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A school-based nomogram for predicting non-suicidal self-injury among middle-school adolescents in northern China: development, internal validation, and clinical utility

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Abstract

Background: Non-suicidal self-injury (NSSI) typically onsets at ages 12–14, often before adolescents seek any professional help. Most existing prediction models were developed in clinical samples and cannot be used for universal school screening. We developed a nomogram to identify NSSI risk among general middle-school students before they present to mental-health services, using readily collectible variables.

Methods: Baseline data from 1,624 adolescents aged 12–18 in the China Depression Cohort Study (Shijiazhuang, Hebei). NSSI was defined as score ≥1 on the self-harm subscale. Candidate predictors covered demographics, lifestyle, adverse experiences, and psychosocial scales. LASSO regression with 5-fold cross-validation selected variables, entered into multivariable logistic regression. Discrimination, calibration, and clinical

utility were assessed by C-index, Hosmer–Lemeshow test, Brier score, calibration curve, and decision curve analysis (DCA), with 2000 bootstrap resamples.

Results: Of 1,624 adolescents (829 boys, 795 girls), 318 (19.6%) reported NSSI. Thirteen predictors were retained. Childhood abuse (aOR 7.34, 95% CI 2.80–19.26), bullying (aOR 1.83), chronic pain (aOR 1.71), female sex (aOR 1.45), higher PHQ-9 (aOR 1.15/pt), loneliness (aOR 1.13), aggression (aOR 1.05), negative life events (aOR 1.06), stool frequency (aOR 1.30), younger age (aOR 0.83/yr), and lower social support (aOR 0.98/pt) were independently associated with NSSI. Bootstrap-corrected C-index was 0.851; calibration was acceptable (HL p=0.165; Brier score=0.105); DCA showed positive net benefit at 5%–40% thresholds. A simplified model without psychiatric scales retained AUC=0.824. Applying the model stratified students into low-risk (actual NSSI 4.9%), moderate-risk (17.0%), and high-risk groups (56.3%).

Conclusions: This internally validated nomogram incorporates childhood abuse, bullying, chronic pain, depressive symptoms, loneliness, aggression, and social support. It may serve as a brief school-based screening tool for NSSI, pending external validation.

Keywords

non-suicidal self-injury; adolescent; nomogram; prediction model; LASSO; cross-sectional study; school mental health; northern China; external validation

Background

Non-suicidal self-injury (NSSI) affects roughly 17%–22% of adolescents and is the strongest distal predictor of later suicide attempts [1-7]. NSSI typically onsets at ages 12–

14, before most young people seek professional help. Universal school-based screening offers the only feasible window for early identification [8,9].

Existing NSSI prediction models are limited. Most were developed in clinical samples of adolescents already diagnosed with depression or hospitalized for mental disorders, and rely on clinician-rated variables that are not feasible for routine school screening [10-14]. The few school-based models target vocational high school students [30] or use machine-learning methods front-line staff cannot interpret [31]. No transparent, parsimonious tool exists for school nurses to administer during routine health examinations, to identify middle-school students before they present to mental-health services.

We developed and internally validated a nomogram for NSSI in 1,624 general middle-school students, using LASSO-selected demographic, lifestyle, adverse-experience, and psychosocial variables. We also tested a simplified model omitting psychiatric symptom scales, simulating a school-screening scenario without on-site mental-health staff.

Methods

Study design and participants

This cross-sectional analysis used baseline data from one site of the China Depression Cohort Study, a multi-site community-based cohort approved by the Institutional Review Board of the Second Xiangya Hospital, Central South University (approval no. (2022) 010). Participants were adolescents aged 12–18 years recruited from a public middle school in Gaocheng District, Shijiazhuang, Hebei Province, northern China, between August and October 2023. This single-site analysis was conducted as a first step before multi-site external validation. Written informed consent was obtained from both

participants and their legal guardians. We excluded participants with missing data on the outcome or candidate predictors. The final analytic sample comprised 1,624 adolescents.

Measures

All variables were collected via standardized self-report questionnaires administered in the classroom by trained research staff.

Non-suicidal self-injury was assessed using the self-harm subscale of the survey. A binary indicator (NSSI yes/no) was defined as a score ≥1, consistent with prior NSSI assessment practice [2].

Candidate predictors included: (1) demographic variables: age, sex; (2) lifestyle: stool frequency category, chronic pain (none vs any); (3) adverse experiences: school bullying (none vs any) [15], childhood abuse (ACE, defined as any positive response on the 14-item childhood-adversity scale) [16]; (4) psychosocial scales: negative life events (LES), UCLA loneliness [17], aggression scale, social support (SSRS); and (5) psychiatric symptom scales: PHQ-9 (depression) [18], GAD-7 (anxiety) [19], and ISI (insomnia) [20].

Statistical analysis

Continuous variables are reported as median (interquartile range) and compared using the Mann–Whitney U test; categorical variables are reported as n (%) and compared using the chi-square test.

We used LASSO logistic regression with 5-fold cross-validation (using the one-standard-error rule) to select predictors associated with NSSI [21]. Variables with non-zero

coefficients were entered into a multivariable logistic regression model. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were reported.

Model performance was evaluated using the C-index (AUC), calibration curve, Hosmer–Lemeshow test, Brier score, and decision curve analysis (DCA) [22]. Internal validation was performed using 2000 bootstrap resamples to quantify optimism in the C-index and calibration slope [23]. We plotted the multivariable model as a nomogram, converting each regression coefficient into a point score. Reporting followed the TRIPOD statement [24].

Sensitivity analyses included: (a) a simplified model omitting PHQ-9, GAD-7, and ISI to simulate a school-screening scenario without psychiatric symptom scales; and (b) gender-stratified models. All analyses were performed in Python 3.12 (scikit-learn, statsmodels). Two-sided $p<0.05$ was considered statistically significant. Large language models (LLMs) were used solely to assist with language editing and clarity of this manuscript; the study design, data analysis, and interpretation were performed entirely by the authors, who take full responsibility for the content.

Results

The final nomogram comprised 13 predictors and achieved a bootstrap-corrected C-index of 0.851, with acceptable calibration (Hosmer–Lemeshow $p=0.165$) and positive net benefit across threshold probabilities of 5%–40% on decision curve analysis. A simplified version omitting psychiatric symptom scales retained an AUC of 0.824. When applied to the cohort, the model stratified students into low-risk (<10%, actual NSSI rate

4.9%), moderate-risk (10–25%, 17.0%), and high-risk (>25%, 56.3%) groups, with observed NSSI rising from 4.9% to 56.3% across tiers.

Participant characteristics

Of 1,624 adolescents, 829 (51.0%) were boys and 795 (49.0%) were girls; the median age was 13 years (IQR 13–14). Overall, 318 (19.6%) met criteria for NSSI. Compared with adolescents without NSSI, those with NSSI were more likely to be girls, report chronic pain, school bullying, and childhood abuse, and had higher LES, loneliness, aggression, PHQ-9, GAD-7, and ISI scores, and lower social support (all $p<0.001$). Baseline characteristics are summarized in Table 1.

Table 1. Baseline characteristics of adolescents with and without NSSI.

Variable	No NSSI (n=1306)	NSSI (n=318)	p
Age, median (IQR)	13.0 (13.0–14.0)	13.0 (13.0–14.0)	0.042
Female sex, n (%)	610 (46.7%)	185 (58.2%)	<0.001
Stool frequency, median (IQR)	1.0 (1.0–2.0)	2.0 (1.0–3.0)	<0.001
Chronic pain, n (%)	160 (12.3%)	114 (35.8%)	<0.001
School bullying, n (%)	179 (13.7%)	138 (43.4%)	<0.001
Childhood abuse (any), n (%)	10 (0.8%)	24 (7.5%)	<0.001
LES, median (IQR)	0.0 (0.0–1.0)	2.0 (0.0–5.0)	<0.001
UCLA loneliness, median (IQR)	0.0 (0.0–2.0)	3.0 (1.0–5.0)	<0.001
Aggression, median (IQR)	3.0 (0.0–7.0)	7.0 (3.0–11.0)	<0.001
Social support, median (IQR)	25.0 (18.0–30.0)	19.0 (13.0–26.0)	<0.001
PHQ-9, median (IQR)	0.0 (0.0–2.0)	6.0 (2.0–10.0)	<0.001
GAD-7, median (IQR)	0.0 (0.0–0.0)	3.0 (0.0–6.0)	<0.001
ISI, median (IQR)	4.0 (3.0–5.0)	6.0 (4.0–9.0)	<0.001

Values are median (IQR) for continuous variables and n (%) for categorical variables. p values are from Mann–Whitney U (continuous) and chi-square (categorical) tests. LES, Life Events Scale; SSRS, Social Support Rating Scale. $p<0.05$ was considered statistically significant.

LASSO variable selection and multivariable model

LASSO regression selected 13 non-zero predictors: age, sex, stool frequency, chronic pain, bullying, childhood abuse, LES, loneliness, aggression, social support, PHQ-9, GAD-7, and ISI. In the multivariable model, childhood abuse was the strongest risk factor (aOR 7.34, 95% CI 2.80–19.26; $p<0.001$). School bullying (aOR 1.83), chronic pain (aOR 1.71), female sex (aOR 1.45), higher PHQ-9 (1.15 per point), higher loneliness (aOR 1.13), higher aggression (aOR 1.05), higher LES (aOR 1.06), and higher stool-frequency category (aOR 1.30) were independently associated with higher odds of NSSI. Younger age (aOR 0.83 per year) and higher social support (aOR 0.98 per point) were protective. GAD-7 and ISI were no longer significant after adjustment (Figure 5, forest plot). The full multivariable model is presented in Table 2.

Table 2. Multivariable logistic regression of factors associated with NSSI.

Predictor	aOR	95% CI	p
Age (per year)	0.83	0.73–0.95	0.006
Female sex	1.45	1.06–1.97	0.020
Stool frequency (per category)	1.30	1.10–1.53	0.002
Chronic pain	1.71	1.18–2.46	0.004
School bullying	1.83	1.29–2.58	<0.001
Childhood abuse (any)	7.34	2.79–19.26	<0.001
Negative life events (per point)	1.06	1.00–1.13	0.047
Loneliness (per point)	1.13	1.06–1.22	<0.001
Aggression (per point)	1.05	1.01–1.09	0.005
Social support (per point)	0.98	0.96–1.00	0.022
PHQ-9 (per point)	1.15	1.09–1.20	<0.001
GAD-7 (per point)	1.04	0.97–1.11	0.242
ISI (per point)	1.04	0.97–1.10	0.262

aOR, adjusted odds ratio; CI, confidence interval. Adjusted for all other predictors selected by LASSO. $p<0.05$ was considered statistically significant.

Nomogram and model validation

A nomogram was developed based on the multivariable model (Figure 1). The apparent C-index was 0.856 (95% CI 0.829–0.883), and the bootstrap-corrected C-index was 0.851, indicating minimal optimism. The calibration curve showed good agreement between predicted and observed probabilities (Hosmer–Lemeshow χ^2=11.70, p=0.165; Figure 2). The Brier score was 0.105. DCA showed that the nomogram provided positive net benefit across threshold probabilities of approximately 5%–40% compared with either treat-all or treat-none strategies (Figure 3). The relative importance of each predictor is shown in Figure 6 (standardized coefficient plot), and the correlation structure among predictors is shown in Figure 8.

Sensitivity analyses

When psychiatric symptom scales (PHQ-9, GAD-7, ISI) were omitted, the simplified model yielded an AUC of 0.824, only modestly lower than the full model (0.856; Figure 4). Childhood abuse (aOR 6.60, 95% CI 2.60–16.72), school bullying (aOR 2.09), chronic pain (aOR 2.23), female sex (aOR 1.60), loneliness (aOR 1.24 per point), aggression (aOR 1.07), negative life events (aOR 1.14), and lower social support (aOR 0.98) remained independently associated with NSSI (all p<0.01). In gender-stratified analyses, the model showed better discrimination in girls (AUC=0.887) than in boys (AUC=0.824). School bullying, chronic pain, and PHQ-9 were consistent correlates across sexes. The conceptual framework summarizing the hypothesized pathway is presented in Figure 7.

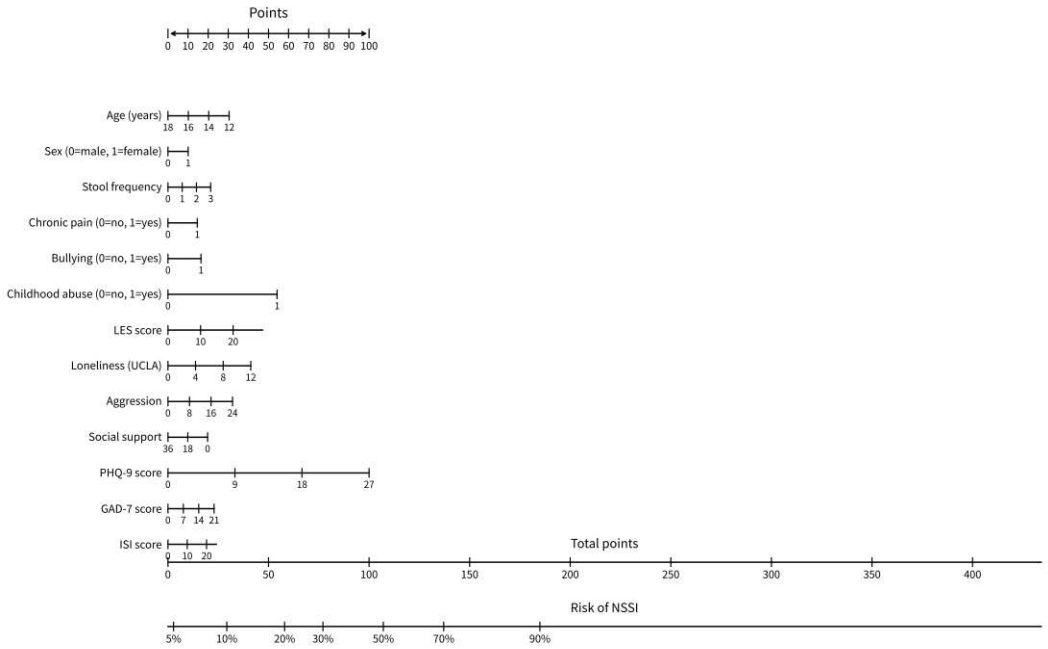

Figure 1. Nomogram for predicting NSSI risk among middle-school adolescents in Hebei, northern China. To use the nomogram, locate each patient's value on each variable axis, draw a vertical line upward to determine the points contributed by each variable, sum the points, and read the corresponding probability of NSSI on the total-points axis.

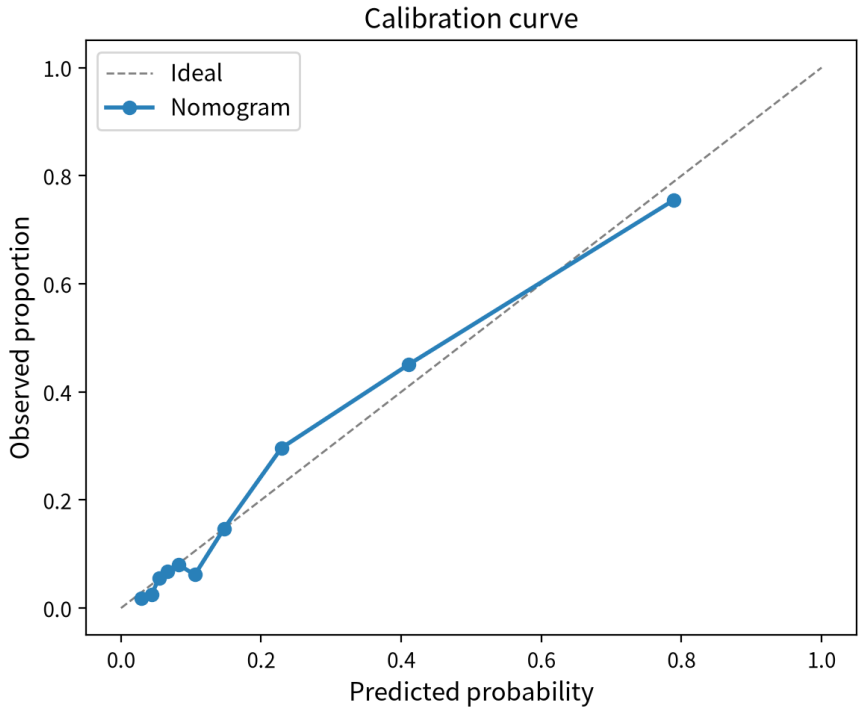

Figure 2. Calibration curve of the nomogram. The diagonal dashed line represents perfect prediction; the solid line represents the model's apparent performance.

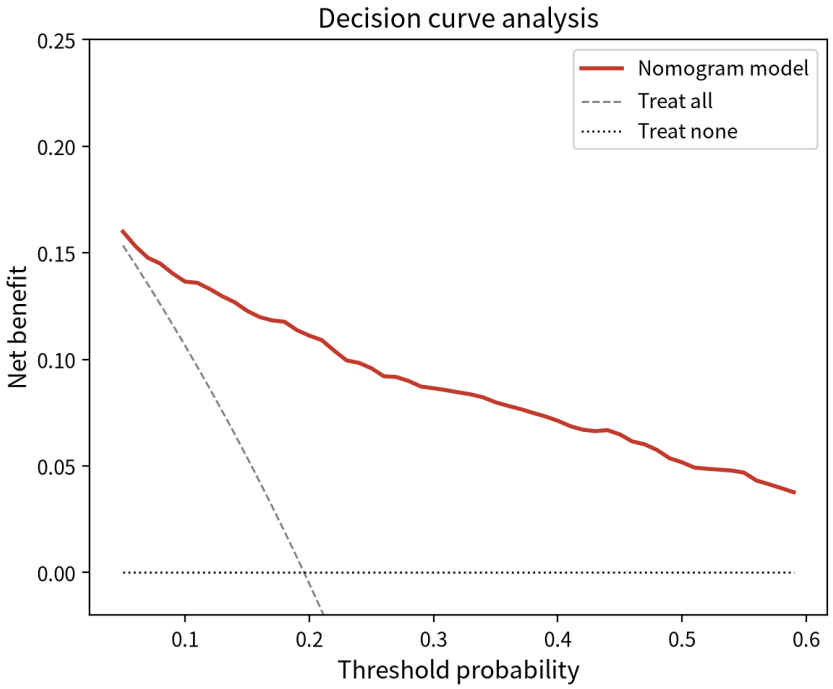

Figure 3. Decision curve analysis. The y-axis measures net benefit; the red line represents the nomogram, the gray dashed line represents treat-all, and the black dotted line represents treat-none.

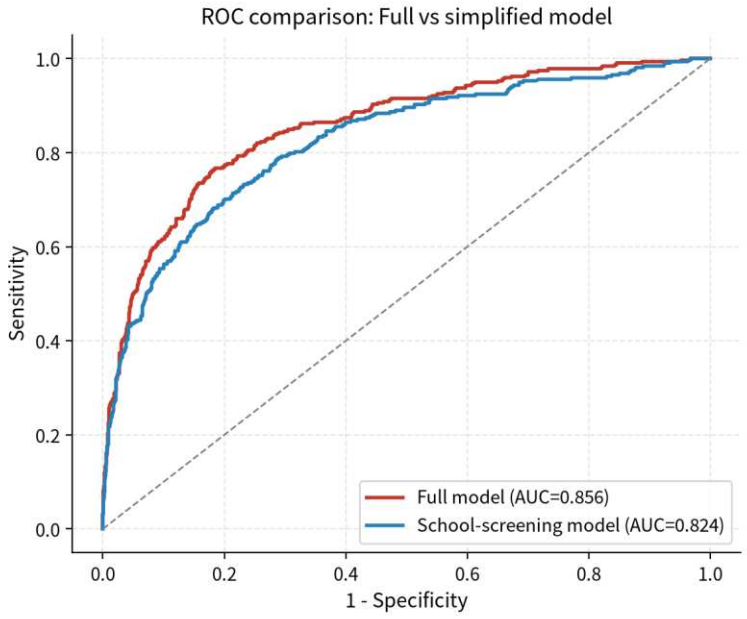

Figure 4. ROC comparison between the full model and the simplified school-screening model. The simplified model excludes PHQ-9, GAD-7, and ISI and uses only demographics, lifestyle, adverse-experience, and psychosocial variables.

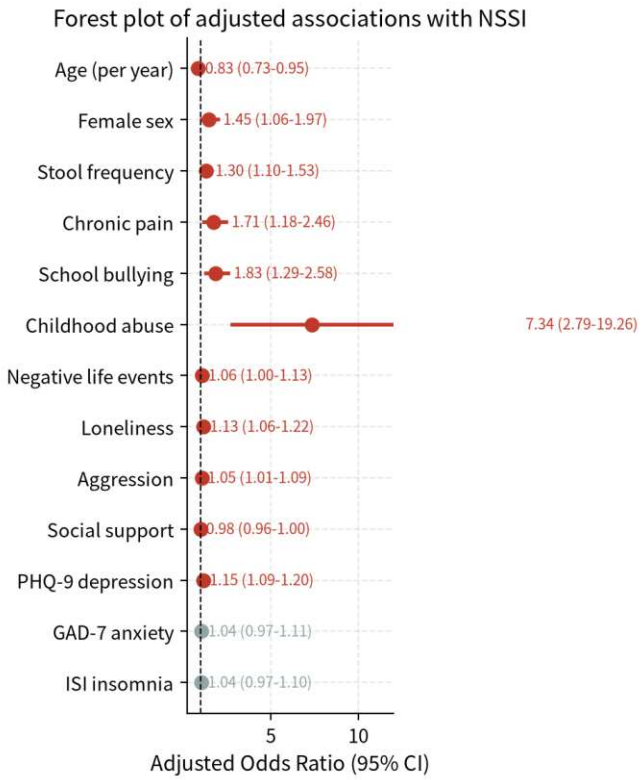

Figure 5. Forest plot of adjusted odds ratios for predictors of NSSI in the full model. Red markers indicate statistically significant associations ($p<0.05$).

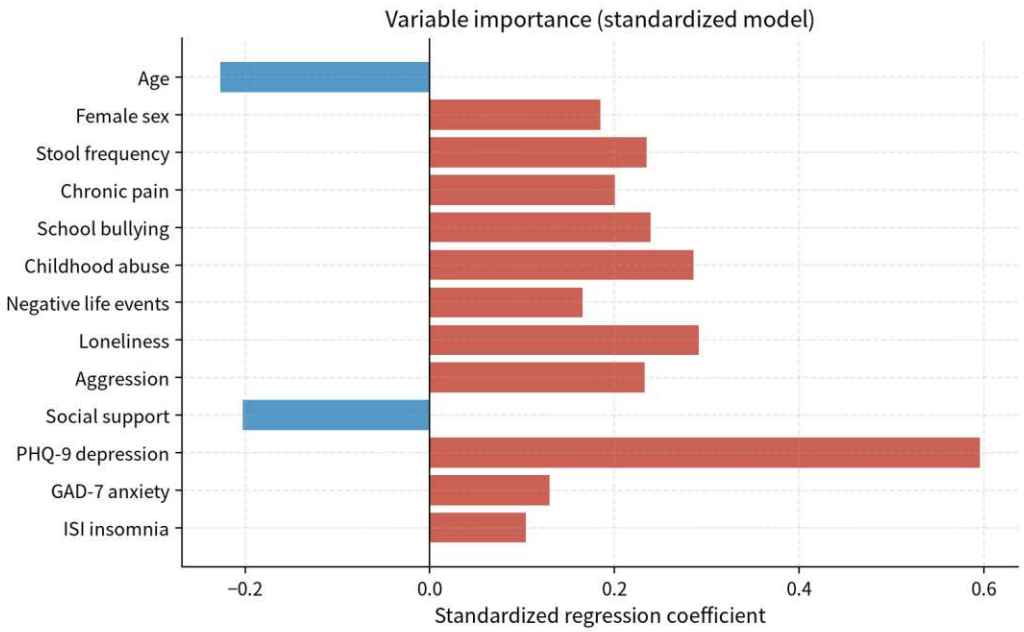

Figure 6. Standardized coefficient plot showing the relative importance of each predictor in the multivariable model. Red bars indicate risk factors; blue bars indicate protective factors.

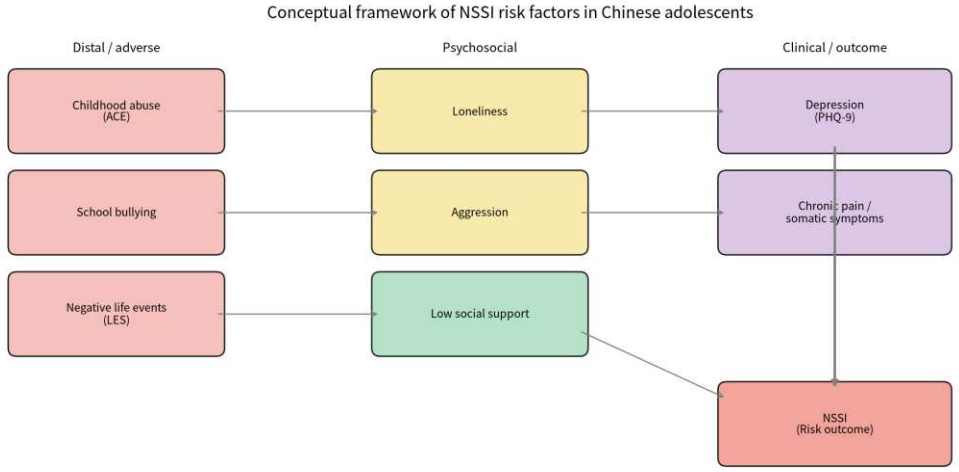

Figure 7. Conceptual framework of NSSI risk factors across distal-to-proximal levels. Adverse childhood and school experiences are hypothesized to act through psychosocial mediators (loneliness, aggression, social support) and clinical symptoms (depression, anxiety, insomnia) to NSSI.

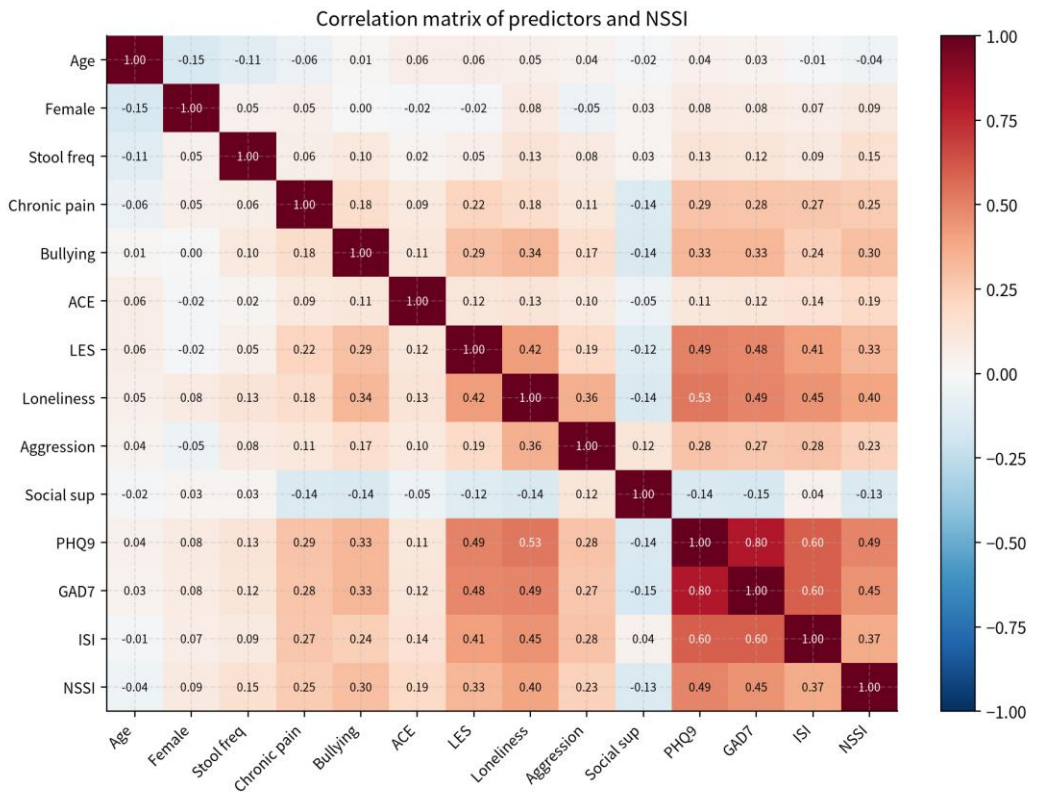

Figure 8. Correlation heatmap among candidate predictors and NSSI. Spearman correlation coefficients are displayed; cell color intensity reflects the strength and direction of the association (red, positive; blue, negative).

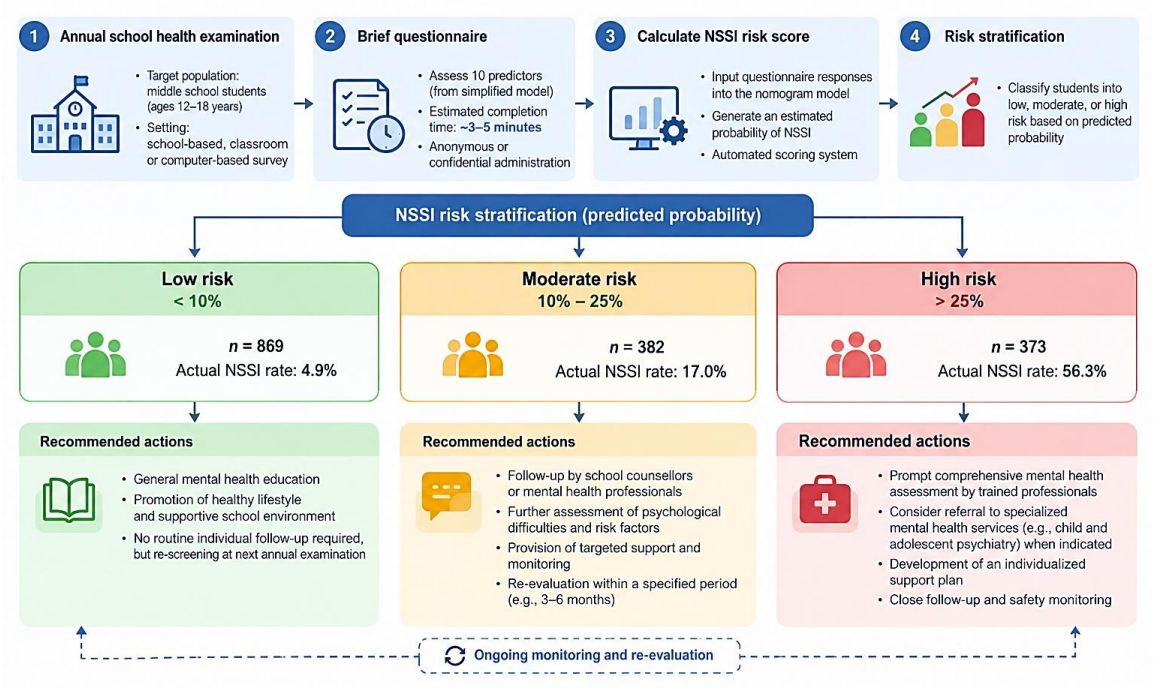

Figure 9. Proposed school-based screening and referral pathway for non-suicidal self-injury (NSSI) risk among middle school students. The figure illustrates a potential implementation pathway based on the simplified nomogram model developed in this study. The 10 predictors include demographic, lifestyle, psychosocial and clinical factors as shown in Figure 1. This pathway is proposed for educational and research purposes and requires further evaluation in real-world school settings.

Discussion

Among 1,624 adolescents from one district in Hebei, we built and internally validated a 13-predictor NSSI nomogram. The bootstrap-corrected C-index was 0.851, calibration was acceptable (Hosmer–Lemeshow p=0.165), and DCA showed positive net benefit at threshold probabilities of 5%–40%. Most prior NSSI nomograms came from clinical samples of depressed or hospitalized adolescents [25-29]. Two recent school-based efforts targeted vocational high school students [30] or used machine-learning methods [31]; no earlier LASSO-based nomogram for general middle-school students was

identified. The simplified version, omitting PHQ-9, GAD-7, and ISI, retained AUC=0.824, supporting use without on-site mental-health staff.

Childhood abuse was the strongest correlate (aOR 7.34; 95% CI 2.80–19.26), consistent with prior ACE work linking early maltreatment to later self-injury [10,16]. Bullying (aOR 1.83) and chronic pain (aOR 1.71) were also independent correlates, supporting routine enquiry about peer victimization and somatic complaints among students who self-injure [11,15].

PHQ-9 remained strongly associated with NSSI after adjustment; GAD-7 and ISI lost independent effects. In this sample, the cross-sectional association between anxiety/insomnia and NSSI appears largely carried by depressive symptoms. Loneliness and aggression were independently associated with NSSI, consistent with NSSI serving both emotion-regulation (loneliness/negative affect) and social/communication (aggression) functions [2,32].

Dropping PHQ-9, GAD-7, and ISI only modestly reduced discrimination (AUC 0.824 versus 0.856). School staff rarely have the time or training to administer full psychiatric scales; demographics, adverse experiences, and a few brief psychosocial questions already capture most of the predictive signal.

Higher social support was protective (aOR 0.98 per point), a modifiable target for school-based interventions [10,12]. The unexpected association between higher stool-frequency category and NSSI warrants replication. It may reflect the gut–brain axis: chronic stress and anxiety alter intestinal motility and visceral sensitivity, and adolescents with higher NSSI risk also report more somatic distress. Alternatively, stool frequency may act as a

nonspecific marker of autonomic arousal rather than a causal risk factor; it should not be over-interpreted mechanistically.

In China, middle-school students receive annual physical examinations with accompanying mental-health screening. Our nomogram could embed into this workflow: the simplified model (10 items, 3–5 minutes) can be administered via tablet or anonymous web-based questionnaire during the routine health check. Students are triaged into low risk (<10%, universal classroom promotion), moderate risk (10–25%, counselor follow-up), and high risk (>25%, urgent psychiatric referral). This stepped-care pathway (Figure 9) fits Chinese school mental-health guidelines and stretches limited counselor resources. Implementation requires nurse training, a digital scoring platform, a clear referral pathway, and ongoing monitoring of false-positive rates and student acceptance.

Students may conceal NSSI due to stigma, fear of parental reaction, or concerns about academic consequences, producing false negatives. Anonymous web-based or WeChat mini-program administration, rather than teacher-handled paper forms, can reduce perceived surveillance. NSSI items should be embedded among routine health questions to reduce stigma. Only the risk tier (not item-level responses) should be visible to school staff, with raw data encrypted and accessible only to the clinical team. Students and parents should be assured that results do not affect academic records or college admission. Future implementation studies should compare paper, tablet, and anonymous web modalities, and validate against objective outcomes such as medical records.

Limitations

First, this is a single-site, school-based sample from one district in Hebei Province, northern China; although the sample size is substantial, the findings may not generalize to other regions of China, urban versus rural settings, or clinical populations. The model has not yet been externally validated; bootstrap internal validation, though useful for estimating optimism, cannot substitute for testing in a geographically or demographically independent cohort. External validation across multiple sites, including different provinces, urban–rural settings, and age bands, is essential before the nomogram can be deployed in routine school screening. Second, because the design is cross-sectional, the model cannot establish temporal ordering or causality, and it requires prospective validation [24]. Third, all predictors and the outcome were self-reported, so shared-method variance and under-reporting of NSSI cannot be ruled out. Such under-reporting likely produces false negatives and attenuates observed associations. Future studies should use anonymous digital administration and validate against objective outcomes such as medical records or clinician-rated interviews. Fourth, the childhood-abuse prevalence was only 2.1% (34/1,624), which inflated its confidence interval despite a large point estimate; this predictor should be interpreted cautiously. Finally, we omitted structural variables such as household income, parental education, and family functioning, which could add predictive value [28].

Conclusions

A simple nomogram incorporating childhood abuse, school bullying, chronic pain, depressive symptoms, loneliness, aggression, life events, social support, age, sex, and stool frequency showed good discrimination and calibration for identifying NSSI risk in this school-based sample from northern China. The model retained good performance

even when psychiatric symptom scales were omitted, making it potentially embeddable into the routine annual middle-school health examination as a 10-item triage instrument. A stepped-care pathway, with universal promotion for low-risk students, counselor follow-up for moderate-risk students, and urgent psychiatric referral for high-risk students, could maximize the limited counseling resources available in Chinese schools. External validation in independent, geographically diverse samples and prospective testing of the screening implementation are needed before broad clinical or school-based deployment.

List of abbreviations

NSSI: non-suicidal self-injury; LASSO: least absolute shrinkage and selection operator; PHQ-9: Patient Health Questionnaire-9; GAD-7: Generalized Anxiety Disorder-7; ISI: Insomnia Severity Index; LES: Life Events Scale; SSRS: Social Support Rating Scale; ACE: adverse childhood experience; AUC: area under the curve; DCA: decision curve analysis; aOR: adjusted odds ratio; CI: confidence interval; IQR: interquartile range; TRIPOD: Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Second Xiangya Hospital, Central South University (approval no. (2022) 010). Written informed consent was obtained from all participants and their legal guardians.

Consent for publication

Not applicable.

Availability of data and materials

The data analyzed in this study are available from the corresponding author upon reasonable request, subject to the data-sharing policy of the China Depression Cohort Study.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YS: Conceptualization, Methodology, Formal analysis, Software, Visualization, Writing—original draft. SZ: Data curation, Investigation. YuS: Data curation, Investigation. GJ: Resources, Validation. YW: Supervision, Funding acquisition, Writing—review & editing, Project administration. All authors read and approved the final manuscript.

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