

Academic Pressure and Psychological Imbalance in High School Students: Predictors of Depression via Polynomial Regression and Response Surface Analysis

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Objective: The purpose of this study was to explore how the congruence between academic pressure and psychological imbalance affects depressive symptoms in adolescents and to further explore grade-level differences in these effects among high school students.

Methods: The study population consisted of 29,975 high school students from 20 schools in Liuyang City, Hunan Province. The Mental Health Scale for Secondary School Students (MSSMHS) and Self-Depression Scale (SDS) were used to assess academic pressure, psychological imbalance and depressive symptoms. The effects of academic pressure and psychological imbalance were examined by polynomial regression and response surface analysis.

Results: The results showed that the lowest level of academic pressure ($F = 35.99$, $p < 0.001$), psychological imbalance ($F = 54.50$, $p < 0.001$), and depressive symptoms ($F = 9.36$, $p < 0.001$) was found in repeaters, while the highest level was found in twelfth graders. Academic pressure was positively associated with psychological disequilibrium, and both were positively associated with adolescent depressive symptoms. Furthermore, when academic pressure and psychological imbalance are aligned, adolescent depressive symptoms increase with the first two. In addition, adolescent depressive symptoms decreased as the difference between academic pressure and psychological imbalance increased.

Conclusion: This study elucidates the non-linear relationship between academic pressure, psychological imbalance and depressive symptoms, and that adopting appropriate strategies to reduce academic pressure and adjust psychological balance is crucial for the prevention of depression in adolescents.

Keywords: adolescents, depressive symptoms, academic pressure, psychological imbalance, polynomial regression analysis

Introduction

Adolescent depression has become a global public health challenge.¹ Approximately 10–20% of adolescents worldwide suffer from depressive symptoms, and this proportion has been rising in recent years.² A study lists adolescent depression among the top ten most common diseases globally, emphasizing its societal burden.³ Adolescent depression not only affects individual mental health but can also lead to academic decline, interpersonal issues, and even suicide.⁴ Therefore, investigating the causes of adolescent depression and developing effective interventions is crucial for promoting the well-being and social development of adolescents.⁵

Academic pressure and psychological imbalance are considered significant factors contributing to adolescent depressive symptoms.⁶ Academic pressure refers to the stress students face from personal expectations, family, school, and

society during their studies.⁷ Psychological imbalance denotes a state of cognitive, emotional, and behavioral dissonance, such as concerns about one's abilities and future or difficulties in managing interpersonal relationships.⁸ According to the stress-vulnerability model, academic pressure and psychological imbalance can act as stressors that trigger or exacerbate existing vulnerabilities,⁹ leading to depressive symptoms.¹⁰ For instance, academic pressure may result in anxiety and insomnia, while psychological imbalance may hinder stress management, precipitating depressive symptoms.¹¹

High school students at different grade levels face varied academic tasks and challenges. The first grade of senior high school (tenth grade) encounter new subjects and learning environments, requiring them to adapt to stricter academic demands while managing new interpersonal relationships, potentially leading to stress and discomfort.¹² The second grade of senior high school (eleventh grade) become more focused on their studies, preparing for the intense study demands of junior year and high school proficiency exams.^{13,14} They might also contemplate their future, including college and career choices, causing anxiety and stress that affect their mental health.¹⁵ The third grade of senior high school (twelfth grade) face the crucial college entrance examination (Gaokao), a significant milestone in the Chinese education system. Gaokao results are often seen as pivotal in determining students' educational and career paths, leading to immense pressure during preparation.¹⁶ This can negatively impact their mental health, resulting in exam anxiety, insomnia, and depression. Repeat students, those opting for an additional year to improve their Gaokao scores, face even greater pressure due to previous exam failure.¹⁷ This pressure can lead to feelings of isolation, frustration, and anxiety, adversely affecting their mental health.¹⁸ Thus, high school students at different grade levels experience varying degrees of academic pressure and psychological imbalance, influencing the occurrence and development of depressive symptoms.

Traditional linear regression methods have limitations when it comes to capturing non-linear relationships and complex interactions between variables.¹⁹ Specifically, these methods assume a uniform effect of predictors, which fails to account for the possibility that the influence of academic pressure and psychological imbalance on depressive symptoms may vary across different levels or thresholds. In contrast, polynomial regression allows us to model such non-linear relationships, providing a more accurate representation of these complex dynamics.²⁰ Furthermore, response surface analysis offers an advantage in exploring the interaction effects between academic pressure and psychological imbalance.²¹ This method enables us to visualize how the combined effects of these variables influence adolescent depressive symptoms in a more intuitive and comprehensive way. Unlike traditional regression, response surface analysis uncovers the nuanced interactions and varying impacts of the predictors, offering deeper insights that are crucial for identifying targeted intervention points.

This study aims to use polynomial regression and response surface analysis to explore the impact of the consistency between academic pressure and psychological imbalance on adolescent depressive symptoms, while examining the differences among students at various grade levels. Compared to traditional regression analysis, response surface analysis offers a more intuitive representation of the relationships between variables and reveals non-linear interactions.²² The anticipated results of this study can provide valuable insights for schools and parents, helping them better understand the factors influencing adolescent depressive symptoms and implement targeted interventions to prevent these symptoms.²³

Method

Participants

The whole cluster sampling method was adopted in 2023, targeting high school students of all grades from 20 high schools (18 ordinary high schools and 2 vocational high schools) in Liuyang City, Hunan Province. Participants were invited to answer the questionnaire if they met the following criteria: (1) were in grades 10–12 and repeaters (repeaters were defined as students who chose to stay in high school to review the exam content after the college entrance examination and then retake the exam the following year), and (2) fully understood the content of the questionnaire. Exclusion criteria were as follows: (1) refused to participate in the survey, and (2) did not complete the questionnaire carefully. After excluding incomplete questionnaires, a total of 29,975 valid questionnaires were collected. This study was part of the China Depression Cohort Study (CDCS) and was approved by the Ethics Committee of the Second Xiangya Hospital of Central South University. The data were collected uniformly by the Liuyang City Education Bureau. The Liuyang City Education Bureau, in accordance with the requirements of the Ministry of Education of the People's Republic of China to strengthen the monitoring of the mental health of primary and secondary school students, uniformly

provides informed consent to parents in the form of group notification. If parents did not consent this data would not be collected. Similarly, verbal consent was obtained from students by classroom teachers at the site of data collection, and students were excluded from data collection if they refused to participate. The content of the questionnaire was in line with the Declaration of Helsinki.

Measures

The Middle School Student Mental Health Scale (MSSMHS), developed by Professor Wang Jisheng, a renowned psychologist in China, assesses ten dimensions of common psychological problems among secondary school students.^{14,24} These dimensions include obsessive-compulsive symptoms, paranoia, hostility, interpersonal sensitivity, depression, anxiety, academic pressure, maladjustment, emotional instability, and psychological imbalance. Each dimension consists of six items, rated on a five-point scale from 1 (not at all consistent) to 5 (completely consistent), with higher scores indicating more severe mental health problems. In this study, the Cronbach's alpha coefficient for the overall MSSMHS was 0.978, demonstrating excellent reliability. The specific dimensions involved in this study also showed high reliability, with a Cronbach's alpha coefficient of 0.878 for academic pressure and 0.792 for psychological imbalance. To assess the construct validity of the MSSMHS, we conducted Confirmatory Factor Analysis (CFA). The CFA results indicated that the model showed an acceptable fit to the data ($\chi^2/df = 109.14$, CFI = 0.85, RMSEA = 0.06), supporting the scale's validity in measuring the intended psychological constructs in adolescents.

Self-Rating Depression Scale (SDS) is a measurement tool compiled by William W.K. Zung in 1965 to assess the level of depressive symptoms and consists of four components with 20 items including psycho-emotional symptoms, physical, psychomotor disorders, and psychological disorders, with ten positive and ten negative scores.²⁵ Participants rated each item on a four-point Likert scale based on the frequency of symptoms in the past seven days. Higher scores meant more severe depressive symptoms. The Chinese version of the SDS was used in the survey, which has good reliability and its validity has been confirmed in previous studies.²⁶

Data Analyses

Descriptive statistics, analysis of variance, Pearson correlation matrix, and hierarchical regression analysis were performed using SPSS version 26.0. Subsequently, polynomial regression and response surface analysis were conducted to examine the consistent impact of academic pressure and psychological imbalance on adolescent depressive symptoms, with a three-dimensional response surface plot created using EXCEL. Specifically, before calculating the quadratic terms, the total scores for academic pressure and psychological imbalance were obtained by summing the relevant items from the MSSMHS scale. These scores were then standardized to reduce multicollinearity. Following the recommendations of Fleenor,²⁷ the absolute difference between the two standardized scores was calculated. A cutoff of 0.5 standard deviations was used for analyzing horizontal differences: 23.7% of cases had higher academic pressure than psychological imbalance, 52.7% had equal levels, and 23.6% had lower academic pressure than psychological imbalance. The case distribution was balanced, making it suitable for response surface analysis. And then regressed adolescent depressive symptoms on the control variables, with the significance of ΔR^2 implying that the regression equations could significantly explain the variation in adolescent depressive symptoms. Academic pressure (AP), Psychological imbalance (PI), the square of academic pressure (AP²), academic pressure multiplied by psychological imbalance (AP × PI) and the square of psychological imbalance (PI²). The applied equations are as follows:

$$\text{Depressive symptoms} = b_0 + b_1 \text{ AP} + b_2 \text{ PI} + b_3 \text{ AP}^2 + b_4 \text{ AP} * \text{ PI} + b_5 \text{ PI}^2 + e$$

Regression coefficients were used to plot three-dimensional response surfaces, where academic pressure and psychological imbalance were plotted on the vertical horizontal axis and depressive symptoms were plotted on the vertical axis. The curvature and slope of the congruent line (AP = PI) examines how academic pressure and psychological imbalance relate to adolescent depressive symptoms when they are congruent, and the curvature and slope of the incongruent line (AP = - PI) examines how academic pressure and psychological imbalance relate to adolescent depressive symptoms when they are incongruent.

Results

Descriptive Statistics and Analysis of Variance

The gender distribution, academic pressure, psychological imbalance and depressive symptoms among high school students across different grades are listed in Table 1. The analyses showed that there were significant differences in academic pressure ($F = 35.99$, $p < 0.001$), psychological imbalance ($F = 54.50$, $p < 0.001$), and depressive symptoms ($F = 9.36$, $p < 0.001$) among the different grades. Specifically, repeaters had the lowest levels of academic pressure and psychological imbalance, while the twelfth-grade students had the highest levels of psychological imbalance and depressive symptoms. Post-hoc comparisons showed that academic pressure was significantly lower among repeaters than all other groups, and the level of psychological imbalance gradually increased from repeaters to the twelfth-grade students. In terms of depressive symptoms, the twelfth-grade students scored significantly higher than the tenth-grade students and the eleventh-grade students, while repeaters had the lowest scores.

Correlation Analysis

The means, standard deviations, and Pearson correlation coefficients among the study variables are presented in Table 2. Based on guidelines for interpreting effect sizes,²⁸ there is a large positive correlation between academic pressure and psychological imbalance, both academic pressure and psychological imbalance in adolescents were moderately positively associated with depressive symptoms. There was a small correlation between gender, grade, and depressive symptoms in adolescents.

Testing for (in)congruence Effects on Adolescents' Depressive Symptoms

We conducted polynomial regression analyses to examine the effects of academic pressure (AP) and psychological imbalance (PI) on adolescent depressive symptoms (Table 3). Model 1 included linear terms for academic pressure and psychological imbalance, both of which significantly predicted depressive symptoms ($B = 0.37$, $t = 59.55$,

Table 1 Descriptive Statistics, ANOVA, and Post-Hoc Comparisons

Variables	Tenth-Grade (n=12322)	Eleventh-Grade (n=9797)	Twelfth-Grade (n=7508)	Repeaters (n=348)	F	LSD
Gender						
Male	5839(47.39%)	4528(46.22%)	3366(44.83%)	217(62.36%)	–	–
Female	6483(52.61%)	5269(53.78%)	4142(55.17%)	131(37.64%)	–	–
Age	15.12±0.88	16.11±0.95	17.13±2.81	17.80±0.73	2605.42***	1<2<3<4
Academic pressure	2.20±0.98	2.15±0.94	2.22±0.95	1.73±0.71	35.99***	4<2<1,3
Psychological imbalance	1.46±0.56	1.48±0.57	1.56±0.61	1.36±0.50	54.50***	4<1<2<3
Depressive symptoms	53.73±11.02	53.69±10.77	53.01±11.09	52.26±10.33	9.36***	1,2<3; 4

Notes: N=29975, Tenth-grade = 1, Eleventh-grade = 2, Twelfth-grade = 3, repeaters = 4, * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 2 Means, Standard Deviations, Pearson-Correlations, and Spearman Correlation Among Variables

Variables	Mean	S.D.	1	2	3	4	5
1. Gender	–	–	1				
2. Grade	–	–	0.01*	1			
3. Academic pressure	2.18	0.96	0.22***	–0.01	1		
4. Psychological imbalance	1.49	0.58	0.09***	0.06***	0.59**	1	
5. Depressive symptoms	53.52	10.95	0.10***	–0.02***	0.48**	0.41**	1

Notes: N=29975, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3 Polynomial Regressions of Academic Pressure-Psychological Imbalance on Depressive Symptoms

Variables	Model 1		Model 2	
	B(SE)	t	B(SE)	t
Constant	0.00(0.005)	0.00	0.01(0.007)	1.48
Academic pressure (AP)	0.37(0.006)	59.55***	0.35(0.008)	44.87***
Psychological imbalance (PI)	0.19(0.006)	31.01***	0.25(0.009)	28.67***
AP ²			0.02(0.006)	3.05**
AP*PI			0.01(0.008)	1.69
PI ²			-0.04(0.004)	-8.18***
R ²	0.255		0.258	
F	5141.98***		2083.79***	
ΔR ²			0.003***	
CS (AP=PI)			0.59(0.008)	78.20***
CC (AP=PI)			-0.01(0.005)	-1.02
IS (AP=-PI)			0.10(0.015)	6.60***
IC (AP=-PI)			-0.03(0.015)	-2.10*

Notes: *p < 0.05. **p < 0.01. ***p < 0.001. N, 29975.

Abbreviations: CS, the slope of the congruence line; CC, the curvature of the congruence line; IS, the slope of the incongruence line; IC, the curvature of the incongruence line.

p < 0.001, for academic pressure; B = 0.19, t = 31.01, p < 0.001, for psychological imbalance), explaining 25.5% of the variance (R² = 0.255, F = 5141.98, p < 0.001). With the addition of the quadratic and interaction terms in Model 2, the fit of the model was significantly improved (ΔR² = 0.003, p < 0.001), and although the increase effect was small, the theoretical and practical significance embedded in it should not be ignored, reflecting the existence of an interdependent and non-linear relationship between academic pressure and psychological imbalance and depressive symptoms. The curvature of the congruence line (CC) of the congruence line is not significant, indicating that there is a line of agreement along the linear correlation between academic pressure and psychological imbalance associated with depressive symptoms in adolescents. The slope of the congruence line (CS) was significantly positive (B = 0.59, t = 78.20, p < 0.001), indicating that depressive symptoms in adolescents increased with academic pressure and psychological imbalance. The curvature of the inconsistency line (IC) was negative and significant (B = -0.03, t = -2.10, p < 0.05), suggesting that the level of depressive symptoms among adolescents decreases as the difference between academic pressure and psychological imbalance increases. The slope of the inconsistency line (IC) was positive and significant (B = 0.10, t = 6.60, p < 0.001), suggesting that adolescents had higher levels of depressive symptoms when high academic pressure-low psychological imbalance than when low academic pressure-high psychological imbalance.

In addition, Figure 1 provides RSA plots showing a visual illustration of the results of the four grade-level models. As shown in Figure 1a and b, the effects of academic pressure and psychological imbalance on adolescent depressive symptoms were roughly the same in the tenth grade students and the eleventh grade students, and for the twelfth grade students, only the secondary term for psychological imbalance (PI²) was significant in the quadratic term (B = -0.03, t = -3.74, p < 0.001), and the fit of the model was significantly higher (ΔR² = 0.002, p < 0.001). Repeaters' RSA plots differed significantly from those of students in other grades, with neither the quadratic term nor the interaction term significantly improving model fit (ΔR² = 0.002, p > 0.05), and the curvature of the congruent and incongruent lines was not significant among repeaters, suggesting that congruence or incongruence between academic pressure and psychological disequilibrium was not associated with depressive symptoms among repeaters.

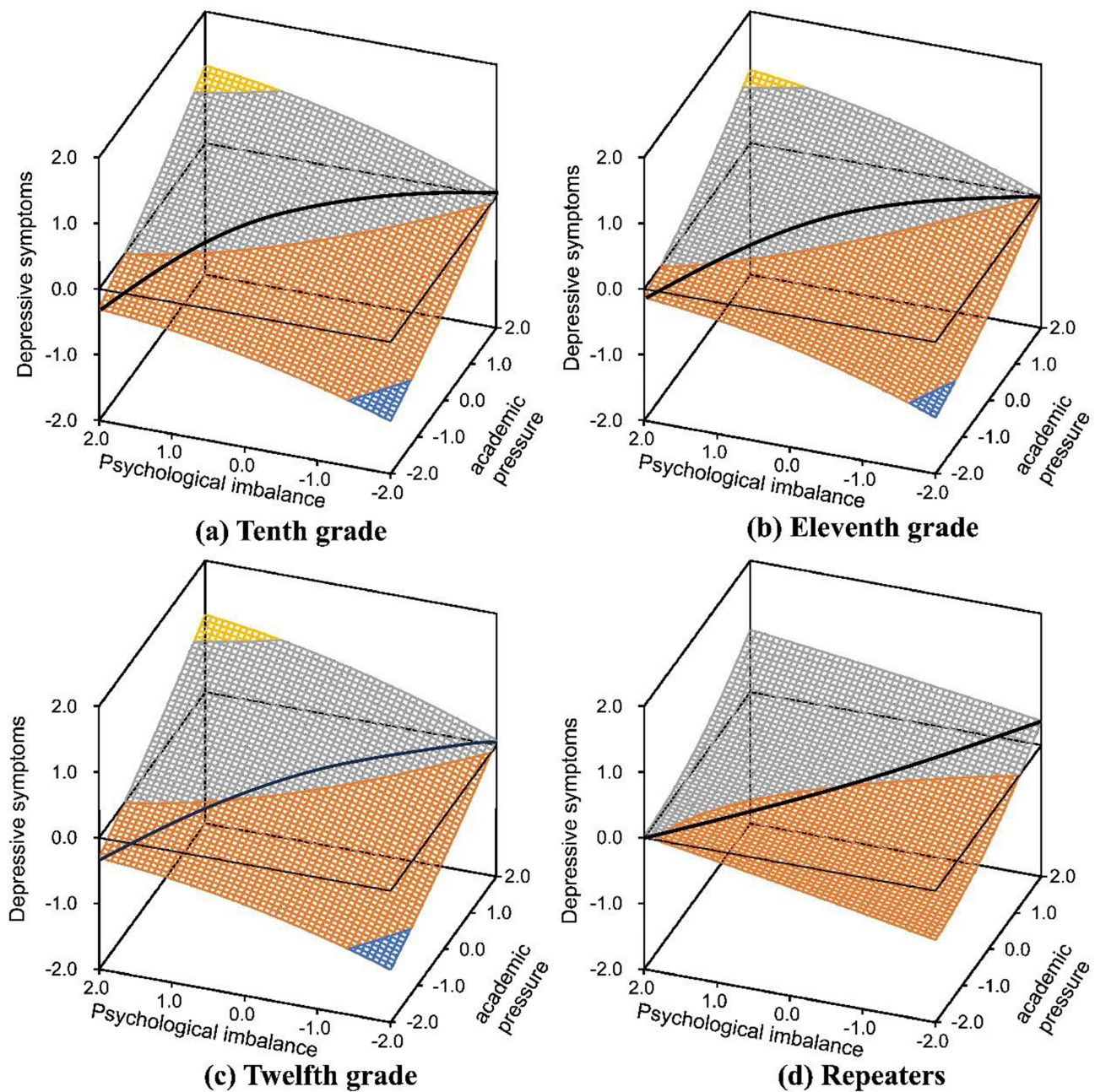


Figure 1 Congruence and incongruence effects of academic pressure-psychological imbalance on depressive symptoms across high school grades.

Note: The response surfaces illustrate how varying levels of academic pressure and psychological imbalance correlate with depression scores in each group. (a) Tenth grade, (b) Eleventh grade, (c) Twelfth grade, and (d) Repeaters.

Discussion

This study employs polynomial regression and response surface analysis to elucidate the complex nonlinear relationships between academic pressure, psychological imbalance, and depressive symptoms among high school students, identifying both consistency and inconsistency effects. When levels of academic pressure and psychological imbalance are congruent, they act synergistically to exacerbate depressive symptoms. Whereas, when the levels of academic pressure and psychological imbalance are not congruent, individuals may adopt positive coping styles to regulate their psychological state, thereby reducing the risk of depressive symptoms. These findings are of significant social importance, aiding in better understanding and prevention of adolescent depression and providing a theoretical basis for effective intervention strategies.

The unique contribution of this study lies in revealing the intricate nonlinear relationships between academic pressure, psychological imbalance, and depressive symptoms, and in explaining these mechanisms through the stress-vulnerability model. This model posits that individuals with higher psychological vulnerability (eg, psychological imbalance) are more likely to experience negative emotions and psychological disorders when under stress. Our study finds that when academic pressure and psychological imbalance levels are consistent, individuals' psychological vulnerability is amplified, leading to more severe depressive symptoms. This amplification may result from the excessive depletion of psychological resources, rendering individuals less capable of effectively coping with external stress.²⁹ Consequently, their emotional regulation diminishes, fostering feelings of helplessness and hopelessness, thus worsening depressive symptoms.³⁰ The psychological collapse induced by this consistency effect triggers internal cognitive dissonance, causing individuals to focus more on negative information, creating a vicious cycle that further deteriorates their mental state.³¹ In contrast, when academic pressure and psychological imbalance levels are inconsistent, individuals may recognize the need to take action to adjust their psychological state.³² This self-awareness and proactive coping mechanism can help identify and mitigate stressors, promoting mental health. By establishing a stable psychological state and positive coping strategies, individuals can better manage stress, avoiding the vicious cycle of depression. This regulatory mechanism underscores the critical role of psychological balance and coping strategies in preventing depressive symptoms.³³

Additionally, the study highlights differences in the relationships between academic pressure, psychological imbalance, and depressive symptoms across different grade levels. For instance, the twelfth grade students face greater pressure related to college entrance exams, making the impact of psychological imbalance more pronounced.³⁴ This could be due to the dual pressures of exams and future planning, which more easily destabilize their mental state.³⁵ In contrast, repeaters exhibit the lowest levels of depression, contrary to existing research suggesting worse emotional states among them. This may be because repeat students, having gone through the Gaokao once, have a deeper understanding of academic pressure and have learned more effective coping strategies, such as developing reasonable study plans and maintaining a positive attitude, thereby reducing the risk of depressive symptoms.³⁶

The results of this study offer important insights for educators, parents, and students. For educators, it is recommended to develop differentiated psychological interventions tailored to students at different grade levels. For the tenth grade students and the eleventh grade students, efforts should focus on helping them manage academic pressure and psychological imbalance, fostering a positive learning attitude and coping strategies.³³ For juniors, the emphasis should be on interventions targeting psychological imbalance, aiding them in alleviating college entrance exam pressure and maintaining a healthy mental state.³⁷ Parents should encourage their children to adopt positive coping strategies, such as seeking social support and participating in relaxation activities, to manage academic pressure. Students themselves should be aware of and regulate their psychological state, cultivating positive coping mechanisms to reduce the risk of depressive symptoms.³⁸

However, this study may be limited in its generalizability due to the influence of certain additional variables. One important confounding variable is personality traits, as they can influence how individuals perceive and respond to stress. For instance, adolescents with higher levels of neuroticism may be more vulnerable to depressive symptoms under academic pressure and psychological imbalance,³⁹ whereas those with higher resilience or emotional stability might be better equipped to cope with stress, potentially reducing the impact of these factors on mental health. Additionally, social support can act as a protective buffer against stress, helping adolescents manage academic pressure and psychological imbalance more effectively.⁴⁰ As this study did not directly measure social support, its presence or absence could have influenced the results. Finally, socioeconomic status (SES) may also play a role, with adolescents from lower SES backgrounds potentially facing additional stressors—such as financial instability or family-related challenges—that could exacerbate the effects of academic pressure and psychological imbalance.⁴¹ Future research should consider these variables to provide a more comprehensive understanding of the factors contributing to adolescent depression.

This study also has some limitations. First, the cross-sectional design cannot establish causality; future research should employ longitudinal designs to verify causal relationships. Second, the sample is limited to high school students in Liuyang, Hunan Province, which may not be generalizable to other regions; future studies should expand the sample range. Moreover, the study did not consider other factors that might influence the relationships between academic pressure, psychological imbalance, and depressive symptoms, such as personality traits and social support. Future research should explore the roles of these factors further.

Conclusion

In summary, this study uses polynomial regression and response surface analysis to uncover the complex nonlinear relationships between academic pressure, psychological imbalance, and depressive symptoms among high school students, identifying both consistency and inconsistency effects. These findings not only enhance our understanding of adolescent mental health issues but also provide important theoretical foundations and practical recommendations for educators, parents, and students, aiding in more effective prevention and intervention of adolescent depressive symptoms. Future research could delve deeper into longitudinal design, sample diversity, and influencing factors to enhance the generalizability and applicability of the results.

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Disclosure

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