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Machine Learning Classification of Suicidal Ideation in Adolescents with Attention-Deficit/Hyperactivity Disorder: A Random Forest Approach Incorporating Impulsivity, Emotional Dysregulation, and Family Cohesion

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A B S T R A C T

The present study aimed to develop and evaluate a Random Forest machine learning model for classifying suicidal ideation among adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD) based on impulsivity, emotional dysregulation, and family cohesion. This cross-sectional predictive modeling study was conducted among 468 Canadian adolescents aged 13–18 years with a confirmed diagnosis of ADHD. Participants were recruited from outpatient psychiatric clinics, mental health centers, and educational counseling services across multiple provinces. Suicidal ideation was assessed using the Suicidal Ideation Questionnaire-Junior (SIQ-JR), impulsivity was measured using the Barratt Impulsiveness Scale-11 (BIS-11), emotional dysregulation was evaluated using the Difficulties in Emotion Regulation Scale (DERS), and family cohesion was assessed using the Family Adaptability and Cohesion Evaluation Scales IV (FACES-IV). Data were analyzed using a Random Forest classification algorithm implemented in Python. The dataset was divided into training and testing subsets using an 80:20 ratio, and 10-fold cross-validation was employed to optimize model performance. Classification accuracy, precision, recall, specificity, F1-score, and area under the receiver operating characteristic curve (AUC-ROC) were used to evaluate predictive performance. Feature importance analyses were conducted to identify the relative contribution of each predictor. The Random Forest model demonstrated excellent classification performance, achieving an accuracy of 88.2%, precision of 86.4%, recall of 90.1%, specificity of 86.7%, F1-score of 88.2%, and an AUC-ROC of .934. Suicidal ideation was positively associated with impulsivity ($r = .54$, $p < .01$) and emotional dysregulation ($r = .67$, $p < .01$) and negatively associated with family cohesion ($r = -.49$, $p < .01$). Feature importance analysis revealed that emotional dysregulation was the strongest predictor of suicidal ideation (35.8%), followed by family cohesion (28.5%) and impulsivity (24.4%). The confusion

matrix further indicated high sensitivity and low rates of classification error. The findings demonstrate that machine learning approaches can accurately classify suicidal ideation among adolescents with ADHD and highlight emotional dysregulation, family cohesion, and impulsivity as key determinants of suicide risk. These results underscore the importance of integrating psychological and family-related factors into suicide prevention efforts and support the potential clinical utility of machine learning-based screening tools for early identification of high-risk adolescents.

Keywords: *Attention-Deficit/Hyperactivity Disorder; Suicidal Ideation; Random Forest; Machine Learning; Impulsivity; Emotional Dysregulation; Family Cohesion*

1. Introduction

Suicide among adolescents has emerged as one of the most pressing public health concerns worldwide, representing a leading cause of mortality and long-term psychosocial impairment during developmental years. Suicidal ideation, which encompasses thoughts, wishes, and plans related to self-inflicted death, is increasingly recognized as a critical precursor to suicide attempts and completed suicide. Contemporary research has emphasized that suicidal ideation often develops through complex interactions among biological vulnerabilities, psychiatric disorders, emotional difficulties, family influences, and environmental stressors. Recent epidemiological investigations have demonstrated that substantial proportions of children and adolescents report suicidal thoughts before reaching adulthood, highlighting the urgent need for early identification and prevention strategies (Lawrence et al., 2021; Liu et al., 2022). Advances in suicide research have further demonstrated that suicidal ideation and non-suicidal self-injury frequently coexist and may share overlapping psychological mechanisms, thereby increasing the risk of progression toward more severe suicidal behaviors (Marcelo et al., 2022; Predescu & Șipoș, 2023). Consequently, researchers and clinicians have increasingly prioritized the development of predictive frameworks capable of identifying high-risk youth before suicidal thoughts escalate into attempts or fatalities (Barzilay & Apter, 2022; Rensa, 2022).

Among psychiatric disorders associated with elevated suicide risk, Attention-Deficit/Hyperactivity Disorder (ADHD) has received growing scientific attention. ADHD is a neurodevelopmental disorder characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with social, academic, and emotional functioning. Although traditionally conceptualized as a disorder primarily affecting attention and behavioral regulation, recent evidence suggests that ADHD is also associated with substantial emotional difficulties, interpersonal challenges, and increased vulnerability to self-harm and suicidality (Gagliano et al., 2024; Raible & D'Souza, 2023). Multiple studies have reported that adolescents with ADHD experience significantly higher rates of suicidal ideation, suicide attempts, and self-injurious behaviors compared to their non-ADHD peers (Todzia-Kornaś et al., 2023; Trivedi et al., 2022). Furthermore, systematic reviews and meta-analyses have concluded that ADHD constitutes an independent risk factor for suicidal thoughts and behaviors across developmental stages, even after accounting for several psychiatric comorbidities (Austgulen et al., 2023; Garas et al., 2025). Recent reviews have additionally highlighted the importance of examining mediating and moderating mechanisms that explain why some adolescents with ADHD develop suicidal ideation while others do not (Rother et al., 2025).

The relationship between ADHD and suicidality appears to be multifaceted and influenced by numerous cognitive, emotional, and social factors. Longitudinal investigations have demonstrated that youth with ADHD frequently encounter academic failures, peer rejection, family conflict, emotional distress, and low self-esteem, all of which may contribute to increased suicide risk over time (Choi & Kim, 2023; Thornton et al., 2024). Evidence further suggests that adolescents with ADHD are more likely to experience depressive symptoms, anxiety disorders, and behavioral dysregulation, conditions that are strongly associated with suicidal thoughts and behaviors (Demo et al., 2025; Upshaw et al., 2025). Research has also shown that the coexistence of externalizing psychopathology significantly amplifies suicidal risk among vulnerable youth populations (Duncan et al., 2025). Similarly, adolescents with ADHD who exhibit depressive symptoms, hostility, frustration intolerance, or exposure to bullying appear particularly susceptible to suicidal ideation (Liu et al., 2021). These findings indicate that suicide risk within ADHD populations cannot be adequately understood through diagnostic status alone and instead requires examination of specific psychological mechanisms that may influence vulnerability.

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Impulsivity has consistently emerged as one of the most important psychological characteristics linking ADHD and suicidality. Impulsivity refers to a tendency toward rapid, unplanned reactions without adequate consideration of potential consequences. Because impulsivity constitutes a core feature of ADHD, many researchers have proposed that it may increase vulnerability to suicidal thoughts by reducing inhibitory control, increasing emotional reactivity, and facilitating maladaptive coping responses during periods of psychological distress (Thornton et al., 2024; Trivedi et al., 2022). Previous investigations have found that impulsive adolescents are more likely to engage in self-harming behaviors, experience suicidal ideation, and progress from suicidal thoughts to suicide attempts (Marcelo et al., 2022; Shahnovsky et al., 2022). Moreover, studies examining neurocognitive functioning have suggested that impairments in executive control processes and decision-making capacities may contribute to suicidal thinking among vulnerable youth (Sharkey et al., 2021; Wiglesworth et al., 2021). The significance of impulsivity is further reinforced by findings indicating that persistence deficits and ineffective problem-solving skills during childhood predict later suicidal ideation during adolescence (Sarkisian et al., 2021). Collectively, these findings support the hypothesis that impulsivity represents a crucial predictor of suicidal ideation among adolescents with ADHD.

Another psychological factor receiving increasing attention in suicide research is emotional dysregulation. Emotional dysregulation refers to difficulties understanding, managing, and responding adaptively to emotional experiences. Although emotional dysregulation is not formally included within the diagnostic criteria for ADHD, growing evidence suggests that it represents a central feature of the disorder and contributes substantially to psychosocial impairment. Adolescents with ADHD frequently experience intense emotional reactions, irritability, frustration, and difficulty recovering from negative emotional states, which may increase vulnerability to suicidal thinking (Gagliano et al., 2024; Rother et al., 2025). Research involving psychiatric adolescent populations has demonstrated that emotional instability, depressive symptoms, feelings of worthlessness, and personality-related emotional difficulties are strongly associated with suicidal ideation and behaviors (Gifuni et al., 2023; Katzenmajer-Pump et al., 2022). In ADHD populations specifically, emotional dysregulation may amplify the effects of impulsivity by increasing the likelihood that negative emotional experiences will trigger maladaptive cognitive responses and suicidal thoughts. Emerging theoretical frameworks suggest that emotional dysregulation may therefore serve as a key mechanism linking neurodevelopmental vulnerabilities to suicidal outcomes (Austgulen et al., 2023; Moseley et al., 2024).

Family functioning represents another important domain influencing adolescent mental health and suicide risk. Family cohesion, characterized by emotional bonding, support, trust, and connectedness among family members, has been identified as a protective factor against a wide range of psychological difficulties. Adolescents who perceive their families as supportive and emotionally available generally report lower levels of depression, anxiety, self-harm, and suicidal ideation. Conversely, family conflict, neglect, maltreatment, and adverse childhood experiences have been consistently associated with elevated suicide risk (Hornor & Tucker, 2022; Shahnovsky et al., 2022). Within ADHD populations, family relationships may be particularly important because behavioral difficulties and emotional challenges often place considerable stress on family systems. Recent evidence indicates that positive childhood experiences can significantly reduce suicide risk among youth exhibiting ADHD-related traits, highlighting the protective role of supportive developmental environments (Adachi et al., 2025). Similarly, clinical and educational interventions emphasizing family support and psychosocial engagement have demonstrated beneficial effects on emotional adjustment among adolescents experiencing ADHD and related psychiatric conditions (Goff et al., 2022). These findings suggest that family cohesion may function as a critical protective factor capable of buffering the effects of emotional and behavioral vulnerabilities associated with suicidality.

Despite growing knowledge regarding risk and protective factors for adolescent suicidality, significant challenges remain in accurately identifying youth at elevated risk. Traditional statistical approaches often focus on isolated predictors and linear relationships, which may fail to capture the complex interactions underlying suicidal ideation. Suicide risk emerges from the dynamic interplay of multiple biological, psychological, and environmental factors, necessitating more sophisticated analytical approaches capable of modeling nonlinear patterns and high-dimensional relationships (Barzilay & Apter, 2022; Joo et al., 2022). In recent years, machine learning techniques have demonstrated considerable promise for improving psychiatric prediction by integrating diverse predictors into comprehensive classification models. These approaches have shown superior predictive performance in identifying

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suicidal thoughts and behaviors across various clinical populations and developmental contexts (Rensa, 2022; Wiglesworth et al., 2021). Random Forest algorithms are particularly advantageous because they can manage complex interactions, reduce overfitting, accommodate correlated predictors, and generate interpretable estimates of variable importance. Such characteristics make Random Forest modeling especially suitable for examining suicide risk among adolescents with ADHD, where multiple interconnected risk factors are likely involved.

Although substantial evidence supports associations among ADHD, impulsivity, emotional dysregulation, family functioning, and suicidality, relatively few studies have integrated these factors within a machine learning framework specifically designed to classify suicidal ideation among adolescents with ADHD. Existing studies have frequently examined individual correlates of suicidality, such as depression, self-esteem, perfectionism, worthlessness, psychiatric comorbidity, or self-harm behaviors (Boylan et al., 2025; Choi & Kim, 2023; Katzenmajer-Pump et al., 2021; Katzenmajer-Pump et al., 2022). Additional research has highlighted the influence of environmental stressors, psychiatric symptoms, substance use, and neurodevelopmental characteristics on suicide risk (Demo et al., 2025; Feibus et al., 2025; Gagliano et al., 2024). However, there remains a notable gap concerning the combined predictive contribution of impulsivity, emotional dysregulation, and family cohesion within a robust machine learning classification model. Addressing this gap may facilitate earlier identification of vulnerable adolescents and contribute to the development of targeted prevention and intervention strategies.

Therefore, the aim of the present study was to develop and evaluate a Random Forest machine learning model for the classification of suicidal ideation among Canadian adolescents with Attention-Deficit/Hyperactivity Disorder based on impulsivity, emotional dysregulation, and family cohesion.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive modeling design to develop and evaluate a machine learning classification model for identifying suicidal ideation among adolescents diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). The study was conducted between January and September 2025 in Canada and focused on adolescents receiving psychological and psychiatric services through outpatient mental health clinics, child and adolescent psychiatry centers, and educational counseling facilities across the provinces of Ontario, British Columbia, and Alberta. The target population consisted of adolescents aged 13 to 18 years who had received a formal diagnosis of ADHD according to the diagnostic criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). A total of 482 adolescents were recruited using a stratified cluster sampling approach to ensure adequate representation across age groups, gender, and geographical regions.

Eligibility criteria included a confirmed ADHD diagnosis by a licensed psychiatrist or clinical psychologist, age between 13 and 18 years, sufficient cognitive ability to complete self-report assessments, and informed consent obtained from both adolescents and their parents or legal guardians. Adolescents with severe intellectual disability, psychotic disorders, neurological conditions affecting cognitive functioning, or incomplete questionnaire responses exceeding 10% of total items were excluded from the study. Following data screening and quality control procedures, complete data from 468 participants were retained for machine learning analyses. Among these participants, 211 adolescents reported clinically significant suicidal ideation, whereas 257 adolescents did not meet the threshold for suicidal ideation.

2.2. Measures

Suicidal ideation was assessed using the Suicidal Ideation Questionnaire-Junior (SIQ-JR) developed by Reynolds (1988). The SIQ-JR is a widely used self-report instrument designed to measure the frequency and severity of suicidal thoughts among adolescents. The questionnaire consists of 15 items rated on a 7-point Likert scale ranging from 0 (I never had this thought) to 6 (Almost every day). Higher scores indicate greater levels of suicidal ideation. The instrument has demonstrated excellent psychometric properties across adolescent populations, with reported Cronbach's alpha coefficients exceeding .90 and strong evidence of construct and criterion validity. Consistent with established clinical guidelines, participants scoring above the recommended cutoff point were classified as exhibiting significant suicidal ideation and assigned to the positive classification category for machine learning analyses.

Impulsivity was measured using the Barratt Impulsiveness Scale–11 (BIS-11) developed by Barratt and

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colleagues. The BIS-11 contains 30 items scored on a 4-point Likert scale ranging from 1 (Rarely/Never) to 4 (Almost Always/Always). The instrument evaluates three primary dimensions of impulsivity, including attentional impulsivity, motor impulsivity, and non-planning impulsivity. Total scores range from 30 to 120, with higher scores reflecting greater impulsive tendencies. Previous studies involving adolescents with ADHD have reported satisfactory internal consistency coefficients ranging from .79 to .87, as well as acceptable convergent and discriminant validity. The BIS-11 has been extensively utilized in research examining self-regulation difficulties and risk-taking behaviors among adolescents.

Emotional dysregulation was assessed using the Difficulties in Emotion Regulation Scale (DERS) developed by Gratz and Roemer (2004). The DERS consists of 36 items rated on a 5-point Likert scale from 1 (Almost Never) to 5 (Almost Always). The scale measures six dimensions of emotion regulation difficulties, including nonacceptance of emotional responses, difficulties engaging in goal-directed behavior, impulse control difficulties, lack of emotional awareness, limited access to emotion regulation strategies, and lack of emotional clarity. Higher scores indicate more severe emotional dysregulation. Numerous studies have demonstrated strong reliability for the DERS, with Cronbach's alpha values typically exceeding .90 for the total scale and acceptable reliability across subscales. The instrument has been validated in adolescent clinical populations and has shown particular relevance in studies examining suicide risk and ADHD-related emotional difficulties.

Family cohesion was measured using the Family Adaptability and Cohesion Evaluation Scales IV (FACES-IV) developed by Olson (2011). The cohesion dimension of the scale assesses emotional bonding, support, connectedness, and interpersonal relationships among family members. Participants responded to 21 items using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Higher scores indicate stronger family cohesion and healthier family functioning. Previous psychometric investigations have reported satisfactory internal consistency coefficients above .80 and strong evidence for construct validity. Family cohesion has been identified as an important protective factor against suicidal behavior and emotional maladjustment among adolescents, making it particularly relevant for predictive modeling in ADHD populations.

Demographic and clinical information was collected through a researcher-developed questionnaire. Variables included age, gender, socioeconomic status, parental educational attainment, ADHD subtype, duration since diagnosis, medication status, history of psychiatric treatment, and previous mental health diagnoses. These variables were included as supplementary predictors during preliminary feature exploration and model optimization procedures.

2.3. Data Analysis

Data analysis was conducted using Python version 3.12 and the Scikit-learn machine learning framework. Initially, descriptive analyses were performed to examine distributions, missing values, and outliers. Missing values representing less than 5% of observations were imputed using median replacement for continuous variables. Continuous predictor variables were standardized to facilitate model stability and interpretation. The outcome variable was binary, indicating the presence or absence of clinically significant suicidal ideation.

The Random Forest classification algorithm was selected due to its ability to model complex nonlinear relationships, manage multicollinearity among predictors, and provide robust performance in psychological prediction tasks. Predictor variables entered into the model included total impulsivity scores, emotional dysregulation scores, family cohesion scores, and relevant demographic characteristics. The dataset was randomly divided into training and testing subsets using an 80:20 ratio. To reduce the risk of overfitting and enhance model generalizability, a 10-fold cross-validation procedure was implemented on the training dataset. Hyperparameter optimization was performed using grid search techniques, examining the number of trees, maximum tree depth, minimum samples required for node splitting, and minimum samples required for leaf nodes.

Model performance was evaluated using multiple classification metrics, including accuracy, precision, recall, F1-score, area under the receiver operating characteristic curve (AUC-ROC), sensitivity, and specificity. Confusion matrices were generated to assess classification effectiveness across outcome categories. Feature importance analyses were conducted using Gini importance scores to determine the relative contribution of impulsivity, emotional dysregulation, and family cohesion in predicting suicidal ideation. Additionally, permutation importance analysis was performed to confirm the stability of predictor rankings and

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enhance interpretability. Statistical significance for preliminary descriptive comparisons was evaluated at a significance level of $p < .05$, while machine learning performance was assessed primarily through predictive accuracy and cross-validation outcomes. This analytical approach enabled the identification of key psychological and family-related predictors contributing to suicidal ideation risk among adolescents with ADHD while maximizing predictive performance and clinical applicability.

3. Findings and Results

A total of 468 adolescents diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) were included in the final analyses. Participants ranged in age from 13 to 18 years, with a mean age of 15.42 years (SD = 1.67). Of the participants, 283 (60.5%) were male and 185 (39.5%) were female. Based on the Suicidal Ideation Questionnaire-Junior (SIQ-JR), 211 adolescents (45.1%) met the criterion for clinically significant suicidal ideation, whereas 257 participants (54.9%) were classified as non-suicidal. Regarding ADHD subtype, 39.1% were diagnosed with the predominantly inattentive presentation, 21.8% with the predominantly hyperactive-impulsive presentation, and 39.1% with the combined presentation. Approximately 63.7% of participants were receiving pharmacological treatment at the time of data collection, while 36.3% were not taking ADHD medication. No substantial differences were observed between the training and testing datasets with respect to demographic or clinical characteristics, indicating successful random partitioning of the sample.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variable	Mean	SD	1	2	3	4
1. Suicidal Ideation	28.74	14.62	—			
2. Impulsivity	71.35	11.28	.54**	—		
3. Emotional Dysregulation	92.17	18.45	.67**	.58**	—	
4. Family Cohesion	59.82	12.11	-.49**	-.37**	-.52**	—

Table 1 presents the descriptive statistics and bivariate correlations among the principal study variables. The results demonstrated that emotional dysregulation exhibited the strongest positive association with suicidal ideation ($r = .67$, $p < .01$), indicating that adolescents reporting greater difficulties in regulating emotions were substantially more likely to report suicidal thoughts. Impulsivity also showed a significant positive relationship with suicidal ideation ($r = .54$, $p < .01$), suggesting that impulsive tendencies contribute meaningfully to suicide risk in adolescents with ADHD. Family cohesion was negatively associated with suicidal ideation ($r = -.49$, $p < .01$), demonstrating a protective effect of supportive and emotionally connected family environments. Additionally, emotional dysregulation was positively correlated with impulsivity ($r = .58$, $p < .01$) and negatively correlated with family cohesion ($r = -.52$, $p < .01$), indicating substantial interrelationships among the predictor variables.

Table 2

Random Forest Classification Performance on the Test Dataset

Performance Metric	Value
Accuracy	0.882
Precision	0.864
Recall (Sensitivity)	0.901
Specificity	0.867
F1-Score	0.882
AUC-ROC	0.934
Balanced Accuracy	0.884
Cohen's Kappa	0.763

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The performance evaluation of the Random Forest model revealed excellent classification capability for identifying adolescents with suicidal ideation. The overall classification accuracy reached 88.2%, indicating that nearly nine out of every ten participants were correctly classified. The model achieved an AUC-ROC value of .934, reflecting outstanding discrimination between suicidal and non-suicidal adolescents. Sensitivity was particularly high (90.1%), suggesting that the model was highly effective in identifying adolescents at elevated suicide risk. Specificity also remained strong (86.7%), demonstrating adequate identification of participants without suicidal ideation. The F1-score of .882 confirmed a balanced performance between precision and recall. Collectively, these findings indicate that the Random Forest algorithm provided a highly reliable predictive framework for suicide risk classification among adolescents with ADHD.

Table 3

Confusion Matrix for Random Forest Classification

Actual Classification	Predicted Non-Suicidal	Predicted Suicidal
Non-Suicidal	45	7
Suicidal	5	37

The confusion matrix analysis further illustrated the effectiveness of the classification model. Among adolescents without suicidal ideation, 45 participants were correctly classified, whereas only 7 were incorrectly identified as suicidal. Similarly, among adolescents with suicidal ideation, 37 were correctly classified and only 5 were incorrectly categorized as non-suicidal. The relatively small number of classification errors highlights the robustness of the Random Forest model and demonstrates its ability to distinguish high-risk individuals with considerable accuracy. From a clinical perspective, the low number of false negatives is particularly important because failure to identify adolescents experiencing suicidal ideation may have severe consequences. The findings therefore support the practical utility of machine learning approaches for early screening and intervention planning in ADHD populations.

Table 4

Feature Importance Rankings from the Random Forest Model

Predictor Variable	Mean Decrease in Gini	Relative Importance (%)
Emotional Dysregulation	0.312	35.8
Family Cohesion	0.248	28.5
Impulsivity	0.213	24.4
ADHD Medication Status	0.043	4.9
Socioeconomic Status	0.029	3.3
Age	0.017	1.9
Gender	0.009	1.2

Feature importance analysis revealed that emotional dysregulation was the most influential predictor in the classification model, accounting for 35.8% of the overall predictive contribution. This finding suggests that difficulties managing emotional experiences constitute the strongest risk factor for suicidal ideation among adolescents with ADHD. Family cohesion emerged as the second most important predictor, contributing 28.5% of the total model importance. The negative relationship between family cohesion and suicidal ideation highlights the protective role of supportive family relationships. Impulsivity ranked third, accounting for 24.4% of predictive importance, indicating that impulsive tendencies remain a significant contributor to suicide risk even after accounting for emotional and family-related factors. Demographic and clinical variables contributed comparatively less to prediction, emphasizing the central role of psychological and family functioning variables in explaining suicidal ideation.

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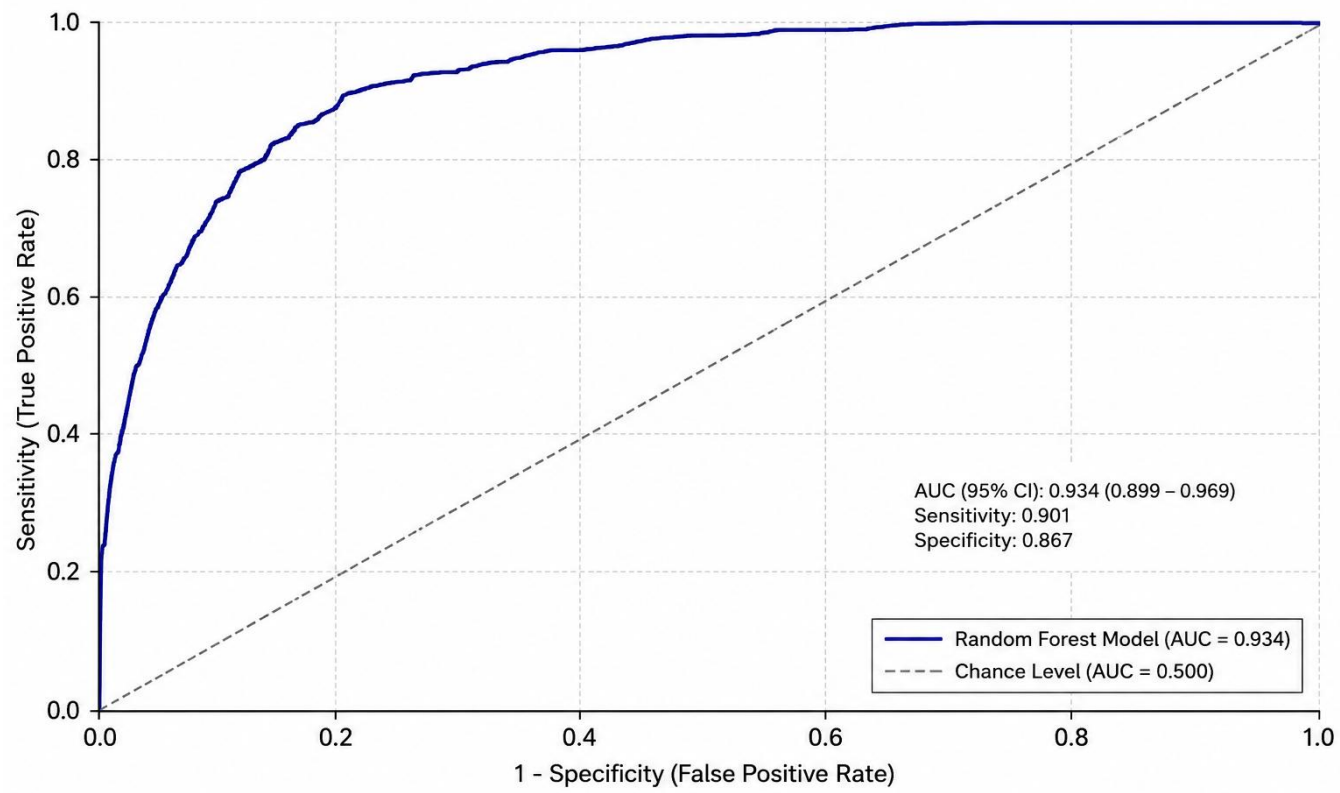
Figure 1

Receiver Operating Characteristic (ROC) Curve for the Random Forest Model Predicting Suicidal Ideation in Adolescents with ADHD



The ROC analysis demonstrated excellent model discrimination, yielding an area under the curve (AUC) of .934. Examination of the ROC curve indicated consistently high true-positive rates across a wide range of decision thresholds while maintaining relatively low false-positive rates. The curve remained substantially above the diagonal reference line throughout the entire range of classification thresholds, providing strong evidence that the model possessed excellent diagnostic accuracy. These findings reinforce the robustness of the machine learning framework and suggest that the integration of impulsivity, emotional dysregulation, and family cohesion variables can facilitate highly accurate identification of adolescents with ADHD who may be at risk for suicidal ideation. Overall, the classification results demonstrate that psychological vulnerabilities and family functioning characteristics collectively provide a powerful basis for suicide risk detection and may serve as valuable targets for prevention and intervention efforts.

4. Discussion

The present study sought to develop and evaluate a Random Forest machine learning model for classifying suicidal ideation among adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD) using impulsivity, emotional dysregulation, and family cohesion as primary predictors. The findings demonstrated that the proposed model achieved excellent predictive performance, with an overall accuracy of 88.2%, sensitivity of 90.1%, specificity of 86.7%, and an area under the receiver operating characteristic curve (AUC) of .934. Furthermore, emotional dysregulation emerged as the most influential predictor of suicidal ideation, followed by family cohesion and impulsivity. Correlational analyses revealed that suicidal ideation was positively associated with impulsivity and emotional dysregulation and negatively associated with family cohesion. These findings collectively suggest that psychological self-regulatory difficulties and family relational processes play central roles in understanding suicidal ideation among adolescents with ADHD and that

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machine learning approaches can effectively integrate these factors into clinically meaningful predictive models.

One of the most important findings of the present study was the strong predictive performance of the Random Forest algorithm. The model successfully distinguished adolescents with suicidal ideation from those without suicidal ideation, indicating that machine learning techniques may offer substantial advantages over traditional statistical methods in suicide risk assessment. Suicidal ideation develops through the interaction of multiple risk factors rather than a single causal mechanism, and machine learning algorithms are particularly well suited for capturing such complex relationships. This finding aligns with recent research emphasizing the need for advanced predictive frameworks capable of integrating biological, psychological, and environmental factors in suicide prevention efforts (Barzilay & Apter, 2022). Similarly, studies investigating prediction models of suicidal thoughts and behaviors have reported that multivariable approaches generally outperform simpler risk assessment strategies because they account for nonlinear interactions among predictors (Rensa, 2022). Research using large-scale developmental datasets has also demonstrated that complex behavioral and neurocognitive indicators can successfully contribute to suicide risk classification among youth populations (Wiglesworth et al., 2021). Therefore, the present findings support the growing consensus that machine learning approaches may represent valuable tools for early identification of adolescents at elevated suicide risk.

The results further revealed that emotional dysregulation was the strongest predictor of suicidal ideation among adolescents with ADHD. This finding is consistent with contemporary conceptualizations of ADHD as a disorder characterized not only by attentional and behavioral difficulties but also by significant impairments in emotional functioning. Emotional dysregulation may contribute to suicidal ideation by increasing the intensity, duration, and frequency of negative emotional experiences while simultaneously reducing an individual's capacity to employ adaptive coping strategies. Adolescents experiencing persistent emotional instability may become overwhelmed by feelings of hopelessness, frustration, and psychological distress, thereby increasing vulnerability to suicidal thoughts. Previous investigations have similarly identified emotional difficulties as critical contributors to suicidality across adolescent psychiatric populations (Gifuni et al., 2023; Predescu & Șipoș, 2023). Furthermore, narrative reviews of suicide among individuals with neurodevelopmental disorders have emphasized that emotional dysregulation constitutes one of the most significant mechanisms linking developmental vulnerabilities to suicidal outcomes (Gagliano et al., 2024). Research examining ADHD-specific pathways to suicidality has also highlighted the importance of emotional processes in explaining elevated suicide risk among affected youth (Rother et al., 2025). Consequently, the current findings reinforce the view that interventions targeting emotional regulation capacities may represent a particularly effective strategy for reducing suicidal ideation among adolescents with ADHD.

The strong relationship between emotional dysregulation and suicidal ideation may also be interpreted through contemporary theories of suicide. According to several psychological models, suicidal thoughts often emerge when individuals experience intense emotional pain that exceeds their perceived coping resources. Adolescents with ADHD frequently encounter repeated academic failures, interpersonal conflicts, social rejection, and emotional frustrations, all of which may contribute to chronic emotional distress. When emotional regulation capacities are compromised, these stressors may accumulate and lead to feelings of entrapment, hopelessness, and suicidality. Evidence from studies of depressive symptoms, psychiatric comorbidities, and emotional functioning among youth supports the importance of emotional vulnerability as a precursor to suicidal thoughts and behaviors (Demo et al., 2025; Duncan et al., 2025; Upshaw et al., 2025). Thus, the present findings extend previous literature by demonstrating that emotional dysregulation not only correlates with suicidal ideation but also serves as the most powerful predictor within a comprehensive machine learning classification framework.

Another notable finding was the substantial predictive contribution of family cohesion. Adolescents who reported stronger family cohesion exhibited significantly lower levels of suicidal ideation, and family cohesion emerged as the second most important predictor in the Random Forest model. This finding highlights the critical role of family relationships in protecting vulnerable adolescents from suicide risk. Family cohesion provides emotional security, social support, validation, and opportunities for adaptive coping, all of which may reduce the likelihood that adolescents interpret stressful experiences as overwhelming or inescapable. Previous studies have consistently demonstrated that positive family environments serve as protective factors against self-harm and suicidal behavior (Shahnovsky et al., 2022). Likewise, research examining

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childhood adversity has shown that exposure to family dysfunction, neglect, abuse, and trauma significantly increases the likelihood of suicidality during adolescence (Hornor & Tucker, 2022). Importantly, recent population-based evidence indicates that positive childhood experiences and supportive family relationships can substantially reduce suicide risk among youth exhibiting ADHD traits (Adachi et al., 2025). The present findings therefore extend existing evidence by demonstrating that family cohesion remains a powerful protective factor even when considered alongside individual psychological vulnerabilities such as impulsivity and emotional dysregulation.

The protective role of family cohesion may be particularly important within ADHD populations because adolescents with ADHD often experience persistent difficulties across multiple life domains. Family support may buffer the effects of peer rejection, academic challenges, emotional instability, and behavioral difficulties. Strong family cohesion may also facilitate early recognition of emotional distress, increase access to mental health services, and promote adaptive problem-solving strategies. Clinical interventions involving family participation have previously demonstrated beneficial outcomes for adolescents experiencing ADHD and co-occurring psychological difficulties (Goff et al., 2022). Therefore, enhancing family cohesion may represent a promising target for suicide prevention initiatives aimed at adolescents with ADHD.

Impulsivity also emerged as a significant predictor of suicidal ideation and demonstrated a moderate-to-strong positive association with suicidal thoughts. This finding is highly consistent with existing theoretical and empirical literature regarding the role of impulsivity in suicidal behavior. Impulsivity has long been recognized as a core characteristic of ADHD and is frequently implicated in self-harm, risk-taking, and suicidal actions. Impulsive individuals may be more likely to react rapidly to emotional distress without considering long-term consequences, thereby increasing susceptibility to suicidal thoughts and behaviors. Prior studies have reported strong associations between impulsive tendencies and suicidality among adolescents with ADHD (Thornton et al., 2024; Trivedi et al., 2022). Similarly, investigations examining executive functioning have found that deficits in inhibitory control, cognitive flexibility, and decision-making are associated with increased suicidal ideation (Sharkey et al., 2021). Research has also shown that childhood persistence deficits and ineffective problem-solving strategies predict later suicidal ideation during adolescence (Sarkisian et al., 2021). The present findings therefore support the growing body of evidence identifying impulsivity as a critical psychological vulnerability contributing to suicide risk.

Interestingly, although impulsivity significantly predicted suicidal ideation, its relative importance was lower than that of emotional dysregulation and family cohesion. This pattern suggests that impulsivity alone may not fully explain suicidal vulnerability among adolescents with ADHD. Instead, impulsivity may operate in conjunction with emotional difficulties and environmental factors to influence suicide risk. Such an interpretation is consistent with systematic reviews indicating that ADHD-related suicidality is best understood through multifactorial models incorporating emotional, cognitive, interpersonal, and contextual variables (Austgulen et al., 2023; Garas et al., 2025). Furthermore, evidence suggests that impulsivity may increase the likelihood that emotional distress translates into suicidal thoughts, whereas supportive family environments may interrupt this pathway. Thus, the relative ranking of predictors observed in the present study provides valuable insight into the complex interplay among individual and environmental risk factors.

The correlational findings further support the conceptual validity of the predictive model. Emotional dysregulation demonstrated the strongest positive correlation with suicidal ideation, whereas family cohesion demonstrated a significant negative association. Additionally, emotional dysregulation was positively associated with impulsivity and negatively associated with family cohesion. These interrelationships are theoretically meaningful and consistent with prior research demonstrating that emotional difficulties, behavioral dysregulation, and family functioning are closely interconnected determinants of adolescent mental health. Studies examining self-esteem, depression, hostility, and frustration intolerance among adolescents with ADHD have similarly documented complex relationships among emotional and behavioral vulnerabilities associated with suicidality (Choi & Kim, 2023; Liu et al., 2021). Findings from studies investigating self-harm and suicidal ideation among youth have likewise emphasized the importance of considering multiple interacting risk factors rather than isolated predictors (Boylan et al., 2025; Marcelo et al., 2022). Consequently, the present study contributes to the literature by demonstrating how these interconnected factors collectively influence suicide risk within a machine learning framework.

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5. Conclusion

The current findings also contribute to the growing literature concerning ADHD-specific pathways to suicidality. Previous research has identified numerous correlates of suicide risk among adolescents with ADHD, including perfectionism, feelings of worthlessness, psychiatric comorbidity, bullying involvement, depressive symptoms, and self-injurious behaviors (Katzenmajer-Pump et al., 2021; Katzenmajer-Pump et al., 2022; Liu et al., 2021; Todzia-Kornaś et al., 2023). Additionally, studies investigating interpersonal theories of suicide have proposed that social disconnection, perceived burdensomeness, and emotional distress may contribute to suicidal outcomes among individuals with ADHD and related neurodevelopmental conditions (Moseley et al., 2024). The present study complements these findings by identifying emotional dysregulation, family cohesion, and impulsivity as particularly influential predictors of suicidal ideation. Together, these results suggest that both intrapersonal and interpersonal processes should be considered when assessing suicide risk among adolescents with ADHD.

The findings of this study should be interpreted in light of several limitations. First, the cross-sectional design prevents causal conclusions regarding the relationships among impulsivity, emotional dysregulation, family cohesion, and suicidal ideation. Second, all psychological variables were measured using self-report instruments, which may introduce response biases and shared method variance. Third, the sample consisted exclusively of Canadian adolescents diagnosed with ADHD, potentially limiting the generalizability of findings to other cultural contexts and clinical populations. Fourth, although the Random Forest model demonstrated strong predictive performance, additional predictors such as depressive symptoms, anxiety, bullying experiences, trauma exposure, and peer relationships were not included in the model. Finally, external validation using independent datasets was not conducted and is necessary before widespread clinical implementation.

Future research should employ longitudinal designs to examine how impulsivity, emotional dysregulation, and family cohesion interact over time to influence the development of suicidal ideation and behavior. Studies should also investigate additional psychological, biological, social, and environmental factors that may enhance predictive accuracy. Future machine learning research may benefit from comparing multiple algorithms, including gradient boosting methods, support vector machines, neural networks, and explainable artificial intelligence approaches. Researchers should additionally explore cross-cultural samples and diverse clinical populations to evaluate the generalizability of predictive models. The inclusion of ecological momentary assessment, digital phenotyping, and real-time behavioral monitoring may further improve suicide risk prediction in adolescents.

From a practical perspective, the findings suggest that suicide prevention efforts for adolescents with ADHD should extend beyond symptom management and incorporate comprehensive assessments of emotional regulation capacities and family functioning. Mental health professionals should routinely evaluate emotional dysregulation and impulsivity when conducting suicide risk assessments. Family-based interventions aimed at strengthening cohesion, communication, and emotional support may serve as important protective mechanisms against suicidal ideation. Schools, clinicians, and community organizations should collaborate to identify vulnerable adolescents early and provide targeted psychosocial support. Furthermore, machine learning-based screening tools may eventually assist clinicians in identifying high-risk individuals and allocating preventive resources more efficiently. Such approaches have the potential to improve early detection, enhance intervention planning, and ultimately reduce the burden of suicidal ideation among adolescents with ADHD.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

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

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