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Unraveling the Interplay Between Non-Suicidal Self-Injury Functions, Anxiety, and Addictive Features Among Chinese Adolescents: A Large Cross-Sectional Network and Bayesian Analysis

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Abstract

Background

Non-suicidal self-injury (NSSI) is prevalent among adolescents and frequently co-occurs with addictive features and anxiety symptoms. However, evidence is dominated by prevalence estimates and pairwise correlations, offering limited insight into multivariate dependency structures. This study aimed to investigate the complex interplay and directional relationships among NSSI functions, anxiety, and addictive features in a large cross-sectional adolescent sample.

Methods

A total of 10,479 valid questionnaires were collected from students aged 9–18 years in 12 primary and middle schools. Measures included the Modified Adolescents Self-Harm Scale (MASHS), the Ottawa Self-Injury Inventory (OSI) for the functions and addictive features of NSSI, and the Revised Child Manifest Anxiety Scale (RCMAS). We estimated an undirected partial-correlation network using a graphical Gaussian model with EBICglasso, computing expected influence and bridge expected influence. We also applied Bayesian network structure to delineate candidate directional dependencies among domains.

Results

Among all participants, 2,654 (25.3%) reported at least one NSSI episode in the past 12 months. In the undirected network, internal emotion regulation (IER) was the most central NSSI function, bridging the addictive feature clustered to the anxiety cluster. External emotion regulation and physical anxiety also emerged as important bridge nodes. Bayesian network analysis further highlighted IER as a key starting point driving subsequent addictive symptoms and anxiety-related manifestations.

Conclusions

These findings highlight the prominent role of IER in influencing NSSI addictive features and anxiety and unveiling the putative pathways. Targeting maladaptive emotion regulation may help prevent or reduce NSSI and its associated harms.

1. Introduction

Non-suicidal self-injury (NSSI) has become a notable public health concern due to its high prevalence among adolescents (Plener et al., 2015). It is defined as the deliberate, direct destruction of one's own body tissue—such as through cutting, burning, or hitting—without suicidal intent (Nock, 2010). Longitudinal studies underscored a robust association between NSSI and subsequent suicidal behaviors

during adolescence (Hawton et al., 2015), making it one of the strongest predictors of suicide attempts and deaths (Morgan et al., 2017). Moreover, adolescents who frequently engage in NSSI may exhibit addiction-like behavioral patterns, which are associated with increased suicide risk and worse clinical outcomes (Jiang et al., 2024; Ying et al., 2024).

Such addiction-like features typically include strong urges to self-injure, diminished control over the behavior, and escalating frequency or severity over time. Consequently, an emerging perspective categorizes NSSI as a novel subtype of behavioral addiction, alongside gambling and gaming disorder (Lüthi & Lüscher, 2014; Mancinelli et al., 2021; Nixon et al., 2002; Pritchard et al., 2021). Consistent with substance addiction, cravings for self-injury among adolescents predominantly occur in the context of negative emotions (Victor et al., 2012), thereby distinguishing NSSI from other maladaptive behaviors. Though instruments such as the Ottawa Self-Injury Inventory quantify addictive features, the etiology and maintenance pathways of NSSI addiction remain insufficiently understood, underscoring the need for mechanism-informed research.

Most adolescents who engage in NSSI report doing so to relieve negative emotion. Anxiety, in particular, has been identified as a key factor in the development and maintenance of NSSI (Bentley et al., 2015; McEvoy et al., 2023). Evidence from both a large-scale Chinese survey and a longitudinal study indicates that anxiety not only predicts NSSI engagement but may also decrease following self-injury, thereby reinforcing the behavior through negative reinforcement mechanisms (Wang et al., 2025). Beyond its role in NSSI, anxiety is also closely linked to the development of addictive behaviors. Epidemiological and neurobiological evidence suggests a bidirectional relationship, with anxiety increasing the risk for addiction and vice versa (Lai et al., 2015; Anker & Kushner, 2019; al'Absi, 2020). Given the emerging conceptualization of NSSI as a behavioral addiction, these findings imply that anxiety may serve as a key pathogenic driver of compulsive self-injury—an idea that warrants further investigation.

While emotion regulation is a primary motivation for NSSI, adolescents also self-injure for other reasons. The widely recognized four-function model (Martin et al., 2013a) integrates earlier work and categorizes NSSI motives into internal emotion regulation, external emotion regulation, social influence, and sensation seeking (Lloyd-Richardson et al., 2007; Barrocas et al., 2011). Internal- and external-regulation factors map onto affect regulation (Holm & Severinsson, 2010), self-punishment (Nock, 2009), and anti-dissociation motives (Horne & Csipke, 2009), whereas social influence reflects interpersonal influence (Nock, 2009; Brooke & Horn, 2010). Notably, the model incorporates the addictive features of NSSI, represented by sensation seeking. Previous studies suggested that different NSSI functions contribute to the development of addiction-like symptoms to varying degrees (Luo et al., 2024), yet the specific pathways linking individual motives to distinct addictive features remain largely unexplored.

Although the functions, anxiety, and addictive features of NSSI are closely intertwined, the relative contribution of each factor and their interactions remain poorly understood, particularly the role and positioning of anxiety within this interconnected network (Wu et al., 2023). Traditional statistical methods, such as regression analysis or factor analysis, are limited in capturing the interdependencies

and complex interactions among multiple variables (Borsboom, 2017). To address this gap, the present study employs network analysis to map the complex interplay among functions, anxiety, and addictive features of NSSI, identifying the most central and bridging factors within the structure. Given the uncertain position of anxiety within the NSSI–addiction loop, we further applied a Bayesian network approach using directed acyclic graphs (DAGs) to learn directional dependencies and delineate putative pathways from cross-sectional data (Moffa et al., 2017).

Based on the above context, we conducted a large-scale cross-sectional study among Chinese adolescents to investigate the mutual interaction and potential sequential relationships among NSSI functions, anxiety, and NSSI addictive features with the target to propose new directions for improving treatment strategies and promoting a more effective allocation of limited medical resources.

2. Methods

2.1 Study design and participants

This was a large-sample cross-sectional study conducted in two western provinces in China from March to May 2021. We recruited participants aged 9–18 years from 12 local primary and middle schools. Only students who had obtained informed consent from both them and their guardians were ultimately included in the study, and they were then administered self-reported, anonymous online questionnaires. The study was conducted in accordance with the Declaration of Helsinki and obtained ethical approval from the Ethics Committee of West China Hospital, Sichuan University (NO. 2019 – 907). Finally, a total of 10,781 questionnaires were received in this survey. Among these, 302 samples were excluded for incomplete responses or obvious mistakes.

2.2 Measures

2.2.1 Modified Adolescents Self-Harm Scale (MASHS)

The Modified Adolescents Self-Harm Scale (MASHS) was utilized to detect the presence of any NSSI behaviors. This scale, specifically developed for Chinese adolescents, assesses the frequency and severity of self-harm behaviors by asking participants to review a list of 18 behaviors (e.g., deliberate cutting, scrubbing or burning skin) and report their engagement over the past month (Feng & Jiang, 2008). Each item was rated from 0 to 4 (0 = none, 1 = only once, 2 = 2–4 times, 3 = 5 or more times). Participants who reported at least one instance of self-harm behavior (scoring ≥ 1) were included in the following statistical analysis.

2.2.2 Ottawa Self-Injury Inventory (OSI)

The Ottawa Self-Injury Inventory (OSI) is a comprehensive self-report measure of NSSI developed based on empirical evidence (Cloutier & McDonald, 2003). It allows the simultaneous assessment of both functional and addictive characteristics of NSSI. The functions of NSSI were assessed using 24 items, which describe common reasons for engaging in NSSI. Each item was rated on a scale from 0 (never a

reason) to 4 (always a reason). Previous studies conducted within Chinese adolescents have validated the reliability of the OSI and confirmed the four functions of NSSI: internal emotion regulation (IER), external emotion regulation (EER), social influence (SI), and sensation seeking (SS) (Chen et al., 2022a; Guérin-Marion et al., 2018). The Cronbach's α coefficients for each factor were 0.896, 0.859, 0.854, and 0.637, respectively (Nixon et al., 2015).

The addictive features of NSSI were evaluated using seven items derived from the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) criteria for substance dependence, with scores ranging from 0 to 4 (0 = never, 1 = occasionally, 2 = sometimes, 3 = often, 4 = always) (Guérin-Marion et al., 2018; Martin et al., 2013b). The Chinese version is valid and reliable (Chen et al., 2022a). The Cronbach's α coefficient was 0.84 in the adolescent sample (Nixon et al., 2015). We label the seven addiction-feature items as OSI22 because, in the Chinese version of the OSI used in this study, they constitute the 22nd subscale. The items and their labels are summarized in Table 2.

2.2.3 The Revised Child Manifest Anxiety Scale (RCMAS)

The Revised Child Manifest Anxiety Scale (RCMAS) is an updated version of the Child Manifest Anxiety Scale (CMAS) created by Castaneda et.al (Castaneda et al., 1956; Reynolds & Richmond, 1978). Designed for children and adolescents aged 6–19, the RCMAS is a self-report tool where “Yes” indicates the presence of a symptom (scored as 1) and “No” indicates its absence (scored as 0). The scale consists of 37 items across four subscales: physiological anxiety (PA, 10 items), worry and oversensitivity (WOS, 11 items), social concern and concentration (SCC, 7 items), and lie (9 items). The total anxiety score is derived from the first three subscales (28 items). The Lie scale is often used as an indicator of defensiveness and social desirability (Pina et al., 2001). The Cronbach's α coefficients for PA, WOS and SCC in this study were 0.83, 0.95 and 0.82, respectively.

2.3 Data analysis

2.3.1 Estimation of undirected network

We used the R package *qgraph* and *glasso* to construct the partial correlation network based on the following variables: (i) four functions of NSSI; (ii) seven symptoms of NSSI’s addictive features; (iii) three anxiety symptoms as measured by the RCMAS among participants who reported at least once NSSI engagement during the past 12 months. The estimation model was Graphical Gaussian Model (GGM), which is suitable for the continuous or ordinal nature of all variables, and was modified using the Extended Bayesian Information Criterion (EBIC) glasso (Briganti et al., 2018; Y. Zhou et al., 2023). In the graphical network, each node represents a symptom, while the thickness of the edges reflects the magnitude of the regularized partial correlations linking two distinct symptoms. Additionally, blue edges represent positive regularized partial correlations, while red edges represent negative ones.

The centrality indices for each network were calculated using the *centralityPlot* function in *qgraph*, focusing on expected influence (EI), which measures a node's cumulative impact while retaining the sign of edge weights (Robinaugh et al., 2016). One-step EI assesses a node's influence through immediate

neighbors. Nodes linking different communities (distinguished by colors) were identified as “bridge nodes,” and their bridge expected influence (bEI) was calculated to identify key connectors (Jones et al., 2021).

The accuracy of edge weights and the stability of centrality and bridge centrality indices (EI and bEI) were assessed using the bootstrap method with the *bootnet* package (Epskamp et al., 2018). Non-parametric bootstrapping was used to estimate 95% confidence intervals (CIs) for edge weights, followed by an edge weight comparison test to identify significant differences. To evaluate centrality stability, case-dropping bootstrapping was applied, and the centrality-stability coefficient (CS-coefficient, ideally above 0.5) was calculated, indicating the maximum proportion of samples that could be excluded while maintaining a 95% probability that centrality correlations remain above 0.7 (Epskamp & Fried, 2018; Jin et al., 2022). Finally, a centrality difference test was performed to identify significant differences between centrality estimates. All bootstrap procedures were set to 2000 iterations.

We further conducted a comparative analysis of the network models between genders utilizing the Network Comparison Test (NCT) (van Borkulo et al., 2023). This approach enabled us to assess potential differences in both global network strength and global network structure between the two networks.

2.3.2 Estimation of Bayesian network

To further investigate the directional dependencies and potential pathways, we conducted a Bayesian network analysis, which is characterized by the integration of a directed acyclic graph (DAG) and a probability distribution (Briganti et al., 2023). The DAG presents the direction and conditional independence relationships between symptoms (Briganti et al., 2023; Pearl, 2009). We employed the package *bnlearn* and opted for a hill-climbing algorithm for model estimation. Additionally, a non-parametric bootstrapping procedure with 2,000 iterations was performed to ensure the stability of the network structure. To ensure optimal compatibility, we retain the edges present in 85% of the networks and the directions present in over 50% of the networks (Briganti et al., 2023; J. Zhou et al., 2022). Thereafter, the average network is computed and visualized using the R package *Rgraphviz* package. All analyses were carried out in R 4.4.2.

3. Results

3.1 Study sample and description of variables

In total, 10,479 valid questionnaires were involved in the final statistical analysis. Among all participants, 2,654 individuals (25.3%, 95% CI: 24.5% – 26.2%) reported engaging in NSSI within the past 12 months, of whom 1,121 were male. The majority of the adolescents were aged between 9 and 15, with only 9.42% exceeding 16 years of age. The mean scores and standard deviations of RCMAS factors and functions of NSSI were presented in Table 1. The OSI22 items (i.e., addiction-feature items of NSSI) displayed significantly skewed distributions and were reported as ordinal variables in the descriptive statistics (for network analysis, these variables were nonetheless analyzed as continuous variables).

Table 1
Basic information of participants and description of variables.

Variables	Male	Female	Total
	(N = 1,121)	**(N = 1,533)**	**(N = 2,654)**
age (years, %)			
– 9–12	333 (29.7%)	429 (28%)	762 (28.7%)
– 13–15	674 (60.1%)	968 (63.1%)	1,642 (61.9%)
– 16–18	114 (10.2%)	136.00 (8.87%)	250.00 (9.42%)
RCMAS factors			
Physiological anxiety	3.49 ± 2.72	4.55 ± 2.88	4.10 ± 2.86
Worry and oversensitivity	5.09 ± 3.56	6.83 ± 3.58	6.09 ± 3.67
Social concern and concentration	2.57 ± 2.14	3.39 ± 2.27	3.04 ± 2.25
Functions of NSSI			
Internal emotion regulation	4.70 ± 6.37	5.66 ± 6.60	5.25 ± 6.52
External emotion regulation	2.61 ± 2.91	3.06 ± 2.90	2.87 ± 2.91
Social influence	4.47 ± 6.09	4.47 ± 5.89	4.47 ± 5.97
Sensation seeking	1.82 ± 2.74	1.64 ± 2.49	1.72 ± 2.60
NSSI's addictive features			
OSI22_1			
– 0	935 (83.4%)	1,083 (70.7%)	2,018 (76%)
– 1	108.00 (9.63%)	233 (15.2%)	341 (12.8%)
– 2	46 (4.1%)	131.00 (8.55%)	177.00 (6.67%)
– 3	18.00 (1.61%)	46 (3%)	64.00 (2.41%)
– 4	14.00 (1.25%)	40.00 (2.61%)	54.00 (2.03%)
OSI22_2			
– 0	981 (87.5%)	1,220 (79.6%)	2,201 (82.9%)
– 1	81.00 (7.23%)	176 (11.5%)	257.00 (9.68%)
– 2	31.00 (2.77%)	76.00 (4.96%)	107.00 (4.03%)
– 3	13.00 (1.16%)	27.00 (1.76%)	40.00 (1.51%)
– 4	15.00 (1.34%)	34.00 (2.22%)	49.00 (1.85%)

Variables	Male	Female	Total
	(N = 1,121)	(N = 1,533)	(N = 2,654)
OSI22_3			
− 0	1,011 (90.2%)	1,297 (84.6%)	2,308 (87%)
− 1	60.00 (5.35%)	131.00 (8.55%)	191 (7.2%)
− 2	26.00 (2.32%)	63.00 (4.11%)	89.00 (3.35%)
− 3	11.00 (0.98%)	17.00 (1.11%)	28.00 (1.06%)
− 4	13.00 (1.16%)	25.00 (1.63%)	38.00 (1.43%)
OSI22_4			
− 0	1,000 (89.2%)	1,278 (83.4%)	2,278 (85.8%)
− 1	60.00 (5.35%)	139.00 (9.07%)	199 (7.5%)
− 2	27.00 (2.41%)	60.00 (3.91%)	87.00 (3.28%)
− 3	16.00 (1.43%)	28.00 (1.83%)	44.00 (1.66%)
− 4	18.00 (1.61%)	28.00 (1.83%)	46.00 (1.73%)
OSI22_5			
− 0	916 (81.7%)	1,083 (70.7%)	1,999 (75.3%)
− 1	111 (9.9%)	219 (14.3%)	330 (12.4%)
− 2	45.00 (4.01%)	104.00 (6.78%)	149.00 (5.61%)
− 3	20.00 (1.78%)	65.00 (4.24%)	85 (3.2%)
− 4	29.00 (2.59%)	62.00 (4.04%)	91.00 (3.43%)
OSI22_6			
− 0	922 (82.2%)	1,086 (70.8%)	2,008 (75.7%)
− 1	102 (9.1%)	228 (14.9%)	330 (12.4%)
− 2	49.00 (4.37%)	109.00 (7.11%)	158.00 (5.95%)
− 3	20.00 (1.78%)	44.00 (2.87%)	64.00 (2.41%)
− 4	28 (2.5%)	66.00 (4.31%)	94.00 (3.54%)
OSI22_7			
− 0	967 (86.3%)	1,267 (82.7%)	2,234 (84.2%)
− 1	78.00 (6.96%)	140.00 (9.13%)	218.00 (8.21%)

Variables	Male	Female	Total
	(N = 1,121)	(N = 1,533)	(N = 2,654)
− 2	48.00 (4.28%)	69 (4.5%)	117.00 (4.41%)
− 3	9 (0.8%)	27.00 (1.76%)	36.00 (1.36%)
− 4	19.00 (1.69%)	30.00 (1.96%)	49.00 (1.85%)

Note: The statistical distribution of RCMAS factors and the functions of NSSI were presented as mean ± standard deviation, while the distribution of OSI22 items was presented as a percentage based on scores (0 = never, 1 = occasionally, 2 = sometimes, 3 = often, 4 = always). RCMAS, Revised Children's Manifest Anxiety Scale; NSSI, non-suicidal self-injury; OSI, Ottawa Self-Injury Inventory.

Table 2
Items of OSI's Addictive Features scale and their labels in this study.

Node name	Item	Label
OSI22_1	The self-injurious behaviour occurs more often than intended?	Frequency
OSI22_2	The severity in which the self-injurious behaviour occurs has increased (e.g., deeper cuts, more extensive parts of your body)?	Severity
OSI22_3	If the self-injurious behaviour produced an effect when started, you now need to self-injure more frequently or with greater intensity to produce the same effect?	Tolerance
OSI22_4	This behaviour or thinking about it consumes a significant amount of your time (e.g., planning and thinking about it, collecting and hiding sharp objects, doing it and recovering from it)?	Occupy time
OSI22_5	Despite a desire to cut down or control this behaviour, you are unable to do so?	Hard to control
OSI22_6	You continue this behaviour despite recognizing that it is harmful to you physically and/or emotionally?	Continued despite harm
OSI22_7	Important social, family, academic or recreational activities are given up or reduced because of this behaviour?	Neglect social life

Note: OSI, Ottawa Self-Injury Inventory.

3.2 Undirected network

Figure 1 shows the network structure, EI and bEI of the integrative symptom network of anxiety, NSSI functions, and addictive features among adolescents. The mean predictability of all nodes was 0.66. The node *f_IER* demonstrated the highest positive EI and bEI values, indicating that the function of internal emotion regulation was the most influential item in the network, integrating all three clusters. Addictive features of *OSI22_6* (continued despite harm), *OSI22_5* (hard to control), *OSI22_2* (severity)" and anxiety

symptom *WOS* (worry and oversensitivity) could also be identified as key nodes, with extremely close EI values, second only to *f_IER*. It is estimated by bEI that *f_EER* (external emotion regulation) and *PA* (physical anxiety) function as two additional primary bridge nodes within the network. Conversely, *f_SS* (sensation seeking) exerts the most negative bridging role. Other centrality indices (strength, closeness and betweenness) are displayed in Figure S1. The strongest correlations were found between *SCC* (social concern and concentration) and *f_IER* (r = 0.54), *WOS* and *OSI22_6* (r = 0.49), and *f_SS* and *OSI22_5* (r = 0.49).

The network model exhibited great robustness (Fig. 2), as indicated by a CS-coefficient for EI and bEI of 0.75. The bootstrapped 95% CIs of each edge weight are demonstrated in Figure S2, while the outcome of the edge weight comparison test and centrality difference test are presented in Figures S3 & S4. The comparison of network models between male (n = 1,121) and female (n = 1,533) adolescents with NSSI revealed no significant differences in global network strength (male: 6.90, female: 6.94, p = 0.84; Figures S5 & S6) or edge weights (M = 0.19, p = 0.21).

3.3 Bayesian network

Figure 3 shows the DAG learned from the Bayesian network, indicating directional dependencies among anxiety symptoms, NSSI functions, and addictive features. Arrows denote putative orientations consistent with the data rather than causal effects. In this graph, *f_IER* is positioned at the highest level, indicating its priority in the causal chain, while *OSI22_7* (neglect of social life) is placed at the bottom as an outcome factor. Starting from *f_IER*, three main branches can be identified: (1) f_IER → f_EER → anxiety symptoms; (2) f_IER → OSI22_1 (frequency) → other addictive features → OSI22_7; (3) f_IER → f_SI → OSI22_7. Additionally, the node *OSI22_1* appears to serve as a critical bridge between *f_IER* and *PA*.

4. Discussion

In this large school-based sample of Chinese adolescents with past-year NSSI, we integrated anxiety symptoms, NSSI functions, and addictive features within a single network framework. Using EBICglasso networks and Bayesian structure learning on cross-sectional data, we found that deficits in internal emotion regulation (IER) emerged as the most central node and a key bridge linking anxiety and addictive features. The DAG further delineated candidate directional dependencies, suggesting that IER may connect to higher NSSI addictive features and anxiety symptoms, ultimately relating to social neglect. To our knowledge, this is one of the earlier studies to examine these constructs jointly using network-based approaches, extending prior work that typically considered motives, anxiety, or addictive features in isolation.

We first consider how NSSI functions contribute to addictive features. Among all functions, IER emerged as the central symptom and occupied the top position in the DAG, playing a predominant role in activating other NSSI functions, anxiety symptoms, and addictive features. This finding aligns with previous reports identifying IER as the most frequently endorsed function of NSSI, indicating that the

primary purpose of self-injury in adolescents is to alleviate negative emotional states, such as despair, sadness, and hopelessness (Chapman et al., 2006; Ding et al., 2023). When adolescents encounter overwhelming negative emotions, NSSI may become their primary coping strategy despite its maladaptive nature (Klonsky et al., 2014). The centrality of IER also reflects adolescence as a unique developmental period characterized by heightened emotional reactivity, significantly increasing vulnerability to mood disorders (Casey et al., 2008; Guan et al., 2024). Supporting these behavioral findings, neuroimaging studies have similarly revealed differences in emotional processing, with fMRI data indicating altered limbic system activation in adolescents with NSSI compared to healthy adolescents (Plener et al., 2012). Taken together, these results highlight IER as a critical proximal factor in the development of addictive features associated with NSSI behaviors.

Network analysis suggests that the EER function is a crucial bridge, second only to IER, aligning with evidence that emotion regulation difficulties are upstream contributors to anxiety (Ruan et al., 2023). However, EER's influence on addictive features was weaker than IER's, implying that internal emotion regulation deficits more directly drive addictive behaviors (Hand et al., 2024). SI serves as the bridge by which IER indirectly escalates NSSI into addictive outcomes: intrapersonal motives heighten NSSI frequency, then peer processes reinforce and spread the behavior—consistent with intrapersonal-dominant functions and peer-socialization evidence (Klonsky et al., 2015; Schwartz-Mette & Lawrence, 2019). Finally, SS emerged as an independent downstream symptom with the lowest centrality, consistent with reports that sensation seeking is generally less pronounced among Chinese adolescents (Chen et al., 2022b).

Within the directed addiction-feature cluster, the function of IER first linked to higher NSSI frequency (OSI22_1), which subsequently connected to classic addiction-like features—loss of control (OSI22_5) and continued self-injury despite harm (OSI22_6) —culminating in social withdrawal (OSI22_7). Frequent NSSI can provide immediate emotional relief, thereby reinforcing the behavior (Blasco-Fontecilla et al., 2016; Gray et al., 2022). The transition from higher frequency to loss of control mirrors typical addiction trajectories, mediated by neurobiological negative reinforcement mechanisms involving endogenous opioids and HPA axis modulation (Stanley et al., 2010; Johnson et al., 2022). Complementing the negative-reinforcement account, repeated relief from NSSI likely recruits and sensitizes mesolimbic reward circuitry, shifting control from ventral to dorsal striatum and weakening prefrontal inhibitory control—thereby converting goal-directed coping into rigid, compulsive habits (Berridge & Robinson, 2016; Koob & Volkow, 2016). Persisting in NSSI despite harm is thus associated with chronic, difficult-to-control behavior and downstream impairments in academic, occupational, and social functioning (Turner et al., 2017). In parallel, greater frequency was associated with greater tolerance (OSI22_3), which was linked to higher severity (OSI22_2) and longer time occupation (OSI22_4)—an escalation pattern needed to achieve the same relief and mirroring core addiction mechanisms (Kalin, 2020; Volkow & Boyle, 2018). Taken together, these findings highlight frequency and tolerance as early leverage points to prevent progression toward uncontrollable, socially impairing NSSI.

Neglect of social life (OSI22_7) emerged as the terminal node in the addiction-related pathway, implying that social dysfunction is the cumulative endpoint of a self-reinforcing NSSI cycle, rather than a by-product (Lee et al., 2014; R. T. Liu et al., 2014). One possible explanation is that adolescents experiencing emotional distress may seek social support; however, due to an adverse social environment and heightened sensitivity to rejection—factors commonly observed in NSSI adolescent— such efforts are often ineffective, resulting in further social withdrawal (Wolff et al., 2014; Haliczer & Dixon-Gordon, 2023). Correspondingly, longitudinal work shows that peer NSSI, dysfunctional friendships, and heightened rejection sensitivity accelerate this spiral (Barrocas et al., 2011; J. Liu et al., 2022; You et al., 2013). Neuroimaging studies further reveal hyper-reactive medial and ventrolateral prefrontal responses to exclusion in NSSI adolescents (Groschwitz et al., 2016), underscoring their vulnerability to social stress. Therefore, effective interventions should combine emotion-regulation training with strategies aimed at restoring peer support networks and reducing social stressors.

Interestingly, our findings revealed an apparent contradiction: PA appeared as a key bridge node associated with both NSSI functions and addictive features in the undirected network yet appeared downstream in the DAG. This discrepancy likely reflects the limitation of DAGs, which can only represent unidirectional relationships and thus fail to capture feedback loops (Crielaard et al., 2023; Briganti et al., 2024). In reality, each NSSI episode temporarily reduce physiological arousal through negative reinforcement (Novak & Meyer, 2021), but repeated cycle can disrupt stress-response systems, such as the HPA axis, leading to blunted cortisol reactivity (Kaess et al., 2012; Menke, 2024). Rather than a contradiction, this supports the reciprocal dynamic between NSSI and physiological anxiety within an addiction-related reinforcement cycle. Moreover, we observed that WOS (worry/oversensitivity) influences PA via SCC (social concern/concentration), aligning with cognitive models linking worry to somatic vigilance (Leigh & Clark, 2018; Freyler et al., 2013; Kumar et al., 2019). These upstream mechanisms may heighten physical arousal and contribute to NSSI maintenance and addictive features. Clinically, targeting both IER deficits and physiological hyperarousal may offer an effective strategy for disrupting this cycle.

Among 10,479 valid questionnaires, 25.3% of adolescents reported engaging in NSSI at least once in the past 12 months, which is higher than the 15.5% prevalence rate in Hong Kong (Tang et al., 2011). This difference may be related to economic factors (Lim et al., 2019). Although females exhibit a higher prevalence of NSSI compared to males, consistent with previous research (Bresin & Schoenleber, 2015), no significant gender differences were found in our network analysis. This suggests shared mechanisms across genders. Additionally, we observed a higher incidence of NSSI in early to mid-adolescence, which aligns with prior studies (Brown & Plener, 2017) This may reflect the relatively active brain development during early adolescence (Casey et al., 2008).

Despite the insights provided by this study, several limitations should be acknowledged. First, although the DAG provides preliminary insights into both the strength and direction of potential connections among the analyzed variables, caution is warranted, as causal inference is only fully justifiable when all underlying assumptions are met (Moffa et al., 2017). Longitudinal studies on the progression of NSSI are

needed for further validation. Second, our findings rely on self-report questionnaires, which may introduce bias. Previous research has shown that the method of assessment—self-report versus interview—can significantly impact the evaluation of NSSI severity (Akbari et al., 2024). Given the strong association between NSSI and social life observed in our study, future research should consider alternative assessment methods to better capture the complexity of these relationships.

5. Conclusion

In summary, our findings offer novel insights into the symptom progression pathways underlying adolescent NSSI, illustrating a potential originating from internal and external emotional dysregulation, passing through physiological anxiety and escalating addictive features, and ultimately culminating in social dysfunction. Identifying IER as the central and upstream node underscores its primary role as the initiating point in the complex cascade leading to severe addictive manifestations and impaired social functioning. Clinically, these results highlight the necessity of early interventions focused specifically on enhancing adaptive emotion regulation strategies, mitigating physiological anxiety, and strengthening social support networks. Such targeted approaches may interrupt the progressive chain of symptoms, thereby effectively preventing the consolidation and chronicity of NSSI behaviors in adolescents.

Declarations

Ethics approval and consent to participate:

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of West China Hospital, Sichuan University (approval number: NO. 2019-907). Written informed consent was obtained from all participants and their guardians prior to study enrollment.

Consent for publication: Not applicable.

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Competing interests:

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions Statement

Qiyuan Cao: Data curation, Investigation, Visualization, Writing – original draft.Jiaqi Xu: Conceptualization, Methodology, Writing – review & editing.Zhixiong Li: Investigation.Kexin Zhou: Investigation.Lan Wei: Investigation.Jing Li: Funding acquisition, Supervision, Validation.Xiacan Chen:

Supervision, Writing – review & editing.Jiajun Xu: Project administration, Supervision, Writing – review & editing.All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

Data Availability

Data in the current study is available from the corresponding author on reasonable request

References

1. Akbari M, Seydavi M, Firoozabadi MA, Babaeifard M. Distress tolerance and lifetime frequency of non-suicidal self-injury (NSSI): A systematic review and meta-analysis. Clin Psychol Psychother. 2024;31(1):e2957. https://doi.org/10.1002/cpp.2957.
2. al'Absi M. The influence of stress and early life adversity on addiction: Psychobiological mechanisms of risk and resilience. Int Rev Neurobiol. 2020;152:71–100. https://doi.org/10.1016/bs.irn.2020.03.012.
3. Anker JJ, Kushner MG. Co-Occurring Alcohol Use Disorder and Anxiety. Alcohol Research: Curr Reviews. 2019;40(1). https://doi.org/10.35946/arcr.v40.1.03. arcr.v40.1.03.
4. Barrocas AL, Jenness JL, Davis TS, Oppenheimer CW, Technow JR, Gulley LD, Badanes LS, Hankin BL. Developmental perspectives on vulnerability to nonsuicidal self-injury in youth. Adv Child Dev Behav. 2011;40:301–36. https://doi.org/10.1016/b978-0-12-386491-8.00008-6.
5. Bentley KH, Cassiello-Robbins CF, Vittorio L, Sauer-Zavala S, Barlow DH. The association between nonsuicidal self-injury and the emotional disorders: A meta-analytic review. Clin Psychol Rev. 2015;37:72–88. https://doi.org/10.1016/j.cpr.2015.02.006.
6. Berridge KC, Robinson TE. Liking, Wanting and the Incentive-Sensitization Theory of Addiction. Am Psychol. 2016;71(8):670–9. https://doi.org/10.1037/amp0000059.
7. Blasco-Fontecilla H, Fernández-Fernández R, Colino L, Fajardo L, Perteguer-Barrio R, de Leon J. The Addictive Model of Self-Harming (Non-suicidal and Suicidal) Behavior. Front Psychiatry. 2016;7:8. https://doi.org/10.3389/fpsyt.2016.00008.
8. Borsboom D. A network theory of mental disorders. World Psychiatry: Official J World Psychiatric Association (WPA). 2017;16(1). Article 1. https://doi.org/10.1002/wps.20375.
9. Bresin K, Schoenleber M. Gender differences in the prevalence of nonsuicidal self-injury: A meta-analysis. Clin Psychol Rev. 2015;38:55–64. https://doi.org/10.1016/j.cpr.2015.02.009.
10. Briganti G, Kempenaers C, Braun S, Fried EI, Linkowski P. Network analysis of empathy items from the interpersonal reactivity index in 1973 young adults. Psychiatry Res. 2018;265:87–92. https://doi.org/10.1016/j.psychres.2018.03.082.
11. Briganti, G., Scutari, M., Epskamp, S., Borsboom, D., Hoekstra, R. H. A., Golino,H. F., Christensen, A. P., Morvan, Y., Ebrahimi, O. V., Costantini, G., Heeren, A.,de Ron, J., Bringmann, L. F., Huth, K., Haslbeck, J. M. B., Isvoranu, A., Marsman,M., Blanken, T., Gilbert, A., … McNally, R. J. (2024). Network analysis:

An overview for mental health research. International Journal of Methods in Psychiatric Research,33(4), e2034. https://doi.org/10.1002/mpr.2034.

12. Briganti G, Scutari M, McNally RJ. A tutorial on bayesian networks for psychopathology researchers. Psychol Methods. 2023;28(4):947–61. https://doi.org/10.1037/met0000479.
13. Brooke S, Horn N. The meaning of self-injury and overdosing amongst women fulfilling the diagnostic criteria for 'borderline personality disorder'. Psychol Psychotherapy: Theory Res Pract. 2010;83(2):113–28. https://doi.org/10.1348/147608309X468211.
14. Brown RC, Plener PL. Non-suicidal Self-Injury in Adolescence. Curr Psychiatry Rep. 2017;19(3):20. https://doi.org/10.1007/s11920-017-0767-9.
15. Casey BJ, Jones RM, Hare TA. The adolescent brain. Ann N Y Acad Sci. 2008;1124:111–26. https://doi.org/10.1196/annals.1440.010.
16. Castaneda A, Mccandless BR, Palermo DS. (1956). The children's form of the manifest anxiety scale. Child Dev, 27(3).
17. Chapman AL, Gratz KL, Brown MZ. Solving the puzzle of deliberate self-harm: The experiential avoidance model. Behav Res Ther. 2006;44(3):371–94. https://doi.org/10.1016/j.brat.2005.03.005.
18. Chen H, Pan B, Zhang C, Guo Y, Zhou J, Wang X. Revision of the non-suicidal self-injury behavior scale for adolescents with mental disorder. J Cent South Univ Med Sci (Vol. 2022a;47(3):301–8.
19. Chen H, Pan B, Zhang C, Guo Y, Zhou J, Wang X. Revision of the non-suicidal self-injury behavior scale for adolescents with mental disorder. Zhong Nan Da Xue Xue Bao. Yi Xue Ban = Journal of Central South University. Med Sci. 2022b;47(3):301–8. https://doi.org/10.11817/j.issn.1672-7347.2022.210549.
20. Cloutier A, McDonald PP. (2003). Transcription factor activation in human neutrophils. https://doi.org/10.1159/000071553
21. Crielaard L, Quax R, Sawyer ADM, Vasconcelos VV, Nicolaou M, Stronks K, Sloot PMA. Using network analysis to identify leverage points based on causal loop diagrams leads to false inference. Sci Rep. 2023;13:21046. https://doi.org/10.1038/s41598-023-46531-z.
22. Ding H, Cao B, Sun Q. The association between problematic internet use and social anxiety within adolescents and young adults: A systematic review and meta-analysis. Front Public Health. 2023;11. https://doi.org/10.3389/fpubh.2023.1275723.
23. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: A tutorial paper. Behav Res Methods. 2018;50(1):195–212. https://doi.org/10.3758/s13428-017-0862-1.
24. Epskamp S, Fried EI. A tutorial on regularized partial correlation networks. Psychol Methods. 2018;23(4):617–34. https://doi.org/10.1037/met0000167.
25. Feng Y, Jiang G. (2008). The relationship between adolescent self-injury behaviors and individual emotional factors and family environmental factors [Master's Thesis]. In Central China Normal University.

26. Freyler A, Kohegyi Z, Köteles F, Kökönyei G, Bárdos G. Modern health worries, subjective somatic symptoms, somatosensory amplification, and health anxiety in adolescents. J Health Psychol. 2013;18(6):773–81. https://doi.org/10.1177/1359105313479629.
27. Gray N, Hasking P, Boyes M. Cognitive and emotional factors associated with the desire to cease non-suicidal self-injury. J Clin Psychol. 2022;78(9):1896–911. https://doi.org/10.1002/jclp.23336.
28. Groschwitz RC, Plener PL, Groen G, Bonenberger M, Abler B. Differential neural processing of social exclusion in adolescents with non-suicidal self-injury: An fMRI study. Psychiatry Res Neuroimaging. 2016;255:43–9. https://doi.org/10.1016/j.pscychresns.2016.08.001.
29. Guan M, Liu J, Li X, Cai M, Bi J, Zhou P, Wang Z, Wu S, Guo L, Wang H. The impact of depressive and anxious symptoms on non-suicidal self-injury behavior in adolescents: A network analysis. BMC Psychiatry. 2024;24(1). https://doi.org/10.1186/s12888-024-05599-1. Article 1.
30. Guérin-Marion C, Martin J, Deneault A-A, Lafontaine M-F, Bureau J-F. The functions and addictive features of non-suicidal self-injury: A confirmatory factor analysis of the Ottawa self-injury inventory in a university sample. Psychiatry Res. 2018;264:316–21. https://doi.org/10.1016/j.psychres.2018.04.019.
31. Haliczer LA, Dixon-Gordon KL. Social stressors, emotional responses, and NSSI urges and behaviors in daily life. J Affect Disord. 2023;338:601–9. https://doi.org/10.1016/j.jad.2023.06.043.
32. Hand LJ, Paterson LM, Lingford-Hughes AR. Re-evaluating our focus in addiction: Emotional dysregulation is a critical driver of relapse to drug use. Translational Psychiatry. 2024;14(1):467. https://doi.org/10.1038/s41398-024-03159-5.
33. Hawton K, Bergen H, Cooper J, Turnbull P, Waters K, Ness J, Kapur N. Suicide following self-harm: Findings from the Multicentre Study of self-harm in England, 2000–2012. J Affect Disord. 2015;175:147–51. https://doi.org/10.1016/j.jad.2014.12.062.
34. Holm AL, Severinsson E. Desire to survive emotional pain related to self-harm: A Norwegian hermeneutic study. Nurs Health Sci. 2010;12(1):52–7. https://doi.org/10.1111/j.1442-2018.2009.00485.x.
35. Horne O, Csipke E. From feeling too little and too much, to feeling more and less? A nonparadoxical theory of the functions of self-harm. Qual Health Res. 2009;19(5):655–67. https://doi.org/10.1177/1049732309334249.
36. Jiang Y, Yu H, Zheng Q, Zhu Y, Qin Q, Zhang J, Cui R, Wu W, Wu C, Li T, Ji C, Jiao D, Wang W. Effects of decision making and impulsivity on the addictive features of non-suicidal self-injury behaviors in adolescents with depressive disorder. BMC Psychiatry. 2024;24(1):708. https://doi.org/10.1186/s12888-024-06121-3.
37. Jin Y, Sha S, Tian T, Wang Q, Liang S, Wang Z, Liu Y, Cheung T, Su Z, Ng CH, Xiang Y-T. Network analysis of comorbid depression and anxiety and their associations with quality of life among clinicians in public hospitals during the late stage of the COVID-19 pandemic in China. J Affect Disord. 2022;314:193. https://doi.org/10.1016/j.jad.2022.06.051.

38. Johnson BN, McKernan LC, Bruehl S. A Theoretical Endogenous Opioid Neurobiological Framework for Co-occurring Pain, Trauma, and Non-suicidal Self-injury. Curr Pain Headache Rep. 2022;26(6):405–14. https://doi.org/10.1007/s11916-022-01043-9.
39. Jones PJ, Ma R, McNally RJ. (2021). Bridge centrality: A network approach to understanding comorbidity. Multivariate Behavioral Research. https://www.tandfonline.com/doi/abs/10.1080/00273171.2019.1614898
40. Kaess M, Hille M, Parzer P, Maser-Gluth C, Resch F, Brunner R. Alterations in the neuroendocrinological stress response to acute psychosocial stress in adolescents engaging in nonsuicidal self-injury. Psychoneuroendocrinology. 2012;37(1):157–61. https://doi.org/10.1016/j.psyneuen.2011.05.009.
41. Kalin NH. Substance Use Disorders and Addiction: Mechanisms, Trends, and Treatment Implications. Am J Psychiatry. 2020;177(11):1015–8. https://doi.org/10.1176/appi.ajp.2020.20091382.
42. Klonsky ED, Glenn CR, Styer DM, Olino TM, Washburn JJ. The functions of nonsuicidal self-injury: Converging evidence for a two-factor structure. Child Adolesc Psychiatry Mental Health. 2015;9:44. https://doi.org/10.1186/s13034-015-0073-4.
43. Klonsky ED, Victor SE, Saffer BY. Nonsuicidal self-injury: What we know, and what we need to know. Can J Psychiatry. 2014;59(11):565–8. https://doi.org/10.1177/070674371405901101.
44. Koob GF, Volkow ND. Neurobiology of addiction: A neurocircuitry analysis. Lancet Psychiatry. 2016;3(8):760–73. https://doi.org/10.1016/S2215-0366(16)00104-8.
45. Kumar V, Avasthi A, Grover S. Correlates of worry and functional somatic symptoms in generalized anxiety disorder. Industrial Psychiatry J. 2019;28(1):29–36. https://doi.org/10.4103/ipj.ipj_31_19.
46. Lai HMX, Cleary M, Sitharthan T, Hunt GE. Prevalence of comorbid substance use, anxiety and mood disorders in epidemiological surveys, 1990–2014: A systematic review and meta-analysis. Drug Alcohol Depend. 2015;154:1–13. https://doi.org/10.1016/j.drugalcdep.2015.05.031.
47. Lee Y-T, Liu S-I, Huang H-C, Sun F-J, Huang C-R, Yeung A. Validity and reliability of the Chinese version of the Short Form of Quality of Life Enjoyment and Satisfaction Questionnaire (Q-LES-Q-SF). Qual Life Res. 2014;23(3):907–16. https://doi.org/10.1007/s11136-013-0528-0.
48. Leigh E, Clark DM. (2018). Understanding Social Anxiety Disorder in Adolescents and Improving Treatment Outcomes: Applying the Cognitive Model of Clark and Wells (1995). Clinical Child and Family Psychology Review, 21(3), 388–414. https://doi.org/10.1007/s10567-018-0258-5
49. Lim K-S, Wong CH, McIntyre RS, Wang J, Zhang Z, Tran BX, Tan W, Ho CS, Ho RC. Global Lifetime and 12-Month Prevalence of Suicidal Behavior, Deliberate Self-Harm and Non-Suicidal Self-Injury in Children and Adolescents between 1989 and 2018: A Meta-Analysis. Int J Environ Res Public Health. 2019;16(22):4581. https://doi.org/10.3390/ijerph16224581.
50. Liu J, Gao Y, Liang C, Liu X. The potential addictive mechanism involved in repetitive nonsuicidal self-injury: The roles of emotion dysregulation and impulsivity in adolescents. J Behav Addictions. 2022;11(4):953–62. https://doi.org/10.1556/2006.2022.00077.

51. Liu RT, Kraines MA, Massing-Schaffer M, Alloy LB. Rejection Sensitivity and Depression: Mediation by Stress Generation. Psychiatry: Interpers Biol Processes. 2014;77(1):86–97. https://doi.org/10.1521/psyc.2014.77.1.86.
52. Lloyd-Richardson EE, Perrine N, Dierker L, Kelley ML. Characteristics and functions of non-suicidal self-injury in a community sample of adolescents. Psychol Med. 2007;37(8):1183–92. https://doi.org/10.1017/S003329170700027X.
53. Luo D, Tan L, Huang X, Lai M, Shi H, Li J, Chen X, Xu J, Guo W. Functions of nonsuicidal self-injury and repeated nonsuicidal self-injury among adolescents: A moderating role of addictive features. J Psychiatr Res. 2024;175:251–8. https://doi.org/10.1016/j.jpsychires.2024.04.049.
54. Lüthi A, Lüscher C. Pathological circuit function underlying addiction and anxiety disorders. Nat Neurosci. 2014;17(12):1635–43. https://doi.org/10.1038/nn.3849.
55. Mancinelli E, Sharka O, Lai T, Sgaravatti E, Salcuni S. Self-injury and Smartphone Addiction: Age and gender differences in a community sample of adolescents presenting self-injurious behavior. Health Psychol Open. 2021;8(2):20551029211038811. https://doi.org/10.1177/20551029211038811.
56. Martin J, Cloutier PF, Levesque C, Bureau J-F, Lafontaine M-F, Nixon MK. Psychometric properties of the functions and addictive features scales of the Ottawa Self-Injury Inventory: A preliminary investigation using a university sample. Psychol Assess. 2013a;25(3):1013–8. https://doi.org/10.1037/a0032575.
57. Martin J, Cloutier PF, Levesque C, Bureau J-F, Lafontaine M-F, Nixon MK. Psychometric properties of the functions and addictive features scales of the Ottawa Self-Injury Inventory: A preliminary investigation using a university sample. Psychol Assess. 2013b;25(3):1013–8. https://doi.org/10.1037/a0032575.
58. McEvoy D, Brannigan R, Cooke L, Butler E, Walsh C, Arensman E, Clarke M. Risk and protective factors for self-harm in adolescents and young adults: An umbrella review of systematic reviews. J Psychiatr Res. 2023;168:353–80. https://doi.org/10.1016/j.jpsychires.2023.10.017.
59. Menke A. The HPA Axis as Target for Depression. Curr Neuropharmacol. 2024;22(5):904–15. https://doi.org/10.2174/1570159X21666230811141557.
60. Moffa G, Catone G, Kuipers J, Kuipers E, Freeman D, Marwaha S, Lennox BR, Broome MR, Bebbington P. Using Directed Acyclic Graphs in Epidemiological Research in Psychosis: An Analysis of the Role of Bullying in Psychosis. Schizophr Bull. 2017;43(6):1273–9. https://doi.org/10.1093/schbul/sbx013.
61. Morgan C, Webb RT, Carr MJ, Kontopantelis E, Green J, Chew-Graham CA, Kapur N, Ashcroft DM. Incidence, clinical management, and mortality risk following self harm among children and adolescents: Cohort study in primary care. BMJ. 2017;359:j4351. https://doi.org/10.1136/bmj.j4351.
62. Nixon MK, Cloutier PF, Aggarwal S. Affect Regulation and Addictive Aspects of Repetitive Self-Injury in Hospitalized Adolescents. J Am Acad Child Adolesc Psychiatry. 2002;41(11):1333–41. https://doi.org/10.1097/00004583-200211000-00015.

63. Nixon MK, Levesque C, Preyde M, Vanderkooy J, Cloutier PF. The Ottawa Self-Injury Inventory: Evaluation of an assessment measure of nonsuicidal self-injury in an inpatient sample of adolescents. Child Adolesc Psychiatry Mental Health. 2015;9:26. https://doi.org/10.1186/s13034-015-0056-5.
64. Nock MK. Why do People Hurt Themselves? New Insights Into the Nature and Functions of Self-Injury. Curr Dir Psychol Sci. 2009;18(2):78–83. https://doi.org/10.1111/j.1467-8721.2009.01613.x.
65. Nock MK. (2010). Self-Injury. Annual Review of Clinical Psychology, 6(Volume 6, 2010), 339–363. https://doi.org/10.1146/annurev.clinpsy.121208.131258
66. Novak MA, Meyer JS. A Rhesus Monkey Model of Non-suicidal Self-Injury. Front Behav Neurosci. 2021;15. https://doi.org/10.3389/fnbeh.2021.674127.
67. Pearl J. (2009). Causality (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511803161
68. Pina AA, Silverman WK, Saavedra LM, Weems CF. An analysis of the RCMAS lie scale in a clinic sample of anxious children. J Anxiety Disord. 2001;15(5):443–57. https://doi.org/10.1016/s0887-6185(01)00075-5.
69. Plener PL, Bubalo N, Fladung AK, Ludolph AG, Lulé D. Prone to excitement: Adolescent females with Non-suicidal self-injury (NSSI) show altered cortical pattern to emotional and NSS-related material. Psychiatry Res. 2012;203(2–3):146–52. https://doi.org/10.1016/j.pscychresns.2011.12.012.
70. Plener PL, Schumacher TS, Munz LM, Groschwitz RC. The longitudinal course of non-suicidal self-injury and deliberate self-harm: A systematic review of the literature. Borderline Personality Disorder Emot Dysregulation. 2015;2:2. https://doi.org/10.1186/s40479-014-0024-3.
71. Pritchard TR, Fedchenko CA, Lewis SP. Self-Injury Is My Drug: The Functions of Describing Nonsuicidal Self-Injury as an Addiction. J Nerv Mental Disease. 2021;209(9):628–35. https://doi.org/10.1097/NMD.0000000000001359.
72. Reynolds CR, Richmond BO. What I think and feel: A revised measure of children's manifest anxiety. J Abnorm Child Psychol. 1978;6(2):271–80. https://doi.org/10.1007/BF00919131.
73. Robinaugh DJ, Millner AJ, McNally RJ. Identifying highly influential nodes in the complicated grief network. J Abnorm Psychol. 2016;125(6):747–57. https://doi.org/10.1037/abn0000181.
74. Ruan Q-N, Chen C-M, Yang J-S, Yan W-J, Huang Z-X. Network analysis of emotion regulation and reactivity in adolescents: Identifying central components and implications for anxiety and depression interventions. Front Psychiatry. 2023;14. https://doi.org/10.3389/fpsyt.2023.1230807.
75. Schwartz-Mette RA, Lawrence HR. Peer Socialization of Non-Suicidal Self-Injury in Adolescents' Close Friendships. J Abnorm Child Psychol. 2019;47(11):1851–62. https://doi.org/10.1007/s10802-019-00569-8.
76. Stanley B, Sher L, Wilson S, Ekman R, Huang Y, Mann JJ. Non-suicidal self-injurious behavior, endogenous opioids and monoamine neurotransmitters. J Affect Disord. 2010;124(1–2):134–40. https://doi.org/10.1016/j.jad.2009.10.028.

77. Tang J, Yu Y, Wu Y, Du Y, Ma Y, Zhu H, Zhang P, Liu Z. Association between non-suicidal self-injuries and suicide attempts in Chinese adolescents and college students: A cross-section study. PLoS ONE. 2011;6(4):e17977. https://doi.org/10.1371/journal.pone.0017977.
78. Turner BJ, Wakefield MA, Gratz KL, Chapman AL. Characterizing Interpersonal Difficulties Among Young Adults Who Engage in Nonsuicidal Self-Injury Using a Daily Diary. Behav Ther. 2017;48(3):366–79. https://doi.org/10.1016/j.beth.2016.07.001.
79. van Borkulo CD, van Bork R, Boschloo L, Kossakowski JJ, Tio P, Schoevers RA, Borsboom D, Waldorp LJ. Comparing network structures on three aspects: A permutation test. Psychol Methods. 2023;28(6):1273–85. https://doi.org/10.1037/met0000476.
80. Victor SE, Glenn CR, Klonsky ED. Is non-suicidal self-injury an addiction? A comparison of craving in substance use and non-suicidal self-injury. Psychiatry Res. 2012;197(1):73–7. https://doi.org/10.1016/j.psychres.2011.12.011.
81. Volkow ND, Boyle M. Neuroscience of Addiction: Relevance to Prevention and Treatment. Am J Psychiatry. 2018;175(8):729–40. https://doi.org/10.1176/appi.ajp.2018.17101174.
82. Wang Y, Lin J, Zhu Z, Chen S, Zou X, Wang Y, Huo L, Zhou Y. Quantifying the importance of factors in predicting non-suicidal self-injury among depressive Chinese adolescents: A comparative study between only child and non-only child groups. J Affect Disord. 2025;369:834–44. https://doi.org/10.1016/j.jad.2024.10.031.
83. Wolff JC, Frazier EA, Esposito-Smythers C, Becker SJ, Burke TA, Cataldo A, Spirito A. Negative cognitive style and perceived social support mediate the relationship between aggression and NSSI in hospitalized adolescents. J Adolesc. 2014;37(4):483–91. https://doi.org/10.1016/j.adolescence.2014.03.016.
84. Wu B, Zhang H, Chen J, Chen J, Liu Z, Cheng Y, Yuan T, Peng D. Potential mechanisms of non-suicidal self-injury (NSSI) in major depressive disorder: A systematic review. Gen Psychiatry. 2023;36(4):e100946. https://doi.org/10.1136/gpsych-2022-100946.
85. Ying W, Shen Y, Ou J, Chen H, Jiang F, Yang F, Li J, Qian X, Luo W, Wang G, Dong H. Identifying clinical risk factors correlated with addictive features of non-suicidal self-injury among a consecutive psychiatric outpatient sample of adolescents and young adults. Eur Arch Psychiatry Clin NeuroSci. 2024;274(2):291–300. https://doi.org/10.1007/s00406-023-01636-4.
86. You J, Lin MP, Fu K, Leung F. The best friend and friendship group influence on adolescent nonsuicidal self-injury. J Abnorm Child Psychol. 2013;41(6):993–1004. https://doi.org/10.1007/s10802-013-9734-z.
87. Zhou J, Zhou J, Feng L, Feng Y, Xiao L, Chen X, Yang J, Wang G. The associations between depressive symptoms, functional impairment, and quality of life, in patients with major depression: Undirected and bayesian network analyses. Psychol Med. 2022;53(14):6446. https://doi.org/10.1017/S0033291722003385.
88. Zhou Y, Lv X, Wang L, Li J, Gao X. What increases the risk of gamers being addicted? An integrated network model of personality–emotion–motivation of gaming disorder. Comput Hum Behav.

2023;141:107647. https://doi.org/10.1016/j.chb.2022.107647.

Figures

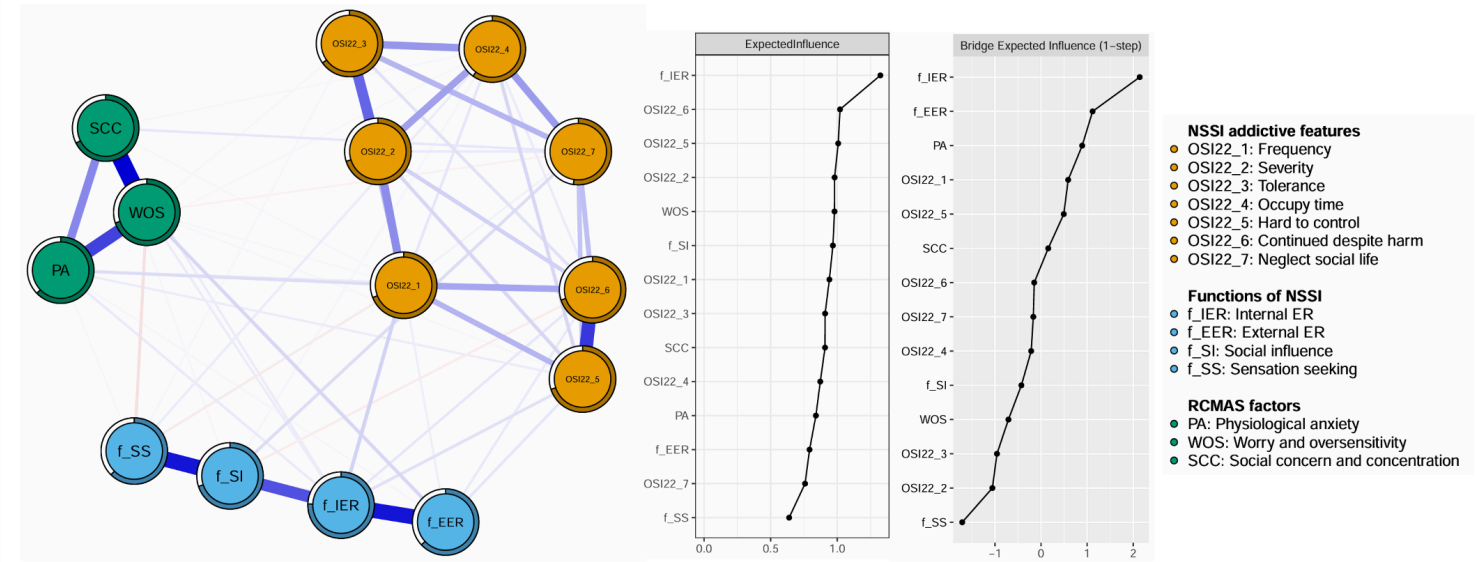


Figure 1

Undirected network structure of RCMAS factors, NSSI functions and addictive features among adolescents with NSSI behaviors.

Note: NSSI, non-suicidal self-injury. The expected influence and bridge expected influence (effect size) of each node are displayed in line graphs. The blue edges represent positive correlations, while the red edges represent negative ones. The thickness and saturation of an edge indicate its weight. The ring chart surrounding each node represents the predictability percentage. Abbreviation list for each node was shown on the right side.

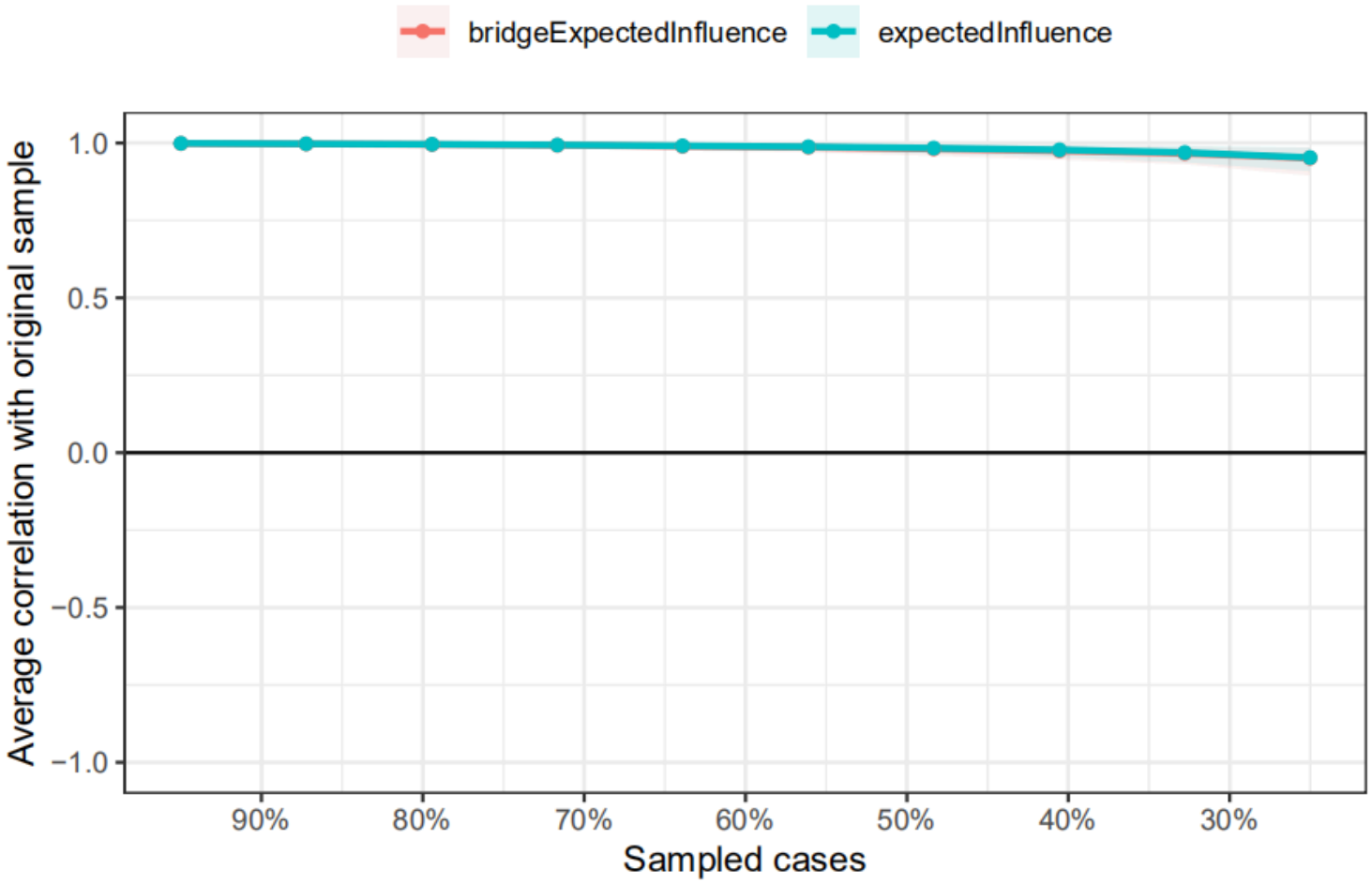


Figure 2

The stability of expected influence and bridge expected influence using case-dropping bootstrap.

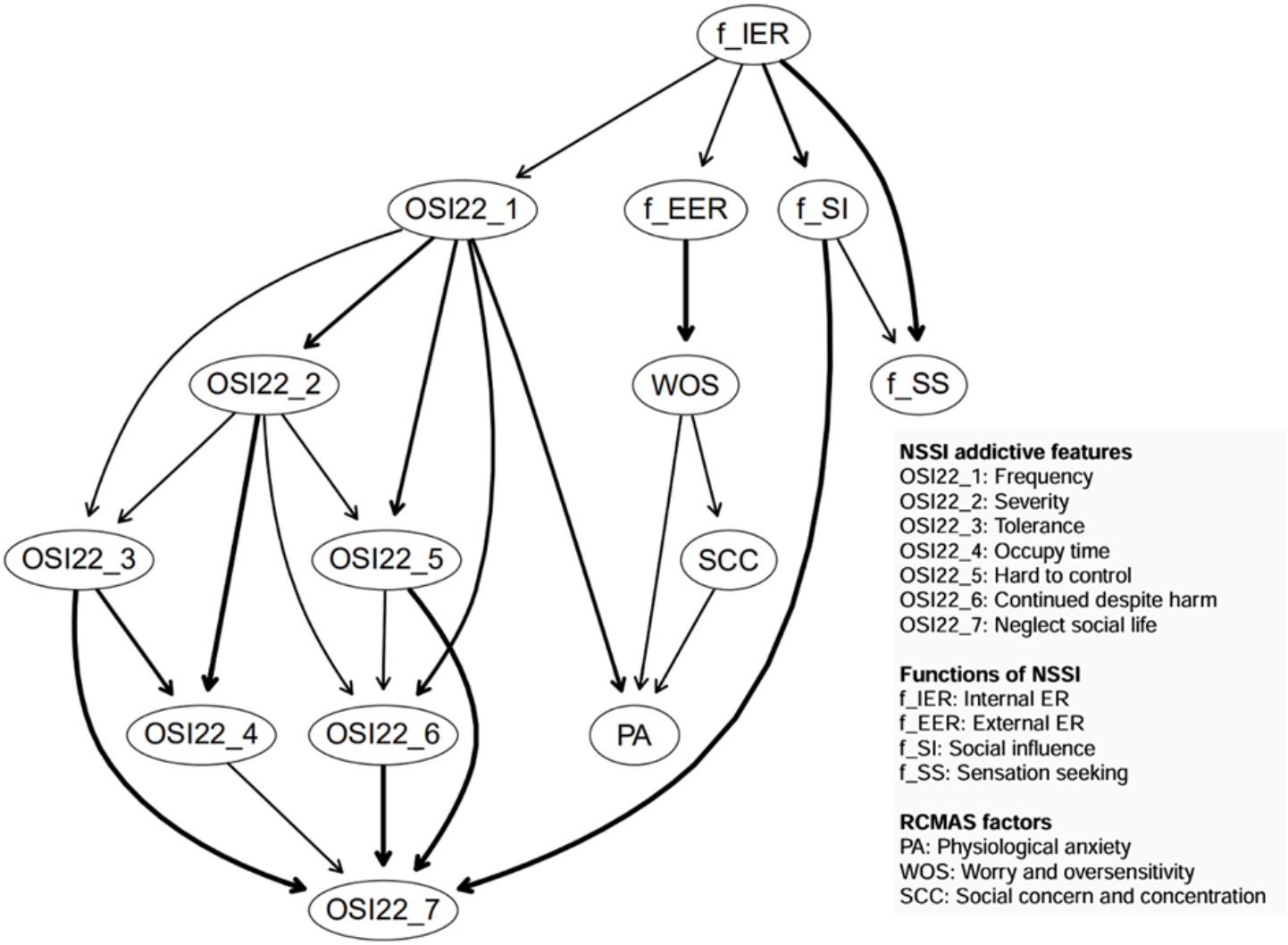


Figure 3

Directed acyclic graph (DAG) of anxiety symptoms, self-injury functions and addictive features among adolescents with NSSI behaviors.

Note: Edge thickness indicates the probability of edge direction.