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Using Random Forest Models to Identify Predictors of Adolescent Aggression

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A B S T R A C T

Objective: The objective of this study was to identify and rank the most important individual, familial, and contextual predictors of adolescent aggression using a Random Forest machine learning approach.

Methods and Materials: This study employed a cross-sectional predictive design involving adolescents aged 13–18 years recruited from public secondary schools in Tehran, Iran. Data were collected using validated self-report instruments assessing aggression and a broad range of psychological, family, peer, and school-related variables. After data screening and preprocessing, a Random Forest model was developed to predict levels of adolescent aggression. The dataset was partitioned into training and testing subsets, and model hyperparameters were optimized using cross-validation procedures. Model performance was evaluated using explained variance and error-based indices, and variable importance metrics were extracted to determine the relative contribution of each predictor.

Findings: The Random Forest model demonstrated strong predictive performance, explaining a substantial proportion of variance in adolescent aggression and maintaining good generalizability across training and testing samples. Emotion regulation difficulties emerged as the strongest predictor of aggression, followed by impulsivity and peer victimization. Self-control, parental monitoring, academic stress, and family cohesion also contributed meaningfully to the model, while demographic variables showed comparatively weaker predictive power. Incremental analyses indicated that individual psychological variables accounted for the largest increase in explained variance, with additional contributions from family and peer–school contextual factors.

Conclusion: The findings highlight the utility of Random Forest modeling for capturing the complex, multilevel determinants of adolescent aggression and demonstrate that emotional and self-regulatory processes play a central role in aggressive behavior.

Keywords: *Adolescent aggression; Random Forest; machine learning; emotion regulation; impulsivity*

1. Introduction

Adolescent aggression represents a multifaceted behavioral phenomenon with significant implications for individual development, family functioning, school climate, and broader social systems. During adolescence, rapid biological maturation, emotional volatility, identity formation, and expanding social networks converge to heighten vulnerability to dysregulated behavior, including various forms of aggression. Aggressive behaviors in this developmental period range from overt physical and verbal acts to relational, cyber, and covert manifestations, each associated with adverse academic, psychological, and social outcomes. Empirical evidence consistently links adolescent aggression to later externalizing disorders, substance misuse, interpersonal difficulties, and involvement with the justice system, underscoring the necessity of early identification and prevention strategies (Gupta & Gupta, 2025; Wangsa, 2024).

Contemporary research increasingly conceptualizes adolescent aggression as the outcome of dynamic interactions among individual psychological characteristics, family processes, peer contexts, and broader sociocultural influences. Individual-level factors such as impulsivity, emotion dysregulation, self-control deficits, and negative affectivity have been repeatedly identified as proximal predictors of aggressive behavior. Emotion regulation, in particular, has emerged as a central mechanism through which adolescents manage frustration, anger, and perceived threat, with deficits in this domain strongly associated with both reactive and proactive aggression (Antikaningsih & Sarajar, 2025; Gong & Popescu, 2024). Neurobiological research further complements these findings by highlighting the role of hormonal systems, including cortisol and testosterone, in modulating stress responsivity and aggressive tendencies during adolescence (Cima et al., 2025; Dekkers et al., 2025).

Family dynamics constitute another critical layer in the etiology of adolescent aggression. Parenting styles, parental monitoring, emotional warmth, and parent–child synchrony play protective or risk-enhancing roles depending on their quality and consistency. Negative parenting practices, including harsh discipline, emotional neglect, and inconsistent supervision, have been associated with heightened aggression and related maladaptive behaviors, both offline and online (Oh et al., 2024; Tafà et al., 2025). Conversely, positive parenting and supportive family environments can buffer adolescents against individual vulnerabilities such as alexithymia and emotional dysregulation, reducing the likelihood of aggressive responses to stressors (Abbasi & Nejad, 2025; Lindsey, 2025). Family cohesion and parental involvement also interact with adolescents' developing self-regulatory capacities, shaping behavioral outcomes across social contexts.

Peer relationships and school environments further contribute to the complexity of aggressive behavior during adolescence. Peer victimization, bullying, and exposure to violence—whether direct or vicarious—have been shown to both predict and reinforce aggressive tendencies, often through reciprocal processes that escalate over time. Longitudinal evidence suggests bidirectional associations between peer victimization and aggression, indicating that adolescents may oscillate between victim and perpetrator roles depending on situational and emotional factors (Zhou et al., 2024). School-related stressors, including academic pressure and social competition, may exacerbate these dynamics, particularly when combined with low self-control and maladaptive coping strategies (Kim et al., 2025; Undiyaundeye et al., 2024).

The digital environment has introduced additional pathways for the expression and reinforcement of aggression. Cyber aggression, online delinquency, and problematic gaming behaviors have become increasingly salient in adolescents' lives, often intersecting with emotional dysregulation, internalizing symptoms, and morbid curiosity. Studies indicate that aggression may function both as an outcome and a mediator within digital behavior patterns, linking negative emotions, smartphone dependency, and online risk-taking (Jabarian et al., 2024; Kim & Cho, 2024; Pan et al., 2024). These findings highlight the need for integrative models that can accommodate multiple, interacting predictors across offline and online domains.

In response to the multifactorial nature of adolescent aggression, intervention research has expanded to include diverse therapeutic and preventive approaches. School-based programs targeting social skills, nonviolent communication, and bullying prevention have demonstrated varying degrees of effectiveness under real-world conditions (Leff et al., 2024; Sobhani Najafabadi et al., 2024). Clinical interventions such as cognitive-behavioral therapy, motivational interviewing, psychodrama, and parent-involved treatment models aim to modify maladaptive beliefs, emotional responses, and interaction patterns that sustain aggression (Braithel & Allaouna, 2025; Mansouri &

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Khodabakhshi-Koolaee, 2024; Matthys & Schutter, 2024). While these approaches provide valuable insights into mechanisms of change, their effectiveness often depends on accurately identifying the most salient risk and protective factors for specific adolescent populations.

Despite substantial progress, much of the existing literature on adolescent aggression relies on traditional statistical methods that assume linear relationships and limited interactions among predictors. Such approaches may inadequately capture the complex, nonlinear, and hierarchical nature of factors contributing to aggressive behavior. Recent advances in data science and machine learning offer promising alternatives by enabling the analysis of high-dimensional data and uncovering intricate patterns that may remain obscured in conventional models. Among these techniques, Random Forest models have gained prominence for their robustness to multicollinearity, capacity to model nonlinear relationships, and ability to rank predictor importance without stringent parametric assumptions.

The application of machine learning methods to aggression research remains relatively nascent but increasingly relevant. Emerging studies have begun to employ predictive modeling to identify key contributors to aggressive behavior, emphasizing the value of data-driven approaches for early detection and targeted intervention. By integrating psychological, familial, peer-related, and contextual variables into a single predictive framework, Random Forest models can offer a more nuanced understanding of how diverse factors jointly shape adolescent aggression (Isaksson et al., 2025; Mg et al., 2025). Moreover, such models align with contemporary calls for precision prevention and personalized intervention strategies in developmental psychopathology.

Cross-cultural considerations further underscore the importance of context-sensitive predictive research. Much of the evidence base on adolescent aggression originates from Western populations, potentially limiting its generalizability to non-Western sociocultural settings. Adolescents in urban contexts such as Tehran experience unique configurations of family structures, educational pressures, social norms, and media environments that may influence the expression and determinants of aggression. Recent regional and international studies emphasize the need to examine aggression within specific cultural and societal frameworks to inform locally relevant prevention and intervention efforts (Rean et al., 2024; Wulandari, 2025). Incorporating advanced analytical techniques within such contexts can enhance both theoretical understanding and practical applicability.

In sum, adolescent aggression is best understood as a product of interacting individual, familial, peer, biological, and contextual influences that unfold within specific sociocultural environments. While prior research has identified numerous correlates and risk factors, there remains a critical need for integrative, data-driven models capable of prioritizing predictors and capturing complex relationships among them. Leveraging Random Forest modeling provides an opportunity to move beyond isolated risk factors toward a comprehensive predictive framework that can inform early identification and targeted intervention strategies. Accordingly, the aim of the present study was to use Random Forest models to identify and rank the most important predictors of adolescent aggression among adolescents in Tehran.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a cross-sectional, predictive-analytic design aimed at identifying the most salient predictors of adolescent aggression using a Random Forest modeling approach. The study population consisted of adolescents residing in Tehran, Iran, and enrolled in public secondary schools during the academic year in which data collection was conducted. A multistage cluster sampling strategy was used to ensure adequate representation across different geographical districts of Tehran and to capture socioeconomic heterogeneity. In the first stage, several educational districts were randomly selected; in the second stage, schools within each district were randomly chosen; and in the final stage, classrooms were selected and all eligible students within those classrooms were invited to participate. Inclusion criteria comprised being between 13 and 18 years of age, enrollment in a regular educational program, and the ability to comprehend and respond to self-report questionnaires. Adolescents with diagnosed severe neurodevelopmental disorders or acute psychiatric conditions that could interfere with questionnaire completion were excluded. Participation was voluntary, and written informed consent was obtained from parents or legal guardians, alongside assent from the adolescents themselves. Ethical approval for the study was granted by the relevant institutional review board, and all procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki, with particular attention to

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confidentiality, anonymity, and the right to withdraw at any stage without penalty.

2.2. *Measures*

Data were collected using a structured battery of standardized self-report instruments administered in a classroom setting under the supervision of trained research assistants. Adolescent aggression, as the primary outcome variable, was assessed using a validated aggression questionnaire that captures multiple dimensions of aggressive behavior, including physical aggression, verbal aggression, anger, and hostility. Predictor variables were selected based on prior theoretical and empirical literature on adolescent aggression and encompassed individual, familial, and psychosocial domains. Individual-level variables included demographic characteristics such as age and gender, as well as psychological constructs such as impulsivity, emotion regulation difficulties, empathy, and self-control. Familial variables comprised perceived parenting styles, parental monitoring, family cohesion, and exposure to interparental conflict. Psychosocial and contextual variables included peer relationships, experiences of bullying or victimization, academic stress, perceived social support, and media exposure, particularly to violent content. All instruments used in the study had been previously translated into Persian and psychometrically validated in Iranian adolescent populations, demonstrating acceptable levels of internal consistency and construct validity. Questionnaires were administered in paper-and-pencil format during regular school hours, and participants were instructed to respond honestly and independently. To minimize response bias, assurances were provided that responses would remain confidential and would be used solely for research purposes.

2.3. *Data Analysis*

Data analysis was conducted using a combination of conventional statistical preprocessing and machine learning techniques, with Random Forest modeling serving as the primary analytic framework. Prior to model development, data were screened for completeness, plausibility, and outliers. Missing values were handled using appropriate imputation procedures suitable for machine learning contexts, ensuring that the underlying distribution of variables was preserved. Continuous variables were standardized where necessary, while categorical variables were encoded using suitable transformation methods to facilitate model training. The Random Forest algorithm was chosen due to its robustness to multicollinearity, capacity to model complex non-linear relationships, and suitability for high-dimensional data. The dataset was randomly partitioned into training and testing subsets, with the training set used to build the model and the testing set reserved for evaluating predictive performance. Model tuning was performed by optimizing key hyperparameters, including the number of trees, maximum tree depth, and the number of variables considered at each split, using cross-validation procedures to reduce the risk of overfitting. Model performance was assessed using multiple indices, such as explained variance and error-based metrics, to provide a comprehensive evaluation of predictive accuracy. Variable importance measures derived from the Random Forest model were used to rank predictors of adolescent aggression, allowing identification of the most influential factors contributing to aggressive behavior. All analyses were conducted using specialized statistical and machine learning software, and analytical decisions were guided by best practices in predictive modeling and reproducible research.

3. Findings and Results

The findings section presents the results of the descriptive analyses and the Random Forest predictive modeling conducted to identify key predictors of adolescent aggression. The results are organized to first describe the characteristics of the study variables, followed by the performance of the Random Forest model, the relative importance of predictors, and the stability and explanatory contribution of the model. Tables and one figure are used to present the empirical evidence in a clear and systematic manner.

The first set of results is presented in Table 1, which provides descriptive statistics for the main study variables. This table offers an overview of the distributional properties of adolescent aggression and its candidate predictors, serving as a foundation for the subsequent predictive analyses.

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Table 1

Descriptive statistics of adolescent aggression and predictor variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Total aggression	46.82	11.37	21	79
Physical aggression	12.94	4.21	5	25
Verbal aggression	10.87	3.68	4	22
Anger	11.56	3.94	4	24
Hostility	11.45	3.71	4	23
Impulsivity	32.18	7.65	15	52
Emotion regulation difficulties	78.64	16.22	36	118
Empathy	54.73	9.84	28	78
Self-control	41.09	8.57	19	65
Parental monitoring	27.56	6.34	12	45
Family cohesion	34.22	7.11	16	54
Peer victimization	18.47	5.96	8	36
Academic stress	29.88	7.42	14	51

As shown in Table 1, the mean level of total aggression among adolescents was moderate, with noticeable variability, indicating meaningful individual differences suitable for predictive modeling. Among the aggression subdimensions, physical aggression displayed slightly higher dispersion compared to verbal aggression, anger, and hostility. Predictor variables also demonstrated adequate variability, particularly emotion regulation difficulties, impulsivity, and academic stress, suggesting that the sample provided sufficient heterogeneity to examine complex predictive relationships.

The predictive accuracy of the Random Forest model is summarized in Table 2, which reports key performance indicators for the training and testing datasets. These indices were used to evaluate how well the model explained variance in adolescent aggression and how accurately it generalized to unseen data.

Table 2

Random Forest model performance indices

Dataset	R^2	RMSE	MAE
Training set	0.74	4.82	3.71
Testing set	0.68	5.46	4.12

The results in Table 2 indicate that the Random Forest model demonstrated strong predictive performance. The model explained a substantial proportion of variance in adolescent aggression in both the training and testing sets, with only a modest decline in performance when applied to new data. The relatively small difference between training and testing errors suggests that overfitting was effectively controlled and that the model exhibited good generalizability.

Table 3 presents the variable importance rankings derived from the Random Forest analysis. Importance values reflect the relative contribution of each predictor to reducing prediction error across the ensemble of decision trees.

Table 3

Variable importance rankings from the Random Forest model

Predictor variable	Importance score
Emotion regulation difficulties	0.184
Impulsivity	0.162
Peer victimization	0.141
Self-control	0.128
Parental monitoring	0.112
Academic stress	0.097

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Family cohesion	0.083
Empathy	0.071
Media exposure to violence	0.062
Age	0.044
Gender	0.036

As reported in Table 3, emotion regulation difficulties emerged as the most influential predictor of adolescent aggression, followed closely by impulsivity and peer victimization. Self-control and parental monitoring also demonstrated substantial predictive value, highlighting the combined influence of individual self-regulatory capacities and family-level factors. Demographic variables such as age and gender contributed comparatively less to the model, indicating that psychosocial variables played a more central role in explaining aggressive behavior within this sample.

To further assess the robustness of the model, Table 4 reports the incremental contribution of predictor blocks by examining changes in explained variance when groups of variables were sequentially introduced into the Random Forest framework.

Table 4

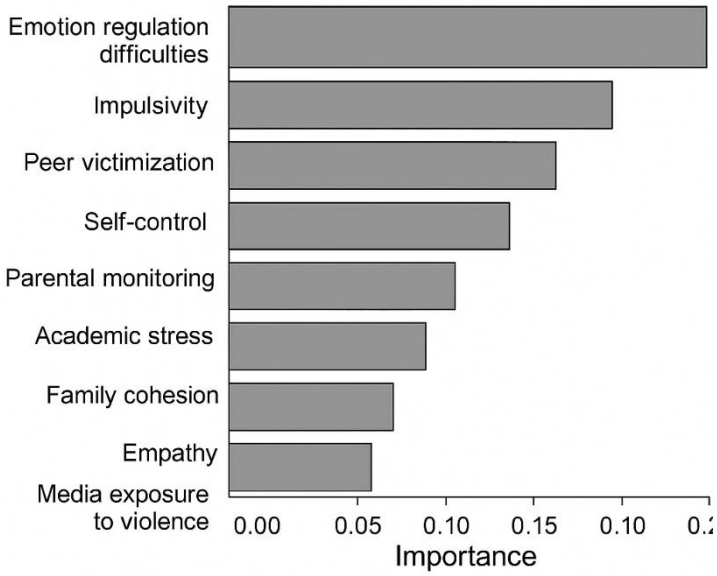
Incremental explanatory contribution of predictor blocks

Predictor block	Cumulative R^2
Demographic variables	0.12
Individual psychological variables	0.49
Family variables	0.61
Peer and school-related variables	0.68

The results in Table 4 demonstrate that individual psychological variables accounted for the largest increase in explained variance beyond demographic factors. The addition of family variables further enhanced predictive power, while peer and school-related variables provided additional, though smaller, gains. This pattern underscores the multilevel nature of adolescent aggression, with individual emotional and behavioral regulation factors forming the core predictive foundation.

Figure 1

Relative importance of key predictors of adolescent aggression based on the Random Forest model



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Overall, the findings indicate that the Random Forest approach effectively identified a hierarchy of predictors of adolescent aggression, emphasizing the dominant role of emotion regulation difficulties, impulsivity, and adverse peer experiences, while also highlighting meaningful contributions from family and academic contexts.

4. Discussion

The present study sought to identify and prioritize predictors of adolescent aggression using a Random Forest modeling approach, and the findings provide a comprehensive, data-driven understanding of the relative importance of individual, familial, and contextual factors. Overall, the results demonstrated that the Random Forest model achieved strong predictive performance, explaining a substantial proportion of variance in adolescent aggression while maintaining good generalizability across training and testing datasets. This finding is consistent with growing evidence that machine learning methods are particularly well suited to modeling complex behavioral outcomes characterized by nonlinear relationships and high intercorrelations among predictors (Gupta & Gupta, 2025; Isaksson et al., 2025). The relatively small gap between training and testing performance further suggests that the model captured robust patterns rather than sample-specific noise, supporting the methodological value of this approach for aggression research.

Among all predictors, emotion regulation difficulties emerged as the most influential factor in explaining adolescent aggression. This result aligns closely with a substantial body of literature emphasizing emotion dysregulation as a core mechanism underlying aggressive behavior during adolescence. Adolescents who struggle to identify, modulate, and express emotions adaptively are more likely to respond to frustration, threat, or interpersonal conflict with aggressive reactions. Prior empirical studies have consistently shown that deficits in emotion regulation predict both reactive and proactive aggression, as well as aggressive responses across offline and online contexts (Antikaningsih & Sarajar, 2025; Gong & Popescu, 2024). The prominence of emotion regulation difficulties in the present model underscores their central role not merely as correlates but as primary drivers of aggressive behavior when multiple risk factors are considered simultaneously.

Impulsivity was identified as the second most important predictor of adolescent aggression, reinforcing theoretical models that conceptualize aggression as, in part, a failure of inhibitory control. Adolescence is marked by an imbalance between rapidly developing socioemotional systems and still-maturing executive control processes, rendering impulsive adolescents particularly vulnerable to acting on aggressive urges. The strong predictive contribution of impulsivity in the current study is consistent with prior research linking impulsive traits to heightened aggression, risk-taking, and conduct problems (Isaksson et al., 2025; Kim et al., 2025). Importantly, the Random Forest results suggest that impulsivity retains substantial explanatory power even when emotion regulation and environmental factors are taken into account, highlighting its independent and additive role in aggression risk.

Peer victimization ranked as the third most influential predictor, emphasizing the critical role of peer dynamics in adolescent aggression. This finding supports transactional models proposing that victimization and aggression are reciprocally related, with adolescents who are victimized becoming more likely to engage in aggressive behavior as a defensive or retaliatory strategy. Longitudinal evidence has demonstrated that peer victimization can both precede and result from aggressive behavior, creating a self-reinforcing cycle that intensifies over time (Zhou et al., 2024). The present results extend this literature by demonstrating that peer victimization remains a key predictor even within a multivariate, machine-learning framework, suggesting that peer-related stressors are among the most salient contextual contributors to aggression in adolescence.

Self-control also emerged as a significant predictor, inversely associated with aggressive behavior. Adolescents with stronger self-control capacities are better able to inhibit aggressive impulses, delay gratification, and employ adaptive coping strategies in emotionally charged situations. This finding aligns with prior studies showing that self-control mediates or moderates the effects of stress, negative emotions, and problematic behaviors on aggression (Kapoor et al., 2024; Pan et al., 2024). In the context of the present model, self-control appears to function as a protective factor that counterbalances risk associated with impulsivity and emotional dysregulation, reinforcing the importance of self-regulatory skills in aggression prevention.

Family-related variables, particularly parental monitoring and family cohesion, made meaningful contributions to the prediction of adolescent aggression, though to a lesser extent than individual psychological factors. Higher levels of parental monitoring were associated with lower aggression, consistent with research indicating that attentive supervision and clear behavioral expectations reduce opportunities for

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aggressive behavior and promote internalization of social norms (Oh et al., 2024; Tafà et al., 2025). Family cohesion similarly demonstrated a protective effect, supporting evidence that emotionally supportive and cohesive family environments buffer adolescents against stressors that might otherwise elicit aggression (Abbasi & Nejad, 2025; Lindsey, 2025). The relative ranking of these variables suggests that while family factors remain important, their influence may be partially mediated through adolescents' emotional and self-regulatory capacities.

Academic stress also contributed to the prediction of aggression, reflecting the role of school-related pressures in shaping adolescents' emotional and behavioral responses. High academic demands, performance anxiety, and perceived failure can generate chronic stress, which may exacerbate irritability and aggressive reactions, particularly among adolescents with limited coping resources (Kim et al., 2025; Undiyaundeye et al., 2024). The inclusion of academic stress among the top predictors highlights the need to consider educational environments as integral contexts for understanding and addressing aggression.

In contrast, empathy and media exposure to violence demonstrated relatively lower importance scores, though they still contributed to the overall model. Lower empathy has been linked to increased aggression in prior research, particularly in relation to callous-unemotional traits and reduced sensitivity to others' distress (Mg et al., 2025; Rean et al., 2024). The modest importance of empathy in the present study may reflect its indirect role, operating through emotion regulation or moral reasoning processes rather than exerting a direct effect. Similarly, exposure to violent media has been associated with aggressive behavior, but its impact may depend on individual susceptibility and contextual moderators, potentially explaining its lower ranking in a multivariate model (Jabarian et al., 2024; Wangsa, 2024).

The incremental analysis of predictor blocks further clarified the hierarchical structure of aggression risk. Individual psychological variables accounted for the largest increase in explained variance beyond demographic factors, underscoring the centrality of internal emotional and regulatory processes. Family variables added meaningful explanatory power, followed by peer and school-related factors, collectively supporting an ecological perspective on adolescent aggression. This pattern is consistent with integrative models that emphasize the interaction of intrapersonal vulnerabilities with interpersonal and contextual stressors (Gupta & Gupta, 2025; Tafà et al., 2025). Importantly, the Random Forest approach allowed these contributions to be evaluated without imposing linear assumptions, offering a more nuanced depiction of their relative importance.

5. Conclusion

Taken together, the findings provide empirical support for the use of Random Forest models in aggression research and contribute to a growing body of evidence advocating for data-driven, multilevel approaches. By identifying a clear hierarchy of predictors, the study advances understanding of which factors warrant priority in assessment and intervention efforts. The dominance of emotion regulation difficulties and impulsivity suggests that interventions targeting these mechanisms may yield the greatest reductions in adolescent aggression, particularly when embedded within supportive family and school contexts. These results are broadly consistent with intervention studies demonstrating the effectiveness of emotion-focused, self-regulation, and parent-involved programs in reducing aggressive behavior (Braithel & Allaouna, 2025; Mansouri & Khodabakhshi-Koolaee, 2024; Matthys & Schutter, 2024).

6. Limitations & Suggestions

The study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design precludes causal inference, and the identified predictors should be understood as correlates rather than definitive causes of aggression. Second, reliance on self-report measures may have introduced response biases, including social desirability and shared method variance. Third, the sample was drawn from adolescents in Tehran, which may limit the generalizability of the findings to rural areas or other cultural contexts. Finally, although Random Forest models offer strong predictive performance, they do not provide the same level of interpretability as some traditional statistical approaches, which may complicate theoretical integration.

Future research should prioritize longitudinal designs to examine how the identified predictors interact over time and to clarify causal pathways leading to adolescent aggression. Incorporating multi-informant data from parents, teachers, and peers, as well as objective behavioral or physiological measures, would strengthen the validity of future models. Additionally, comparing Random Forest models with other machine learning techniques and traditional statistical methods could further refine predictive accuracy and

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interpretability. Cross-cultural replication studies are also needed to determine whether the observed predictor hierarchy holds across diverse sociocultural settings.

From a practical perspective, the findings underscore the importance of early screening and targeted intervention focusing on emotion regulation and impulsivity in adolescents. School-based programs that teach emotional awareness, coping skills, and self-control may be particularly effective when combined with family-based strategies that enhance parental monitoring and cohesion. Educators and mental health practitioners should also attend to peer victimization and academic stress as modifiable contextual risk factors. Integrating data-driven risk assessment tools into school and community settings may facilitate more precise identification of at-risk adolescents and the delivery of tailored preventive interventions.

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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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Authors' Contributions

All authors equally contributed to this article.

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