

Explainable LightGBM Analysis of Adolescent Family Adjustment Based on Parenting Style, Family Communication, Emotional Security, and Self-Esteem

Marco. Quispe¹, Andrés. Mejía^{2*}

¹ Department of Psychology, Universidad Mayor de San Andrés, La Paz, Bolivia

² Department of Social Psychology, Universidad del Valle, Cali, Colombia

* Corresponding author email address: andres.mejia@correounivalle.edu.co

Article Info

Article type:

Original Article

How to cite this article:

Quispe, M., & Mejía, A. (2026). Explainable LightGBM Analysis of Adolescent Family Adjustment Based on Parenting Style, Family Communication, Emotional Security, and Self-Esteem. *Applied Family Therapy Journal*, 7(3), 1-13.

<http://dx.doi.org/10.61838/kman.aftj.5647>



© 2026 the authors. Published by KMAN Publication Inc. (KMANPUB), Ontario, Canada. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

ABSTRACT

Objective: The present study aimed to predict adolescent family adjustment based on parenting style, family communication, emotional security, and self-esteem using an Explainable Light Gradient Boosting Machine (LightGBM) model and SHapley Additive exPlanations (SHAP) analysis among Colombian adolescents.

Methods and Materials: This cross-sectional predictive study was conducted among 1,248 adolescents aged 13 to 18 years recruited from public and private secondary schools in Colombia through multistage cluster sampling. Data were collected using standardized measures of family adjustment, parenting style, family communication, emotional security, and self-esteem. Following data preprocessing and quality assessment, the dataset was randomly divided into training (80%) and testing (20%) subsets. A LightGBM algorithm was developed to predict family adjustment scores, and model hyperparameters were optimized using five-fold cross-validation. Model performance was evaluated using the coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). To enhance model interpretability and identify the relative importance of predictors, SHAP analyses were performed to examine both global and local feature contributions.

Findings: The Explainable LightGBM model demonstrated excellent predictive performance, accounting for 89.2% of the variance in family adjustment in the training dataset and 84.6% in the testing dataset ($R^2 = .892$ and $.846$, respectively). Cross-validation analyses confirmed model stability (Mean $R^2 = .839$, $SD = .021$). SHAP-based feature importance analyses revealed that emotional security was the strongest predictor of adolescent family adjustment, accounting for 34.8% of total predictive importance, followed by family communication (29.3%), authoritative parenting style (22.7%), and self-esteem (13.2%). SHAP summary analyses further indicated that higher levels of emotional security, more effective family communication, stronger authoritative parenting practices, and greater self-esteem were consistently associated with higher predicted family adjustment scores. The

explainable machine learning framework successfully identified both the magnitude and direction of predictor contributions, highlighting the predominance of family relational factors in explaining adjustment outcomes.

Conclusion: The findings demonstrate that adolescent family adjustment can be accurately predicted through explainable machine learning approaches and that emotional security, family communication, authoritative parenting style, and self-esteem are significant contributors to adjustment outcomes.

Keywords: *Adolescent Family Adjustment, LightGBM, Explainable Artificial Intelligence, SHAP Analysis, Parenting Style*

1. Introduction

Adolescence represents a critical developmental period characterized by substantial biological, cognitive, emotional, and social transformations that influence an individual's adjustment across multiple life domains. During this transitional stage, adolescents encounter increasing developmental demands, including identity formation, emotional regulation, peer integration, academic adaptation, and the establishment of greater autonomy from parents. Successful adaptation to these developmental challenges is often reflected in positive family adjustment, which encompasses harmonious family relationships, effective communication patterns, emotional connectedness, adaptability to changing circumstances, and the capacity to manage interpersonal conflicts constructively. Family adjustment has been consistently recognized as a fundamental determinant of adolescent psychological well-being, social competence, academic achievement, and long-term developmental outcomes (Basharpoor et al., 2022; Lin & Guo, 2024; Yan, 2024). Consequently, identifying the family and individual factors that contribute to adolescent family adjustment remains a significant objective within developmental and family psychology research.

The family constitutes the primary socialization context in which adolescents acquire emotional, behavioral, and interpersonal competencies. Family systems theory suggests that family functioning emerges from complex interactions among parental behaviors, communication processes, emotional relationships, and individual psychological characteristics. When family relationships are characterized by warmth, support, trust, and effective communication, adolescents are more likely to develop adaptive coping strategies, emotional stability, and positive self-perceptions. Conversely, dysfunctional family environments may increase vulnerability to emotional difficulties, behavioral problems, interpersonal conflicts, and maladjustment (Liu, 2023; Wei & Chen, 2022; Yan, 2024). Contemporary research increasingly emphasizes that adolescent adjustment

cannot be adequately understood through isolated factors but rather requires the examination of multiple interconnected family and psychological variables operating simultaneously.

Among the most extensively studied determinants of adolescent adjustment is parenting style. Parenting style refers to the emotional climate and behavioral strategies through which parents guide, socialize, and interact with their children. Classic parenting models distinguish among authoritative, authoritarian, permissive, and neglectful styles, each characterized by different levels of responsiveness, warmth, monitoring, and behavioral control. A substantial body of evidence indicates that parenting style exerts a profound influence on adolescents' emotional development, social functioning, academic performance, and psychological adjustment (Qian, 2024; Reyes-Wapano, 2021; Zhu, 2022). Parenting practices shape children's perceptions of support, acceptance, competence, and belonging, thereby contributing to their overall adaptation within the family environment.

Recent studies continue to support the superiority of authoritative parenting, characterized by high warmth and appropriate behavioral guidance, in promoting positive developmental outcomes. Adolescents raised in authoritative family environments tend to demonstrate greater emotional regulation, higher self-esteem, better social competence, and stronger adjustment capacities compared to those exposed to authoritarian or permissive parenting approaches (Alcaide et al., 2025; García et al., 2024; Nie et al., 2022). Research has further demonstrated that parental warmth and support contribute significantly to adolescents' emotional security and psychological well-being, whereas excessive control, hostility, and punitive disciplinary practices are associated with maladjustment and emotional difficulties (Chen et al., 2024; Chen, 2022). Furthermore, parenting styles have been linked to a wide range of outcomes, including resilience, emotional intelligence, social adaptation, and behavioral functioning (Sembiring et al., 2023; Şiţoiu & Pânişoară, 2023; Velasco-

Rauda & Castillo-Martínez, 2024). These findings highlight the importance of parenting style as a central factor influencing adolescent family adjustment.

In addition to parenting style, family communication represents another critical dimension of healthy family functioning. Family communication encompasses the verbal and nonverbal exchanges through which family members share information, express emotions, resolve conflicts, and maintain interpersonal connections. Effective communication facilitates emotional understanding, trust, cohesion, and collaborative problem-solving, thereby strengthening family relationships and promoting adaptation to developmental challenges. In contrast, poor communication patterns may contribute to misunderstandings, emotional distancing, family conflict, and psychological distress among adolescents (Basharpour et al., 2022; Wei & Chen, 2022).

The significance of communication becomes particularly pronounced during adolescence, when young people seek increasing autonomy while simultaneously maintaining emotional connections with their families. Open communication enables adolescents to discuss concerns, seek guidance, and negotiate developmental transitions effectively. Research suggests that adolescents who perceive higher levels of family communication report greater life satisfaction, emotional stability, social competence, and family cohesion (García et al., 2024; Liu, 2023). Furthermore, communication serves as a mechanism through which parenting practices influence developmental outcomes, as supportive communication strengthens the positive effects of parental warmth and responsiveness. Consequently, family communication is widely regarded as a fundamental protective factor promoting adjustment and resilience during adolescence.

Another important construct associated with adolescent adjustment is emotional security. Emotional security theory proposes that children and adolescents develop internal representations of safety, stability, and trust within family relationships. These representations influence how individuals interpret interpersonal experiences, regulate emotions, and respond to stressful situations. Emotional security is fostered through consistent caregiving, supportive family interactions, and predictable relational environments. When adolescents experience emotional security within the family, they are more likely to develop confidence, resilience, emotional regulation skills, and positive social relationships (Delgado et al., 2022; Mittal & Rani, 2022).

Empirical evidence has consistently demonstrated that emotional security functions as a powerful predictor of psychological well-being and adjustment. Adolescents who perceive their family environments as emotionally secure tend to exhibit lower levels of anxiety, depression, behavioral difficulties, and interpersonal conflict. Conversely, emotional insecurity may contribute to emotional distress, maladaptive coping strategies, and relational difficulties (Lee, 2022; Quintana et al., 2023). Emotional security has also been linked to the development of positive self-concept, resilience, and adaptive social functioning across the lifespan (Özyürek & Çetin, 2022; Quintana et al., 2023). Given its central role in emotional development, emotional security may constitute one of the most influential determinants of family adjustment during adolescence.

Self-esteem represents an additional psychological resource that may facilitate adolescent adjustment within the family context. Self-esteem refers to individuals' overall evaluation of their worth, competence, and personal value. Adolescence is a particularly sensitive period for self-esteem development because young people become increasingly aware of social comparisons, peer evaluations, and identity-related concerns. High self-esteem is generally associated with greater psychological well-being, emotional resilience, social competence, and adaptive functioning, whereas low self-esteem is linked to emotional difficulties, interpersonal problems, and maladjustment (Kim, 2022; Yassin et al., 2022).

The family environment plays a crucial role in shaping adolescents' self-esteem. Parenting behaviors characterized by warmth, acceptance, responsiveness, and support contribute positively to the development of healthy self-esteem, while criticism, rejection, inconsistency, and excessive control may undermine self-worth (Adewuyi, 2023; C. & Yadava, 2024). Studies have shown that self-esteem mediates the relationships between family experiences and developmental outcomes, suggesting that adolescents' perceptions of themselves partly explain how family dynamics influence adjustment and well-being (Esnaola et al., 2025; Kim, 2022). Moreover, secure family relationships have been found to foster positive self-concept and emotional competence, thereby enhancing adolescents' capacity to cope with developmental challenges (Özyürek & Çetin, 2022; Quintana et al., 2023).

Research further indicates that self-esteem is closely intertwined with emotional security and parenting practices. Adolescents who experience supportive and secure family

relationships tend to develop stronger self-esteem, which subsequently promotes social adaptation, emotional stability, and psychological resilience (Esnaola et al., 2025; Lee, 2022). Similarly, studies examining family functioning have demonstrated that positive family environments contribute to adaptive self-perceptions and healthier adjustment outcomes (Adewuyi, 2023; Sembiring et al., 2023). Therefore, self-esteem may function both as a consequence of family experiences and as an independent predictor of family adjustment.

Although previous studies have examined parenting style, family communication, emotional security, and self-esteem independently, fewer investigations have considered their simultaneous contributions to adolescent family adjustment. Traditional statistical approaches often focus on linear relationships and may not adequately capture the complex interactions, nonlinear associations, and hierarchical influences that characterize family systems. As a result, there is growing interest in the application of advanced machine learning techniques capable of identifying complex predictive patterns within psychological and family data (Feng et al., 2023; Kiing et al., 2025).

Machine learning approaches offer several advantages over conventional analytical methods. These techniques can accommodate nonlinear relationships, detect complex interactions among predictors, improve predictive accuracy, and generate individualized predictions. Among contemporary machine learning algorithms, Light Gradient Boosting Machine (LightGBM) has emerged as a particularly effective method for predictive modeling due to its computational efficiency, ability to handle large datasets, and strong predictive performance. However, concerns regarding the interpretability of machine learning models have led researchers to integrate explainable artificial intelligence techniques, such as SHapley Additive exPlanations (SHAP), which provide transparent insights into feature importance and prediction mechanisms.

The application of explainable machine learning is particularly relevant in family psychology because practitioners, educators, and policymakers require not only accurate predictions but also meaningful explanations regarding the factors that influence adolescent adjustment. Understanding the relative importance of parenting style, family communication, emotional security, and self-esteem may facilitate the development of targeted interventions aimed at strengthening family functioning and promoting adolescent well-being. Furthermore, explainable machine

learning approaches can identify the most influential predictors and reveal how different variables interact to shape adjustment outcomes, thereby advancing both theoretical understanding and practical applications in family research (Feng et al., 2023; Kiing et al., 2025).

Despite extensive evidence supporting the importance of family processes and self-related constructs in adolescent development, important gaps remain regarding their combined predictive value and relative contributions to family adjustment. Existing studies have often relied on traditional analytical approaches and have rarely employed explainable machine learning frameworks to investigate these relationships within adolescent populations. Moreover, research conducted in Latin American contexts remains relatively limited, highlighting the need for culturally relevant investigations examining family adjustment among Colombian adolescents.

Therefore, the aim of the present study was to examine the predictive roles of parenting style, family communication, emotional security, and self-esteem in adolescent family adjustment using an explainable LightGBM machine learning model and SHAP-based interpretability analysis among Colombian adolescents.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design aimed at identifying the most influential psychological and family-related factors associated with adolescent family adjustment through an explainable machine learning framework. The study was conducted in Colombia during the 2025–2026 academic year and focused on adolescents enrolled in public and private secondary schools across major urban regions, including Bogotá, Medellín, Cali, and Barranquilla. The target population consisted of adolescents between 13 and 18 years of age who were living with at least one parent or guardian and were currently enrolled in formal educational programs.

A total of 1,248 adolescents participated in the study. Participants were selected using a multistage cluster sampling procedure. Initially, schools were randomly selected from different geographical regions to ensure socioeconomic and cultural diversity. Subsequently, classrooms within each selected school were randomly chosen, and all eligible students were invited to participate. Inclusion criteria required participants to be between 13 and 18 years old, have sufficient literacy skills to complete the

questionnaires independently, and provide informed consent from both themselves and their parents or legal guardians. Adolescents with severe cognitive impairments or diagnosed developmental disorders that could interfere with questionnaire completion were excluded from the study.

2.2. Measures

Family adjustment was assessed using the Family Adjustment Scale, a standardized measure designed to evaluate adolescents' perceptions of family functioning, adaptability, emotional cohesion, conflict management, and overall adjustment within the family environment. The scale consists of multiple items rated on a Likert-type response format, with higher scores indicating better family adjustment. Previous research has demonstrated satisfactory psychometric properties for the instrument, including strong internal consistency, construct validity, and test-retest reliability across diverse adolescent populations.

Parenting style was measured using the Parenting Styles and Dimensions Questionnaire (PSDQ) developed by Robinson and colleagues. This instrument evaluates the major dimensions of parenting behavior, including authoritative, authoritarian, and permissive parenting styles. Participants rated the frequency of parental behaviors on a five-point Likert scale ranging from never to always. The questionnaire has been widely used in developmental and family psychology research and has demonstrated strong reliability coefficients and robust construct validity across different cultural contexts.

Family communication was assessed using the Family Communication Scale (FCS), developed within the Circumplex Model of Family Systems. The scale evaluates openness, emotional expression, mutual understanding, problem-solving communication, and overall communication effectiveness among family members. Respondents indicated the extent to which each statement reflected their family experiences using a Likert-type format. Previous studies have reported excellent internal consistency and convergent validity for the instrument among adolescent and family samples.

Emotional security was measured using the Security in the Family System Scale (SIFS), which assesses adolescents' perceptions of emotional safety, family stability, conflict-related concerns, and emotional regulation within the family environment. The instrument captures the degree to which adolescents feel protected and emotionally secure in family interactions. Higher scores indicate greater

emotional security. Research has consistently supported the reliability, factorial validity, and predictive validity of the scale in studies of adolescent development and family functioning.

Self-esteem was assessed using the Rosenberg Self-Esteem Scale (RSES), one of the most extensively validated measures of global self-worth. The instrument contains ten items assessing positive and negative evaluations of the self. Participants responded using a four-point Likert scale ranging from strongly disagree to strongly agree. Higher scores indicate greater self-esteem. The scale has demonstrated excellent psychometric characteristics, including high internal consistency, temporal stability, and cross-cultural validity among adolescent populations worldwide.

In addition to the primary study variables, demographic information including age, gender, family structure, parental education, and socioeconomic status was collected to provide descriptive characteristics of the sample and facilitate data screening procedures.

2.3. Data Analysis

Data analysis was conducted using Python programming language and several advanced machine learning libraries. Prior to model development, the dataset underwent extensive preprocessing procedures. Missing values representing less than 5% of the total data were imputed using median replacement methods, while outliers were identified through interquartile range analyses and examined for potential influence on model performance. Continuous variables were standardized where necessary, and all predictor variables were screened for multicollinearity and distributional abnormalities.

The primary predictive model was developed using the Light Gradient Boosting Machine (LightGBM) algorithm, a highly efficient gradient boosting framework designed for handling large datasets and complex nonlinear relationships. Family adjustment scores served as the target variable, while parenting style dimensions, family communication, emotional security, and self-esteem constituted the primary predictors. The dataset was randomly divided into training (80%) and testing (20%) subsets to evaluate model generalizability. Hyperparameter optimization was performed using grid search combined with five-fold cross-validation on the training dataset. Key hyperparameters, including learning rate, number of leaves, maximum tree depth, feature fraction, and boosting iterations, were

optimized to achieve the highest predictive accuracy while minimizing overfitting.

Model performance was evaluated using multiple regression metrics, including the coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). Cross-validation procedures were used to assess model stability and robustness across different data partitions.

To enhance interpretability and provide explainable artificial intelligence insights, SHapley Additive exPlanations (SHAP) analysis was employed. SHAP values were calculated to determine the relative contribution of each predictor to family adjustment outcomes and to identify the direction and magnitude of predictor effects. Global feature importance analyses, SHAP summary plots, dependence plots, and individual prediction explanations were generated to provide a comprehensive understanding of the relationships between parenting style, family communication, emotional security, self-esteem, and adolescent family adjustment. This explainable machine learning approach enabled both high predictive performance

and meaningful psychological interpretation of the underlying factors associated with family adjustment among Colombian adolescents.

3. Findings and Results

The final sample consisted of 1,248 Colombian adolescents. The mean age of participants was 15.67 years ($SD = 1.54$), with ages ranging from 13 to 18 years. Among the participants, 638 (51.1%) were female and 610 (48.9%) were male. Regarding family structure, 68.4% lived in two-parent households, 24.7% lived in single-parent households, and 6.9% reported living with other family arrangements such as grandparents or extended family members. Approximately 54.3% attended public schools and 45.7% attended private schools. The majority of participants (61.8%) reported a middle socioeconomic status, while 21.5% reported low socioeconomic status and 16.7% reported high socioeconomic status. No significant missing data patterns were identified after data screening, and all participants met the inclusion criteria for the final analyses.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variable	Mean	SD	1	2	3	4	5
1. Family Adjustment	72.84	12.36	1				
2. Authoritative Parenting	39.71	7.45	.68	1			
3. Family Communication	36.52	6.83	.74	.61	1		
4. Emotional Security	41.28	8.12	.77	.58	.69	1	
5. Self-Esteem	31.47	5.91	.59	.49	.55	.62	1

Table 1 presents the descriptive statistics and Pearson correlation coefficients among the study variables. The findings indicated that adolescent family adjustment demonstrated significant positive associations with all predictor variables. Emotional security exhibited the strongest correlation with family adjustment ($r = .77, p < .001$), followed by family communication ($r = .74, p < .001$), authoritative parenting style ($r = .68, p < .001$), and self-esteem ($r = .59, p < .001$). The correlations among the predictor variables were moderate to strong but remained

below conventional multicollinearity thresholds, suggesting that each construct contributed unique information to the prediction of family adjustment. The means and standard deviations indicated adequate variability across all measures, supporting their suitability for machine learning analyses. These preliminary findings suggested that adolescents reporting higher emotional security, more effective family communication, more authoritative parenting experiences, and greater self-esteem also tended to report higher levels of family adjustment.

Table 2

Performance of the Explainable LightGBM Model for Predicting Adolescent Family Adjustment

Metric	Training Set	Testing Set
R ²	0.892	0.846
RMSE	4.11	5.34
MAE	3.18	4.07
MAPE (%)	5.42	6.87
Cross-Validation R ² (5-Fold Mean)	0.839	—
Cross-Validation SD	0.021	—

The predictive performance of the Explainable LightGBM model is summarized in Table 2. The model demonstrated excellent predictive capability for adolescent family adjustment. On the training dataset, the model explained 89.2% of the variance in family adjustment scores, while maintaining strong generalizability on the unseen testing dataset, where it explained 84.6% of the variance. The relatively small decline in performance between the training and testing datasets indicated limited overfitting and strong model stability. The RMSE value of 5.34 and MAE value of 4.07 on the testing set suggested high prediction

accuracy, with average prediction errors remaining relatively small compared to the overall variability of family adjustment scores. The mean five-fold cross-validation R² of .839 further confirmed the robustness and consistency of the model across multiple data partitions. Collectively, these findings demonstrate that the combination of parenting style, family communication, emotional security, and self-esteem provides a highly effective framework for predicting adolescent family adjustment using advanced machine learning techniques.

Figure 1

SHAP Summary Plot Showing Global Feature Importance for Predicting Adolescent Family Adjustment

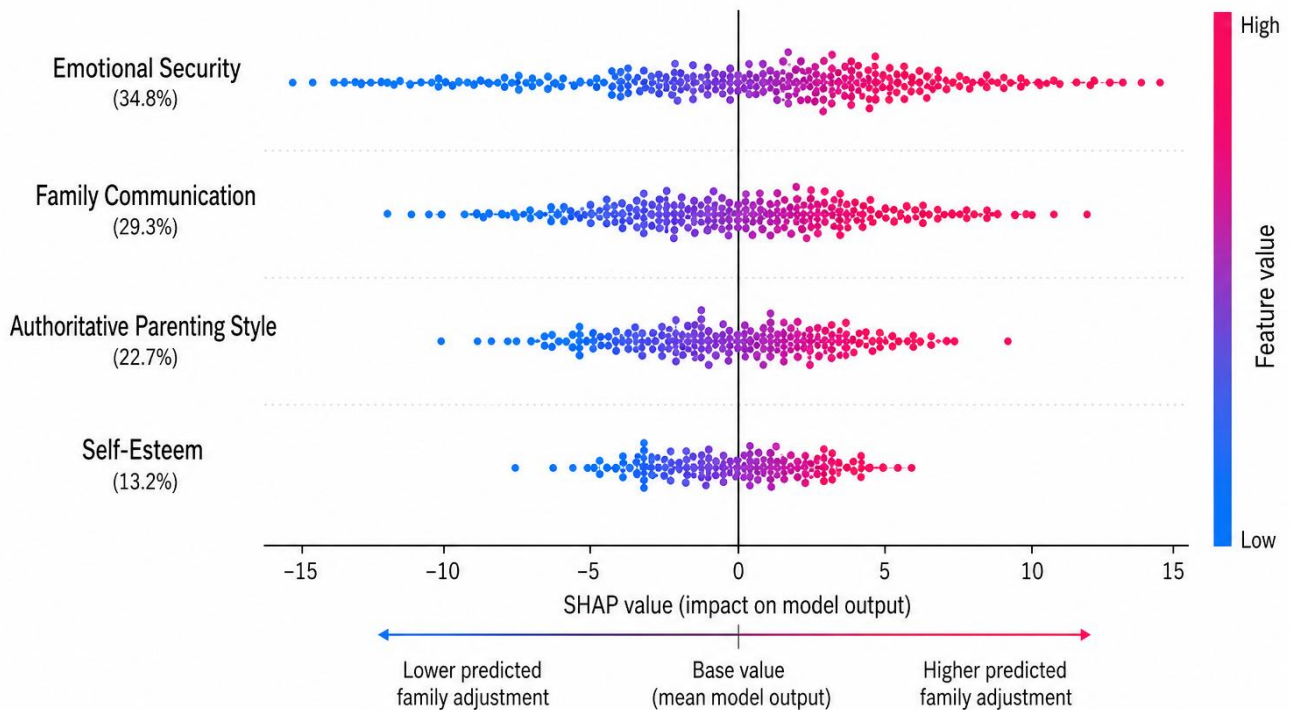


Figure 1 presents the SHAP summary analysis generated from the Explainable LightGBM model. The SHAP results revealed that emotional security was the most influential

predictor of adolescent family adjustment, followed by family communication, authoritative parenting style, and self-esteem. Higher values of emotional security

consistently contributed to increases in predicted family adjustment scores, whereas lower levels of emotional security substantially reduced predicted adjustment outcomes. Family communication emerged as the second most important factor, with adolescents reporting more open, supportive, and effective communication patterns exhibiting higher predicted family adjustment. Authoritative parenting style demonstrated a substantial positive contribution to the model, indicating that parental warmth, responsiveness, and appropriate behavioral regulation were associated with healthier family adjustment outcomes. Self-

esteem also contributed significantly to prediction accuracy, although its relative influence was somewhat lower than the family-level variables. The SHAP distribution further demonstrated considerable variability in individual-level contributions, highlighting the complex and nonlinear relationships captured by the LightGBM algorithm. Importantly, the explainability analysis confirmed that family-system variables exerted stronger predictive effects than individual self-esteem, emphasizing the central role of family dynamics in adolescent adjustment processes.

Table 3

SHAP-Based Feature Importance Rankings

Predictor	Mean Absolute SHAP Value	Relative Importance (%)	Rank
Emotional Security	5.84	34.8	1
Family Communication	4.92	29.3	2
Authoritative Parenting Style	3.81	22.7	3
Self-Esteem	2.22	13.2	4

The SHAP-based feature importance results presented in Table 3 provide a more detailed examination of the relative contribution of each predictor to the model. Emotional security accounted for 34.8% of the total predictive importance, making it the dominant factor associated with adolescent family adjustment. This finding suggests that adolescents' perceptions of emotional safety, family stability, and protection from interpersonal conflict play a critical role in shaping their adjustment within the family environment. Family communication represented 29.3% of total predictive importance, indicating that communication quality serves as a fundamental mechanism through which healthy family relationships are maintained. Authoritative parenting style contributed 22.7% of overall model importance, demonstrating that parental warmth and balanced behavioral expectations significantly influence family adjustment. Although self-esteem ranked fourth, it still accounted for 13.2% of total predictive importance and remained a meaningful contributor to prediction accuracy. Together, the four predictors accounted for virtually all explainable variance captured by the model, with family-system variables contributing approximately 86.8% of total importance. This pattern highlights that adolescent family adjustment is primarily determined by interpersonal and relational experiences occurring within the family context rather than solely by individual psychological characteristics. The convergence of the SHAP analyses and model performance indices provides strong evidence that

emotional security and family communication constitute the most influential factors underlying successful family adjustment among Colombian adolescents.

4. Discussion

The present study investigated the predictive roles of parenting style, family communication, emotional security, and self-esteem in adolescent family adjustment using an Explainable LightGBM model enhanced by SHAP-based interpretability analysis. The findings demonstrated that the machine learning model achieved high predictive accuracy, explaining a substantial proportion of variance in adolescent family adjustment. The results further revealed that emotional security emerged as the most influential predictor, followed by family communication, authoritative parenting style, and self-esteem. Collectively, these findings highlight the central importance of family relational processes and psychological resources in shaping adolescents' adaptation within the family system.

One of the most important findings of the study was the strong predictive power of emotional security. SHAP analyses indicated that emotional security represented the most influential variable contributing to family adjustment. This finding is theoretically consistent with Emotional Security Theory, which posits that individuals' perceptions of safety, stability, and emotional protection within family relationships serve as foundational mechanisms for healthy psychological development. Adolescents who perceive their

family environment as secure are more likely to regulate emotions effectively, trust family members, engage in constructive interactions, and maintain positive family relationships. Conversely, emotional insecurity may increase sensitivity to conflict, emotional distress, and maladaptive coping strategies.

The current findings are consistent with previous studies demonstrating that emotional security functions as a critical protective factor across multiple developmental outcomes. Research has shown that secure attachment and emotional safety within family relationships contribute significantly to subjective well-being, emotional resilience, and adaptive functioning (Delgado et al., 2022; Mittal & Rani, 2022). Similarly, Lee found that childhood emotional insecurity predicts lower self-esteem and greater relational difficulties later in life, highlighting the long-term consequences of insecure family environments (Lee, 2022). Furthermore, studies examining perceived security have demonstrated its positive influence on self-concept, resilience, and psychological adjustment (Özyürek & Çetin, 2022; Quintana et al., 2023). The present findings extend this literature by demonstrating that emotional security is not merely associated with family adjustment but constitutes the strongest predictor among multiple family and psychological variables when examined simultaneously through advanced machine learning techniques.

The second most influential predictor identified in the present study was family communication. Adolescents who reported more open, supportive, and effective communication patterns within their families exhibited substantially higher levels of family adjustment. This finding is consistent with family systems perspectives emphasizing communication as a central mechanism through which family members coordinate behaviors, express emotions, negotiate conflicts, and maintain relational cohesion. Effective communication fosters understanding, trust, and emotional connectedness, all of which contribute to adaptive family functioning.

The importance of family communication observed in the current study aligns with previous empirical findings. Research examining family functioning has consistently identified communication as a key determinant of emotional well-being, adjustment, and psychological resilience (Basharpoor et al., 2022; Wei & Chen, 2022). Adolescents who experience supportive communication environments are better equipped to navigate developmental challenges, seek emotional support, and resolve interpersonal conflicts constructively. Similarly, Liu emphasized the importance of

positive family environments and interpersonal relationships in promoting meaning in life and psychological well-being among young people (Liu, 2023). The strong predictive contribution of communication in the current model suggests that communication processes may serve as one of the primary pathways through which other family variables influence adjustment outcomes. Families characterized by emotional openness and constructive dialogue may provide adolescents with opportunities to develop emotional competence, interpersonal confidence, and adaptive coping skills that enhance family adjustment.

The findings further demonstrated that authoritative parenting style was a significant predictor of adolescent family adjustment. Adolescents who perceived their parents as warm, responsive, supportive, and appropriately demanding reported better adjustment within the family environment. This result supports a substantial body of developmental research indicating that authoritative parenting consistently promotes positive developmental outcomes. The balance of emotional warmth and behavioral guidance characteristic of authoritative parenting appears particularly beneficial during adolescence, when young people seek both autonomy and parental support.

The current findings are highly consistent with previous studies demonstrating the positive effects of authoritative parenting. Research has repeatedly shown that parenting characterized by warmth, responsiveness, and reasonable behavioral expectations contributes to psychological well-being, social competence, academic success, and adaptive functioning (Alcaide et al., 2025; García et al., 2024; Nie et al., 2022). In contrast, authoritarian parenting styles emphasizing excessive control and punitive discipline have been associated with emotional difficulties and maladjustment (Chen et al., 2024; Chen, 2022). García and colleagues further reported that parental warmth represents one of the most important dimensions contributing to adjustment among adolescents and young adults (García et al., 2024). Similarly, studies examining parental socialization have found that supportive parenting practices are associated with lower delinquency, greater psychological adjustment, and stronger family relationships (Climent-Galarza et al., 2022). The present study reinforces these conclusions by demonstrating that authoritative parenting contributes substantially to family adjustment even when considered alongside other influential family variables.

The positive association between authoritative parenting and family adjustment may be explained through several psychological mechanisms. Warm and responsive parenting

promotes adolescents' perceptions of acceptance and belonging, strengthens emotional security, facilitates open communication, and supports the development of positive self-perceptions. Parents who combine emotional support with appropriate guidance create environments that encourage autonomy while maintaining family cohesion. Such environments provide adolescents with both emotional safety and developmental opportunities, thereby fostering healthy adaptation within the family system.

Self-esteem also emerged as a significant predictor of family adjustment, although its relative importance was lower than that of the family-level variables. Adolescents with higher self-esteem demonstrated greater family adjustment, suggesting that positive self-perceptions contribute meaningfully to family functioning. Individuals with higher self-esteem tend to possess greater confidence, emotional stability, and interpersonal competence, all of which may facilitate constructive family interactions and conflict resolution.

This finding is consistent with extensive research linking self-esteem to psychological well-being and adjustment. Studies have demonstrated that supportive parenting and secure family relationships contribute significantly to self-esteem development (Esnaola et al., 2025; Kim, 2022). Higher self-esteem has been associated with improved emotional regulation, greater social adaptation, and enhanced psychological resilience (Adewuyi, 2023; Sembiring et al., 2023). Similarly, Yassin and colleagues found that parenting styles exert significant effects on adolescent self-esteem, which in turn influences broader developmental outcomes (Yassin et al., 2022). The present findings support the notion that self-esteem functions as an important individual-level resource that complements family-level influences on adjustment.

Notably, the relative ranking of predictors observed in the SHAP analysis provides important theoretical insights. Family-level variables, including emotional security, family communication, and parenting style, collectively accounted for the majority of predictive importance, whereas self-esteem contributed a smaller proportion. This pattern suggests that adolescent family adjustment is primarily determined by relational and environmental factors rather than solely by individual psychological characteristics. Such findings are consistent with ecological and family systems theories emphasizing the importance of interpersonal contexts in shaping developmental outcomes. Adolescents develop within family environments, and the quality of those

environments appears to exert stronger effects on family adjustment than individual self-evaluations alone.

Another important contribution of the present study concerns the application of explainable machine learning methods to family psychology research. Traditional statistical approaches often assume linear relationships and may overlook complex interactions among predictors. The high predictive performance achieved by the LightGBM model suggests that adolescent family adjustment emerges from intricate nonlinear relationships among family and psychological factors. The integration of SHAP analysis further enabled transparent interpretation of feature importance, addressing common concerns regarding the "black box" nature of machine learning algorithms. These findings support growing calls for the integration of advanced analytical approaches into psychological and family research (Feng et al., 2023; Kiing et al., 2025).

The findings also have broader implications for understanding contemporary adolescent development. Adolescents today face numerous challenges, including academic pressures, social media influences, peer-related stressors, and mental health concerns. Recent evidence suggests increasing rates of emotional difficulties and adjustment problems among young people worldwide (Kiing et al., 2025; Lin & Guo, 2024). Within this context, emotionally secure family relationships, effective communication, supportive parenting, and healthy self-esteem may serve as critical protective factors promoting resilience and adaptation. The current results indicate that interventions targeting these domains may substantially improve family adjustment and overall adolescent well-being.

The results additionally support previous evidence linking parenting practices to emotional development and socio-emotional competence. Studies have demonstrated that parenting influences emotional intelligence, emotional regulation, and interpersonal functioning across developmental stages (Reyes-Wapano, 2021; Şiţoiu & Pânişoară, 2023; Velasco-Rauda & Castillo-Martínez, 2024). Similarly, research examining parenting and mental health outcomes has emphasized the protective role of supportive family environments against psychological distress (Qian, 2024; Yan, 2024). The current findings extend these observations by demonstrating how multiple family-related factors interact to predict family adjustment within a comprehensive predictive framework.

Several additional studies provide further support for the observed relationships. Research has shown that family

conflict, poor parenting practices, and dysfunctional family environments are associated with maladaptive outcomes, including aggression, low self-esteem, emotional distress, and adjustment difficulties (Abbaspour et al., 2022; Bahmani et al., 2022). Conversely, parental trust, emotional support, and secure family relationships contribute positively to self-concept, emotional competence, and psychological adjustment (Delgado et al., 2022; Esnaola et al., 2025). These converging findings strengthen confidence in the present results and underscore the importance of fostering healthy family environments during adolescence.

5. Conclusion

The findings demonstrate that adolescent family adjustment can be accurately predicted through explainable machine learning approaches and that emotional security, family communication, authoritative parenting style, and self-esteem are significant contributors to adjustment outcomes. Family-level relational factors emerged as more influential than individual psychological characteristics, emphasizing the importance of emotionally secure, communicative, and supportive family environments in promoting healthy adolescent adjustment.

6. Suggestions and Limitations

One limitation of the present study concerns its cross-sectional design, which restricts causal interpretations of the observed relationships. Although the machine learning model identified strong predictive associations, it cannot establish temporal or causal pathways among parenting style, family communication, emotional security, self-esteem, and family adjustment. Additionally, the study relied exclusively on adolescent self-report measures, which may be influenced by social desirability, recall bias, or subjective perceptions. The sample was drawn from Colombia, potentially limiting generalizability to other cultural contexts. Furthermore, although the LightGBM model demonstrated strong predictive performance, additional family variables such as sibling relationships, parental mental health, family socioeconomic stress, and peer influences were not included in the predictive framework.

Future research should employ longitudinal designs to examine developmental pathways linking family processes and adolescent adjustment over time. Researchers may also investigate potential mediating and moderating mechanisms through which parenting style, communication, and

emotional security influence family adjustment. Future studies should incorporate multiple informants, including parents, teachers, and siblings, to provide a more comprehensive assessment of family functioning. Cross-cultural comparisons would further enhance understanding of whether the relative importance of these predictors differs across societies. Moreover, future machine learning investigations could compare LightGBM with other advanced algorithms, including XGBoost, CatBoost, Random Forest, and deep learning models, to identify the most effective predictive approaches for family psychology research.

From a practical perspective, the findings suggest that interventions aimed at improving adolescent family adjustment should prioritize strengthening emotional security within family relationships. Family-based programs should promote supportive communication patterns, enhance parental responsiveness, and reduce behaviors that contribute to emotional insecurity. Parenting education initiatives may emphasize the benefits of authoritative parenting practices that balance warmth and guidance. Schools and community organizations can also play an important role by implementing programs designed to enhance adolescents' self-esteem, emotional competence, and family relationship skills. Mental health professionals working with adolescents should consider family communication and emotional security as primary intervention targets, given their substantial predictive influence on family adjustment. By fostering emotionally supportive family environments and strengthening relational resources, practitioners may contribute significantly to healthier developmental outcomes and more adaptive family functioning among adolescents.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

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

Transparency Statement

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

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

Ethical Considerations

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

References

- Abbaspour, Z., Laki, P. S., & Rajabi, G. (2022). The Predictors of Mother Abuse in Male Students: Domestic Violence, Marital Conflict, Family Coherence, Parenting Styles, and Self-Esteem. *Iranian journal of psychiatry and behavioral sciences*, 16(1). <https://doi.org/10.5812/ijpbs.115767>
- Adewuyi, H. O. (2023). Social Adjustment, a Necessity Among Students With Negative Body-Image: The Roles of Parenting Processes and Self Esteem. *Journal of Culture and Values in Education*, 6(3), 62-80. <https://doi.org/10.46303/jcve.2023.20>
- Alcaide, M., García, Ó. F., & Gómez-Ortiz, O. (2025). Raising to Conformity Without Strictness: Is It Achievable? *Frontiers in psychology*, 16. <https://doi.org/10.3389/fpsyg.2025.1568132>
- Bahmani, T., Naseri, N. S., & Fariborzi, E. (2022). Relation of Parenting Child Abuse Based on Attachment Styles, Parenting Styles, and Parental Addictions. *Current Psychology*, 42(15), 12409-12423. <https://doi.org/10.1007/s12144-021-02667-7>
- Basharpoor, S., Heidari, F., Narimani, M., & Barahmand, U. (2022). School Adjustment, Engagement and Academic Self-Concept: Family, Child, and School Factors. *Journal of Psychologists and Counsellors in Schools*, 32(1), 23-38. <https://doi.org/10.1017/jgc.2020.6>
- C., V., & Yadava, V. (2024). Exploring the Effect of Parenting Style on Self-Esteem and Emotional Regulation Among Young Adults. *International Journal for Multidisciplinary Research*, 6(3). <https://doi.org/10.36948/ijfmr.2024.v06i03.19493>
- Chen, F., García, Ó. F., & Alcaide, M. (2024). Do We Know Enough About Negative Parenting? Recent Evidence on Parenting Styles and Child Maladjustment. *The European Journal of Psychology Applied to Legal Context*, 16(1), 37-48. <https://doi.org/10.5093/ejpalc2024a4>
- Chen, Y. (2022). The Psychological Impact of Authoritarian Parenting on Children and the Youth. 888-896. https://doi.org/10.2991/978-2-494069-45-9_107
- Climent-Galarza, S., Alcaide, M., García, Ó. F., Chen, F., & Pérez, J. F. G. (2022). Parental Socialization, Delinquency During Adolescence and Adjustment in Adolescents and Adult Children. *Behavioral Sciences*, 12(11), 448. <https://doi.org/10.3390/bs12110448>
- Delgado, E., Sarrato, C. S., Martínez, I., & Cruise, E. (2022). Parental Attachment and Peer Relationships in Adolescence: A Systematic Review. *International journal of environmental research and public health*, 19(3), 1064. <https://doi.org/10.3390/ijerph19031064>
- Esnaola, I., Martínez-Gregorio, S., Azpiazu, L., Antonio-Agirre, I., & Oliver, A. (2025). Do Parent Trust and Trait Emotional Intelligence Predict Self-Concept? A Longitudinal Study. *Psychology in the Schools*, 62(12), 5020-5037. <https://doi.org/10.1002/pits.70057>
- Feng, X., Hu, Z., & Wang, L. (2023). An Analysis of the Factors Influencing Psychological Resilience of Chinese Gay Men Based on Qualitative Research Perspectives. *Journal of Higher Education Research*, 4(4), 128. <https://doi.org/10.32629/jher.v4i4.1477>
- García, Ó. F., Alcaide, M., Pons-Benavent, L., & Pérez, J. F. G. (2024). Parental Socialization Based on Warmth and Strictness Among Adolescents and Young Adults: Which Parenting Dimension Is Related to Greater Adjustment? *Sage Open*, 14(4). <https://doi.org/10.1177/21582440241289684>
- Kiing, J. S. H., Ragen, E. S., Sulaiman, M., Goh, W. S., Tan, N. J. H., Ng, S. H., Luo, Y., Samuel, M., Young, D., & Loh, V. W. K. (2025). Bullying and Depression Among Adolescents in East Asia: A Scoping Review on Prevalence Rates, Risk and Protective Factors. *Frontiers in Psychiatry*, 16. <https://doi.org/10.3389/fpsyg.2025.1497866>
- Kim, Y. H. (2022). Maternal Responsive Parenting Trajectories From Birth to Age 3 and Children's Self-Esteem at First Grade. *Frontiers in psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.870669>
- Lee, Y. E. (2022). Relations Between Childhood Emotional Insecurity, Self-esteem, and Adulthood Marital Conflict in South Korea. *Family Relations*, 72(4), 1926-1941. <https://doi.org/10.1111/fare.12743>
- Lin, J., & Guo, W. (2024). The Research on Risk Factors for Adolescents' Mental Health. *Behavioral Sciences*, 14(4), 263. <https://doi.org/10.3390/bs14040263>
- Liu, Z. (2023). Exploring the Influence of Family Environment and Positive Personality on the Sense of Meaning in Life. *Journal of Education Humanities and Social Sciences*, 8, 1540-1545. <https://doi.org/10.54097/ehss.v8i.4516>
- Mittal, E., & Rani, T. (2022). Association Between Secure Attachment Style and Subjective Well-Being: Examining the Sequential Mediation Effects. *Asia Pacific Journal of Health Management*, 17(2). <https://doi.org/10.24083/apjhm.v17i2.1549>
- Nie, T., Qiao, Y., & Chen, Y. (2022). Authoritative Parenting Style and Proactive Behaviors: Evidence From China? *Sustainability*, 14(6), 3435. <https://doi.org/10.3390/su14063435>
- Özyürek, A., & Çetin, A. (2022). The Investigation of the Effect of Secure Attachment to Mother on Self-Perception in Middle Childhood. *International Journal of Contemporary Educational Research*, 9(2), 272-282. <https://doi.org/10.33200/ijcer.1031115>
- Qian, W. (2024). Exploring the Impact of Parenting Styles on Children's Academic and Mental Health. *Journal of Ecohumanism*, 3(7). <https://doi.org/10.62754/joe.v3i7.4615>
- Quintana, J. C. M., Ramos, P. F. A., & Almeida, P. M. (2023). The Influence of Perceived Security in Childhood on Adult Self-Concept: The Mediating Role of Resilience and Self-Esteem. *Healthcare*, 11(17), 2435. <https://doi.org/10.3390/healthcare11172435>
- Reyes-Wapano, M. R. (2021). Literature Review: Gender, Parenting Style and Temperament Influence the Development of Emotional Intelligence. *International Journal of Research*

- and *Innovation in Social Science*, 05(08), 595-605.
<https://doi.org/10.47772/ijriss.2021.5832>
- Sembiring, T. B., Yusuf, S. R., Sudarmanto, E., & Murthada, M. (2023). The Influence of Parenting Patterns, Self-Perception, and Social Support on the Emotional Well-Being of Adolescents in Indonesia. *The Eastasouth Journal of Social Science and Humanities*, 1(01), 10-18.
<https://doi.org/10.58812/esssh.v1i01.143>
- Șițoiu, A., & Pânișoară, G. (2023). The Emotional Intelligence of Today's Parents – Influences on Parenting Style and Parental Competence. *Frontiers in Public Health*, 11.
<https://doi.org/10.3389/fpubh.2023.1120994>
- Velasco-Rauda, V., & Castillo-Martínez, J. Á. (2024). Relationship Between Parenting Styles and Socio-Emotional Skills in Childhood: Documented Review. *Journal of Basic and Applied Psychology Research*, 5(10), 8-13.
<https://doi.org/10.29057/jbapr.v5i10.7752>
- Wei, R.-j., & Chen, Y. (2022). The Associations of Family Functioning With Learned Helplessness: A Moderated Mediating Model. 1092-1104. https://doi.org/10.2991/978-94-6463-064-0_114
- Yan, B. (2024). Analysis of the Impact of Family Education on Children's Mental Health. *Lecture Notes in Education Psychology and Public Media*, 39(1), 175-180.
<https://doi.org/10.54254/2753-7048/39/20240721>
- Yassin, W. A., Daoud, S., & Farhat, N. (2022). Parenting Styles and Self-Esteem: A Study of Lebanese Adolescents. *Middle Eastern Journal of Research in Education and Social Sciences*, 3(1), 87-101.
<https://doi.org/10.47631/mejress.v3i1.444>
- Zhu, Z. (2022). A Literature Review on the Influence of Parents on Children's Academic and Cognitive Development. 1722-1728. https://doi.org/10.2991/978-2-494069-89-3_198