

Classification of Adolescents With High Versus Low Emotion-Regulation Difficulties Using k-Nearest Neighbors and Psychological Indicators

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Article Info

Article type:

Original Research

How to cite this article:

Kováčik, A., & Chen, E. (2026). Classification of Adolescents With High Versus Low Emotion-Regulation Difficulties Using k-Nearest Neighbors and Psychological Indicators. *Journal of Adolescent and Youth Psychological Studies*, 7(9), 1-17.

<https://dx.doi.org/10.61838/kman.jayps.6286>



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ABSTRACT

Objective: This study aimed to classify adolescents with high versus low emotion-regulation difficulties using a k-nearest neighbors (KNN) machine-learning algorithm based on self-esteem, depressive symptoms, anxiety symptoms, perceived stress, and psychological resilience.

Methods and Materials: This quantitative, cross-sectional predictive classification study was conducted among 684 adolescents aged 13–18 years enrolled in secondary schools in Ontario, Canada. Participants were classified into high and low emotion-regulation difficulty groups based on scores obtained from the Difficulties in Emotion Regulation Scale. Psychological predictors were assessed using the Rosenberg Self-Esteem Scale, Patient Health Questionnaire-9, Generalized Anxiety Disorder-7, Perceived Stress Scale-10, and Brief Resilience Scale. The dataset was divided using stratified sampling into an 80% training set and a 20% independent test set. Predictor variables were standardized before model development. Candidate KNN models with odd values of k ranging from 3 to 25 and both uniform and distance-weighted voting were evaluated using stratified 10-fold cross-validation. The final model was selected according to cross-validated F1 score and balanced accuracy and was subsequently assessed on the independent test set using accuracy, sensitivity, specificity, precision, F1 score, balanced accuracy, ROC-AUC, and confusion-matrix indices.

Findings: Adolescents with high emotion-regulation difficulties had significantly lower self-esteem and resilience and significantly higher depressive symptoms, anxiety symptoms, and perceived stress than those with low difficulties (all $p < .001$), with large effect sizes. The optimal classifier used $k = 9$ with distance-weighted voting and achieved cross-validated accuracy of .855, $F1 = .858$, and balanced accuracy = .855. In the independent test sample, the model achieved accuracy = .861, sensitivity = .870, specificity = .853, precision = .857, $F1 = .863$, balanced accuracy = .861, and ROC-AUC = .923. The classifier correctly identified 60 of 69 adolescents with high difficulties and 58 of 68 adolescents with low difficulties.

Conclusion: A multivariate psychological profile comprising self-esteem, depressive symptoms, anxiety, perceived stress, and resilience can distinguish adolescents with high versus low emotion-regulation difficulties with strong out-of-sample accuracy.

Keywords: Emotion Regulation Difficulties; Adolescents; k-Nearest Neighbors; Machine Learning; Depression; Anxiety; Perceived Stress; Resilience; Self-Esteem

1. Introduction

Adolescence is a developmental period characterized by rapid biological maturation, cognitive restructuring, increasing autonomy, intensified peer involvement, and substantial changes in interpersonal and emotional functioning. These transitions create important opportunities for psychological growth, but they may also increase vulnerability to emotional instability and the emergence of psychopathological symptoms. Contemporary evidence indicates that adolescent mental health is shaped by a complex combination of individual, family, social, behavioral, and developmental factors rather than by isolated risk variables. Differences in emotional and behavioral functioning are also evident across age and gender, suggesting that the psychological processes underlying adolescent adjustment are heterogeneous and may manifest differently across subgroups (Levkovich et al., 2025; Wiedermann et al., 2026). Adolescents reporting poorer subjective health, maladaptive health behaviors, and greater exposure to high-risk behaviors tend to display more pronounced mental health difficulties, further demonstrating the multidimensional nature of psychological vulnerability during this developmental period (Bezborodovs & Villeruša, 2024). At the same time, assessments of adolescent psychological functioning may differ substantially depending on whether information is obtained directly from adolescents or from parents, highlighting the importance of evaluating internal emotional processes through indicators that are sufficiently sensitive to the adolescent's own psychological experience (Caqueo-Urizar et al., 2022).

Among the psychological processes implicated in adolescent mental health, emotion regulation has received particular attention because of its central role in adaptation to internal and external demands. Emotion regulation broadly refers to the processes through which individuals monitor, evaluate, modify, and express emotional responses in ways that are consistent with contextual demands and personal goals. Effective regulation does not simply involve reducing negative affect; it includes recognizing emotional states, understanding emotional experiences, accepting distressing emotions, controlling impulsive behavior under emotional activation, maintaining goal-directed action, and having access to appropriate regulatory strategies. Difficulties in these domains may increase susceptibility to a wide range of internalizing and externalizing problems. Evidence from adolescent populations has shown that better emotional regulation is associated with more favorable

mental well-being, whereas dysregulation is associated with greater psychological difficulties (Devi, 2023). Similarly, research examining emotional reactivity suggests that the association between emotional processes and psychopathology may not always be purely linear, indicating that both unusually high and contextually inappropriate patterns of emotional reactivity can be relevant to adolescent psychological development (Chiang & Chen, 2025).

The family environment represents one important context within which adolescent emotional regulation develops and operates. Parent and adolescent emotional variability may interact in ways that contribute to adolescent psychopathology, demonstrating that emotional functioning should not be considered solely as an intrapersonal characteristic (Chiang et al., 2023). Attachment processes are also closely connected to emotion regulation because attachment relationships influence the manner in which adolescents interpret interpersonal experiences, seek support, manage distress, and construct representations of themselves and others. A recent synthesis of the literature has emphasized the interconnection between adolescent attachment, mentalization, and emotion-regulation processes, suggesting that regulatory difficulties may arise partly from disruptions in the capacity to understand and manage emotional experiences within interpersonal contexts (Salavou et al., 2026). In clinically severe populations, these processes may have practical implications for the course of psychiatric care. Emotion regulation and attachment style have, for example, been examined as predictors of hospitalization duration among suicidal adolescents, illustrating the relevance of regulatory capacities even among young people experiencing acute psychiatric crises (Isack et al., 2026).

Mentalization-related processes provide another conceptual bridge between emotion regulation and adolescent psychosocial adjustment. The ability to interpret one's own and others' behavior in terms of underlying mental states may facilitate more adaptive emotional responses, whereas inaccurate or excessive interpretation of mental states may contribute to interpersonal difficulties. Emotion regulation has been shown to mediate associations between hypermentalizing and interpersonal problems among young people, indicating that deficits in regulating emotions may constitute one pathway through which distorted interpretations of social information translate into relational dysfunction (Sotomayor-Enriquez et al., 2024). Trauma-related symptoms are similarly connected with mentalizing capacities, although different forms of adversity may

contribute differently to subsequent psychological functioning (Wais et al., 2024). Related evidence from developmental psychopathology research further indicates that reflective functioning and general psychopathology may mediate associations between earlier conduct problems and later aggression, emphasizing the long-term relevance of emotional and mentalizing mechanisms for behavioral outcomes (Yirmiya et al., 2024).

Adverse experiences and childhood trauma constitute particularly important risk contexts for the development of emotion-regulation difficulties. Exposure to threat, deprivation, maltreatment, or chronic relational adversity may interfere with the acquisition of flexible strategies for understanding and modulating emotional states. Recent work examining family-related experiences, childhood trauma, and cognitive-emotional correlates in adolescent depression has reinforced the importance of considering the combined influence of family adversity and emotional processes across psychopathological domains (Wang, 2026). Childhood trauma has also been associated with externalizing symptoms through its relationship with emotional regulation, suggesting that regulatory impairment may connect early adversity with subsequent behavioral dysregulation (Sharma et al., 2024). The effects of adversity may also extend beyond common psychiatric symptom clusters. Research examining childhood threat and deprivation has linked these experiences to mental health and health-risk behaviors while identifying mindfulness and emotion regulation as potentially differentiated psychological processes involved in those associations (Poon et al., 2026). Moreover, exposure to collective trauma and large-scale societal crises may alter emotional functioning and contribute to maladaptive behavioral patterns, including disturbances in eating-related behavior (Latzer & Stein, 2026).

Acute environmental stressors provide further evidence of the interaction between emotional functioning and psychopathology. Research following major earthquakes has demonstrated that youth trauma responses are influenced not only by direct exposure but also by parental and family-related factors, underscoring the relational context of post-traumatic adjustment (Giannakopoulos et al., 2025). Similarly, the COVID-19 pandemic provided a unique context in which developmental stress, social restriction, emotional expression, and psychological well-being could be examined simultaneously. Adolescents' representations of the pandemic have been associated with well-being and alexithymia, indicating that difficulties in identifying and

describing emotional experiences may influence how stressful circumstances are psychologically processed (Farina & Pepe, 2024). Structural modeling research conducted in adolescents during the pandemic has likewise demonstrated that psychopathological symptoms and protective factors form interconnected systems rather than independent domains (Scheiner et al., 2023). Together, these findings suggest that emotion-regulation difficulties may serve as a transdiagnostic vulnerability that becomes particularly consequential when adolescents encounter heightened environmental, social, or developmental stress.

Several psychological constructs are especially relevant when attempting to discriminate between adolescents with relatively high and low emotion-regulation difficulties. One such construct is self-esteem. Global self-esteem reflects an individual's overall evaluation of personal worth and may influence emotional responses to social comparison, failure, rejection, criticism, and interpersonal conflict. Adolescents with more fragile self-evaluations may be more reactive to negative events and may have greater difficulty maintaining adaptive emotional responses under stress. Psychological functioning in adolescence also involves broader personality-related capacities. Research on personality functioning and psychological distress in clinical youth samples suggests that impairments in self and interpersonal functioning are meaningfully associated with emotional distress (Slegten et al., 2025). Such findings support the inclusion of self-evaluative and personality-related indicators when investigating emotional dysregulation as part of a broader psychological configuration rather than as an isolated symptom dimension.

Depression and anxiety represent two of the most important internalizing correlates of emotion-regulation difficulties. Developmental psychopathology models describe depressive and anxiety disorders as outcomes of interacting biological, cognitive, interpersonal, and environmental risk processes (Gökdağ & Kızıltepe, 2023). Cognitive emotion-regulation strategies show differential associations with depression, anxiety, and other psychological outcomes during adolescence and early adulthood, suggesting that the type of strategy adolescents employ may be as important as their overall regulatory capacity (Zagaría et al., 2023). Similarly, bullying victimization has been associated with adolescent depression, anxiety, and stress through cognitive emotion-regulation mechanisms, demonstrating that regulatory processes may partly explain why adverse interpersonal experiences result in psychological distress (Vacca et al.,

2023). Comparative research across cultural contexts has also found meaningful associations between maladaptive symptoms and emotion regulation, emphasizing that the connection between regulatory difficulties and psychopathology is observable across different sociocultural settings (Vatandoost et al., 2023).

Emotional dysregulation is also prominent among adolescents displaying self-harm, suicidality, antisocial behavior, and other severe forms of maladaptive functioning. Adolescents engaging in self-harm frequently demonstrate distinctive profiles involving psychopathological symptoms, alexithymia, and suicidality-related characteristics (Raffagnato et al., 2023). Alexithymia itself is increasingly recognized as a multidimensional construct associated with youth psychopathology, with different alexithymic dimensions showing distinct relationships with specific symptoms and with broader general psychopathology (Gosar & Primec, 2026). Antisocial behavior in children and adolescents similarly arises from multiple psychological and contextual pathways, including emotional, interpersonal, cognitive, and environmental influences (Mazza et al., 2025). These findings are important because they indicate that difficulty recognizing, interpreting, and regulating emotional states may be shared across clinically diverse outcomes. Rather than corresponding to only one diagnostic category, emotion-regulation impairment may therefore represent a transdiagnostic process expressed across internalizing, externalizing, self-destructive, and interpersonal problems.

Perceived stress constitutes another potentially important indicator of emotion-regulation difficulty. Adolescents experiencing high levels of stress must repeatedly recruit regulatory resources to manage academic demands, family tensions, social evaluation, uncertainty, and developmental changes. When available regulatory capacities are insufficient relative to these demands, maladaptive emotional reactions may become more frequent and persistent. The association between emotional functioning and stress can also be intensified in young people experiencing chronic physical or neurological conditions. Research on adolescents and young people living with serious chronic illness has emphasized the interaction between cognitive characteristics, psychopathology, and psychosocial resources (Tizzoni et al., 2025). Although such clinical populations differ from community samples, this evidence illustrates a broader principle: emotional adaptation depends on the balance between psychological demands and available personal and social resources.

Resilience and psychological flexibility may, conversely, function as protective psychological resources. Resilience reflects the capacity to recover or maintain adaptive functioning in the presence of stress or adversity, while psychological flexibility concerns the ability to remain in contact with present experiences and modify behavior in accordance with situational demands and personally meaningful goals. Measurement research in adolescents has highlighted the importance of distinguishing psychological flexibility from inflexibility and carefully evaluating the validity of youth self-reports of these processes (Farley & Renshaw, 2025). Interventions targeting attentional awareness, acceptance, and regulatory capacity may also help adolescents respond more adaptively to difficult emotional states. A recent systematic review of mindfulness-based interventions reported their application to emotional dysregulation in adolescents and emphasized the potential utility of approaches intended to strengthen awareness and regulation rather than focusing solely on symptom suppression (Sharma et al., 2025). Such findings reinforce the view that protective variables such as resilience and flexibility should be considered alongside symptom-based indicators when attempting to identify adolescents with elevated regulatory difficulties.

The measurement of emotion-regulation difficulties is therefore of substantial importance for both research and prevention. Instruments derived from the Difficulties in Emotion Regulation Scale have been developed and psychometrically examined to facilitate the assessment and screening of regulatory problems. Recent evidence supporting a brief DERS-based screening measure indicates that emotion-regulation difficulties can be assessed reliably and efficiently in population-based and clinical contexts (Larionow et al., 2025). Nonetheless, conventional approaches often rely on total scores, mean comparisons, correlations, or regression coefficients that assume relatively simple and frequently linear associations between predictors and outcomes. Such techniques are valuable for identifying average relationships, but they may not fully capture the multivariate similarity structures through which several psychological indicators collectively characterize adolescents with different levels of emotional difficulty.

This limitation creates a rationale for incorporating supervised machine-learning approaches into adolescent psychological research. Machine-learning classifiers can examine multivariable patterns and generate predictions for previously unseen observations, thereby shifting part of the analytical focus from statistical association to out-of-sample

discrimination. Among these methods, k-nearest neighbors is particularly suitable when classification is expected to depend on local similarity among individuals. KNN is a nonparametric instance-based algorithm that assigns a new observation to a class according to the class membership of its most similar observations in the feature space. In psychological applications, this principle is conceptually intuitive: an adolescent whose standardized profile of self-esteem, depressive symptoms, anxiety, perceived stress, and resilience resembles profiles previously observed among adolescents with high emotion-regulation difficulties would be more likely to receive the same classification. Because KNN does not require the relationship between predictors and the outcome to conform to a predetermined linear equation, it can accommodate complex local patterns that may be obscured by conventional models.

The potential value of such an approach is further supported by the growing recognition that adolescent psychological characteristics are multidimensional and often interact in nonlinear or context-dependent ways. Emotional reactivity may show curvilinear relationships with psychopathology (Chiang & Chen, 2025), and emotional, cognitive, interpersonal, and behavioral indicators frequently cluster together rather than operating independently. Even biological correlates have been investigated in relation to child and adolescent mental health, illustrating the multilevel complexity of psychopathological development (Scott et al., 2023). A classification framework that evaluates adolescents on the basis of their overall psychological configuration may therefore provide information that complements variable-centered analyses. At the same time, predictive models must be developed cautiously because high apparent performance in the data used to construct a model does not necessarily imply successful classification in new participants. Procedures such as feature standardization, stratified training-test separation, cross-validation, hyperparameter optimization, and independent test-set evaluation are consequently essential when estimating the practical discriminative performance of KNN.

Despite the expanding literature on adolescent emotion regulation, trauma, psychopathology, attachment, mentalization, and protective psychological resources, comparatively less attention has been given to the direct classification of adolescents into high versus low emotion-regulation difficulty groups using a multivariate combination of common psychological indicators. Existing research has established important associations between

dysregulation and internalizing symptoms, externalizing behavior, self-harm, adversity, stress, alexithymia, and interpersonal dysfunction, but association alone does not establish how accurately an adolescent's regulatory status can be identified from an integrated psychological profile. Examining classification performance may therefore extend the existing literature by determining whether routinely measurable indicators contain sufficient joint information to discriminate between adolescents with substantially different levels of regulatory difficulty. Such an approach may also clarify whether the psychological characteristics that are theoretically linked with dysregulation retain practical discriminatory value when considered simultaneously within an out-of-sample machine-learning framework.

Accordingly, the aim of the present study was to classify Canadian adolescents with high versus low emotion-regulation difficulties using a k-nearest neighbors machine-learning algorithm based on self-esteem, depressive symptoms, anxiety symptoms, perceived stress, and psychological resilience.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a quantitative, cross-sectional predictive classification design to classify adolescents with high versus low levels of emotion-regulation difficulties using psychological indicators and the k-nearest neighbors (KNN) machine-learning algorithm. The study population consisted of adolescents enrolled in public secondary schools in Ontario, Canada, during the 2025–2026 academic year. A total of 684 adolescents were recruited through multistage cluster sampling. First, schools were selected from participating school districts, and subsequently, classes within the selected schools were randomly identified and invited to participate. Participants ranged in age from 13 to 18 years and were required to be currently enrolled in Grades 8–12, have sufficient English proficiency to understand the questionnaires, and provide informed assent together with written parental or guardian consent when required. Adolescents were excluded when questionnaires contained substantial missing data, when response patterns indicated careless or invariant responding, or when circumstances prevented independent completion of the assessment battery. Following initial screening and data-quality assessment, all 684 eligible participants with sufficiently complete records were retained for the primary analyses. Data were collected

using standardized self-report questionnaires administered in supervised school settings through a secure electronic survey platform. Participation was voluntary, and students were informed that they could discontinue participation at any stage without academic or personal consequences. No identifying information was included in the analytical dataset. The primary outcome was classification into high versus low emotion-regulation difficulty groups. Group membership was established from scores on the Difficulties in Emotion Regulation Scale, with adolescents scoring at or above the sample median classified into the high-difficulty group and those scoring below the median classified into the low-difficulty group. This binary classification strategy was selected to provide a clearly defined outcome appropriate for supervised machine-learning classification while maintaining adequate representation of both classes.

2.2. Measures

Difficulties in Emotion Regulation Scale. Emotion-regulation difficulties were assessed using the Difficulties in Emotion Regulation Scale (DERS), originally developed by Gratz and Roemer in 2004. The DERS is a widely used 36-item self-report instrument designed to provide a multidimensional assessment of problems in emotional regulation. It measures six domains: 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. Items are rated on a 5-point Likert-type scale ranging from 1, indicating “almost never,” to 5, indicating “almost always.” After appropriate reverse scoring, item scores are summed to obtain a total score, with higher scores reflecting greater overall difficulties in regulating emotions. The total DERS score was used to construct the binary dependent variable for the KNN classification model, whereas its component scores were not entered as predictors in order to prevent information leakage between the classification target and predictor variables. The DERS has demonstrated satisfactory internal consistency, construct validity, convergent validity, and test–retest reliability in adolescent and young populations, and previous psychometric research has supported its use for assessing multidimensional emotion-regulation difficulties.

Rosenberg Self-Esteem Scale. Self-esteem was assessed using the Rosenberg Self-Esteem Scale (RSES), developed by Rosenberg in 1965. The instrument contains 10 items

measuring an individual's global evaluation of personal worth and self-acceptance. Five items are positively worded and five are negatively worded, with negatively phrased items reverse scored before calculation of the total score. Responses are typically recorded on a 4-point Likert scale ranging from strongly disagree to strongly agree. Total scores are obtained by summing responses after reverse coding, with higher scores indicating greater global self-esteem. The RSES is one of the most extensively used measures of self-esteem in psychological and adolescent research and has demonstrated adequate internal consistency, factorial validity, convergent validity, and test–retest reliability across diverse cultural and adolescent samples. The total score was included as a continuous predictor in the machine-learning analysis.

Patient Health Questionnaire-9. Depressive symptoms were measured using the Patient Health Questionnaire-9 (PHQ-9), developed by Kroenke, Spitzer, and Williams in 2001. The PHQ-9 consists of nine items corresponding to the core symptoms of depressive disorders and asks respondents to indicate how frequently each symptom has been experienced during the preceding two weeks. Items are rated from 0, representing “not at all,” to 3, representing “nearly every day,” producing a total score ranging from 0 to 27. Higher scores indicate greater severity of depressive symptomatology. Although originally developed for clinical screening, the PHQ-9 has subsequently been extensively evaluated among adolescent populations and has shown satisfactory internal consistency, criterion validity, convergent validity, and diagnostic accuracy. In the present study, the continuous total score was used as a psychological predictor rather than for clinical diagnosis.

Generalized Anxiety Disorder-7. Anxiety symptoms were assessed using the Generalized Anxiety Disorder-7 scale (GAD-7), developed by Spitzer, Kroenke, Williams, and Löwe in 2006. The GAD-7 contains seven items evaluating the frequency of common anxiety symptoms during the previous two weeks. Each item is scored on a 4-point response scale ranging from 0, “not at all,” to 3, “nearly every day,” resulting in a possible total score between 0 and 21. Higher scores represent greater severity of anxiety symptoms. The measure has demonstrated strong internal consistency, convergent and criterion-related validity, and acceptable factorial properties across clinical and community populations, including adolescents. The continuous GAD-7 total score was entered into the KNN model as an indicator of psychological distress potentially associated with emotion-regulation difficulties.

Perceived Stress Scale. Perceived stress was measured using the 10-item Perceived Stress Scale (PSS-10), derived from the scale originally developed by Cohen, Kamarck, and Mermelstein in 1983. The PSS evaluates the extent to which respondents perceive situations in their lives as unpredictable, uncontrollable, and overwhelming. The 10 items refer to experiences during the preceding month and are scored on a 5-point Likert scale ranging from 0, “never,” to 4, “very often.” Positively phrased items are reverse scored before calculating the overall score. Higher total scores indicate greater perceived stress. The PSS-10 has demonstrated satisfactory internal consistency, construct validity, and convergent validity across adolescent, student, and general-population samples. The total score was included as a continuous predictor because perceived stress is theoretically associated with reduced regulatory capacity and heightened emotional reactivity.

Brief Resilience Scale. Psychological resilience was assessed using the Brief Resilience Scale (BRS), developed by Smith and colleagues in 2008. The BRS contains six items specifically designed to measure an individual's perceived ability to recover or “bounce back” following stress and adversity. Three items are positively worded and three are negatively worded. Responses are provided on a 5-point Likert scale ranging from strongly disagree to strongly agree, with negatively phrased items reverse scored. A mean score is calculated across the six items, and higher scores represent greater psychological resilience. Previous research has supported the scale's internal consistency, test–retest reliability, convergent validity, and discriminant validity in different age groups and cultural contexts. The BRS score was treated as a continuous protective psychological indicator in the classification model.

2.3. Data Analysis

Data analysis was conducted using Python with standard statistical and machine-learning libraries. Before model development, the dataset was examined for missing values, implausible responses, extreme observations, and duplicate records. Descriptive statistics were calculated to characterize the distributions of the continuous psychological indicators and the frequencies of the binary outcome classes. Missing predictor values, when present at a limited level, were imputed using the median calculated from the training data to prevent information from the test set from influencing model development. Because the k-nearest neighbors algorithm calculates similarity on the basis of distances

between observations and is therefore highly sensitive to differences in measurement scale, continuous predictors were standardized using z-score transformation so that each variable had a mean of 0 and a standard deviation of 1. Standardization parameters were estimated exclusively from the training partition and subsequently applied to the validation and test data to avoid data leakage. The dependent variable was binary group membership representing high versus low emotion-regulation difficulties. Psychological predictor variables included self-esteem, depressive symptoms, anxiety symptoms, perceived stress, and resilience.

The dataset was randomly divided using stratified sampling into a training set comprising 80% of participants and an independent test set comprising the remaining 20%, preserving the relative distribution of the two emotion-regulation classes in both partitions. Model development and hyperparameter optimization were performed exclusively within the training data. A k-nearest neighbors classifier using Euclidean distance was fitted, and alternative values of k were evaluated because model performance can vary substantially depending on the number of neighboring observations included in classification. Candidate values of k from 3 to 25 using odd-numbered increments were examined through stratified 10-fold cross-validation within the training set. Both uniform voting, in which all selected neighbors contribute equally, and distance-weighted voting, in which observations located closer to the target case exert greater influence, were evaluated during model optimization. The final hyperparameter configuration was selected according to the highest mean cross-validated F1 score, with balanced accuracy considered as an additional criterion when competing configurations produced similar performance.

After hyperparameter selection, the optimized KNN classifier was refitted using the complete training dataset and evaluated once on the previously unseen test set. Classification performance was assessed using accuracy, sensitivity or recall, specificity, precision, F1 score, balanced accuracy, and the area under the receiver operating characteristic curve (ROC-AUC). A confusion matrix was additionally generated to quantify true-positive, true-negative, false-positive, and false-negative classifications. Because overall accuracy can be misleading when class frequencies differ, interpretation emphasized the combined pattern of sensitivity, specificity, F1 score, balanced accuracy, and ROC-AUC rather than relying on accuracy alone. Predicted class probabilities derived from the

proportion or distance-weighted contribution of neighboring observations were used for ROC analysis. To assess stability, cross-validation performance estimates were summarized using their mean and standard deviation across folds. The analytical workflow was implemented as a preprocessing-and-classification pipeline so that imputation, standardization, and model fitting were performed separately within each training fold, thereby minimizing optimistic bias and preventing preprocessing information from leaking across validation partitions. All statistical tests used for preliminary comparisons were two-tailed with a significance level of .05; however, the primary evaluation of the machine-learning model was based on out-of-sample predictive performance rather than null-hypothesis significance testing.

3. Findings and Results

A total of 684 adolescents were included in the final analysis after completion of the data-screening procedures. Participants ranged in age from 13 to 18 years, with a mean age of 15.46 years ($SD = 1.42$). Of the total sample, 352 participants (51.46%) were girls and 332 (48.54%) were boys. With respect to school grade, 104 adolescents

(15.20%) were enrolled in Grade 8, 128 (18.71%) in Grade 9, 145 (21.20%) in Grade 10, 158 (23.10%) in Grade 11, and 149 (21.78%) in Grade 12. Based on the predefined classification criterion derived from the Difficulties in Emotion Regulation Scale, 342 adolescents (50.00%) were categorized as having high emotion-regulation difficulties and 342 (50.00%) were categorized as having low emotion-regulation difficulties. The mean DERS score was 111.26 ($SD = 13.48$) in the high-difficulty group and 73.84 ($SD = 11.92$) in the low-difficulty group, indicating clear separation between the two outcome categories. Stratified partitioning preserved this class distribution across the model-development and independent evaluation samples. Accordingly, 547 participants (79.97%) were allocated to the training dataset and 137 participants (20.03%) to the test dataset. The training dataset consisted of 273 adolescents with high and 274 with low emotion-regulation difficulties, whereas the independent test dataset contained 69 adolescents with high and 68 with low emotion-regulation difficulties. Examination of the predictor variables indicated no substantial distributional anomalies after data preprocessing, and the psychological variables provided adequate variability for subsequent classification analysis.

Table 1

Descriptive Statistics and Between-Group Comparisons of Psychological Indicators According to Emotion-Regulation Difficulty Group

Psychological indicator	Low difficulties (n = 342), M $\pm$ SD	High difficulties (n = 342), M $\pm$ SD	Total sample (N = 684), M $\pm$ SD	t	p	Cohen's d
Self-esteem	30.91 $\pm$ 4.87	23.77 $\pm$ 5.42	27.34 $\pm$ 6.22	18.11	< .001	1.38
Depressive symptoms	5.86 $\pm$ 4.03	11.92 $\pm$ 5.34	8.89 $\pm$ 5.61	-16.76	< .001	1.28
Anxiety symptoms	4.71 $\pm$ 3.51	9.86 $\pm$ 4.62	7.29 $\pm$ 4.84	-16.41	< .001	1.25
Perceived stress	15.43 $\pm$ 5.14	23.88 $\pm$ 5.93	19.66 $\pm$ 6.99	-19.92	< .001	1.52
Resilience	3.54 $\pm$ 0.67	2.79 $\pm$ 0.71	3.17 $\pm$ 0.79	14.22	< .001	1.09

As presented in Table 1, adolescents classified as having high emotion-regulation difficulties demonstrated a consistently less favorable psychological profile than those classified as having low difficulties across all five predictor variables. The high-difficulty group reported substantially lower self-esteem, with a mean score of 23.77 ($SD = 5.42$), compared with 30.91 ($SD = 4.87$) among adolescents with low emotion-regulation difficulties. This difference was statistically significant, $t = 18.11$, $p < .001$, and represented a large standardized effect ($d = 1.38$). Similarly, depressive symptom scores were markedly higher in the high-difficulty

group ($M = 11.92$, $SD = 5.34$) than in the low-difficulty group ($M = 5.86$, $SD = 4.03$), $t = -16.76$, $p < .001$, $d = 1.28$. A comparable pattern was observed for anxiety symptoms, with mean GAD-7 scores of 9.86 ($SD = 4.62$) among adolescents with high emotion-regulation difficulties and 4.71 ($SD = 3.51$) among those with low difficulties, $t = -16.41$, $p < .001$, $d = 1.25$. Perceived stress showed the largest standardized difference between the two groups. Adolescents in the high-difficulty group had a mean perceived stress score of 23.88 ($SD = 5.93$), whereas those in the low-difficulty group had a mean score of 15.43 ($SD =$

5.14), $t = -19.92$, $p < .001$, corresponding to a Cohen's d of 1.52. Conversely, resilience was higher among adolescents with low emotion-regulation difficulties ($M = 3.54$, $SD = 0.67$) than among those with high difficulties ($M = 2.79$, $SD = 0.71$), $t = 14.22$, $p < .001$, $d = 1.09$. Therefore, every psychological indicator included in the predictive model

significantly differentiated the two outcome groups at the univariate level, and the magnitude of all differences was large. These findings provided preliminary evidence that the selected indicators contained meaningful discriminatory information for subsequent machine-learning classification.

Table 2

Ten-Fold Cross-Validation Performance of Candidate k -Nearest Neighbors Models in the Training Dataset

Number of neighbors (k)	Voting method	Cross-validated accuracy	Cross-validated F1 score	Balanced accuracy
3	Uniform	.810	.813	.810
5	Uniform	.826	.829	.826
7	Uniform	.839	.841	.839
9	Uniform	.846	.848	.846
11	Uniform	.842	.844	.842
13	Uniform	.835	.837	.835
15	Uniform	.830	.832	.830
17	Uniform	.824	.826	.824
19	Uniform	.819	.821	.819
21	Uniform	.815	.817	.815
23	Uniform	.808	.810	.808
25	Uniform	.805	.807	.805
3	Distance-weighted	.821	.824	.821
5	Distance-weighted	.839	.842	.839
7	Distance-weighted	.850	.853	.850
9	Distance-weighted	.855	.858	.855
11	Distance-weighted	.851	.854	.851
13	Distance-weighted	.846	.849	.846
15	Distance-weighted	.840	.843	.840
17	Distance-weighted	.835	.838	.835
19	Distance-weighted	.830	.833	.830
21	Distance-weighted	.825	.828	.825
23	Distance-weighted	.820	.823	.820
25	Distance-weighted	.816	.819	.816

Table 2 presents the results of the hyperparameter-selection procedure conducted within the training dataset using stratified 10-fold cross-validation. Overall, model performance initially improved as the number of neighboring observations increased from very small values and subsequently declined when increasingly large neighborhoods were used. Under uniform voting, the F1 score increased from .813 for $k = 3$ to a maximum of .848 at $k = 9$, after which performance gradually decreased, reaching .807 at $k = 25$. Distance-weighted voting consistently produced slightly better classification performance than uniform voting for comparable values of k , suggesting that assigning greater influence to psychologically more similar neighboring cases improved discrimination between the two emotion-regulation groups. The optimal configuration was obtained with $k = 9$ and distance-weighted voting, which produced a mean cross-

validated accuracy of .855, a mean F1 score of .858, and a balanced accuracy of .855. Increasing the neighborhood to $k = 11$ resulted in a slight reduction in F1 score to .854, while smaller neighborhoods such as $k = 3$ and $k = 5$ yielded lower F1 scores of .824 and .842, respectively. Models with larger values of k showed a progressive decline in classification performance, consistent with excessive smoothing of the local decision boundaries as increasingly dissimilar participants were incorporated into the neighborhood used for classification. On the basis of the prespecified optimization criterion, the distance-weighted KNN classifier with nine nearest neighbors was therefore selected as the final model. The relatively similar values of accuracy, F1 score, and balanced accuracy for this configuration also indicated that the optimized classifier was not achieving its overall performance by disproportionately favoring one outcome category.

Table 3

Classification Performance of the Optimized k-Nearest Neighbors Model in the Independent Test Dataset

Performance metric	Value
Accuracy	.861
Sensitivity (recall)	.870
Specificity	.853
Precision	.857
F1 score	.863
Balanced accuracy	.861
ROC-AUC	.923

The final optimized model was subsequently evaluated using the independent test dataset, which had not been used during preprocessing parameter estimation, hyperparameter selection, cross-validation, or model training. As shown in Table 3, the KNN classifier correctly classified 86.1% of adolescents in the independent test sample. Sensitivity was .870, indicating that 87.0% of adolescents who actually belonged to the high emotion-regulation difficulty group were correctly identified by the model. Specificity was .853, demonstrating that 85.3% of adolescents with low emotion-regulation difficulties were correctly classified as belonging to the low-difficulty category. Precision was .857, meaning that 85.7% of adolescents predicted by the classifier as having high emotion-regulation difficulties actually belonged to that group. The F1 score, which jointly considers precision and sensitivity, was .863 and therefore indicated a favorable balance between the model's ability to

detect adolescents with high difficulties and its ability to limit false-positive classifications. Balanced accuracy was .861 and was essentially identical to the overall accuracy, further demonstrating that classification performance was comparable across the two outcome categories rather than being driven by superior prediction of only one class. The receiver operating characteristic analysis yielded an area under the curve of .923, indicating a high level of discrimination across alternative classification thresholds. Taken together, these results demonstrate that the pattern formed by self-esteem, depressive symptoms, anxiety symptoms, perceived stress, and resilience contained sufficient information for the optimized KNN algorithm to distinguish adolescents with high versus low emotion-regulation difficulties with strong out-of-sample performance.

Table 4

Confusion Matrix for the Optimized k-Nearest Neighbors Classifier in the Independent Test Dataset

Actual group	Predicted low difficulties	Predicted high difficulties	Total
Low emotion-regulation difficulties	58	10	68
High emotion-regulation difficulties	9	60	69
Total	67	70	137

The confusion matrix presented in Table 4 provides a more detailed representation of the classification decisions underlying the performance indices reported above. Of the 68 adolescents who actually belonged to the low emotion-regulation difficulty group, 58 were correctly classified as having low difficulties, representing true-negative classifications, whereas 10 were incorrectly assigned to the high-difficulty group and therefore constituted false-positive classifications. Among the 69 adolescents who actually belonged to the high emotion-regulation difficulty group, 60 were correctly identified by the classifier as having high

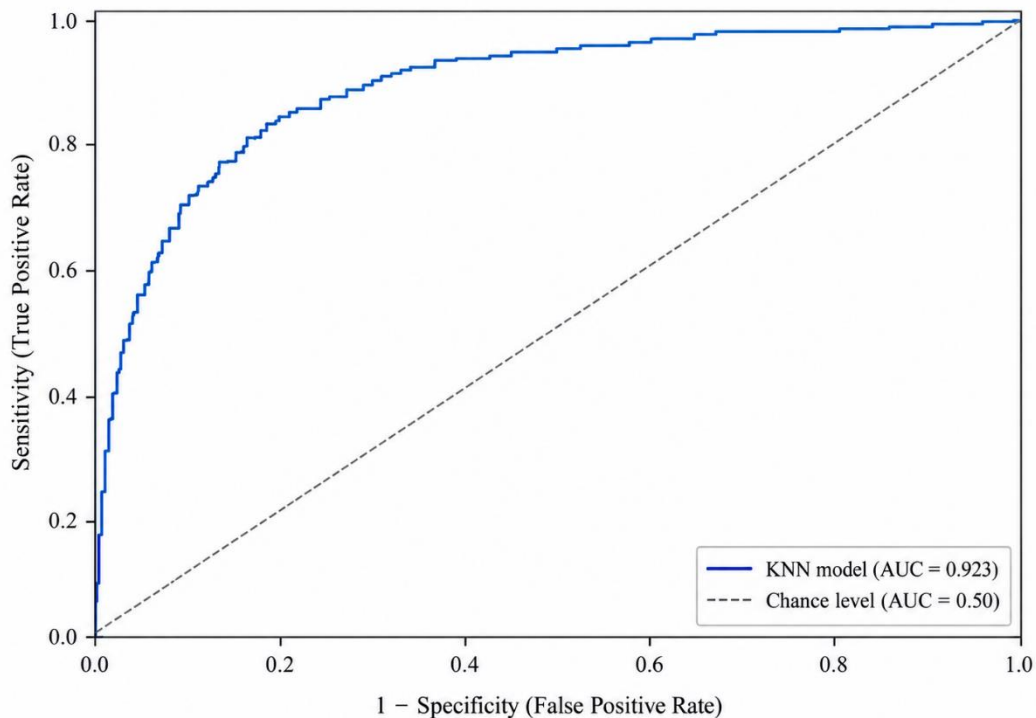
difficulties, whereas 9 were incorrectly classified as having low difficulties. Consequently, 118 of the 137 adolescents in the independent test sample were classified correctly, while only 19 were misclassified. The distribution of errors was relatively balanced, with 10 false-positive and 9 false-negative predictions, indicating that the classifier did not demonstrate a marked tendency to systematically overidentify or underidentify emotion-regulation difficulties. From a screening perspective, the relatively small number of false-negative predictions was particularly notable because the model successfully detected 60 of the 69

adolescents belonging to the high-difficulty category. At the same time, the comparable false-positive rate demonstrates that this sensitivity was not achieved through indiscriminate classification of adolescents into the high-difficulty group. The confusion matrix therefore supports the conclusion

derived from the overall performance indicators that the optimized KNN classifier achieved a balanced distinction between adolescents with high and low emotion-regulation difficulties.

Figure 1

Receiver Operating Characteristic Curve for the Optimized k-Nearest Neighbors Model in Classifying High Versus Low Emotion-Regulation Difficulties



The receiver operating characteristic curve further demonstrated the discriminatory ability of the optimized KNN classifier across the full range of possible decision thresholds. The curve remained substantially above the diagonal reference line representing chance-level discrimination, and the corresponding ROC-AUC value was .923. This value indicates that when one adolescent with high emotion-regulation difficulties and one adolescent with low difficulties were randomly selected, the model had a high probability of assigning the higher predicted probability of membership in the high-difficulty group to the adolescent who actually belonged to that group. The shape of the ROC curve indicated that substantial gains in sensitivity could be obtained while maintaining relatively low false-positive rates across a broad range of classification thresholds. At the default classification threshold applied to the test data, the model achieved sensitivity of .870 and specificity of .853, representing a balanced operating point for distinguishing

the two categories. The high area under the curve, together with the balanced sensitivity and specificity observed at the selected operating point, indicates that predictive discrimination was not dependent on a single arbitrary threshold. Instead, the psychological indicator profile captured by the KNN model provided stable separation between adolescents with relatively high and relatively low levels of emotion-regulation difficulties across alternative decision criteria.

4. Discussion

The present study examined whether adolescents with high versus low emotion-regulation difficulties could be accurately classified using a k-nearest neighbors machine-learning model based on self-esteem, depressive symptoms, anxiety symptoms, perceived stress, and psychological resilience. The findings indicated that the selected

psychological indicators meaningfully differentiated the two groups and that the optimized KNN classifier achieved strong out-of-sample performance. Adolescents in the high emotion-regulation difficulty group reported substantially lower self-esteem and resilience and markedly higher depressive symptoms, anxiety symptoms, and perceived stress than adolescents in the low-difficulty group. All between-group differences were statistically significant and large in magnitude. The optimized model, which used nine nearest neighbors with distance-weighted voting, achieved an accuracy of .861, sensitivity of .870, specificity of .853, an F1 score of .863, balanced accuracy of .861, and ROC-AUC of .923 in the independent test set. The confusion matrix further demonstrated relatively balanced classification errors, with 60 of 69 high-difficulty adolescents and 58 of 68 low-difficulty adolescents correctly classified. These findings indicate that emotion-regulation difficulties are associated with a broad and coherent psychological profile rather than with a single isolated symptom domain and that this profile can be captured effectively through a nonparametric machine-learning approach.

The pronounced differences in depressive and anxiety symptoms between the two groups are consistent with developmental psychopathology research positioning emotion dysregulation as a transdiagnostic mechanism across internalizing disorders. Adolescents who have difficulty identifying, accepting, and modifying emotional responses may be more vulnerable to sustained negative affect, repetitive negative thinking, avoidance, and heightened physiological arousal, all of which can intensify depressive and anxiety symptoms. Previous research has identified emotion regulation as an important correlate of adolescent mental well-being, with poorer regulation associated with greater psychological distress (Devi, 2023). Similarly, developmental models of depression and anxiety emphasize the interaction of emotional, cognitive, interpersonal, and environmental risk factors rather than single-cause explanations (Gökdağ & Kızıltepe, 2023). The present findings also align with evidence that cognitive emotion-regulation strategies are differentially associated with depression, anxiety, and related symptoms during adolescence and early adulthood (Zagaria et al., 2023). Taken together, these studies support the interpretation that adolescents classified as high in emotion-regulation difficulties are likely to show a broader internalizing symptom burden because ineffective regulatory processes

may intensify both the duration and perceived uncontrollability of negative emotional experiences.

The higher perceived stress observed among adolescents with elevated emotion-regulation difficulties was particularly notable and represented the largest between-group effect. This result suggests that perceived stress may be one of the most salient psychological features distinguishing adolescents who experience substantial regulatory difficulties. Stressful experiences require adolescents to appraise emotional demands, mobilize coping responses, inhibit impulsive reactions, and maintain goal-directed behavior despite discomfort. When these regulatory capacities are compromised, everyday academic, interpersonal, and family stressors may be experienced as more overwhelming and less manageable. This interpretation is consistent with evidence linking bullying victimization to depression, anxiety, and stress through cognitive emotion-regulation processes (Vacca et al., 2023). It also accords with research showing that childhood trauma and adverse experiences are associated with emotional-regulation impairment and externalizing symptoms (Shama et al., 2024). More recent studies examining family-related adversity and childhood trauma similarly indicate that cognitive-emotional processes are closely intertwined with adolescent psychopathology across multiple domains (Wang, 2026). Thus, the strong association between perceived stress and emotion-regulation difficulty in the present study likely reflects a reciprocal process in which dysregulation increases vulnerability to stress while repeated stress further taxes regulatory resources.

The finding that adolescents with high emotion-regulation difficulties had lower self-esteem also fits with broader models of adolescent psychological vulnerability. Self-esteem may influence how adolescents interpret social evaluation, failure, rejection, conflict, and perceived inadequacy. Adolescents with lower self-worth may experience negative events as more self-relevant and threatening, making emotional responses more intense and difficult to regulate. Conversely, persistent difficulty managing emotions may generate repeated interpersonal and academic problems that undermine self-confidence over time. Although the present study was not designed to establish directionality, the observed difference is consistent with work suggesting that broader personality functioning and psychological distress are closely connected among youth (Slegten et al., 2025). The association also fits with findings emphasizing that adolescent psychopathology is shaped by interconnected self-related and interpersonal

capacities rather than by symptom categories alone. From this perspective, low self-esteem may operate not simply as an independent risk factor but as part of a wider maladaptive psychological configuration that includes heightened distress, poor emotional control, and diminished coping resources.

The lower resilience scores observed in the high-difficulty group further reinforce the importance of protective psychological resources. Resilience reflects the capacity to recover from adversity, adapt to stress, and maintain functioning despite emotional challenges. Adolescents with stronger resilience may have access to a broader range of coping strategies, more flexible appraisals, and greater confidence in their capacity to manage distress, thereby reducing the likelihood that intense emotional states will become prolonged or dysregulated. The present findings are conceptually compatible with research on psychological flexibility, which highlights the importance of adaptive responding rather than rigid attempts to avoid or suppress difficult internal experiences (Farley & Renshaw, 2025). They are also consistent with evidence that mindfulness-oriented interventions can improve emotion-regulation processes among adolescents (Sharma et al., 2025). The implication is that resilience and flexibility may function as buffers against dysregulation, whereas their absence may leave adolescents more dependent on maladaptive strategies when emotional demands increase.

The results also support the broader view that emotion-regulation difficulties operate across multiple forms of adolescent psychopathology rather than being confined to depression or anxiety. Previous studies have linked dysregulation with self-harm, suicidality, antisocial behavior, alexithymia, and broader psychopathological functioning. Adolescents who engage in self-harm have been found to display distinctive symptom and alexithymia profiles, suggesting substantial impairment in emotional awareness and regulation (Raffagnato et al., 2023). Likewise, recent evidence has shown that different alexithymia dimensions are associated with both specific psychopathological symptoms and a general factor of psychopathology in youth (Gosar & Primec, 2026). Antisocial behavior in children and adolescents has also been conceptualized as the outcome of interacting emotional, cognitive, interpersonal, and contextual processes (Mazza et al., 2025). These converging findings help explain why a multivariable classifier based on common psychological indicators was able to discriminate adolescents with high and low regulatory difficulties with

relatively high accuracy. The KNN model may be capturing a broader latent pattern of emotional vulnerability that cuts across conventional diagnostic categories.

The role of interpersonal and family processes is also relevant to interpreting the findings. Emotional regulation develops within relational contexts, and adolescents learn how to understand, tolerate, and respond to emotional experiences partly through interactions with parents and other attachment figures. Parent and adolescent emotional variability have been associated with adolescent psychopathology, indicating that regulatory processes may be embedded within family emotional systems (Chiang et al., 2023). Attachment and mentalization are similarly intertwined with emotion regulation, with recent reviews emphasizing their importance in adolescent emotional and psychological functioning (Salavou et al., 2026). Emotion regulation has also been shown to mediate associations between hypermentalizing and interpersonal difficulties in young people (Sotomayor-Enriquez et al., 2024). Although family variables were not included in the present classifier, the psychological indicators used here may partly reflect the downstream effects of these interpersonal processes. For example, chronic family conflict or inconsistent emotional support may contribute simultaneously to lower self-esteem, greater anxiety, higher perceived stress, and reduced resilience, which in turn form the multivariate pattern associated with emotion-regulation difficulty.

Trauma-related processes offer another explanatory framework. Adolescents exposed to childhood threat, deprivation, or traumatic experiences may develop heightened emotional reactivity and reduced capacity to modulate distress. This is consistent with evidence linking childhood trauma to emotional dysregulation and broader psychopathological outcomes (Sharma et al., 2024; Wang, 2026). Research on young people exposed to major disasters similarly demonstrates that trauma-related symptoms are influenced by both direct exposure and parental factors (Giannakopoulos et al., 2025). Studies of mentalizing among traumatized adolescents also indicate that the psychological consequences of adversity are partly shaped by the capacity to understand internal states (Wais et al., 2024). These findings are relevant to the present study because depressive symptoms, anxiety, stress, and low resilience may jointly reflect prior exposure to adversity even when trauma history is not directly measured. The strong classification performance therefore may derive partly from the fact that the selected predictors are sensitive to multiple developmental pathways leading to regulatory impairment.

The finding that the best-performing model used distance-weighted KNN with $k = 9$ is also theoretically informative. Unlike linear regression-based classifiers, KNN does not assume that each predictor contributes additively or linearly across the full sample. Instead, it classifies individuals according to similarity within a multidimensional psychological space. This feature may be particularly appropriate for emotion regulation because adolescent psychological functioning is unlikely to conform to a single uniform pattern. Research has already demonstrated that emotional reactivity may show curvilinear rather than strictly linear associations with psychopathology (Chiang & Chen, 2025). Moreover, the broader adolescent mental-health literature increasingly recognizes heterogeneous symptom profiles and overlapping risk configurations. The present model may therefore have benefited from its ability to identify local clusters of psychologically similar adolescents without imposing a rigid global relationship between predictors and class membership.

The high ROC-AUC of .923 further indicates that the classifier maintained strong discrimination across a range of decision thresholds rather than only at a single cutoff. This is important because screening applications often involve tradeoffs between sensitivity and specificity. The present model achieved both high sensitivity and high specificity, suggesting that it was capable of identifying adolescents with substantial emotion-regulation difficulties without generating an excessive number of false positives. The relatively balanced confusion matrix supports the same conclusion. This performance is especially meaningful in light of concerns regarding the measurement of adolescent psychological functioning. Discrepancies between adolescent self-report and parental report are well documented (Caqueo-Úrizar et al., 2022), and therefore classification based on self-reported psychological indicators may capture internal experiences that are not always externally observable. At the same time, the use of self-report data may also introduce response biases, which should be considered when interpreting the findings.

The present results also underscore the usefulness of validated emotion-regulation measures for identifying adolescents at elevated psychological risk. Shorter DERS-based instruments have demonstrated satisfactory psychometric properties for screening emotion-regulation difficulties (Larionow et al., 2025). The current study extends this measurement literature by showing that regulatory difficulty status can also be inferred with

substantial accuracy from a constellation of related psychological indicators. This does not imply that machine-learning classification should replace direct assessment of emotion regulation. Rather, it suggests that multivariable predictive models may complement standardized instruments by identifying psychological profiles associated with regulatory vulnerability, particularly when several routinely collected indicators are already available.

5. Conclusion

The findings are consistent with the broader understanding of adolescent mental health as multidimensional. Research examining subjective health, health behaviors, and high-risk behaviors has demonstrated that adolescent mental-health problems are associated with multiple domains of functioning (Bezborodovs & Villeruša, 2024). Biological correlates have likewise been investigated in relation to child and adolescent mental health, underscoring the multilevel nature of psychopathology (Scott et al., 2023). Studies of chronic medical conditions and collective trauma similarly illustrate the interaction of cognitive, emotional, and psychosocial resources in shaping psychological adaptation (Latzer & Stein, 2026; Tizzoni et al., 2025). The present study adds to this literature by demonstrating that even a relatively parsimonious set of five psychological indicators can generate a strong classification signal when analyzed as a multivariate pattern rather than as isolated predictors.

6. Limitations & Suggestions

The findings should nevertheless be interpreted within several limitations. First, the cross-sectional design prevents conclusions regarding temporal or causal relationships among self-esteem, depressive symptoms, anxiety, perceived stress, resilience, and emotion-regulation difficulties. Second, all psychological variables were assessed using self-report instruments, which may be affected by shared-method variance, response styles, social desirability, and temporary mood states. Third, the sample was drawn from adolescents in Ontario, Canada, and the resulting model may not generalize equally well to adolescents from different cultural, socioeconomic, educational, or clinical contexts. Fourth, the binary classification of emotion-regulation difficulties using a median-based cutoff simplified what is fundamentally a continuous and multidimensional construct. Fifth, although the independent test set provided an appropriate internal

estimate of generalization, the model was not externally validated in a completely separate population. Finally, KNN performance is sensitive to feature scaling, sample density, and the choice of distance metric, and other algorithms might produce different patterns of predictive performance.

Future research should replicate the model in larger and more diverse adolescent samples and assess its performance across different countries, age groups, school settings, and clinical populations. Longitudinal designs would be particularly valuable for determining whether the same psychological indicators can prospectively predict the development or persistence of emotion-regulation difficulties over time. Future studies should also compare KNN with other classification approaches such as logistic regression, support vector machines, random forests, gradient boosting, and neural networks using identical training and validation procedures. Incorporating additional predictors, including family functioning, peer victimization, sleep quality, trauma exposure, executive functioning, social support, and school-related stress, may improve classification and provide a more comprehensive representation of adolescent emotional functioning. External validation using independent datasets and calibration analyses should also be prioritized before considering real-world implementation.

In practice, the findings suggest that adolescents who simultaneously present with low self-esteem, elevated depressive and anxiety symptoms, high perceived stress, and low resilience may warrant closer assessment for emotion-regulation difficulties. Schools, youth mental-health services, and primary care settings could use brief multivariable screening frameworks to identify adolescents who may benefit from more detailed psychological evaluation. Preventive interventions may be strengthened by targeting multiple domains concurrently, including emotion-regulation skills, coping with stress, self-evaluative processes, resilience, and symptoms of depression and anxiety. Machine-learning tools such as KNN should be used as decision-support instruments rather than substitutes for professional assessment, and any practical application should incorporate transparent thresholds, clinician oversight, and appropriate referral pathways for adolescents identified as being at elevated risk.

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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