

Current Status and Influencing Factors of Insomnia Severity in Adolescents: A Cross-Sectional Study

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Aim: To investigate the status and influencing factors of insomnia severity among Chinese urban adolescents and to develop a predictive model for early identification.

Design: A multi-center cross-sectional study.

Methods: A survey was conducted with 4288 secondary school students from Wuhan, China. A nested case-control sampling method was used within the cross-sectional survey to enhance statistical power for predictive modeling. Data were collected using standardized scales including the Insomnia Severity Index (ISI), the Three-dimensional Psychological Pain Scale (TDPPS), and the Patient Health Questionnaire-9 (PHQ-9). Statistical analyses included univariate analysis, correlation analysis, and multivariable binary logistic regression to identify independent predictors and construct a prediction model.

Results: Psychological pain was the strongest risk factor (OR=1.444), followed by depression (OR=1.292) and parental absence >3 months (OR=1.290). Increasing age (OR=0.361) and higher paternal education (OR=0.644) were protective. The final optimized prediction model demonstrated excellent goodness-of-fit (Nagelkerke $R^2 = 0.761$), with an overall correct classification rate of 88.6% and a sensitivity of 87.2%.

Conclusion: This study identifies psychological pain as the strongest predictor of adolescent insomnia, exceeding the influence of depression and anxiety. We developed a streamlined 9-variable prediction model with high accuracy (88.6%), offering a practical tool for efficient, large-scale insomnia screening in school settings. This enables early identification and paves the way for targeted, preventive interventions.

Implications for Practice: Clinical assessments for adolescent insomnia should incorporate the evaluation of psychological pain. The model enables school nurses and mental health professionals to efficiently identify at-risk adolescents, promoting precision-based preventive care.

Impact: This study addresses the multifactorial nature of adolescent insomnia and the lack of practical screening tools. Findings will benefit school health systems and mental health practitioners.

Reporting Method: This study was reported in accordance with the STROBE guidelines for cross-sectional studies.

Patient or Public Contribution: Patients or the public were not involved in the design, conduct, analysis, interpretation, or preparation of the manuscript for this study.

Keywords: adolescent, insomnia, binary logistic regression, risk factors, protective factors

Introduction

Adolescence is a critical period for brain development and the remodeling of sleep-wake rhythms. Insomnia during this stage is not only highly prevalent but can also have profound negative effects on cognitive function, emotional regulation, and long-term mental health.¹ Global evidence indicates a continuous rise in the prevalence of adolescent insomnia, closely related to modern societal stressors such as excessive digital media use and intensified academic competition, making it a pressing public health crisis.^{2,3} The relationship between sleep and mental health in adolescents is complex and may involve chain-mediating pathways.⁴ Despite increasing academic attention to adolescent insomnia,

existing research has notable limitations and gaps. Firstly, theoretical perspectives are often narrow. Many studies treat insomnia merely as a symptom of depression or anxiety,⁵ or focus only on general psychological factors like stress, overlooking psychological pain—a more fundamental and broader construct of suffering. Psychological pain, encompassing unbearable internal experiences and strong escape motivation, is considered a core driver of various maladaptive behaviors, including suicide and self-harm,⁶ but its role in insomnia, particularly among the general adolescent population, remains underexplored. Secondly, there is a lack of systematic integration of risk factors. Most studies focus either on individual psychology or family environment, lacking models that simultaneously incorporate and compare the relative contributions of multi-level variables from individual (eg, psychological pain), family (eg, parental companionship, paternal education), and social (eg, bullying) domains, leading to a fragmented understanding of insomnia's etiology.^{7,8} Finally, and most crucially, there is a gap in translating research findings into practice. Existing studies mostly stop at identifying and reporting risk factors, rarely integrating them into quantifiable, computable, and readily applicable prediction models or screening tools.^{9,10} This leaves frontline institutions like schools and communities without effective means to efficiently identify at-risk adolescents, hindering the timeliness and precision of preventive interventions.

Therefore, this study aims to achieve three objectives through a large-sample cross-sectional survey, seeking breakthroughs in both theory and practice: (1) To test the independent predictive power of psychological pain relative to traditional emotional indicators for insomnia, expanding the understanding of insomnia's psychological drivers; (2) To compare and confirm the independent predictive roles of factors from individual, family, and social levels within a comprehensive model, particularly exploring often-overlooked structural family variables; (3) Based on the analytical results, to construct a highly predictive and easily disseminable insomnia risk prediction equation, providing a directly applicable empirical tool for implementing precise and efficient sleep health screening in Chinese secondary school settings.

Method

Participants and Sample Size

This study employed a multi-center cross-sectional survey design. Using random cluster sampling, two regular junior high schools and two regular senior high schools were randomly selected from seven central urban districts of Wuhan City, Hubei Province, as survey sites. All enrolled students from the selected schools underwent cluster questionnaire surveys. The data collection was conducted in October 2025.

Inclusion criteria: ① Adolescents aged 12 to 18 years (inclusive); ② The student understood the study purpose and voluntarily provided oral consent to participate in the assessment; ③ Able to understand Chinese and possessing the basic comprehension skills necessary to complete standardized questionnaires; ④ Able to complete the baseline assessment questionnaire within the scheduled school time.

Exclusion criteria: ① Excessively short response time or obviously patterned answers; ② Extensive missing key information (any core predictor variable missing or the number of missing items exceeding 20% of the total items for any scale); ③ Failure to complete the assessment for the core dependent variable of this study (ISI-7 scale).

The sample size for the initial cross-sectional survey was calculated using the formula for estimating a single population proportion:

$$n = \frac{Z_{\alpha/2}^2 \times P(1 - P)}{d^2}$$

With a confidence level of 95% ($Z = 1.96$), an estimated insomnia prevalence (P) of 2.1% based on previous literature,¹¹ and a margin of error (d) of $0.15P$, a minimum of 7960 participants was required. Accounting for a potential 20% non-response rate, the final required sample size was 9950. Our final sample of 30,833 valid responses far exceeded this requirement, ensuring sufficient precision for prevalence estimation and providing a robust basis for the subsequent nested case-control analysis.

From this initial sample, 2144 students were identified as having moderate-to-severe insomnia, defined by an Insomnia Severity Index (ISI) total score > 14 . To construct a dataset suitable for robust binary logistic regression analysis and to clearly identify risk factors, a nested case-control design was implemented within the cross-sectional data. All 2144 students with moderate-to-severe insomnia were included as the case group. For the control group, a random sample of 2144 students with mild or no insomnia (ISI total score ≤ 14) was selected from the remaining pool of participants. This process resulted in a final analytical sample of 4288 participants, with a balanced 1:1 ratio between cases and controls, which optimizes the statistical power for predictive modeling.¹² It is important to clarify that, despite the use of a nested case-control sampling strategy for the analytical phase, the fundamental design of this study remains cross-sectional. This approach was adopted solely to enhance statistical power and efficiency in identifying risk factors within the logistic regression framework, and it does not imply a longitudinal or causal design. All data were collected at a single time point, and therefore, the findings indicate associations rather than causal relationships.

This study was reported in accordance with the STROBE guidelines for cross-sectional studies. The data underlying this study are not publicly available due to ethical restrictions. Access can be requested from the corresponding author with approval from the our Ethics Committee.

Ethics

This study was performed in accordance with the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology (TJ-IRB202510009). As the study involved adolescents aged 12–18 years, the ethics committee approved a dual-consent process: written informed consent was obtained from parents or legal guardians, and verbal assent was obtained from the adolescent participants themselves. This procedure was deemed appropriate given the non-invasive nature of the survey, the adolescents' capacity to understand the study, and the importance of respecting their autonomy while ensuring parental oversight.

Measurements and Variable Definition

Study variables included one dependent variable and 18 predictor variables. The dependent variable was “mild insomnia vs severe insomnia,” assessed via the ISI-7 total score. Data with a total score greater than 14 were coded as 2 (severe group), and those with a total score less than or equal to 14 were coded as 1 (mild group).

The 18 predictor variables covered multiple categories. Demographic variables included gender (male/female), age (in years), only-child status (yes/no), and residence (rural/urban). Family environment variables included subjective family economic status, paternal education level, maternal education level (both ordinal variables), parental marital relationship, and family parenting style. Academic and psychosocial variables involved several validated scales. Academic performance was assessed via self-reported academic ranking (ordinal variable).

School bullying behavior was assessed using the Multidimensional Peer Victimization Scale (MPVS). Developed by Mynard and Joseph,¹³ this scale includes physical victimization, verbal victimization, social manipulation, and property damage. The revised version (MPVS-R) added a cyberbullying dimension, forming five core dimensions with 20 items total. The scale uses a frequency scoring method, with higher scores indicating more severe victimization.¹⁴ This scale has been used in Chinese children and adolescents with good reliability and validity.¹⁵

Friendship quality was assessed using the short version of Parker's Friendship Quality Questionnaire.¹⁶ This questionnaire contains 18 items rated on a 5-point Likert scale (1 = completely does not apply, 5 = completely applies). Higher scores reflect better friendship quality, represented by the total score.

Psychological pain was assessed using the Three-dimensional Psychological Pain Scale (TDPPS). Developed by Li et al,⁷ this scale contains 17 items covering three dimensions: pain experience, pain arousal, and pain avoidance. It uses a 5-point Likert scale, Total score ranges from 17 to 85, with higher total scores indicating higher levels of psychological pain.

Depression was assessed using the Patient Health Questionnaire-9 (PHQ-9). Developed by Kroenke et al,¹⁷ the PHQ-9 consists of 9 items rated on a 4-point scale. Higher scores indicate greater risk of depression. A total score greater than 13 suggests the presence of depressive symptoms.

Anxiety was assessed using the Generalized Anxiety Disorder-7 (GAD-7). Developed by Spitzer et al,¹⁸ the GAD-7 consists of 7 items assessing anxiety symptoms over the past two weeks.

Insomnia was assessed using the Insomnia Severity Index (ISI). Developed by Morin¹⁹ and revised by Bastien et al,²⁰ the ISI is used to assess the severity of insomnia symptoms and their impact on function over the past two weeks. The ISI consists of 7 items rated on a 5-point Likert scale, with higher total scores indicating greater insomnia severity.

Perceived stress level was measured using the Chinese version of the Perceived Stress Scale (CPSS). This scale includes two dimensions-tension and loss of control-and consists of 14 items (including 7 reverse-scored items). Higher total scores indicate higher levels of perceived stress. This scale is a revised version of Cohen’s Perceived Stress Scale (PSS-14) adapted for the Chinese cultural context, introduced and validated by Yang Tingzhong.²¹ It is widely used in domestic research, with Cronbach’s α typically above 0.70, demonstrating good psychometric properties.²²

Resilience was assessed using the Resilience Scale for Chinese Adolescents (RSCA). This localized scale contains 27 items rated on a 5-point Likert scale. It covers five dimensions: goal focus, emotional control, positive cognition, interpersonal assistance, and family support. The total score is the sum of all item scores, with higher scores indicating higher levels of psychological resilience in adolescents.²³

All the above scales have been widely used in relevant domestic and international research, with Chinese versions demonstrating good reliability and validity, providing reliable measurement tools for this study. The internal consistency reliability (Cronbach’s α coefficient) for each scale was calculated using the entire sample (N=4288), and all results were above 0.70, indicating good data reliability. A summary of all research variables, their measurement tools, and scoring methods is provided in Table 1.

Table 1 Research Variables and Their Measurement Tool Definitions

Variable Category	Variable Name	Measurement Tool	Dimensions/Description	Scoring Method and Meaning	Score Range/Clinical Significance
Dependent Variable	Insomnia Severity	ISI-7		0=Mild Insomnia, 1=Moderate-to-Severe Insomnia	Total score range: 0–28. >14 indicates moderate-to-severe insomnia.
Predictor Variables	Gender	Self-report	–	1=Male, 2=Female	
	Age	Self-report	Years	Continuous variable	
Demographic Variables	Only Child	Self-report	–	1=Yes, 2=No	
	Residence	Self-report	–	1=Urban, 2=Rural	
	Subj. Family Econ. Status	Likert Scale	Single item	Likert scale points, higher score indicates better subjective economic status.	
	Paternal Education Level	Self-report	–	Ordinal variable (eg, 1=Primary school or below, 2=Junior high, 3=Senior high/Technical secondary, 4=College/University or above)	
	Maternal Education Level	Self-report	–	Same as “Paternal Education Level”	
Family Environment	Parental Marital Relationship	Likert Scale	Single item	Likert scale points, higher score indicates poorer relationship quality.	

(Continued)

Table 1 (Continued).

Variable Category	Variable Name	Measurement Tool	Dimensions/Description	Scoring Method and Meaning	Score Range/Clinical Significance
Academic & Psychosocial	Family Parenting Style	Self-report		Ordinal variable (eg, 1=Democratic, 2=Authoritarian, 3=Indulgent, 4=Neglectful)	
	Academic Ranking	Self-report	–	Ordinal variable (eg, 1=Top 10%, 2=10%-30%, 3=30%-50%, 4=50%-70%, 5=Bottom 30%)	
	Anxiety	GAD-7	Anxiety symptom severity	7 items, 4-point scale. Higher score indicates greater anxiety risk.	Total score range: 0–21. 0–4: Normal; 5–9: Mild; 10–14: Moderate; 15–21: Severe.
	Depression	PHQ-9	Depressive symptom severity	9 items, 4-point scale. Higher score indicates more severe depressive symptoms.	Total score range: 0–27. 0–4: None; 5–9: Mild; 10–14: Moderate; 15–19: Moderately severe; 20–27: Severe.
	Psychological Pain	TDPPS	Pain Experience, Pain Arousal, Pain Avoidance	17 items, 5-point scale. Higher total score indicates higher psychological pain level.	Total score range: 17–85. Higher scores indicate greater psychological pain.
	Friendship Quality	FQQ	–	18 items, 5-point scale. Higher total score indicates better friendship quality.	Total score range: 18–90. Higher scores indicate better perceived friendship quality.
	Bullying	MPVS-R	Physical, Verbal, Social Manipulation, Property Damage, Cyberbullying	20 items, frequency scoring. Higher total score indicates more severe victimization.	Frequency-based scoring. Higher scores indicate more frequent peer victimization.
	Perceived Stress	CPSS	Tension, Loss of Control	14 items, 5-point scale (incl. 7 reverse-scored items). Higher total score indicates higher perceived stress level.	Total score range: 14–70. Higher scores indicate greater perceived stress.
Resilience	RSCA	Goal Focus, Emotion Control, Positive Cognition, Interpersonal Assistance, Family Support	27 items, 5-point scale (incl. 12 reverse-scored items). Higher total score indicates higher psychological resilience level.	Total score range: 27–135. Higher scores indicate higher resilience.	

Statistical Analysis

All data analyses were performed using SPSS 26.0. First, univariate analysis was conducted using chi-square tests for categorical variables and Mann–Whitney *U*-tests for continuous variables due to their non-normal distribution to preliminarily screen variables associated with insomnia risk. Pearson correlation analysis was then performed to examine the bivariate relationships between continuous variables and insomnia severity. To assess multicollinearity among predictor variables, variance inflation factor (VIF) and tolerance statistics were calculated using linear regression models, with each predictor variable regressed onto all other predictors included in the final logistic regression model. VIF values below 5 and tolerance values above 0.2 were considered indicative of no significant multicollinearity. Subsequently, all variables showing a univariate association with insomnia severity at $p < 0.25$ were entered into an initial binary logistic regression model for further screening, following methodological recommendations to avoid excluding potential

predictors. Results are presented as odds ratios (OR) with their 95% confidence intervals (CI). Model fit was assessed using the Hosmer-Lemeshow test, -2 log-likelihood, Cox & Snell R^2 , and Nagelkerke R^2 . A p -value < 0.05 was considered statistically significant.

Result

Univariate Analysis

This study included 4288 valid adolescent samples. Based on the Insomnia Severity Index (ISI) score (cut-off >14), they were divided into two groups: the mild insomnia group ($n=2144$, 50.0%) and the moderate-to-severe insomnia group ($n=2144$, 50.0%). Univariate analysis aimed to preliminarily screen factors associated with adolescent insomnia severity. Chi-square tests were used for all categorical variables, and independent samples t -tests or Mann–Whitney U -tests were used for continuous variables. Results are shown in Table 2. All variables except for resilience ($p = 0.559$) met the pre-specified threshold of $p < 0.25$ for inclusion in the subsequent multivariable logistic regression model.

Correlation Analysis

To further explore the bivariate relationships between continuous variables and insomnia severity, Pearson correlation analysis was conducted. As shown in Table 3, all variables demonstrated significant correlations with insomnia severity ($p < 0.001$). Depression ($r = 0.637$), anxiety ($r = 0.583$), and psychological pain ($r = 0.496$) showed strong positive correlations with insomnia severity, indicating close associations between emotional problems and sleep disturbances. Perceived stress ($r = 0.450$) and bullying experiences ($r = 0.317$) demonstrated moderate positive correlations.

Among family environment variables, parenting style ($r = 0.232$) and parental marital relationship ($r = 0.222$) showed weak positive correlations with insomnia severity. Notably, protective factors including paternal education level ($r = -0.040$), maternal education level ($r = -0.039$), subjective family economic status ($r = -0.164$), and friendship quality ($r = -0.138$) showed significant negative correlations with insomnia severity.

Examination of intercorrelations among predictor variables revealed several notable relationships: depression and anxiety were highly correlated ($r = 0.827$), as were psychological pain with anxiety ($r = 0.694$) and depression ($r = 0.687$). Paternal and maternal education levels were strongly correlated ($r = 0.728$). All variance inflation factors (VIFs) in subsequent regression analyses were below 5, indicating acceptable levels of multicollinearity.

Multivariable Analysis

Multicollinearity diagnostics revealed that all variance inflation factor (VIF) values were below 5 (range: 1.053–4.623) and tolerance values were all greater than 0.2, indicating that multicollinearity was not significant and would not have a major impact on the model estimates. To identify independent predictors of adolescent insomnia severity, all variables significant ($p < 0.25$) in the univariate analysis were included in a binary logistic regression model, resulting in Table 4. The Omnibus Test of Model Coefficients showed a chi-square value of 3643.089 ($p < 0.001$), indicating the model as a whole was statistically significant. The Nagelkerke R^2 value was 0.763, meaning this combination of predictor variables explained approximately 76.3% of the variance in insomnia severity. The model's overall prediction accuracy was 88.8%, with a sensitivity of 87.2% for identifying individuals with moderate-to-severe insomnia, demonstrating excellent classification and discrimination ability.

Multivariable analysis results showed that, after controlling for all other variables, a total of 9 variables were independent predictors of adolescent insomnia severity ($p < 0.05$). Psychological pain was the strongest risk factor (OR = 1.465, 95% CI: 1.253–1.713), indicating that for each unit increase, insomnia risk increased by 46.5%. Depression level (OR = 1.298, 95% CI: 1.254–1.344) and parental absence for more than 3 months (OR = 1.277, 95% CI: 1.124–1.451) were also very strong risk predictors, increasing insomnia risk by approximately 29.8% and 27.7%, respectively. Additionally, bullying experiences (OR = 1.042), anxiety symptoms (OR = 1.038), and poor parental marital relationship (OR = 1.159) all showed independent predictive effects. Regarding protective factors, increasing age (OR = 0.359) showed the strongest protective effect, followed by female gender (OR = 0.724) and higher paternal education level (OR = 0.697). Only-child status, residence, maternal

Table 2 Univariate Analysis Results for Adolescent Insomnia Severity

Variable Category	Variable Name	Classification/Description	Mild Insomnia Group (n=2144)	Moderate-to-Severe Insomnia Group (n=2144)	Statistic	P-Value
Demographic Variables	Gender	Male	1208 (56.3%)	1011 (47.2%)	$\chi^2 = 36.247$	<0.001
		Female	936 (43.7%)	1133 (52.8%)		
	Age (years)	Continuous variable	14.0 (13.0, 16.0)	14.0 (13.0, 16.0)	$\chi^2 = 1449.996^\dagger$	<0.001
	Only Child	Yes	1442 (67.3%)	1143 (53.3%)	$\chi^2 = 87.081$	<0.001
Family Environment	Residence	No	702 (32.7%)	1001 (46.7%)	$\chi^2 = 44.213$	<0.001
		Urban/Town Center	2104 (98.1%)	2022 (94.3%)		
		Urban-Rural Fringe	38 (1.8%)	106 (4.9%)		
	Paternal Education Level	Rural	2 (0.1%)	16 (0.7%)	$\chi^2 = 254.760$	<0.001
		Primary school or below	22 (1.0%)	64 (3.0%)		
		Junior high school	143 (6.7%)	361 (16.8%)		
		Senior high / Technical	388 (18.1%)	560 (26.1%)		
		College/Associate degree	278 (13.0%)	309 (14.4%)		
	Maternal Education Level	University/Bachelor's degree	925 (43.1%)	655 (30.6%)	$\chi^2 = 197.279$	<0.001
		Master's degree or above	388 (18.1%)	195 (9.1%)		
		Primary school or below	35 (1.6%)	107 (5.0%)		
		Junior high school	173 (8.1%)	365 (17.0%)		
Senior high / Technical		408 (19.0%)	532 (24.8%)			
Parental Marital Relationship	College/Associate degree	321 (15.0%)	322 (15.0%)	$\chi^2 = 400.353$	<0.001	
	University/Bachelor's degree	905 (42.2%)	645 (30.1%)			
	Master's degree or above	302 (14.1%)	173 (8.1%)			
	Very Good	1045 (48.7%)	534 (24.9%)			
	Good	638 (29.8%)	617 (28.8%)			
Family Parenting Style	Average	337 (15.7%)	515 (24.0%)	$\chi^2 = 367.176$	<0.001	
	Poor	59 (2.8%)	223 (10.4%)			
	Very Poor	65 (3.0%)	255 (11.9%)			
	Democratic	1768 (82.5%)	1128 (52.6%)			
	Authoritarian	276 (12.9%)	671 (31.3%)			
Indulgent	44 (2.1%)	87 (4.1%)				
Neglectful	56 (2.6%)	258 (12.0%)				

(Continued)

Table 2 (Continued).

Variable Category	Variable Name	Classification/Description	Mild Insomnia Group (n=2144)	Moderate-to-Severe Insomnia Group (n=2144)	Statistic	P-Value		
Academic & Psychosocial	Parental Absence >3 months	Neither parent absent	1733 (80.8%)	1343 (62.6%)	$\chi^2 = 228.007$	<0.001		
		Father absent, mother present	357 (16.7%)	521 (24.3%)				
		Both parents absent	28 (1.3%)	115 (5.4%)				
		Other	26 (1.2%)	165 (7.7%)				
	Subj. Family Econ. Status	Very Poor	31 (1.4%)	111 (5.2%)	$\chi^2 = 151.487$	<0.001		
		Poor	64 (3.0%)	210 (9.8%)				
		Average	871 (40.6%)	986 (46.0%)				
		Good	937 (43.7%)	656 (30.6%)				
	Academic Ranking	Very Good	241 (11.2%)	181 (8.4%)	$\chi^2 = 66.196$	<0.001		
		Top 10%	481 (22.4%)	359 (16.7%)				
		10%~30%	577 (26.9%)	483 (22.5%)				
		30%~50%	477 (22.2%)	472 (22.0%)				
		50%~70%	382 (17.8%)	455 (21.2%)				
	Depression Score (PHQ-9)	70%~100%	227 (10.6%)	375 (17.5%)	$\chi^2 = 1985.351†$	<0.001		
		Continuous variable	17.0 (15.0, 21.0)	23.0 (19.0, 27.5)				
Anxiety Score (GAD-7)		Continuous variable	14.0 (11.0, 17.0)	18.0 (14.0, 23.0)			$\chi^2 = 1644.616†$	<0.001
Resilience Score (RSCA)		Continuous variable	15.7 (14.7, 16.8)	15.7 (14.6, 16.9)			$\chi^2 = 0.341†$	0.559
Psychological Pain (TDPPS)		Continuous variable	2.8 (2.1, 3.4)	3.4 (2.8, 3.9)			$\chi^2 = 1488.222†$	<0.001
Friendship Quality (FQQ)		Continuous variable	3.3 (2.8, 3.8)	3.2 (2.7, 3.8)			$\chi^2 = 48.370†$	<0.001
Bullying (MPVS-R)		Continuous variable	8.0 (6.0, 12.0)	11.0 (7.0, 17.0)			$\chi^2 = 665.977†$	<0.001
Perceived Stress (CPSS)	Continuous variable	6.3 (5.7, 7.1)	7.1 (6.3, 7.9)	$\chi^2 = 1174.988†$	<0.001			

Notes: Continuous variables were described as Median (Interquartile Range) and compared using the Mann–Whitney *U*-test due to non-normal distribution. The test statistic is presented as a Chi-square (χ^2) value as converted by SPSS for reporting purposes (†). Categorical variables were described as n (%) and compared using the Chi-square test (χ^2). Except for the resilience score, differences for all variables between insomnia groups were statistically significant ($p < 0.001$).

Table 3 Pearson Correlation Analysis Between Variables and Insomnia Severity

Variable	Correlation with Insomnia (r)	p-Value	Strength of Correlation
Depression	0.637	<0.001	Strong
Anxiety	0.583	<0.001	Strong
Psychological Pain	0.496	<0.001	Moderate
Perceived Stress	0.450	<0.001	Moderate
Bullying	0.317	<0.001	Moderate
Parenting Style	0.232	<0.001	Weak
Parental Marital Relationship	0.222	<0.001	Weak
Parental Absence >3 months	0.115	<0.001	Weak
Academic Ranking	0.109	<0.001	Weak
Age	0.066	<0.001	Weak
Resilience	0.063	<0.001	Weak
Gender	0.055	<0.001	Weak
Only Child	0.045	<0.001	Weak
Residence	0.021	<0.001	Very Weak
Maternal Education	-0.039	<0.001	Weak Negative
Paternal Education	-0.040	<0.001	Weak Negative
Subjective Family Economic Status	-0.164	<0.001	Weak Negative
Friendship Quality	-0.138	<0.001	Weak Negative

Notes: $|r| \geq 0.5$ = Strong correlation; $0.3 \leq |r| < 0.5$ = Moderate correlation; $0.1 \leq |r| < 0.3$ = Weak correlation; $|r| < 0.1$ = Very weak correlation.

Table 4 Multivariable Binary Logistic Regression Analysis Results for Adolescent Insomnia Severity

Variable Category	Variable Name	B	S.E.	p-Value	OR (95% CI)	Factor Attribute	Tolerance	VIF
Demographic Variables	Gender	-0.323	0.111	0.004	0.724 (0.582–0.901)	Protective	0.932	1.073
	Age	-1.024	0.048	<0.001	0.359 (0.327–0.395)	Protective	0.762	1.312
	Only Child	-0.026	0.112	0.816	0.974 (0.782–1.212)	Not Significant	0.924	1.083
Family Environment	Residence	-0.172	0.281	0.54	0.842 (0.485–1.461)	Not Significant	0.95	1.053
	Paternal Education Level	-0.36	0.059	<0.001	0.697 (0.621–0.782)	Protective	0.47	2.129
	Maternal Education Level	-0.134	0.058	0.021	0.875 (0.781–0.980)	Protective	0.472	2.118
	Parental Marital Relationship	0.147	0.053	0.005	1.159 (1.045–1.286)	Risk	0.72	1.389
	Family Parenting Style	0.12	0.071	0.088	1.128 (0.981–1.297)	Not Significant	0.792	1.263
	Parental Absence >3 months	0.245	0.065	<0.001	1.277 (1.124–1.451)	Risk	0.873	1.146
	Subj. Family Econ. Status	0.089	0.072	0.219	1.093 (0.949–1.259)	Not Significant	0.781	1.281
Academic & Psychosocial	Academic Ranking	0.072	0.042	0.085	1.075 (0.990–1.167)	Not Significant	0.945	1.059
	Depression Level (PHQ-9)	0.261	0.017	<0.001	1.298 (1.254–1.344)	Risk	0.216	4.623
	Anxiety Level (GAD-7)	0.037	0.016	0.02	1.038 (1.006–1.071)	Risk	0.237	4.219
	Psychological Pain (TDPPS)	0.382	0.079	<0.001	1.465 (1.253–1.713)	Risk	0.359	2.784
	Friendship Quality (FQQ)	0.081	0.075	0.277	1.085 (0.937–1.257)	Not Significant	0.926	1.08
	Bullying (MPVS-R)	0.041	0.009	<0.001	1.042 (1.024–1.060)	Risk	0.715	1.398
	Perceived Stress (CPSS)	-0.092	0.064	0.152	0.912 (0.805–1.034)	Not Significant	0.368	2.717
	Constant	11.043	1.022	<0.001				

education level, family parenting style, subjective family economic status, academic ranking, friendship quality, and perceived stress were no longer significant ($p > 0.05$) after multivariable adjustment, suggesting their associations shown in univariate analysis may be mediated by other psychosocial factors.

To further optimize model efficiency, only the 9 predictor variables that showed significance in both univariate and multivariable analyses were included in the final binary logistic regression model, with results shown in Table 5. The Omnibus Test of Model Coefficients showed a chi-square value of 3627.583 ($p < 0.001$). The Nagelkerke R^2 value was 0.761, meaning this streamlined combination of predictor variables explained approximately 76.1% of the variance in insomnia severity. The model’s overall prediction accuracy was 88.6%, with a sensitivity of 87.2% for identifying individuals with moderate-to-severe insomnia, indicating that the model maintained excellent classification and discrimination ability after simplification.

Multivariable analysis results confirmed that all 9 included variables were independent predictors of adolescent insomnia severity ($p < 0.05$). Psychological pain remained the strongest risk factor (OR = 1.444, 95% CI: 1.241–1.680). Depression level (OR = 1.292, 95% CI: 1.251–1.334) and parental absence for more than 3 months (OR = 1.290, 95% CI: 1.138–1.463) followed closely as important risk predictors. Bullying experiences (OR = 1.044) and poor parental marital relationship (OR = 1.153) also showed independent risk predictive effects. Regarding protective factors, increasing age (OR = 0.361) and higher paternal education level (OR = 0.644) showed significant protective effects, with the protective effect of paternal education level being particularly notable. Female gender (OR = 0.743) was also a significant protective factor. Notably, in this optimized model, anxiety level ($p = 0.064$) did not reach the 0.05 significance level.

Based on the regression coefficients (B values) from the final optimized model, we constructed the following streamlined Logistic regression prediction equation:

$$\text{logit}(P) = \ln \frac{P}{1-P} = 11.078 - 0.297 \times \text{Gender} - 1.018 \times \text{Age} - 0.439 \times \text{Paternal Education} + 0.142 \times \text{Parental Marital Relationship} + 0.255 \times \text{Parental Absence} + 0.256 \times \text{Depression} + 0.367 \times \text{Psychological Pain} + 0.043 \times \text{Bullying}$$

This equation integrates core influencing factors from individual emotional/psychological, family environment, and social experiences, excluding redundant variables. All continuous variables (eg, depression level, psychological pain) are entered using their original scores; for categorical variables, gender is entered as Male=1, Female=2; paternal education

Table 5 Multivariable Binary Logistic Regression Analysis Results for Adolescent Insomnia Severity (Optimized Model)

Variable Category	Variable Name	B	S.E.	p-Value	OR (95% CI)	Factor Attribute	Tolerance	VIF
Demographic Variables	Gender	-0.297	0.109	0.007	0.743 (0.600–0.920)	Protective	0.953	1.049
	Age	-1.018	0.047	<0.001	0.361 (0.329–0.396)	Protective	0.775	1.29
Family Environment	Paternal Education Level	-0.439	0.042	<0.001	0.644 (0.594–0.699)	Protective	0.949	1.054
	Parental Marital Relationship	0.142	0.05	0.004	1.153 (1.046–1.271)	Risk	0.797	1.254
	Parental Absence >3 months	0.255	0.064	<0.001	1.290 (1.138–1.463)	Risk	0.882	1.133
Emotional & Psych.	Depression Level (PHQ-9)	0.256	0.016	<0.001	1.292 (1.251–1.334)	Risk	0.234	4.273
	Anxiety Level (GAD-7)	0.029	0.015	0.064	1.029 (0.998–1.061)	Not Significant	0.251	3.978
Psychosocial	Psychological Pain (TDPPS)	0.367	0.077	<0.001	1.444 (1.241–1.680)	Risk	0.384	2.606
	Bullying (MPVS-R)	0.043	0.009	<0.001	1.044 (1.026–1.063)	Risk	0.718	1.392
	Constant	11.078	0.783	<0.001	64,744.301	-		

level is entered in its ordinal form; parental marital relationship is entered using the Likert score; parental absence is entered as Yes=1, No=0.

This final model significantly enhances the tool's simplicity and practicality while maintaining high prediction accuracy (88.6%) and high sensitivity (87.2%). This equation provides a powerful empirical tool for implementing rapid, efficient, large-scale insomnia risk screening in school settings, possessing significant practical application value.

Discussion

The Level of Insomnia Severity and the Rationale for Grouping

This study was embedded within a large-scale community survey of 30,833 urban adolescents. From this population, 2144 individuals (a prevalence of approximately 7.0%) were identified as suffering from moderate-to-severe insomnia based on the established ISI cutoff. This substantial absolute number underscores the significant and often underrecognized burden of clinically relevant insomnia in this demographic, warranting heightened clinical and public health attention.

The subsequent nested case-control sampling strategy, which included all 2144 identified cases and an equal number of randomly selected controls, was deliberately employed to fulfill the methodological requirements of binary logistic regression analysis. This 1:1 distribution enhances the statistical power for robustly identifying risk and protective factors, particularly for a prevalent but complex condition like insomnia, and is well-suited for developing predictive models.¹² Correlation analyses conducted prior to modeling revealed strong associations between emotional variables (eg, depression, anxiety, psychological pain) and insomnia severity, providing preliminary evidence for their central role and justifying their inclusion in the subsequent multivariable model.

Insomnia Severity in Adolescents Was Influenced by Multiple Factors Psychological Pain Was the Core Predictor of Insomnia Severity

In this study, psychological pain was the strongest risk factor (OR = 1.444) for predicting moderate-to-severe insomnia, its predictive power surpassing traditional indicators of depression and anxiety. This finding aligns closely with the recent research trend viewing psychological pain as a “transdiagnostic mechanism” that transcends specific diagnoses.²⁴ Our research suggests that insomnia may not only be a symptom of emotional disorders but also a behavioral manifestation through which adolescents attempt to escape or alleviate intense internal psychological pain.⁶ Research provides a possible physiological basis for this, indicating an association between psychological pain and overactivity in brain networks responsible for processing negative emotions and self-referential thoughts in insomnia patients.^{25,26} Therefore, future insomnia interventions should not stop at sleep hygiene education or emotion management but should deeply assess and address the internal, often unspoken, psychological pain experienced by adolescents, for example, by incorporating acceptance and commitment therapy-based techniques.²⁷

Family Structural Factors Were Significant Influencers of Insomnia Severity

This study revealed risk patterns specific to Chinese culture. Paternal education level as a significant protective factor (OR=0.644) reflects the crucial role of fathers in resource acquisition and educational decision-making within Chinese families. Surveys indicate a positive correlation between paternal education level and the scientific nature of parenting styles.²⁸ The identification of parental absence for more than three months as an important risk factor (OR=1.290) directly corresponds to the social reality of large-scale rural-urban migration in China, where many adolescents experience emotional absence during critical growth periods.²⁹

Furthermore, poorer parental marital relationship (indicated by a higher self-reported score) was identified as an independent risk factor for insomnia (OR=1.153). This aligns with established literature linking family conflict and discord with adverse child outcomes, including sleep disturbances.^{30,31} In the Chinese context, a higher score reflecting a poorer relationship may encompass overt conflict, chronic tension, or emotional detachment within the family. Such an environment can directly increase adolescent stress and anxiety, disrupting sleep regulation mechanisms. It may also indirectly affect sleep through impacting parenting practices and the overall emotional security of the adolescent.

Emotional and Social Factors Were Also Independent Predictors

This study also confirmed cross-culturally consistent risk factors. Depression (OR=1.292) remains a strong predictor of insomnia, consistent with abundant existing evidence that the two are often considered comorbid conditions with a bidirectional relationship.³² The predictive effect of anxiety was overshadowed by psychological pain and depression and was no longer significant in the final optimized model, supporting emerging theories that psychological pain may be the common underlying driver of depression, anxiety, and insomnia.³³ Regarding social factors, although the effect size for bullying experience as a risk factor (OR = 1.044) was small, its cumulative and chronic impact should not be overlooked. Bullying creates a persistent state of social threat, leading to sustained activation of the Hypothalamic-Pituitary-Adrenal (HPA) axis, disrupting the normal secretion rhythm of melatonin, and consequently impairing sleep architecture.³⁴ Bullying victimization not only directly harms adolescent mental health but also, through disrupting sleep—a key pathway—can trigger both internalizing and externalizing problems.^{35,36}

Regarding protective factors, increasing age (OR = 0.361) showed the strongest protective effect, which may be related to the development of more mature emotion regulation strategies and prefrontal cortex function with advancing age.³⁷ The finding of female gender as protective (OR=0.743) contrasts with some previous studies, which may reflect the specificity of this sample or suggest that, within this specific cultural context, female adolescents might have advantages in seeking social support and emotional expression, thereby better buffering insomnia risk.^{38,39}

The Value of the Prediction Model for Clinical Practice

The streamlined prediction model developed in this study demonstrates promising utility for initial screening. While maintaining high predictive performance in our sample (Nagelkerke $R^2 = 0.761$, overall accuracy 88.6%), the model includes only 9 easily assessable variables, which enhances its feasibility for potential application as a primary screening tool in resource-limited settings like schools. By quickly identifying high-risk individuals using the developed prediction equation, early warning for insomnia and precise allocation of intervention resources could be achieved, potentially shifting preventive care towards a more evidence-based approach. However, it is crucial to emphasize that the reported performance reflects internal validation. External validation in independent, population-based samples is necessary to confirm its generalizability and calibrate its true clinical utility before widespread implementation.

Limitation

This study has several limitations. First, the cross-sectional design cannot infer causality; longitudinal studies are necessary in the future. Second, the data came from student self-reports and may be influenced by common method bias and social desirability. Third, the sample was drawn from central urban areas of a large city; caution is needed when generalizing conclusions to rural areas, smaller cities, or adolescents from different cultural backgrounds. Future research should validate the model in broader populations. Fourth, the case-control design may inflate the model's reported performance. External validation in a community sample is necessary to assess its true clinical utility.

Relevance to Clinical Practice

This study advances the field by identifying psychological pain as the strongest predictor of adolescent insomnia, surpassing traditional factors like depression and anxiety. It integrates individual, family, and social factors into a single, highly accurate predictive model. The primary clinical contribution is the development of a streamlined, 9-variable risk equation, providing a practical and efficient tool for early, large-scale insomnia screening in school settings. This enables targeted interventions and shifts preventive care towards a more precise, evidence-based approach.

Conclusion

Based on a sample of adolescents from major Chinese cities, this study systematically identified individual, family, and social multi-level risk and protective factors influencing insomnia severity and successfully constructed a binary logistic regression prediction model containing nine core variables. The research confirmed that psychological pain is the strongest risk factor for predicting moderate-to-severe insomnia, its role surpassing traditional indicators of depression

and anxiety, suggesting that alleviating psychological pain should be an important target for insomnia intervention. Simultaneously, the study highlighted the non-negligible independent contributions of structural family variables, particularly paternal education level and parental absence, to adolescent insomnia, deepening the understanding of the association between family environment and sleep health within the Chinese cultural context.

The final streamlined prediction model demonstrated excellent goodness-of-fit (Nagelkerke $R^2 = 0.761$) and classification accuracy (88.6%). While ensuring high predictive performance, it significantly enhanced the tool's simplicity and practicality. This model effectively translates theoretical research findings into a quantifiable screening tool usable in school environments, providing a solid empirical basis for implementing large-scale, precise early identification of insomnia risk and tiered intervention among Chinese secondary school student populations, holding significant public health practice value.

Data Sharing Statement

The data supporting the findings of this study are not publicly available due to ethical restrictions protecting participant privacy. De-identified data will be made available upon reasonable request to the corresponding author, subject to approval by the our Ethics Committee.

Ethics Approval

This study was performed in accordance with the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Medical Ethics Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology (TJ-IRB202510009).

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Author Contributions

Haishan Huang: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft. Zhuoyan Zhang: Conceptualization, Methodology, Supervision, Project Administration, Funding Acquisition, Writing – Original Draft, Writing – Review & Editing. Rong Xv: Investigation, Data Curation, Writing – Review & Editing. All authors took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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