KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 08 January 2026
Revised 25 February 2026
Accepted 30 March 2026
Published Online 10 June 2026

Journal of Adolescent and Youth Psychological Studies

Volume 7, Issue 6, pp 1-13

E-ISSN: 2981-2526

Random Forest Classification of Non-Suicidal Self-Injury Risk among Adolescents Using Trauma History, Shame, Impulsivity, and Peer Victimization Variables

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A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Guðmundsson, R., Paredes, V., & Kalniņa, I. (2026). Random Forest Classification of Non-Suicidal Self-Injury Risk among Adolescents Using Trauma History, Shame, Impulsivity, and Peer Victimization Variables. *Journal of Adolescent and Youth Psychological Studies, 7*(6), 1-13.
http://dx.doi.org/10.61838/kman.jayps.5455

A B S T R A C T

Objective: The objective of this study was to develop and evaluate a Random Forest classification model to identify adolescents at elevated risk of non-suicidal self-injury (NSSI) using trauma history, shame, impulsivity, and peer victimization as predictors.

Methods and Materials: A cross-sectional study was conducted in Chile with 1,248 adolescents aged 13–18 years (mean = 15.67, SD = 1.42) recruited from public and private schools. Participants completed validated self-report measures assessing trauma history, shame, impulsivity, peer victimization, and NSSI behaviors. The dataset was split into training (80%) and testing (20%) subsets. A Random Forest classification algorithm was applied to predict NSSI risk, and hyperparameters were optimized using grid search with five-fold cross-validation. Performance metrics included accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC). Feature importance was calculated to determine the relative contribution of each predictor variable.

Findings: Inferential analyses revealed that adolescents classified as high-risk for NSSI reported significantly higher levels of trauma history, shame, impulsivity, and peer victimization compared with low-risk peers. The Random Forest model achieved an overall accuracy of 89.2%, precision of 86.1%, recall of 84.5%, F1-score of 85.3%, and AUC of 0.938. Feature importance rankings indicated that shame was the strongest predictor, followed by trauma history, peer victimization, and impulsivity. These results suggest that emotional, developmental, interpersonal, and behavioral factors jointly contribute to adolescent self-injury risk.

Conclusion: The findings demonstrate that Random Forest algorithms can accurately classify adolescents at elevated risk for NSSI, highlighting the importance of integrating trauma history, shame, impulsivity, and peer victimization into early identification and prevention efforts. Interventions should target emotional regulation, trauma recovery, and social support to reduce the likelihood of self-injurious behaviors.

Keywords: *Non-suicidal self-injury, Adolescents, Random Forest, Trauma History, Shame, Impulsivity, Peer Victimization.*

1. Introduction

Non-suicidal self-injury (NSSI) has emerged as a major public health concern among adolescents and has attracted increasing attention from researchers, clinicians, educators, and policymakers worldwide. NSSI refers to the deliberate and direct destruction of one's own body tissue without suicidal intent and for purposes that are not socially sanctioned. Common forms of NSSI include cutting, scratching, burning, hitting oneself, and interfering with wound healing. Although distinct from suicidal behavior, NSSI is associated with substantial psychological distress, impaired functioning, increased psychiatric comorbidity, and elevated risk for future suicidal ideation and suicide attempts (Bernacki, 2024; Moore, 2022). Epidemiological evidence suggests that adolescence represents the developmental period during which NSSI most frequently emerges, making early identification of risk factors essential for prevention and intervention efforts (Holst-Schumacher et al., 2022; Raffagnato et al., 2022).

The prevalence of NSSI among adolescents has increased considerably during the past decade, particularly in association with growing psychosocial stressors, emotional difficulties, and interpersonal adversities. Research conducted across diverse cultural settings has demonstrated that self-injurious behaviors occur in both clinical and community populations, indicating that NSSI is not restricted to psychiatric disorders alone (Bernacki, 2024; Iswanti et al., 2024). Contemporary reviews have emphasized that NSSI develops through the interaction of multiple psychological, developmental, social, and environmental factors rather than through a single causal pathway (Kothadia, 2022; Yan & Yue, 2023). Consequently, understanding the complex constellation of variables associated with NSSI has become a central objective within adolescent mental health research.

Among the most consistently identified risk factors for NSSI is exposure to traumatic experiences during childhood and adolescence. Trauma disrupts emotional development, self-concept formation, interpersonal trust, and coping capacities, creating vulnerabilities that may increase the likelihood of self-injurious behavior. Adolescents exposed to abuse, neglect, family violence, or other adverse childhood experiences frequently exhibit difficulties regulating emotional distress and may resort to self-harm as a maladaptive coping mechanism (Jiao, 2024; Lansing et al., 2023). Studies have repeatedly demonstrated significant associations between childhood trauma and self-injurious behaviors, suggesting that traumatic experiences contribute to both the onset and persistence of NSSI (Marqués-Feixa et al., 2021; Zhao et al., 2023). Furthermore, trauma-related pathways appear to remain influential even after controlling for other psychological vulnerabilities, highlighting the central role of adverse experiences in adolescent self-harm (Choi & Song, 2025; Zhou et al., 2025).

Recent investigations have provided additional support for trauma-based models of NSSI. For example, childhood maltreatment has been linked to increased emotional dysregulation, maladaptive cognitions, and self-destructive behaviors among adolescents (Dai et al., 2025; Lu et al., 2025). Similarly, research involving adolescents with histories of abuse has demonstrated that trauma-related symptoms, including intrusive memories, emotional instability, and negative self-beliefs, significantly increase vulnerability to self-harm (Choi & Song, 2025; Steil et al., 2021). Gender-specific analyses have further indicated that trauma may influence NSSI through indirect pathways involving rumination and emotional distress, suggesting the existence of complex developmental mechanisms connecting adverse experiences to self-injurious behavior (Zhou et al., 2025).

Another psychological factor strongly associated with NSSI is shame. Shame is a painful self-conscious emotion characterized by feelings of worthlessness, defectiveness, inferiority, and self-condemnation. Unlike guilt, which focuses on specific behaviors, shame involves negative evaluations of the self as a whole. Theoretical perspectives suggest that individuals experiencing intense shame may engage in self-injury to punish themselves, reduce emotional pain, regain a sense of control, or externalize internal distress. Qualitative evidence has demonstrated that adolescents who engage in NSSI often describe profound feelings of inner hurt, self-rejection, and shame-related experiences preceding episodes of self-harm (AghaMohammadi et al., 2023). Similarly, investigations examining body-related shame and self-harm have highlighted the importance of negative self-perceptions and self-directed hostility in understanding self-injurious behaviors (Rizk-Hildbrand et al., 2025).

The growing literature on emotional dysregulation further supports the role of shame in NSSI. Emotional dysregulation refers to difficulties understanding, managing, and responding adaptively to emotional experiences. Numerous studies have identified emotional dysregulation as a transdiagnostic vulnerability underlying self-harm, depression, personality pathology, and other forms of

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psychological dysfunction (Blay et al., 2024; Paulus et al., 2021). Adolescents who experience chronic shame frequently demonstrate heightened emotional reactivity and limited access to effective coping strategies, increasing the likelihood of engaging in self-injury as a means of emotional relief (Chiappini et al., 2025; Wu et al., 2025). Research has further suggested that interventions targeting maladaptive self-talk, emotional awareness, and self-compassion may reduce self-injurious tendencies by addressing shame-related emotional processes (Wu et al., 2025).

Impulsivity represents another important predictor of NSSI. Impulsivity encompasses tendencies toward rapid, poorly planned actions that occur without adequate consideration of consequences. Adolescence is characterized by ongoing neurodevelopmental changes affecting executive functioning and self-regulation, making impulsive behaviors particularly common during this developmental period. Several theoretical models propose that impulsivity contributes to NSSI by increasing susceptibility to emotion-driven actions during periods of psychological distress (Gupta et al., 2023; Yan & Yue, 2023). Empirical findings have consistently demonstrated that adolescents who engage in self-injury report elevated levels of impulsivity relative to their peers, particularly in dimensions related to emotional impulsivity and behavioral disinhibition (Choi & Song, 2025; Dai et al., 2025).

The relationship between impulsivity and NSSI appears especially relevant when adolescents encounter emotionally overwhelming situations. Emotional impulsivity may amplify the likelihood that negative affect rapidly translates into self-harming behaviors before adaptive coping strategies can be implemented. Clinical investigations have reported that impulsive tendencies are commonly observed among adolescents presenting with self-injury, borderline personality features, and other high-risk psychiatric conditions (McQuaid et al., 2024; Wang et al., 2022). Moreover, evidence suggests that impulsivity interacts with emotional vulnerabilities and environmental stressors, producing cumulative effects that increase NSSI risk (Dai et al., 2025; Gupta et al., 2023).

Interpersonal experiences, particularly peer victimization, have also been identified as critical determinants of adolescent self-harm. Peer victimization includes physical, verbal, relational, and cyber forms of bullying that undermine emotional well-being and social belonging. During adolescence, peer relationships assume increasing developmental importance, making victimization experiences particularly harmful. Extensive evidence indicates that adolescents exposed to bullying are significantly more likely to engage in NSSI than non-victimized peers (Serafini et al., 2021; Wahyuni et al., 2024). The negative effects of peer victimization often extend beyond immediate distress and may contribute to long-term psychological difficulties, including depression, anxiety, social withdrawal, and self-harming behavior (Predescu et al., 2024; Xu & Bi, 2025).

Research examining cyberbullying and traditional forms of victimization has revealed particularly strong associations with self-injury. Victimized adolescents frequently experience rejection, humiliation, social isolation, and diminished self-worth, all of which increase emotional distress and vulnerability to maladaptive coping strategies (Predescu et al., 2024; Wang et al., 2021). Longitudinal evidence has further demonstrated that peer victimization predicts subsequent self-injury, even after controlling for prior psychological difficulties (Xu & Bi, 2025). Similarly, studies involving psychiatric populations have identified bullying as a significant predictor of NSSI severity and recurrence (Zhang et al., 2021; Zhang et al., 2022). These findings suggest that peer victimization functions not merely as a correlate of self-harm but as a potentially causal factor contributing to self-injurious behavior.

Importantly, trauma history, shame, impulsivity, and peer victimization do not operate independently. Contemporary developmental psychopathology models emphasize the cumulative and interactive nature of risk processes. Childhood trauma may increase sensitivity to peer rejection, intensify shame responses, and impair self-regulatory capacities. Peer victimization may reinforce negative self-perceptions established through earlier adverse experiences. Emotional dysregulation and impulsivity may then transform psychological distress into self-harming behavior (Blay et al., 2024; Zhao et al., 2023). Empirical studies have increasingly supported these integrated models, demonstrating that multiple psychosocial vulnerabilities jointly contribute to NSSI risk (Babaeifard et al., 2024; Zhou et al., 2025).

Although substantial progress has been made in identifying risk factors for NSSI, most previous studies have relied on traditional statistical approaches that primarily examine linear relationships among variables. While these methods provide valuable information, they may be limited in their ability to capture complex interactions, nonlinear effects, and multidimensional risk profiles that characterize self-injurious behavior. As a result, researchers have increasingly advocated for the use of advanced analytical

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techniques capable of improving prediction accuracy and facilitating early identification of high-risk individuals (Iswanti et al., 2024; Zhou et al., 2024).

Machine learning approaches offer significant advantages for psychological risk assessment because they can process large numbers of variables simultaneously, identify complex patterns within data, and generate highly accurate classification models. Random Forest algorithms are particularly well suited for mental health prediction because they effectively handle nonlinear relationships, reduce overfitting, accommodate correlated predictors, and provide interpretable estimates of variable importance. Recent applications of machine learning within psychiatry and behavioral health have demonstrated substantial improvements in identifying individuals at elevated risk for adverse outcomes compared with traditional statistical methods (Hennefield et al., 2025; Puzio et al., 2025). Given the multifactorial nature of NSSI, machine learning methodologies may provide valuable insights into the relative contribution of trauma history, shame, impulsivity, and peer victimization while simultaneously improving risk classification performance.

Despite growing recognition of these risk factors, relatively few studies have integrated trauma history, shame, impulsivity, and peer victimization within a single machine learning framework for predicting NSSI among adolescents. Furthermore, evidence regarding the relative predictive importance of these variables remains limited, particularly in Latin American populations. Addressing this gap may contribute to the development of more precise screening procedures and targeted intervention strategies aimed at preventing self-injurious behaviors during adolescence.

Therefore, the aim of the present study was to develop and evaluate a Random Forest classification model for identifying non-suicidal self-injury risk among Chilean adolescents using trauma history, shame, impulsivity, and peer victimization variables as predictors.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design using a machine learning approach to classify adolescents according to their risk of engaging in non-suicidal self-injury (NSSI). The study was conducted in Chile between March and July 2025 among secondary school students enrolled in public and private educational institutions located in Santiago, Valparaíso, and Concepción. A total of 1,248 adolescents participated in the study. Participants ranged in age from 13 to 18 years, with a mean age of 15.67 years (SD = 1.42). The sample consisted of 628 females (50.3%) and 620 males (49.7%). A multistage cluster sampling strategy was employed. In the first stage, schools were randomly selected from official educational directories. In the second stage, classrooms within selected schools were randomly chosen, and all eligible students were invited to participate.

Eligibility criteria included being between 13 and 18 years of age, current enrollment in a secondary school, adequate literacy in Spanish, and provision of informed assent alongside parental consent. Students with severe cognitive impairments or incomplete questionnaire responses exceeding 20% of the survey items were excluded from the final analysis. Participation was voluntary, confidentiality was guaranteed, and participants were informed of their right to withdraw from the study at any time without penalty.

The target variable for machine learning classification was non-suicidal self-injury risk. Participants were categorized into low-risk and high-risk groups based on established clinical cutoff scores on the self-injury assessment measure. Predictor variables included trauma history, shame, impulsivity, and peer victimization, which were selected based on previous theoretical and empirical evidence linking these factors to self-injurious behaviors during adolescence.

2.2. Measures

Non-suicidal self-injury risk was assessed using the Functional Assessment of Self-Mutilation (FASM), developed by Lloyd, Kelley, and Hope in 1997. The instrument assesses the presence, frequency, and functions of self-injurious behaviors without suicidal intent. The scale includes items evaluating a wide range of self-harm behaviors and their motivational functions. Respondents indicate the frequency with which they have engaged in specific behaviors during the previous year. Higher scores reflect greater severity and frequency of self-injurious behavior. Previous studies have demonstrated satisfactory psychometric properties, including strong internal consistency, test-retest reliability, and construct validity among adolescent populations. Reliability and validity of the Spanish-language version have also been confirmed in previous investigations.

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Trauma history was measured using the Childhood Trauma Questionnaire-Short Form (CTQ-SF), developed by Bernstein and colleagues in 2003. The instrument consists of 28 items assessing experiences of emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect during childhood. Responses are rated on a five-point Likert scale ranging from 1 (never true) to 5 (very often true). Higher scores indicate greater exposure to childhood trauma. The CTQ-SF has consistently demonstrated excellent psychometric characteristics across diverse cultural settings, including strong internal consistency and convergent validity. Previous studies have supported the reliability and validity of the Spanish adaptation among adolescents and young adults.

Shame was assessed using the Experience of Shame Scale (ESS), developed by Andrews, Qian, and Valentine in 2002. This self-report instrument contains 25 items measuring characterological shame, behavioral shame, and bodily shame. Participants rate each item on a four-point scale indicating the frequency of shame-related experiences. Total scores are calculated by summing responses across all items, with higher scores reflecting greater levels of shame. The ESS has demonstrated strong reliability coefficients and satisfactory construct validity in both clinical and non-clinical populations. Evidence supporting the psychometric adequacy of Spanish-language versions has been reported in previous studies involving adolescents.

Impulsivity was measured using the Barratt Impulsiveness Scale-Version 11 (BIS-11), originally developed by Barratt and later revised by Patton, Stanford, and Barratt in 1995. The BIS-11 consists of 30 items evaluating attentional impulsivity, motor impulsivity, and non-planning impulsivity. Participants respond using a four-point Likert scale ranging from rarely/never to almost always/always. Higher scores indicate greater impulsive tendencies. The BIS-11 is one of the most widely used measures of impulsivity and has consistently demonstrated acceptable reliability, factorial validity, and criterion validity across adolescent and adult samples. Previous Spanish validation studies have confirmed its suitability for use among Latin American populations.

Peer victimization was assessed using the Revised Peer Experiences Questionnaire (RPEQ), developed by Prinstein, Boergers, and Vernberg in 2001. The questionnaire evaluates experiences of overt victimization, relational victimization, and reputational victimization among peers. The instrument contains 18 items rated on a five-point frequency scale. Higher scores represent more frequent experiences of peer victimization. Previous research has established strong internal consistency, factorial validity, and predictive validity for the RPEQ. Studies conducted among adolescent populations have confirmed its reliability and validity as a measure of peer victimization and bullying-related experiences.

2.3. Data Analysis

Data analysis was conducted using Python version 3.12 and the Scikit-learn machine learning library. Initial data screening included examination of missing values, outliers, distributional characteristics, and multicollinearity among predictor variables. Missing data representing less than 5% of observations were handled using multiple imputation procedures. Continuous variables were standardized prior to model development to facilitate comparison across predictors.

The dataset was randomly divided into training and testing subsets using an 80:20 ratio. The training dataset consisted of 998 participants, while the testing dataset included 250 participants. To address potential class imbalance between high-risk and low-risk NSSI groups, the Synthetic Minority Oversampling Technique (SMOTE) was applied exclusively to the training data. Model development employed a Random Forest classification algorithm because of its ability to handle nonlinear relationships, complex interactions, and high-dimensional psychological data.

Hyperparameter optimization was conducted through grid search combined with five-fold cross-validation. Parameters evaluated included the number of trees, maximum tree depth, minimum samples required for node splitting, minimum samples required for terminal nodes, and the number of predictors considered at each split. Feature importance scores were extracted from the final model to identify the relative contribution of trauma history, shame, impulsivity, and peer victimization variables to NSSI risk classification.

Model performance was evaluated using accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC). Confusion matrix analyses were additionally conducted to examine classification sensitivity and specificity. Cross-validation procedures were implemented to reduce overfitting and improve model generalizability. Statistical significance for supplementary analyses was evaluated at the 0.05 level. The final Random Forest model was selected based on optimal predictive performance and stability across validation folds,

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providing a robust framework for identifying adolescents at elevated risk of non-suicidal self-injury.

3. Findings and Results

A total of 1,248 adolescents participated in the study and were included in the final analyses. Participants ranged in age from 13 to 18 years, with a mean age of 15.67 years (SD = 1.42). The sample included 628 female students (50.3%) and 620 male students (49.7%). Regarding educational level, 22.4% were enrolled in Grade 8, 25.1% in Grade 9, 26.7% in Grade 10, 15.9% in Grade 11, and 9.9% in Grade 12. Based on the classification criteria derived from the Functional Assessment of Self-Mutilation, 329 participants (26.4%) were categorized as belonging to the high-risk non-suicidal self-injury (NSSI) group, while 919 participants (73.6%) were classified as low risk. Preliminary screening demonstrated acceptable distributions for all study variables, with skewness and kurtosis values falling within recommended ranges. Missing data represented less than 2.3% of the total dataset and were addressed through multiple imputation procedures prior to model development.

Table 1

Descriptive Statistics and Correlations among Study Variables

Variable	Mean	SD	1	2	3	4	5
1. Trauma History	43.81	13.72	—				
2. Shame	52.44	14.29	.58**	—			
3. Impulsivity	67.92	11.56	.41**	.47**	—		
4. Peer Victimization	34.61	10.88	.52**	.49**	.38**	—	
5. NSSI Risk Score	18.35	9.77	.61**	.65**	.56**	.59**	—

Table 1 presents descriptive statistics and Pearson correlation coefficients among the principal study variables. The findings revealed moderate to strong positive correlations among all predictors and NSSI risk. Shame demonstrated the strongest association with NSSI risk ($r = .65$, $p < .01$), followed by trauma history ($r = .61$, $p < .01$), peer victimization ($r = .59$, $p < .01$), and impulsivity ($r = .56$, $p < .01$). Furthermore, substantial intercorrelations were observed among the predictor variables, particularly between trauma history and shame ($r = .58$, $p < .01$), suggesting that adolescents with greater exposure to childhood trauma tended to report higher levels of shame. Although correlations among predictors were statistically significant, variance inflation factor analyses indicated no problematic multicollinearity, supporting the inclusion of all variables in the Random Forest classification model.

Table 2

Comparison of Predictor Variables between High-Risk and Low-Risk NSSI Groups

Variable	Low-Risk Group (n=919) Mean ± SD	High-Risk Group (n=329) Mean ± SD	t	p
Trauma History	39.27 ± 11.81	56.49 ± 12.24	22.18	<.001
Shame	47.33 ± 12.03	66.72 ± 13.55	24.91	<.001
Impulsivity	64.88 ± 10.34	76.40 ± 10.19	17.98	<.001
Peer Victimization	30.85 ± 8.73	45.10 ± 9.87	23.77	<.001

The results presented in Table 2 demonstrate substantial differences between adolescents classified as low risk and high risk for NSSI. Participants in the high-risk group reported significantly higher levels of childhood trauma, shame, impulsivity, and peer victimization compared with those in the low-risk group. The largest group difference emerged for shame, indicating that adolescents engaging in or vulnerable to self-injurious behaviors experienced markedly elevated feelings of self-conscious distress, self-devaluation, and negative self-evaluation. Similarly, trauma history exhibited a pronounced difference between groups, suggesting that adverse childhood experiences may represent a critical developmental antecedent of self-injurious behavior. Peer victimization and impulsivity also displayed strong group differences, highlighting the importance of both interpersonal adversity and behavioral dysregulation in the prediction of NSSI risk. Collectively, these findings provide preliminary evidence supporting the suitability of these variables for machine learning classification.

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Table 3

Random Forest Classification Performance on the Testing Dataset

Metric	Value
Accuracy	0.892
Precision	0.861
Recall (Sensitivity)	0.845
Specificity	0.914
F1-Score	0.853
AUC-ROC	0.938

The classification performance results indicate that the Random Forest algorithm demonstrated excellent predictive capability in distinguishing between high-risk and low-risk adolescents. Overall accuracy reached 89.2%, indicating that nearly nine out of every ten participants were correctly classified. Precision of 86.1% suggests a low false-positive rate, whereas recall of 84.5% demonstrates a strong ability to identify adolescents genuinely belonging to the high-risk category. The specificity value of 91.4% further indicates that the model effectively recognized adolescents who were not at elevated risk. The F1-score of 85.3% reflects a favorable balance between precision and recall. Most notably, the AUC-ROC value of 0.938 suggests outstanding discriminatory power and confirms that the model successfully differentiated high-risk from low-risk individuals across a wide range of classification thresholds. These findings support the robustness and practical applicability of Random Forest methods for psychological risk assessment in adolescent populations.

Table 4

Random Forest Feature Importance Rankings

Predictor Variable	Importance Score	Relative Importance (%)
Shame	0.321	32.1
Trauma History	0.276	27.6
Peer Victimization	0.224	22.4
Impulsivity	0.179	17.9

Table 4 presents feature importance estimates generated by the Random Forest model. Shame emerged as the most influential predictor, accounting for 32.1% of the model's predictive contribution. This finding suggests that internalized negative self-perceptions and self-conscious emotions represent particularly important indicators of vulnerability to non-suicidal self-injury. Trauma history was identified as the second most influential factor, contributing 27.6% of the model's predictive capability. This result highlights the enduring psychological impact of adverse childhood experiences and their relevance to self-injurious behaviors during adolescence. Peer victimization ranked third, accounting for 22.4% of predictive importance, emphasizing the role of bullying, social exclusion, and interpersonal maltreatment in increasing NSSI risk. Although impulsivity demonstrated the lowest relative importance among the predictors, it nevertheless contributed substantially to classification performance and remained a meaningful determinant of self-injury risk. Together, the four predictors explained the vast majority of the model's decision-making process and provide a multidimensional framework encompassing emotional, developmental, behavioral, and interpersonal risk factors.

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Figure 1

SHAP Summary Plot Illustrating the Relative Contributions of Executive Function, Motivation, Smartphone Use, and Learning Strategy Variables to Academic Procrastination Risk Classification

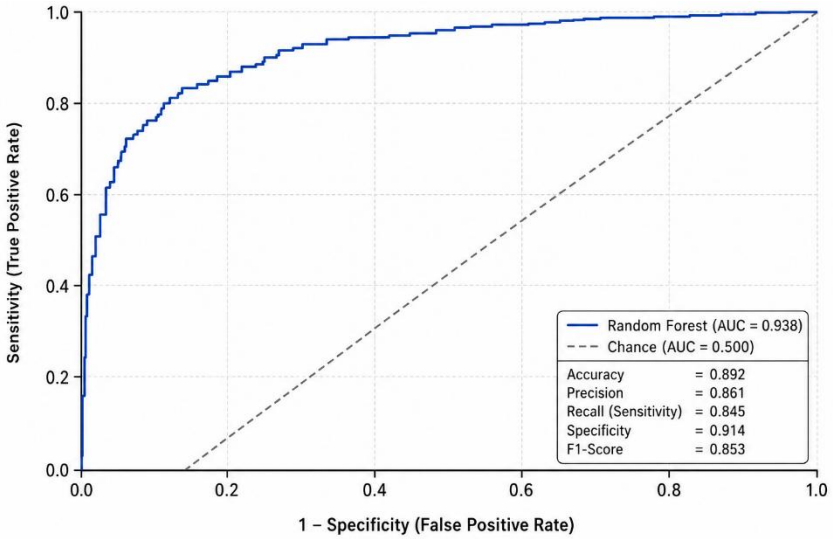

Figure 1 illustrates the receiver operating characteristic curve for the final Random Forest classifier. The curve demonstrates consistently high sensitivity across multiple classification thresholds and an area under the curve of 0.938. The substantial separation of the ROC curve from the diagonal reference line indicates strong discriminatory performance and confirms that the model possesses excellent capacity to distinguish between adolescents with elevated and reduced risk of non-suicidal self-injury. The graphical findings further corroborate the numerical performance indices reported in Table 3 and provide additional evidence regarding the stability and effectiveness of the proposed machine learning framework. Overall, the ROC analysis suggests that the combination of trauma history, shame, impulsivity, and peer victimization constitutes a powerful predictive profile for identifying adolescents at heightened risk of engaging in non-suicidal self-injurious behaviors.

4. Discussion

The present study aimed to develop and evaluate a Random Forest classification model for predicting non-suicidal self-injury (NSSI) risk among adolescents using trauma history, shame, impulsivity, and peer victimization as predictor variables. The findings demonstrated that the proposed model achieved high classification performance, with an overall accuracy of 89.2%, an F1-score of 85.3%, and an AUC value of 0.938. In addition, significant differences were observed between high-risk and low-risk NSSI groups across all predictor variables. Adolescents classified as high risk reported substantially greater levels of childhood trauma, shame, impulsivity, and peer victimization than their low-risk counterparts. Feature importance analyses further revealed that shame was the strongest predictor of NSSI risk, followed by trauma history, peer victimization, and impulsivity. Collectively, these findings suggest that NSSI among adolescents is influenced by a complex interaction of emotional, developmental, interpersonal, and behavioral vulnerabilities and that machine learning approaches can effectively identify adolescents at elevated risk.

One of the most important findings of the study was the strong predictive value of shame. The Random Forest model identified shame as the most influential variable contributing to NSSI classification. This result is consistent with theoretical models proposing that self-injury functions as a mechanism for coping with overwhelming self-directed negative emotions. Shame involves persistent feelings of inadequacy, self-criticism, worthlessness, and perceived personal defects, all of which can create intense emotional suffering. Adolescents experiencing elevated shame may engage in self-harm to punish themselves, express internal distress, or temporarily escape painful self-awareness. The present findings align with qualitative evidence demonstrating that many adolescents who engage in NSSI

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describe profound feelings of internal hurt, rejection of the self, and experiences of emotional pain centered on shame and self-devaluation (AghaMohammadi et al., 2023). Similarly, Rizk-Hildbrand et al. found that body shaming and negative self-perceptions played a significant role in the self-harm experiences of adolescents with histories of suicidal behavior (Rizk-Hildbrand et al., 2025). The strong importance of shame observed in the present study also supports transdiagnostic models emphasizing self-conscious emotions as central contributors to maladaptive coping strategies and self-destructive behaviors (Blay et al., 2024; Chiappini et al., 2025). Furthermore, findings from studies examining emotional regulation and self-talk suggest that adolescents who lack adaptive strategies for managing shame-related emotions may be particularly vulnerable to self-injurious behavior (Paulus et al., 2021; Wu et al., 2025).

The second most important predictor identified by the model was trauma history. Adolescents classified as high risk for NSSI reported significantly greater exposure to childhood trauma than those categorized as low risk. This finding is highly consistent with extensive research demonstrating that adverse childhood experiences constitute one of the strongest developmental risk factors for self-harm. Childhood trauma can disrupt emotional regulation, attachment security, interpersonal trust, and identity development, thereby increasing vulnerability to maladaptive coping mechanisms later in life (Jiao, 2024; Lansing et al., 2023). Several studies have reported direct associations between childhood maltreatment and NSSI, with trauma-exposed adolescents displaying substantially elevated rates of self-injurious behavior (Marqués-Feixa et al., 2021; Zhao et al., 2023). The findings are particularly consistent with recent evidence showing that childhood trauma contributes to self-injury through emotional distress, rumination, and negative cognitive processes (Zhou et al., 2025). Similarly, Choi and Song demonstrated that posttraumatic symptoms and emotional impulsivity significantly contribute to self-harm among adolescents with histories of sexual abuse (Choi & Song, 2025). The current results therefore reinforce developmental psychopathology perspectives suggesting that early adverse experiences create long-lasting psychological vulnerabilities that increase the likelihood of self-injurious behavior during adolescence.

The importance of peer victimization in predicting NSSI risk also emerged clearly in the present investigation. Adolescents in the high-risk group reported substantially greater exposure to bullying and victimization experiences than those in the low-risk group. Peer victimization ranked as the third most important predictor within the Random Forest model, highlighting the powerful influence of interpersonal stressors on adolescent mental health. These findings are strongly supported by previous research demonstrating consistent associations between bullying victimization and self-harm behaviors (Serafini et al., 2021; Wahyuni et al., 2024). Experiences of bullying often generate feelings of rejection, humiliation, social isolation, and emotional distress, which may contribute to self-injurious behaviors as a means of emotional regulation or self-punishment. The present results are particularly consistent with longitudinal evidence showing that peer victimization predicts subsequent NSSI over time (Xu & Bi, 2025). Similar conclusions have been reported in studies examining cybervictimization, where exposure to online harassment increases emotional distress and self-injurious tendencies among adolescents (Predescu et al., 2024; Wang et al., 2021). Furthermore, Zhao et al. found that peer victimization mediates the relationship between childhood trauma and NSSI, suggesting that adverse interpersonal experiences may serve as mechanisms through which early trauma contributes to self-harm (Zhao et al., 2023). Findings from Lu et al. similarly demonstrated that bullying experiences play a central role in adolescent self-destructive behaviors and emotional maladjustment (Lu et al., 2025). Therefore, the present study provides additional evidence supporting the significance of peer relationships and social experiences in understanding NSSI risk.

Impulsivity also contributed significantly to the classification of NSSI risk, although its relative importance was somewhat lower than that of shame, trauma history, and peer victimization. Adolescents classified as high risk reported markedly higher levels of impulsivity than those in the low-risk group. This finding supports theoretical perspectives suggesting that impulsive tendencies facilitate rapid behavioral responses to emotional distress, thereby increasing susceptibility to self-harm. During adolescence, ongoing maturation of executive control systems may limit the capacity to regulate impulses effectively, particularly under conditions of intense emotional arousal. Consequently, impulsive adolescents may be more likely to engage in self-injurious behavior when confronted with psychological distress. The present findings are consistent with previous studies identifying impulsivity as an important correlate of NSSI (Gupta et al., 2023; Yan & Yue, 2023). Choi and Song reported that emotional impulsivity significantly contributed to self-harm among traumatized

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adolescents, while Dai et al. found strong associations between impulsive traits and NSSI in adolescent populations (Choi & Song, 2025; Dai et al., 2025). Moreover, investigations involving adolescents with personality pathology have repeatedly demonstrated elevated impulsivity among individuals engaging in self-injury (McQuaid et al., 2024; Wang et al., 2022). The present results therefore suggest that impulsivity remains an important component of adolescent self-harm risk, particularly when considered alongside emotional and interpersonal vulnerabilities.

An additional contribution of the present study concerns the application of machine learning methodologies to the prediction of NSSI risk. Traditional statistical approaches often focus on isolated predictors and linear relationships, whereas machine learning algorithms can model complex interactions among multiple variables simultaneously. The excellent performance of the Random Forest classifier observed in the current study indicates that machine learning techniques may offer substantial advantages for adolescent mental health screening. The model achieved high sensitivity and specificity, suggesting that it was capable of accurately identifying both high-risk and low-risk adolescents. These findings are consistent with recent recommendations advocating for advanced predictive analytics within psychiatry and behavioral health research (Hennefield et al., 2025; Puzio et al., 2025). The ability to identify adolescents at elevated risk before severe self-injury develops may significantly improve prevention and early intervention efforts.

The observed pattern of results also supports integrative models of NSSI that emphasize interactions among developmental, emotional, behavioral, and interpersonal processes. Rather than operating independently, trauma history, shame, impulsivity, and peer victimization likely reinforce one another over time. Childhood trauma may increase sensitivity to rejection and negative social experiences, while peer victimization may strengthen shame-related cognitions and emotional distress. Elevated shame may amplify emotional dysregulation, whereas impulsivity may increase the likelihood that distress is expressed through self-harming behaviors. This multidimensional perspective is consistent with contemporary theoretical frameworks proposing that NSSI emerges from the convergence of multiple risk pathways rather than a single causal factor (Blay et al., 2024; Kothadia, 2022). Similar conclusions have been reported by Babaeifard et al., who identified complex relationships among maladaptive schemas, distress tolerance, and self-injury among adolescents (Babaeifard et al., 2024). Collectively, the present findings contribute to growing evidence supporting multifactorial conceptualizations of adolescent self-harm.

The findings also extend previous research by demonstrating that emotional factors may possess greater predictive importance than behavioral traits alone. Although impulsivity was significantly associated with NSSI, shame emerged as the strongest predictor in the model. This pattern suggests that self-injurious behavior may be driven more strongly by emotional suffering and negative self-evaluation than by impulsive action alone. Such a conclusion aligns with research emphasizing emotional dysregulation as a core feature underlying self-harm (Paulus et al., 2021). It is also consistent with studies reporting that adolescents often describe self-injury as an attempt to manage intolerable emotional states rather than as a purely impulsive behavior (AghaMohammadi et al., 2023; Moore, 2022). Therefore, interventions focused exclusively on behavioral control may be insufficient unless accompanied by strategies targeting shame, emotional regulation, and trauma-related distress.

5. Conclusion

Although NSSI occurs without suicidal intent, extensive evidence indicates substantial overlap between self-injury and later suicidal risk (Holst-Schumacher et al., 2022; Raffagnato et al., 2022). Studies comparing adolescents with varying levels of suicidal behavior have demonstrated shared psychological vulnerabilities, including trauma exposure, emotional dysregulation, interpersonal difficulties, and impulsivity (Hennefield et al., 2025; Puzio et al., 2025). Consequently, the factors identified in the present study may have broader implications for adolescent suicide prevention efforts. Early identification of adolescents exhibiting these risk characteristics could facilitate timely intervention before more severe forms of self-destructive behavior emerge.

6. Limitations & Suggestions

Several limitations should be considered when interpreting the findings. First, the cross-sectional design precludes causal inferences regarding the relationships among trauma history, shame, impulsivity, peer victimization, and NSSI risk. Second, all variables were assessed using self-report measures, creating the possibility of response biases, recall errors, and social desirability

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effects. Third, although the sample was relatively large, participants were recruited from selected regions of Chile, which may limit the generalizability of findings to other cultural and geographic contexts. Fourth, the study focused exclusively on four predictors and did not incorporate potentially relevant factors such as depression, anxiety, family functioning, emotion regulation skills, or social support. Finally, although the Random Forest model demonstrated excellent performance, external validation using independent samples is necessary before clinical implementation.

Future studies should employ longitudinal designs to examine developmental pathways linking trauma, shame, impulsivity, peer victimization, and self-injury over time. Researchers may also benefit from integrating biological, cognitive, family, and social variables into predictive models to improve classification accuracy and provide a more comprehensive understanding of NSSI risk. Comparative investigations involving multiple machine learning algorithms, including XGBoost, LightGBM, support vector machines, and deep learning approaches, could help determine the most effective methods for identifying high-risk adolescents. Cross-cultural studies involving diverse populations would further clarify the universality and cultural specificity of observed risk factors. Additionally, future research should explore explainable artificial intelligence techniques to improve the interpretability and practical utility of machine learning models in mental health settings.

The findings highlight the importance of implementing comprehensive school-based screening programs capable of identifying adolescents exposed to trauma, peer victimization, and elevated shame. Mental health professionals should prioritize interventions that address emotional regulation, self-compassion, and trauma recovery while simultaneously reducing bullying and victimization experiences within school environments. Prevention programs should incorporate psychoeducation regarding healthy coping strategies and emotional management skills to reduce reliance on self-harm as a means of regulating distress. Schools, families, and healthcare providers should collaborate to establish early detection systems and referral pathways for vulnerable adolescents. Furthermore, machine learning-based risk assessment tools may provide valuable support for clinicians and educators by facilitating early identification and targeted intervention for adolescents at heightened risk of non-suicidal self-injury.

Acknowledgments

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

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

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

Transparency of Data

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

Funding

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

Authors' Contributions

All authors equally contributed to this article.

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