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Preplanned Studies

Outbreak Reports

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Preplanned Studies

Intervention of Hypertension by Occupational Health Management Among Dock Workers — Shenzhen City, Guangdong Province, China, 2020–2024

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Summary

What is already known about this topic?

Hypertension predisposes dock workers to higher health risks in their work environments, requiring urgent intervention via comprehensive health management.

What is added by this report?

This study explored occupational health management in hypertension among dock workers and found that occupational health management measures helped reduce the blood pressure of patients with hypertension, curb the incidence, and slow the growth rate of its prevalence.

What are the implications for public health practice?

The intervention measures adopted in this study should be promoted in similar occupational environments.

ABSTRACT

Introduction: Hypertension predisposes dock workers to high health risks in their work environments, requiring urgent intervention via comprehensive health management.

Methods: In 2020, 1,145 dock workers from Shenzhen, China, were enrolled via cluster sampling for an intervention trial over the following 4 years. Annual blood pressure (BP) monitoring and questionnaires regarding basic characteristics and work information were administered. The occupational health management measures for hypertension intervention included daily pre-shift BP monitoring and hierarchical management, regular health training, dietary management, and exercise promotion. Annual BP values and hypertension incidence and prevalence were analyzed to evaluate outcomes.

Results: The median age of the cohort was 46 years, with a median body mass index of 25.08 kg/m^2 at baseline. The median systolic and diastolic BP of patients with baseline hypertension were significantly reduced during the intervention period (all P<0.001), showing downward trends (both P_{trend}<0.001). The incidence of hypertension in the cohort showed a decreasing trend during the intervention period (P_{trend}<0.001). Although the prevalence of hypertension increased annually during the intervention (P_{trend}<0.001), its growth rate decreased annually.

Conclusion: These intervention measures helped control BP and reduce the incidence of hypertension in dock workers, which should be promoted in similar occupational environments.

Hypertension is the primary risk factor for cardiovascular and cerebrovascular diseases (*1*). Dock workers are generally older and are often exposed to occupational factors related to hypertension risk, such as high-intensity physical labor, shift work, noise, and psychological pressure. Multiple studies have shown that the prevalence of hypertension is significantly higher than in the general population (*2*–*3*). Moreover, hypertension predisposes dock workers to higher health risks in their work environments. Although the Chinese Guidelines for the Prevention and Treatment of Hypertension (CGPTH) emphasize the importance of comprehensive intervention (*4*), systematic health management research on the special occupational environment of seaports remains scarce. Therefore, this study evaluated occupational health management of hypertension among dock workers with the aim of providing a scientific basis for formulating targeted prevention and control strategies.

In early 2020, 1,200 dock workers were enrolled from a port company in Shenzhen, China, via cluster sampling. After 4 years of continuous health

intervention, 1,145 participants were included. The participant selection process is shown in Supplementary Figure S1 (available at https://weekly.chinacdc.cn/).

Blood pressure (BP) monitoring and health surveys were administered annually in the cohort from 2020 (baseline) to 2024. The survey questionnaire included questions regarding basic characteristics, occupational information, lifestyle, and medical history. Doctors and nurses evaluated the participants and diagnosed hypertension. According to the CGPTH, the diagnostic criteria for hypertension were systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg.

The occupational health management interventions were as follows:

First, hierarchical management by pre-shift BP: Study participants measured their BP daily before going on duty and were managed hierarchically according to the results. Participants with SBP<120 mmHg and DBP<80 mmHg (normal BP) could continue to work in their current positions; those with SBP≥120 mmHg but <140 mmHg or DBP≥80 mmHg but <90 mmHg (high-normal level) were required to complete daily health education by watching videos; and those with SBP≥140 mmHg or DBP≥90 mmHg (hypertension) were temporarily restricted from high-risk operations on that day and were referred for medical intervention.

Second, regular health training: On-site training lectures were held quarterly, covering the hazards of hypertension, reasonable diet (low-salt and low-fat), regular exercise, and stress management.

Third, dietary and exercise intervention: The on-site canteen provided low-salt healthy food options and established dietary health education boards. The labor union organized work-break exercises, walking competitions, and built fitness areas.

Uniformly trained investigators guided the participants in completing the questionnaires. Pre-shift BP monitoring and hierarchical management were supervised by the company's occupational health management personnel and enforced among all participants. Regular health training, dietary management, and exercise promotion were organized by the company's labor unions and were mandatory for all participants.

R Statistical Software (version 4.3.3, R Development Core Team, Vienna, Austria) (*5*) was used for data analysis. The *Wilcoxon* signed-rank test was used for between-group comparisons of BP. The *Pearson* χ^2 test (or *Fisher*'s exact test) and McNemar's test were used for between-group comparisons of incidence and prevalence, respectively. Linear regression was used for BP trend analysis, and the Cochran-Armitage trend test was used for incidence and prevalence trend analysis. The priori α significance level was set at $P<0.05$.

As shown in Table 1, the cohort had a median age of 46 years at baseline. They were primarily male (97.6%), married (91.0%), and Han Chinese (95.7%). The median body mass index (BMI) was 25.08 kg/m^2, indicating that more than half of the study population was overweight, according to the World Health Organization (WHO) criteria. Those who smoked, used alcohol, and regularly exercised accounted for 23.4%, 12.2%, and 45.2% of the participants, respectively. The median time of employment was 12 years.

The median SBPs of the cohort at baseline and during the intervention were <130 mmHg, but the median DBPs were ≥80 mmHg (Table 2). According to the American Heart Association criteria, more than half of the cohort required long-term intervention. Although the median BP showed small fluctuations during the intervention and slightly increased compared with the baseline level in some intervention periods (Table 2), the median BP at all time points was lower than the hypertension diagnostic criteria of China and the WHO (*6*).

Table 2 shows that the median SBP and DBP of patients with baseline hypertension during the intervention were all lower than the hypertension diagnostic criteria. Compared with the baseline level in 2020, the SBP of patients with baseline hypertension in 2021–2024 decreased significantly (V=23,702, $P<0.001$, V=19,975, $P<0.001$, V=25,853, $P<0.001$, and V=27,738, $P<0.001$, respectively), and the DBP in 2021–2024 decreased significantly (V=19,972, $P<0.001$, V=24,386, $P<0.001$, V=26,636, $P<0.001$, and V=30,696, $P<0.001$, respectively), and both SBP and DBP showed significant downward trends with the extension of the intervention time ($\beta=-2.32$, $P_{trend}<0.001$, and $\beta=-2.66$, $P_{trend}<0.001$, respectively).

Compared to the baseline level in 2020, the SBP and DBP of participants without baseline hypertension slightly increased in 2021–2024 (Table 2). However, the median SBP and DBP of participants without baseline hypertension during the intervention were lower than the diagnostic criteria for hypertension.

The incidence of hypertension in the cohort showed

TABLE 1. Baseline characteristics of the cohort (*n*=1,145).

Characteristics	*N* (%)
Age (years)	
≤30	104 (9.1)
31–40	250 (21.8)
41–50	502 (43.8)
≥51	289 (25.2)
Sex	
Male	1,118 (97.6)
Female	27 (2.4)
Ethnicity	
Han	1,096 (95.7)
Others	49 (4.3)
Marital status	
Married	1,042 (91.0)
Others	103 (9.0)
Education	
Junior high school or lower	560 (48.9)
High school or technical secondary school	439 (38.3)
College or higher	146 (12.8)
Body mass index (kg/m^2)	
<18.5	16 (1.4)
18.5–23.9	373 (32.6)
24.0–27.9	552 (48.2)
≥28.0	204 (17.8)
Smoking	
Current smoker	268 (23.4)
Never or occasional smoker	417 (36.4)
Former smoker	460 (40.2)
Alcohol use	
Current alcohol user	140 (12.2)
Non- or occasional alcohol user	613 (53.6)
Former alcohol user	392 (34.2)
Regular exerciser	
Yes	518 (45.2)
No	627 (54.8)
Job type	
Loading and unloading driver	280 (24.4)
Tally clerk	214 (18.7)
Repair worker	93 (8.2)
Others	558 (48.7)
Time of employment (years)	
1–10	497 (43.4)
11–20	477 (41.6)
≥21	171 (14.9)

Note: Current smoker refers to an individual who smoked at least 1 cigarette per day and continued for 6 months or longer before the survey; occasional smokers refer to individuals who reported smoking within 6 months before the survey but did not meet the criteria for current smoker; and former smoker refers to an individual who smoked before but did not smoke within 6 months before the survey.
Current alcohol user refers to an individual who drank at least 1 alcohol beverage 1 time per week and continued for 6 months or longer before the survey; occasional alcohol user refers to an individual who reported alcohol consumption within 6 months before the survey but did not meet the criteria for current alcohol user; and former alcohol user refers to an individual who drank before but did not drink within 6 months before the survey.
Regular exerciser was defined as a person who engaged in at least twice per week of ≥30 min moderate-intensity (causing accelerated breathing and heart rate) physical activity and continued for 6 months or longer before the survey.

TABLE 2. Comparison of blood pressure at baseline and during the intervention period.

Cohort	Year	Systolic blood pressure			Diastolic blood pressure		
		Value [mmHg, *M* (P_{25}, P_{75})]	Statistics	*P**	Value [mmHg, *M* (P_{25}, P_{75})]	Statistics	*P**
Total (*n*=1,145)	2020	126.0 (116.0, 136.0)			80.0 (73.0, 88.0)		
	2021	126.0 (116.0, 136.0)	282,202	1.000	84.0 (76.0, 89.0)	202,923	<0.001
	2022	128.0 (118.0, 137.0)	235,506	<0.001	82.0 (75.0, 88.0)	248,110	<0.001
	2023	127.0 (118.0, 136.0)	265,700	0.108	81.0 (75.0, 87.0)	276,620	1.000
	2024	128.0 (118.5, 136.0)	287,931	0.316	81.0 (74.0, 86.0)	327,424	0.004
Baseline hypertensive patients (*n*=255)	2020	143.0 (136.0, 150.0)			94.0 (90.0, 98.0)		
	2021	136.0 (128.0, 143.0)	23,702	<0.001	90.0 (85.0, 97.0)	19,972	<0.001
	2022	139.0 (130.5, 148.0)	19,975	<0.001	88.0 (83.0, 95.0)	24,386	<0.001
	2023	134.5 (127.0, 139.0)	25,853	<0.001	87.0 (82.0, 90.0)	26,636	<0.001
	2024	135.0 (128.0, 139.0)	27,738	<0.001	85.0 (78.5, 89.0)	30,696	<0.001
Baseline non-hypertensive participants (*n*=890)	2020	122.0 (114.0, 129.0)			77.0 (72.0, 83.0)		
	2021	123.0 (114.0, 133.0)	133,660	<0.001	81.0 (75.0, 87.0)	86,335	<0.001
	2022	125.0 (117.0, 134.0)	110,024	<0.001	80.0 (74.0, 86.0)	104,478	<0.001
	2023	125.0 (116.0, 133.0)	112,166	<0.001	80.0 (73.0, 86.0)	114,304	<0.001
	2024	125.0 (117.0, 134.0)	122,374	<0.001	79.0 (72.0, 85.0)	134,842	<0.001

* Compared with baseline levels in 2020 and adjusted using the Bonferroni method for multiple comparisons.

a decreasing trend during the intervention period (Z=−8.16, P_{trend}<0.001). Compared with 2021, the hypertension incidence in 2023–2024 decreased significantly (χ^2=53.32, *P*<0.001 and χ^2=47.40, *P*<0.001, respectively); compared with 2022, the incidence in 2023–2024 also decreased significantly (χ^2=44.04, *P*<0.001 and χ^2=38.80, *P*<0.001, respectively) (Table 3).

The prevalence of hypertension significantly increased each year in 2021–2023 when compared with the previous year (all *P*<0.05), but it was not significantly different between 2023 and 2024. Although the hypertension prevalence in the cohort showed an increasing trend during the intervention period (Z=−13.33, P_{trend}<0.001), its rate of increase decreased annually (Table 3).

DISCUSSION

This study explored occupational health management as an intervention for hypertension among dock workers. The results showed that systematic occupational health management might confer dual benefits for the prevention and control of hypertension in dock workers: it could effectively control the BP of patients and reduce the risk of new-onset hypertension. First, patients with hypertension may benefit significantly. The baseline BP of patients with hypertension dropped below the diagnostic criteria (Table 2), which may be directly related to pre-shift BP monitoring, hierarchical referral, and continuous health management. Daily monitoring helps achieve early detection and intervention, avoiding further increases in BP. Second, the incidence of hypertension in the cohort decreased, and the growth rate of its prevalence slowed. Health training, exercise, and dietary interventions may improve health awareness, and the incidence in the last 2 years of intervention was significantly lower than that in the first 2 years (all *P*<0.001) (Table 3), indicating that the intervention could reduce the risk of new-onset hypertension. Although population aging might increase the prevalence of hypertension, the intervention reduced the growth rate (annual growth rate decreased from 50.7% to 4.4%) (Table 3), suggesting that management measures might partially offset age-related risks and slow the growth rate of the disease.

The small fluctuations and increases in the median BP of the cohort during some intervention periods may be attributed to aging. As the intervention time increased, the median age of the cohort increased from 46 to 50 years, and age is an independent risk factor for BP elevation (*7*). Although the intervention reduced the BP of patients with hypertension, the BP of participants without hypertension increased slightly

TABLE 3. Incidence and prevalence of hypertension at baseline and during the intervention period.

Year	Incidence			Prevalence		
	Rate (%)	Statistics	*P*	Rate (%)	Statistics	*P*
2020				22.45		
2021	14.64			33.83	243.56	<0.001*
2022	13.45	0.38	1.000†	42.88	168.81	<0.001*
					66.14	<0.001†
2023	3.25	53.32	<0.001†	45.22	146.83	<0.001*
		44.04	<0.001§		52.14	<0.001†
					14.69	0.001§
2024	3.59	47.40	<0.001†	47.23	83.78	<0.001*
		38.80	<0.001§		43.15	<0.001†
		0.03	1.000¶		10.06	0.020§
					6.28	0.122¶
	Trend	−8.16	<0.001	*Trend*	−13.33	<0.001

Note: *P* values were adjusted using the Bonferroni method for multiple comparisons;
* Compared with the rate in 2020;
† Compared with the rate in 2021;
§ Compared with the rate in 2022;
¶ Compared with the rate in 2023.

(Table 2), probably due to increasing age, thus leading to fluctuations and slight increases in the median BP of the entire cohort (Table 2).

The findings of this study have at least three limitations. First, it was not a randomized controlled trial; thus, accurately evaluating the effect of the management measures was impossible. Second, the dock worker population was mainly male, which limited the extrapolation of the intervention effects to females. Finally, this study did not evaluate the cost-effectiveness of the intervention measures, which might limit their application and promotion.

In conclusion, this study demonstrated that an occupational health management strategy for dock workers could significantly reduce the BP of patients with hypertension, effectively decrease the growth in incidence, and slow the rate of prevalence, which seems worthy of application and promotion in similar occupational environments. Based on these findings, we recommend incorporating daily pre-shift BP monitoring into relevant regulations to better protect the health of dock workers. Public health professionals should develop related health guidelines and establish a screening-referral loop with evaluations. Dock workers should actively participate in monitoring and health training, follow management arrangements, and adopt healthy diets and exercise.

Ethical statement: Approved by the Medical Ethics Committee of the Shenzhen Prevention and Treatment Center for Occupational Diseases (*Approval No.* LL2020-34), in accordance with the 1975 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent obtained from all the participants or their legal guardians.

Conflicts of interest: No conflicts of interest.

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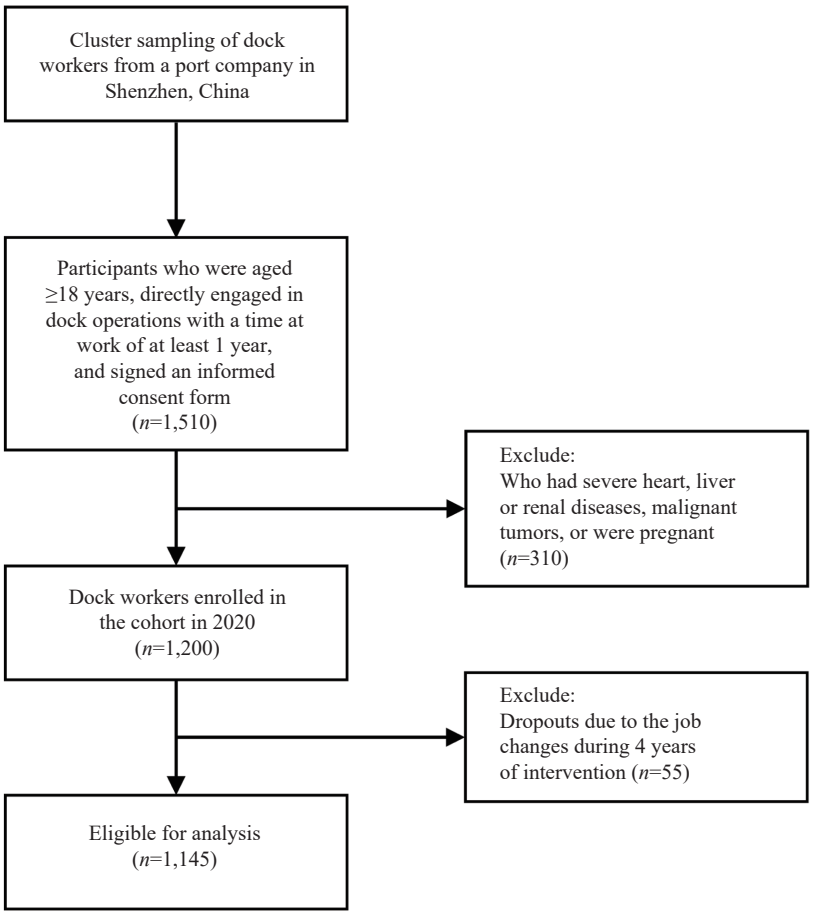
SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. Flowchart for participants selection.

Preplanned Studies

Accessible Blood Based Biomarkers Reflecting Inflammation-Lipid Dysregulation in Silicosis Progression — Jiangsu Province, China, 2021–2024

Rong Jiang[1,&]; Qianqian Gao[2,&]; Lang Zhou[2]; Feng Shi[1]; Yunfeng Hua[1]; Feifei Wang[1]; Zhen Hong[1,#]; Lei Han[2,#]

Summary

What is already known about this topic?

Silicosis, an occupational lung disease caused by exposure to silica dust, is characterized by persistent inflammation and lipid dysregulation. Clinicians typically rely on radiographic imaging and pulmonary function tests instead of accessible blood-based biomarkers to quantify inflammation-lipid imbalance and predict functional decline in disease management.

What is added by this report?

We evaluate two novel hematological indices — Neutrophil-to-HDL Ratio (NHR) and Platelet-to-HDL Ratio (PHR) — in 160 patients with silicosis and 123 silica-exposed controls from Jiangsu Province, China. Both the NHR and PHR of patients in the silicosis group are significantly higher than those in the control group, with the highest levels observed in advanced stages (Stage II–III). Both ratios show significant negative correlations with lung function decline (FVC%, FEV_1%, FEV_1/FVC), and these correlations strengthen in patients with advanced silicosis.

What are the implications for public health practice?

NHR and PHR are low-cost, accessible biomarkers of inflammation-lipid dysregulation during the progression of silicosis. Incorporating these ratios into routine occupational health screening for silica-exposed workers could serve as a complementary method to radiographic examination or spirometry tests, thereby improving silicosis monitoring and management.

ABSTRACT

Introduction: The activation of inflammatory cells and lipid metabolism disorder initiated by silica are the key pathological mechanisms of silicosis. This study aims to analyze easily accessible blood biomarkers that reflect this inflammation-lipid imbalance and improve disease monitoring and management.

Methods: A cross-sectional investigation was conducted in 160 male patients with silicosis, and 123 silica-exposed control workers (male ceramic workers without silicosis). Neutrophil-to-HDL ratio (NHR) and Platelet-to-HDL ratio (PHR) were calculated from routine blood counts and high-density lipoprotein (HDL). Pulmonary function parameters (FVC%, FEV_1%, FEV_1/FVC) were evaluated by pulmonary function test. We studied group differences and correlations using statistical analysis.

Results: The NHR and PHR of patients in the silicosis group were significantly higher than those in the control group, with the highest levels in advanced stages (Stage II–III). All lung function parameters were significantly reduced in silicosis patients. NHR and PHR showed significant negative correlations with lung function decline (FVC%, FEV_1%, FEV_1/FVC), and these correlations strengthened in patients with advanced silicosis.

Conclusion: NHR and PHR are elevated and inversely correlate with worsening lung function in patients with silicosis, especially in advanced disease. These ratios are readily available, cost-effective biomarkers for monitoring inflammation-lipid dysregulation and functional decline during the progression of silicosis. Incorporating NHR and PHR into routine occupational health screening for workers exposed to silica could help in risk stratification and disease management.

Silicosis, a serious occupational lung disease prevalent among ceramic workers, miners, and construction workers, is driven by persistent inflammation and pulmonary fibrosis following exposure to crystalline silica exposure. Recently, it has been discovered that the activation of inflammatory

cells and lipid metabolism disorder initiated by silica are the key pathological mechanisms of silicosis (*1*). Currently, no effective strategies exist to delay silicosis progression; therefore, exploring biomarkers related to its pathological processes is essential for facilitating reliable monitoring and, guiding clinical management. C-reactive protein (CRP), Interleukin-6 (IL-6), and erythrocyte sedimentation rate (ESR) are well-known inflammatory markers of silicosis. However, they cannot be obtained from routine, low-cost blood tests that are widely used in clinical practice, limiting their application in the health surveillance of silica-exposed workers. Furthermore, these markers do not reflect lipid metabolic dysregulation, which is central to the pathogenesis of silicosis. In contrast, hematological ratios combining leukocytes with high-density lipoprotein (HDL) could function as representative indices for evaluating lipid metabolism disorder and the level of inflammatory response level (*2*). Moreover, these ratios serve as cost-effective and technically accessible biomarkers for subclinical inflammation detection, requiring only routine blood parameters. Several recent studies have suggested that the Neutrophil-HDL Ratio (NHR) could quantify the imbalance between inflammatory components and lipid parameters, and has been widely used in many inflammatory conditions, including malignancies, acute coronary syndromes, cerebrovascular events and neurodegenerative disorders (*3*). Similarly, the Platelet-HDL Ratio (PHR) correlates thrombo-inflammatory burden with lipid metabolic dysregulation, wherein elevated values denote heightened thrombo-inflammatory activity and altered lipid metabolism homeostasis (*4*). Several studies with NHR and PHR have demonstrated that these blood indices could detect inflammation-lipid dysregulation status in interstitial lung disease (ILD); however, no reports have been published on patients with silicosis, and even less is known about the relationship between these parameters and pulmonary functional decline during silicosis progression.

Therefore, this cross-sectional study aimed to determine whether patients with silicosis exhibit an activated inflammatory response and lipid metabolic disorder using potential biomarkers obtained from regular blood tests. Moreover, we evaluated their relationships with the pulmonary functional parameters.

Data were collected from medipopulationcal records of the Jiangsu Provincial Center for Disease Control and Prevention, spanning between January 2021 and December 2024. The study included ceramic workers engaged in raw material crushing, trimming, glazing, and product polishing, who were referred for occupational health screening due to suspected silicosis. A definitive diagnosis requires multidisciplinary consensus, a history of silica dust exposure, and radiological confirmation according to the International Labour Organization (ILO) classification criteria (*5*). Exclusion criteria eliminated individuals with acute infections [clinical diagnosis or laboratory evidence (e.g., body temperature >38 °C, leukocyte count >10×10^9/L) of any acute infection (e.g., respiratory, urinary) within the past 4 weeks], chronic inflammatory conditions (a history of systemic autoimmune or chronic inflammatory disorders, e.g., rheumatoid arthritis, systemic lupus erythematosus, inflammatory bowel disease), chronic infectious diseases [e.g., chronic viral hepatitis B or C, tuberculosis, or human immunodeficiency virus (HIV) infection], metabolic and endocrine disorders leading to lipid metabolic disturbance (e.g., diabetes mellitus, hyperlipidemia), malignancies, or use of medications affecting hematological parameters. The study analyzed 160 patients with silicosis, and 123 silica-exposed controls (radiographically healthy ceramic workers) from Jiangsu Province, China. Based on ILO pneumoconiosis classifications, the silicosis severity distribution was as follows: 106 patients (66.25%) had silicosis at Stage I (early stage of silicosis), and 54 patients (33.75%) had Stage II–III silicosis (advanced stage of silicosis). Peripheral blood samples were collected to calculate NHR and PHR from complete blood counts and HDL measurements. We assessed pulmonary function parameters including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and FEV_1/FVC. Data analysis was performed using SPSS version 25.0 (IBM Corp., NY, USA). Continuous variables were classified as mean±standard deviation (parametric) or median (interquartile range) (non-parametric). For intergroup differences, parametric data underwent one-way analysis of variance (ANOVA) test while non-parametric distributions were analyzed via Kruskal-Wallis test. Two-group comparisons were performed using Student's *t*-tests (parametric) or Mann-Whitney *U*-tests (non-parametric). Spearman's correlation coefficient was used to measure bivariate associations. Statistical significance was indicated as $P<0.05$. For the

significant Kruskal-Wallis test results (e.g., for NHR, PHR, lung function), post-hoc pairwise comparisons were conducted to identify the differences between two groups (e.g., Control *vs*. Stage I, Control *vs*. Stage II–III and Stage I *vs*. Stage II–III). To decrease the risk of type I error due to these multiple comparisons, a Bonferroni-corrected *P* threshold of <0.017 (0.05/3) was applied.

All participants were male workers aged ≥60 years, with detailed sociodemographic information presented in Table 1. Compared to controls, patients with silicosis exhibited significantly prolonged silica exposure duration (*P*=0.00) and higher smoking prevalence (*P*=0.01). No intergroup differences were observed in age or alcohol consumption patterns. Routine hematological analysis (Table 2) revealed that the total leukocyte count did not differ between the three groups studied (Control, Stage I, and Stage II–III). Moreover, a non-significant increasing trend was observed in the neutrophil counts. Similarly, the platelet count was notably elevated in the Stage I and Stage II–III silicosis groups compared to that in the control group, but intergroup differences lacked statistical significance. Moreover, lymphocyte counts and HDL concentrations did not differ between controls and either patients groups, although downward trends were observed for lymphocytes and HDL concentrations in both parameters in the Stage I and Stage II–III silicosis groups.

A significant increase in NHR levels was observed in

TABLE 1. Basic sociodemographic characteristics of the study population.

Characteristics	Overall (*n*=283)	Control (*n*=123)	Silicosis (*n*=160)	*P*
Age (years)	70.26±5.40	70.06±5.38	70.41±5.44	0.58
Duration of exposure (years)	24.00 (10.00, 32.00)	9.00 (5.00, 15.00)	29.50 (25.00, 36.00)	0.00
Smoking status, *n* (%)				0.01
Smoker	136 (48.06)	48 (39.02)	88 (55.00)	
Non-smoker	147 (51.94)	75 (60.98)	72 (45.00)	
History of alcohol intake, *n* (%)				0.47
Yes	115 (40.64)	47 (38.21)	68 (42.50)	
No	168 (59.36)	76 (61.79)	92 (57.50)	

Note: Data are presented as median (interquartile range), mean±standard deviation, or *n* (%). Significance was set as *P*<0.05.

TABLE 2. Laboratory data of the study population.

Characteristics	Control (*n*=123)	Stage Ⅰ silicosis (*n*=106)	Stage II–III silicosis (*n*=54)	*P*
Laboratory findings				
WBC (x10^9/L)	6.46 (5.43, 7.67)	6.60 (5.40, 7.90)	6.95 (5.81, 8.25)	0.16
Neutrophils (x10^9/L)	3.90 (3.07, 4.70)	3.98 (3.24, 4.92)	4.23 (3.46, 5.30)	0.06
Lymphocytes (x10^9/L)	2.14 (1.62, 2.67)	2.05 (1.47, 2.77)	1.99 (1.63, 2.40)	0.59
Platelet (x10^9/L)	175.00 (147.00, 208.00)	190.50 (147.75, 221.00)	188.50 (153.50, 221.50)	0.10
HDL (mmol/L)	1.37 (1.19, 1.60)	1.33 (1.11, 1.64)	1.30 (1.14, 1.52)	0.29
NHR (10^9/mmol)	2.82 (2.04, 3.73)	3.07 (2.07, 3.94)	3.08 (2.60, 4.72)*	0.02
PHR (10^9/mmol)	120.13 (95.62, 154.17)	134.04 (103.30, 187.62)	145.70 (112.40, 167.28)*	0.02
Lung functions				
FVC (% pred)	78.00 (73.00 , 85.00)	75.50 (66.75, 85.00)	68.00 (54.75, 78.25)*,**	0.00
FEV1 (% pred)	77.00 (72.00, 83.00)	73.00 (67.53, 81.50)*	65.00 (46.00, 73.25)*,**	0.00
FEV1/FVC%	85.00 (80.00, 91.00)	78.98 (63.75, 86.12) *	65.93 (56.00, 79.25)*,**	0.00

Note: Data are presented as median (interquartile range), or mean±standard deviation. *P*<0.05: *P* from the Kruskal-Wallis *H* test across the three groups (Control, Stage I, Stage II–III).
Abbreviation: HDL=high-density lipoprotein; NHR=neutrophil to HDL ratio; PHR=platelet to HDL ratio; FVC=forced vital capacity; FEV1=forced expiratory volume in 1 second.
* *P*<0.017 (Bonferroni-corrected): compared to the controls in the Mann-Whitney *U* test;
** *P*<0.017 (Bonferroni-corrected): compared to Stage Ⅰ silicosis in the Mann-Whitney *U* test.

patients with silicosis [3.07 (2.07, 3.94) in Stage I and 3.08 (2.60, 4.72) in Stage II–III] compared with controls [2.82 (2.04, 3.73)]. There was a significant difference between all the three cohorts (P=0.02). The post-hoc pairwise comparisons revealed that NHR was elevated in both Stage I (P=0.03) and Stage II–III patients (P=0.01) compared with controls. However, only the difference between Stage II–III patients and controls was statistically significant after Bonferroni correction (P<0.017). No significant difference in NHR was observed between Stage I and Stage II–III patients. PHR also exhibited a significant progressive increase in patients with silicosis [134.04 (103.30, 187.62) in Stage I and 145.70 (112.40, 167.28) in Stage II–III] and showed a significant difference among all the groups studied (P=0.015). The post-hoc pairwise comparisons revealed that compared to controls, PHR was elevated in both Stage I (P=0.04) and Stage II–III patients (P=0.01) compared with controls. Similarly, only the difference between Stage II–III patients and controls was statistically significant after Bonferroni correction. All pulmonary function parameters (FEV1%, FVC% and FEV1/FVC) showed significant overall differences among the three groups (all P=0.00). Post-hoc pairwise comparisons revealed that compared with controls, patients with silicosis exhibited significant functional impairment. Compared with controls, Stage I patients had lower FVC% (P=0.04), FEV_1% (P=0.00), and FEV_1/FVC (P=0.00). Stage II-III patients also showed more significant pulmonary dysfunction in all parameters than controls (all P=0.00). Furthermore, advanced-stage patients manifested more severe functional deterioration than early-stage counterparts, with lower FVC% (P=0.00), FEV_1% (P=0.00) and FEV_1/FVC (P=0.00).

Spearman's correlation analysis results (Table 3) demonstrated that NHR presented significant negative correlations with FVC (r=−0.25, P=0.00), FEV_1 (r=−0.26, P=0.00) and FEV1/FVC (r=−0.22, P=0.01). Similarly, PHR was negatively correlated with FVC (r=−0.20, P=0.01), FEV_1 (r=−0.24, P=0.00), and FEV1/FVC (r=−0.24, P=0.00). Hence, these findings suggested significant correlations between hematological ratios and disease severity in patients with silicosis. Notably, the strength of these correlations intensified in patients with Stage II–III silicosis. Especially, NHR-FEV1/FVC (r=−0.39, P=0.00) and PHR-FEV_1 (r=−0.41, P=0.00) correlations in Stage II–III silicosis were nearly equivalent to −0.4, reflecting the stronger impact of neutrophilic or lymphatic inflammation and HDL dysfunction on spirometry deterioration in advanced-stage of silicosis.

DISCUSSION

Current evidence confirms the clinical utility of accessible hematological indices, including NHR, PHR, systemic inflammation indices and aggregate inflammation markers as minimally invasive inflammatory biomarkers (*3*–*4*). However, their roles in the pathogenesis of silicosis remain unexplored. Crucially, no previous investigations have been established to explore the relationship between NHR or PHR and respiratory functional decline in cohorts with silicosis. This cross-sectional analysis demonstrated that novel hematological ratios integrating immune cells with lipid parameters-specifically NHR and PHR cav serve as sensitive indicators associated with pulmonary function tests in ceramic workers with silicosis. Quantitative analysis demonstrated significantly elevated NHR and PHR in patients with silicosis compared with silica-exposed controls. These ratios exhibited stage-dependent amplification, with Stage II–III patients, displaying the most pronounced elevations (Stage I: moderate increase; Stage II–III: marked enhancement). Notably,

TABLE 3. Correlations between NHR, PHR and pulmonary function in silicosis.

Characteristics		FVC (% pred)		FEV1 (% pred)		FEV1/FVC%	
		r	*P*	*r*	*P*	*r*	*P*
Silicosis (*n*=160)	NHR	−0.25	0.00	−0.26	0.00	−0.22	0.01
	PHR	−0.20	0.01	−0.24	0.00	−0.24	0.00
Stage II–III (*n*=54)	NHR	−0.28	0.04	−0.34	0.01	−0.39	0.00
	PHR	−0.33	0.02	−0.41	0.00	−0.25	0.07

Note: Significance was set as P<0.05.
Abbreviation: NHR=neutrophil to high-density lipoprotein ratio; PHR=platelet to HDL ratio; FVC=forced vital capacity; FEV1=forced expiratory volume in 1 second.

these ratios demonstrated negative correlations with pulmonary function parameters such as FEV_1%, FVC% and FEV_1/FVC ratio, which suggested that the inflammation-lipid imbalance occurred in parallel with pulmonary function impairment.

Silica particle phagocytosis mediated by alveolar macrophages initiates of the pathogenic cascade of silicosis, which ultimately leads to pulmonary fibrosis (*1*). The activation of inflammatory cells and lipid metabolism disorder initiated by silica are key pathological mechanisms of silicosis. Neutrophils, the most abundant leukocyte subtype, promoted diseases progression by secreting pro-inflammatory cytokines, reactive oxygen species and proteolytic effectors. Researchers have found that the neutrophils counts are significantly upregulated not only in the serum but also in the lung tissues of patients with silicosis (*6*). In contrast, lymphocytes, another abundant subtype of leukocytes, were significantly lower in the serum of patients with silicosis. This may be because lymphocytes primarily mediated immune responses primarily through T cells, particularly the regulatory T (Treg) cells, which could suppress inflammation and promote silicosis development (*7*). In addition to their roles in thrombosis, platelets are now recognized to have immune regulatory and inflammatory signaling properties. Platelet activation can promote inflammatory cytokine secretion, stimulate leukocyte recruitment and disrupt endothelial function, all of which contribute to pulmonary inflammation and fibrosis (*8*). Moreover, elevated platelet-activation factor (PAF) in silicosis plasma and amelioration of silica-induced fibrosis by PAF antagonists in models collectively delineate the thrombo-inflammatory contributions. Critically, neutrophils, platelets and lymphocytes exhibited integrated roles in the pathogenesis of silicosis, with dynamic lipid remodeling, particularly LDL elevation and HDL reduction. HDL, traditionally associated with lipid metabolism, is now recognized as a key mediator involved in anti-inflammatory, antioxidant and antifibrotic responses. Current evidence indicates its significant association with idiopathic pulmonary fibrosis onset, progression and prognosis (*8*). Our data showed that although total leukocyte and platelet counts exhibited no intergroup differences, patients with advanced stages of silicosis presented with non-significant neutrophilia. Moreover, although lymphocyte counts and HDL concentrations did not reveal any differences between controls and patients with silicosis, downward trends were observed in the Stage I and Stage II–III silicosis groups.

The novel inflammatory-metabolic indices NHR and PHR, which integrate neutrophil/platelet (inflammatory markers) with HDL (anti-inflammatory/antioxidant marker) ratios, reflected the imbalance between inflammatory processes and lipid metabolism. In this study, NHR was significantly upregulated in patients with silicosis compared to silica-exposed controls, with significant differences observed across all the three cohorts, showing an increasing trend from Stage I silicosis to Stage II–III silicosis. A possible explanation for this might be that early radiographic stages are characterized by localized, low-grade inflammation at silica deposition sites, whereas advanced stages manifest with inflammation-lipid dysregulation proportional to the cumulative silica burden. PHR could serve as a validated quantitative indicator for assessing thrombo-inflammatory responses and lipid metabolic disorder across diverse pathologies. Clinical studies have confirmed the diagnostic and prognostic utility of PHR in chronic respiratory pathologies, including chronic obstructive pulmonary disease (COPD) and acute pulmonary vascular events such as embolism (*9*). Our analysis demonstrated that PHR also presented a significant progressive increase in patients with silicosis. Although the difference did not reach statistical significance, Stage II–III patients exhibited higher PHR values than their Stage I counterparts. Additionally, we found that single indices showed no significant differences, while combined ratios (NHR and PHR) showed significant differences between the groups, indicating the superiority of hematological parameters combining inflammatory cells with HDL in the evaluation of inflammatory response and lipid dysregulation during silicosis.

Significant inverse correlations were observed between hematological indices and pulmonary function parameters in the silicosis group. Even though the strength of correlation coefficients was modest (r ranged from −0.2 to −0.4), their practical significance remained important. This is because low-cost and readily available indicators make it easier for high-risk patients with silicosis to be quickly identified and treated early. Moreover, in patients with advanced stage silicosis, the correlations were stronger ($r \approx -0.4$ for several pairs). The gradual strengthening of correlations in Stage II–III silicosis suggests more pronounced associations between inflammation-lipid

dysregulation, as assessed by NHR and PHR, and the decline in spirometry parameters with disease progression. These findings are consistent with those of Kang HY et al., who indicated that several systemic immune inflammation indices presented significant inverse correlations with pulmonary function in a silicosis cohort (*10*).

Our findings provide important guidance for clinical practice. First, the discovery of blood combined biomarkers, including NHR and PHR, opens a new perspective on the potential pathological mechanisms of silicosis, suggesting a potential role of lipid metabolism and inflammatory responses. Second, NHR and PHR not only correlated with lung dysfunction but also associated with the presence and progression of silicosis. These findings both optimize the diagnostic process of silicosis and suggest new therapeutic targets for future treatment strategies.

The findings in this report are subject to at least 4 limitations. First, the absence of detailed information on potential confounders, including workplace exposure histories, quantitative dust measurements, and smoking status limited the potential confounders analysis and the independent prognostic capacity of NHR and PHR. Second, silica-exposed controls were not matched to silicosis cases on key potential confounders such as age, duration of silica exposure or smoking status, thus, matched designs for potential confounders would be included in subsequent studies. Third, all participants in the study were male workers aged ≥60 years, therefore, generalizability of our findings to female silicosis patients, younger individuals, or workers from other silica-exposed industries (e.g., mining, construction) should be apporached with caution and warrants further exploration. Finally, since the sample size of the advanced-stage subgroup was small, larger cohort studies arre required to confirm the stability and reliability of the stronger correlations in this subgroup.

NHR and PHR are accessible, low-cost blood-based biomarkers that reflect the degree of inflammation-lipid dysregulation in silicosis patients and are significantly associated with the decline in pulmonary function, with a stronger correlation observed particularly in advanced-stage silicosis. Based on these findings, it is recommended that NHR and PHR be incorporated into the routine occupational health surveillance system for silica-exposed workers, serving as supplementary indicators of chest imaging and pulmonary function tests.

Conflicts of interest: No conflicts of interest.

Ethical statement: All participants provided written informed consent prior to participation. Ethical approval was obtained from Jiangsu Provincial Center for Disease Control and Prevention (Approval JSJK2022-B002-01) and all procedures adhered to the Helsinki Declaration.

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Preplanned Studies

Classroom Environmental Determinants of Poor Vision in Chinese Schoolchildren — Guangdong Province, China, 2024

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Summary

What is already known about this topic?

The prevalence of poor vision among Chinese children and adolescents has been progressively increasing, constituting a significant public health concern. As the primary visual setting for students, the classroom environment may have a profound impact on ocular health.

What is added by this report?

This study revealed a poor vision detection rate of 60.22% among primary and junior high school students. The statistically significant relevant factors were blackboard reflectance, desk-chair allocation compliance rate, and desktop illuminance uniformity.

What are the implications for public health practice?

This study provides scientific evidence and prioritizes recommendations for modifying classroom environments. It supports targeted environmental interventions as a priority in school-based myopia prevention strategies.

ABSTRACT

Introduction: Classroom environments — the primary visual setting for students — may significantly influence ocular health. This study examined key modifiable factors of poor vision related to primary and junior high school classroom environments in Guangdong, China.

Methods: We analyzed population-based data (of 180,584 students and 3,905 classrooms) from the Surveillance Program for Common Student Diseases and Health Risk Factors implemented in Guangdong in 2024. Multivariable logistic regression was employed to examine associations between poor vision and classroom conditions. XGBoost modeling and Shapley Additive Explanations (SHAP) were applied to rank the relative importance of environmental predictors.

Results: The prevalence of poor vision was 60.22%. An unqualified desk-chair allocation compliance rate, blackboard reflectance, and desktop illuminance uniformity were independently associated with higher odds of poor vision, with adjusted odds ratios (95% confidence interval) of 1.05 (1.01, 1.08), 1.09 (1.06, 1.11), and 1.05 (1.02, 1.08), respectively. The SHAP analysis identified blackboard reflectance as the most influential factor, followed by blackboard average illuminance, desk-chair allocation compliance rate, and desktop illuminance uniformity.

Conclusions: Blackboard reflectance, desk-chair allocation compliance rate, and desktop illuminance uniformity were critical modifiable factors. A multisectoral collaboration mechanism aligned with national myopia prevention policies is recommended to ensure compliance with visual environmental standards in educational settings.

The increasing prevalence and earlier onset of poor vision among school-aged children constitute a growing public health concern with profound implications for adolescent development. Beyond immediate visual dysfunction, these impairments contribute to progressive myopia and retinal complications, affecting long-term quality of life and creating socioeconomic burdens. As classrooms serve as the primary setting for sustained near-vision tasks, the physical characteristics of the classroom environment are critically associated with ocular health (*1*). In resource-limited districts, where comprehensive upgrades may not be immediately feasible, prioritizing the most impactful interventions is essential. However, empirical evidence to guide such prioritization remains scarce.

This study examined the association between classroom environmental factors and poor vision among primary and junior high school students in Guangdong Province, China. It evaluated the relative importance of these modifiable determinants to inform

targeted, evidence-based interventions aimed at improving visual health within educational settings.

Data from the 2024 "Surveillance Program for Common Student Diseases and Health Risk Factors" in Guangdong Province, China were used, which employed multistage stratified random sampling across 21 prefecture-level cities. After processing, 180,584 students and 3,905 classrooms were retained for statistical modeling (Supplementary Figure S1, available at https://weekly.chinacdc.cn/).

Demographic data were collected using standardized questionnaires. Uncorrected visual acuity (UCVA) was assessed by professionals from district/county CDC following standardized protocols, with poor vision defined as UCVA<5.0 in at least one eye. Classroom environmental parameters were evaluated by trained personnel using calibrated instruments, adhering to the Functional Sizes and Technical Requirements for School Desks and Chairs (GB/T 3976–2014) and Hygienic Standards for Daylighting and Illumination in Classrooms (GB 7793–2010).

Statistical analyses were performed using Stata (version 18.0; StataCorp LLC, College Station, Texas, USA) and Python (version 3.12.6; Python Software Foundation, Wilmington, Delaware, USA). Categorical variables were summarized as numbers and percentages, with chi-square tests comparing poor vision detection rates across groups. Multivariable logistic regression was used to examine the association between classroom environmental factors and poor vision, with statistical significance set at $P<0.05$. Extreme Gradient Boosting (XGBoost) evaluated the impact of each environmental factor. Hyperparameters of the XGBoost model were optimized via a grid search combined with 5-fold stratified cross-validation to ensure robust model performance. The Shapley Additive Explanations (SHAP) methodology quantified the contribution of each predictor to model performance.

Of the 180,584 students included in the analysis, 108,741 (60.22%) had poor vision. The mean age was 10.17 years (SD=2.61). Table 1 shows that students with poor vision were older, more likely to be female, enrolled in junior high school, more prevalent as grades increased, and resided in urban areas. After adjusting for gender, educational stage, and region, lower desk-chair allocation compliance rate, unqualified blackboard reflectance, and inappropriate desktop illuminance uniformity were associated with higher odds of poor vision in students, with adjusted odds ratios (*OR*) [95% confidence interval (*CI*)] of 1.05 (1.01, 1.08), 1.09 (1.06, 1.11), and 1.05 (1.02, 1.08), respectively (Table 2).

In the SHAP analysis derived from the XGBoost model, adjusted for gender, educational stage, and region, blackboard reflectance accounted for the largest contribution to the prediction of poor vision, followed by blackboard illuminance, desk-chair allocation compliance rate, desktop illuminance uniformity, average desktop illuminance, and blackboard illuminance uniformity (Figure 1). Compared to logistic regression, SHAP has methodological advantages in not requiring strict statistical assumptions and better capturing nonlinear relationships and variable interactions.

Sensitivity analyses showed significant effect modification by educational stage, sex, and area. For educational stage, unqualified desk-chair allocation compliance had a stronger association with poor vision in primary school students (P for interaction=0.021); unqualified desktop illuminance uniformity was more pronounced in junior high school students (P for interaction=0.004). Blackboard illuminance uniformity affected females more strongly than males (P for interaction=0.030). Multiple classroom environmental factors displayed marked area interactions: unqualified blackboard illuminance uniformity was associated with increased poor vision risk only in rural areas (P for interaction=0.004); unqualified desktop average illuminance were correlated with higher poor vision risk only in urban areas (P for interaction <0.001). Furthermore, unqualified desktop illuminance uniformity was linked to elevated poor vision risk in urban areas (P for interaction=0.008). Non-optimal blackboard reflectance remained significantly associated with higher odds of poor vision in all subgroups (all $P<0.05$) (Supplementary Tables S1–S3, available at https://weekly.chinacdc.cn/).

DISCUSSION

This large, representative study of more than 180,000 students in Guangdong Province, China, provides compelling evidence that specific classroom environmental conditions are correlated with poor vision in school-aged children. These findings highlight the significance of modifiable school-based exposure in childhood visual impairment. In constrained resource contexts, prioritizing interventions targeting blackboard reflectance and classroom lighting standards may offer substantial ocular health benefits.

TABLE 1. Basic information and the prevalence of poor vision among primary and junior high school students in Guangdong Province, China, 2024 [*N* (%)].

Variables	Overall	Poor vision		*P*
		Yes	No	
Number of participants	180,584 (100.00)	108,741 (60.22)	71,843 (39.78)	
Age, mean (SD)	10.17 (2.61)	10.65 (2.61)	9.45 (2.44)	<0.001
Gender				<0.001
Boy	95,652 (52.97)	53,707 (56.15)	41,945 (43.85)	
Girl	84,932 (47.03)	55,034 (64.80)	29,898 (35.20)	
Education stage				<0.001
Primary school	123,548 (68.42)	66,273 (53.64)	57,275 (46.36)	
Junior high school	57,036 (31.58)	42,468 (74.46)	14,568 (25.54)	
Grade				<0.001
Grade 1	19,940 (11.04)	10,220 (51.25)	9,720 (48.75)	
Grade 2	20,820 (11.53)	9,004 (43.25)	11,816 (56.75)	
Grade 3	20,591 (11.40)	9,463 (45.96)	11,128 (54.04)	
Grade 4	20,458 (11.33)	10,997 (53.75)	9,461 (46.25)	
Grade 5	20,765 (11.50)	12,569 (60.63)	8,196 (39.47)	
Grade 6	20,974 (11.61)	14,020 (66.84)	6,954 (33.16)	
Grade 7	19,889 (11.01)	14,069 (70.74)	5,820 (29.26)	
Grade 8	18,448 (10.22)	13,825 (74.94)	4,623 (25.06)	
Grade 9	18,699 (10.35)	14,574 (77.94)	4,125 (22.06)	
Area				<0.001
Urban	58,264 (32.26)	35,568 (61.05)	22,696 (38.95)	
Rural	122,320 (67.74)	73,173 (59.82)	49,147 (40.18)	

Note: Age is presented as mean (standard deviation, SD).
Abbreviation: *N*=number; SD=standard deviation.

Crucially, this study used a SHAP plot to generate interpretable rankings of the relative contributions of classroom environmental factors to students' poor vision. In our study, optimal blackboard reflectance was the factor most strongly associated with a lower risk of poor vision, with consistent cross subgroup effects. Elevated blackboard reflectance can cause glare and, thus, visual discomfort and impaired performance owing to uneven luminance and extreme contrast (*2*). Glare has two mechanisms: discomfort glare induces frequent pupillary adjustments and visual fatigue (*3*), and disability glare disrupts retinal image quality and diminishes text-background contrast (*4*). Our findings prompt the regulation and optimization of classroom blackboard reflectance, specifically addressing excessive reflectance.

Moreover, students with unqualified desk-chair allocation compliance rates had a significantly higher risk of poor vision, particularly those in primary schools. Reportedly, the prolonged use of ill-fitting desks and chairs among primary school students could lead to abnormal reading and writing postures, hinder adherence to behavioral guidelines, and increase myopia risk (*5*). Primary and junior high school periods involve rapid height growth; thus, insufficient desk-chair adjustments may cause dynamic mismatches. We recommend accelerating the standardized implementation of adjustable desks and chairs to meet the physical growth needs of students.

Furthermore, students with unqualified desktop illuminance uniformity, particularly among junior high school students and those living in urban areas, had a significantly higher risk of poor vision. Notably, substandard desktop illuminance uniformity can increase the risk of screen-detected myopia (*6*). Junior high school students face heavier academic workloads and prolonged near-vision activities in fixed seating positions, which explains their increased susceptibility to this factor. This urban-specific association may be related to heavier academic workloads and longer

TABLE 2. Associations between classroom environmental indicators and students' visual impairment.

Variables	Number of participants (*N*, %)	Crude model		Adjusted model	
		OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
Desk-chair allocation compliance rate			0.001		0.005
Qualified	21,093 (11.68)	1.00		1.00	
Unqualified	159,491 (88.32)	1.05 (1.02, 1.08)		1.05 (1.01, 1.08)	
Blackboard reflectance			<0.001		<0.001
Qualified	64,003 (35.44)	1.00		1.00	
Unqualified	116,581 (64.56)	1.04 (1.02, 1.06)		1.09 (1.06, 1.11)	
Blackboard average illuminance			0.961		0.433
Qualified	136,694 (75.70)	1.00		1.00	
Unqualified	43,890 (24.30)	1.00 (0.98, 1.03)		0.99 (0.96, 1.02)	
Blackboard illuminance uniformity			0.270		0.283
Qualified	147,833 (81.86)	1.00		1.00	
Unqualified	32,751 (18.14)	0.99 (0.96, 1.01)		1.01 (0.99, 1.04)	
Desktop average illuminance			0.185		0.731
Qualified	163,996 (90.81)	1.00		1.00	
Unqualified	16,588 (9.19)	1.03 (0.99, 1.06)		0.99 (0.96, 1.03)	
Desktop illuminance uniformity			<0.001		0.002
Qualified	155,603 (86.17)	1.00		1.00	
Unqualified	24,981 (13.83)	1.06 (1.03, 1.09)		1.05 (1.02, 1.08)	

Note: The model was adjusted for gender, education stage, and urban/rural area.
Abbreviation: *N*=number; *OR*=odds ratio; *CI*=confidence interval.

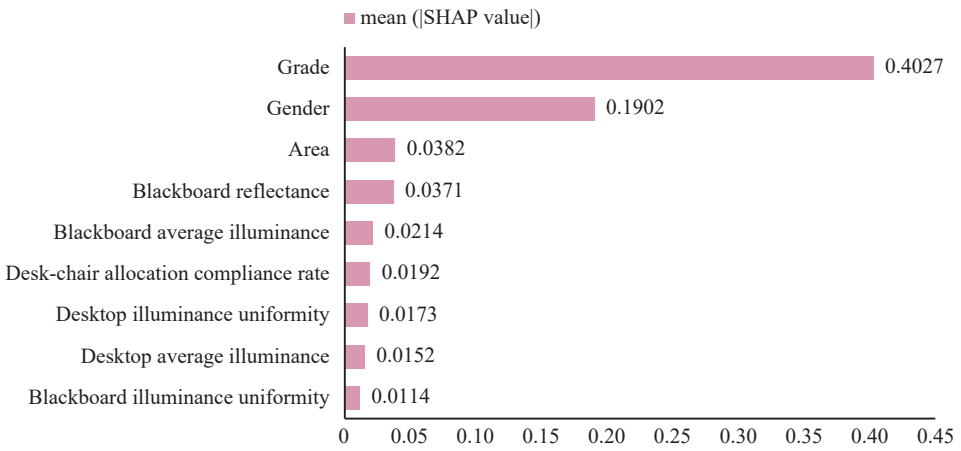

FIGURE 1. SHAP summary plot of variable contributions to the XGBoost model.
Abbreviation: SHAP=Shapley additive explanations; XGBoost=extreme gradient boosting.

classroom-based learning durations in urban schools.

Although the blackboard average illuminance did not reach statistical significance in the multivariable analysis, it ranked second in SHAP importance ordering. Unlike multivariable logistic regression, machine learning methods do not require strict statistical assumptions and can capture nonlinear relationships and interactions (*7*). This advantage aligns with the complexity of real-world classroom environments, where multiple environmental factors interact dynamically rather than acting independently. Thus, with limited resources and the need to pinpoint impactful factors for targeted improvement, SHAP-derived results should be prioritized to guide practical intervention strategies. This discrepancy indicates that blackboard lighting, despite its limited independent impact, likely affects visual health through its interactions with other classroom environmental

factors. Reportedly, substandard average blackboard illuminance increases the risk of screen-detected myopia (*8*).

Marked urban-rural disparities were observed in blackboard illuminance uniformity and desktop average illuminance, with substandard levels correlating with elevated poor vision risk in rural and urban areas, respectively. These differences likely stem from regional resource allocation gaps. Rural schools have historically faced funding shortages, inadequate professional expertise, and insufficient lighting maintenance supervision, directly inducing more severe blackboard illuminance inconsistency and greater adverse visual impacts than their urban counterparts (*9*). Conversely, urban classrooms may have higher baseline lighting levels but stricter demands for stable desktop illuminance, owing to longer indoor study hours.

In resource-constrained rural areas, upgrading blackboard facilities is critical to safeguard students' visual health. SHAP analyses identified blackboard reflectance as the most impactful classroom environmental factor with consistent cross-subgroup effects. However, despite its low overall SHAP-derived impact, blackboard illuminance uniformity's context-specific link to rural students' poor vision risk further supports the necessity of targeted blackboard improvements. In summary, given limited resources, replacing outdated blackboards or upgrading blackboard-specific lighting systems should be prioritized over other measures to improve classroom environments.

Notably, the modest adjusted odds ratios of classroom environmental factors for poor vision do not undermine the public health significance. First, exposure to suboptimal conditions is highly prevalent. For instance, 88.32% of students faced unqualified desk-chair allocation. Given China's large school-aged population, such modest effect sizes can translate to numerous preventable poor vision cases, consistent with the population attributable fraction (PAF) core logic (*10*). Importantly, these factors are highly modifiable and amenable to low-cost interventions. As childhood myopia is a progressive public health concern, even minor population-level risk reduction can generate substantial long-term benefits.

This study has several limitations. First, its cross-sectional design precludes the establishment of a causal relationship between classroom environment and poor vision. Second, residual confounding factors — unmeasured visual health behaviors, genetic factors, and extracurricular activity duration — cannot be fully ruled out. Finally, as a preliminary screening survey, this study calls for future research to incorporate refractive examination data and comprehensive classroom environmental factors to conduct more rigorous and targeted analyses.

In summary, this population-based study provided robust evidence that specific classroom environmental factors are independently associated with poor vision among school-aged children. These findings support targeted environmental interventions, particularly blackboard reflectance regulation, as a priority in school-based myopia prevention strategies. Aligned with China's Comprehensive Implementation Plan for Preventing and Controlling Myopia among Children and Adolescents, we recommend that educational authorities focus on these three indicators and establish multisectoral collaborations to ensure compliance with classroom visual environment standards.

Ethical statement: Granted exemption by the Medical Research Ethics Review Committee of the Guangdong Provincial Center for Disease Control and Prevention due to the use of anonymous information from "Surveillance for common disease and health risk factors among students" in Guangdong Province.

Conflicts of interest: No conflicts of interest.

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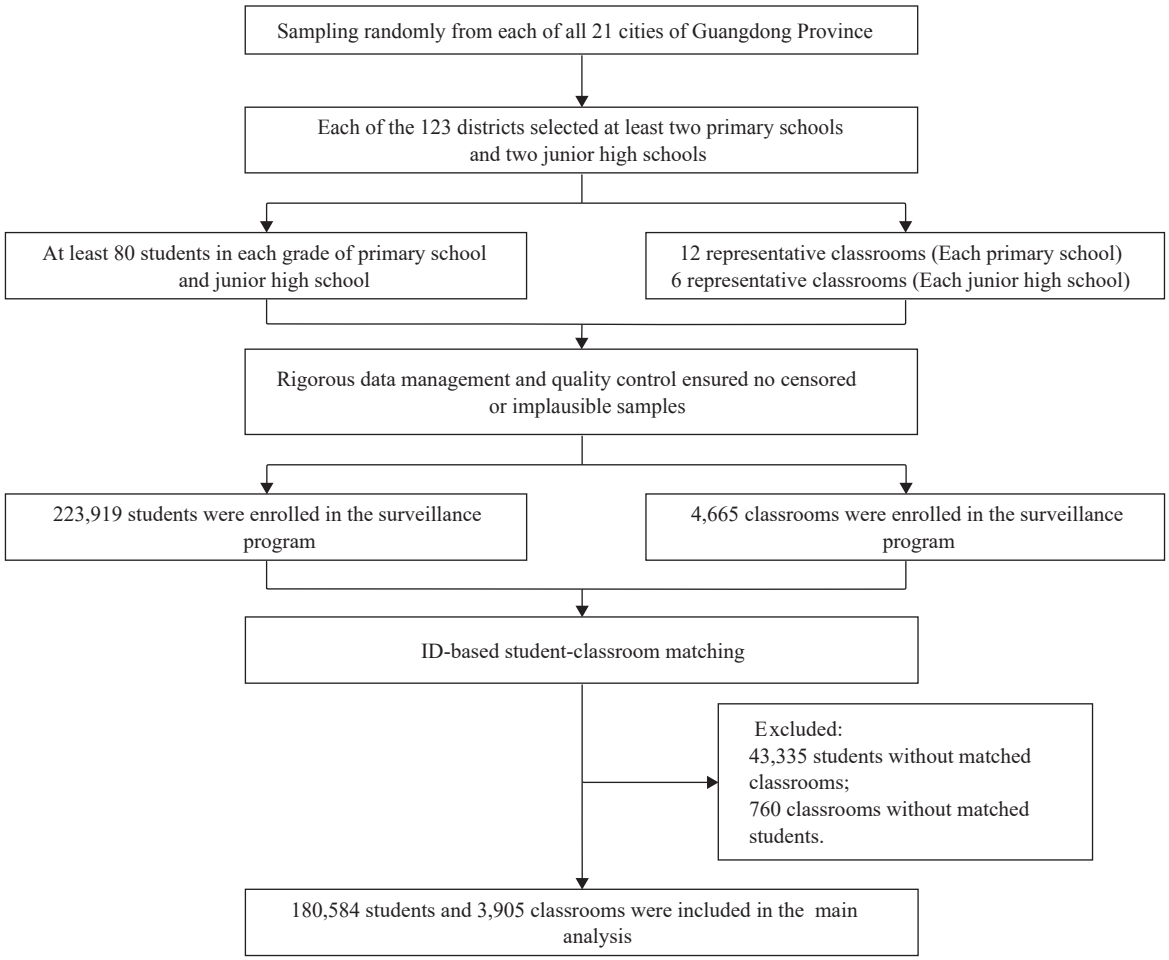
SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. Flowchart of the sampling process in this study.

SUPPLEMENTARY TABLE S1. Association between classroom environmental indicators and students' visual impairment, stratified by gender.

Variables	Boys		Girls		*P* for interaction
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*	
Desk-chair allocation compliance rate		0.289		0.002	0.057
Qualified	1.00		1.00		
Unqualified	1.02 (0.98, 1.07)		1.08 (1.03, 1.13)		
Blackboard reflectance		<0.001		<0.001	0.846
Qualified	1.00		1.00		
Unqualified	1.08 (1.05, 1.11)		1.09 (1.06, 1.13)		
Blackboard average illuminance		0.693		0.099	0.998
Qualified	1.00		1.00		
Unqualified	1.01 (0.97, 1.04)		0.97 (0.93, 1.01)		
Blackboard illuminance uniformity		0.592		0.030	0.049
Qualified	1.00		1.00		
Unqualified	0.99 (0.96, 1.03)		1.04 (1.00, 1.08)		
Desktop average illuminance		0.163		0.311	0.087
Qualified	1.00		1.00		
Unqualified	0.96 (0.92, 1.01)		1.03 (0.97, 1.09)		
Desktop illuminance uniformity		0.096		0.005	0.179
Qualified	1.00		1.00		
Unqualified	1.03 (0.99, 1.07)		1.06 (1.02, 1.11)		

Abbreviation: *OR*=odds ratio; *CI*=confidence interval.

SUPPLEMENTARY TABLE S2. Association between classroom environmental indicators and students' visual impairment, stratified by education stage.

Variables	Primary school		Junior high school		*P* for interaction
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*	
Desk-chair allocation compliance rate		<0.001		0.602	0.021
Qualified	1.00		1.00		
Unqualified	1.07 (1.03, 1.11)		0.98 (0.93, 1.04)		
Blackboard reflectance		<0.001		0.004	0.145
Qualified	1.00		1.00		
Unqualified	1.10 (1.07, 1.12)		1.06 (1.02, 1.10)		
Blackboard average illuminance		0.829		0.060	0.436
Qualified	1.00		1.00		
Unqualified	1.00 (0.97, 1.03)		0.95 (0.90, 1.00)		
Blackboard illuminance uniformity		0.218		0.847	0.404
Qualified	1.00		1.00		
Unqualified	1.02 (0.99, 1.05)		1.01 (0.95, 1.06)		
Desktop average illuminance		0.184		0.169	0.160
Qualified	1.00		1.00		
Unqualified	0.97 (0.93, 1.01)		1.05 (0.98, 1.14)		
Desktop illuminance uniformity		0.295		<0.001	0.004
Qualified	1.00		1.00		
Unqualified	1.02 (0.98, 1.05)		1.13 (1.07, 1.20)		

Abbreviation: *OR*=odds ratio; *CI*=confidence interval.

SUPPLEMENTARY TABLE S3. Associations between classroom environmental indicators and students' visual impairment, stratified by area.

Variables	Urban		Rural		*P* for interaction
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*	
Desk-chair allocation compliance rate					0.227
Qualified	1.00		1.00		
Unqualified	1.01 (0.95, 1.06)	0.752	1.05 (1.02, 1.09)	0.004	
Blackboard reflectance					0.090
Qualified	1.00		1.00		
Unqualified	1.04 (1.01, 1.09)	0.016	1.10 (1.07, 1.12)	<0.001	
Blackboard average illuminance					0.851
Qualified	1.00		1.00		
Unqualified	0.96 (0.92, 1.01)	0.169	1.01 (0.98, 1.04)	0.515	
Blackboard illuminance uniformity					0.004
Qualified	1.00		1.00		
Unqualified	0.94 (0.90, 0.99)	0.021	1.03 (1.01, 1.06)	0.021	
Desktop average illuminance					<0.001
Qualified	1.00		1.00		
Unqualified	1.10 (1.02, 1.18)	0.009	0.95 (0.90, 0.99)	0.014	
Desktop illuminance uniformity					0.008
Qualified	1.00		1.00		
Unqualified	1.10 (1.04, 1.16)	< 0.001	1.02 (0.98, 1.05)	0.266	

Abbreviation: *OR*=odds ratio; *CI*=confidence interval.

Preplanned Studies

Prevalence and Influencing Factors of Myopia Among Primary and Secondary School Students — Zhejiang Province, China, 2023

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Summary

What is already known about this topic?

Myopia prevalence among Chinese children and adolescents ranks among the highest globally. Although numerous studies have investigated myopia risk factors, findings remain inconsistent across populations.

What is added by this report?

This study demonstrates that overall myopia prevalence among primary and secondary school students in Zhejiang Province reached 68.87% in 2023, with high myopia affecting 5.82% of students. Notably, regular consumption of a meat and egg-based breakfast emerged as a protective factor against myopia [odds ratio (*OR*)=0.96, 95% confidence interval (*CI*): 0.92, 0.99].

What are the implications for public health practice?

Effective myopia prevention requires intersectoral collaboration to reduce academic burden, promote outdoor activities, and implement early screening programs with targeted interventions for high-risk children.

ABSTRACT

Introduction: Myopia prevalence is rising globally, with particularly high rates observed in East Asia. This study evaluated the prevalence and associated factors of myopia among primary and secondary school students in Zhejiang Province, China.

Methods: A total of 192,704 students from 521 primary and secondary schools in Zhejiang Province were enrolled through multistage stratified cluster sampling as participants in the School-Based Chinese Adolescents' Health Survey (SCAHS) in 2023. All participants underwent comprehensive ophthalmic examinations. Demographic characteristics, parental myopia status, visual and lifestyle behaviors, and dietary habits were collected through structured questionnaires.

Results: The overall myopia prevalence among primary and secondary school students in Zhejiang Province was 68.87%, with a high myopia prevalence of 5.82%. Multilevel logistic regression analysis demonstrated that female sex, parental myopia, higher body mass index (BMI), an advanced school stage, homework duration ≥3 hours per day, and prolonged sedentary behavior were significantly associated with increased myopia risk. Conversely, residence in suburban counties, outdoor rest after class, outdoor exercise ≥3 hours per day, and vegetable intake ≥twice per day were associated with reduced myopia risk. Notably, consuming a meat and egg-based breakfast [odds ratio (*OR*)=0.96, 95% confidence interval (*CI*): 0.92, 0.99] emerged as a protective factor against myopia.

Conclusions: Myopia prevalence remains high among primary and secondary school students in Zhejiang Province, China. Future prevention efforts should prioritize early screening and targeted interventions for high-risk children and adolescents.

Myopia represents one of the most prevalent eye diseases globally, with its burden continuing to escalate (*1*). Projections indicate that by 2050, the global prevalence of myopia will reach 50% (approximately 5 billion individuals), with high myopia affecting 10% (approximately 1 billion individuals) (*2*). Asian children and adolescents experience the highest myopia rates, with an estimated 80% of school-aged children affected (*1*). In China, the 2022 overall myopia prevalence among children and adolescents was 51.9%, demonstrating a marked progression across educational stages: 36.7% in primary school, 71.4% in junior high school, and 81.2% in senior high school (*3*). Beyond

refractive error alone, the rapid increase in myopia prevalence parallels rising rates of vision-threatening complications, including macular degeneration, glaucoma, and blindness (*4*), thereby imposing substantial economic burdens on healthcare systems and society. Despite extensive research on myopia prevalence, regional variations and modifiable risk factors remain incompletely characterized, particularly in high-burden provinces. This study therefore investigated the prevalence and associated factors of myopia among primary and secondary school students in Zhejiang Province, China, to inform targeted prevention and early intervention strategies.

This cross-sectional study utilized data from the 2023 School-based Chinese Adolescents' Health Survey (SCAHS) conducted in Zhejiang Province. We employed a multistage stratified cluster random sampling method to obtain a representative sample of children and adolescents aged 6 to 21 years. The first stage involved stratification by urban districts and suburban counties within each city. From each urban district, we randomly selected two primary schools, two junior high schools, and three senior high schools, whereas from each suburban county, we randomly selected two primary schools, two junior high schools, and one senior high school. In the second stage, we randomly selected multiple classes from each grade within the chosen schools and enrolled all students from these selected classes. Sample size was calculated using the formula ($N = Z^2_{\alpha/2} \cdot P \cdot (1-P)/\delta^2$), with the expected myopia prevalence (P) set at 0.519 (*3*), α at 0.05, and the allowable error (δ) at 0.1P. Accounting for an expected non-response rate of 20%, the minimum required sample size was determined to be 428 participants. Ultimately, 193,823 children and adolescents from 521 schools across 11 cities participated in the survey, providing a representative assessment of myopia status among primary and secondary school students in Zhejiang Province.

Trained ophthalmologists performed refractive examinations using an automatic refractometer (RM-800, TOPCON, Tokyo, Japan). The spherical equivalent (SE) was calculated as the spherical power plus half of the cylindrical power (SE=sphere+1/2 cylinder). Myopia was defined as SE≤–0.50 D, and high myopia as SE≤–6.00 D. Weight was measured with an electronic scale (accuracy: 0.1 kg) and height with a stadiometer (accuracy: 0.1 cm). Body mass index (BMI) was calculated as weight divided by the square of height (kg/m^2). All participants were confirmed to be free of systemic diseases and ocular disorders through medical history review and clinical examination. Trained researchers administered a structured questionnaire to collect demographic, behavioral, and dietary data. Demographic variables included sex, age, nationality (Han/non-Han), school stage (primary school/junior high school/senior high school), and region (urban district/suburban county, based on 2023 administrative divisions of Zhejiang Province). Parental myopia status was categorized as none, one parent with myopia, or both parents with myopia. Behavioral variables encompassed daily homework load (<3 hours/≥3 hours), daily screen time duration (hours), performance of eye exercises (yes/no), break intervals for near work (<3 hours/≥3 hours, defined as the continuous duration of writing or reading before taking a break), after-class rest location (indoors/outdoors), daily outdoor activity duration (<3 hours/≥3 hours), daily sleep duration (hours), daily sedentary time (hours), and secondhand smoke exposure (yes/no). Dietary variables assessed intake frequency over the past 7 days for sugary drinks, fried foods, milk and soy drinks (never/<once per day/≥once per day), fruits and vegetables (never/<twice per day/≥ twice per day), and breakfast composition including grains and tubers (yes/no), meat and eggs (yes/no), and dairy products (yes/no). After excluding 1,119 participants with unavailable refractive data, 192,704 participants were included in the final analysis, of whom 138,330 completed valid questionnaires.

Statistical analyses were performed using R statistical software (version 4.4.1, R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were presented as mean ± standard deviation, while categorical variables were expressed as frequency (percentage). Independent samples *t*-tests, Welch *t*-tests, and chi-square tests were employed to compare differences between myopia and non-myopia groups (Supplementary Tables S1 and S2, available at https://weekly.chinacdc.cn/). To account for the hierarchical data structure — with students nested within schools and schools nested within cities — we applied multilevel logistic regression models with random intercepts at both the school and city levels to identify factors associated with myopia. Multicollinearity was assessed and ruled out by examining variance inflation factors. Effect sizes were reported as odds ratios (*OR*) with 95% confidence intervals (*CI*). Statistical significance was defined as P<0.05.

This study included 192,704 children and adolescents aged 6 to 21 years (mean age: 11.85±3.47

years), comprising 101,527 males and 91,177 females. The overall myopia prevalence was 68.87%, with high myopia affecting 5.82% of participants. Females demonstrated a significantly higher myopia rate (70.94%) compared to males (67.01%, *P*<0.001). Myopia prevalence increased markedly with age, rising from 24.23% at age 6 years to 93.20% at 18 years and older (*P*<0.001). Significant differences in myopia prevalence were observed across educational stages: 51.04% in primary school, 85.36% in junior high school, and 92.71% in senior high school (*P*<0.001). Notable variation was observed in myopia rates across cities in Zhejiang Province. Hangzhou exhibited the highest prevalence (72.42%), followed by Quzhou (72.18%), whereas Wenzhou (64.93%), Jinhua (65.60%), and Lishui (67.04%) demonstrated comparatively lower rates. Urban districts (70.43%) had significantly higher myopia rates than suburban counties (67.53%, *P*<0.001) (Figure 1 and Table 1).

Multiple multilevel logistic regression analyses demonstrated that myopia risk was significantly elevated in females compared to males (*OR*=1.37, 95% *CI*: 1.33, 1.41). Children with one myopic parent exhibited increased risk (*OR*=1.64, 95% *CI*: 1.58, 1.70), while those with both parents myopic showed substantially higher risk (*OR*=2.60, 95% *CI*: 2.47, 2.73) relative to children with non-myopic parents. Compared to primary school students, myopia risk was markedly higher among junior high school students (*OR*=2.87, 95% *CI*: 2.61, 3.15) and senior high school students (*OR*=7.03, 95% *CI*: 6.31, 7.83). Several modifiable factors were associated with increased myopia risk, including higher BMI (*OR*=1.05, 95% *CI*: 1.03, 1.06), homework duration ≥3 hours per day (*OR*=1.07, 95% *CI*: 1.01, 1.13), and prolonged sedentary time (*OR*=1.05, 95% *CI*: 1.03, 1.07). Conversely, several protective factors were identified. Students residing in suburban counties demonstrated lower myopia risk than those in urban districts (*OR*=0.80, 95% *CI*: 0.69, 0.93). Children who rested outdoors after class had reduced risk compared to those resting indoors (*OR*=0.94, 95% *CI*: 0.91, 0.97). Additional protective factors included outdoor activities ≥3 hours per day (*OR*=0.95, 95% *CI*: 0.92, 0.98), vegetable intake ≥twice per day (*OR*=0.92, 95% *CI*: 0.86, 0.99), and consuming a meat and egg-based breakfast (*OR*=0.96, 95% *CI*: 0.92, 0.99) (Table 2). The multilevel model revealed substantial clustering effects, with a random intercept variance of 0.171 (95% *CI*: 0.145, 0.201) at the school level and 0.010 (95% *CI*: 0.005, 0.027) at the city level, confirming significant variability across both hierarchical levels.

DISCUSSION

In 2023, the overall myopia prevalence among primary and secondary school students in Zhejiang Province reached 68.87%, with high myopia affecting 5.82% of students. This prevalence substantially exceeds that reported in Hubei Province (34.35% among children aged 3–18 years) (*5*) but aligns closely with findings from Shaanxi Province (67.4%, with high myopia at 4.6%) (*6*), demonstrating considerable

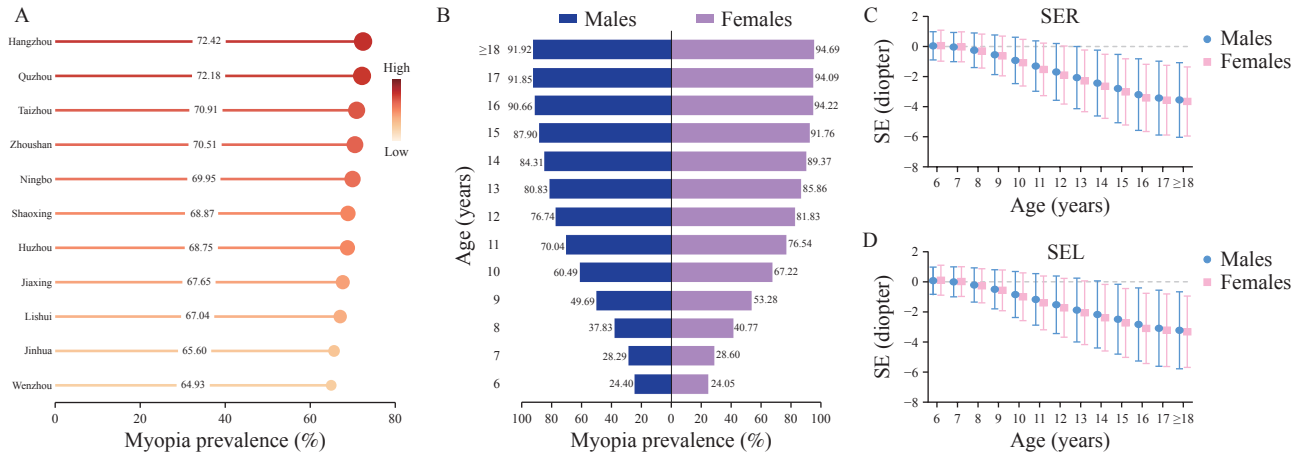

FIGURE 1. Epidemiological characteristics of myopia among primary and secondary school students in Zhejiang Province, China, 2023. (A) Myopia prevalence across different cities; (B) Myopia prevalence stratified by sex and age groups; (C) Refractive distribution of the right eye by sex and age groups; (D) Refractive distribution of the left eye by sex and age groups.
Abbreviation: SER=spherical equivalent right; SEL=spherical equivalent left.

TABLE 1. Prevalence of myopia and refractive status among primary and secondary school students in Zhejiang Province, China, 2023.

Variables	Count	Myopia [*n* (%)]	High myopia [*n* (%)]	SER (D)	SEL (D)
Total	192,704	132,722 (68.87)	11,216 (5.82)	−1.71±2.21	−1.54±2.18
Sex					
Male	101,527	68,038 (67.01)	5,725 (5.64)	−1.64±2.20	−1.47±2.17
Female	91,177	64,684 (70.94)	5,491 (6.02)	−1.79±2.21	−1.62±2.19
Age (years)					
6	6,582	1,595 (24.23)	14 (0.21)	0.05±0.98	0.09±0.95
7	20,098	5,716 (28.44)	52 (0.26)	−0.03±0.98	0.01±0.99
8	15,654	6,138 (39.21)	56 (0.36)	−0.27±1.14	−0.23±1.14
9	17,643	9,060 (51.35)	76 (0.43)	−0.58±1.32	−0.53±1.32
10	15,405	9,807 (63.66)	154 (1.00)	−0.99±1.55	−0.92±1.56
11	16,760	12,254 (73.11)	300 (1.79)	−1.40±1.71	−1.28±1.75
12	15,810	12,513 (79.15)	505 (3.19)	−1.78±1.91	−1.62±1.94
13	16,223	13,490 (83.15)	890 (5.49)	−2.16±2.06	−1.96±2.12
14	16,166	14,018 (86.71)	1,329 (8.22)	−2.53±2.16	−2.27±2.22
15	14,916	13,385 (89.74)	1,580 (10.59)	−2.90±2.24	−2.60±2.31
16	14,580	13,469 (92.38)	2,111 (14.48)	−3.30±2.31	−2.96±2.39
17	13,851	12,874 (92.95)	2,403 (17.35)	−3.49±2.39	−3.15±2.47
≥18*	9,016	8,403 (93.20)	1,736 (19.25)	−3.60±2.40	−3.26±2.47
School stage					
Primary school	101,578	51,842 (51.04)	889 (0.88)	−0.68±1.50	−0.61±1.49
Junior high school	49,007	41,833 (85.36)	3,407 (6.95)	−2.38±2.13	−2.15±2.19
Senior high school	42,119	39,047 (92.71)	6,920 (16.43)	−3.42±2.36	−3.08±2.44
Region					
Urban districts	89,223	62,844 (70.43)	5,818 (6.52)	−1.82±2.26	−1.64±2.24
Suburban counties	103,481	69,878 (67.53)	5,398 (5.22)	−1.62±2.15	−1.46±2.13

Abbreviation: SER=spherical equivalent right; SEL=spherical equivalent left; D=diopter.
* The maximum age was 21 years.

regional variation across China. Internationally, Zhejiang's myopia rates markedly surpass those observed in Western countries, where prevalence ranges from 3.3% to 19.9% in Ireland (*7*). These disparities likely reflect regional differences in genetic susceptibility, educational systems, academic pressure, lifestyle behaviors, and socioeconomic conditions.

Our findings are consistent with previous studies (*5*,*8*). Elevated myopia risk was associated with female sex, parental myopia, higher BMI, an advanced school stage, homework duration ≥3 hours, and prolonged sedentary behavior. Conversely, protective factors included residence in suburban counties, outdoor rest after class, ≥3 hours of outdoor activity per day, and vegetable intake ≥twice per day. Collectively, these findings underscore the critical influence of genetic, academic, and lifestyle factors on myopia development among children and adolescents. Accordingly, myopia prevention and control strategies should prioritize female students, implement early targeted interventions for children with myopic parents, reduce academic workload, and promote outdoor activities and physical exercise.

A particularly noteworthy finding was that consuming a meat and egg-based breakfast was associated with reduced myopia risk (*OR*=0.96, 95% *CI*: 0.92, 0.99). This protective effect may be explained by the high-quality protein content of meat and eggs. Supporting this interpretation, Yin et al. (*8*) reported that a protein-rich dietary pattern significantly reduced myopia risk in Chinese children (*OR*=0.78, 95% *CI*: 0.66, 0.92). Current evidence indicates that the scleral extracellular matrix (ECM) remodeling represents a key pathological mechanism underlying myopia onset

TABLE 2. Regression analysis of factors associated with myopia.

Variables	Simple analysis		Multiple analysis	
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
Sex				
Male	Ref.		Ref.	
Female	1.23 (1.20, 1.26)	<0.001	1.37 (1.33, 1.41)	<0.001
BMI (per 1 SD)*	1.26 (1.24, 1.27)	<0.001	1.05 (1.03, 1.06)	<0.001
Nationality				
Han	Ref.		Ref.	
Non-Han	0.89 (0.83, 0.95)	<0.001	0.99 (0.90, 1.09)	0.779
School stage				
Primary school	Ref.		Ref.	
Junior high school	5.86 (5.36, 6.41)	<0.001	2.87 (2.61, 3.15)	<0.001
Senior high school	13.44 (12.19, 14.82)	<0.001	7.03 (6.31, 7.83)	<0.001
Region				
Urban districts	Ref.		Ref.	
Suburban counties	0.82 (0.68, 1.00)	0.053	0.80 (0.69, 0.93)	0.022
Parental myopia status				
None	Ref.		Ref.	
One parent	1.65 (1.59, 1.70)	<0.001	1.64 (1.58, 1.70)	<0.001
Both parents	2.60 (2.47, 2.73)	<0.001	2.60 (2.47, 2.73)	<0.001
Homework				
<3 hours	Ref.		Ref.	
≥3 hours	1.10 (1.05, 1.16)	<0.001	1.07 (1.01, 1.13)	0.013
Screen time (per 1 SD)*	1.22 (1.19, 1.24)	<0.001	0.99 (0.97, 1.00)	0.163
Eye exercises				
No	Ref.		Ref.	
Yes	0.94 (0.85, 1.05)	0.285	0.98 (0.87, 1.11)	0.762
Near-work break interval				
<3 hours	Ref.		Ref.	
≥3 hours	1.04 (0.98, 1.11)	0.218	1.05 (0.97, 1.13)	0.243
Resting place				
Indoors	Ref.		Ref.	
Outdoors	0.87 (0.85, 0.90)	<0.001	0.94 (0.91, 0.97)	<0.001
Outdoor activity				
<3 hours	Ref.		Ref.	
≥3 hours	0.93 (0.90, 0.96)	<0.001	0.95 (0.92, 0.98)	0.035
Sleep duration (per 1 SD)*	0.98 (0.96, 0.99)	0.026	1.02 (1.00, 1.04)	0.051
Sedentary time (per 1 SD)*	1.10 (1.08, 1.11)	<0.001	1.05 (1.03, 1.07)	<0.001
Sugary drinks				
Never	Ref.		Ref.	
<Once per day	1.08 (1.01, 1.17)	0.033	1.02 (0.93, 1.11)	0.711
≥Once per day	1.09 (1.00, 1.18)	0.048	1.02 (0.93, 1.12)	0.707
Fried foods				
Never	Ref.		Ref.	

Continued

Variables	Simple analysis		Multiple analysis	
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
<Once per day	1.03 (1.00, 1.07)	0.087	1.00 (0.96, 1.05)	0.847
≥Once per day	0.99 (0.92, 1.07)	0.872	1.00 (0.91, 1.09)	0.930
Fresh fruits				
Never	Ref.		Ref.	
<Twice per day	0.99 (0.96, 1.02)	0.579	0.99 (0.95, 1.03)	0.677
≥Twice per day	0.96 (0.90, 1.02)	0.216	0.99 (0.91, 1.07)	0.725
Vegetables				
Never	Ref.		Ref.	
<Twice per day	0.99 (0.92, 1.04)	0.639	0.97 (0.90, 1.03)	0.361
≥Twice per day	0.92 (0.86, 0.98)	0.011	0.92 (0.86, 0.99)	0.023
Grains and tubers				
No	Ref.		Ref.	
Yes	1.07 (1.04, 1.10)	<0.001	1.02 (0.99, 1.05)	0.279
Meat and eggs				
No	Ref.		Ref.	
Yes	0.96 (0.93, 1.00)	0.013	0.96 (0.92, 0.99)	0.032
Dairy products				
No	Ref.		Ref.	
Yes	1.00 (0.97, 1.03)	0.962	0.98 (0.95, 1.01)	0.168

Abbreviation: *OR*=odds ratio; *CI*=confidence interval; BMI=body mass index; SD=standard deviation.
* Continuous variables were z-score standardized, and *ORs* are reported per one standard deviation increase.

and progression, with collagen — the major ECM component — playing a critical role in scleral remodeling (*9*). Consequently, increased protein intake may mitigate myopia development by promoting scleral collagen synthesis. Furthermore, monitoring data from 101,464 students in Liaoning Province revealed that students who only occasionally consumed breakfast exhibited a 4% higher myopia risk compared to those eating breakfast daily (*OR*=1.04, 95% *CI*: 1.01, 1.08) (*10*). These findings collectively suggest that regular consumption of protein-rich breakfasts, particularly those containing meat and eggs, may serve as a protective factor against myopia in children and adolescents.

Despite its considerable strengths, including a large sample size and broad geographic coverage, this study has several important limitations. First, we employed non-cycloplegic automated refraction rather than cycloplegic refraction, the clinical gold standard, which may have resulted in misclassification of some myopia cases. Second, data on influencing factors were collected via self-reported questionnaires, introducing potential recall and reporting biases. Third, the cross-sectional design only permits inference of associations but not causality. Finally, results may not be generalizable to other regions with different educational and dietary contexts.

In conclusion, our study revealed high myopia prevalence among primary and secondary school students in Zhejiang Province. To effectively prevent myopia, it is essential to strengthen early identification and targeted interventions for susceptible children and adolescents. Additionally, intersectoral collaboration among health, education, and family sectors should be mobilized to establish a comprehensive prevention system. Future longitudinal studies are needed to confirm causal relationships.

Ethical statement: Adhered to the principles of the Declaration of Helsinki and received approval from the Ethics Committee of the Zhejiang Provincial Center for Disease Control and Prevention (Ethics approval number 2024-026-01). Written informed consent was obtained from parents or legal guardians of all participants following comprehensive explanation of the study objectives and methodology.

Conflicts of interest: No conflicts of interest.

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SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. Demographic characteristics of participants.

Variables	Total	Non-myopia	Myopia	*P*
Sex* [*n* (%)]				<0.001
Male	101,527	33,489 (32.99)	68,038 (67.01)	
Female	91,177	26,493 (29.06)	64,684 (70.94)	
Age (years)†	11.85±3.47	9.38±2.79	12.96±3.16	<0.001
Height (cm)†	148.60±21.19	136.21±21.02	154.20±18.75	<0.001
Weight (kg)†	43.83±20.84	33.88±20.24	48.32±19.51	<0.001
BMI (kg/m^2)†	18.98±4.13	17.43±3.60	19.67±4.16	<0.001
SER (D)§	−1.71±2.21	0.31±0.74	−2.62±2.04	<0.001
SEL (D)§	−1.54±2.18	0.36±0.81	−2.40±2.06	<0.001
Nationality* [*n* (%)]				<0.001
Han	187,611	58,128 (30.98)	129,483 (69.02)	
Non-Han	5,093	1,854 (36.40)	3,239 (63.60)	
School stage* [*n* (%)]				<0.001
Primary school	101,578	49,736 (48.96)	51,842 (51.04)	
Junior high school	49,007	7,174 (14.64)	41,833 (85.36)	
Senior high school	42,119	3,072 (7.29)	39,047 (92.71)	
Region* [*n* (%)]				<0.001
Urban districts	89,223	26,379 (29.57)	62,844 (70.43)	
Suburban counties	103,481	33,603 (32.47)	69,878 (67.53)	

Abbreviation: SER=spherical equivalent right; SEL=spherical equivalent left; D=diopter.
* Chi-square test.
† Independent samples *t*-test.
§ Welch *t*-test.

SUPPLEMENTARY TABLE S2. Comparison of factors between myopia and non-myopia participants [*n* (%)].

Variables	Total	Non-myopia	Myopia	*P*
Parental myopia status*				<0.001
None	69,329	14,869 (21.45)	54,460 (78.55)	
One parent	46,996	7,534 (16.03)	39,462 (83.97)	
Both parents	22,005	2,622 (11.92)	19,383 (88.08)	
Homework*				<0.001
<3 hours	114,398	22,179 (19.39)	92,219 (80.61)	
≥3 hours	19,780	2,181 (11.03)	17,599 (88.97)	
Unknown	4,152	665 (16.02)	3,487 (83.98)	
Screen time†	1.03±1.91	0.89±1.83	1.07±1.93	<0.001
Eye exercises*				<0.001
No	4,596	497 (10.81)	4,099 (89.19)	
Yes	133,734	24,528 (18.34)	109,206 (81.66)	
Near-work break interval*				<0.001
<3 hours	130,011	23,838 (18.34)	106,173 (81.66)	
≥3 hours	8,319	1,187 (14.27)	7,132 (85.73)	

Continued

Variables	Total	Non-myopia	Myopia	*P*
Resting place*				<0.001
Indoors	103,276	17,506 (16.95)	85,770 (83.05)	
Outdoors	35,054	7,519 (21.45)	27,535 (78.55)	
Outdoor activity*				<0.001
<3 hours	113,615	20,357 (17.92)	93,258 (82.08)	
≥3 hours	16,109	3,174 (19.70)	12,935 (80.30)	
Unknown	8,606	1,494 (17.36)	7,112 (82.64)	
Sleep duration†	8.13±1.30	8.50±1.27	8.04±1.29	<0.001
Sedentary time†	5.57±4.51	4.46±4.08	5.81±4.56	<0.001
Secondhand smoke*				0.354
No	74,953	13,493 (18.00)	61,460 (82.00)	
Yes	63,377	11,532 (18.20)	51,845 (81.80)	
Sugary drinks*				<0.001
Never	33,451	6,597 (19.72)	26,854 (80.28)	
<Once per day	94,269	16,821 (17.84)	77,448 (82.16)	
≥Once per day	10,610	1,607 (15.15)	9,003 (84.85)	
Fried foods*				<0.001
Never	29,031	5,823 (20.06)	23,208 (79.94)	
<Once per day	102,573	18,181 (17.72)	84,392 (82.28)	
≥Once per day	6,726	1,021 (15.18)	5,705 (84.82)	
Fresh fruits*				<0.001
Never	5,994	1,024 (17.08)	4,970 (82.92)	
<Twice per day	112,134	19,920 (17.76)	92,214 (82.24)	
≥Twice per day	20,202	4,081 (20.20)	16,121 (79.80)	
Vegetables*				<0.001
Never	10,881	1,905 (17.51)	8,976 (82.49)	
<Twice per day	40,789	7,144 (17.51)	33,645 (82.49)	
≥Twice per day	86,660	15,976 (18.44)	70,684 (81.56)	
Milk and soy drinks*				0.065
Never	4,822	884 (18.33)	3,938 (81.67)	
<Once per day	47,354	8,408 (17.76)	38,946 (82.24)	
≥Once per day	86,154	15,733 (18.26)	70,421 (81.74)	
Grains and tubers*				<0.001
No	43,443	8,187 (18.85)	35,256 (81.15)	
Yes	94,887	16,838 (17.75)	78,049 (82.25)	
Meat and eggs*				<0.001
No	68,704	12,045 (17.53)	56,659 (82.47)	
Yes	69,626	12,980 (18.64)	56,646 (81.36)	
Dairy products*				<0.001
No	40,998	7,185 (17.53)	33,813 (82.47)	
Yes	97,332	17,840 (18.33)	79,492 (81.67)	

* Chi-square test.
† Independent samples *t*-test.

Outbreak Reports

Investigation of an Infectious Diarrhea Outbreak Associated with Direct Drinking Water in a High School — Baisha County, Hainan Province, China, November 2024

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Summary

What is already known about this topic?

Diarrheagenic *Escherichia coli* (DEC) represents a major causative agent of diarrheal outbreaks in China. Transmission occurs through consumption of contaminated food or drinking water and through person-to-person contact, frequently resulting in clustered infections.

What is added by this report?

Between November 6 and 20, 2024, an outbreak of infectious diarrhea affected 344 students at a high school in Baisha County, Hainan Province. Comprehensive field epidemiological and environmental investigations, combined with laboratory testing, identified DEC as the causative agent. This outbreak was primarily attributed to consumption of direct drinking water supplied by substandard water dispensers that inadequately filtered contaminated municipal water.

What are the implications for public health practice?

Substandard direct drinking water dispensers equipped only with polypropylene (PP) cotton and activated carbon filters cannot effectively remove microorganisms. When source water is contaminated, the warm water produced by mixing cold and hot water outputs from such dispensers fails to meet required hygienic standards. Ensuring municipal drinking water compliance and strict implementation of quality and safety management regulations for direct drinking water dispensers are therefore essential for drinking water safety. The public and all relevant sectors should be reminded to purchase and use only qualified direct drinking water dispensers, particularly in schools, collective establishments, and public venues.

ABSTRACT

Introduction: This study investigated the causes and transmission pathways of an infectious diarrhea outbreak at a high school in Baisha County during November 2024 to inform response strategies for similar outbreaks.

Methods: Field epidemiological methods were employed to investigate and characterize the outbreak's epidemic features, while risk factors were analyzed through a case-control study. Case specimens underwent multipathogen polymerase chain reaction (PCR) chip screening combined with real-time fluorescent PCR to identify the causative pathogen. Reserved cafeteria food samples were tested for diarrheagenic *Escherichia coli* (DEC)-specific virulence genes using real-time fluorescent PCR. Environmental water samples were analyzed by the culture method (*1*) to quantify total bacterial count, total coliforms, and *Escherichia coli*.

Results: A total of 344 cases were identified, yielding an attack rate of 11.44%. The most common clinical manifestations were diarrhea (80.23%) and abdominal pain (76.74%). Attack rates showed no statistically significant differences by gender or between boarding and day students (P>0.05). Case-control analysis demonstrated that consumption of school-provided direct drinking water was the primary risk factor for illness (odds ratio=3.87, 95% confidence interval: 1.18, 12.68). Laboratory testing identified DEC in both patient specimens and inlet tap water samples from the dispensers; the DEC positivity rate in patient specimens reached 63.3% (19/30), with escV and pic+astA as the predominant virulence genes (either singly or in combination). Hygienic surveys revealed that the school's direct drinking water dispensers failed to meet required standards; after these dispensers were deactivated, the incidence of new cases declined markedly.

Conclusion: This outbreak was caused by DEC. The primary transmission route was consumption of direct drinking water supplied by substandard dispensers

using contaminated source water, with person-to-person transmission occurring during the later stages of the outbreak.

On November 12, 2024, the Baisha County CDC received notification from the County Education Bureau regarding multiple students at a local high school presenting with diarrhea and vomiting. County CDC public health professionals were promptly dispatched to the school for on-site verification. Rectal swabs collected from affected patients were analyzed using a multiplex pathogen polymerase chain reaction (PCR) array, with results confirming the presence of diarrheagenic *Escherichia coli* (DEC). To enable comprehensive source tracing and outbreak containment, six technical specialists from the provincial CDC were deployed on November 15 to conduct a joint field investigation.

INVESTIGATION AND RESULTS

The affected senior high school in Baisha County has 60 classes across three grades, with a total of 3,006 students enrolled and 308 faculty and staff members, including one school doctor. Beginning November 6, 2024, acute gastroenteritis cases emerged sporadically, followed by a sharp increase in case numbers.

We defined a suspected case as diarrhea (≥3 episodes/24 hours) and/or vomiting (≥2 episodes/24 hours) with onset on or after November 4, 2024, in the school community. A confirmed case required laboratory detection of DEC in a relevant clinical specimen. Cases were identified by cross-referencing school reports with student absenteeism records, medical consultation logs, and interviews with school and cafeteria personnel.

A total of 344 ill students were identified, with an attack rate of 11.44%. The predominant clinical manifestations were diarrhea (80.23%, 276/344), abdominal pain (76.74%, 264/344), nausea (60.76%, 209/344), and vomiting (44.48%, 153/344). Most cases experienced 3 episodes of diarrhea daily (44.77%), followed by 4 episodes daily (17.44%), with 5–8 episodes daily accounting for 18.02%. Similarly, vomiting occurred most commonly at 2 episodes daily (26.45%), followed by 3 episodes daily (10.47%), with 4–6 episodes daily accounting for 7.56%. Fever was uncommon (2.33%, 8/344), and no cases required hospitalization or progressed to severe illness.

The index case developed symptoms at 21:30 on November 6 and was a boarding student from Class 6, Grade 10. This case had no history of dining outside the school or consuming raw food within 3 days prior to onset. The epidemic curve indicated sustained common-exposure transmission, with cases predominantly concentrated between November 11 and 13 (75.87%, 261/344) (Figure 1).

Among the 344 cases, attack rates showed no significant differences by gender (male: 11.89%, n=160; female: 11.08%, n=184) or boarding status (boarders: 12.13%, n=259; day students: 9.75%,

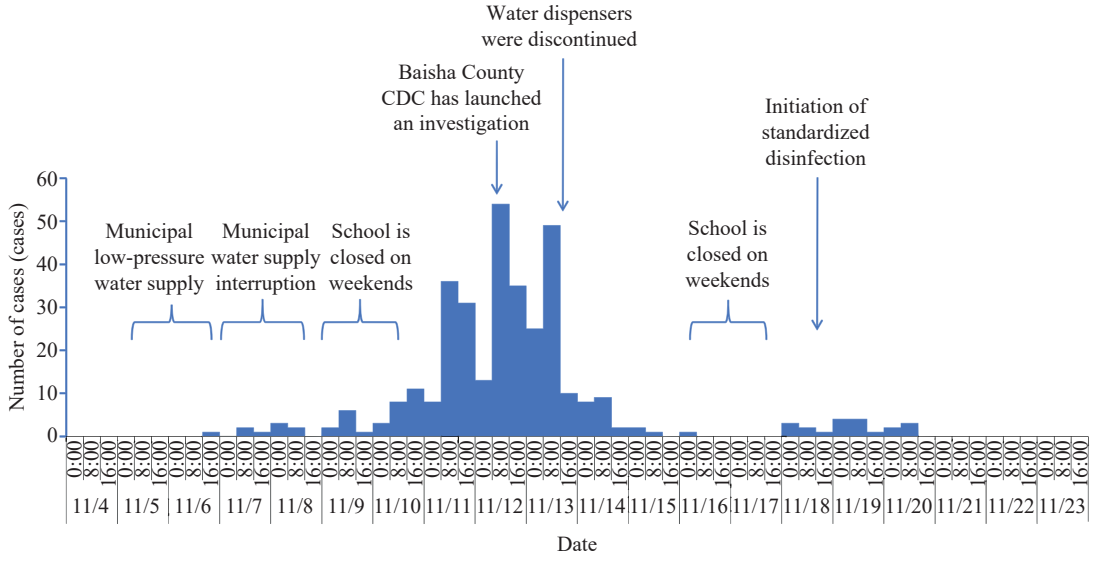

FIGURE 1. Epidemic curve of the infectious diarrhea outbreak at a high school in Baisha County, November 2024.

n=85). Although day students did not consume cafeteria meals, they did drink water from the on-campus dispensers. The absence of statistical significance (*P*>0.05) across these comparisons preliminarily excluded foodborne transmission, identifying direct drinking water as the probable transmission vehicle.

No cases occurred among faculty and staff. Although faculty and staff shared identical cafeteria meals with students at the two on-campus dining facilities, they consumed their own boiled water rather than water from the dispensers used by students. This key distinction further ruled out cafeteria meals as the outbreak source and reinforced the identification of students' drinking water as the likely vehicle of transmission.

Based on the descriptive epidemiological analysis, we conducted a case-control study enrolling 60 early-onset cases matched 1∶1 by age (±1 year) and class with 60 healthy controls. Data were collected using a standardized, purpose-designed questionnaire. Univariate logistic regression analysis confirmed that consumption of direct drinking water constituted a significant risk factor [odds ratio (*OR*)=3.87, 95% confidence interval (*CI*): 1.18, 12.68]. Conversely, no statistical associations were observed between illness and consumption of raw food, cafeteria meals, or boarding status (*P*>0.05) (Table 1).

Environmental investigation revealed that the senior high school received municipal water supply through a pipeline passing beneath the Yacha River. This same water source served a neighboring junior high school and nearby village residents (Figure 2).

The municipal water supply experienced low pressure from November 5 to 6, 2024, followed by complete shutdown from November 7 to 8, 2024. Field testing conducted on November 14 and 17 demonstrated that residual chlorine in endpoint water samples from the school's security office and teaching buildings was undetectable (0 mg/L). Furthermore, the school's direct drinking water dispensers were equipped only with PP cotton, pre-filter carbon, and post-filter carbon filters, lacking the critical ultrafiltration or reverse osmosis membranes necessary for effectively removing bacteria, viruses, and other microorganisms. The filters had not been replaced every 3 to 6 months as required by the instruction manual; instead, only simple cleaning was conducted without thorough disinfection before the start of the semester. Physical inspections revealed severe contamination of the internal filters. The water quality was turbid. The "warm water" supplied to students was produced by mixing filtered cold water with heated water (Figure 3).

To further trace the outbreak source, the investigation team conducted an expanded survey of additional off-campus schools and surrounding communities on November 17. A neighboring junior high school (943 students total) that shared the same municipal water source and utilized the same model of direct drinking water dispensers reported 55 students experiencing symptoms including diarrhea and abdominal pain beginning November 8, yielding an attack rate of 5.83%. One affected student tested positive for DEC during medical consultation. Among 272 residents in the adjacent community, 6 sporadic cases occurred between November 1 and 17, representing a significant increase compared with the same period in the previous month (0 cases). No similar outbreaks were identified in the municipal water supply area upstream of the Yacha River, including schools and communities within that region.

Laboratory testing demonstrated that among 30 rectal swab samples from ill students, 19 tested positive for DEC (positivity rate: 63.3%), with the *uidA* gene detected in all positive samples. The predominant virulence genes identified were *escV* and *pic+astA* (either alone or in combination). Among 43 drinking water samples analyzed, 1 municipal terminal water sample collected from the school's security office on November 14 (before entering the direct drinking water dispensers) tested positive for *Escherichia coli*. Five water samples collected from the filter containers

TABLE 1. Case-control study of an infectious diarrhea outbreak at a high school in Baisha County, November 2024.

Exposure factors	Case group (*n*=60)		Control group (*n*=60)		*P*	*OR* (95% *CI*)
	Cases	Percentage (%)	Cases	Percentage (%)		
Consumption of water from direct drinking water dispensers	56	93.33	47	78.33	0.025	3.872 (1.183, 12.676)
Consumption of raw food	4	6.67	3	5.00	0.698	1.357 (0.290, 6.341)
Consumption of school cafeteria meals	46	76.67	48	80.00	0.658	0.821 (0.344, 1.962)
Boarding status	49	81.67	46	76.67	0.501	1.356 (0.559, 3.289)

Abbreviation: *OR*=odds ratio; *CI*=confidence interval.

FIGURE 2. Spatial configuration of the municipal water distribution infrastructure in Baisha County.

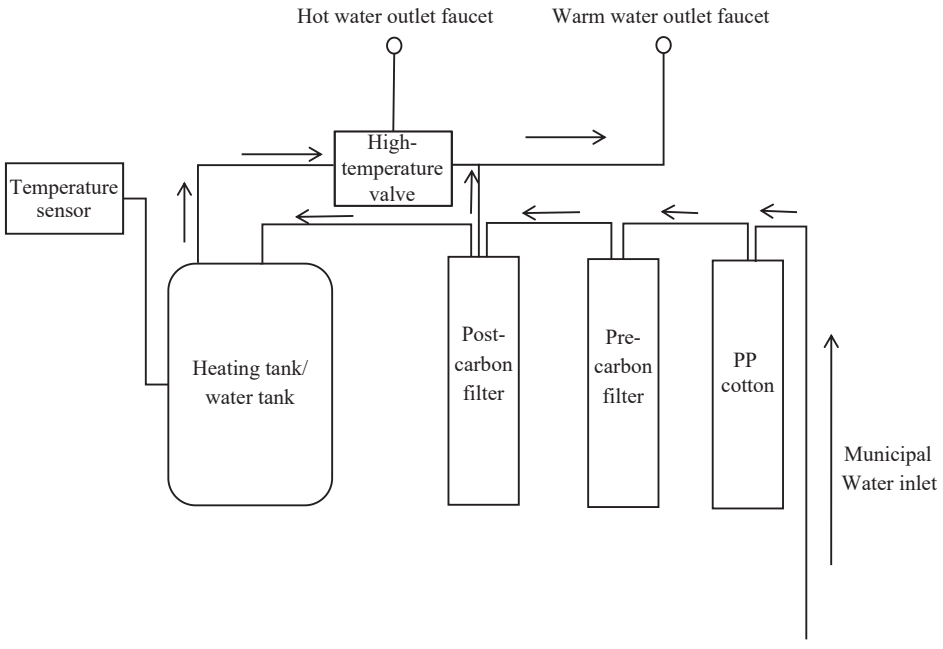

FIGURE 3. Purification process of the water dispensers at a high school in Baisha County, November 2024.
Abbreviation: PP=polypropylene.

of Direct Drinking Water Dispensers No. 1 and No. 2 on the first floor of Teaching Buildings 1 and 2, and Dispenser No. 7 on November 15 and 18 exhibited excessive total bacterial counts. Four water samples

collected on November 18 — including those from a community resident's home, the terminal water of a canteen faucet in the junior high school, and the filter containers of two direct drinking water dispensers on the second floor of the teaching building — demonstrated excessive total coliforms. All 93 reserved food samples from the canteen tested negative for DEC virulence genes.

Following the hypothesis that drinking water contamination was driving the outbreak, the school deactivated all direct drinking water dispensers on November 14, resulting in a sharp decline in new cases. However, because terminal disinfection was not properly implemented in classrooms, dormitories, and toilets according to established standards, 20 additional cases emerged between November 18 and 20 after students returned to school. Among these later cases, 19 had documented contact with diarrheal patients prior to symptom onset: 8 cases shared both classrooms and dormitories with infected students, 3 cases attended the same classes as infected students but resided in different dormitories, 7 cases belonged to different classes but shared toilets on the same floor with infected students, and 1 case had close contact with an infected peer. These epidemiological patterns strongly suggest that person-to-person transmission accounted for these secondary cases.

PUBLIC HEALTH RESPONSE

Case management protocols required a 3-day home isolation for all affected individuals. Substandard direct drinking water dispensers were immediately deactivated, and boiled drinking water from the cafeteria was provided as an alternative. Following the emergence of additional cases on November 18, trained cleaning staff were deployed to perform disinfection of public areas twice daily, while standardized procedures for disposal of students' vomitus and feces were implemented. Concurrently, the daily epidemic reporting system was rigorously enforced, and both health education initiatives and risk communication strategies were intensified. These comprehensive control measures successfully contained the outbreak.

DISCUSSION

Integrated findings from field, environmental, and laboratory investigations confirmed this outbreak as a DEC infection associated with consumption of drinking water supplied by substandard water dispensers that inadequately filtered contaminated municipal water (*2*). The probable contamination source was river water infiltration into the municipal water supply pipeline — which passes beneath a river — during periods of low-pressure water supply and service interruption. Person-to-person transmission subsequently occurred during the later stages of the outbreak. The principal supporting evidence is as follows:

1) Foodborne transmission was definitively excluded. Faculty and staff consumed identical cafeteria meals as students but remained unaffected. Attack rates showed no statistically significant difference between boarding students and day students (who did not consume cafeteria meals). The case-control study revealed no association between specific cafeteria meals or food items and illness onset. Furthermore, all retained food samples from the cafeteria tested negative for DEC.

2) Multiple lines of evidence support waterborne transmission through contaminated drinking water. First, faculty and staff who consumed only boiled water rather than dispenser water remained unaffected, whereas students who consumed dispenser water experienced high attack rates regardless of boarding status. The case-control study identified dispenser water consumption as a significant risk factor for illness. Second, according to relevant standards (*3*), public terminal direct drinking water dispensers should be equipped with high-efficiency purification filter elements such as ultrafiltration membranes or nanofiltration membranes. However, the direct drinking water dispensers in this school were equipped only with PP cotton, pre-filter carbon, and post-filter carbon filters, failing to meet these requirements. Additionally, inadequate maintenance rendered them unable to effectively remove microorganisms. Following deactivation of the direct drinking water dispensers, the number of cases declined sharply. Third, *Escherichia coli* was detected in water samples from the school's security office, and on-site testing revealed zero residual chlorine, indicating that the supplied tap water failed to meet safety standards and that the water source was continuously contaminated. Finally, Jiang Haibo et al. (*4*) demonstrated that intermittent water supply can generate negative pressure in water supply pipelines, and the resulting back-siphonage can allow sewage infiltration from outside the pipeline. Source-tracing investigation

revealed that a neighboring junior high school using the same municipal water source also experienced a similar diarrheal outbreak, suggesting that river water infiltration occurred due to negative pressure during periods of municipal low-pressure water supply and water suspension.

3) Person-to-person transmission was also documented in the later phase of the outbreak. Sporadic cases emerged after November 18, with 95% of these cases having clear contact history with diarrheal cases prior to onset, indicating that interpersonal contact transmission became the primary transmission route for these subsequent cases.

DEC represents a major pathogen responsible for diarrheal outbreaks in China (*5*). It can be transmitted through food, water, and person-to-person contact (*6*–*9*), characterized by rapid onset and a high propensity to cause clustered infections. This investigation confirmed that the outbreak of infectious diarrhea was associated with consumption of drinking water supplied by substandard direct drinking water dispensers that inadequately filtered contaminated tap water.

Similar reports are rare in China. Lu Rutou et al. (*10*) documented in 2006 the only comparable incident — an infectious diarrhea outbreak in a school caused by direct drinking water dispensers that failed to meet hygienic requirements. In that case, filters were neither replaced nor disinfected regularly, receiving only superficial cleaning.

Direct drinking water dispensers are now widely deployed in collective settings throughout China, particularly in schools and other institutional facilities. However, most dispensers provide only filtration functions and generally lack disinfection and sterilization capabilities (*11*). When water sources fail to meet quality standards and dispenser products do not comply with national requirements, drinking water safety cannot be assured, creating conditions conducive to infectious diarrhea outbreaks.

Therefore, schools and other collective institutions should use direct drinking water dispensers only when water sources are demonstrably safe. They must purchase dispensers that meet national standards and conduct regular maintenance as specified by manufacturers and regulatory requirements.

At the government level, a multi-department collaborative prevention and control mechanism for diarrheal outbreaks should be established with clearly defined responsibilities: health commissions and CDC should implement health monitoring and provide emergency technical guidance; water authorities should strengthen routine supervision of drinking water systems to ensure source water safety; market supervision departments should rigorously control the quality of direct drinking water dispensers entering the market; education departments should oversee all aspects of centralized procurement of direct drinking water dispensers in schools; water supply companies should notify schools in advance of planned water suspensions and immediately investigate suspected pipeline contamination; when outbreaks occur, schools should report promptly, designate trained personnel for daily dispenser maintenance, and arrange for thorough cleaning and disinfection of dispensers before resuming water supply following municipal low-pressure events or water suspensions. This coordinated regulatory framework should ensure clear division of responsibilities and efficient inter-departmental collaboration.

This investigation has an important limitation: the Baisha County Center for Disease Control and Prevention laboratory lacked gene sequencing capabilities, preventing genetic sequencing and homology analysis of DEC strains isolated from patient specimens and environmental samples. This technical constraint precluded molecular-level confirmation that environmental pathogens and those causing human infections shared a common source, leaving the etiological association without direct molecular evidence.

This investigation demonstrates that contaminated water sources combined with inadequately equipped direct drinking water dispensers — lacking sufficient filtration capacity to remove bacteria, viruses, and other microorganisms — compromise drinking water safety and facilitate clustered infection outbreaks. To prevent similar incidents, we advise all sectors of society, particularly collective institutions such as schools, to purchase only compliant direct drinking water dispensers and to use such equipment exclusively when water sources meet safety standards. Furthermore, molecular tracing technology should be prioritized as a critical component of future outbreak investigations.

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