risk factors

A network analysis was performed to elucidate the complex interrelationships among the risk and protective factors identified as significant in the multivariable logistic regression, using data from the high-risk IGD subgroup (IGDSF≥21, n=2143). To construct a fine-grained architecture of symptomatology, variables were expanded into their constituent subscales or conceptually related components, forming several thematic clusters within the network. These clusters included a Mood Disorder group (comprising Depression, Anxiety, and Interaction Anxiousness), an Adverse Childhood

Experiences (ACE) group, a Cognitive Failures (CFQ) group, an Impulsivity (UPPS-P) group, a Motivation (BAS) group, and a Psychological Resilience group. This structure enabled a detailed examination of symptom-level interactions and cross-domain connectivity between psychopathological risk and protective mechanisms (Figure 2).

Figure 2. Network of Interrelationships Among Risk and Protective Factors in the High-Risk IGD Population.



Insert Figure 2 here

Note. Each node represents an item, with its color indicating the domain to which it belongs. The light orange nodes represent items of adverse childhood experiences, the blue nodes represent items of cognitive failures, the green nodes represent items of impulsivity, the yellow nodes represent items of mood disorders, the purple nodes represent items of the behavioral activation system, the dark orange nodes represent items of psychological resilience, and the dark blue nodes represent suicide. The edges

between node pairs represent the conditional correlations between them. The edges are color-coded, and their thickness indicates the strength of the correlation. Solid blue edges represent positive correlations, while dashed red edges represent negative correlations. The distance between nodes also reflects the strength of the correlation between them.

Strength centrality identified Distraction (a facet of cognitive failures), Tenacity, and Strength (both facets of psychological resilience) as the most central nodes. This indicates that attentional control and psychological resilience—particularly perseverance and inner strength—are the most interconnected and influential components within the IGD risk architecture, functioning as dynamically active protective factors.

Bridge centrality analysis revealed Interaction Anxiousness, Distraction, and Sensation Seeking as key bridges. This suggests that: Interaction Anxiousness may link internalizing distress with compensatory gaming for social avoidance; Distraction acts both as a core cognitive issue and a connector to other domains; and Sensation Seeking bridges motivational drives with engagement in stimulating gaming environments.

In summary, the network model conceptualizes IGD risk as orchestrated by three core mechanisms: cognitive dysfunction (Distraction), social-emotional deficits (Interaction Anxiousness), and motivational-impulsive tendencies (Sensation Seeking).

Importantly, psychological resilience emerged as a central, active protective system. These findings imply that interventions targeting attentional control, social anxiety management, and especially resilience building may be most effective in disrupting the network that maintains IGD.

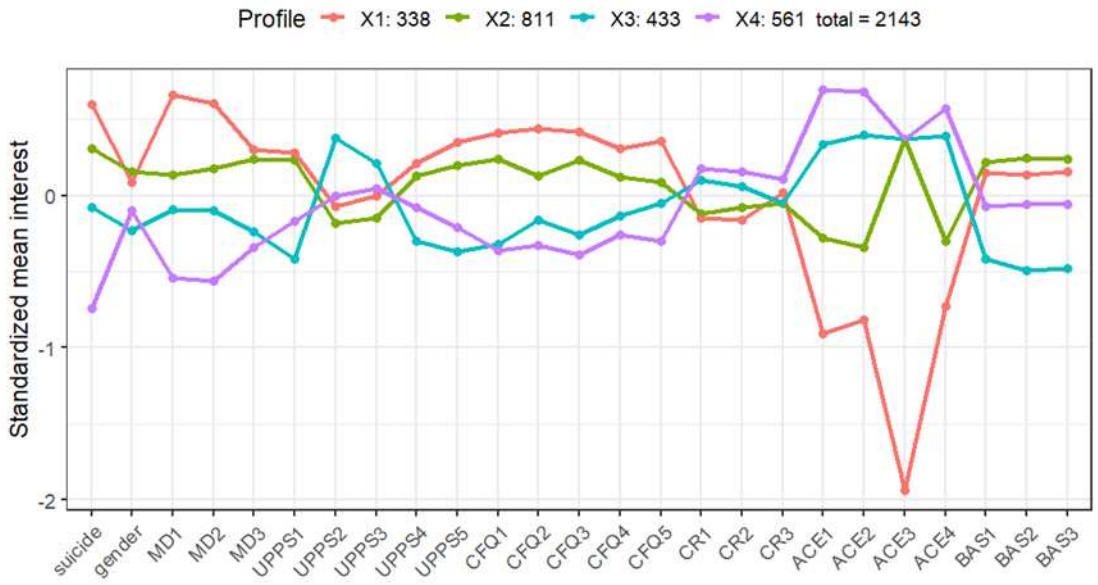
Latent profiles of IGD risk factors

To examine heterogeneity within the high-risk IGD population, a latent profile analysis was conducted to identify distinct configurations of risk and protective factors derived from the multivariable analysis. Model fit indices (Supplementary Table 2) supported both 4-profile and 5-profile models; the 4-profile solution was selected for clinical relevance and parsimony (Figure 3).

Latent profile analysis (LPA) identified four distinct risk configurations within the high-risk IGD population (n=2143, IGDSF≥21).

Insert Figure 3 here

Figure 3. Heterogeneous Clinical Presentations of Risk and Protective Factors in high-risk IGD.



Note. MD1: anxiety, MD2: depression, MD3: IAS; UPPS1: negative urgency, UPPS2: lack of perseverance, UPPS3: lack of premeditation, UPPS4: sensation seeking, UPPS5: positive urgency; CFQ1: distraction, memory, CFQ2: interpersonal failures, CFQ3: motor coordination, CFQ4: person name memory; CR1:tenacity, CR2:strength, CR3:optimism; ACE1: abuse and neglect, ACE2: extra family violence, ACE3: family dysfunction, ACE4: parent loss; BAS1: reward responsiveness, BAS2: drive, BAS3: fun seeking.

Profile X1 – Emotional–Cognitive Dysfunction (n=338): Defined by the most severe current psychopathology (highest suicidality, mood disorders, cognitive failures) alongside the lowest levels of adverse childhood experiences (ACEs). This suggests a pathway to severe IGD linked to pronounced psychopathology without significant retrospective trauma.

Profile X2 – Moderate-Risk with Prevalent Family Dysfunction (n=811): The

largest subgroup, showing moderate elevations across most risk domains. It is distinctively characterized by pronounced family dysfunction (ACE3), a pervasive vulnerability shared by most of the high-risk sample, indicating a moderate-risk profile where intermediate symptoms coexist with adverse family environments.

Profile X3 – Executive Dyscontrol (n=433): Marked by severe self-regulation deficits, exhibiting the highest levels of lack of perseverance and premeditation, but the lowest reward sensitivity and emotional urgency. This suggests an IGD subtype driven primarily by executive control impairment rather than impulsivity or high reward drive.

Profile X4 – High-Adversity Compensatory (n=561): Presents the highest burden of specific childhood adversities (abuse/neglect, extra-familial violence, parent loss), yet the lowest levels of current psychopathology. This counterintuitive pattern suggests a compensatory pathway where excessive gaming may serve as a primary coping mechanism, mitigating overt psychiatric symptoms.

The aggregation of Profile X4 (high ACEs, low pathology) with profiles like X1 (low ACEs, high pathology) creates a statistical confound, explaining the apparent protective association of ACEs observed at the group level. A post-hoc analysis confirmed ACEs as a risk factor when comparing X4 to healthy controls, indicating the finding is an artifact of heterogeneity.

Notably, Profiles X1 and X3 both exhibited severe IGD via divergent pathways, illustrating equifinality. This aligns with network analysis: the central node Distraction defines X1, while the key bridge node Sensation Seeking characterizes X3, delineating one pathway driven by cognitive-emotional dysfunction and another by executive deficits with sensation seeking.

The clinical distinctiveness and predictive validity of the four-profile solution were further evaluated using a supervised machine learning approach. A random forest classifier achieved high accuracy (85.3%) in distinguishing the profiles on a held-out test set, providing robust support for their statistical separability. SHapley Additive exPlanations (SHAP) analysis identified adverse childhood experiences—particularly family dysfunction—as the most powerful features for discriminating between subgroups (for detailed methodology and results, including feature importance plots, see Supplementary Materials S4).

DISCUSSION

This study developed an integrated analytical framework that advances the understanding of Internet Gaming Disorder (IGD) by sequentially combining risk factor assessment, network analysis, latent profile analysis (LPA), and explainable machine learning (Random Forest with SHAP). Methodologically, this integrated approach is the first to dissect IGD heterogeneity through such a multi-level lens. Empirically, we

found the IGD high-risk population to be highly heterogeneous. Network analysis revealed the complex psychopathological architecture, identifying cognitive failure (specifically, distraction) and psychological resilience as the most central nodes, and interaction anxiety and sensation seeking as critical bridges connecting symptom clusters. Subsequently, LPA validated this heterogeneity by identifying four clinically distinct subgroups: the "Emotional–Cognitive Dysfunction" group, the "Moderate-Risk with Prevalent Family Dysfunction" group, the "Executive Dyscontrol" group, and the "High-Adversity Compensatory" group. Crucially, these profiles represent at least two dissociable pathways to severe IGD. A supervised machine learning model confirmed their high discriminability and, via SHAP analysis, pinpointed a concise set of features—most notably, adverse childhood experiences—as potent subgroup identifiers. Furthermore, the "High-Adversity Compensatory" profile resolves the paradoxical link between childhood adversity and IGD risk. Collectively, these results establish a data-driven, personalized typology of IGD risk, moving the field beyond a one-size-fits-all model and providing a foundation for precise assessment and targeted intervention.

Integration of network architecture and latent profiles: a synergistic framework

The primary methodological innovation of this study lies in the sequential integration of network and person-centered analyses. This combined approach provides a more comprehensive understanding of IGD heterogeneity than either method alone

[14, 15]. Network analysis elucidated the dynamic interactions and architecture of risk factors, while latent profile analysis identified homogeneous subgroups based on these interacting factors. The convergence of these analytical levels underscores the unique value of integrating variable-centered and person-centered approaches in psychopathology research [15, 16], enhancing both the interpretability and mechanistic insight into IGD.

First, the network model provides a systems-level explanation for the distinct clinical presentations of the latent profiles. Building on regression findings, network analysis moved beyond identifying independent predictors to reveal the dynamic architecture of IGD risk. The resulting network identified CFQ1 (Distraction) and the facets of psychological resilience (Tenacity and Strength) as the nodes with the highest strength centrality. This signifies that attentional control deficits and core resilience components are the most active and influential elements within the psychopathological system, suggesting fundamental therapeutic targets. The central role of resilience is supported by longitudinal evidence establishing it as a key mechanism in IGD progression (Canale et al., 2019; Lin et al., 2021). Furthermore, bridge centrality analysis highlighted CFQ1 (Distraction), Interaction Anxiousness (MD3) and Sensation Seeking (UPPS4) as primary connectors between symptom clusters. The bridging roles of social anxiety and sensation seeking are well-established: social anxiety operates through escapism and metacognitions [20, 21], while sensation seeking indirectly influences IGD by elevating impulsivity [22, 23]. This indicates that social-emotional

deficits and motivational-impulsive tendencies serve as critical pathways through which distress or reward sensitivity propagate to sustain problematic gaming. In synthesis, the network model portrays IGD not as a list of discrete symptoms, but as an orchestrated system of interacting components.

The central and bridging nodes identified in the network were directly reflected in the defining features of the latent profiles. For instance, the "Emotional–Cognitive dysfunction" (X1) profile, characterized by the most severe cognitive failures and emotional distress, personifies the network's core pathology around the central node Distraction. This aligns with evidence that attentional dysregulation occupies a central, influential position in psychopathological networks and may act as a key transdiagnostic driver [24]. Conversely, the "Executive Dyscontrol" (X3) profile, defined by a clinical presentation dominated by Sensation Seeking—a key bridge node—and profound self-regulation deficits, operationalizes the network's bridging structure. This illustrates how a motivational-impulsive tendency, when interconnected with other domains, can constitute a primary pathway to severe IGD, consistent with findings that anhedonia is a central component of IGD withdrawal [25].

Second, this integrated framework elucidates the phenomenon of equifinality in IGD—the principle that different risk pathways can lead to a similar severe outcome. Our data clearly demonstrate this: the X1 and X3 profiles, despite their divergent architectures (emotion–cognition axis breakdown versus motivation–impulsivity–

control dysregulation), both exhibited the highest IGD severity. The network model makes this intelligible by showing these as semi-independent constellations within the same broader system.

Finally, the integration helps resolve apparent paradoxes. The counterintuitive inverse association between ACEs and IGD risk is explained by the "High-Adversity Compensatory" (X4) profile, characterized by high childhood adversity but low current psychopathology. This subgroup embodies the "functional substitute" hypothesis, where gaming may serve to suppress typical traumatic sequelae like suicidality. This hypothesized coping mechanism is supported by our network analysis, which identified a specific pathway (ACEs → -Suicidality → +Depression) consistent with this profile, and aligns with established models [26, 27]. The case of the X4 subgroup demonstrates that the clinical meaning of risk factors like ACEs is not fixed but is context-dependent and profile-specific.

In conclusion, the synergy between network and latent profile analyses moves the field from a static "risk factor" model toward a dynamic "risk architecture" model of IGD. This framework posits IGD as a final common pathway for multiple distinct, systems-level dysfunctions, a critical step toward developing personalized interventions that target the specific architecture of risk maintaining the disorder in a given individual.

Clinical translation and subgroup identification

The high discriminative accuracy of the random forest model, combined with the SHAP-based feature analysis, provides a direct pathway for translating the identified risk profiles into clinical practice. This approach aligns with the current advancements in the field, as it not only provides robust out-of-sample predictive performance but also elucidates the direction and magnitude of each feature's contribution to the outcome, bridging the gap between complex algorithms and clinically actionable insights [28]. The model's robust performance (85.3% accuracy, Kappa = 0.795) confirms that the four latent profiles represent statistically distinct and reliably identifiable clinical entities.

Importantly, the SHAP analysis distilled the complex array of risk factors into a concise set of key identifiers for each profile. For example, the universal discriminative power of family dysfunction (ACE3) makes it a critical screening element, while the presence of suicidality or pronounced distraction can help further differentiate between specific subgroups.

In summary, the supervised machine learning approach validates the clinical utility of the risk profiles by demonstrating that they can be accurately distinguished using a manageable set of core features. This provides a foundation for streamlined diagnostic protocols capable of facilitating rapid, individualized subtyping of IGD presentations in clinical settings.

Strengths, limitations, and future directions

This study has several notable strengths, including its large, well-defined sample of high-risk adolescents, the application of a novel integrative analytical framework combining network and person-centered methods, and the validation of empirically derived groups via a robust machine learning approach.

However, several limitations should be considered. First, the cross-sectional design precludes causal inferences regarding the directionality of associations or the temporal stability of the identified profiles. Second, the reliance on self-report measures may introduce biases, such as recall or social desirability, potentially attenuating true effects. Finally, the generalizability of findings may be limited to Chinese adolescent populations, necessitating cross-cultural replication.

These limitations delineate clear research pathways. Longitudinal studies are needed to establish temporal precedence and profile stability. Future work should incorporate multi-method assessments and evaluate targeted interventions for each profile to advance personalized strategies for IGD.

CONCLUSION

In conclusion, this study demonstrates that IGD in adolescents is not a unitary condition, but rather a heterogeneous syndrome arising from distinct constellations of risk and protective factors. By integrating network and person-centered analyses, we have moved beyond a simple list of risk factors to delineate a complex psychopathological architecture and translate it into empirically derived, clinically distinct subgroups. We have identified two dissociable pathways to severe IGD—one driven by emotional–cognitive dysfunction and another by executive control deficits—and provided a plausible explanatory model for counterintuitive findings such as the protective effect of ACEs. The validation of these subgroups via machine learning confirms their practical utility for assessment. Collectively, this refined, typological understanding of IGD provides a necessary foundation for departing from one-size-fits-all approaches and paves the way for a new era of precise assessment and personalized intervention for adolescents with this disorder.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Figure 1. Identification of eligible participants

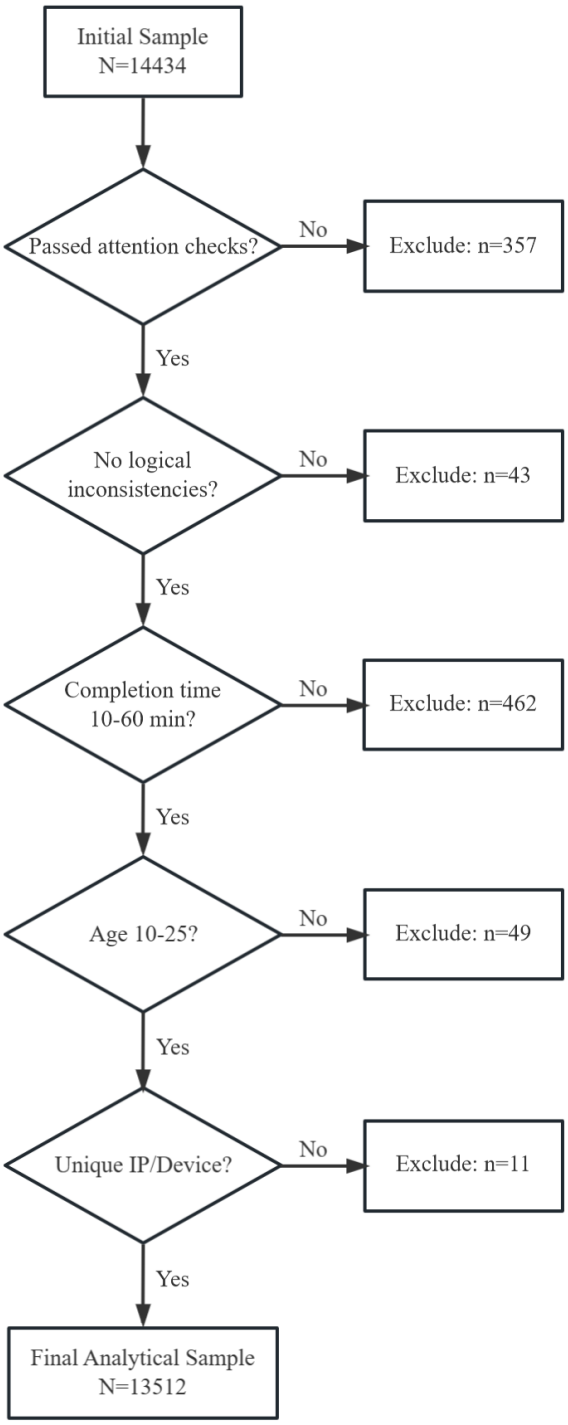
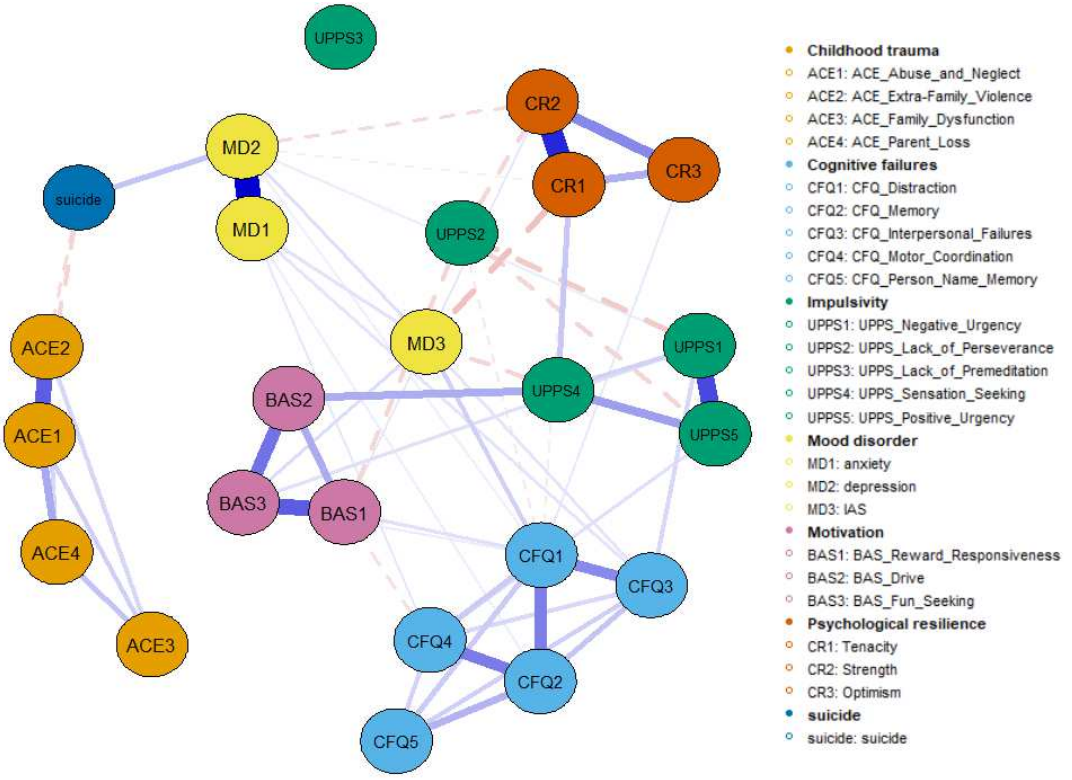
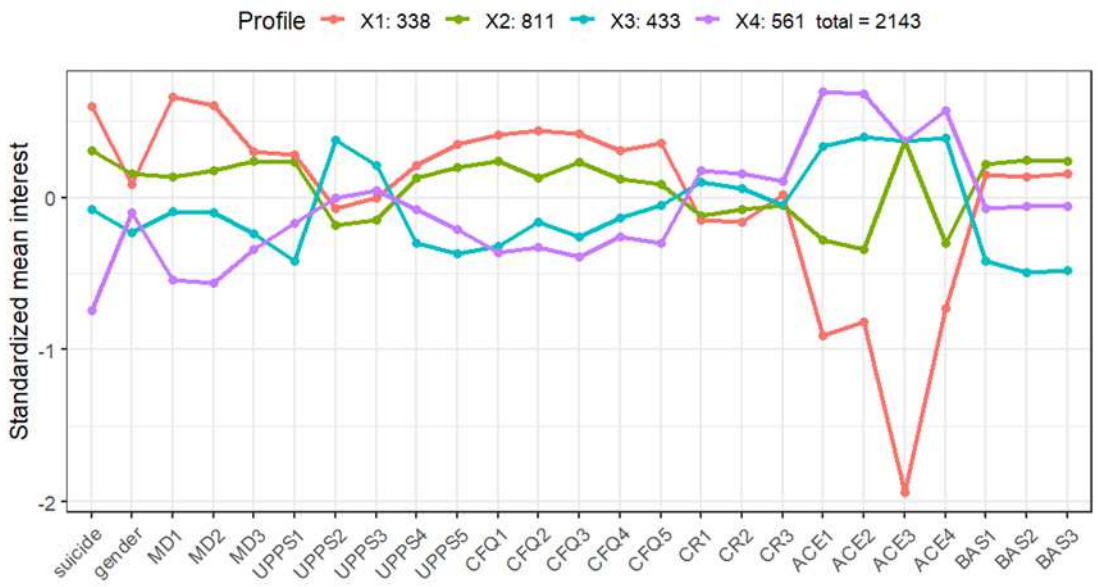


Figure 2. Network of Interrelationships Among Risk and Protective Factors in the High-Risk IGD Population.



Note. Each node represents an item, with its color indicating the domain to which it belongs. The light orange nodes represent items of adverse childhood experiences, the blue nodes represent items of cognitive failures, the green nodes represent items of impulsivity, the yellow nodes represent items of mood disorders, the purple nodes represent items of the behavioral activation system, the dark orange nodes represent items of psychological resilience, and the dark blue nodes represent suicide. The edges between node pairs represent the conditional correlations between them. The edges are color-coded, and their thickness indicates the strength of the correlation. Solid blue edges represent positive correlations, while dashed red edges represent negative correlations. The distance between nodes also reflects the strength of the correlation between them.

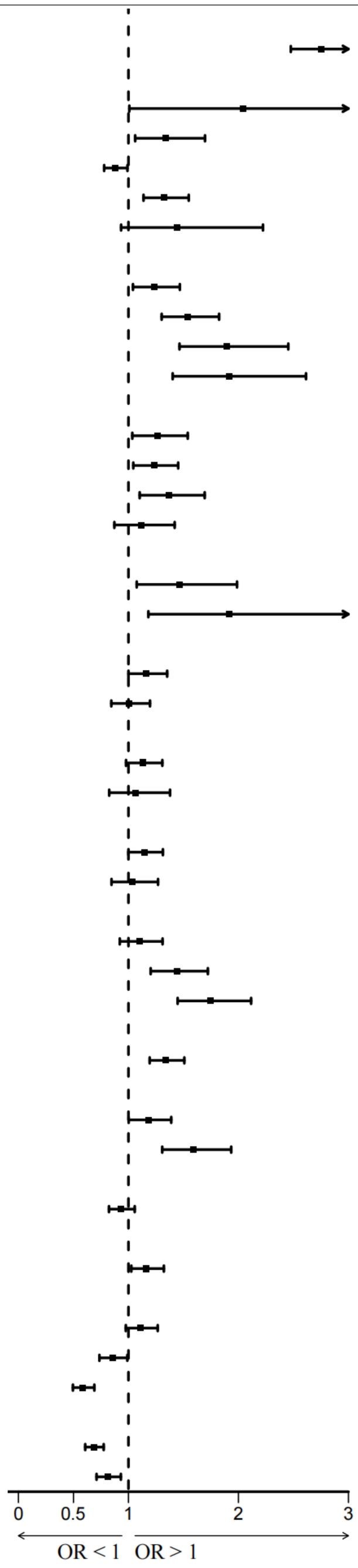
Figure 3. Heterogeneous Clinical Presentations of Risk and Protective Factors in high-risk IGD.



Note. MD1: anxiety, MD2: depression, MD3: IAS; UPPS1: negative urgency, UPPS2: lack of perseverance, UPPS3: lack of premeditation, UPPS4: sensation seeking, UPPS5: positive urgency; CFQ1: distraction, memory, CFQ2: interpersonal failures, CFQ3: motor coordination, CFQ4: person name memory; CR1:tenacity, CR2:strength, CR3:optimism; ACE1: abuse and neglect, ACE2: extra family violence, ACE3: family dysfunction, ACE4: parent loss; BAS1: reward responsiveness, BAS2: drive, BAS3: fun seeking.

Table 1. Univariate analysis of Internet Gaming Disorder Severity by Sociodemographic and Clinical Variables

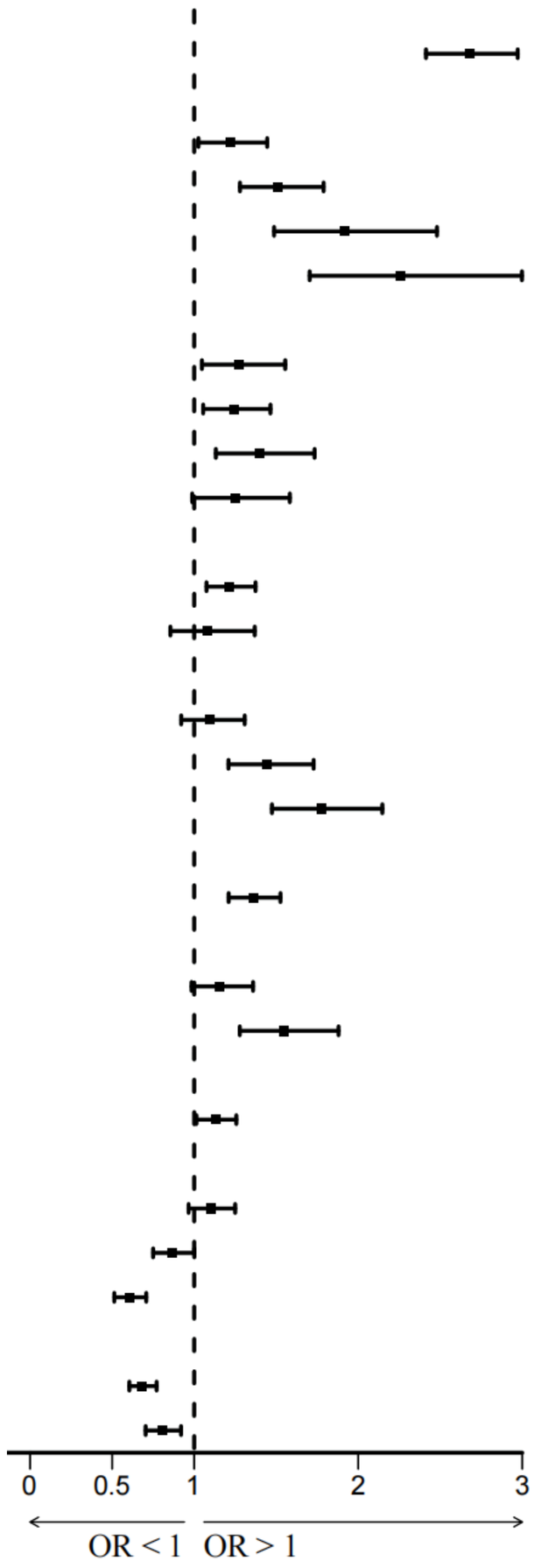
Variable		OR(95%CI)	P value
Gender	Female	Reference	
	Male	2.75 (2.48,3.06)	<0.001
Educational background	Senior high school	Reference	
	Elementary school	2.04 (1.01,4.14)	0.048
	Junior high school	1.34 (1.06,1.70)	0.014
	College degree	0.88 (0.78,0.99)	0.035
	Bachelor's degree	1.33 (1.14,1.55)	<0.001
	Master's degree	1.44 (0.93,2.22)	0.100
DASS-Depression rank	Normal	Reference	
	Mild	1.24 (1.04,1.47)	0.015
	Moderate	1.54 (1.30,1.82)	0.008
	Severe	1.90 (1.46,2.45)	0.014
	Extremely Severe	1.91 (1.40,2.61)	0.021
DASS-Anxiety rank	Normal	Reference	
	Mild	1.26 (1.03,1.54)	0.004
	Moderate	1.23 (1.04,1.45)	0.391
	Severe	1.37 (1.10,1.69)	<0.001
	Extremely Severe	1.11 (0.87,1.42)	0.016
DASS-Stress rank	Normal	Reference	
	Mild	1.46 (1.07,1.99)	<0.001
	Moderate	1.92 (1.18,3.12)	<0.001
Self-mutilation	Never thought	Reference	
	Intended to but didn't	1.16 (1.00,1.35)	0.051
	Have tried	1.00 (0.84,1.20)	0.957
Suicide	Never thought	Reference	
	Intended to but didn't	1.13 (0.98,1.31)	0.096
	Have tried	1.07 (0.82,1.38)	0.625
Eating attitudes test rank	Normal	Reference	
	Tendency	1.15 (1.00,1.31)	0.050
	High tendency	1.04 (0.85,1.27)	0.734
CFQ rank	Low	Reference	
	Moderate-low	1.10 (0.92,1.31)	0.296
	Moderate-high	1.44 (1.20,1.72)	<0.001
	High	1.75 (1.45,2.12)	<0.001
IAS rank	Normal	Reference	
	IAS	1.34 (1.19,1.51)	<0.001
Impulsive rank	Low	Reference	
	Moderate	1.18 (1.00,1.39)	0.047
	High	1.59 (1.31,1.93)	<0.001
BIS rank	Low	Reference	
	High	0.93 (0.82,1.06)	0.273
BAS rank	Low	Reference	
	High	1.16 (1.03,1.32)	0.018
Resilience rank	Low	Reference	
	Moderate-low	1.11 (0.98,1.27)	0.112
	Moderate-high	0.85 (0.74,0.99)	0.036
	High	0.58 (0.49,0.69)	<0.001
ACE rank	Low	Reference	
	Moderate	0.69 (0.61,0.78)	<0.001
	High	0.81 (0.71,0.93)	0.003



Note. DASS: Depression-Anxiety-Stress Scale, CFQ: Cognitive Failures Questionnaire, IAS: Interaction Anxiousness Scale, UPPS: The UPPS-P Impulsive Behavior Scale, BIS: Behavioral Inhibition System, BAS: Behavioral Activation System, ACE: Adverse Childhood Experiences.

Table 2. Factors associated with IGD in Multivariable Logistic Regression Analysis

Variable		OR(95%CI)	P value
Gender	Femal	Reference	
	Male	2.68 (2.41,2.97)	<0.001
DASS-Depression rank	Normal	Reference	
	Mild	1.22 (1.03,1.45)	0.024
	Moderate	1.51 (1.28,1.79)	<0.001
	Severe	1.92 (1.49,2.48)	<0.001
	Extremely severe	2.26 (1.70,3.00)	<0.001
DASS-Anxiety rank	Normal	Reference	
	Mild	1.28 (1.05,1.55)	0.016
	Moderate	1.24 (1.05,1.47)	0.009
	Severe	1.40 (1.13,1.73)	0.002
	Extremely severe	1.25 (0.99,1.58)	0.063
Suicide	Never thought	Reference	
	Intended to but didn't	1.22 (1.07,1.37)	0.002
	Have tried	1.08 (0.85,1.37)	0.511
CFQ rank	Low	Reference	
	Moderate-low	1.10 (0.92,1.31)	0.297
	Moderate-high	1.45 (1.21,1.73)	<0.001
	High	1.78 (1.47,2.15)	<0.001
IAS rank	Normal	Reference	
	IAS	1.36 (1.21,1.53)	<0.001
Impulsive rank	Low	Reference	
	Moderate	1.16 (0.98,1.36)	0.079
	High	1.55 (1.28,1.88)	<0.001
BAS rank	Low	Reference	
	High	1.13 (1.01,1.26)	0.027
Resilience rank	Low	Reference	
	Moderate-low	1.10 (0.97,1.25)	0.151
	Moderate-high	0.87 (0.75,1.00)	0.052
	High	0.60 (0.51,0.71)	<0.001
ACE rank	Low	Reference	
	Moderate	0.68 (0.60,0.77)	<0.001
	High	0.80 (0.70,0.92)	0.001



Note. DASS: Depression-Anxiety-Stress Scale, UPPS: The UPPS-P Impulsive Behavior Scale, CFQ: Cognitive Failures Questionnaire, ACE: Adverse Childhood Experiences, BAS: Behavioral Activation System, IAS: Interaction Anxiousness Scale

Supplementary Files

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