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Establishment and validation of a risk assessment model for myopia among Chinese primary school students during the COVID-19 pandemic: A lasso regression approach

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ABSTRACT

Purpose: To construct a risk assessment model for forecasting the likelihood of myopia in elementary school students.
Design: A cross-sectional study.
Methods: This study utilized convenient sampling and questionnaire survey to collect data from eligible elementary students and their parents during the coronavirus disease 2019 (COVID-19) pandemic period from March to December 2020. The data were divided into training and testing sets in a 7:3 ratio. Lasso regression was employed to screen variables for inclusion in the model to establish a generalized linear model, with a nomogram model as the final result.
Results: The study included 1139 elementary students, comprising 54.5 % male and 45.5 % female participants. A total of 37 variables were obtained, which were analyzed using lasso regression. Cross-validation revealed that the best lambda value was 0.04201788. Five variables affecting myopia were identified: three risk and two protective factors. The three risk factors were student age (OR = 1.32), family location (urban vs. rural, OR = 2.33), and parents' occupation (compared with farmer: worker, OR = 2.03; teacher, OR = 1.62; medical worker, OR = 5.64; self-employed, OR = 1.78; civil servant, OR = 1.65; company employee, OR = 1.45; service industries, OR = 3.38; and others, OR = 3.20). The two protective factors were eye distance score (OR = 0.83) and eye health exercise score (OR = 0.95). The model was verified and showed good accuracy with an AUC of 0.778 and Brier score of 0.122 in addition to satisfactory clinical effects.
Conclusions: The model effectively predicted the risk of myopia in elementary school students during the COVID-19 pandemic. Using this model, high-risk groups can be identified to provide a

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foundation for early intervention and follow-up, thereby reducing the incidence of myopia in this population.

1. Introduction

Myopia, a common condition often referred to as nearsightedness, affects many individuals, particularly children and young adults. The condition arises because of several factors, including an overextended eye axis that focuses the images of distant objects in the front of the retina, leading to blurry vision. The progression of myopia is most rapid between the ages of 6 and 7 years and tends to slow down after the ages of 11–12 years [1–3]. Hence, the period of elementary school years is critical for preventing myopia [4,5]. It has been projected that by the year 2050, approximately half of the global population will suffer from myopia unless new effective measures are implemented to address this issue [6]. In East Asia and Southeast Asia, myopia has become a widespread condition, with myopia rates among young and middle-aged adults ranging from 80 % to 90 % and high myopia rates among the same demographic reaching 10%–20 % [7]. The several health implications of myopia caused by its associated complications and severity, including retinal detachment, neovascularization of the retina, early cataract formation, and glaucoma [8], highlight the urgent need for the prevention and control of myopia. In response to this issue, the Chinese Ministry of Education released a comprehensive plan in 2018 aimed at reducing the incidence of myopia among children and adolescents and controlling its progression [9]. The control of myopia is particularly important during childhood and adolescence [10,11]. At present, various methods exist for controlling myopia, including OK glasses and low concentration atropine, among others [4,9]. With the emergence of methods to decelerate the development of myopia, two important steps have been identified for reducing the global burden of myopia: identifying patients who need intervention and determining the timing of the intervention [12]. Myopia can emerge as early as childhood, and because myopia that develops at an early age is more likely to become high myopia, proactively identifying children who are most likely to develop either of these conditions is highly valuable [12]. Moreover, the environment plays a significant role in the development and progression of myopia. Indeed, multiple studies have indicated that factors such as outdoor activities, illumination, and lifestyles may affect the occurrence and development of myopia [13,14]. However, during the coronavirus disease 2019 (COVID-19) pandemic, behavioral changes were observed in students, including increased online learning, extended use of electronic devices, and prolonged time spent at home [15]. This situation possibly influenced the development of myopia. Therefore, exploring factors that affected myopia during the COVID-19 pandemic may have positive implications for preventing myopia in primary school students. Moreover, identifying high-risk individuals and providing behavioral interventions may provide valuable information for the clinical prevention and treatment of myopia in children and adolescents, ultimately improving their overall eye health.

2. Methods

2.1. Participants

In this study, a cross-sectional survey was employed. Students who met the enrollment criteria were included from March 2020 to December 2020. The inclusion criterion was students studying in grades 1 to 6 of elementary school. The exclusion criteria included students diagnosed with acute or chronic ocular diseases affecting vision other than myopia (such as high hyperopia, high astigmatism, corneal disease, congenital cataract, congenital or developmental glaucoma, hereditary retinal detachment, and others) and those suffering from mental illness or intellectual disabilities.

Myopia is a common eye disorder that develops when the refractive power of the eye is too strong or when the axial length of the eye is too long, causing light to focus in front of the retina instead of directly on it [1,2]. The students with myopia included in this study were individuals diagnosed with myopia based on their medical history.

Data were collected through an online questionnaire administered via the Wenjuanxing platform, which is equivalent to Amazon Mechanical Turk. The questionnaire was completed by the parents of students who met the inclusion and exclusion criteria. A total of 1267 completed questionnaires were received through convenience sampling, and after screening, 1139 students were included in the study. The study was approved by the Ethics Committee of Shanghai Ninth People's Hospital (reference number: SH9H-2022-T49-2), and the data collected were used solely for academic research purposes.

3. Questionnaires

3.1. Assessment questionnaire of vision care related behavior for students (AQVCRBS)

The AQVCRBS questionnaire was developed by Gao Guopeng [16, 17] and contains three sub-questionnaires that assess 10 dimensions: eye relaxation behavior, dietary habits, eye distance, reading environment selection, reading and writing posture, eye health exercises, illumination, prolonged use of eyes, outdoor activities, and grip posture. The scores of each dimension are transformed into the following four evaluation levels: 1 represents a frequency of almost no healthy vision care behavior, 2 represents occasional healthy vision care behavior, 3 represents frequent healthy vision care behavior, and 4 represents basic healthy vision care behavior. Thus, the higher the score, the better the vision care behavior. The questionnaire consists of three parts: 1–3 grade questionnaire (40 items), 4–6 grade questionnaire (43 items), and junior high school questionnaire (43 items). The reliability of the questionnaire, as measured via Cronbach's α coefficient, was 0.761, 0.804, and 0.792 for the three sub-questionnaires, respectively. The validity of the questionnaire was also validated using the Guttman Split-Half coefficients, which were 0.847, 0.874, and 0.863 for the three sub-questionnaires, respectively. Thus, the AQVCRBS questionnaire is considered to have credible reliability and validity.

3.2. The perceived stress scale (PSS-4)

PSS-4, developed by Cohen [18], is used to evaluate an individual's level of stress perception. It has good reliability and validity [19,20]. A modified version with only four questions (PSS-4) was used in this study, which has reliable predictive value improved response rate owing to its simplicity [21,22]. The scale consists of four items with Likert five-point scoring, ranging from 0 to 4 that represent "never" to "very much," respectively. PSS-4 has two factor structures: positive items and negative items. The total score of the four items is the overall stress perception score, and a higher score indicates a greater level of stress perception.

3.3. Generalized anxiety disorder 7-item (GAD-7)

GAD-7 is a brief self-assessment questionnaire developed by Spitzer [23] et al. based on the diagnostic criteria of DSM-IV. It has good reliability, validity, and construct validity [24,25]. The questionnaire, consisting seven questions, is a concise self-assessment tool for patients. It is a quick, credible, and effective method to detect if a patient has anxiety symptoms. The total score ranges

Table 1
General data of the included pediatric patients (n = 1139).

Variable	Overall cohort
Gender (male/female), (%)	621 (54.5)/518 (45.5)
Age, quartiles/median (Q1, Q3)	9.40 (7.70,11.07)
Type of school (public/private), (%)	1056 (92.7)/83 (7.3)
Academic performance (excellent/good/average), (%)	148(13.0)/535(47.0)/456(40.0)
Myopia (yes/no), (%)	165(14.5)/974(85.5)
Sleep time (<6/6–8/8-9/9–10/>10) h, (%)	3(0.3)/150(13.2)/561(49.3)/351(30.8)/74 (6.5)
Last 7 days, the average time students spent watching television (<0.5/0.5–2/2–4/>4) h, (%)	223(19.6)/551(48.4)/287(25.2)/78(6.8)
Last 7 days, the average time spent on online classes (<0.5/0.5–2/2–4/>4) h, (%)	100(8.8)/604(53.0)/359(31.5)/76(6.7)
Last 7 days, the average time spent on computer to watch videos, chat, and other activities (excluding online classes) (<0.5/0.5–2/2–4/>5) h, (%)	544(47.8)/392(34.4)/154(13.5)/49(4.3)
Last 7 days, the average time spent playing with electronic devices such as mobile phone, PDA, and other devices (<0.5/0.5–2/2–4/>6) h, (%)	507(44.5)/405(35.6)/161(14.1)/66(5.8)
Family Location (rural/urban), (%)	967 (84.9)/172 (15.1)
Family situation (general/single parent/remarried/other), (%)	1069(93.9)/43(3.8)/21(1.8)/6(0.5)
Family economic status (compared to home location) (very good/good/moderate/poor/very poor), (%)	25(2.2)/71(6.2)/858(75.3)/151(13.3)/34 (3.0)
[a]Relationship with students (father/mother), (%)	402(35.3)/736(64.6)
Myopia of parents (neither myopia/both myopia/one myopia/unclear), (%)	91(8.0)/669(58.7)/324(28.4)/55(4.8)
Parents' age, quartiles/median (Q1, Q3)	35.0 (32.0,39.0)
Parent's occupation (farmer/worker/teacher/medical worker/self-employed/civil servant/company employee/ service industries/other), (%)	371(32.6)/103(9.0)/12(1.1)/9(0.8)/349 (30.6) /5(0.4)/79(6.9)/66(5.8)/145(12.7)
Education (primary school and below/junior high school/secondary or high school/college or university/master's degree/doctor's degree), (%)	163(14.3)/699(61.4)/163(14.3)/106(9.3)/8 (0.7)/0(0)
Do parents pay attention to their children's reading and writing habits (yes/no), (%)	1036(91.0)/103(9.0)
Quality of sleep for parents during Covid-19 pandemic (good/fair/insomnia/restless sleep), (%)	468(41.1)/588(51.6)/17(1.5)/66(5.8)
Parental health during Covid-19 pandemic (very good/good/fair/poor), (%)	604(53.0)/444(39.0)/86(7.6)/5(0.4)
Parental stress perception total score quartiles/median (Q1, Q3)	8.0(7.0,9.0)
Total anxiety score, quartiles/median (Q1, Q3)	4.0(1.0,7.0)
Anxiety (positive/negative), (%)	111(9.7)/1028(90.3)
Anxiety level (none/mild/moderate/severe), (%)	678(59.5)/350(30.7)/83(7.3)/28(2.5)
Total depression score, quartiles/median (Q1, Q3)	1.0(0.0,2.0)
Depression (positive/negative), (%)	93(8.2)/1046(91.8)
Eye distance score, quartiles/median (Q1, Q3)	11.0(9.0,12.0)
Reading and writing posture score quartiles/median (Q1, Q3)	14.0(13.0,15.0)
Pencil grip score, quartiles/median (Q1, Q3)	4.0(3.0,5.0)
Reading environment selection score quartiles/median (Q1, Q3)	16.0(15.0,16.0)
Illumination light score, quartiles/median (Q1, Q3)	12.0(11.0,18.0)
Continuous eye use score, quartiles/median (Q1, Q3)	17.0(14.0,21.0)
Eye relaxation score, quartiles/median (Q1, Q3)	12.0(9.0,15.0)
Diet score, quartiles/median (Q1, Q3)	14.0(12.0,18.0)
Eye health exercises score, quartiles/median (Q1, Q3)	12.0(11.0,15.0)
Outdoor activity score, quartiles/median (Q1, Q3)	5.0(4.0,7.0)
Student vision care behavior total score quartiles/median (Q1, Q3)	120.0(112.0,127.0)

[a] One record was treated as a missing value.

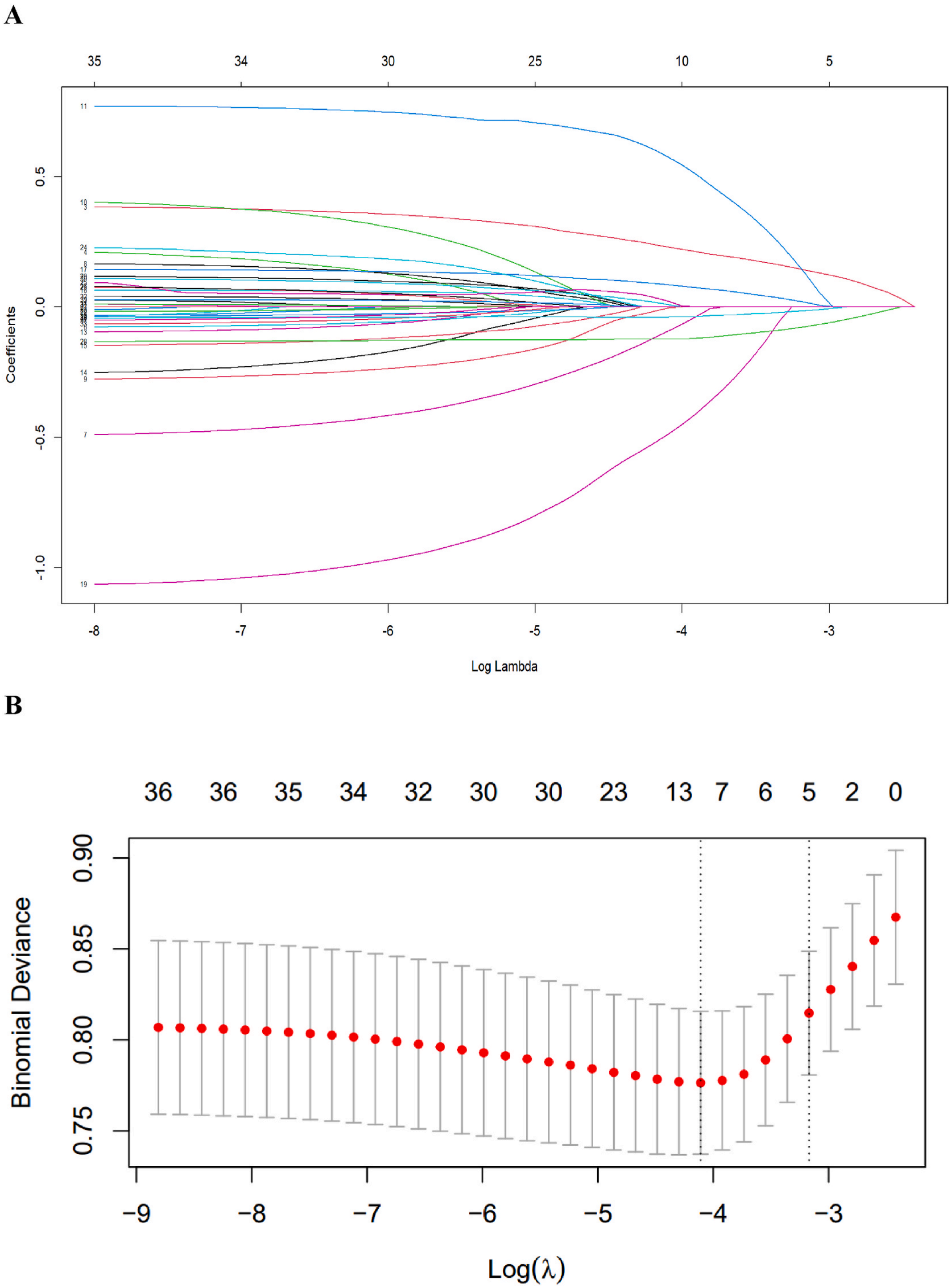

Fig. 1. Myopic factors were selected using LASSO regression. (A) LASSO regression was used to identify the predictive factors. (B) Cross-validation was used to adjust the penalty coefficient in the LASSO model.

from 0 to 21. A score of 0–4 indicates no significant anxiety, score of 19–21 indicates severe anxiety, and intermediate score of 5–18 indicates mild to moderate to severe anxiety.

3.4. Patient health questionnaire-2 (PHQ-2)

Kroenke et al. [24] designed PHQ-2, and it assesses the frequency of depressive moods and loss of speech in the past 2 weeks. The two items are "lack of interest or pleasure in doing things" and "feeling down, depressed, or hopeless." For each item, the response options are "not at all," "several days," "more than half the days," and "nearly every day," respectively, scored as 0, 1, 2, and 3. Thus, the PHQ-2 score range is 0–6 points. A PHQ-2 score >3 points has a sensitivity of 83 % for severe depression and specificity of 92 %. The odds ratio (OR) and receiver operating characteristic (ROC) curve analysis determined that a PHQ-2 score of 3 points was the optimal cutoff point for screening. Yin et al. verified the validity of PHQ-2 through a systematic review. For PHQ-2, Cronbach's alpha was between 0.727 and 0.785, with a sensitivity of 0.84 (95 % CI 0.80–0.87) and specificity of 0.87 (95 % CI 0.78–0.93) [25].

3.5. Data analysis

Data management and statistical analysis were performed using R 4.2.2 software. Considering the small proportion of missing values for a few variables, the analysis was performed without imputing the missing data. Quantitative data with normal distribution are described as mean ± standard deviation ($\bar{x} \pm s$), otherwise as median (Q1, Q3). Qualitative data are described as percentages. A generalized linear model was established and validated by dividing the data into a training set and testing set in a 7:3 ratio. The lasso regression method was used to screen variables for inclusion into the model. Finally, the generalized linear model was used to establish a nomogram model. The prediction capability of the model was evaluated by calculating the area under curve (AUC) of ROC curve. All tests were two-sided, and a P value of <0.05 was considered statistically significant.

4. Results

4.1. Characteristics of students and their parents

A total of 1139 elementary school students were included in this study, including 621 boys (54.5 %) and 518 girls (45.5 %). Among the parents of the students, 402 were fathers (35.5 %) and 736 were mothers (64.6 %). One parent was recorded as "parents" without specifying the sex and was treated as a missing value. Among the surveyed students, 14.5 % (165 students) were near-sighted. The variable data of the surveyed students is displayed in Table 1.

4.2. Selection of myopia variables

The data were randomly divided into training and testing sets according to the ratio of 7:3, with 798 and 382 students, respectively. Based on the information in the training set, a model was established using the lasso regression method to screen the variables in the model. According to cross-validation, the optimal λ was 0.04201788, as shown in Fig. 1A and B. After screening, the number of variables affecting myopia prediction was reduced from 37 to 5, which included student age, family location, eye distance score, eye health exercise score, and parents' occupation. Among these, student age was a risk factor, with an OR value of 1.32. Family location was also a risk factor, with an OR value of 2.33 for urban residents compared with rural residents. Moreover, parents' occupation was a risk factor when compared with the farmer occupation, with an OR value of 2.03 for workers, 1.62 for teachers, 5.64 for medical workers, 1.78 for self-employed individuals, 1.65 for individual businesses, 1.45 for company employees, 3.38 for the service industry,

Table 2
Predictive factors for myopia in students.

Variable	OR	P value
Age	1.3180869	<**0.001**
Family Location		
rural	1	
urban	2.3337526	**0.003493**
Parent's Occupation		
farmer	1	
worker	2.0318245	0.070413
teacher	1.6195002	0.57752
medical worker	5.6419993	0.060153
self-employed	1.7840291	**0.047662**
civil servant	1.6462482	0.709202
company employee	1.4475248	0.450938
service industries	3.3835143	**0.002931**
other	3.2020828	<**0.001**
Eye Distance Score	0.8346834	<**0.001**
Eye Health Exercise Score	0.9462624	0.218749

and 3.20 for others. The eye distance score and eye health exercise score were protective factors, with OR values of 0.83 and 0.95, respectively, as shown in Table 2.

4.3. Development of nomogram

The five variables selected via the lasso regression were entered into the logistic regression model, and a nomogram model was established for predicting myopia (Fig. 2).

4.4. Verification of accuracy for the prediction model

The model was verified using the testing set. The ROC (Fig. 3), calibration (Fig. 4), clinical decision (Fig. 5), and clinical impact curves (Fig. 6) showed that the model had good accuracy with an AUC of 0.778 and Brier score of 0.122. The calibration curve was very close to the theoretical situation, indicating a high consistency between the predicted and actual values. In addition to accuracy, the clinical decision and impact curves indicated that the model has good clinical effects and is of practical value.

5. Discussion

During the COVID-19 pandemic, there was a significant change in the lifestyles and psychological states of individuals, particularly children and adolescents [26]. Hence, this study investigated changes in students' behaviors during the pandemic. In addition, research has shown that the myopia development rate is fastest at the ages of 6–7 years, which then slows down at the ages of 11–12 [3]. These age ranges coincide with the primary school stage. Thus, this study also examined the prevalence and risk factors of myopia among primary school students by exploring relevant parental factors and their impact on their children's myopia. As parents play a crucial role in the supervision and education of their children in the various aspects of life and learning, they undoubtedly have a significant impact on primary school students and may indirectly affect their myopia. Xiyan Zhang et al. studied the myopia rates in different family types and revealed the rates of 60.0 %, 52.0 %, 54.7 %, and 50.9 % in the nuclear family, extended family, single-parent family, and left-behind family, respectively, indicating the impact of family on children's myopia [27]. After variable selection through lasso regression, five factors affecting myopia were identified in the present study: student age, family location, eye distance score, eye health exercise score, and parents' occupation. Student's age, family location, and parents' occupation were identified as risk factors, whereas eye distance score and eye health exercise score were identified as protective factors. Certain factors related to the parents' psychological state, such as anxiety and depression, were not selected into the prediction model. Therefore, further research is required to examine the impact of parents' mental health on myopia.

The prediction model in this study showed that student age was a risk factor of myopia, with an OR value of 1.32, suggesting that with every yearly increase in age, the risk of myopia increases 1.32 times. This is in line with previous research findings. Wang et al.

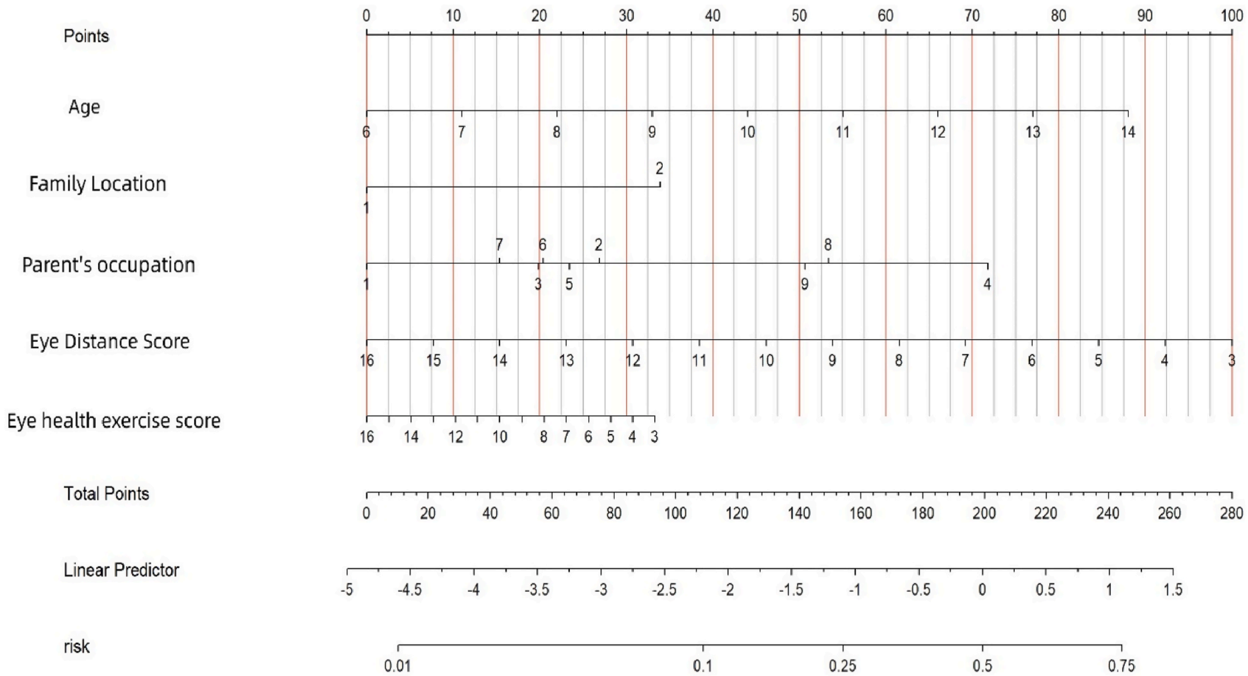

Fig. 2. The nomogram for Myopia Prediction.

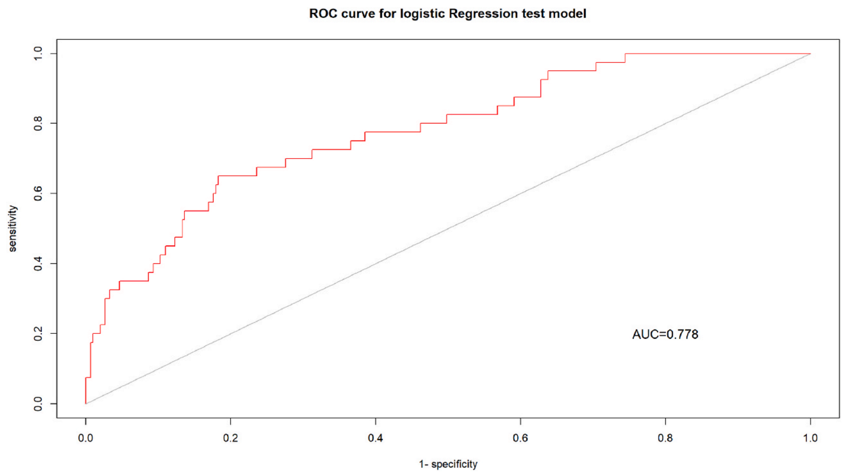

Fig. 3. Receiver operating characteristic curve for the predictive model for Myopic students.

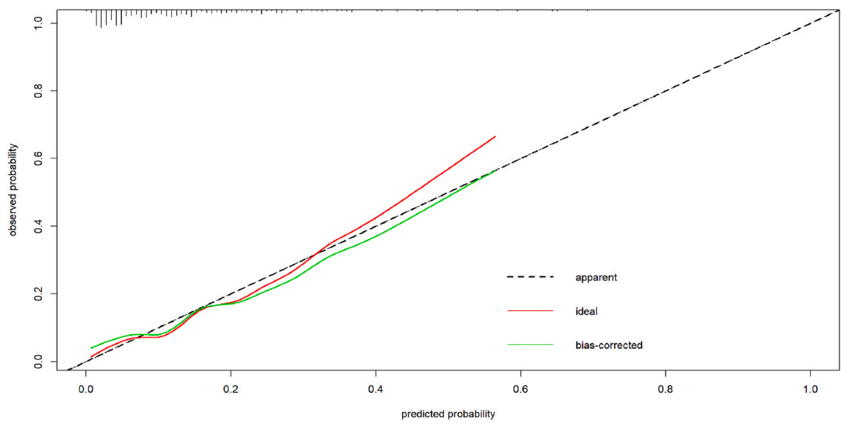

Fig. 4. Curve Calibration curve of the model for predicting Myopia.

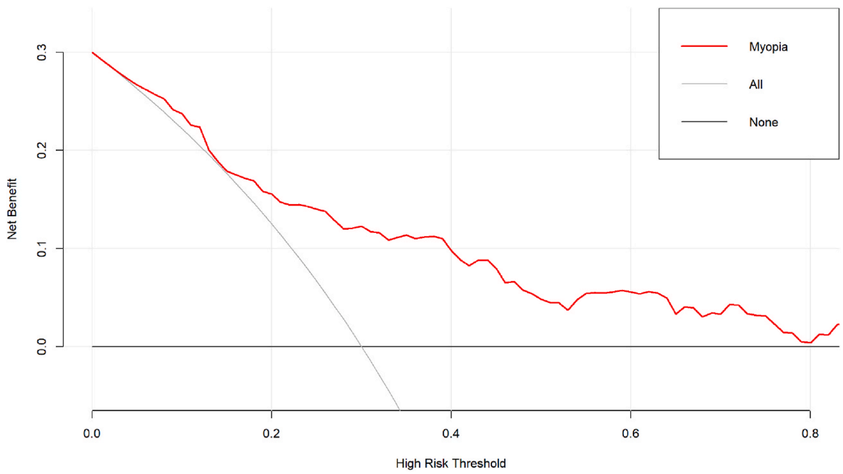

Fig. 5. Decision curve analysis of the nomogram for the prediction model for Myopia.

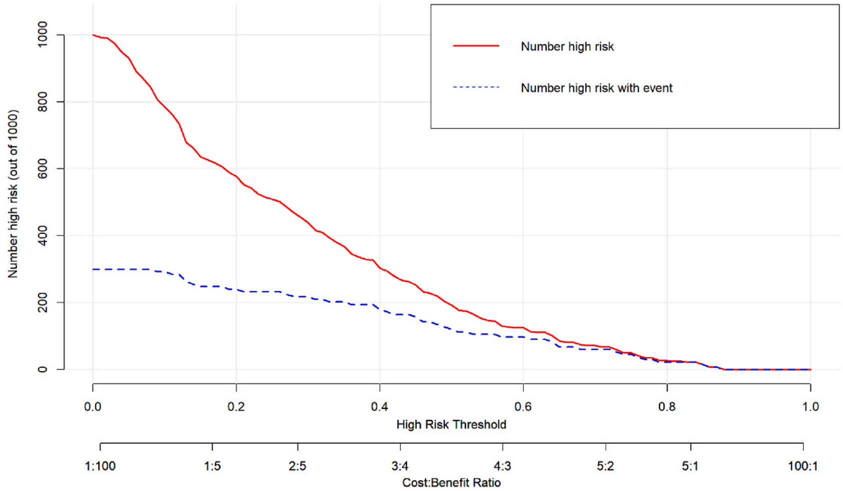

Fig. 6. The clinical impact curve of the nomogram for the prediction model for Myopia.

conducted a follow-up study on elementary and secondary school students and found that each year, 20%–30 % of students without myopia developed myopia from the first grade of elementary school [5]. In 2018, the National Health Commission of the People's Republic of China reported the prevalence of myopia after screening among children from nursery school (aged 6 years) to high school. The results showed that 14.3 % 6-year-old nursery school children, 35.6 % elementary school students, 71.1 % junior high school students, and 80.5 % high school students had myopia [28]. Of note, the prevalence of myopia in adolescents significantly increases with age [29–31].

In the current study, the factor of family location showed that the risk of myopia was higher in urban than in rural areas, with an OR value of 2.33, indicating that the risk was 2.33 times higher than that in rural areas. This is consistent with the findings of a meta-analysis report that showed that children from cities are 2.6 times more likely to have myopia than those from rural areas [32]. This has also been confirmed by other studies [13,33,34]. Although the difference between the role of urban and rural areas in myopia may be complex owing to different aspects, population density can partially explain the urban–rural differences; however, myopia is still influenced by the combination of environmental and behavioral factors [35,36]. City-dwelling children have relatively better economic conditions than rural children and therefore relatively have access to more electronic products, extracurricular tutoring, and extracurricular interests, leading to prolonged eye use, which may account for the differences.

The parents' occupation was also included in the myopia prediction model in this study. Compared with farmers, the OR values of the other eight occupations were higher, as shown in Table 2. Previous research on occupation and myopia showed that the incidence of myopia was very low in occupations without long-term close-range work, such as that of farmers [37]. However, there is a lack of research on the influence of parental occupation on their children's myopia. In the present study, students whose parents were medical workers had the highest risk of developing myopia, with an OR value 5.64 times higher than that of farmers. It is speculated that the impact of parents' occupation on myopia is indirect and may be caused by various factors, such as genetic factors, education on children's eye habits, differences in income caused by different occupations, differences in supervision time for children's learning caused by varying lengths of accompanying time owing to different occupations, and others. These factors have been shown to affect myopia previously [13,38,39]. In the future, the impact of parents' occupation on children's myopia should be given more attention and analyzed comprehensively.

In this study, the scores for eye distance and eye health exercises were the two dimensions of the AQVCRBS scale, which were quantified via related questions. These scores measured the quality of eye distance and eye health exercises, with higher scores indicating better student habits in these areas [16,17]. The OR values in this study reflect this aspect, with OR values of 0.83 and 0.95, respectively, indicating these factors as protective in myopia. Relevant studies have also indicated that close-range visual activities and eye health exercises are associated with myopia [13,40,41]. Although the P value of the eye health score was not significant, it was selected as a factor affecting myopia via the lasso regression analysis, with an OR value of 0.95 but with a relatively weak protective effect.

Most schools in China conduct regular visual screenings for their students each semester primarily using the traditional visual acuity chart method. If a student's visual acuity is $<$ 20/20 on the chart, it is considered problematic and the student is advised to visit a hospital for further examination. Although this method can effectively identify young people with visual problems, myopia is irreversible and can only be controlled, not cured. Traditional methods are unable to screen children who do not have myopia yet have a high risk of developing it. They can only serve as a secondary prevention strategy. However, the results of the current study can make up for this deficiency. The validated and established model developed in this study showed good results in terms of accuracy and practicality. In schools, teachers can conduct a questionnaire survey based solely on these five questions and compare the results with a nomogram, which is a simple and easy-to-read graph. This would enable the teachers to identify whether a child belongs to the high-risk myopia group. With simple training, anyone can conduct the survey and perform such assessments, indicating the advantages of the nomogram. This method is simple and feasible and can be applied in primary schools with relatively low myopia incidence rates to identify children with normal vision who have a high risk of developing myopia and require close follow-up and behavior control. Moreover, the method can serve as a supplementary method to assist traditional visual screening measures for primary prevention and achieve the goal of avoiding or delaying myopia. This model would be particularly useful in areas with relatively underdeveloped economies where screening methods are limited or medical conditions are poor, thereby improving the eye health of young people.

This study has certain limitations. Convenience sampling was used in this study, possibly resulting in selection bias. The model only underwent internal validation, and further external validation would be more helpful in promoting the model. Some factors, such as the spherical equivalent and axial length, were not included in this study, and their incorporation may be beneficial for the model. Finally, the model can only be used to judge the risk of myopia and therefore is not used in the population that has already developed myopia for controlling its progression.

6. Conclusion

This study utilized the lasso regression method to screen and identify five factors that had a significant impact on elementary school students' myopia during the COVID-19 pandemic. These factors included student age, family location, eye distance score, eye health exercise score, and parents' occupation, and they were used to build a predictive model. Validation analysis for the model revealed good results and showed that it can be used to predict the risk of myopia in elementary school students. This predictive model can be used to screen elementary school students at high risk for developing myopia, thereby providing a foundation for early intervention and follow-up. This can help reduce the incidence of myopia in this population not only during pandemics but also during non-pandemic periods caused by infectious diseases.

Ethics Committee approval

The study was approved by the Ethics Committee of Shanghai Ninth People's Hospital, with the reference number of SH9H-2022-T49-2, and the data collected will be used solely for academic research purposes.

Informed consent

The Shanghai Ninth People's Hospital Ethics Committee approved waiving informed consent as it would not negatively impact the rights and interests of the participants.

Data availability statement

The datasets used and analyzed for this study available from the corresponding author Changjuan Zeng on reasonable request.

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CRediT authorship contribution statement

Shijie Chen: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Lin Li:** Writing – review & editing. **Liangyu He:** Writing - original draft. **Shanshan Xiong:** Investigation, Data curation. **Na Du:** Investigation, Data curation. **Huifang Chen:** Supervision, Conceptualization. **Lili Hou:** Supervision, Conceptualization. **Changjuan Zeng:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20638.

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