

Random Forest Classification of Suicide Risk Using Hopelessness, Defeat, Entrapment, and Psychological Pain

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ABSTRACT

Objective: This study aimed to develop and evaluate a Random Forest classification model for predicting suicide risk among Moroccan adults using hopelessness, defeat, entrapment, and psychological pain as psychological predictors.

Methods and Materials: This cross-sectional predictive study was conducted among 1,284 adults from Morocco. Participants completed standardized self-report measures assessing suicide risk, hopelessness, defeat, entrapment, and psychological pain. Suicide risk was classified as a binary outcome variable, distinguishing low-risk and high-risk participants according to standardized suicide risk scores. Data were screened for missing values, distributional properties, and outliers before analysis. The dataset was divided into training and testing subsets using an 80:20 stratified split to preserve the proportion of suicide risk categories. A Random Forest classifier was trained on the training dataset, and hyperparameter tuning was performed using grid search with five-fold stratified cross-validation. Model performance was evaluated on the independent test dataset using accuracy, sensitivity, specificity, precision, F1-score, balanced accuracy, ROC-AUC, Cohen's Kappa, Matthews Correlation Coefficient, and confusion matrix indices. Feature importance was examined using Gini importance, permutation importance, and SHAP-based interpretability analysis.

Findings: Hopelessness, defeat, entrapment, and psychological pain were all positively associated with suicide risk, with psychological pain showing the strongest relationship. The optimized Random Forest model demonstrated excellent classification performance, with accuracy of 92.61%, sensitivity of 88.96%, specificity of 93.87%, precision of 90.74%, F1-score of 89.84%, balanced accuracy of 91.42%, and ROC-AUC of 0.964. Cohen's Kappa was 0.819 and the Matthews Correlation Coefficient was 0.824, indicating strong agreement beyond chance. Feature-importance results showed that psychological pain was the strongest predictor, followed by entrapment, hopelessness, and defeat. SHAP

analysis confirmed that higher levels of all four predictors increased the probability of classification into the high-suicide-risk group.

Conclusion: The findings indicate that Random Forest classification can accurately distinguish suicide risk levels using theoretically grounded psychological variables. Psychological pain and entrapment were the most influential predictors, suggesting that unbearable emotional suffering and perceived inability to escape distress are central markers of elevated suicide risk. The model may provide a useful decision-support approach for suicide risk screening, although it should complement rather than replace professional clinical judgment.

Keywords: *Suicide risk; Random Forest; hopelessness; defeat; entrapment; psychological pain; machine learning; Morocco.*

1. Introduction

Suicide risk is a complex, multidimensional psychological and public health phenomenon that cannot be adequately explained by a single symptom, diagnosis, or life event. Contemporary suicide research increasingly emphasizes that suicidal ideation and suicidal behavior emerge through the interaction of cognitive, affective, interpersonal, motivational, and contextual processes that intensify psychological distress and reduce perceived alternatives for coping. This perspective has moved the field beyond simple risk-factor enumeration toward integrative explanatory and predictive models capable of identifying how specific psychological vulnerabilities combine to produce elevated risk. Comprehensive approaches to suicidal behavior have therefore highlighted the importance of examining proximal and theoretically meaningful constructs rather than relying exclusively on broad psychiatric categories or demographic indicators (Kiani et al., 2021). Prospective evidence further suggests that suicidal ideation is shaped by dynamic psychological processes that may fluctuate over time and that prediction improves when models incorporate core subjective experiences related to future expectations, perceived escape, emotional pain, and cognitive-affective rigidity (Wetherall et al., 2021). Recent systematic evaluations of ideation-to-action theories have also emphasized the need to distinguish factors associated with suicidal thoughts from those associated with suicidal behavior, because many individuals who experience suicidal ideation do not proceed to attempt suicide (Kirshenbaum et al., 2024). Within this theoretical context, hopelessness, defeat, entrapment, and psychological pain represent central psychological mechanisms that may meaningfully contribute to suicide risk classification.

The Integrated Motivational-Volitional model has been particularly influential in explaining how background vulnerability, defeat, entrapment, motivational moderators, and volitional factors contribute to the emergence and

progression of suicidal ideation and behavior. In this framework, feelings of defeat and humiliation may generate a perception that one has failed or lost control, while entrapment transforms this distress into an urgent desire to escape from unbearable internal or external circumstances. Structural modeling research has supported the relevance of these pathways by showing that motivational and volitional processes interact in the explanation of suicide-related outcomes (Sardarzehi et al., 2023). Similarly, research on experiential avoidance within the Integrated Motivational-Volitional model has shown that attempts to avoid or suppress aversive internal experiences may strengthen the pathway from psychological distress to suicidal ideation (Ordóñez-Carrasco et al., 2021). The model has also been extended to population-specific contexts, including studies examining the role of social identity, rejection sensitivity, and psychological vulnerability in suicide risk among Black women (Clement et al., 2023). Other theoretical traditions, such as the interpersonal-psychological theory of suicide, have further emphasized the importance of perceived burdensomeness, thwarted belongingness, and acquired capability, illustrating that suicide risk is not reducible to emotional distress alone but includes interpersonal and motivational dimensions (Schomberg et al., 2025). These theoretical developments collectively support the use of multidimensional predictive models that can capture the combined contribution of several psychologically meaningful constructs.

Hopelessness has long been considered one of the most robust cognitive predictors of suicidal ideation and suicidal behavior because it reflects a generalized expectation that desired outcomes will not occur and that distressing conditions are unlikely to improve. Rather than representing ordinary pessimism, clinical hopelessness involves a rigid and negatively biased orientation toward the future, in which individuals perceive limited possibility for relief, change, or personal agency. Research on depressive predictive certainty

has shown that being certain negative events will occur, or being certain positive events will not occur, is associated with changes in suicidal ideation over time, underscoring the predictive relevance of future-oriented cognition (Rosario-Williams et al., 2021). Work clarifying the interrelationships among defeat, entrapment, and hopelessness has further indicated that these constructs are closely connected but not identical, suggesting that hopelessness may operate as a cognitive amplifier of other distress-related experiences (Oakey-Frost et al., 2022). Studies examining internal and external entrapment have also shown that hopelessness is strongly linked to suicidal ideation, especially when individuals perceive themselves as unable to escape from their own thoughts, emotions, or life circumstances (Höller et al., 2022). Intervention research has correspondingly demonstrated the clinical relevance of future-oriented processes, as future-oriented group training has been investigated as a method for suicidal individuals, reflecting the importance of modifying future expectations in suicide prevention contexts (Jaegere et al., 2023). These findings suggest that hopelessness should be included in predictive models not merely as a correlate of depression but as a specific cognitive vulnerability that may increase suicide risk.

Defeat and entrapment are central constructs in contemporary suicide theory because they describe a transition from perceived failure to perceived inability to escape. Defeat refers to the experience of losing struggle, status, control, or personal effectiveness, whereas entrapment refers to the perception that escape from painful internal or external conditions is blocked. Ecological momentary assessment research has provided evidence that defeat, entrapment, and suicidal ideation are temporally related, supporting the view that these constructs may fluctuate in close proximity to suicide-related thoughts (Ballegooijen et al., 2022). Recent work comparing suicidal ideation and suicidal behavior has further demonstrated that repetitive negative thinking, defeat, and entrapment may interact differently across individuals with suicidal thoughts versus those with suicidal behavior, suggesting that these constructs may help discriminate levels of clinical severity (Dies et al., 2024). In high-risk institutional populations, perceived entrapment, goal adjustment, and goal ambivalence have also been identified as relevant predictors of suicidal ideation, indicating that perceived blocked escape may be especially salient when individuals are exposed to restrictive environments or limited future opportunities (Huddy et al., 2025). Experimental findings have

additionally linked positive future thinking, defeat, entrapment, and death-related mental imagery, reinforcing the importance of cognitive-affective processes that shape how individuals imagine their future and interpret escape from suffering (Köse et al., 2025). Protective factors may also modify these pathways, as ethnic identity has been shown to buffer the impact of defeat and entrapment on suicidal ideation in African American young adults (Hollingsworth & Polanco-Roman, 2022). Together, these findings support the inclusion of defeat and entrapment as theoretically grounded predictors in classification models of suicide risk.

Psychological pain, sometimes conceptualized as psychache or unbearable mental suffering, represents another essential dimension of suicide risk. It refers to the subjective experience of intense emotional anguish that may become intolerable when individuals believe that the pain cannot be resolved, endured, or escaped. The concept is closely aligned with contemporary work on suicide crisis states, in which acute affective disturbance, cognitive constriction, entrapment, and loss of control may converge into a clinically significant risk condition. The suicide crisis syndrome literature has emphasized the importance of identifying acute, pre-suicidal mental states and evaluating their diagnostic validity as indicators of imminent risk (Galynker et al., 2025). Cross-cultural validation of the Revised Suicide Crisis Inventory has further demonstrated the relevance of crisis-related symptoms in suicide risk assessment outside Western contexts, supporting the broader applicability of crisis-based conceptualizations (Park et al., 2023). Psychological pain may also be intensified by self-critical cognitive styles, as self-criticism has been linked with suicide probability and may contribute to harsh internal evaluation and perceived personal failure (O'Neill et al., 2021). Conversely, the presence of life meaning and reasons for living may protect against the association between entrapment and suicidal ideation, suggesting that psychological pain becomes especially dangerous when it is accompanied by loss of meaning and diminished reasons for survival (Moscardini et al., 2021). Integrative models in minority populations, including research among Israeli LGBT individuals, have further shown that suicide risk is embedded in complex psychological and social vulnerability pathways, reinforcing the need for models that incorporate both internal suffering and contextualized distress (Levi-Belz et al., 2022).

Cognitive and metacognitive processes also contribute to suicide risk by shaping how individuals interpret distress,

regulate intrusive thoughts, and evaluate future possibilities. Experience sampling research has shown that metacognitive beliefs are associated with suicidal ideation, suggesting that beliefs about thinking itself may intensify distress when individuals perceive their thoughts as uncontrollable or threatening (Aadahl et al., 2021). Inflexible interpretations of ambiguous social situations have likewise been identified as predictors of suicidal ideation and related beliefs, indicating that rigid negative interpretation may contribute to perceived social threat and hopelessness (Everaert et al., 2021). The relevance of perceived entrapment has also been conceptually examined in relation to the COVID-19 pandemic, where feelings of being trapped were interpreted through broader systems of psychological stress and adaptation (Lee & Park, 2021). Among nurses during the pandemic, psychological burden and suicidal ideation were associated with occupational strain, illustrating how acute contextual pressures may interact with internal vulnerability to increase suicide-related distress (Höller & Forkmann, 2021). In people with bipolar disorder, social support has been examined as a direct and indirect factor in psychological pathways underlying suicidal ideation, showing that interpersonal resources can influence the extent to which internal vulnerabilities translate into suicide risk (Owen et al., 2022). These findings indicate that suicide risk classification should consider constructs that reflect internal suffering, perceived escape, and cognitive orientation toward the future.

Accurate assessment of suicide risk remains challenging because suicidal ideation and related psychological states are often unstable, private, and influenced by rapidly changing emotional and contextual conditions. Measurement studies have therefore focused on improving the reliability and sensitivity of instruments designed to capture suicidal ideation, crisis states, and suicide-related constructs. The Suicidal Ideation Attributes Scale has demonstrated psychometric utility in longitudinal samples of individuals experiencing non-affective psychosis, supporting the importance of reliable dimensional assessment across high-risk clinical groups (Harris et al., 2021). Implicit methods have also been explored, including research on death-related implicit associations among psychiatric inpatients with differing suicide risk, reflecting the ongoing effort to identify markers that may capture risk processes not fully accessible through explicit self-report (Rath et al., 2021). Ecological momentary assessment protocols have been developed to examine sleep disturbance and suicidality among psychiatric inpatients transitioning to the community,

illustrating the field's movement toward intensive and temporally sensitive risk assessment (Dewa et al., 2022). Dynamic time-warp analyses of single-case time series have further shown that suicide ideation and related symptoms may cluster and change together over time, supporting person-specific and dynamic approaches to risk understanding (Beurs et al., 2024). The development of multidimensional computerized adaptive testing for intensive longitudinal suicide risk assessment similarly reflects the need for efficient, individualized, and repeated measurement strategies that can capture within-person changes in risk-relevant domains (McClure, 2025). These developments highlight the need for predictive models that are both empirically accurate and clinically interpretable.

Recent research has also emphasized the importance of validating suicide-related constructs across cultures, languages, and developmental groups. The Entrapment Scale has been psychometrically examined in Spanish adolescents and emerging adults, demonstrating the continued relevance of measuring internal and external entrapment in younger populations (Arco et al., 2025). Similarly, the validity and reliability of the Entrapment Scale have been evaluated in Iranian adolescents, where entrapment was associated with suicidal ideation, supporting the cross-cultural importance of this construct in non-Western settings (Kulemarzi et al., 2024). Digital and linguistic approaches have also expanded the assessment of suicide risk, as theory-driven network analysis of online written expression has been used to profile uncensored suicidal thought and behavior, suggesting that suicide risk may be reflected in naturalistic psychological language as well as standardized questionnaire responses (Lekkas et al., 2023). These advances are particularly relevant for research in Morocco and other North African contexts, where culturally responsive assessment is necessary to avoid overgeneralizing findings from Western samples. Although the constructs of hopelessness, defeat, entrapment, and psychological pain have been examined in several populations, relatively little predictive modeling research has focused on their combined classification utility within Moroccan adult samples. This gap is important because suicide risk screening tools must be sensitive not only to universal psychological mechanisms but also to cultural and contextual differences in distress expression, help-seeking, stigma, and perceived escape.

Machine learning approaches offer a promising methodological direction for suicide risk research because they can model complex, nonlinear, and interactive

relationships among psychological predictors. Traditional regression-based approaches are useful for estimating average associations, but they may be limited when the objective is to classify individuals into clinically meaningful risk categories. Random Forest classification is especially suitable for this purpose because it combines multiple decision trees, reduces overfitting through ensemble aggregation, handles nonlinear effects, and provides estimates of variable importance that can be interpreted in relation to theoretical constructs. In the context of suicide risk, this approach allows researchers to examine whether hopelessness, defeat, entrapment, and psychological pain can jointly distinguish individuals at high versus low risk. It also permits evaluation of which predictors contribute most strongly to classification performance, thereby linking predictive accuracy with psychological theory. Given the evidence that suicide risk is shaped by future-oriented cognition, perceived defeat, blocked escape, intolerable psychological suffering, cognitive rigidity, and dynamic symptom clustering, an interpretable machine learning framework may provide a valuable bridge between theoretical suicide research and practical screening needs.

Accordingly, this study aimed to develop and evaluate a Random Forest classification model for predicting suicide risk among Moroccan adults using hopelessness, defeat, entrapment, and psychological pain as theoretically grounded psychological predictors.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design to develop and evaluate a machine learning model for classifying suicide risk based on psychological risk factors. The study was conducted between January and August 2025 in Morocco through collaboration with university counseling centers, community mental health clinics, and public healthcare facilities located in Casablanca, Rabat, Marrakesh, Fez, and Tangier. A total of 1,284 adults participated in the study. Participants were recruited using stratified convenience sampling to ensure representation across different regions, age groups, educational backgrounds, and socioeconomic levels. Eligibility criteria included being between 18 and 65 years of age, residing in Morocco for at least five years, possessing sufficient literacy to complete standardized questionnaires in Arabic or French, and providing written informed consent. Individuals diagnosed with severe neurocognitive disorders, active

psychotic disorders, intellectual disability, or those unable to complete the assessment because of acute psychiatric instability were excluded. Participants completed all assessments individually in private clinical or university settings under the supervision of trained psychologists. Prior to data collection, participants were informed about the study objectives, confidentiality procedures, voluntary participation, and their right to withdraw from the study at any point without consequences.

2.2. Measures

Data were collected using standardized psychological instruments with well-established psychometric properties. Suicide risk was assessed using the Suicidal Behaviors Questionnaire-Revised (SBQ-R), originally developed by Osman et al. (2001). The SBQ-R consists of four items evaluating lifetime suicidal ideation and attempts, frequency of suicidal thoughts during the previous year, communication of suicidal intent, and future likelihood of suicidal behavior. Items are scored using weighted response categories, yielding total scores ranging from 3 to 18, with higher scores indicating greater suicide risk. The SBQ-R has consistently demonstrated excellent internal consistency, satisfactory test-retest reliability, and strong concurrent validity across both clinical and community populations. The Arabic and French versions have shown appropriate psychometric characteristics in previous international studies.

Hopelessness was measured using the Beck Hopelessness Scale (BHS), developed by Beck, Weissman, Lester, and Trexler (1974). The instrument contains 20 true-false statements that assess pessimistic attitudes toward the future, expectations regarding personal success, and feelings of helplessness. Scores range from 0 to 20, with higher scores reflecting greater hopelessness. The scale has consistently demonstrated excellent internal consistency, strong convergent validity with depressive symptoms and suicidal ideation, and substantial predictive validity for suicidal behavior in numerous international investigations. Previous validation studies have confirmed the reliability and construct validity of Arabic and French adaptations.

Defeat was assessed using the Defeat Scale developed by Gilbert and Allan (1998). The questionnaire consists of 16 items measuring perceptions of failed struggle, loss of social status, diminished personal achievement, and feelings of inferiority. Responses are recorded on a five-point Likert scale ranging from 0 (never) to 4 (always), producing total

scores between 0 and 64. Higher scores indicate stronger perceptions of defeat. The Defeat Scale has demonstrated excellent internal consistency, robust construct validity, and stable factor structure across diverse cultural settings. Previous studies have confirmed acceptable psychometric properties for translated versions used in Middle Eastern and North African populations.

Entrapment was measured using the Entrapment Scale developed by Gilbert and Allan (1998). The scale contains 16 items assessing both internal entrapment, reflecting the desire to escape one's own thoughts and emotions, and external entrapment, referring to perceptions of being trapped by external circumstances or social situations. Participants respond on a five-point Likert scale ranging from 0 (not at all like me) to 4 (extremely like me). Higher total scores indicate greater feelings of entrapment. Numerous studies have reported excellent reliability coefficients, strong convergent validity with depression and suicidal ideation, and satisfactory discriminant validity. Previous research has also supported the validity and reliability of translated Arabic and French versions.

Psychological pain was evaluated using the Psychache Scale developed by Holden, Mehta, Cunningham, and McLeod (2001). The instrument consists of 13 items measuring unbearable emotional suffering, internal psychological distress, feelings of emptiness, and intolerable mental pain. Responses are scored on a five-point Likert scale ranging from 1 (never) to 5 (always), with higher scores representing greater psychological pain. The Psychache Scale has demonstrated excellent internal consistency, strong criterion validity, and substantial predictive value for suicidal ideation and suicidal behavior across clinical and non-clinical populations. Previous investigations have confirmed that the scale possesses satisfactory reliability and validity in translated Arabic and French versions.

2.3. Data analysis

Data analysis was conducted using Python version 3.12 employing the Scikit-learn, Pandas, NumPy, SHAP, and Matplotlib libraries. Preliminary analyses included examination of missing values, descriptive statistics, variable distributions, multicollinearity, and outlier detection. Missing values accounting for less than 5% of observations were imputed using median substitution. Continuous predictor variables were standardized to facilitate model interpretation, although Random Forest

algorithms do not require feature scaling for optimal performance. The dataset was randomly divided into training and testing subsets using an 80:20 ratio while preserving class proportions through stratified sampling. A Random Forest classifier was developed using the training dataset, with hyperparameters optimized through grid search combined with five-fold stratified cross-validation. The optimization process considered the number of trees, maximum tree depth, minimum samples required for node splitting, minimum samples required for leaf nodes, and the number of predictor variables considered at each split. Model performance was evaluated on the independent testing dataset using accuracy, sensitivity, specificity, precision, recall, F1-score, balanced accuracy, receiver operating characteristic area under the curve (ROC-AUC), and confusion matrix indices. Feature importance was estimated using both Gini importance and permutation importance methods, while model interpretability was enhanced through SHapley Additive exPlanations (SHAP), allowing visualization of the contribution of hopelessness, defeat, entrapment, and psychological pain to individual predictions. Calibration analysis and receiver operating characteristic curves were also examined to evaluate classification reliability and discrimination ability. Statistical analyses accompanying descriptive comparisons were performed using IBM SPSS Statistics version 29, with statistical significance established at $p < .05$ for all inferential analyses.

3. Findings and Results

Data from 1,284 participants were included in the final analyses, as all questionnaires met the predefined completeness criteria after data screening. The mean age of the participants was 31.84 years ($SD = 10.62$), with an age range of 18 to 65 years. Among the participants, 678 (52.8%) were female and 606 (47.2%) were male. Regarding marital status, 54.1% were single, 41.6% were married, and the remaining participants were divorced or widowed. Approximately 39.7% had completed secondary education, 46.3% possessed a university degree, and 14.0% had postgraduate qualifications. Most participants (61.5%) resided in urban areas, whereas 38.5% lived in rural communities. Based on the SBQ-R classification criterion, 967 participants (75.3%) were categorized as belonging to the low suicide risk group, while 317 participants (24.7%) were classified as belonging to the high suicide risk group. No statistically significant demographic differences were

observed between the training and testing datasets, confirming that stratified random sampling successfully preserved the characteristics of the original sample.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variable	Mean	SD	1	2	3	4	5
1. Suicide Risk	6.41	3.08	—				
2. Hopelessness	8.94	4.83	.71**	—			
3. Defeat	31.82	11.37	.66**	.69**	—		
4. Entrapment	34.56	12.41	.74**	.76**	.81**	—	
5. Psychological Pain	38.91	10.85	.79**	.72**	.75**	.83**	—

Table 1 presents the descriptive statistics and Pearson correlation coefficients for the primary study variables. Participants demonstrated moderate average scores on hopelessness, defeat, entrapment, and psychological pain, with substantial variability across all measures, indicating adequate dispersion for predictive modeling. Suicide risk exhibited strong positive correlations with all four psychological predictors. The strongest association was observed between psychological pain and suicide risk ($r = .79, p < .001$), followed by entrapment ($r = .74, p < .001$), hopelessness ($r = .71, p < .001$), and defeat ($r = .66, p < .001$). In addition, the predictor variables demonstrated moderate-

to-strong positive intercorrelations, particularly between entrapment and psychological pain ($r = .83, p < .001$) and between defeat and entrapment ($r = .81, p < .001$). Although these correlations indicate considerable conceptual overlap among the psychological constructs, preliminary diagnostics revealed acceptable multicollinearity indices, supporting the simultaneous inclusion of all variables in the Random Forest model. Overall, the descriptive findings suggest that greater hopelessness, perceptions of defeat, feelings of entrapment, and psychological pain are consistently associated with elevated suicide risk, providing a strong empirical basis for subsequent machine learning classification analyses.

Table 2

Performance of the Random Forest Classification Model on the Independent Test Dataset

Performance Metric	Value
Accuracy	92.61%
Precision	90.74%
Recall (Sensitivity)	88.96%
Specificity	93.87%
F1-Score	89.84%
Balanced Accuracy	91.42%
ROC-AUC	0.964
Matthews Correlation Coefficient	0.824
Cohen's Kappa	0.819

The predictive performance of the Random Forest classifier is summarized in Table 2. The optimized model demonstrated excellent discriminative capability across all evaluation indices. Overall classification accuracy reached 92.61%, indicating that the model correctly classified nearly ninety-three percent of participants into low- and high-suicide-risk groups. Precision exceeded 90%, suggesting that the vast majority of individuals identified as high risk by the algorithm were correctly classified. Sensitivity was 88.96%, reflecting the model's strong ability to detect

participants genuinely belonging to the high-risk category, while specificity reached 93.87%, demonstrating excellent identification of low-risk individuals and minimizing false-positive classifications. The F1-score of 89.84% confirmed a favorable balance between precision and recall, indicating stable predictive performance across outcome categories. Furthermore, the ROC-AUC value of 0.964 demonstrated outstanding discrimination between the two suicide risk groups, suggesting that the algorithm was highly effective in distinguishing individuals with elevated suicide risk from

those with lower levels of risk. Additional agreement statistics, including Cohen's Kappa (0.819) and Matthews Correlation Coefficient (0.824), indicated substantial agreement beyond chance and confirmed the robustness of the classification model. Collectively, these findings

demonstrate that the Random Forest algorithm achieved high predictive accuracy while maintaining excellent sensitivity and specificity, supporting its usefulness as a decision-support tool for suicide risk screening.

Table 3

Variable Importance Rankings in the Random Forest Model

Predictor	Mean Decrease in Gini	Permutation Importance	Relative Importance (%)
Psychological Pain	0.314	0.231	33.7
Entrapment	0.278	0.205	28.9
Hopelessness	0.222	0.163	21.0
Defeat	0.186	0.141	16.4

Table 3 summarizes the contribution of each predictor variable to the Random Forest classification model. Psychological pain emerged as the most influential predictor, accounting for approximately one-third of the total predictive importance. This finding indicates that intolerable emotional suffering contributed more to distinguishing high-risk individuals than any other psychological factor included in the model. Entrapment ranked as the second most influential predictor, emphasizing the critical role of perceived inability to escape adverse internal or external circumstances in suicide risk classification. Hopelessness represented the third strongest predictor, contributing substantially to the model through pessimistic expectations

regarding the future and diminished expectations of improvement. Defeat demonstrated the lowest relative importance among the four variables; however, its contribution remained considerable, accounting for more than sixteen percent of the overall predictive power. The close agreement between Gini importance and permutation importance rankings indicates stable feature importance estimates and suggests that the model relied consistently on the psychological constructs across repeated decision trees. These findings further demonstrate that suicide risk is best understood through the combined influence of multiple interconnected psychological vulnerabilities rather than reliance on a single predictor.

Figure 1

SHAP Summary Plot Illustrating the Relative Contribution of Hopelessness, Defeat, Entrapment, and Psychological Pain to Suicide Risk Classification

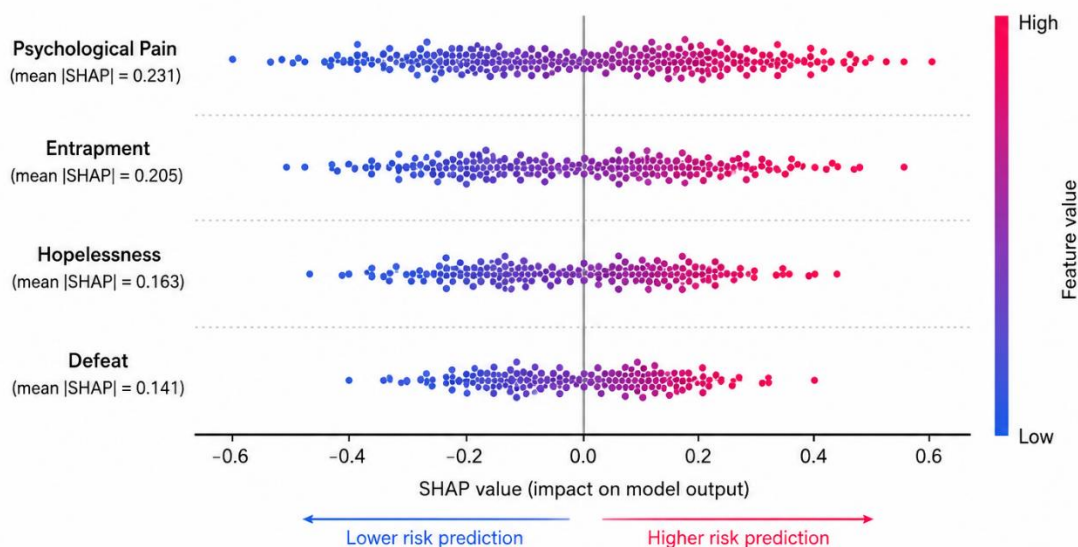


Figure 1 presents the SHAP summary plot generated from the optimized Random Forest classifier. The visualization illustrates both the relative importance of each predictor and the direction of its influence on model predictions. Psychological pain demonstrated the largest average SHAP values, indicating that increases in psychological pain produced the greatest increases in the probability of classification into the high-suicide-risk group. Entrapment exhibited the second largest SHAP values and similarly showed a positive relationship with predicted suicide risk, whereby higher perceptions of being trapped substantially increased model output toward the high-risk classification. Hopelessness also exerted a strong positive influence, particularly among individuals reporting severe pessimism regarding the future. Defeat contributed consistently across participants, although its influence was somewhat smaller than that of the other predictors. The SHAP distributions additionally revealed limited overlap between low-value and high-value observations for psychological pain and entrapment, suggesting that these variables provided the greatest discriminatory information for classification. Overall, the explainability analysis confirmed that the Random Forest model generated clinically interpretable predictions and that the combined effects of psychological pain, entrapment, hopelessness, and defeat jointly determined suicide risk classification rather than any single variable acting independently. The SHAP findings therefore provide transparent evidence supporting the reliability and practical applicability of the machine learning model for identifying individuals at elevated risk of suicidal behavior.

4. Discussion

The present study developed and evaluated a Random Forest classification model for identifying suicide risk among Moroccan adults using hopelessness, defeat, entrapment, and psychological pain as theoretically grounded predictors. The findings demonstrated that the four psychological variables were strongly and positively associated with suicide risk, and that the optimized Random Forest model achieved high classification performance on the independent test dataset. The model correctly classified participants with an overall accuracy of 92.61%, sensitivity of 88.96%, specificity of 93.87%, F1-score of 89.84%, balanced accuracy of 91.42%, and ROC-AUC of 0.964. These results indicate that the combination of hopelessness, defeat, entrapment, and psychological pain provided substantial discriminatory information for distinguishing

individuals with elevated suicide risk from those with lower levels of risk. The high ROC-AUC value is particularly important because it suggests that the model was not merely accurate because of class distribution but was able to meaningfully separate high-risk and low-risk participants across classification thresholds. The sensitivity value indicates that the model identified a large proportion of individuals classified as high risk, which is clinically relevant because false negatives in suicide risk screening may have serious consequences. At the same time, the high specificity suggests that the model also limited unnecessary high-risk classification among low-risk individuals, thereby supporting its potential value as a screening-support approach rather than a replacement for clinical assessment.

The correlational findings showed that psychological pain had the strongest association with suicide risk, followed by entrapment, hopelessness, and defeat. This pattern is consistent with contemporary suicide theories emphasizing that suicidal states often emerge when emotional suffering becomes subjectively unbearable and is experienced as impossible to escape. Psychological pain may function as the affective core of suicide risk because it captures the individual's direct experience of intolerable mental suffering, rather than only cognitive expectations or social circumstances. The prominent role of psychological pain aligns with the suicide crisis syndrome framework, which emphasizes acute cognitive-affective distress, entrapment, and loss of control as clinically meaningful indicators of suicide risk (Galynker et al., 2025). It is also consistent with validation work on suicide crisis assessment showing that crisis-related symptoms can be organized into measurable constructs with relevance across cultural settings (Park et al., 2023). The finding that psychological pain was the strongest predictor in the Random Forest model further supports the view that suicide risk is not only a function of depressive cognition or social adversity but is deeply connected to the subjective intensity of emotional suffering. This interpretation is also compatible with research showing that self-criticism is associated with suicide probability, since harsh self-evaluation may intensify psychological pain by transforming distress into a stable perception of personal failure or unworthiness (O'Neill et al., 2021).

Entrapment emerged as the second most important predictor in the model, accounting for 28.9% of relative importance. This finding supports the theoretical proposition that suicidal ideation becomes more likely when distress is accompanied by the perception that escape is blocked. Entrapment is especially relevant because it links internal

suffering with motivational urgency: individuals may not only feel distressed but may also perceive that no tolerable solution exists. This is closely aligned with the Integrated Motivational-Volitional model, in which entrapment represents a central motivational pathway through which defeat and adversity may contribute to suicidal ideation (Sardarzehi et al., 2023). The result also corresponds with ecological momentary assessment evidence showing temporal relationships between defeat, entrapment, and suicidal ideation, suggesting that these constructs may vary dynamically and may be especially relevant during periods of acute risk (Ballegooijen et al., 2022). Cross-sectional research examining internal and external entrapment has similarly shown that entrapment is closely associated with hopelessness and suicidal ideation, particularly when individuals report feeling trapped in their own thoughts and emotions (Höller et al., 2022). The present findings extend this evidence by demonstrating that entrapment also contributes meaningfully to machine learning classification of suicide risk in a Moroccan adult sample.

Hopelessness was the third most important predictor and remained a substantial contributor to the classification model. This finding confirms the enduring relevance of hopelessness in suicide risk research. Hopelessness may intensify suicide risk by narrowing future expectations and reducing the perceived likelihood that distress will improve. In this sense, hopelessness may act as a cognitive mechanism that stabilizes or prolongs psychological pain and entrapment. The current finding is consistent with research indicating that certainty about negative future events and the perceived absence of positive future outcomes are associated with changes in suicidal ideation over time (Rosario-Williams et al., 2021). It also aligns with studies showing that future-oriented processes are clinically relevant in suicidal individuals and may be targeted through intervention approaches designed to strengthen positive future thinking and reduce suicide-related cognition (Jaegere et al., 2023). Experimental work on positive future thinking, defeat, entrapment, and death-related mental imagery further suggests that the way individuals imagine the future may shape the intensity of suicide-related vulnerability (Köse et al., 2025). Therefore, the contribution of hopelessness in the present model supports the view that suicide risk classification should include future-oriented cognition rather than focusing solely on current emotional distress.

Defeat demonstrated the lowest relative importance among the four predictors, but its contribution remained meaningful. This finding should not be interpreted as

indicating that defeat is unimportant; rather, it suggests that defeat may exert part of its influence through its association with entrapment, hopelessness, and psychological pain. Defeat reflects the perception of failed struggle, diminished agency, humiliation, or loss of personal effectiveness. These experiences may contribute to suicide risk when they are transformed into a perception that escape is impossible or when they generate persistent psychological pain. This interpretation is consistent with research clarifying the interrelationships among defeat, entrapment, and hopelessness, which suggests that these constructs are closely related but conceptually distinct components of suicidogenic distress (Oakey-Frost et al., 2022). Findings from studies of repetitive negative thinking, defeat, and entrapment among individuals with suicidal ideation and suicidal behavior also suggest that defeat may be embedded in broader cognitive-affective pathways and may be particularly important when combined with entrapment and persistent negative thinking (Dies et al., 2024). Moreover, evidence that ethnic identity can protect against the effects of defeat and entrapment on suicidal ideation indicates that defeat may be moderated by identity-based and interpersonal resources, rather than functioning uniformly across all individuals (Hollingsworth & Polanco-Roman, 2022).

The strong intercorrelations among hopelessness, defeat, entrapment, and psychological pain suggest that suicide risk is best understood as an integrated psychological condition rather than as the result of isolated symptoms. The relationship between these constructs is theoretically coherent: defeat may involve perceived failure or loss; entrapment may involve the perceived impossibility of escape; hopelessness may involve the expectation that the future will not improve; and psychological pain may represent the subjective suffering generated by these combined experiences. This interconnected pattern is consistent with comprehensive approaches to suicidal behavior that emphasize the need to examine multiple psychological pathways simultaneously (Kiani et al., 2021). It also aligns with ideation-to-action perspectives showing that factors associated with suicidal ideation and attempts must be considered in combination, because the transition from thought to behavior depends on more than the presence of distress alone (Kirshenbaum et al., 2024). The current findings also correspond with research on experiential avoidance within the Integrated Motivational-Volitional model, suggesting that avoidance of internal experiences may strengthen the association between psychological distress and suicidal ideation (Ordóñez-Carrasco et al.,

2021). In this respect, the present study supports the value of predictive models that can handle overlapping and potentially nonlinear psychological relationships.

The explainability results further strengthened the clinical interpretability of the model. The SHAP analysis showed that higher values of psychological pain, entrapment, hopelessness, and defeat shifted predictions toward the high-suicide-risk classification, whereas lower values shifted predictions toward lower risk. This direction of effect is consistent with theoretical expectations and previous empirical work. For example, perceived entrapment has been linked to suicidal ideation in high-risk prisoners, particularly in relation to goal ambivalence and difficulties in goal adjustment (Huddy et al., 2025). The protective roles of life meaning and reasons for living in the association between entrapment and suicidal ideation also indicate that the effect of entrapment may depend on whether individuals retain meaningful psychological anchors that make survival feel possible (Moscardini et al., 2021). In addition, social support has been shown to influence psychological pathways underlying suicidal ideation among individuals with bipolar disorder, suggesting that the impact of internal vulnerability may be modified by relational resources (Owen et al., 2022). Thus, although the present model focused on four internal psychological predictors, its results are compatible with broader evidence showing that risk is intensified when painful internal states are not buffered by meaning, support, adaptive future thinking, or perceived alternatives.

The high predictive performance of the Random Forest classifier also supports the usefulness of machine learning for suicide risk classification when the predictors are theoretically meaningful and clinically interpretable. Traditional statistical approaches often estimate linear associations, whereas Random Forest models are able to capture nonlinear patterns and complex interactions among predictors. This is important in suicide research because individuals may arrive at similar levels of risk through different psychological pathways. For example, some individuals may be classified as high risk primarily because of extreme psychological pain, whereas others may show risk through the combined presence of moderate hopelessness, defeat, and entrapment. The need for intensive, individualized, and dynamic suicide risk assessment has been emphasized in work on computerized adaptive testing and longitudinal assessment methods (McClure, 2025). Similarly, dynamic time-series research has shown that suicidal ideation and related symptoms may cluster together differently across individuals, supporting the

importance of person-sensitive assessment strategies (Beurs et al., 2024). The present Random Forest approach contributes to this direction by demonstrating that interpretable machine learning can classify suicide risk with strong performance while maintaining psychological transparency through feature importance and SHAP explanations.

The findings are also relevant to cross-cultural suicide risk assessment. Much suicide research has been conducted in Western contexts, yet constructs such as entrapment, defeat, hopelessness, and psychological pain may be expressed differently depending on cultural norms, stigma, family expectations, religious meaning systems, and help-seeking patterns. Psychometric research on the Entrapment Scale in Spanish adolescents and emerging adults supports the relevance of entrapment assessment across developmental and cultural contexts (Arco et al., 2025). Similar validation work among Iranian adolescents has shown that entrapment is reliably measurable and associated with suicidal ideation in a non-Western population (Kulemarzi et al., 2024). Research using online written expression to profile suicidal thought and behavior further demonstrates that suicide-related distress can be investigated through culturally and linguistically situated forms of psychological expression (Lekkas et al., 2023). The present Moroccan sample contributes to this growing cross-cultural evidence by showing that core psychological constructs identified in international suicide theory can meaningfully classify suicide risk in a North African context. However, the findings also imply that future work should examine whether locally specific cultural, spiritual, familial, and social variables improve classification beyond these four psychological predictors.

5. Conclusion

The present results can additionally be interpreted in relation to broader cognitive, occupational, and contextual vulnerability research. Metacognitive beliefs have been associated with suicidal ideation in experience sampling research, suggesting that beliefs about the controllability and danger of thoughts may intensify risk when individuals feel trapped by their own mental activity (Aadahl et al., 2021). Inflexible interpretations of ambiguous social situations have also been shown to predict suicidal ideation, indicating that rigid negative interpretation may contribute to hopelessness and social threat perceptions (Everaert et al., 2021). Studies conducted during the COVID-19 pandemic

further illustrate how entrapment and psychological burden may increase suicide-related distress under conditions of uncertainty, restriction, and chronic stress (Höller & Forkmann, 2021; Lee & Park, 2021). Research on sleep disturbance and suicidality among psychiatric inpatients transitioning to the community also highlights the relevance of acute and fluctuating risk processes that may interact with cognitive-affective vulnerability (Dewa et al., 2022). Finally, assessment studies involving implicit associations with death and psychometric evaluation of suicidal ideation measures reinforce the broader methodological point that suicide risk assessment requires multiple forms of measurement and cannot depend solely on unstructured clinical judgment (Harris et al., 2021; Rath et al., 2021). The current findings therefore support a psychologically integrated and methodologically advanced approach to suicide risk classification.

6. Limitations & Suggestions

Despite its contributions, this study has several limitations that should be acknowledged. First, the cross-sectional design prevents causal interpretation of the relationships among hopelessness, defeat, entrapment, psychological pain, and suicide risk. Although the Random Forest model showed strong classification performance, it cannot determine whether these predictors caused elevated suicide risk or whether they reflected psychological states already shaped by suicide-related distress. Second, all primary variables were assessed using self-report questionnaires, which may be influenced by response bias, social desirability, recall difficulty, literacy level, and reluctance to disclose suicide-related thoughts. Third, although the Moroccan sample was relatively large and geographically diverse, it may not fully represent all Moroccan adults, particularly individuals in rural areas, highly marginalized communities, or those not connected to educational, clinical, or public health settings. Fourth, the outcome variable was based on standardized risk classification rather than prospective observation of future suicidal behavior. Therefore, the model should be interpreted as a screening-support tool for current suicide risk classification, not as a definitive predictor of future suicide attempts or deaths.

Future studies should use longitudinal and prospective designs to evaluate whether hopelessness, defeat, entrapment, and psychological pain predict future changes in suicidal ideation, suicide attempts, and clinical crises over

time. Research should also test the model in independent Moroccan samples and in other North African, Arab, and multilingual populations to examine generalizability and cultural robustness. Future investigations could expand the predictor set by including depression, anxiety, trauma exposure, sleep disturbance, substance use, perceived social support, religious coping, family conflict, emotion regulation, impulsivity, and access to lethal means. It would also be valuable to compare Random Forest models with other machine learning algorithms such as gradient boosting, support vector machines, neural networks, and regularized logistic regression. In addition, future studies should evaluate model calibration, fairness across demographic subgroups, and clinical utility using decision-curve analysis. Finally, ecological momentary assessment and digital phenotyping approaches may help determine whether moment-to-moment changes in entrapment, psychological pain, and hopelessness improve short-term prediction of suicide risk.

The findings suggest that suicide risk screening should pay particular attention to psychological pain, entrapment, hopelessness, and defeat, especially when these experiences occur together. Mental health professionals should assess not only whether a person reports suicidal thoughts, but also whether the person feels unable to escape emotional suffering, perceives the future as closed, experiences persistent failure or humiliation, and describes psychological pain as unbearable. Screening systems in universities, community mental health centers, and primary care settings may benefit from structured assessment tools that incorporate these constructs and use interpretable decision-support methods to identify individuals who require further evaluation. However, machine learning outputs should never replace professional clinical judgment, therapeutic engagement, or crisis intervention protocols. Instead, predictive models should be used as supplementary tools that help clinicians organize information, detect high-risk profiles, prioritize referrals, and guide timely intervention. Practical suicide prevention efforts should also include culturally sensitive psychoeducation, crisis planning, strengthening of social support, reduction of stigma around help-seeking, and interventions focused on restoring hope, meaning, coping flexibility, and perceived alternatives to escape.

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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.

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All authors equally contributed in this article.

Declaration

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

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