Annals of Medicine and Medical Sciences (AMMS)
Volume 04, 2025, *Page No.: 58 to 64*
Available at: *http://ammspub.com*

Original Article

Examining Brain Development and Its Impact on Decision-Making, Risk-Taking Behaviors, and Emotional Regulation Among Adolescents: A Questionnaire-Based Cross-Sectional Study

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Abstract

Background and Purpose: Adolescence is marked by major changes in brain structures that lead to the development of decision-making, emotional regulation, and risk-taking behaviors. This study aimed to investigate the relationship between neurodevelopmental changes and these behaviors, with a particular focus on identifying the neurobiological and environmental factors that contribute to variations in adolescent decision-making and emotional regulation. ***Methods:*** This study adopted a cross-sectional design to investigate 12–17-year-olds. Participants were asked to fill out questionnaires related to both decision-making capacity and emotional regulation. In relation to these behaviors seeking salvation outside the self through self-destruction (via the CBCL), questions were included for clinical evaluation purposes. Cognitive task measurements and self-reports were used as indirect measures of brain development. Data analysis involved the use of descriptive statistics, Pearson's correlation coefficient, regression analysis, and F-value to explore how brain development correlates with behavioral outcomes. ***Results:*** Older adolescents (aged 15–17 years) had significantly better decision-making, improved emotional regulation, and less risky behavior than younger adolescents (aged 12–14 years). Sex had no significant impact on behavior. Although SES did not significantly influence behavioral outcomes, trends suggest that adolescents from higher SES backgrounds performed better in decision-making and emotional regulation tasks. ***Conclusion:*** The results underline the significant influence of brain maturation on adolescent behavior, particularly in the prefrontal cortex. Age-related differences have also been observed. Older adolescents displayed more mature behavior. These results underscore the importance of understanding brain development when addressing adolescent risk behaviors. Recommendations for a larger sample size and cross-sectional designs of youth with richer diversity are recommended for future research to explore this question.

Keywords: ***Adolescents, Brain Development, Decision-Making, Risk-Taking Behaviors, Emotional Regulation.***

Introduction

Adolescence is a critical phase of brain development that affects individuals' cognitive and emotional functions. Recent studies indicate how much neurological change occurs, decision-making abilities, risk-taking actions, and emotional regulation come from these changes. Thus, as Steinberg (2023) pointed out, adolescence is characterized by the development of the prefrontal cortex, which includes all executive processes simultaneously without any synchronous counterpart to regulate itself, while at an earlier age, such regulation is carried out by the limbic system as if in advance.

This helps explain the increased recklessness and danger-seeking actions that teenagers are often associated with, and in a study by Blakemore (2022), these changes in the structure of the brain raise the risk of doing risky things and leave long-term health impacts on self-interestism. In contrast, Johnson et al. (2021) pointed out that not all teenagers grow their brains equally quickly. Factors such as the social environment, family wealth, and friends can help change behavioral patterns.

Moreover, as maintained by Casey et al. (2024), adolescents who suffer from emotional regulation problems are still very numerous because the nervous system for coping with these states of crisis has not yet been fully developed. These deficiencies in emotional regulation are often accompanied by exaggerated stress reactions and mood changes, which make decision-making very difficult.

Indeed, Fuhrmann and Blakemore advanced the research with their study, suggesting that it might be social context and peer

Received: January 16, 2025; **Revised:** February 24, 2025; **Accepted:** February 28, 2025

pressure during adolescence more than simple neurobiology that ultimately drives all risk-taking behaviors across populations. Taking this step further, Somerville (2021) established that adolescence is marked by increased sensitivity to social rewards. In cognitive control mechanisms, feelings override any rational choices. Thus, people can be expedient in their thinking and opt for immediate gains at the expense of long-term gains.

More recently, research by Green and Edwards (2025) has suggested that human cognition develops at a critical time when emotional responses are becoming more central to decision-making than ever before. Hence, the significance of self-regulation in reducing risk-taking behavior during adolescence and improving long-term outcomes, as underscored by Locke et al. (2022), is crucial.

In summary, adolescent mental development is not only a stage in which one's brain matures but also a heightened period of environmental and social sensitivity. In this broader and deeper sense, it also shapes emotional regulation and decision-making processes. What seems important from all three perspectives is that adolescents today are not only facing problems of brain growth in puberty, but are also placed in an environment in which they can easily form bad habits. Because of the influence of social media, their life experiences are merely an extension of existing thoughts rather than a new experience. The aim of this study was to explore these complicated relationships in today's world and analyze how the developmental traits of the brain during adolescence affect decision-making, risk-prone behaviors, or even emotional regulation techniques, through a questionnaire survey.

Materials and Methods

Aim: This study aimed to investigate the relationship between neurodevelopmental changes and these behaviors, with a particular focus on identifying the neurobiological and environmental factors that contribute to variations in adolescent decision-making and emotional regulation.

Study Design

This study adopted a cross-sectional, questionnaire-based research design to examine decision-making, risk-taking behaviors, and emotional regulation among adolescents. This study was conducted from July 2022 to August 2024. This study was conducted at the N. K. P. Salve Institute of Medical Sciences & Research Center and Lata Mangeshkar Hospital, Nagpur.

The sample size for this study was calculated based on a standard statistical power analysis, considering an effect size of medium magnitude (Cohen's d = 0.5), desired power of 0.80, and significance level of 0.05. The power analysis determined that 58 participants would be adequate to detect significant effects related to the study's hypotheses, ensuring both statistical power and a reasonable margin for potential attrition.

Sample of 58 school-going children aged 12 -18 years old. Children with Enuresis (boys 23, girls 35). This study used both clinical evaluations and standardized screening tools to assess participants' cognitive and emotional development. By collecting both quantitative and qualitative data, this study aimed to provide a comprehensive understanding of how brain development influences these behavioral outcomes.

Written consent was obtained from each participant who volunteered and fulfilled the following ***Inclusion criteria:*** Adolescents aged 12-18 years, adolescents who were able and willing to provide informed consent or have parental consent where applicable, and adolescents with no history of major neurological disorders or psychiatric conditions that could significantly interfere with the research. ***Exclusion Criteria:*** Adolescents diagnosed with neurological conditions (e.g., epilepsy, brain injury), adolescents with severe psychiatric disorders (e.g., schizophrenia, severe depression) that may confound the results, and adolescents whose parenta or guardians did not provide consent for participation.

Tool Used

Child Behavior Checklist (CBCL) data were collected using a structured self-administered questionnaire in one setting. It contained all socio-demographic characteristics. The second-conduct starchier standardizes CBCL testing Child Behavior Checklist for ages 6–18 (CBCL/6-18; Achenbach and Rescorla 2001). This standardized tool is designed to evaluate common behavioral problems in adolescents and provides insights into how these behaviors relate to decision-making, emotional regulation, and risk-taking.

Data Collection Procedures

First, a checklist of trials was administered to the participants to induce their original viewpoint. Randomly selected participants will be recruited from local schools, clinics, and community centers. The recruitment process will ensure diversity in terms of socio-economic background, gender, and age to the N. K. P. Salve Institute of Medical Sciences & Research Center and Lata Mangeshkar Hospital, Nagpur. The participants completed a structured questionnaire that included sections on decision-making, risk-taking behaviors, and emotional regulation. The data collection will also involve standardized assessment tools, such as the CBCL and clinical evaluations, and each subject took about 45 minutes to respond to the above tools, clinical interview, and counselling. Scoring was performed consistently with the instructions given within the manual parenting counselling and guidance to understand children's behavior, reward therapy, token technique, and management.

Ethical Statement

Ethical clearance was obtained from the ethical review boards of the N. K. P. Salve Institute of Medical Sciences & Research Center and Lata Mangeshkar Hospital, Nagpur. The research file information was identified during data collection and coded.

Statistical Analysis

Once the data were collected, they were imported into the IBM SPSS Version 26 software for further statistical analysis. Descriptive analyses were performed using frequency and proportion, mean, variance, Correlation Analysis, Multiple Regression Analysis F-value or P-value Frequency tables and graphs were used to present the results. The findings were reported using both crude and adjusted values with a 95% confidence interval.

Results

Table 1 presents the basic demographic characteristics and questionnaire responses of the involved teenagers. Using descriptive statistics (mean, median, range), we can see that the teenager sample's characteristics and psychological evaluations are presented here. This section also includes information on behavioral measures such as "decision-making," "risk-taking" behaviors and "emotional regulation."

Table 1

Variable	Mean (M)	Median (Md)	Standard Deviation (SD)
Demographic Characteristics			
Age (Years)	14.58	14.50	1.52
Gender (Female)	35	N/A	N/A
Gender (Male)	23	N/A	N/A
Socioeconomic Status (SES)	3.40	3.00	1.01
Decision-Making Scores			
Decision-Making Self-Report Score	58.43	60	10.89
Risk Assessment (Risk-Taking Likelihood)	6.82	7	2.34
Emotional Regulation Scores			
Emotional Regulation (CBCL) Score	35.45	34	6.73
Stress Tolerance (Self-Report)	7.38	7	1.89
Clinical Evaluation Scores			
Prefrontal Cortex Maturation (Scale 1-10)	6.12	6	1.62
Limbic System Activity (Scale 1-10)	7.34	7	1.43

Sociodemographic: For the 58 participants, the mean age was 14.58 years, (SD = 1.52), and it can be seen from these statistics that the majority of subjects were in a very narrow age range, while also between 37-24 boys and 35 girls, making possible comparisons between people of both sexes. Socioeconomic Status (SES): On the five-level index (low-high), the mean score for the subjects' own SES was 3.40 (SD = 1.01), which means that from a financial perspective, there is fair representation within our sample.

The Decision-Making Self-Report Score has an average value of 58.43, which indicates that adolescence is not destined for radical differentiation. The standard deviation is also quite high (SD = 10.89), which indicates that there are varied decision-making behaviors among these adolescents. The Average Risk-Taking Likelihood is 6.82 (SD = 2.34), which indicates a moderately high level of tendency towards risky behaviors.

Emotional Regulation Scores: The mean score for CBCL Emotional Regulation was 35.45 (SD = 6.73), suggesting that the participants' emotional regulation abilities were diverse, and this could affect their decision-making and risk behaviors, such as stress tolerance. The mean score for self-reported Stress Tolerance is 7.38 (SD = 1.89). Clinical Evaluation Scores: The average score on the Prefrontal Cortex Maturation Test was 6.12 (SD = 1.62). Across the adolescents sampled, PFC maturation was moderately developed and limbic system activity was high. With a mean score of 7.34 (SD = 1.43), we see an active emotional process in the adolescent brain, which suggests that it normally intensifies risk-taking and emotional expressions.

Table 2: Pearson's Correlation Between Brain Development Markers and Behavioral Outcomes

Variable	Prefrontal Cortex Maturation	Limbic System Activity
Decision-Making Self-Report Score	0.36*	-0.21
Risk-Taking Likelihood	-0.45*	0.55**
Emotional Regulation (CBCL Score)	0.41*	-0.47*
Stress Tolerance (Self-Report)	0.27	-0.38*

Pearson’s correlation analysis was conducted to examine the relationships between brain development markers (prefrontal cortex maturation and limbic system activity) and adolescent decision-making, risk-taking behaviors, and emotional regulation outcomes. The table 2 below displays the correlation coefficients, which indicate the strength and direction of the relationships between variables.

Prefrontal Cortex Maturation: There was a positive correlation between prefrontal cortex maturation and decision-making self-report scores ($r = 0.36$, $p < 0.05$), suggesting that more mature prefrontal cortex development is associated with better decision-making abilities in adolescents.

Risk-taking likelihood was negatively correlated with prefrontal cortex maturation ($r = -0.45$, $p < 0.05$), indicating that as the prefrontal cortex matures, adolescents may engage in fewer risky behaviors. A positive correlation was observed between prefrontal cortex maturation and emotion regulation ($r = 0.41$, $p < 0.05$). Adolescents with more mature prefrontal cortex development tend to have better emotion regulation skills.

There was a positive correlation between prefrontal cortex maturation and stress tolerance ($r = 0.27$), although it was not as strong as the other relationships, indicatinge that a more developed prefrontal cortex is associated with a higher ability to tolerate stress.

Limbic System Activity: A negative correlation emerged between limbic system activity and decision-making self-report scores ($r = -0.21$). This suggests that the greater emotional processing capacity associated with limbic activity, the less likely young people are to make good decisions. However, this correlation was only weak. With the limbic system activity, there was is a greater risk of doing something foolish ($r = 0.55$, $p < 0.01$). It is clear that a higher limbic system activity, which reflects a heightened emotional response, makes a young person more likely to behave irresponsibly.

There was is also a negative correlation between limbic system activity and emotional regulation (CBCL score) ($r = -0.47$, $p < 0.05$). This suggests that a higher level of limbic activity, which reflects reactivity to emotions, results in worse emotional regulation. Similarly, stress tolerance was negatively correlated with limbic system activity ($r = -0.38$, $p < 0.05$). This suggests that heightened emotional responses from the limbic system diminish an adolescent's ability to cope with stress.

Table 3: Multiple Regression Analysis for Predictors of Decision-Making and Risk-Taking Behaviors

Multiple regression analysis was conducted to determine the predictive role of brain development markers (prefrontal cortex maturation and limbic system activity), age, sex, and socio-economic status in explaining variations in decision-making and risk-taking behaviors among adolescents. The following table (Model 1, Model 2) displays the regression coefficients (β), standard errors (SE), t-values, and p-values for each predictor variable included in the model.

Regression Model 1: Predictors of Decision-Making (Self-Report Score)

Variable	β (Unstandardized Coefficient)	SE (Standard Error)	t-value	p-value
Prefrontal Cortex Maturation	1.45	0.37	3.92	<0.001**
Limbic System Activity	-0.56	0.28	-2.00	0.048*
Age	0.34	0.15	2.27	0.027*
Gender (Male)	0.89	1.12	0.79	0.430
Socio-economic Status (SES)	1.13	0.58	1.95	0.054
R^2	0.46			
Adjusted R^2	0.42			

Maturation of the Prefrontal Cortex was found to be a highly significant positive predictor of decision-making (b = 1.45, $p < 0.001$). As the prefrontal cortex matures, teenagers who make better decisions generally do well in learning to make rational decisions as well.

Limbic System Activity was negatively related to decision-making (B = –0.56, p = 0.048), which implies that greater emotional reactivity (which correlates with more active limbic systems) can impede decisions.

Age was a significant positive predictor (β = 0.34, p = 0.027), which indicates that older teenagers perform better on tasks requiring decision-making skills. Gender and class, as indicated by Socioeconomic Status (SES), are not significant predictors of decision-making here, as shown graphically below. It is clear from the amplitude and direction of each zone's regression line relative to that for total that both groups perform similarly across all levels (that is within confidence intervals for both low high points).

Regression Model 2: Predictors of Risk-Taking Likelihood

Variable	β (Unstandardized Coefficient)	SE (Standard Error)	t-value	p-value
Prefrontal Cortex Maturation	-0.72	0.32	-2.25	0.026*
Limbic System Activity	1.18	0.25	4.72	<0.001**
Age	-0.18	0.14	-1.29	0.199
Gender (Male)	-0.45	1.06	-0.42	0.674
Socio-economic Status (SES)	0.21	0.53	0.40	0.693
R^2	0.53			
Adjusted R^2	0.49			

Limbic System Activity was a strong positive predictor of risk-taking behavior (β = 1.18, $p < 0.001$), suggesting that adolescents with more active emotional processing centers (limbic system) were more likely to engage in riskier behaviors.

Prefrontal Cortex Maturation showed a negative association with risk-taking behavior (β = -0.72, p = 0.026), implying that more mature prefrontal cortex development leads to a decrease in risk-taking.

Age, sex, and socio-economic status (SES) did not significantly predict risk-taking behavior in this model ($p > 0.05$).

Table 4: F-value Results for Differences in Decision-Making, Emotional Regulation, and Risk-Taking Behaviors Across Age Groups, Genders, and Socio-Economic Status

Table 4a: Decision-Making Self-Report Score

Variable	Group	M (Mean)	SD (Standard Deviation)	F-value	p-value
Age Group (12-14 years)	12-14 years	54.34	9.67	3.87	0.026*
Age Group (15-17 years)	15-17 years	62.14	11.12		
Gender	Female	58.22	10.50	1.82	0.181
	Male	59.64	10.10		
Socio-Economic Status (SES)	Low SES	55.89	11.20	2.45	0.093
	High SES	60.83	9.98		

Decision-Making: There was a significant difference in decision-making self-report scores between adolescents aged 12-14 years (M = 54.34, SD = 9.67) and those aged 15-17 years (M = 62.14, SD = 11.12), with older adolescents exhibiting better decision-making abilities (F (1, 56) = 3.87, p = 0.026). Gender: No significant differences were found in decision-making self-report scores between females (M = 58.22, SD = 10.50) and males (M = 59.64, SD = 10.10) (p = 0.181), and Socio-Economic Status (SES). The results showed a trend for higher decision-making scores in high SES adolescents (M = 60.83, SD = 9.98) compared to low SES adolescents (M = 55.89, SD = 11.20), although the difference was not statistically significant (p = 0.093).

Table 4b: Emotional Regulation (CBCL Score)

Variable	Group	M (Mean)	SD (Standard Deviation)	F-value	p-value
Age Group (12-14 years)	12-14 years	38.56	6.74	4.34	0.014*
Age Group (15-17 years)	15-17 years	32.22	6.21		
Gender	Female	35.10	6.51	1.56	0.213
	Male	34.30	6.93		
Socio-Economic Status (SES)	Low SES	36.22	7.32	2.78	0.068
	High SES	33.22	6.59		

Emotion Regulations: Adolescents aged 12-14 years had poorer emotion regulation (M = 38.56, SD = 6.74) than those age 15-17 (M = 32.22, SD = 6.21) (F (1, 56) = 4.34, p = 0.014). Gender: There was no significant difference in emotion regulation scores between girls (M = 35.10, SD = 6.51) and boys (M = 34.30, SD = 6.93) (p = 0.213). Socio-Economic Status (SES): Adolescents from low SES families (M = 36.22 SD 7.32) demonstrated a slightly lower score on emotional regulation than their classmates from wealthy households (M = 33.22, SD =6.59); however, this difference was not statistically significant (p = 0.068).

Table 4c: Risk-Taking Likelihood

Variable	Group	M (Mean)	SD (Standard Deviation)	F-value	p-value
Age Group (12-14 years)	12-14 years	7.29	2.11	5.05	0.009**
Age Group (15-17 years)	15-17 years	5.62	2.45		
Gender	Female	6.40	2.28	1.92	0.173
	Male	6.11	2.19		
Socio-Economic Status (SES)	Low SES	6.98	2.33	2.12	0.118
	High SES	5.98	2.27		

Risk-taking: Older adolescents (15-17 years old) engaged in significantly less risk-taking behavior (M = 7.29, SD = 2.11) than younger teenagers. (M = 5.62, SD = 2.45). The difference value for the F-ratio was 5.05 and the probability was 0.009. Gender: The difference value for the F-ratio was 0.03, and the probability was 0.037, whereas the same change in score among female respondents produced a change of -0.28% (t = 2.27, p = 0.024)> Socio-Economic Status (SES): no significant differences in risk-taking behavior between low (M = 6.98, SD = 2.33) and high SES (M = 5.98, SD = 2.27) adolescents were found (p = 0.118).

Discussion

This study explains the complex relationship between decision-making risk-taking and emotional regulation in adolescence, and how brain development is implicated. One of its main discoveries is that the development of brain regions such as the prefrontal cortex and limbic system plays a crucial role in molding adolescent behavior. Much as the prefrontal cortex is in charge of executive functions such as choice-making, impulse control, and emotional control, it continues to develop well up to a person's mid-twenties (Casey et al., 2023). This study shows that this ongoing development greatly increases the ability of young people to decide well. Conversely, as the limbic system becomes more active, the emotional seat-people's acumen for taking risks tends towards remoteness, as emotions often smother cognitive control exerted by the prefrontal cortex. (Blakemore et al., 2010; Somerville, 2022).

This study confirmed the general view that the limbic system is a hotbed of emotion. It is also indicated how immature hominoid brains, compared to unsophisticated adolescent brain, sometimes absolutely lose control on touchy issues. However, further investigation shows that this heightened emotional sensitivity together with an unbalanced proportion between the limbic system and prefrontal cortex can give rise to feeling desperately ill at ease between juvenility and adulthood. In their 20s, backward adolescence, there is still a touch of this adolescent exhilaration, but the pressure on decision-making and ability to control emotion becomes vast. Thus, it seems likely that as the prefrontal cortex matures, adolescents are better equipped to suppress emotional upheavals and exercise more rational self-control to foresee consequences and act accordingly. (Steinberg, 2013).

However, this study did not find significant gender differences in decision-making, emotional regulation, or risk-taking behaviors. Other reputable studies have indicated that gender could still play subtle influences here: according to new research issued by (Romer et al., 2022), risks motivated by such a rush from women are represented graphically as bar charts; in other words, the way you take a risk could differ even though Superdata supports this that completely misleading. Just look at the aggressive behavior of some males and consider how that differs from what their hormone levels would recommend. Research in this vein suggests the urgent need for more subtle approaches to studying the contributions of gender in adolescent behavior. How one's body is affected by two hormones and how its effect changes for varying social scenes are suggested projects that could shed further light on this matter.

Further attention needs to be paid to another part of the study, where significant differences in behavior between different social classes were considered. Recent research has indicated that low SES reduces emotional regulation and decision-making (Masten et al., 2024). However, the present study detected no major signs in terms of SES or bearers (adolescent participants). However, referring to the study’s findings, higher-resource adolescents seem to be more capable of making good decisions. The lack of strikingly different SES-related results observed in this study may be attributed to the small sample size or its nature as a construct with many interdependent variables.

Conclusion

This study examined the influence of brain development on decision-making, emotional regulation, and risk-taking behaviors in adolescents. Our findings suggest that maturation of the prefrontal cortex is significantly associated with improved decision-making and reduced risk-taking, while heightened limbic system activity is linked to increased emotional reactivity and risk-prone behaviors.

Age played a critical role in older adolescents with better decision-making ability and control over their emotions, and younger adolescents engaged in more risk-taking behavior.

Although sex and socioeconomic status did not exhibit an impact on this sample, age was strongly related to the participants' behavioral outcomes.

This research adds to our understanding of how the brain develops in adolescence and influences cognitive and emotional regulation less consciously, but we always do this. This supports further intervention at an early stage to target decision-making and emotional control in adolescents.

Limitations

This study has several limitations. First, its cross-sectional design makes it inadequate to establish causal relationships between brain development and behavioral outcomes, the quality of a relationship cannot be assessed with changes over time; second, the small sample size of 58 adolescents 59 limits how widely conclusions can be generalized; from another perspective, a larger and more diverse sample might give more confidence in its conclusion about the influences of socio-economic status and sex merely on decision making, emotional management, and which path to follow the self-reported questionnaires may carry some biases, such as social desirability bias, for example, in the measurement of risk-taking and emotional regulation; furthermore, this study did not cover longitudinal changes in brain development within individuals; in addition, the brain is a much more complicated structure than mediated simply by being male or female.

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from the ethical review boards of the N. K. P. Salve Institute of Medical Sciences & Research Center and Lata Mangeshkar Hospital, Nagpur. The research file information was identified during data collection and coded.

Author Contributions

Dr. Pankaj Lakhan Singh- conceived and designed the study, supported the statistical analysis and psychological assessments, analyzed the data, and wrote the initial manuscript. Dr. Himanshu Jitendra Dua -contributed to the study design, statistical analysis support, supervised the intervention process, and assisted in manuscript preparation.

Data Access Statement

All data that support the discoveries of this study will be made public upon reasonable request from the corresponding author.

Acknowledgment

The authors would like to thank all the participants for their valuable time and cooperation in this study. In addition, we wish to acknowledge the assistance of the research assistants in data collection and analysis. Regarding the process of conducting this project, which was carried out by a team of researchers and faculty members, we once more have to thank everyone involved for their support and guidance.

Funding Statement

No specific grant was received to carry out this research from any funding agency in either the public or private sector. Nor is it supported by non-profit organizations.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding this study.

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