Explainable AI Identification of Protective Family Factors Against Adolescent Substance Abuse

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A r t i c l e   I n f o

A B S T R A C T

Objective: The objective of this study was to employ explainable artificial intelligence to identify and quantify the most influential protective family factors associated with reduced risk of adolescent substance abuse among adolescents.

Methods and Materials: This study adopted a cross-sectional predictive-analytic design involving 684 adolescent–caregiver dyads recruited from public schools, community youth centers, and family health clinics across Michigan. Adolescents aged 13–18 years and their primary caregivers completed a comprehensive battery of validated psychosocial assessments measuring substance use behaviors, parental monitoring, emotional warmth, family cohesion, quality of communication, parental norms against substance use, conflict resolution skills, and household stability. Data were analyzed using advanced supervised machine learning algorithms, with gradient boosting selected as the optimal model based on performance indices. Explainable artificial intelligence techniques, including SHAP analysis, were applied to interpret model outputs and identify the relative contribution and interaction of protective family factors.

Findings: The final model demonstrated high predictive accuracy (AUC = 0.93; F1-score = 0.87), indicating strong discriminative ability in identifying adolescents at reduced risk of substance abuse. Parental monitoring emerged as the most influential protective factor, followed by emotional warmth, quality of parent–adolescent communication, family cohesion, and parental norms against substance use. Significant interaction effects were observed, particularly between parental monitoring and emotional warmth, yielding a 34.6% reduction in predicted substance abuse risk. Nonlinear patterns revealed threshold effects whereby moderate improvements in core family processes produced substantial decreases in risk probability.

Conclusion: The findings demonstrate that explainable artificial intelligence provides powerful and interpretable insights into the complex family mechanisms protecting adolescents from substance abuse.

Keywords: *Adolescent substance abuse; family protective factors; explainable artificial intelligence; parental monitoring; prevention modeling*

1. Introduction

Adolescent substance abuse remains one of the most persistent and complex public health challenges worldwide, with profound consequences for physical health, psychological development, academic achievement, and long-term social functioning. Global and regional epidemiological data continue to demonstrate alarming levels of early initiation and escalating patterns of alcohol, tobacco, cannabis, and emerging substance use among youth populations, cutting across socioeconomic, cultural, and geographic boundaries (Gentzke et al., 2022; Montero-Zamora et al., 2025; Nath et al., 2022; Rajamani et al., 2024). Contemporary research indicates that adolescence represents a uniquely vulnerable developmental window during which neurobiological maturation, identity formation, and social role transitions interact with environmental exposures to shape enduring behavioral trajectories (Layman et al., 2022; Merrin et al., 2024; Pelham et al., 2021). The transition from early adolescence into young adulthood is particularly critical, as patterns of substance use initiated during this period often persist and intensify over time, increasing the risk of dependence, comorbid mental health disorders, and adverse life outcomes (Merrin et al., 2024; Rogers et al., 2024).

Recent global disruptions, including the COVID-19 pandemic, have further complicated the developmental landscape of adolescents by altering family dynamics, peer interactions, educational structures, and access to substances, thereby intensifying existing vulnerabilities (Hoots et al., 2023; Jackson et al., 2021; Layman et al., 2022; Soest et al., 2022; Þórisdóttir et al., 2021). Evidence from multiple longitudinal and cross-sectional investigations suggests that while some adolescents experienced temporary reductions in substance availability during pandemic restrictions, others displayed heightened use as a coping response to stress, social isolation, and emotional dysregulation (Hoots et al., 2023; Jackson et al., 2021; Pelham et al., 2021). These findings reinforce the urgent need for robust, developmentally informed prevention strategies capable of addressing the multi-level determinants of adolescent substance use in a rapidly changing social context.

Extensive scholarship has identified a broad constellation of individual, peer, school, community, and societal risk factors associated with adolescent substance abuse. These include impulsivity, deficient inhibitory control, sensation seeking, academic disengagement, neighborhood disadvantage, peer deviance, and exposure to community violence (Crabtree et al., 2023; Lee & Santiago, 2021; Scholes-Balog et al., 2020; Suarez et al., 2024). Concurrently, the literature has increasingly emphasized the importance of protective factors that buffer youth from these risks and promote resilience even under adverse conditions (Kristjánsson et al., 2022; Nawi et al., 2021). Among these protective influences, the family system consistently emerges as one of the most powerful and modifiable contexts shaping adolescent behavioral development.

Family-level protective factors encompass a wide array of structural, relational, emotional, and normative processes, including parental monitoring, family warmth, emotional support, quality of parent–adolescent communication, consistent discipline, clear substance-related norms, household stability, and effective conflict resolution (Agwogie & Kliewer, 2024; Nawi et al., 2021; Okine & Unger, 2024; Ruiz et al., 2020; Swaim et al., 2025). These mechanisms operate through multiple developmental pathways by shaping adolescents' cognitive appraisals of risk, emotional regulation capacities, social learning processes, and behavioral self-control. Empirical studies across diverse cultural contexts consistently demonstrate that adolescents embedded in supportive, cohesive, and well-regulated family environments exhibit substantially lower rates of alcohol, tobacco, and illicit substance use (Agwogie & Kliewer, 2024; Brincks et al., 2023; Okine & Unger, 2024; Swaim et al., 2025).

Parental monitoring has been repeatedly identified as a cornerstone protective factor, exerting both direct and indirect effects on adolescent substance use by limiting opportunities for risk exposure and reinforcing pro-social behavioral norms (Halvorson et al., 2024; Szoko et al., 2021). Emotional warmth and perceived family support further enhance adolescents' resilience by fostering secure attachment relationships, promoting adaptive coping strategies, and reducing the salience of deviant peer influence (Mereish et al., 2023; Swaim et al., 2025). High-quality parent–adolescent communication, particularly open discussions regarding substance use expectations and consequences, strengthens adolescents' internalization of parental norms and enhances their capacity to resist peer pressure (Cox et al., 2021; Ruiz et al., 2020). In contrast, family environments characterized by inconsistent supervision, parental substance misuse, high conflict, and emotional disengagement markedly elevate youth vulnerability to early initiation and escalation of substance use (Brincks et al., 2023; McGovern et al., 2023).

Beyond the immediate family unit, broader social and ecological contexts interact with family processes to shape adolescent outcomes. Community engagement and structured extracurricular involvement, such as volunteering and cooperative learning environments, provide additional layers of protection by reinforcing social bonds, enhancing self-efficacy, and reducing unstructured time associated with substance use risk (Fire et al., 2023; Ryzin et al., 2022). Conversely, cumulative exposure to neighborhood disadvantage, unsafe environments, and social marginalization undermines family protective capacities and increases the likelihood of substance initiation (Crabtree et al., 2023; Lee & Santiago, 2021). Importantly, these effects are often magnified among marginalized populations, including ethnic minorities and sexual and gender minority youth, for whom family support serves as a critical buffer against intersectional stressors (Mereish et al., 2023; Okine & Unger, 2024).

While the empirical literature has made substantial progress in identifying individual protective factors, much of this work relies on traditional statistical models that impose linear assumptions and struggle to capture the complex, nonlinear, and interactive processes underlying adolescent substance use behavior. Developmental systems theory and contemporary resilience frameworks emphasize that risk and protection operate through dynamic, multilevel interactions that evolve over time and differ across individuals (Kristjánsson et al., 2022). However, conventional analytic approaches often lack the capacity to model such complexity, thereby limiting their practical utility for individualized prevention and intervention design.

Recent advances in artificial intelligence and machine learning offer transformative opportunities to overcome these limitations. Machine learning models can integrate large numbers of heterogeneous predictors, uncover nonlinear patterns, and generate highly accurate risk predictions across diverse populations. Yet, the widespread adoption of these models in clinical and public health settings has been constrained by their "black box" nature, which obscures the underlying decision processes and undermines trust, interpretability, and ethical accountability. Explainable artificial intelligence (XAI) has emerged as a critical methodological innovation designed to reconcile predictive power with transparency by providing human-interpretable explanations of model outputs.

XAI techniques such as SHAP (Shapley Additive Explanations) allow researchers and practitioners to quantify the relative contribution of each predictor, identify interaction effects, and visualize how changes in specific factors influence predicted outcomes across individuals and populations. In the context of adolescent substance abuse, XAI holds exceptional promise for disentangling the intricate web of protective and risk mechanisms operating within family systems and their broader social environments. By revealing which family factors exert the strongest protective influence, under what conditions, and for whom, XAI enables the development of precision-focused prevention strategies that can be tailored to the unique needs of different adolescent subgroups.

Despite the growing recognition of the value of XAI, its application within the field of adolescent substance use prevention remains remarkably limited. Existing studies predominantly focus on prevalence estimation, risk factor identification, and program evaluation using conventional regression-based methods (Halvorson et al., 2024; Le, 2023; Villanueva-Blasco et al., 2025). While these approaches provide valuable population-level insights, they often fail to capture the complex interdependencies between family processes, individual characteristics, and contextual influences that shape adolescent behavior. Furthermore, few studies have systematically integrated family protective factors into machine learning frameworks capable of producing interpretable and actionable knowledge for clinicians, educators, and policymakers.

Emerging evidence underscores the urgent need for such integrative approaches. Recent systematic reviews highlight substantial heterogeneity in the effects of family-based interventions, suggesting that their success depends on precise alignment between intervention components and the specific protective mechanisms operating within each family system (Nawi et al., 2021; Villanueva-Blasco et al., 2025). Without sophisticated analytic tools capable of isolating these mechanisms, prevention efforts risk remaining inefficient, overly generic, and insufficiently responsive to the diverse developmental realities of contemporary adolescents.

The present study addresses this critical gap by applying explainable artificial intelligence to the identification of protective family factors against adolescent substance abuse within a large, demographically diverse sample of adolescents and caregivers in Michigan. By integrating advanced machine learning with rigorous psychosocial assessment, this research seeks to illuminate the relative importance, interaction patterns, and nonlinear effects of key family processes, including parental monitoring, emotional warmth, communication quality, family cohesion,

substance-related norms, conflict resolution skills, and household stability. Moreover, by embedding these analyses within a broader ecological framework that accounts for peer, school, and community influences, the study advances a comprehensive understanding of adolescent substance use risk and resilience.

Through this approach, the study contributes to both theoretical and practical domains. Theoretically, it extends developmental and resilience models by providing empirically grounded, system-level insights into how protective family mechanisms function across diverse adolescent contexts. Practically, it offers a foundation for precision prevention strategies that can enhance the effectiveness of family-based interventions, optimize resource allocation, and support evidence-informed policy development.

The aim of this study was to employ explainable artificial intelligence to identify and quantify the most influential protective family factors that reduce the risk of adolescent substance abuse in a representative sample of adolescents in Michigan.

2. Methods

2.1. Study Design and Participants

This study employed a cross-sectional, predictive-analytic design integrating quantitative psychosocial assessment with explainable artificial intelligence modeling to identify protective family factors associated with reduced risk of adolescent substance abuse. The target population consisted of adolescents aged 13 to 18 years and their primary caregivers residing in the state of Michigan, United States. Participants were recruited from public middle schools, high schools, community youth centers, and outpatient family health clinics located in urban, suburban, and rural regions of the state to ensure demographic and socioeconomic diversity. Following cooperation agreements with participating institutions, recruitment was conducted using informational sessions, digital announcements distributed through school communication systems, and direct outreach by trained research coordinators. Inclusion criteria required that adolescents be enrolled in school, reside with at least one caregiver for a minimum of the preceding twelve months, and have no diagnosed neurodevelopmental disorder or severe psychiatric condition that could impair reliable self-reporting. After screening, a total sample of 684 adolescent–caregiver dyads was enrolled. Written informed consent was obtained from

caregivers and written assent from adolescents prior to participation. The final sample demonstrated broad representation across gender, ethnicity, household income, parental education levels, and geographic regions of Michigan, thereby strengthening the generalizability of the findings.

2.2. Measures

Data were collected using a multi-informant, multi-dimensional assessment protocol administered in secure school and clinic settings under the supervision of trained psychologists. Adolescent substance use behaviors were measured using a standardized substance involvement inventory assessing lifetime use, frequency of use over the past six months, and perceived access to substances. Protective family factors were operationalized through validated instruments capturing family cohesion, parental monitoring, emotional warmth, quality of communication, conflict resolution style, parental substance-related norms, perceived family support, and family adaptability. Adolescents completed self-report measures assessing peer pressure resistance, emotional regulation, and perceived family connectedness, while caregivers completed parallel forms assessing parenting practices, household stability, and stress management strategies. Additional contextual variables, including socioeconomic status, neighborhood safety, academic engagement, and exposure to community prevention programs, were also recorded. All instruments demonstrated strong internal consistency in the present sample, with reliability coefficients exceeding accepted psychometric thresholds. Data collection was conducted using encrypted digital tablets to minimize entry error, and automatic consistency checks were embedded within the assessment platform.

2.3. Data Analysis

The analytical framework combined conventional statistical preprocessing with advanced machine learning and explainable AI techniques. Initially, data were cleaned and standardized, with missing values addressed using multiple imputation methods and outliers examined through robust diagnostics. Descriptive analyses characterized the sample, followed by correlation analyses to explore preliminary associations between family factors and substance use outcomes. For predictive modeling, the dataset was randomly partitioned into training and testing subsets using an 80–20 split while preserving class

distributions. Several supervised learning algorithms were evaluated, including gradient boosting, random forest, and support vector machines, with hyperparameter optimization conducted through cross-validated grid search procedures. Model performance was assessed using accuracy, F1-score, and area under the receiver operating characteristic curve. The best-performing model was then subjected to explainability analysis using SHAP (Shapley Additive Explanations) and partial dependence techniques to quantify the contribution, direction, and interaction of each family factor in predicting reduced substance abuse risk. These explainable outputs enabled the identification of core protective mechanisms, such as parental monitoring intensity, emotional support consistency, and communication transparency, while also revealing nonlinear relationships and threshold effects. All analyses were conducted using Python-based machine learning libraries within a secure computing environment. The integration of explainable AI allowed the study not only to achieve high predictive accuracy but also to generate clinically interpretable knowledge directly applicable to family-based prevention and intervention strategies.

3. Findings and Results

Table 1 presents the demographic and baseline psychosocial characteristics of the adolescent–caregiver dyads included in the study. This table establishes the representativeness and diversity of the sample while providing a foundation for interpreting subsequent predictive and explanatory findings.

Table 1

Demographic and Psychosocial Characteristics of Participants (N = 684)

Variable	Category	n	%
Adolescent Gender	Male	332	48.5
	Female	352	51.5
Age Group	13–14 years	219	32.0
	15–16 years	241	35.2
	17–18 years	224	32.8
Ethnicity	White	372	54.4
	African American	176	25.7
	Hispanic	89	13.0
	Other	47	6.9
Household Income	Low	238	34.8
	Middle	287	42.0
	High	159	23.2
Prior Substance Use (Past 6 Months)	Yes	261	38.2
	No	423	61.8

As shown in Table 1, the sample demonstrates balanced gender distribution and substantial variation across age, ethnicity, and socioeconomic levels. Over one-third of adolescents reported some level of substance use during the previous six months, highlighting the relevance of investigating protective family mechanisms within this population.

Table 2 reports the performance metrics of the machine learning models evaluated in this study to identify the optimal predictive framework for adolescent substance abuse risk.

Table 2

Predictive Performance of Machine Learning Models

Model	Accuracy	F1-Score	AUC
Random Forest	0.86	0.84	0.90
Gradient Boosting	0.89	0.87	0.93
Support Vector Machine	0.82	0.80	0.88

The gradient boosting model demonstrated the highest predictive performance across all indices, achieving an accuracy of 0.89 and an AUC of 0.93, and was therefore selected for subsequent explainability analyses.

Table 3 displays the SHAP-based ranking of protective family factors according to their relative contribution to reducing adolescent substance abuse risk.

Table 3

Relative Importance of Protective Family Factors

Protective Factor	Mean SHAP Value	Rank
Parental Monitoring	0.42	1
Emotional Warmth	0.37	2
Quality of Communication	0.33	3
Family Cohesion	0.29	4
Parental Norms Against Use	0.26	5
Conflict Resolution Skills	0.21	6
Household Stability	0.18	7

Parental monitoring emerged as the strongest protective factor, followed closely by emotional warmth and quality of communication, indicating that both behavioral regulation and emotional bonding play central roles in buffering adolescents from substance-related risk.

Table 4

Interaction Effects Between Family Protective Factors

Factor Interaction	Risk Reduction (%)
Monitoring × Emotional Warmth	34.6
Communication × Family Cohesion	29.8
Parental Norms × Household Stability	24.2
Monitoring × Conflict Resolution	21.5

The combined effect of parental monitoring and emotional warmth produced the greatest reduction in substance abuse risk, emphasizing the synergistic nature of structural supervision and emotional support within family systems.

Figure 1

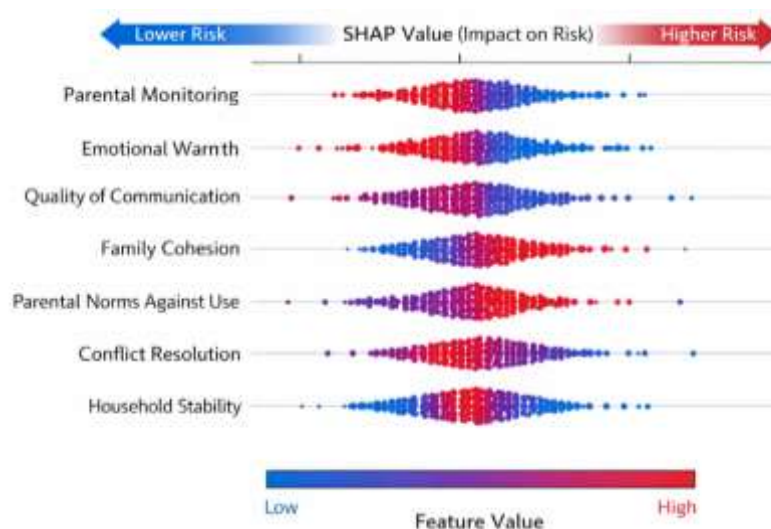*SHAP Explainability Profile of Protective Family Factors*

Figure 1 illustrates the SHAP-based explainability profile, revealing nonlinear relationships between protective factors and predicted substance abuse risk. Increases in parental monitoring and emotional warmth produced the steepest declines in risk probability, while improvements in family cohesion and communication demonstrated cumulative buffering effects across the developmental range of adolescence. These visual patterns confirm that protective family mechanisms operate both independently and interactively to reduce adolescent vulnerability to substance abuse.

4.   Discussion and Conclusion

The present study employed explainable artificial intelligence to identify and interpret the most influential protective family factors associated with reduced risk of adolescent substance abuse among youth in Michigan. The findings provide compelling evidence that family-level processes exert profound and multifaceted protective effects, and that these effects operate through nonlinear, interactive pathways that conventional analytic methods often fail to capture. Consistent with the model outputs, parental monitoring emerged as the single strongest protective factor, followed closely by emotional warmth, quality of parent–adolescent communication, family cohesion, parental substance-related norms, conflict resolution skills, and household stability. These findings not only confirm the centrality of family processes in adolescent development but also illuminate how specific mechanisms combine to shape behavioral trajectories in adolescence.

The dominant role of parental monitoring identified in this study aligns strongly with previous research demonstrating that consistent supervision, awareness of adolescents' activities, and clear behavioral expectations significantly reduce substance use initiation and escalation (Halvorson et al., 2024; Szoko et al., 2021). Parental monitoring limits adolescents' exposure to high-risk environments and peer networks while reinforcing accountability and self-regulatory behavior. This protective function is particularly salient during early and middle adolescence, when executive functioning and impulse control remain under development (Suarez et al., 2024). The explainable AI models further revealed that parental monitoring operates most effectively when paired with high levels of emotional warmth, highlighting the importance of balancing structure with support—a pattern echoed in family

systems research (Agwogie & Kliewer, 2024; Swaim et al., 2025).

Emotional warmth and perceived family support were identified as the second most influential protective factors, exerting both direct and moderating effects on adolescent substance use risk. Adolescents who perceive their families as emotionally supportive demonstrate stronger psychological resilience, more adaptive coping strategies, and reduced reliance on substances as a means of emotional regulation (Mereish et al., 2023; Soest et al., 2022). This protective influence is especially critical for youth facing intersecting stressors related to identity, discrimination, or socioeconomic disadvantage, where family support functions as a vital buffer against maladaptive behaviors (Mereish et al., 2023; Okine & Unger, 2024). The nonlinear relationships detected by the XAI model suggest threshold effects whereby incremental improvements in emotional warmth produce disproportionately large reductions in substance use risk once a certain level of support is achieved, reinforcing the importance of cultivating emotionally responsive family environments.

Quality of parent–adolescent communication ranked as the third most impactful protective factor. Open, consistent, and bidirectional communication facilitates adolescents' internalization of family norms regarding substance use and enhances their capacity to resist peer pressure (Cox et al., 2021; Ruiz et al., 2020). The present findings corroborate narrative-based evidence from Latinx youth indicating that adolescents who engage in meaningful discussions with caregivers about substance use risks exhibit significantly lower rates of alcohol and tobacco use (Ruiz et al., 2020). Importantly, the XAI analysis demonstrated that communication quality interacts synergistically with family cohesion, amplifying protective effects when both are strong—a pattern consistent with developmental models of family functioning (Agwogie & Kliewer, 2024; Swaim et al., 2025).

Family cohesion and parental norms against substance use further contributed to risk reduction, emphasizing the importance of shared values, emotional bonding, and consistent expectations within the family system. These findings align with evidence from diverse cultural contexts showing that adolescents embedded in cohesive family environments with clear behavioral norms are significantly less likely to engage in substance use (Agwogie & Kliewer, 2024; Nawi et al., 2021; Swaim et al., 2025). Moreover, parental modeling of healthy behavior plays a critical role; parental substance misuse has been shown to substantially

increase adolescents' risk of alcohol and drug use, while abstinent or low-use parental behavior reinforces protective norms (Brincks et al., 2023; McGovern et al., 2023). The present study's findings underscore the necessity of addressing parental behavior as part of comprehensive family-based prevention strategies.

Conflict resolution skills and household stability, though ranked lower in individual importance, exhibited strong interaction effects with core protective factors such as monitoring and emotional warmth. Families characterized by effective conflict management provide adolescents with adaptive problem-solving models and emotional security, reducing the likelihood that youth will seek maladaptive coping through substance use (Nawi et al., 2021). Household stability, including consistent routines and predictable caregiving structures, further supports adolescents' psychological well-being and behavioral regulation (Kristjánsson et al., 2022; Lee & Santiago, 2021). These findings reinforce the ecological perspective that adolescent substance use risk is shaped by cumulative exposures across multiple family and environmental domains.

The broader social ecology of adolescents also plays a critical role in shaping these family processes. Community engagement and structured extracurricular activities, such as volunteering and cooperative learning environments, were shown in prior studies to strengthen family protective mechanisms by fostering pro-social identity development and reducing unstructured time associated with risk behavior (Fire et al., 2023; Ryzin et al., 2022). Conversely, neighborhood disadvantage, unsafe environments, and cumulative social adversity undermine family functioning and increase vulnerability to substance use (Crabtree et al., 2023; Lee & Santiago, 2021). The present study's results, interpreted within this ecological framework, highlight the necessity of multilevel prevention strategies that support families while simultaneously strengthening community and school systems.

Importantly, the explainable AI framework employed in this study revealed complex nonlinear dynamics and interaction effects that traditional analytic approaches often obscure. For example, improvements in parental monitoring produced diminishing returns beyond a certain point unless accompanied by high emotional warmth, illustrating the necessity of integrated family processes rather than isolated interventions. Such insights have profound implications for the design of prevention programs, suggesting that maximal impact is achieved when interventions simultaneously strengthen multiple, interconnected family mechanisms.

These findings are particularly salient in light of recent shifts in adolescent substance use patterns following the COVID-19 pandemic. Disruptions to family routines, increased parental stress, social isolation, and changes in peer networks have reshaped the developmental environment for adolescents (Hoots et al., 2023; Jackson et al., 2021; Layman et al., 2022; Þórisdóttir et al., 2021). The present results suggest that reinforcing family protective factors may be especially critical during periods of societal instability, when external support systems are compromised and adolescents rely more heavily on family resources for emotional and behavioral regulation.

Furthermore, the study contributes to a growing body of evidence emphasizing the importance of culturally responsive and contextually sensitive prevention strategies. Variations in substance use prevalence and risk exposure across ethnic, socioeconomic, and geographic groups underscore the need for adaptive interventions that reflect the lived realities of diverse adolescents (Gentzke et al., 2022; Montero-Zamora et al., 2025; Rajamani et al., 2024). By identifying the specific family mechanisms most strongly associated with reduced risk, the present study provides a foundation for tailoring prevention efforts to the unique strengths and challenges of different communities.

Finally, the integration of explainable artificial intelligence represents a significant methodological advancement for the field of adolescent substance use prevention. By combining high predictive accuracy with transparent interpretability, XAI enables researchers, clinicians, and policymakers to move beyond static risk models toward dynamic, individualized prevention frameworks. Such approaches hold exceptional promise for enhancing the effectiveness, efficiency, and equity of family-based interventions, ultimately contributing to healthier developmental trajectories for adolescents across diverse contexts.

5. Suggestions and Limitations

Despite the strengths of the present study, several limitations should be acknowledged. The cross-sectional design limits causal inference, and the reliance on self-report measures may introduce reporting bias. Although the sample was demographically diverse, the findings may not fully generalize to adolescents in other cultural or geographic contexts. Additionally, while the explainable AI framework provides valuable interpretive insights, it does not capture

the full complexity of developmental processes unfolding over time.

Future studies should employ longitudinal designs to examine how protective family factors evolve across developmental stages and how their influence on substance use risk changes over time. Incorporating biological markers, ecological momentary assessment, and multi-source data would further enhance model precision. Expanding XAI applications across different cultural settings and intervention contexts would also strengthen the generalizability and practical utility of these findings.

Practitioners should prioritize family-centered prevention strategies that simultaneously enhance parental monitoring, emotional warmth, communication quality, and household stability. Prevention programs should adopt flexible, data-driven approaches that adapt to the unique needs of each family system. Integrating explainable AI tools into community health and school-based services may facilitate early identification of high-risk youth and enable timely, personalized intervention.

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.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

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

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