


Development and Validation of a Nomogram for Estimating the Risk of Suicide Tendencies Among Chinese Middle School Students: A Cross-Sectional Study

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Objective: This study aims to develop and validate a risk estimation model for identifying suicidal tendencies among middle school students. The effectiveness of the model is evaluated, offering insights for preventing and managing student suicides in educational institutions.

Methods: This study employed a cross-sectional design. From December 2018 to January 2019, a total of 12,798 middle school students from all 18 public schools in an urban district of Suzhou were surveyed. After data cleaning, 12,063 valid questionnaires were included and randomly divided into a training set (n=8,444) and a validation set (n=3,619) in a 7:3 ratio for model development and internal validation, respectively. Predictors were selected through univariate analysis and LASSO regression, with independent associated factors subsequently identified by multivariable logistic regression. Based on these factors, a nomogram risk estimation model was constructed using R software. To assess generalizability, external validation was performed using data from 6,262 valid questionnaires collected from 11 public middle schools in Changshu, Suzhou, in 2023.

Results: The nomogram incorporated nine selected factors: trouble asking for help, parents' marital relationship, gender, school bullying, nightmares, depressive mood (PHQ02), sleep disturbance (PHQ03), feelings of worthlessness (PHQ06), and psychomotor changes (PHQ08). The model demonstrated good discrimination in the internal validation set area under the curve (AUC) 0.807 (95% CI [0.790, 0.824]) and in a temporal external validation cohort AUC 0.764 (95% CI [0.751, 0.778]). Calibration was satisfactory internally but required adjustment in the external cohort.

Conclusion: This study developed and validated a multidimensional nomogram that effectively discriminates middle school students at risk of suicide, providing a framework for initial risk stratification. For application in new settings, local calibration of the model's risk estimates is mandatory. This tool holds potential to aid early identification in school and primary care contexts.

Keywords: suicidal tendencies, middle school students, associated factors, nomogram, risk estimation model

Introduction

Suicide has emerged as a pervasive public health concern among adolescents worldwide, exerting a substantial detrimental influence on individuals, families, and society at large. According to the World Health Organization (WHO), suicide is the second leading cause of death among adolescents aged 10 to 29, with a significant increase in global adolescent suicide rates over the past decade.¹ Since 2017, there has been a marked increase in the suicide rate among Chinese adolescents,² with a suicide rate of 2.9% per 100,000 among adolescents aged 15 to 19.³ It is noteworthy that suicide risk among Chinese



adolescents manifests distinctive regional and gender-related characteristics. Suicide rates are generally higher in rural areas than in urban areas.⁴ Non-suicidal self-injury (NSSI) is more prevalent among females.⁵ Additionally, multiple studies indicate that suicide tendencies among Chinese adolescents ranges from 11% to 25%,⁶ a proportion far higher than that of the general population. Despite substantial global investments in research on suicide risk factors and the development of suicide prevention programs,⁷ China's overall suicide rate has decreased, while the suicide rate among adolescents has been rising annually.⁸ Additionally, there has been an observed increase in suicide mortality rates among adolescents in rural Chinese regions.⁹

Suicidal behavior constitutes a significant public health concern and a multifaceted social phenomenon. The underlying causes of this complex issue are rooted in various fields of study, including biology, psychology, sociology, and cultural studies. A comprehensive review of the extant literature indicates that risk factors for adolescent suicidal behavior include the following: psychological factors (eg., depression, anxiety, and impulsivity),¹⁰ family factors (eg., family conflicts, parental divorce, and lack of family support),¹¹ school factors (eg., academic pressure, school bullying, and interpersonal relationship issues),^{12,13} and social factors (eg., insufficient social support, economic difficulties, and cultural environment).¹⁴ Although machine learning and advanced psychometric algorithms have emerged as promising approaches for identifying individuals at risk of suicide,¹⁵ contemporary suicide tendency risk estimation models continue to exhibit substantial limitations in identifying suicidal tendencies among adolescents.

First, most models focus on the influence of single factors (eg., depressive mood) on adolescent suicidal tendencies,¹⁶ overlooking the complex interactions among multidimensional factors such as family and school environments,¹⁷ leading to inadequate sensitivity and making it difficult to comprehensively identify high-risk individuals.¹⁸ Second, many Western models are constructed within their specific sociocultural contexts and fail to adequately incorporate key factors unique to the Chinese cultural context, such as stigma-influenced “help-seeking barriers” and complex “intergenerational dynamics,” limiting their applicability in Chinese family and community settings.^{19,20} Direct application to Chinese adolescent populations may therefore introduce bias. Third, the majority of existing models are developed based on help-seeking populations, such as psychiatric outpatients or inpatients.¹⁸ This selection bias results in models that perform well in learning the characteristics of “pathological states” but often exhibit substantially reduced specificity and positive predictive value when applied to general middle school populations, which consist predominantly of asymptomatic individuals, thereby failing to meet the needs of early prevention.²¹ Furthermore, few existing models have undergone external validation, particularly cross-temporal validation in Chinese adolescent populations, casting doubt on their generalizability.²² Fourth, many existing high-accuracy models rely on complex clinical interviews, neuropsychological tests, or even biomarkers.²³ Although such indicators are valuable in specialized diagnostic settings, their high time costs and professional requirements limit their feasibility for large-scale school screening or primary care implementation, resulting in insufficient ecological validity.²⁴ Some models additionally rely on complex machine learning algorithms or specialized software, creating high operational barriers that restrict their practical utility in large-scale population screening.²⁵

Therefore, developing a predictive tool that integrates multidimensional risk factors, undergoes localized validation, and is easy to operate is essential for improving the efficiency and accuracy of suicide risk screening among Chinese adolescents. This study aims to construct a comprehensive nomogram for estimating the risk of adolescent suicidal tendencies by integrating multidimensional indicators, including individual psychological characteristics, family environment, school factors, and social support. This model not only enables earlier and more precise identification of adolescents at risk for suicidal tendencies but also, by virtue of its visual and user-friendly nature, holds promise as a practical tool for school-based mental health efforts, providing strong support for educational institutions, families, and society to implement timely and targeted interventions. Given these limitations, there is a pressing need in the current literature for a predictive tool that integrates multidimensional risk factors, undergoes localized validation, and is easy to operate. Such a tool should include only indicators that can be readily obtained through self-report questionnaires or brief interviews, be developed based on a large, representative sample of general students, and undergo rigorous validation across different time periods. Addressing this need is crucial for improving the efficiency and accuracy of suicide risk screening among Chinese adolescents. The present study aims to fill this critical gap by comprehensively considering factors from multiple dimensions individual, family, school, and societal to construct a multivariable nomogram for estimating the risk of adolescent suicidal tendencies.

The core innovation and advantage of this study lie in its exceptional practicality and cross-setting applicability: in schools, school counselors can use this tool for efficient large-scale initial screening; in primary care settings, general practitioners or pediatricians can employ it as a rapid triage tool to identify students who may not meet criteria for specialized psychiatric referral but nonetheless exhibit potential risk; and in family contexts, the concise variable indicators help parents understand risk dimensions, promote parent–child communication, and facilitate timely access to professional help. Furthermore, by incorporating temporal external validation using 2023 data, we have further ensured the robustness of the model in the post-pandemic social context. Its visual and user-friendly characteristics make it a promising practical resource for school-based mental health work, providing educational institutions, primary care systems, and families with a unified, simple, and scientifically grounded decision-support framework to facilitate timely and targeted tiered interventions.

Materials and Methods

Data and Participants

This study utilized data from a community-based, cross-sectional survey conducted from December 2018 to January 2019. The survey encompassed all 12,798 middle school students enrolled in the 18 public schools within a specific urban district of Suzhou City. In the end, 12,354 students provided consent and completed the questionnaire, yielding 12,139 initial responses. Following data cleaning, 175 cases with missing values exceeding 10%, 77 cases with missing key information, and 39 cases with obvious logical errors were excluded. Consequently, 291 questionnaires were deemed invalid, resulting in 12,063 valid questionnaires for analysis (validity rate: 97.64%). The study cohort was then randomly split into a training set and a validation set in a 7:3 ratio for internal validation, resulting in 8,444 students in the training (modeling) group and 3,619 in the validation group. External validation data comes from the results of the same questionnaire survey conducted in 2023 at 11 public middle schools in Changshu, Suzhou, with a total of 6,262 valid questionnaires analyzed.

Clinical Evaluation

A self-administered general information questionnaire was used to collect data across four dimensions: personal, physiological, familial, and environmental, comprising a total of 15 items.

Personal factors included gender, age, and daily exercise (>3 hours or ≤3 hours). Physiological factors included: difficulty in breathing (in the past month, experiencing sleep disturbance due to shortness of breath ≥1 time/week), pain (in the past month, experiencing sleep disturbance due to pain ≥1 time/week), lose weight (Have you tried to lose weight in the past three months?), feel too fat (Have you engaged in compensatory behaviors, such as self-induced vomiting or fasting, to avoid weight gain after eating?), easy to wake up (in the past month, experiencing sleep disturbance due to easily waking up or waking up too early ≥1 time/week), and nightmare (in the past month, experiencing sleep disturbance due to nightmares ≥1 time/week). Family factors included parents' marital relationship (the quality of the parental relationship as perceived by the student, ie., “good” or “poor”), living with parents, and only-child. Environmental factors included school bullying and trouble asking for help (relying on oneself or rarely seeking help from others).

Patient Health Questionnaire-9 (PHQ-9)

This scale is designed to evaluate the severity of depressive symptoms in an individual over the past two weeks. This scale utilizes nine questions to assess the presence and intensity of symptoms, including: (01) anhedonia (02) depressive mood (03) sleep disturbance (04) fatigue (05) appetite change (06) feelings of worthlessness (07) difficulty concentrating (08) psychomotor changes (09) suicidal ideation. Each question on the PHQ-9 is scored on a scale from “0” (none) to “3” (almost every day), with the total score reflecting the severity of depressive symptoms; higher scores indicate more severe depressive symptoms.²⁶ In this study, individual items of the PHQ-9 were converted into binary data, categorized as 0 (none) and 1 (present, including “a few days,” “most days,” or “almost every day”). Previous studies have shown that dichotomizing such screening tools can maintain robust predictive accuracy while improving clinical sensitivity and operational convenience in

large-scale school-based screening settings. The ninth item of the PHQ-9 overlaps with the “suicidal ideation” assessment item, so it was excluded from the questionnaire.

Suicidal Tendencies

The assessment of “suicidal tendencies” involves the evaluation of suicidal thoughts, suicidal plans, and suicidal attempts.²⁷ The assessment of suicidal tendencies was adapted from the suicide module of the Mini-International Neuropsychiatric Interview (MINI). This module evaluates three dimensions: suicidal thoughts (eg., “Did you feel that you would be better off dead or wish you were dead?” and “Did you think about suicide?”), suicide plans (eg., “Have you taken any actions to prepare for self-harm or suicide with the intent to die?”), and suicide attempts (eg., “Have you ever taken measures to attempt suicide in your lifetime?”). The response options for each item were binary (“Yes” or “No”). A participant was categorized as having suicidal tendencies if they responded “Yes” to any of these questions.

Quality Control

The questionnaire was developed by professional physicians and psychologists based on clinical and teaching practices, and its applicability was confirmed through a preliminary survey. The surveyors were homeroom teachers from each school, who received uniform training prior to the survey. During the formal survey, the surveyors explained the purpose and significance of the survey and read the instructions before distributing the questionnaires. Students are required to complete the questionnaire independently on-site, with an estimated response time of approximately 20 minutes. Subsequent to the collection of the questionnaires, those that exhibit overt logical inconsistencies or a response rate below 15% will be excluded from the analysis.

Statistical Analysis

All data were analysed using JingDing Analytics Platform (V6.12) and SPSS V.26.0 (IBM Corporation). The data were described using frequencies or percentages. Intergroup comparisons were conducted using the chi-square test or Fisher’s exact probability test. The total sample was randomly divided into a training set (70%) and an internal validation set (30%). In the training set, univariate χ^2 -tests were used to screen candidate predictors ($P < 0.05$). LASSO regression with 10-fold cross-validation was then applied to select the most parsimonious set of predictors. Multivariable logistic regression was subsequently performed to identify independent factors associated with suicidal tendency, and a nomogram was constructed based on the regression coefficients. The final model’s performance was evaluated in the validation set using the area under the ROC curve (AUC), calibration plots with the Hosmer–Lemeshow test, and decision curve analysis (DCA). External validation was conducted using an independent dataset collected in 2023 ($n=6,262$). A two-sided $P < 0.05$ was considered statistically significant.

Results

Incidence and Baseline Characteristics of Suicidal Tendencies

A total of 12,063 middle school students were included in this study, of whom 2,651 (21.9%) were identified as having suicidal tendencies and 9,412 (78.1%) as non-suicidal. The total sample was randomly divided into a training set (modeling set) and a validation set at a ratio of 7:3. The training set comprised 8,444 participants, including 1,865 with suicidal tendencies (prevalence rate: 22.1%), while the validation set comprised 3,619 participants, including 786 with suicidal tendencies (prevalence rate: 21.7%) See [Figure 1](#).

Univariate Analysis of Factors Associated with Suicidal Tendency in the Training Set

In the training set ($n = 8,444$), a univariate χ^2 -test was performed with suicidal tendency as the dependent variable to screen potential influencing factors. The results showed that, except for age ($P = 0.095$) and only child status ($P = 0.936$), all other variables were significantly associated with suicidal tendency (all $P < 0.001$), as shown in [Table 1](#).

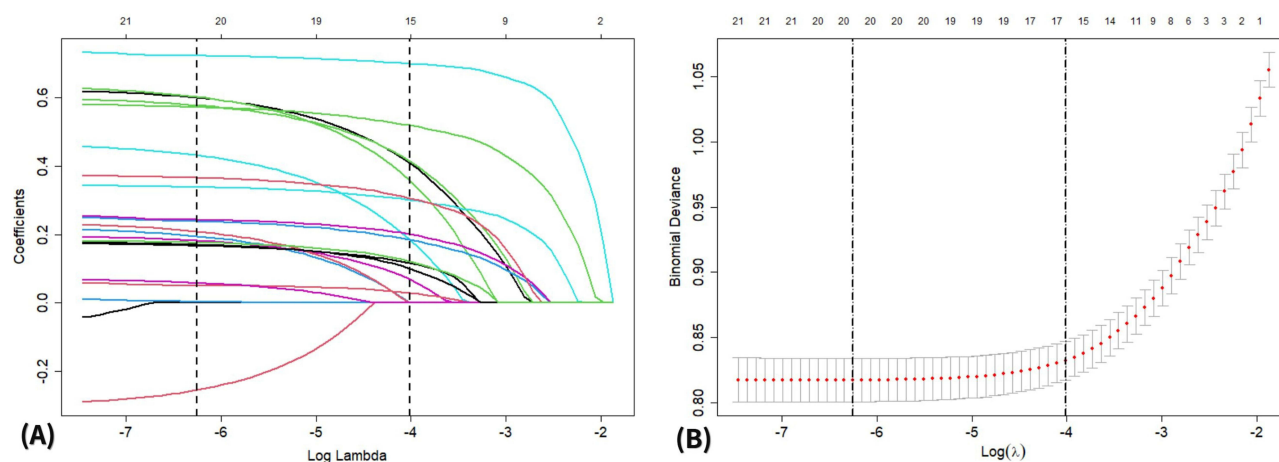


Figure 1 Results of the LASSO regression analysis. **(A)** LASSO regression model screening variable trajectories. **(B)** LASSO Regression Model Factor Selection. **Abbreviations:** LASSO, Least Absolute Shrinkage and Selection Operator.

Lasso Regression Analysis of Factors Associated with Suicidal Tendency

In the training set ($n = 8,444$), the variables with statistically significant differences in Table 1 were entered into a LASSO regression model to further screen predictors. The array of independent variables encompassed a total of 21 elements, including gender, living with parents, parents' marital relationship, daily exercise, trouble asking for help, lose weight, feel too fat, emetic or fasting, school bullying, difficulty in breathing, pain, easy to wake up, nightmare, and PHQ01-PHQ08. Lasso analysis was conducted using R software, ultimately identifying 15 selected factors: trouble asking

Table 1 Univariate Analysis of Factors Associated with Suicidal Tendency in the Training Set [n(%)]

Variable	Number of Cases (n=8444)	Non-Suicidal Tendency Group (n=6579)	Suicidal Tendency Group (n=1865)	P
Age				0.095
≤15 years	6112 (72%)	4791 (73%)	1321 (71%)	
Gender				<0.001
Female	3889 (46%)	2860 (43%)	1029 (55%)	
Only child				0.936
No	5610 (66%)	4369 (66%)	1241 (67%)	
Living with parents				<0.001
No	502 (6%)	348 (5%)	154 (8%)	
Parents' marital relationship				<0.001
poor	2348 (28%)	1521 (23%)	827 (44%)	
Daily exercise				<0.001
≤3h	5693 (67%)	4571 (69%)	1122 (60%)	
Trouble asking for help				<0.001
Yes	3726 (44%)	2562 (39%)	1164 (62%)	
Lose weight				<0.001
Yes	3487 (41%)	2490 (38%)	997 (53%)	
Feel too fat				<0.001
Yes	4151 (49%)	2950 (45%)	1201 (64%)	
Emetic or fasting				<0.001
No	7900 (94%)	6246 (95%)	1654 (89%)	
School bullying				<0.001
Yes	654 (8%)	357 (5%)	297 (16%)	

(Continued)

Table 1 (Continued).

Variable	Number of Cases (n=8444)	Non-Suicidal Tendency Group (n=6579)	Suicidal Tendency Group (n=1865)	P
Easy to wake up				<0.001
Yes	3184 (38%)	2187 (33%)	997 (53%)	
Difficulty in breathing				<0.001
Yes	1291 (15%)	747 (11%)	544 (29%)	
Pain				<0.001
Yes	1269 (15%)	725 (11%)	544 (29%)	
Nightmare				<0.001
Yes	2382 (28%)	1482 (23%)	900 (48%)	
Anhedonia (PHQ01)				<0.001
Yes	3851 (46%)	2443 (37%)	1408 (75%)	
Depressive mood (PHQ02)				<0.001
Yes	3673 (43%)	2220 (34%)	1453 (78%)	
Sleep disturbance (PHQ03)				<0.001
Yes	3819 (45%)	2443 (37%)	1376 (74%)	
Fatigue (PHQ04)				<0.001
Yes	4282 (51%)	2816 (43%)	1466 (79%)	
Appetite change (PHQ05)				<0.001
Yes	3581 (42%)	2282 (35%)	1299 (70%)	
Feelings of worthlessness (PHQ06)				<0.001
Yes	3571 (42%)	2182 (33%)	1389 (74%)	
Difficulty concentrating (PHQ07)				<0.001
Yes	3469 (41%)	2186 (33%)	1283 (69%)	
Psychomotor changes (PHQ08)				<0.001
Yes	2607 (31%)	1505 (23%)	1102 (59%)	

Note: PHQ01-PHQ08 correspond to the first 8 entries in the PHQ-9, respectively.

for help, parents' marital relationship, gender, lose weight, feel too fat, school bullying, difficulty in breathing, nightmare, pain, anhedonia (PHQ01), depressive mood (PHQ02), sleep disturbance (PHQ03), appetite change (PHQ05), feelings of worthlessness (PHQ06), and psychomotor changes (PHQ08) See [Figure 1](#).

Logistic Regression Analysis of Factors Influencing Suicidal Tendency

Using the variables selected by LASSO regression in the training set, a multivariate logistic regression analysis was performed to identify independent factors associated with suicidal tendency. The analysis revealed that trouble asking for help, parents' marital relationship, gender, school bullying, nightmares, depressive mood (PHQ02), sleep disturbance (PHQ03), feelings of worthlessness (PHQ06), and psychomotor changes (PHQ08) were all factors influencing suicidal tendencies among middle school students ($P < 0.05$) See [Table 2](#).

Construction and Validation of the Risk Estimation Model

The study cohort was randomly divided into a training set (70%) and an internal validation set (30%). A nomogram risk estimation model for suicidal tendencies was developed using the nine predictors identified through univariate, LASSO, and logistic regression analyses. See [Figure 2](#). The model demonstrated good discrimination, with an area under the ROC curve (AUC) of 0.818 (95% CI [0.807, 0.828]) in the training set (See [Figure 3A](#)) and 0.807 (95% CI [0.790, 0.824]) in the internal validation set (See [Figure 3B](#)). Calibration was satisfactory in the training set, as evidenced by the Hosmer-Lemeshow test ($\chi^2 = 10.935$, $P = 0.141$; [Figure 4A](#)), and similarly in the internal validation set ($\chi^2 = 6.599$, $P = 0.471$; [Figure 4B](#)). Decision curve analysis (DCA) showed a significant net benefit across a wide range of risk threshold probabilities in both the training set (See [Figure 5A](#)) and the internal validation set (See [Figure 5B](#)).

Table 2 Logistic Regression Analysis of Influencing Factors of Suicidal Tendency

Dependent Variable	B	SE	OR	CI	Z	P
Trouble asking for help	0.653	0.061	1.922	1.922 (1.704–2.169)	10.613	<0.001
Parents' marital relationship	0.636	0.063	1.889	1.889 (1.670–2.137)	10.093	<0.001
Gender	0.527	0.061	1.693	1.693 (1.501–1.910)	8.560	<0.001
School bullying	0.699	0.097	2.012	2.012 (1.661–2.437)	7.146	<0.001
Depressive mood (PHQ02)	0.874	0.081	2.396	2.396 (2.043–2.810)	10.753	<0.001
Sleep disturbance (PHQ03)	0.353	0.075	1.423	1.423 (1.227–1.651)	4.668	<0.001
Feelings of worthlessness (PHQ06)	0.657	0.077	1.928	1.928 (1.658–2.244)	8.503	<0.001
Psychomotor changes (PHQ08)	0.425	0.072	1.530	1.530 (1.326–1.765)	5.839	<0.001
Nightmare	0.505	0.063	1.658	1.658 (1.464–1.877)	7.962	<0.001

Note: PHQ02, PHQ03, PHQ06, and PHQ08 correspond respectively to items 2, 3, 6, and 8 in PHQ-9.

External Validation of the Risk Estimation Model

To assess generalizability, we conducted temporal external validation using the same survey data collected in 2023 from public middle schools in Changshu, Suzhou (n=6262). The nomogram maintained acceptable discrimination in this external cohort, with an AUC of 0.764 (95% CI[0.751,0.778]). See [Figure 6A](#). However, the Hosmer-Lemeshow test indicated significant miscalibration ($\chi^2 = 174.920$, $P < 0.05$), suggesting that while the model's ability to rank risk was preserved, its absolute risk estimates required adjustment for this new temporal context. The calibration plot visually confirmed this deviation, as shown in [Figure 6B](#). These results underscore the utility of the model for risk stratification and highlight the necessity of recalibration prior to its application in different time periods.

Discussion

The present study found that the prevalence rate of suicidal tendencies among middle school students in a certain urban area of Suzhou City was 21.9%. Tan Yafe et al found that 11.50% of the 2,278 middle school students aged 12 to 16 reported suicidal tendencies in the past year.²⁸ A meta-analysis of studies conducted between 2000 and 2012 found that the prevalence rate of suicidal tendencies among Chinese middle school students was 17.99%.²⁹ This underscores the necessity for heightened awareness regarding suicidal tendencies among middle school students.

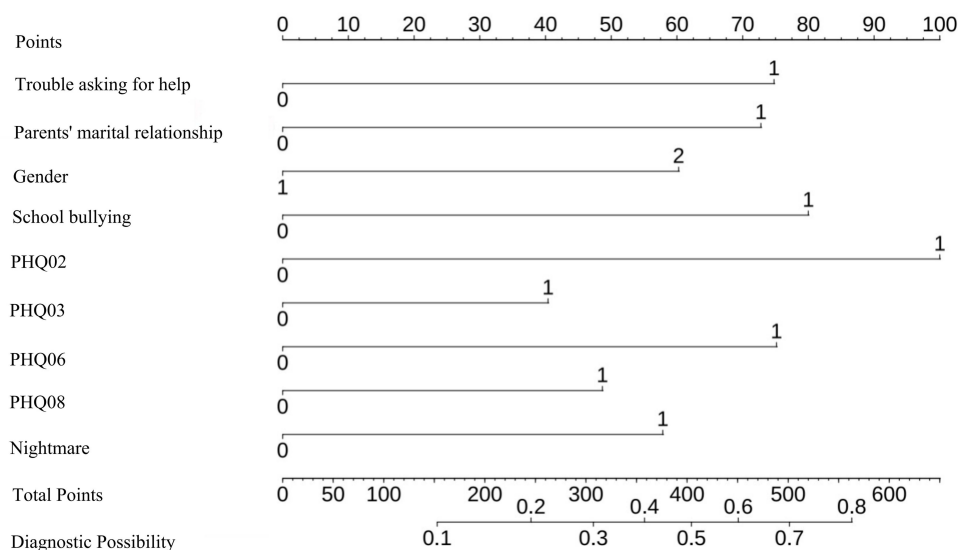


Figure 2 Nomogram for estimating the risk of suicidal tendencies in students. For an individual, each variable corresponds to a single point at the top of nomogram (Points). The total points were summed up by all single points and are indicated in the second line from the bottom (Total Points), and each total point corresponds to a probability of suicidal tendencies.

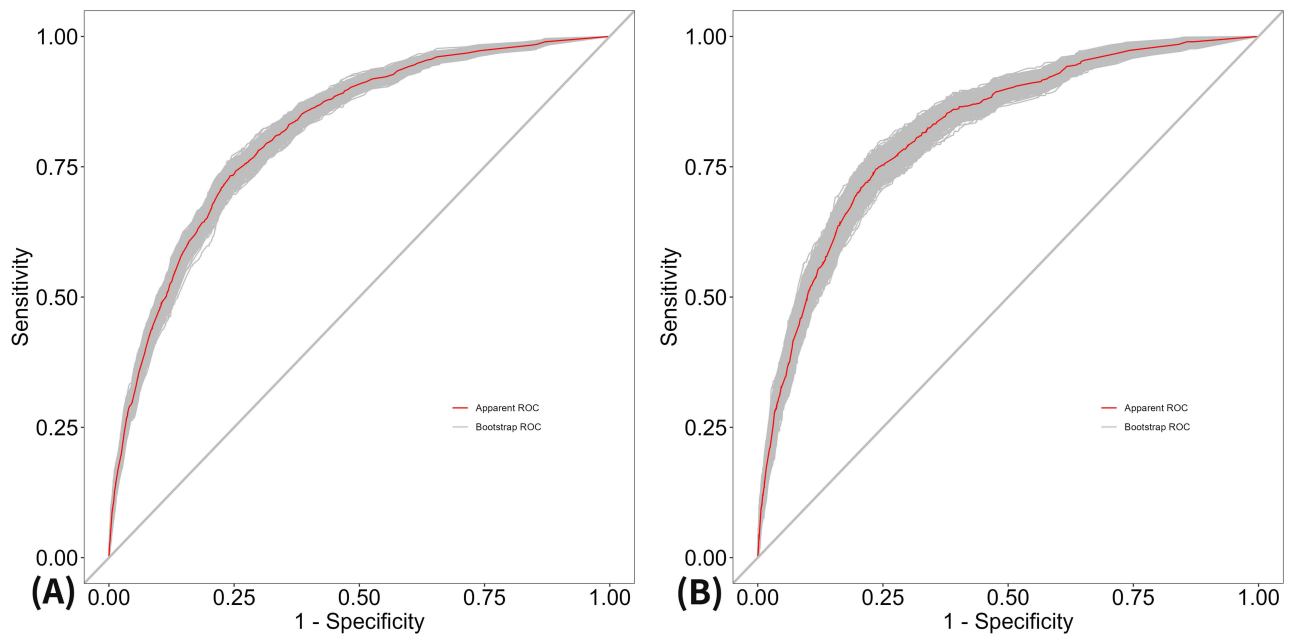


Figure 3 ROC curves of nomogram for estimating the probability of suicidal tendencies in training set (A) and validation set (B). The horizontal axis means the false positive rate of the risk estimation. The vertical axis means the true positive rate of the risk estimation. The color line represents the performance of nomogram.

Abbreviations: ROC, Receiver operating characteristic curve.

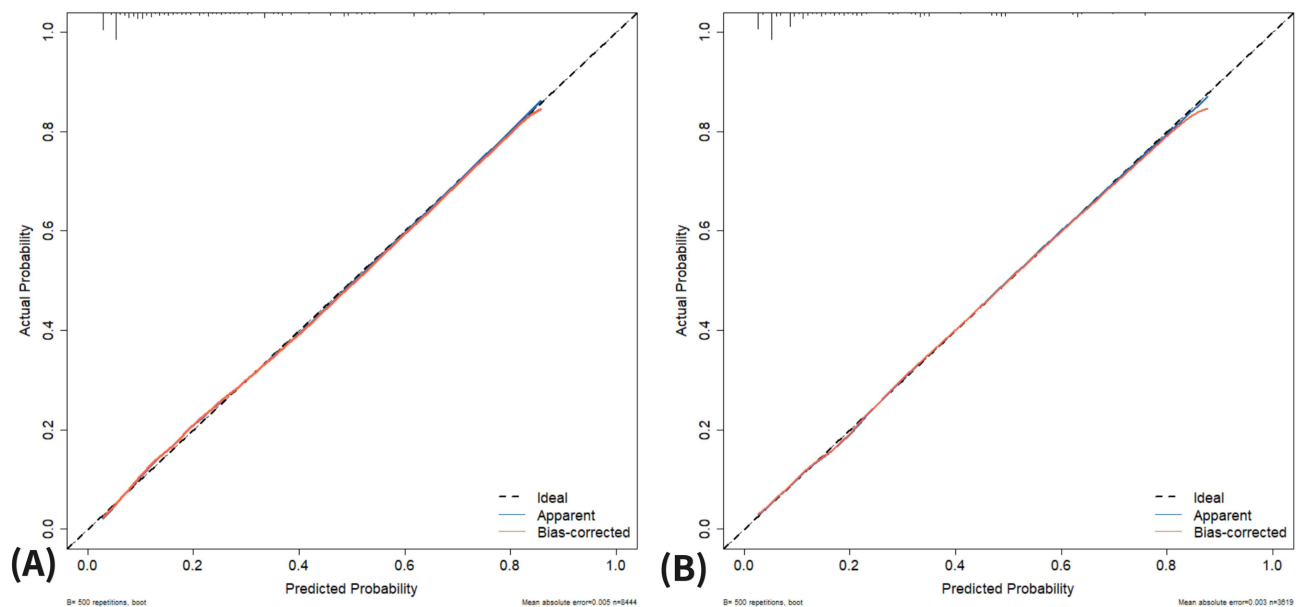


Figure 4 Calibration curve of risk estimation model in training set (A) and validation set (B). Internal validation of the nomogram was performed using a corrected calibration curve within 500 bootstrap samples. The horizontal axis represents the estimated probability of suicidal tendencies. The vertical axis represents the actual suicidal tendencies probability. The diagonal dotted line represents a perfect risk estimation of an ideal model. The red line represents the performance of the nomogram, of which a closer fit to the diagonal dotted line represents a better risk estimation.

This study not only confirmed the strong association between depressive symptoms, anxiety, and suicidal ideation among adolescents, which is consistent with findings from global studies,^{30,31} but more notably, it revealed the independent predictive value of trouble asking for help, parents' marital relationship, school bullying, and sleep disturbances in the model. In certain subgroups, the weights of these factors even surpassed those of traditional psychopathological indicators. This phenomenon may reflect unique psychosocial mechanisms within the Chinese cultural context, unlike the emphasis on individual pain

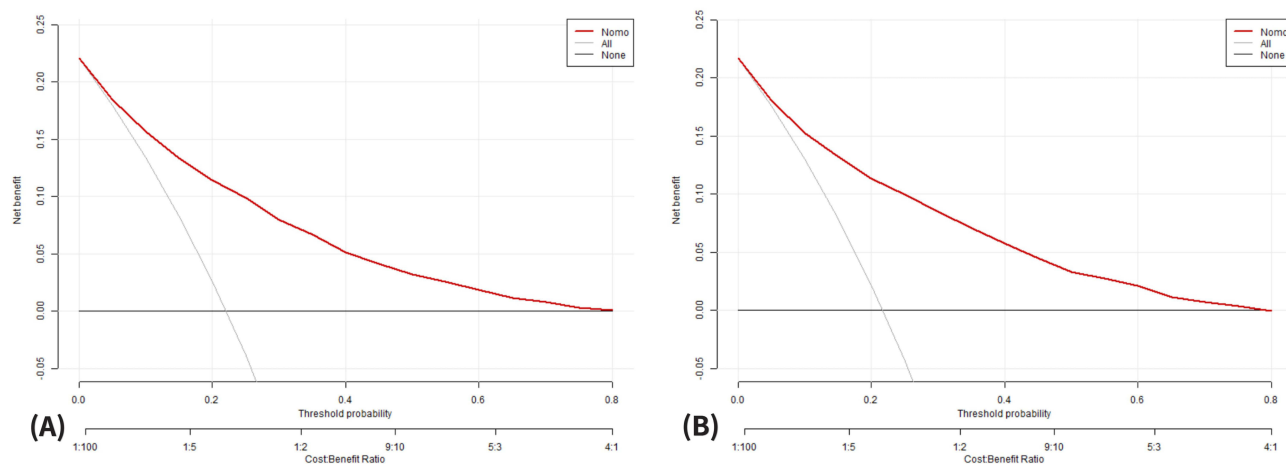


Figure 5 DCA curves of nomogram for estimating the probability of suicidal tendencies in training set (A) and validation set (B). The horizontal and vertical axes represent the threshold probability and net benefit, respectively. The lines between the horizontal axis and vertical axis display the benefit of different included variables. The DCA curves show that using this nomogram in the current study to estimate suicidal tendencies risk could add more benefit.

Abbreviations: DCA, Decision curve analysis.

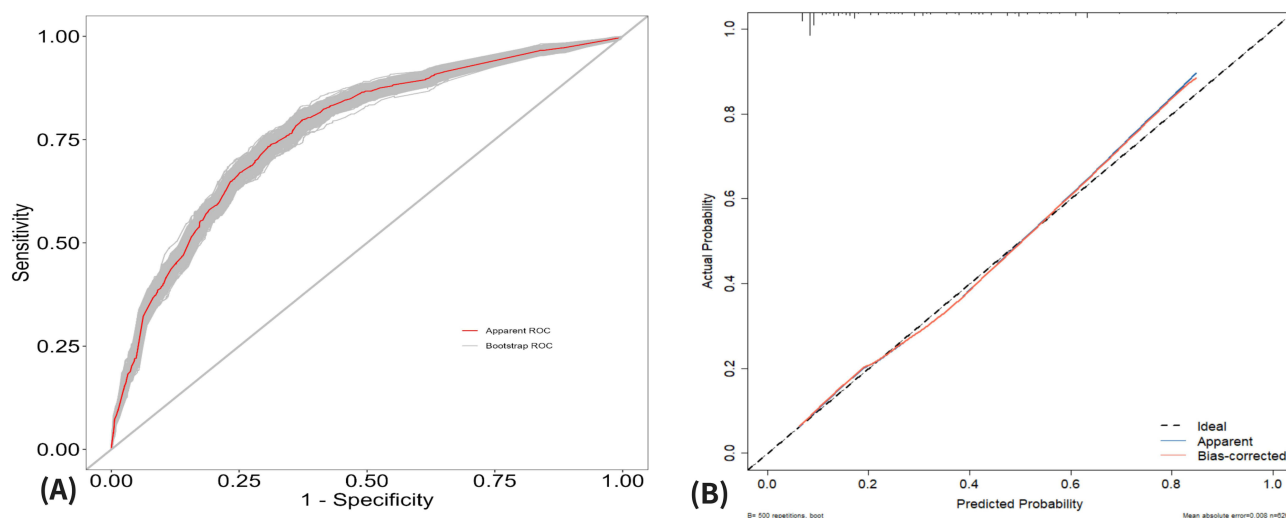


Figure 6 ROC curves of nomogram for the external validation set (A). Calibration curve of risk estimation model in external validation set (B).

experiences in Western individualistic cultures, psychological crises among Chinese adolescents are often deeply embedded in the rupture of interpersonal relationships and the blockage of expressive channels.

Specifically, the high weight assigned to help-seeking difficulties suggests that many adolescents are not unaware of their distress; rather, they actively disconnect from external support systems due to strong stigma and fear of becoming a “burden” to their families.^{32,33} This “silent crisis” means that traditional symptom-based screening tools may miss a subset of high-risk individuals. By incorporating this psychosocial variable, our model successfully captures this hidden risk.

Within the context of traditional Chinese culture, parents’ marital relationship directly determines the integrity of a child’s sense of self-worth. When parental relationships are strained or broken, children experience not only a loss of emotional support but also a disruption in their sense of existence. This deep psychological bond makes it extremely difficult for Chinese adolescents to develop independent autonomy, leaving them unable to construct a psychological buffer zone amid family conflicts.³⁴ The significant association of parental marital harmony reflects not only the direct stress of family conflict but may also symbolize the failure of the family as a “last safe haven” under the high pressure of academic demands.³⁵ This suggests that future intervention strategies should extend beyond clinical symptom alleviation to focus on repairing family systems and

destigmatizing help-seeking culture within schools.³⁶ This shift in perspective from “treating the individual” to “optimizing the ecosystem” represents a novel insight generated by this study based on large-sample data.

Against the backdrop of increasingly severe sleep deprivation among Chinese adolescents (due to evening study sessions and heavy homework burdens), chronic sleep insufficiency not only impairs prefrontal control over emotional impulses,³⁷ but also disrupts neurotransmitter balance at the physiological level, making adolescents more prone to extreme impulses when faced with minor setbacks.³⁸ In fact, the significance of sleep problems as prodromal symptoms of mental disorders such as depression and anxiety is often overlooked,³⁹ resulting in missed opportunities for early intervention. This study found that sleep disturbances significantly increase the risk of suicidal tendencies and behaviors among adolescents,⁴⁰ a finding that warrants attention from parents and adolescents alike. The risk estimation model developed in this study can assist parents, educational institutions, and primary care facilities in rapidly screening adolescents with sleep disorders and suicidal tendencies, thereby enabling timely interventions and reducing suicide risk.

With the proliferation of social media, forms of bullying among Chinese adolescents have shifted from traditional physical conflict to more covert and persistent relational bullying and psychological manipulation.^{41,42} Perpetrators inflict psychological and emotional harm on victims through sustained personal denigration, intimidation of physical harm, and social isolation. The reserved nature of Chinese adolescents makes bullying incidents more concealed and psychologically damaging, thereby increasing the risk of self-harm and suicide.^{43,44} China urgently needs a concise, rapid, and accurate tool for predicting and screening suicidal tendencies among adolescents. The risk estimation model developed in this study fills this technological gap.

In summary, these four variables do not represent isolated risk points but collectively constitute a dynamic risk ecology network with Chinese cultural specificity. By integrating these dimensions, our model offers a more comprehensive early identification perspective than single clinical diagnoses and provides a solid theoretical foundation for developing localized intervention strategies.

Temporal external validation using 2023 data revealed a distinct pattern: the nomogram maintained good discrimination (AUC=0.764) but showed significant miscalibration (HL test, $P<0.05$). This dissociation between preserved discrimination and degraded calibration is commonly observed when risk estimation models are applied to new populations or time periods, reflecting shifts in baseline risk or predictor effects.^{45,46} In our context, this likely stems from temporal changes in adolescents’ psychosocial environment between the pre-pandemic (2018–2019) and post-pandemic eras. Potential causes include: (1) a change in the overall baseline risk of suicidal tendencies; (2) an evolution in the strength of association between certain risk factors and the outcome; or (3) a shift in the distribution of key predictors (eg., increased prevalence of sleep disturbances or depressive symptoms). However, from a clinical triage perspective, the stability of the AUC suggests that our nomogram remains highly effective at identifying the relative hierarchy of risk essentially ensuring that the most vulnerable students are still accurately prioritized for intervention.

Although this study provides important empirical data on factors associated with suicide risk among Chinese adolescents, it is essential to critically examine its methodological limitations and accordingly define the scientific positioning of this research with rigor. First, the cross-sectional design inherently limits causal inference. While we identified statistically significant associations between the nine selected factors and suicidal ideation through multivariable analysis, cross-sectional data function as a “snapshot” and cannot determine whether these exposures preceded the emergence of suicidal ideation (as antecedents), occurred concurrently, or even resulted from it (as consequences). Therefore, this study should be considered hypothesis-generating rather than hypothesis-testing. The strong associations we identified serve as key clues to be prioritized in future longitudinal cohort studies rather than confirmed causal pathways. Second, to enhance the clinical utility of the model in primary care and school-based screening settings, we dichotomized certain continuous variables (eg., depressive symptom scores). Although this approach simplifies the operational procedures of the nomogram and makes it more accessible to non-specialist users, it inevitably results in information loss and may obscure nonlinear dose–response relationships within the variables. Future studies should employ more refined graded scoring systems to explore the specific effects across different risk thresholds. Finally, although we controlled for a range of known confounders, the possibility of residual confounding remains. Some unmeasured dynamic variables such as details of specific traumatic events, transient changes in peer influence, or genetic susceptibility may partially account for the observed associations.

Conclusion

In summary, this study successfully developed and validated a multidimensional nomogram for estimating the risk of suicide tendencies among Chinese middle school students. By integrating readily available demographic factors, family dynamics, and specific depressive symptoms from the PHQ-9, this tool provides a practical screening framework for early risk stratification in school-based mental health programs. The nomogram and its constituent factors are intended to serve as an efficient, user-friendly tool for early risk stratification and large-scale screening, while generating specific scientific hypotheses. These hypotheses identify which psychosocial factors merit priority attention in resource-limited settings and provide direction for future prospective studies and intervention trials aimed at further validating causal mechanisms and long-term risk estimation performance.

The clinical utility of this nomogram lies in its ability to facilitate targeted interventions: in resource-limited educational settings, school counselors can use this visual tool to prioritize students for specialized psychiatric assessment, potentially streamlining the referral pathway from schools to mental health facilities. Although the calibration drift observed in the 2023 cohort highlights the dynamic nature of adolescent mental health in the post-pandemic era, it does not diminish the value of this model as a core triage tool. Instead, this finding underscores the necessity of a “dynamic recalibration” strategy when implementing the tool. We recommend that institutions adopt this nomogram alongside a protocol for periodic updating of baseline risk or adjusting cutoff values using local data, in order to maintain optimal risk estimation accuracy. Ultimately, this evidence-based and flexibly adaptable approach supports the initial identification of vulnerable adolescents, serving as a critical first step in mitigating the rising burden of suicide among youth.

Data Sharing Statement

The data used in this study are available from the corresponding authors (Chen You or Yong Yang) upon reasonable request.

Ethics Approval

This study is a secondary analysis of an existing anonymous dataset collected between December 2018 to January 2019 and during 2023. The original survey was a school-based mental health screening initiative conducted in Suzhou, China. Ethical approval for this specific secondary analysis research project was obtained from the Ethics Committee of Guangji Hospital Affiliated to Soochow University (Approval No: 2024-001-01). The committee reviewed the current study protocol, including its objectives, analysis plan, and data confidentiality measures. Prior to both surveys, written informed consent was obtained from all middle school students and their parents or legal guardians. All procedures adhered to the ethical principles for medical research involving human subjects outlined in the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; 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

All authors hereby declare that they have no conflicts of interest regarding this study.

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