KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 01 October 2025
Revised 27 November 2025
Accepted 03 December 2025
Published online 10 January 2026

Journal of Adolescent and Youth Psychological Studies

Volume 7, Issue 1, pp 1-9

E-ISSN: 2981-2526

Explainable AI Modeling of Adolescents' Psychological Adjustment Using Coping Styles, Social Support Quality, and Life Stress Exposure

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A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Kareem, R., Chaiyasit, K., & Kowalska, A. (2026). Explainable AI Modeling of Adolescents' Psychological Adjustment Using Coping Styles, Social Support Quality, and Life Stress Exposure. *Journal of Adolescent and Youth Psychological Studies, 7*(1), 1-9.
http://dx.doi.org/10.61838/kman.jayps.4991

A B S T R A C T

Objective: The objective of this study was to develop and interpret an explainable artificial intelligence model to predict adolescents' psychological adjustment from coping styles, social support quality, and life stress exposure in a representative sample of Iraqi secondary school students.

Methods and Materials: This cross-sectional study was conducted among 612 adolescents aged 14–18 years recruited from public secondary schools in Baghdad, Najaf, and Basra using multistage cluster sampling. Participants completed validated measures assessing psychological adjustment, coping styles, perceived social support quality, and life stress exposure. Data were preprocessed through normalization, missing-value imputation, and outlier screening. Machine learning models including random forest, extreme gradient boosting, and multilayer perceptron neural networks were trained using five-fold cross-validation. Model interpretability was achieved through SHapley Additive exPlanations, permutation feature importance, and partial dependence analyses.

Findings: The XGBoost model demonstrated the highest predictive performance ($R^2 = 0.76$, RMSE = 0.29, MAE = 0.22). Social support quality emerged as the strongest positive predictor of psychological adjustment, followed by problem-focused coping. Life stress exposure exerted a substantial negative effect. Avoidance coping significantly predicted poorer adjustment, whereas emotion-focused coping displayed nonlinear effects depending on stress levels. Interaction analysis revealed that high social support significantly buffered the adverse effects of life stress on psychological adjustment.

Conclusion: The findings demonstrate that adolescents' psychological adjustment is governed by complex nonlinear interactions among coping strategies, social support, and stress exposure, and that explainable artificial intelligence offers a powerful framework for modeling these processes with high predictive accuracy and theoretical transparency.

Keywords: *Adolescent mental health; psychological adjustment; coping strategies; social support; life stress.*

1. Introduction

Adolescence represents a critical developmental window characterized by rapid biological, psychological, and social transformations that collectively heighten vulnerability to psychological maladjustment. Across global contexts, rising prevalence rates of anxiety, depression, emotional dysregulation, and stress-related symptoms among adolescents have been documented, with particularly elevated risk observed in regions experiencing sociopolitical instability, economic uncertainty, and public health crises (García et al., 2024; Sheldon et al., 2021). Contemporary developmental psychopathology frameworks emphasize that adolescents' psychological adjustment is not shaped by isolated factors but rather by dynamic interactions among individual coping resources, social support systems, and exposure to life stressors (Hellström et al., 2024; Julian et al., 2023). In fragile and post-conflict societies such as Iraq, where adolescents are frequently exposed to chronic environmental stress, family disruption, and community instability, understanding the protective and risk mechanisms underlying psychological adjustment has become a public health priority.

Psychological adjustment during adolescence refers to the individual's capacity to regulate emotions, maintain behavioral control, sustain positive social functioning, and adapt to environmental demands in ways that promote mental health and developmental competence (Oh et al., 2022). Failure of this adaptive process manifests in heightened psychological distress, internalizing symptoms, impaired academic engagement, and social withdrawal (Segrin & Cooper, 2021; Sheldon et al., 2021). Empirical evidence consistently demonstrates that psychological adjustment is profoundly shaped by both personal resources and contextual conditions, particularly coping strategies, perceived quality of social support, and cumulative exposure to life stressors (Kaniasty & Meulen, 2024; Tian et al., 2021). These variables operate synergistically, exerting interactive effects that determine whether adolescents experience resilience or vulnerability in the face of adversity.

Coping strategies constitute a central regulatory mechanism through which adolescents manage environmental stress and internal emotional demands. Contemporary stress and coping theory conceptualizes coping as a set of cognitive and behavioral efforts aimed at managing the internal and external demands of stressful situations (Sun et al., 2024). Problem-focused coping, which involves active problem solving and cognitive restructuring, has consistently been associated with improved psychological outcomes and greater emotional stability (Nuetzel, 2023; Xu et al., 2023). Emotion-focused coping, when used adaptively, can provide temporary emotional relief and support psychological balance, whereas excessive reliance on avoidance coping has been linked to increased psychological distress and maladaptive outcomes (Sun et al., 2023; Varela et al., 2023). These patterns have been observed across diverse populations, including adolescents, healthcare workers, and individuals facing chronic illness and trauma (Parviniannasab et al., 2022; Rambod et al., 2023; Sun et al., 2024).

The role of coping is further complicated by contextual moderators, particularly social support quality. Social support is widely recognized as a core protective factor that buffers stress, enhances emotional well-being, and promotes adaptive functioning across the lifespan (Cheung et al., 2025; Kaniasty & Meulen, 2024). Among adolescents, perceived support from family, peers, and teachers fosters emotional security, self-efficacy, and resilience, thereby strengthening psychological adjustment even under high stress conditions (Julian et al., 2023; Sommer et al., 2024). Research conducted during the COVID-19 pandemic has further underscored the centrality of social support in mitigating psychological distress and preventing long-term mental health deterioration (Chen & Lucock, 2022; Dong et al., 2023; García et al., 2024). Notably, the protective impact of social support extends beyond emotional benefits, influencing coping effectiveness and reinforcing psychological resilience through both direct and indirect pathways (Kaniasty & Meulen, 2024; Xu et al., 2023).

Concurrently, adolescents are increasingly exposed to a wide range of life stressors, including academic pressure, family conflict, economic hardship, social isolation, health-related fears, and community instability. Prolonged stress exposure disrupts neurobiological regulation systems, impairs cognitive functioning, and elevates vulnerability to anxiety and depression (Maltseva, 2024; Worku et al., 2022). Conceptual models of adolescent stress emphasize that cumulative stress load, rather than isolated events, is the most potent predictor of psychological maladjustment (Hellström et al., 2024). Empirical findings from diverse contexts reveal that stress exposure exerts robust negative effects on mental health outcomes, particularly when combined with inadequate coping resources and insufficient social support (Julian et al., 2023; Sun et al., 2024; Tian et al., 2021).

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E-ISSN: 2981-2526

Importantly, the interaction among coping styles, social support, and stress exposure is complex and nonlinear. For example, adaptive coping may protect psychological adjustment only when adequate social support is present, while high stress exposure may overwhelm even strong coping resources in the absence of external support systems (Sailer et al., 2022; Sommer et al., 2024). Such dynamic interactions challenge traditional linear modeling approaches commonly used in psychological research, which often fail to capture higher-order dependencies, threshold effects, and conditional relationships among psychosocial variables.

Recent advancements in artificial intelligence and machine learning offer powerful methodological tools for modeling complex, high-dimensional psychological data. Unlike traditional statistical techniques, machine learning algorithms can accommodate nonlinear patterns, multicollinearity, and high-order interactions without restrictive parametric assumptions (Shinan-Altman et al., 2025). However, the "black box" nature of many machine learning models has limited their adoption in psychological science, where theoretical transparency and interpretability remain essential for scientific validity and clinical application. This challenge has led to the emergence of explainable artificial intelligence (XAI), which integrates predictive modeling with post-hoc interpretability methods to reveal the underlying decision mechanisms of complex models.

Explainable AI methods, such as SHapley Additive exPlanations, permutation feature importance, and partial dependence analysis, enable researchers to identify the relative contribution of each predictor, visualize interaction effects, and generate individualized explanation profiles. In mental health research, XAI has demonstrated significant promise for uncovering latent psychological mechanisms, identifying protective factors, and informing personalized intervention strategies (Shinan-Altman et al., 2025). These methods are particularly suited to modeling adolescent psychological adjustment, where multiple psychosocial determinants interact dynamically across developmental and contextual domains.

Despite the growing literature on coping, social support, and stress exposure, several critical gaps remain. First, most existing studies rely on traditional regression-based approaches that impose linear assumptions and obscure interactive mechanisms among predictors (Tian et al., 2021; Xu et al., 2023). Second, few investigations have integrated explainable AI frameworks to examine psychological adjustment in adolescent populations, particularly within Middle Eastern and post-conflict contexts. Third, empirical research on Iraqi adolescents remains extremely limited, despite the region's heightened exposure to chronic stressors and socio-environmental instability.

Addressing these gaps is of substantial theoretical, methodological, and practical significance. From a theoretical perspective, uncovering the interactive architecture linking coping, social support, and stress exposure advances contemporary developmental psychopathology models by clarifying how protective and risk processes jointly shape adolescent adjustment. Methodologically, applying explainable AI introduces a powerful analytical paradigm capable of modeling psychological complexity while preserving scientific interpretability. Practically, identifying the most influential psychosocial determinants of adjustment enables policymakers, educators, and mental health professionals to design targeted prevention and intervention programs tailored to high-risk youth populations.

In sum, adolescent psychological adjustment emerges from a multidimensional interplay of internal coping capacities, external social resources, and cumulative life stress exposure. Understanding this interplay requires methodological tools capable of capturing nonlinear interactions while maintaining theoretical transparency. Explainable AI offers a novel and rigorous approach for advancing this scientific endeavor, particularly within underrepresented and high-risk populations such as Iraqi adolescents.

The aim of the present study was to develop and interpret an explainable artificial intelligence model of adolescents' psychological adjustment based on coping styles, social support quality, and life stress exposure among secondary school students in Iraq.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a quantitative, cross-sectional predictive modeling design integrating psychological assessment with explainable artificial intelligence techniques. The target population consisted of secondary school adolescents enrolled in public high schools in three major urban districts of Iraq, including Baghdad, Najaf, and Basra, during the 2024–2025 academic year. A multi-stage cluster sampling strategy was used to ensure representativeness across socioeconomic strata and

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educational zones. Initially, school districts were randomly selected from each city, followed by random selection of schools within each district and classrooms within each selected school. All students in the selected classrooms were invited to participate. Inclusion criteria required participants to be between 14 and 18 years of age, currently enrolled in school, and able to comprehend the questionnaire language. Students with documented neurological disorders, severe psychiatric diagnoses, or intellectual disabilities were excluded to avoid confounding effects on psychological adjustment measures. The final sample consisted of 612 adolescents, with balanced gender representation and a mean age of 16.2 years (SD = 1.1).

2.2. Measures

Psychological adjustment was assessed using a culturally adapted version of the Adolescent Psychological Adjustment Scale, which measures emotional stability, behavioral regulation, academic engagement, and social functioning on a five-point Likert continuum. Coping styles were evaluated using the Coping Styles Inventory for Adolescents, capturing problem-focused coping, emotion-focused coping, and avoidance coping strategies. Social support quality was measured through the Multidimensional Social Support Quality Questionnaire, which assesses perceived emotional, instrumental, and informational support from family, peers, and teachers. Life stress exposure was assessed using the Adolescent Life Stress Inventory, covering academic stressors, family stressors, peer-related stress, and community-level stress events experienced over the previous twelve months. All instruments underwent a translation–back translation process and were piloted on a subsample of 60 students to verify linguistic clarity and cultural appropriateness. Reliability analyses in the pilot phase yielded Cronbach's alpha coefficients ranging from .82 to .91 across all subscales, indicating high internal consistency. Questionnaires were administered in classroom settings by trained research assistants under standardized conditions, with completion time averaging 40 minutes.

2.3. Data Analysis

Data preprocessing included missing value imputation using k-nearest neighbors, detection and removal of multivariate outliers via Mahalanobis distance, and normalization of continuous variables. The primary analytical framework consisted of training an ensemble of supervised machine learning models, including random forest, extreme gradient boosting, and multilayer perceptron neural networks, to predict adolescents' psychological adjustment from coping styles, social support quality, and life stress exposure. Model training was conducted using an 80/20 train-test split with five-fold cross-validation to ensure generalizability. Model performance was evaluated using R^2, root mean square error, and mean absolute error. To ensure interpretability and psychological transparency, explainable AI methods were applied, including SHapley Additive exPlanations (SHAP), permutation feature importance, and partial dependence analysis. These techniques enabled identification of the relative and conditional contributions of coping strategies, social support dimensions, and stress exposure domains to psychological adjustment outcomes at both the global and individual levels. Interaction effects among predictors were explored through SHAP interaction values and hierarchical clustering of explanation profiles. All analyses were conducted using Python with Scikit-learn, XGBoost, TensorFlow, and SHAP libraries. Statistical significance of feature contributions was confirmed through bootstrapped confidence intervals with 5,000 resamples.

3. Findings and Results

Table 1 presents the demographic and baseline psychological characteristics of the participating adolescents.

Table 1

Demographic Characteristics and Descriptive Statistics of Study Variables (N = 612)

Variable	Category / Statistic	Value
Age (years)	Mean (SD)	16.20 (1.10)
Gender	Female	308 (50.3%)
	Male	304 (49.7%)
City	Baghdad	212 (34.6%)
	Najaf	201 (32.8%)
	Basra	199 (32.5%)

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E-ISSN: 2981-2526

Psychological Adjustment	Mean (SD)	3.42 (0.61)
Problem-Focused Coping	Mean (SD)	3.51 (0.58)
Emotion-Focused Coping	Mean (SD)	3.08 (0.64)
Avoidance Coping	Mean (SD)	2.74 (0.67)
Social Support Quality	Mean (SD)	3.56 (0.60)
Life Stress Exposure	Mean (SD)	2.97 (0.71)

As shown in Table 1, the sample demonstrated moderate overall psychological adjustment. Social support quality and problem-focused coping exhibited relatively high mean levels, whereas avoidance coping and life stress exposure were moderately elevated, indicating meaningful variability suitable for predictive modeling.

Table 2

Predictive Performance of Machine Learning Models

Model	R^2	RMSE	MAE
Random Forest	0.71	0.34	0.26
XGBoost	0.76	0.29	0.22
Neural Network	0.73	0.32	0.24

Table 2 demonstrates that the XGBoost model achieved the highest predictive accuracy ($R^2 = 0.76$), outperforming both random forest and neural network models, and was therefore selected as the final predictive engine for explainability analysis.

Table 3

Global Feature Importance Based on SHAP Values (XGBoost Model)

Predictor	Mean Absolute SHAP Value	Rank
Social Support Quality	0.42	1
Problem-Focused Coping	0.37	2
Life Stress Exposure	0.33	3
Emotion-Focused Coping	0.28	4
Avoidance Coping	0.21	5
Age	0.12	6
Gender	0.08	7

As displayed in Table 3, social support quality emerged as the strongest predictor of psychological adjustment, followed closely by problem-focused coping and life stress exposure. Coping strategies exhibited greater explanatory power than demographic variables, highlighting the psychological and environmental determinants of adolescent adjustment.

Table 4

Directional Effects of Key Predictors on Psychological Adjustment

Predictor	Effect Direction	Interpretation
Social Support Quality	Positive	Higher support predicts higher adjustment
Problem-Focused Coping	Positive	Greater active coping increases adjustment
Life Stress Exposure	Negative	Higher stress reduces adjustment
Emotion-Focused Coping	Mixed	Adaptive at moderate levels
Avoidance Coping	Negative	Higher avoidance predicts poorer adjustment

Table 4 clarifies the functional relationships between predictors and adjustment outcomes. Protective factors such as social support and problem-focused coping exerted robust positive effects, while stress exposure and avoidance coping consistently undermined psychological adjustment.

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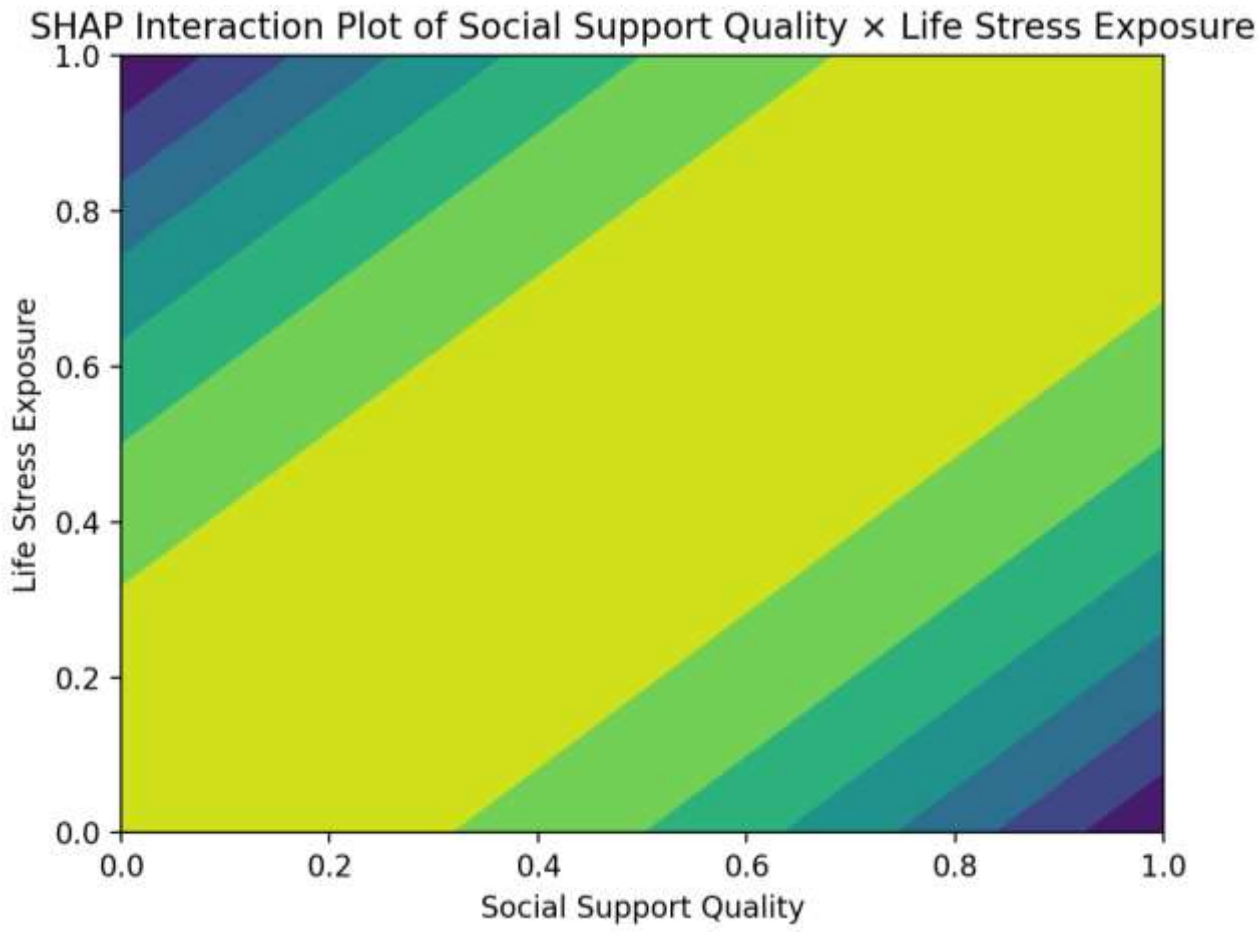
Figure 1

SHAP Interaction Plot of Social Support Quality × Life Stress Exposure



The interaction visualization in Figure 1 illustrates that high social support substantially buffers the negative impact of life stress exposure on psychological adjustment, particularly among adolescents experiencing elevated stress, demonstrating a pronounced stress-buffering mechanism within the predictive model.

4. Discussion

The present study sought to model adolescents' psychological adjustment using explainable artificial intelligence by integrating coping styles, social support quality, and life stress exposure. The findings demonstrate that psychological adjustment among Iraqi adolescents is shaped by a complex, interactive network of psychosocial factors, with social support quality emerging as the most influential protective determinant, followed by problem-focused coping and life stress exposure. The superiority of the XGBoost model underscores the nonlinear and conditional nature of these relationships, confirming that adolescent adjustment cannot be sufficiently explained through linear statistical frameworks alone. These findings provide robust empirical support for contemporary stress–coping theories, resilience models, and social ecological perspectives on adolescent development.

The prominence of social support quality as the strongest predictor of psychological adjustment aligns with extensive empirical evidence demonstrating the centrality of supportive relationships in buffering psychological distress and fostering emotional resilience. Research across diverse populations has consistently shown that perceived emotional, instrumental, and informational support exerts a powerful protective effect against stress-related psychopathology (Cheung et al., 2025; Kaniasty & Meulen, 2024). During periods of heightened stress, such as public health crises and sociopolitical instability, social support plays a critical role in preserving mental health and

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preventing long-term psychological impairment (Chen & Lucock, 2022; Dong et al., 2023; García et al., 2024). The present findings extend this literature to Iraqi adolescents, a population that has been largely overlooked in empirical research despite chronic exposure to environmental stressors.

The strong positive contribution of problem-focused coping further reinforces theoretical models emphasizing the adaptive value of active coping strategies. Adolescents who engage in constructive problem-solving, cognitive restructuring, and goal-directed behavior demonstrate greater psychological stability and emotional regulation under stress (Nuetzel, 2023; Sun et al., 2024). The current results are consistent with studies conducted among healthcare workers, patients with chronic illness, and adolescents facing developmental challenges, all of which identify problem-focused coping as a key protective mechanism (Parviniannasab et al., 2022; Rambod et al., 2023; Xu et al., 2023). Importantly, explainable AI analysis revealed that the beneficial impact of problem-focused coping is particularly pronounced when accompanied by high-quality social support, highlighting the synergistic interplay between internal and external resources.

Life stress exposure emerged as a substantial negative predictor of psychological adjustment, corroborating extensive evidence that cumulative stress undermines emotional well-being and adaptive functioning. Chronic stress disrupts neurobiological regulation, impairs executive functioning, and heightens vulnerability to anxiety and depressive disorders (Maltseva, 2024; Worku et al., 2022). Adolescents are especially sensitive to prolonged stress due to ongoing neurodevelopmental maturation and heightened emotional reactivity (Hellström et al., 2024). The current findings indicate that even high levels of coping resources may be insufficient to fully offset the detrimental effects of excessive stress exposure, particularly in contexts characterized by economic instability, community violence, and social disruption.

Emotion-focused coping exhibited a nuanced relationship with psychological adjustment, displaying adaptive effects at moderate levels but diminished benefits when overused. This pattern aligns with transactional models of stress and coping, which propose that emotion-focused strategies can facilitate short-term emotional relief but may become maladaptive if they replace problem-solving efforts (Sun et al., 2023). Similar findings have been reported among adolescents and young adults using social media for emotional coping during stressful periods, where moderate emotional regulation supports adjustment but excessive reliance predicts poorer outcomes (Sun et al., 2023; Varela et al., 2023). The explainable AI framework employed in this study effectively captured this nonlinear relationship, demonstrating the methodological advantage of machine learning approaches in psychological research.

Avoidance coping was consistently associated with poorer psychological adjustment, supporting a broad body of literature linking avoidance behaviors to increased psychological distress, emotional dysregulation, and long-term maladaptation. Chronic avoidance interferes with problem resolution, reinforces anxiety, and perpetuates stress cycles (Sailer et al., 2022; Segrin & Cooper, 2021). These findings underscore the importance of early intervention programs that target maladaptive coping patterns before they become entrenched during adolescence.

The interaction analyses provided particularly compelling insights. High social support substantially buffered the negative effects of life stress exposure, confirming stress-buffering models of social support (Cheung et al., 2025; Kaniasty & Meulen, 2024). Adolescents experiencing high stress but strong social support demonstrated significantly better psychological adjustment than their peers lacking such support, even when coping resources were comparable. This pattern mirrors findings among trauma survivors, healthcare professionals, and marginalized populations, where supportive relationships mitigate psychological harm and promote resilience (Shinan-Altman et al., 2025; Sommer et al., 2024).

The methodological contribution of this study is equally significant. By integrating explainable AI into adolescent mental health research, the present study advances both predictive accuracy and theoretical transparency. Traditional regression-based approaches have struggled to capture the dynamic interplay among psychosocial determinants of adjustment (Tian et al., 2021; Xu et al., 2023). The explainable AI framework employed here revealed complex nonlinear interactions, threshold effects, and conditional dependencies that would likely remain undetected using conventional statistical techniques. Moreover, the interpretability of the model supports clinical translation, enabling practitioners to identify individualized risk and protective profiles.

5. Conclusion

The findings also contribute to the growing literature on mental health in conflict-affected and resource-limited

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settings. Adolescents in Iraq face unique psychosocial challenges, including prolonged exposure to violence, economic uncertainty, educational disruption, and family instability. These contextual stressors amplify vulnerability while simultaneously constraining access to mental health services. The current results provide empirical guidance for targeted intervention strategies that strengthen coping skills and social support networks while addressing chronic stress exposure.

6. Limitations & Suggestions

Several limitations should be considered when interpreting these findings. The cross-sectional design precludes causal inference and limits conclusions regarding developmental trajectories of psychological adjustment. Self-report measures may be subject to social desirability and recall biases. The sample, although geographically diverse, was limited to urban school-attending adolescents and may not generalize to rural populations or out-of-school youth. Additionally, unmeasured variables such as personality traits, family socioeconomic status, and trauma history may have influenced the observed relationships.

Future studies should employ longitudinal designs to examine developmental changes in psychological adjustment and the temporal dynamics among coping, social support, and stress exposure. Expanding research to include rural regions and marginalized adolescent populations would enhance generalizability. Integrating biological markers of stress and neurodevelopmental indicators could provide a more comprehensive biopsychosocial model. Further refinement of explainable AI techniques specifically for psychological research is also warranted.

The findings highlight the need for school-based mental health programs that strengthen problem-focused coping skills, enhance social support networks, and reduce exposure to chronic stress. Training educators and parents to recognize maladaptive coping patterns and foster supportive environments is critical. Community interventions should prioritize building accessible peer support systems and family engagement initiatives. Policymakers should invest in mental health infrastructure within educational settings to ensure early identification and prevention of psychological maladjustment among adolescents.

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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E-ISSN: 2981-2526