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Preplanned Studies

Trends in Two-Week Prevalence of Fever and Diarrhea Among Infants and Young Children in Rural — China, 2016–2025

Yanli Wei[1]; Lijuan Wang[1,#]; Jian Huang[1]; Jing Sun[1]; Junsheng Huo[1]

Summary

What is already known about this topic?

Infants and young children aged 6–23 months in poor rural China are vulnerable to fever and diarrhea; however, long-term trend data on their two-week prevalence remain scarce.

What is added by this report?

Using ten rounds of cross-sectional data (2016–2025) from the Nutrition Improvement Program for Children in Poor Areas, we analyzed trends among 422,425 children. The two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea decreased significantly from 13.1% (4,236/32,444) to 7.0% (3,139/44,592), 12.3% (3,991/32,444) to 4.2% (1,886/44,592), and 4.1% (1,321/32,444) to 1.4% (640/44,592), respectively (all $P<0.01$).

What are the implications for public health practice?

The significant decline reflects the effectiveness of comprehensive strategies, including economic development, public health management, and nutrition interventions. Sustaining progress will require robust health management systems and continued delivery of nutrition interventions to vulnerable populations.

ABSTRACT

Introduction: Infants and young children (IYC) aged 6–23 months are vulnerable to fever and diarrhea; however, the long-term trend data in poor rural China remain scarce.

Methods: Data were derived from ten rounds of cross-sectional surveys (2016–2025) under the Nutrition Improvement Program for Children in Poor Areas (NIPCPA), using a multi-stage cluster sampling design. Information on fever and diarrhea in the preceding two weeks was collected through caregiver-reported questionnaires. The Cochran–Armitage trend test was used to assess overall and subgroup-specific temporal trends.

Results: A total of 422,425 IYC aged 6–23 months were included. The two-week prevalence of fever declined overall from 13.1% (4,236/32,444) to 7.0% (3,139/44,592), with a nadir of 5.6% (2,408/43,008) in 2021; diarrhea decreased overall from 12.3% (3,991/32,444) to 4.2% (1,886/44,592), with a nadir of 3.9% (1,580/40,707) in 2022; and concurrent fever and diarrhea decreased from 4.1% (1,321/32,444) to 1.4% (640/44,592) (all $P<0.01$). Significant downward trends were observed across all subgroups. Younger children (6–11 months) consistently showed higher prevalence but greater reductions over time. Males had higher baseline prevalence than females but experienced larger declines. Children with normal birth weight exhibited more pronounced improvements than those with low birth weight. Higher maternal education levels and maternal caregiving were associated with lower prevalence.

Conclusion: The two-week prevalence of fever and diarrhea among IYC in poor rural China has decreased substantially, which may reflect the combined effects of economic development, strengthened public health systems, and large-scale nutrition interventions.

Infants and young children (IYC) aged 6–23 months are in a critical developmental period with immature immune function, which increases their susceptibility to fever and diarrhea. Poor rural areas in China have long faced relatively high childhood morbidity burdens. However, population-based data describing the status and long-term trends of the two-week prevalence of common childhood illnesses in these areas remain limited.

Data were obtained from ten rounds of annual cross-sectional surveys conducted from 2016 to 2025 under the Nutrition Improvement Program for Children in Poor Areas (NIPCPA)(*1*). A four-stage cluster sampling strategy was applied across all survey rounds. In the first stage, all 832 national poverty-stricken counties were stratified across 20 provinces and ranked

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by gross domestic product and population size. Seven counties were randomly selected from each province; in the province with only five poverty-stricken counties, all five counties were included. The counties selected in 2016 were retained for all subsequent survey rounds. In the second stage, townships within each county were ranked by per capita net income and population size, and five townships were randomly selected from each county. In the third stage, 3–5 villages were randomly selected from each township. Finally, 12–20 children aged 6–23 months were randomly selected from each village (*2*).

Questionnaires were used to collect basic characteristics of the IYC. Core modules covered the sociodemographic characteristics of children and caregivers, 24-h dietary intake assessed by 24-h dietary recall, and caregiver feeding knowledge (*2*–*3*). All indicators, variable definitions, survey items, and survey timing used in this study were consistent across the 10 survey rounds from 2016 to 2025. According to the survey protocol, children were categorized into three age groups: 6–11, 12–17, and 18–23 months. Birth weight was classified as low (<2,500 g), normal (2,500–3,999 g), or macrosomia (≥4,000 g) birth weight. Caregivers were defined as individuals who cared for the child's diet, daily living, and personal safety, and were categorized as mother, father, grandparents or other caregivers. Maternal education was classified as primary school or below, junior high school, or senior high school or above. Fever was defined as a rectal temperature >37.8 ℃, oral temperature >37.5 ℃, or axillary temperature >37.4 ℃. Diarrhea was defined as the passage of three or more loose or watery stools within a 24-h period. The two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea was ascertained from caregiver self-report of symptoms during the two weeks preceding the survey. For each outcome, two-week prevalence was calculated as the number of children with the symptom or concurrent symptoms divided by the total number of surveyed children.

All investigators received standardized training before each survey. Uniform data-collection protocols were used across survey years. Double data entry and logical checks were performed to ensure data accuracy.

Statistical analyses were performed using R software (version 4.5.2; R Foundation for Statistical Computing, Vienna, Austria). The Cochran–Armitage trend test was used to assess temporal trends in the two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea from 2016 to 2025. All tests were two-sided, and P<0.05 was considered statistically significant.

Among the 422,425 participants, 219,102 were male (51.9%) and 203,323 were female (48.1%). Children aged 6–11, 12–17, and 18–23 months accounted for 33.2% (140,233/422,425), 33.0% (139,546/422,425), and 33.8% (142,646/422,425) of the sample, respectively. As shown in Table 1, mothers were the primary caregivers for most children [75.9% (320,466/422,425)].

As shown in Figure 1, from 2016 to 2025, the two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea among IYC aged 6–23 months in poor rural China decreased from 13.1% [95% confidence interval (*CI*): 12.7, 13.4], 12.3% (95% *CI*: 11.9, 12.7), and 4.1% (95% *CI*: 3.9, 4.3) in 2016 to 7.0% (95% *CI*: 6.8, 7.3), 4.2% (95% *CI*: 4.0, 4.4), and 1.4% (95% *CI*: 1.3, 1.5) in 2025, respectively. Fever prevalence declined from 13.1% (4,236/32,444) in 2016 to 5.6% (2,408/43,008) in 2021; after a slight rebound between 2022 and 2023, it was 7.0% (3,139/44,592) in 2025, corresponding to an overall relative decrease of 46.6% from the 2016 baseline. Diarrhea and concurrent fever and diarrhea showed similar long-term declines. The results were consistent across all subgroups.

Table 2 illustrates the trends in the two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea among IYC in poor rural China from 2016 to 2025, stratified by sex and age. Overall, all three indicators decreased significantly over the ten-year period. The Cochran–Armitage trend tests confirmed significant linear downward trends for fever ($z=-44.081$, P<0.01), diarrhea ($z=-67.214$, P<0.01), and concurrent fever and diarrhea ($z=-34.972$, P<0.01). Males had higher baseline prevalence and larger absolute reductions than females. Children aged 6–11 months had the highest prevalence and the largest declines, with the magnitude of decline gradually decreasing with age. Across birth weight subgroups, children with normal birth weight (2,500–3,999 g) showed the strongest downward trend, whereas those with low birth weight (<2,500 g) exhibited relatively weaker declines. By caregiver type, children cared for by mothers showed the most stable and significant decreases in all three indicators, followed by children cared for by grandparents; the father-care and other-care groups showed smaller reductions and relatively weaker statistical significance for some indicators. By maternal education, higher educational attainment was associated with lower two-

TABLE 1. Characteristics of IYC and their caregivers in 2016–2025 surveys in 20 provinces.

Characteristics	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Number *n*	32,444	38,564	43,814	45,182	45,082	43,008	40,707	44,620	44,412	44,592
Gender, *n* (%)										
Male	16,974 (52.3)	20,031 (51.9)	22,579 (51.5)	23,310 (51.6)	23,319 (51.7)	22,135 (51.5)	21,184 (52.0)	23,247 (52.1)	23,116 (52.0)	23,207 (52.0)
Female	15,470 (47.7)	18,533 (48.1)	21,235 (48.5)	21,872 (48.4)	21,763 (48.3)	20,873 (48.5)	19,523 (48.0)	21,373 (47.9)	21,296 (48.0)	21,385 (48.0)
Age group (month), *n* (%)										
6–11	10,243 (31.6)	13,318 (34.5)	13,796 (31.5)	15,184 (33.6)	14,999 (33.3)	13,736 (31.9)	13,048 (32.1)	15,328 (34.4)	15,382 (34.5)	15,199 (34.1)
12–17	11,386 (35.1)	12,944 (33.6)	14,673 (33.5)	14,594 (32.3)	14,998 (33.3)	14,216 (33.1)	13,783 (33.9)	14,210 (31.8)	13,924 (31.4)	14,818 (33.2)
18–23	10,815 (33.3)	12,302 (31.9)	15,345 (35.0)	15,404 (34.1)	15,085 (33.4)	15,056 (35.0)	13,876 (34.1)	15,082 (33.8)	15,106 (34.0)	14,575 (32.7)
Birth weight (g), *n* (%)										
<2,500	1,199 (3.7)	1,678 (4.4)	1,826 (4.1)	1,873 (4.4)	1,974 (4.5)	1,927 (4.5)	1,862 (4.6)	2,187 (4.9)	2,183 (4.9)	2,315 (5.2)
2,500–3,999	28,790 (88.7)	34,161 (88.6)	38,810 (88.6)	40,052 (88.5)	39,915 (88.5)	38,081 (88.5)	36,172 (88.9)	39,726 (89.0)	39,561 (89.1)	39,722 (89.1)
≥4,000	2,438 (7.5)	2,725 (7.3)	3,178 (7.2)	3,257 (7.1)	3,193 (7.2)	3,000 (7.0)	2,673 (6.6)	2,707 (6.1)	2,668 (6.0)	2,552 (5.7)
Main caregiver, *n* (%)										
Mother	24,171 (74.5)	28,727 (74.5)	32,947 (75.2)	33,514 (74.2)	34,625 (76.8)	32,723 (76.1)	31,869 (78.3)	34,383 (77.1)	33,981 (76.5)	33,506 (75.1)
Father	393 (1.2)	379 (1.0)	403 (0.9)	430 (1.0)	464 (1.0)	419 (1.0)	417 (1.0)	480 (1.1)	464 (1.0)	528 (1.2)
Grandparents	7,750 (23.9)	9,297 (24.1)	10,262 (23.4)	11,053 (24.5)	9,868 (21.9)	9,749 (22.7)	8,269 (20.3)	9,597 (21.5)	9,877 (22.2)	10,423 (23.4)
Others	130 (0.4)	161 (0.4)	202 (0.5)	185 (0.4)	125 (0.3)	117 (0.3)	152 (0.4)	160 (0.4)	90 (0.2)	135 (0.3)
Mother's education, *n* (%)										
Primary school and below	6,424 (19.8)	6,561 (17.0)	7,256 (16.6)	7,020 (15.5)	6,064 (13.4)	5,731 (13.3)	4,267 (10.5)	5,258 (11.8)	4,790 (10.8)	4,408 (9.9)
Junior high school	18,791 (57.9)	21,884 (56.7)	23,783 (54.3)	23,605 (52.2)	23,428 (52.0)	21,103 (49.1)	19,498 (47.9)	19,658 (44.1)	18,896 (42.5)	17,705 (39.7)
Senior high school and above	7,229 (22.3)	10,119 (26.2)	12,775 (29.2)	14,557 (32.2)	15,590 (34.6)	16,174 (37.6)	16,942 (41.6)	19,704 (44.2)	20,726 (46.7)	22,479 (50.4)

Note: Data were collected from annual cross-sectional surveys of the NIPCPA in poor rural China. Values are presented as *n* (%).
Abbreviation: IYC=Infants and Young Children; mo=months; g=grams; NIPCPA=Nutrition Improvement Program for Children in Poor Areas.

week prevalence of fever, diarrhea, and concurrent fever and diarrhea, and all three education subgroups showed significant decreasing trends.

DISCUSSION

This study used ten rounds of repeated cross-sectional surveys (2016–2025) to examine trends in the two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea among IYC in poor rural China.

The findings demonstrate a substantial reductions in disease prevalence from 2016 to 2025, with fever decreasing by 46.6% and diarrhea declining by 65.9%. The declines were most pronounced among children aged 6–11 months, children with normal birth weight, and children cared for by mothers or by caregivers with higher educational levels. In contrast, children with low birth weight and those cared for by non-maternal caregivers improved more slowly. The slight rebound between 2022 and 2023 may be explained by the relaxation of pandemic control measures and partial waning of population immunity to common respiratory and enteric pathogens. Across all survey years, children aged 6–11 months consistently had higher two-week prevalence of fever and diarrhea than older children, despite the overall downward trend.

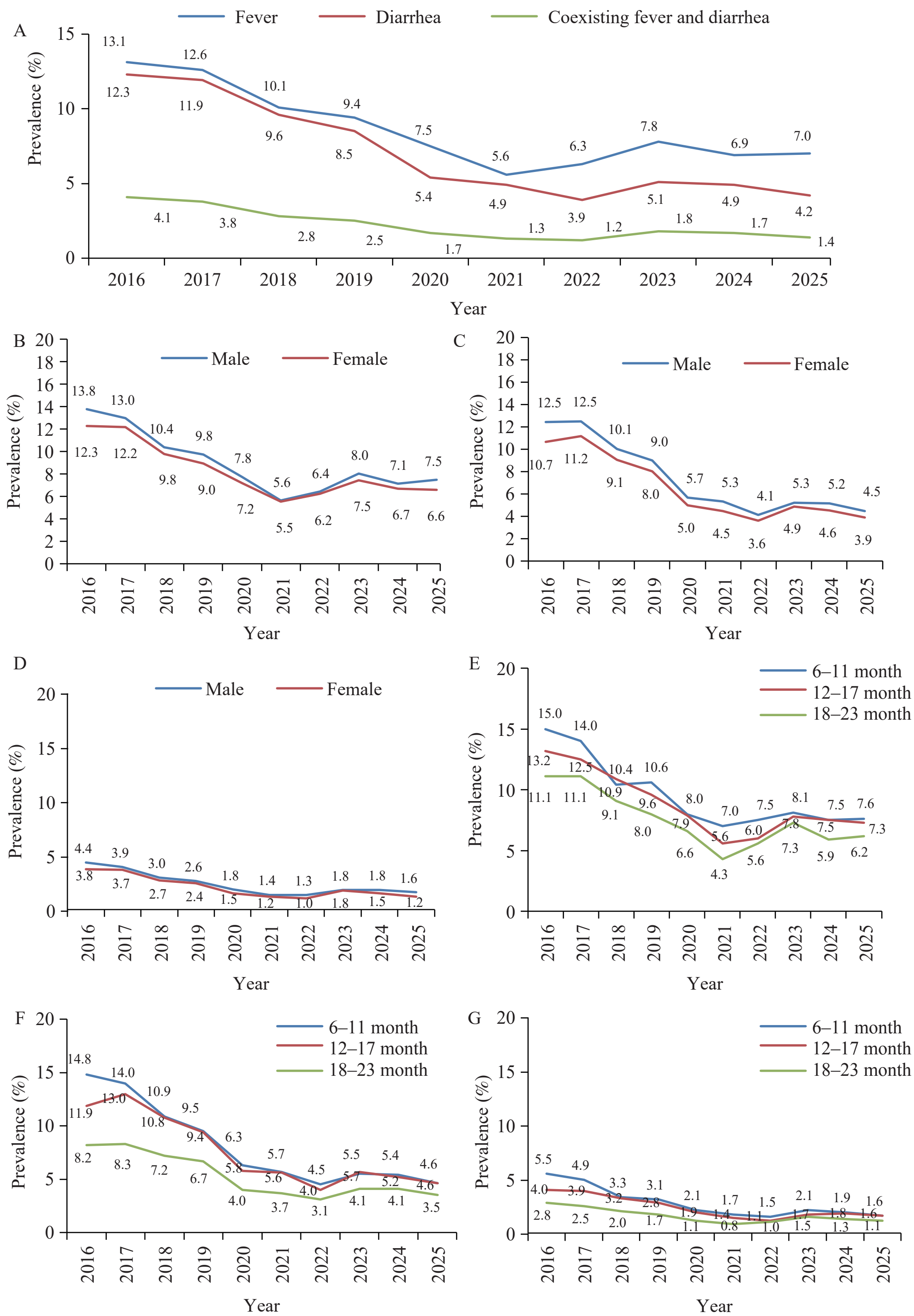

FIGURE 1. Trends in two-week prevalence of fever, diarrhea, and their coexistence among infants and young children in poor rural China, 2016–2025. (A) Overall trends in the two-week prevalence of fever, diarrhea, and coexisting fever and diarrhea. (B) Two-week prevalence of fever by gender. (C) Two-week prevalence of diarrhea by gender. (D) Two-week prevalence of coexisting fever and diarrhea by gender. (E) Two-week prevalence of fever by age group (months). (F) Two-week prevalence of diarrhea by age group (months). (G) Two-week prevalence of coexisting fever and diarrhea by age group (months).

TABLE 2. The prevalence and trends in two-week prevalence by subgroup from 2016 to 2025 in 20 provinces.

Characteristics	Fever					Diarrhea					Coexisting fever and diarrhea				
	2016 (%)	2025 (%)	z	*P*	*P*-int	2016 (%)	2025 (%)	z	*P*	*P*-int	2016 (%)	2025 (%)	z	*P*	*P*-int
Gender					0.416					0.793					0.236
Male	13.8	7.5	−35.451	<0.001		12.5	4.5	−51.404	<0.001		4.4	1.6	−26.592	<0.001	
Female	12.3	6.6	−32.384	<0.001		10.7	3.9	−45.888	<0.001		3.8	1.2	−25.790	<0.001	
Age group (mo)					<0.001					<0.001					0.007
6–11	15.0	7.6	−28.903	<0.001		14.8	4.6	−45.727	<0.001		5.5	1.6	−25.382	<0.001	
12–17	13.2	7.3	−28.220	<0.001		11.9	4.6	−41.556	<0.001		4.0	1.6	−22.114	<0.001	
18–23	11.1	6.2	−25.852	<0.001		8.2	3.5	−30.631	<0.001		2.8	1.1	−15.490	<0.001	
Birth weight (g)					–					–					–
<2,500	14.0	9.1	−7.088	<0.001		11.8	5.4	−13.743	<0.001		3.6	1.7	−7.076	<0.001	
2,500–3,999	13.0	7.0	−45.458	<0.001		11.6	4.2	−64.983	<0.001		4.1	1.4	−34.576	<0.001	
≥4,000	13.2	6.1	−14.903	<0.001		11.5	4.0	−18.600	<0.001		4.3	1.1	−11.637	<0.001	
Main caregivers					<0.001					<0.001					0.031
Mother	12.5	6.5	−39.454	<0.001		11.6	4.0	−59.002	<0.001		4.0	1.3	−31.726	<0.001	
Father	15.3	11.2	−2.618	<0.001		9.2	6.3	−3.422	<0.001		4.6	1.9	−2.475	0.013	
Grandparents	14.8	8.4	−19.501	<0.001		11.8	4.9	−27.764	<0.001		4.2	1.7	−14.581	<0.001	
Others	15.4	11.9	−1.080	0.280		9.2	5.9	−2.811	<0.001		5.4	3.0	−2.288	0.022	
Mother's education					<0.001					<0.001					<0.001
Primary school and below	11.5	7.1	−16.160	<0.001		10.2	4.3	−22.027	<0.001		3.4	1.7	−11.890	<0.001	
Junior high school	12.9	7.6	−28.790	<0.001		11.6	4.5	−44.126	<0.001		4.0	1.6	−23.934	<0.001	
Senior high school and above	14.8	6.6	−27.333	<0.001		12.8	4.0	−40.897	<0.001		4.8	1.3	−20.857	<0.001	
Total	13.1	7.0	−44.081	<0.001		12.3	4.2	−67.214	<0.001		4.1	1.4	−34.972	<0.001	

Note: Prevalence was presented as percentage. *P* are based on two-sided Cochran-Armitage trend tests; *P*<0.01 indicates a statistically significant decreasing trend.
"–" means not estimable due to perfect multicollinearity.
Abbreviation: mo=months; g=grams; *P*-int=*P*-interaction.

These findings suggest that disease prevention and nutrition interventions should prioritize younger infants, who have immature immune function and are in the early stage of complementary feeding. Children with low birth weight exhibited slower improvement and may require more targeted and intensive health support (*4*). Moreover, children cared for by mothers showed a more consistent downward trend in morbidity, and higher maternal educational attainment was associated with lower prevalence of fever and diarrhea. These findings underscore the importance of maternal care capacity and health literacy in reducing common childhood illnesses (*5*).

IYC aged 6–23 months are in a critical growth period with immature immunity, making them susceptible to various diseases, especially fever and diarrhea (*2*,*6*). These symptoms directly affect children's health and substantially increase the medical burden on families and society (*3*). Diarrhea and fever contribute to nutritional deficiencies, reduced resistance to infections and impaired growth and development (*7*). In areas where Ying Yang Bao (YYB) was distributed, children's dietary patterns and nutrient intake improved, and their nutritional status was enhanced through YYB provision and complementary-feeding education. This nutritional improvement may have supported immune system development and strengthened resistance to infections. The two-week prevalence of fever and diarrhea in the study areas was substantially lower than the average estimates for children under five years of age in low- and middle-income countries (LMICs), where the corresponding estimates remained as high as 18.8% and 12.5%, respectively (*8*). This difference persisted through 2025. Our estimates were also lower than the national two-week prevalence reported among children under five years of age in the 6th National Health Service Survey (*9*). Nationally representative data on two-week prevalence after 2018 remain scarce, underscoring the value of these long-term surveillance data for characterizing childhood morbidity trends in understudied poor rural regions of China (*10*).

In conclusion, IYC aged 6–23 months in poor rural China experienced substantial and significant declines in the two-week prevalence of fever, diarrhea, and concurrent fever and diarrhea from 2016 to 2025. These downward trends may reflect the combined contributions of comprehensive strategies, including economic development, strengthened public health management, and sustained nutrition interventions, including YYB consumption and feeding counseling. Continued efforts are needed to maintain robust public health systems and ensure consistent delivery of targeted nutrition interventions for vulnerable young children.

This study has several limitations. First, two-week prevalence was based on caregiver self-report and may therefore be subject to recall bias. Second, the repeated cross-sectional design precludes causal inference and cannot track individual-level changes over time. Third, the observed trends were based on the fixed study population enrolled in 2016; therefore, the findings should be generalized cautiously to the broader and evolving rural population of China in 2025.

Conflicts of interest: No conflicts of interest.

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Preplanned Studies

Impact of Rest Break, Shift Work, and Overtime on Musculoskeletal Disorders — China, 2018–2023

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Summary

What is already known about this topic?

Impact of individual and biomechanical risk factors on musculoskeletal disorders (MSDs) has been researched; however, the factors of intervenable work organization (e.g., overtime and rest breaks) require in-depth investigation, particularly in the context of national policy changes in China by 2025.

What is added by this report?

Among 88,609 participants, 37.5% (33,247/88,609) had MSDs. We found that working hours [prevalence ratio (*PR*)=1.18], shift work (lower back, elbows, hips/thighs, and ankles/feet, *P*<0.05), overtime (*PR*=1.23), staff shortages (*PR*=1.23), covering for absent coworkers (*PR*=1.18), and resuming work after rest (*PR*=1.09) were all likely associated with a significantly increased prevalence of MSDs and pain scores in several body parts (*P*<0.05).

What are the implications for public health practice?

Our findings contribute to efforts to standardize work organization management to prevent MSDs, providing reference for employers and policymakers to regulate rest breaks, manage overtime, and ensure adequate levels of staffing to comply with occupational health regulations.

ABSTRACT

Introduction: This study aimed to explore the association between work organization and musculoskeletal disorders (MSDs).

Methods: A cross-sectional analysis of 88,609 participants was conducted between 2018 and 2023 across seven regions of China. Work organization exposure was assessed using the Chinese version of the MSDs Questionnaire. MSDs were determined using the criteria of the US National Institute for Occupational Safety and Health for musculoskeletal injuries. Log-binomial regression was employed to examine the association between work organization and MSDs, while pain scores were collected to analyze the association with work organization.

Results: Among the participants, 37.5% (33,247/88,609) had MSDs. The most prevalent MSDs were in the neck (22.4%, 19,835/88,609), shoulders (18.7%, 16,535/88,609), and lower back (14.9%, 11,415/88,609). Regarding work organization, the results suggested that working hours [prevalence ratio (*PR*)=1.18], shift work (lower back, elbows, hips/thighs, and ankles/feet, *P*<0.05), overtime (*PR*=1.23), staff shortages (*PR*=1.23), working for colleagues (*PR*=1.18), and resuming work after rest (*PR*=1.09) were likely associated with a significantly increased prevalence of MSDs and pain scores in several body parts (*P*<0.05).

Conclusions: This study showed a positive association between MSD prevalence and factors related to poor work organization, providing evidence on the risks to workers' musculoskeletal health. The findings of this study could be useful for employers and policymakers responsible for managing work environments.

Musculoskeletal disorders (MSDs) are a major global public health concern. The affected proportion has increased with the aging global population; an estimated 1.69 billion individuals are affected, an increase of 26.1% from 2010 (1.48 billion) (*1*). The most commonly reported risk factors for MSDs are demographic variables such as sex, age, and smoking, followed by physically demanding work and psychosocial variables (*2*), indicating that MSDs are common among occupational populations. In China, recently, a nationwide survey of 15 key industries estimated the standardized prevalence of MSDs to be as high as 41.2% (*3*). Occupational MSDs, such as bursal synovitis and carpal tunnel syndrome, were

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included in the List of Occupational Diseases by China in 2025. Since then, MSDs have become an important topic in China as well.

MSD risk factors can be categorized as work- and non-work-related factors. Work-related factors such as shift work, frequency and duration of overtime, work and rest breaks, and level of staffing are associated with the development of MSDs. Several studies have supported the efficacy of interventions aimed at reducing musculoskeletal fatigue and improving work efficiency by adjusting for factors such as break frequency, rest duration, and work type (*4*). Although work organization is important for the prevention of MSDs, research on the impact of these factors on MSDs is insufficient to provide systematic evidence. Therefore, the present study aimed to investigate the effects of work organizations on MSDs in a large sample of the Chinese occupational population, which may serve as a reference for developing interventions targeting work organizations.

This cross-sectional study was based on a national occupational survey conducted by the National Institute of Occupational Health and Poison Control of the Chinese Center for Disease Control and Prevention. This survey selected 29 key industries with large populations and potentially MSDs-relation in seven regions of China (north, east, central, south, southwest, northwest, and northeast). Stratified random sampling categorized enterprises into three classes (large, medium, and small), and representative enterprises were selected. A total of 72 large, 48 medium-sized, and 321 small enterprises were enrolled in this study. All workers with working age ≥1 year who met the inclusion and exclusion criteria were recruited as participants. Building on a previous occupational survey (*3*), the sample size was increased to 88,609 participants. The inclusion criteria were as follows: 1) ≥1 year of working age and 2) voluntary participation. The exclusion criteria were as follows: 1) pregnancy, rheumatoid arthritis, congenital spinal diseases, tumors, and other serious diseases, and 2) having undergone severe trauma or major surgery during the previous year. This study was approved by the Medical Ethical Review Committee of the aforementioned institute and all participants provided informed consent.

This survey was conducted between January 1, 2022, and December 31, 2024. To collect information, we used the Chinese version of the MSDs questionnaire and an electronic questionnaire based on the Nordic Musculoskeletal Questionnaire. The survey was conducted face-to-face; each investigator organized multiple respondents to respond to the questionnaire system and assisted them in defining key terms. The questionnaire was programmed with built-in consistency checks to reduce data entry errors. After collection, the staff reviewed the data for accuracy and completeness of selected items. The criteria of the US National Institute for Occupational Safety and Health for musculoskeletal injuries were used to determine MSDs; the cases were defined as musculoskeletal discomfort within the past year and episodes of discomfort ≥1 time (discomfort exceeding a week-long period) (*5*). Work organization was self-reported, and each participant was asked about their work organization exposure. The pain scores of body parts were assessed using a self-reported 11-point scale as: 0="no pain" and 10="extreme pain".

All statistical analyses were performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Normally distributed continuous variables were expressed as mean±standard deviation (SD) and analyzed using the Student's *t*-test or one-way analysis of variance (ANOVA). The skewed distribution of continuous variables was expressed as median values (P_{25}, P_{75}) and analyzed using the Wilcoxon rank-sum test or the Kruskal-Wallis H test. Categorical variables were expressed as frequency (%) and analyzed using χ^2 test or Fisher's exact test. For significant differences in pain scores between the groups, pairwise multiple comparisons were used (Bonferroni correction). Log-binomial regression was applied to assess the associations between work organization and MSD prevalence while adjusting for covariates.

In the current study, 88,609 participants were included (Table 1), of whom 67.7% (59,989/88,609) were males. The mean age was 32.32 years (32.32±9.16). The mean working age was 7.51 years (7.51±7.19). Among the study participants, 37.5% had MSDs (any body part). The most prevalent MSDs were located in the neck (22.4%, 19,835/88,609), shoulders (18.7%, 16,535/88,609), and lower back (14.9%, 13,194/88,609). With regard to work organization and MSDs, those in jobs with exposure to extended hours/day (working hours >8 hours/day or overtime), staff shortages, working to cover absent colleagues, and those who resumed work after rest were more likely to have a higher prevalence rate of MSDs. Conversely, workers with the option of rest or work and sufficient rest time were more likely to have a lower prevalence of MSDs.

Statistically significant differences in pain scores

TABLE 1. Work organization characteristics of study participants in 2018–2023.

Characteristic	Any body part *n* (%)	Neck *n* (%)	Shoulders *n* (%)	Upper back *n* (%)	Lower back *n* (%)	Elbows *n* (%)	Wrists/hands *n* (%)	Hips/thighs *n* (%)	Knees *n* (%)	Ankles/feet *n* (%)
Rest break frequency (time)										
≤1	12,179 (39.8)	7,702 (25.2)	6,438 (21.0)	4,436 (14.5)	4,852 (15.9)	2,194 (7.2)	3,774 (12.3)	3,191 (10.4)	3,057 (10.0)	3,468 (11.3)
2	9,015 (35.9)	5,355 (21.3)	4,449 (17.7)	2,981 (11.9)	3,515 (14.0)	1,610 (6.4)	2,674 (10.6)	2,255 (9.0)	2,280 (9.1)	2,681 (10.7)
≥3	12,053 (36.6)	6,778 (20.6)	5,648 (17.2)	3,998 (12.2)	4,827 (14.7)	2,170 (6.6)	3,990 (12.1)	2,997 (9.1)	3,268 (9.9)	4,260 (13.0)
Rest break duration (min)										
≤10	9,967 (37.5)	6,071 (22.8)	5,098 (19.2)	3,696 (13.9)	3,898 (14.7)	2,089 (7.9)	3,542 (13.3)	2,747 (10.3)	2,844 (10.7)	3,491 (13.1)
>10 to 30	10,299 (38.9)	6,196 (23.4)	5,203 (19.7)	3,539 (13.4)	4,197 (15.9)	1,888 (7.1)	3,115 (11.8)	2,625 (9.9)	2,667 (10.1)	3,027 (11.4)
>30 to 60	7,712 (36.7)	4,555 (21.7)	3,745 (17.8)	2,536 (12.1)	3,088 (14.7)	1,271 (6.0)	2,276 (10.8)	1,916 (9.1)	1,943 (9.2)	2,266 (10.8)
>60	5,269 (36.2)	3,013 (20.7)	2,489 (17.1)	1,644 (11.3)	2,011 (13.8)	726 (5.0)	1,505 (10.4)	1,155 (7.9)	1,151 (7.9)	1,625 (11.2)
Working days per week (days)										
≤5	14,384 (39.1)	9,073 (24.6)	7,391 (20.1)	4,944 (13.4)	5,597 (15.2)	2,296 (6.2)	4,005 (10.9)	3,435 (9.3)	3,502 (9.5)	4,282 (11.6)
>5 to 7	18,863 (36.4)	10,762 (20.8)	9,144 (17.7)	6,471 (12.5)	7,597 (14.7)	3,678 (7.1)	6,433 (12.4)	5,008 (9.7)	5,103 (9.9)	6,127 (11.8)
Working (h/day)										
≤8	16,059 (35.0)	9,870 (21.5)	8,032 (17.5)	5,473 (11.9)	6,368 (13.9)	2,787 (6.1)	4,571 (10.0)	3,863 (8.4)	4,066 (8.9)	4,467 (9.7)
>8	17,188 (40.3)	9,965 (23.4)	8,503 (19.9)	5,942 (13.9)	6,826 (16.0)	3,187 (7.5)	5,867 (13.7)	4,580 (10.7)	4,539 (10.6)	5,942 (13.9)
Shift work system										
Fixed day shift	13,194 (35.1)	7,903 (21.1)	6,589 (17.6)	4,236 (11.3)	5,130 (13.7)	2,248 (6.0)	3,961 (10.6)	3,023 (8.1)	3,194 (8.5)	3,257 (8.7)
Fwo-shift	12,723 (38.2)	7,298 (21.9)	6,165 (18.5)	4,430 (13.3)	4,922 (14.8)	2,359 (7.1)	4,446 (13.3)	3,311 (9.9)	3,364 (10.1)	4,935 (14.8)
Fhree-shift	3,024 (41.0)	1,814 (24.6)	1,459 (19.8)	1,074 (14.6)	1,299 (17.6)	563 (7.6)	875 (11.9)	949 (12.9)	899 (12.2)	988 (13.4)
Four-shift	1,806 (41.1)	1,168 (26.6)	999 (22.7)	801 (18.2)	851 (19.3)	446 (10.1)	582 (13.2)	585 (13.3)	571 (13.0)	613 (13.9)
Other	2,500 (41.7)	1,652 (27.6)	1,323 (22.1)	874 (14.6)	992 (16.5)	358 (6.0)	574 (9.6)	575 (9.6)	577 (9.6)	616 (10.3)
Overtime	18,429 (42.3)	10,942 (25.1)	9,265 (21.3)	6,601 (15.1)	7,566 (17.4)	3,678 (8.4)	6,319 (14.5)	5,151 (11.8)	5,291 (12.1)	6,704 (15.4)
Sufficient rest	12,353 (27.3)	6,728 (14.9)	5,441 (12.0)	3,370 (7.5)	4,188 (9.3)	1,741 (3.8)	3,209 (7.1)	2,438 (5.4)	2,510 (5.5)	2,988 (6.6)
Resumed work after rest	31,055 (38.1)	18,515 (22.7)	15,527 (19.1)	10,666 (13.1)	12,349 (15.2)	5,522 (6.8)	9,754 (12.0)	7,886 (9.7)	8,057 (9.9)	9,805 (12.0)
Decide work time	5,521 (33.4)	3,150 (19.1)	2,668 (16.2)	1,866 (11.3)	2,113 (12.8)	1,084 (6.6)	1,548 (9.4)	1,326 (8.0)	1,457 (8.8)	1,513 (9.2)
Decide rest time	6,012 (31.0)	3,331 (17.2)	2,860 (14.7)	1,888 (9.7)	2,313 (11.9)	1,051 (5.4)	1,662 (8.6)	1,387 (7.2)	1,525 (7.9)	1,514 (7.8)
Staff shortage	17,512 (45.4)	10,977 (28.4)	9,221 (23.9)	6,747 (17.5)	7,528 (19.5)	3,721 (9.6)	5,923 (15.3)	5,177 (13.4)	5,282 (13.7)	6,140 (15.9)
Often work to cover a colleague	6,146 (48.1)	4,120 (32.2)	3,428 (26.8)	2,635 (20.6)	2,895 (22.6)	1,561 (12.2)	2,200 (17.2)	2,041 (16.0)	2,109 (16.5)	2,310 (18.1)
Total (*N*)	33,247 (37.5)	19,835 (22.4)	16,535 (18.7)	11,415 (12.9)	13,194 (14.9)	5,974 (6.7)	10,438 (11.8)	8,443 (9.5)	8,605 (9.7)	10,409 (11.7)

were associated with differences in the following factors: rest break frequency and duration, working days/week, working hours per day, shift work, overtime, sufficient rest, resumed work after rest, option of rest or work time, staff shortage, and working to cover absent colleagues (P<0.05) (Table 2). Further pairwise comparisons showed that less frequent rest breaks (≤1 time) group had higher pain scores (neck, shoulders, and lower back) than >1 time group, rest break duration ≤10 minutes group had higher neck pain score than 10–30 minutes group, and fixed day shift group had less pain scores (neck, shoulders, and lower back) than three- and four-shift groups (P<0.05) (Supplementary Table S1, available at https://weekly.chinacdc.cn/).

In Table 3, Supplementary Table S2, and Supplementary Table S3 (available at https://weekly.chinacdc.cn/), the log-binomial regression analysis showed that participants who often worked to cover absent colleagues or were affected by staff shortages were 1.18 or 1.23 times more likely to develop MSDs, respectively (P<0.05). Workers who resumed work after rest had a significantly higher prevalence of MSDs [prevalence ratio (PR)=1.09, P<0.05]. The PR for workers who usually worked overtime, more than 5 days/week, or 8 hours/day were 1.23, 1.09, and 1.18, respectively (P<0.05). Similarly, those who worked in two-, three-, or four-shift work systems were more likely to develop MSDs (lower back, elbows, hips/thighs, and ankles/feet) (P<0.05). Conversely, opting for rest time, rest break frequency >1 time, and sufficient rest were protective factors against MSDs (P<0.05).

DISCUSSION

MSDs are common worldwide and have considerable impacts on occupational and public health. The changing nature of the work environment over the past decades has increased the complexity of assessing risk factors for MSDs, and focusing on work organization factors is important for mitigating this risk. However, studies on the impact of work organization on MSDs based on a large population are limited. The data used in this study were obtained from a national occupational survey database (2018 to 2023) investigating workers in key industries since 2018.

In this study, we found that the prevalence of MSDs among the occupational population was 37.5%, and the three body parts with the highest rates of MSDs were the neck, shoulders, and lower back. These results are consistent with those of a previous relevant study (*6*). As a common factor, work organization is an essential component of the occupational system. After controlling for various sociodemographic factors, we found a positive association between the prevalence of MSDs in any body part and the following factors: working days >5 days/week; working hours > 8 hours/day; overtime; resuming work after rest; staff shortages; and working to cover absent colleagues. This could be because of staying longer in a job compresses rest time, which adversely affects the musculoskeletal restitution of work-time-stressed areas, thereby increasing the likelihood of MSDs (*7*). Prior research has reported that job rotation, staff shortage, frequent overtime, and abundant resting time all influence the likelihood of MSDs (*8*). Additionally, we found a significant positive correlation between MSDs in the shift work groups. Shift work, entailing two-, three-, or four-shift rotations during workdays, requires workers to work frequently in the evening or at night. Although the mechanism underlying increased MSDs due to shift work is not well understood, it is likely that shift work disrupts circadian rhythms and sleep patterns. This disruption can contribute to sleep complicate musculoskeletal recovery (*9*).

Notably, the pain scores reported by workers in shift work, extended hours/day, lower rest break frequency, and staff shortage situations were higher than those in groups without the above situations, possibly due to a reduction in rest time. It has also been observed previously that the higher the work-time ratio, the greater the chance of neck or shoulder pain (*10*).

This study has several limitations. First, the data were obtained through a questionnaire. The accuracy of the answers depended on how well each participant could remember the work factors and musculoskeletal discomfort, possibly leading to recall bias in the data. Second, as an observational (rather than experimental) study, the causality between work organization and MSDs cannot be determined.

In conclusion, the prevalence of MSDs among workers in a study population representing key industries in China was 37.5% (33,247/88,609). The highest rates of MSDs were observed in the neck, shoulders, and lower back. A positive association was found between MSD prevalence and the following work organization factors: working days >5 days/week; working hours >8 hours/day; shift work (two-, three-,

TABLE 2. Analysis of MSDs pain scores and work organization factors.

Characteristic	Neck		Shoulders		Upper back		Lower back		Elbows		Wrists/hands		Hips/thighs		Knees		Ankles/feet	
	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H	M (P_{25}, P_{75})	Z/H
Rest break frequency (time)																		
≤1	0 (0, 5)		0 (0, 4)		0 (0, 0)		0 (0, 2)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
2	0 (0, 4)	513.0*§	0 (0, 3)	338.6*§	0 (0, 0)	206.3*§	0 (0, 0)	74.5*§	0 (0, 0)	32.4*§	0 (0, 0)	81.4*§	0 (0, 0)	123.1*§	0 (0, 0)	58.8*§	0 (0, 0)	74.5*§
≥3	0 (0, 4)		0 (0, 3)		0 (0, 0)		0 (0, 1)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Rest break duration (min)																		
≤10	0 (0, 5)		0 (0, 4)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
>10 to 30	0 (0, 4)	42.0*§	0 (0, 4)	59.1*§	0 (0, 0)	59.1*§	0 (0, 3)	102.4*§	0 (0, 0)	150.5*§	0 (0, 0)	93.9*§	0 (0, 0)	64.1*§	0 (0, 0)	84.2*§	0 (0, 0)	56.6*§
>30 to 60	0 (0, 4)		0 (0, 4)		0 (0, 0)		0 (0, 2)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
>60	0 (0, 4)		0 (0, 4)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Working days per week (days)																		
≤5	0 (0, 5)	−20.5†§	0 (0, 4)	−15.1†§	0 (0, 0)	−7.5†§	0 (0, 2)	−2.9†§	0 (0, 0)	7.5†§	0 (0, 0)	6.3†§	0 (0, 0)	0.4	0 (0, 0)	−0.8	0 (0, 0)	−0.2
>5 to 7	0 (0, 4)		0 (0, 3)		0 (0, 0)		0 (0, 1)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Working (h/day)																		
≤8	0 (0, 4)	3.1†§	0 (0, 4)	6.2†§	0 (0, 0)	7.8†§	0 (0, 1)	4.9†§	0 (0, 0)	7.7†§	0 (0, 0)	17.5†§	0 (0, 0)	8.2†§	0 (0, 0)	5.9†§	0 (0, 0)	19.7†§
>8	0 (0, 5)		0 (0, 4)		0 (0, 0)		0 (0, 2)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Shift work system																		
Fixed day shift	0 (0, 4)		0 (0, 4)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Two-shift	0 (0, 4)		0 (0, 3)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Three-shift	0 (0, 5)	685.3*§	0 (0, 4)	432.0*§	0 (0, 0)	485.0*§	0 (0, 4)	426.9*§	0 (0, 0)	304.4*§	0 (0, 0)	216.3*§	0 (0, 0)	571.1*§	0 (0, 0)	467.0*§	0 (0, 0)	983.4*§
Four-shift	0 (0, 5)		0 (0, 5)		0 (0, 4)		0 (0, 5)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 2)		0 (0, 1)	
Other	0 (0, 5)		0 (0, 5)		0 (0, 0)		0 (0, 3)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)		0 (0, 0)	
Overtime	0 (0, 5)	22.3†§	0 (0, 4)	23.2†§	0 (0, 0)	21.6†§	0 (0, 3)	21.7†§	0 (0, 0)	21.2†§	0 (0, 0)	26.9†§	0 (0, 0)	22.8†§	0 (0, 0)	24.2†§	0 (0, 1)	38.0†§
Sufficient rest	0 (0, 2)	−71.8†§	0 (0, 0)	−66.6†§	0 (0, 0)	−61.8†§	0 (0, 0)	−60.1†§	0 (0, 0)	−43.6†§	0 (0, 0)	−56.2†§	0 (0, 0)	−53.4†§	0 (0, 0)	−53.3†§	0 (0, 0)	−60.1†§
Resumed work after rest	0 (0, 5)	19.1†§	0 (0, 4)	18.6†§	0 (0, 0)	11.9†§	0 (0, 2)	14.4†§	0 (0, 0)	5.6†§	0 (0, 0)	13.2†§	0 (0, 0)	9.3†§	0 (0, 0)	11.3†§	0 (0, 0)	15.1†§
Decide work time	0 (0, 4)	−17.7†§	0 (0, 2)	−16.8†§	0 (0, 0)	−12.8†§	0 (0, 0)	−14.9†§	0 (0, 0)	−4.8†§	0 (0, 0)	−17.4†§	0 (0, 0)	−12.4†§	0 (0, 0)	−11.7†§	0 (0, 0)	−18.3†§
Decide rest time	0 (0, 3)	−26.3†§	0 (0, 1)	−24.2†§	0 (0, 0)	−20.3†§	0 (0, 0)	−18.9†§	0 (0, 0)	−11.8†§	0 (0, 0)	−21.8†§	0 (0, 0)	−18.1†§	0 (0, 0)	−16.8†§	0 (0, 0)	−25.6†§
Staff shortage	0 (0, 5)	55.2†§	0 (0, 5)	48.6†§	0 (0, 3)	48.2†§	0 (0, 4)	44.8†§	0 (0, 0)	38.5†§	0 (0, 1)	38.3†§	0 (0, 0)	45.6†§	0 (0, 0)	47.2†§	0 (0, 2)	44.1†§
Often work to cover a colleague	0 (0, 5)	34.6†§	0 (0, 5)	31.0†§	0 (0, 4)	33.7†§	0 (0, 5)	31.0†§	0 (0, 0)	30.3†§	0 (0, 3)	23.6†§	0 (0, 1)	32.0†§	0 (0, 2)	33.9†§	0 (0, 3)	28.1†§

* Wilcoxon rank-sum test;
† Kruskal-Wallis H test.
§ P<0.05.

TABLE 3. Prevalence ratios and 95% confidence intervals (*CI*) of work organization for MSDs.

Characteristic	Any body part *PR* (95% *CI*)	Neck *PR* (95% *CI*)	Shoulders *PR* (95% *CI*)	Lower back *PR* (95% *CI*)
Rest break frequency (time)				
≤1	Ref	Ref	Ref	Ref
2	0.97 (0.95, 0.99)*	0.96 (0.93, 0.99)*	0.96 (0.92, 0.99)*	0.98 (0.94, 1.02)
≥3	0.98 (0.95, 0.99)*	0.97 (0.94, 1.01)	0.98 (0.94, 1.02)	1.01 (0.96, 1.05)
Rest break duration (min)				
≤10	Ref	Ref	Ref	Ref
>10 to 30	1.01 (0.99, 1.03)	0.99 (0.96, 1.02)	0.99 (0.96, 1.03)	1.02 (0.98, 1.06)
>30 to 60	0.99 (0.97, 1.01)	0.96 (0.92, 0.99)*	0.95 (0.91, 0.99)*	1.00 (0.96, 1.05)
>60	0.98 (0.96, 1.01)	0.93 (0.89, 0.97)*	0.93 (0.89, 0.97)*	0.97 (0.92, 1.02)
Working days per week (days)				
≤5	Ref	Ref	Ref	Ref
>5 to 7	1.09 (1.07, 1.11)*	1.09 (1.06, 1.13)*	1.12 (1.08, 1.16)*	1.09 (1.05, 1.14)*
Working (h/day)				
≤8	Ref	Ref	Ref	Ref
>8	1.18 (1.15, 1.20)*	1.17 (1.14, 1.21)*	1.21 (1.17, 1.25)*	1.24 (1.19, 1.28)*
Shift work system				
Fixed day shift	Ref	Ref	Ref	Ref
Two-shift	1.02 (0.99, 1.05)	1.01 (0.96, 1.04)	1.02 (0.97, 1.07)	1.10 (1.04, 1.16)*
Three-shift	1.03 (0.99, 1.06)	0.97 (0.93, 1.03)	0.98 (0.93, 1.04)	1.12 (1.05, 1.19)*
Four-shift	1.03 (0.98, 1.08)	0.99 (0.93, 1.06)	1.03 (0.96, 1.11)	1.16 (1.07, 1.26)*
Other	0.99 (0.96, 1.04)	0.97 (0.92, 1.02)	0.98 (0.92, 1.03)	1.02 (0.95, 1.09)
Overtime	1.23 (1.20, 1.25)*	1.26 (1.22, 1.29)*	1.27 (1.23, 1.31)*	1.29 (1.24, 1.34)*
Sufficient rest	0.72 (0.70, 0.73)*	0.66 (0.64, 0.68)*	0.64 (0.62, 0.66)*	0.64 (0.61, 0.66)*
Resumed work after rest	1.09 (1.05, 1.13)*	1.07 (1.02, 1.13)*	1.17 (1.10, 1.24)*	1.09 (1.02, 1.16)*
Decide work time	0.99 (0.97, 1.02)	0.98 (0.95, 1.02)	1.02 (0.98, 1.06)	0.99 (0.96, 1.05)
Decide rest time	0.95 (0.93, 0.97)*	0.94 (0.91, 0.98)*	0.98 (0.94, 1.02)	0.95 (0.91, 0.99)*
Staff shortage	1.23 (1.21, 1.26)*	1.29 (1.26, 1.33)*	1.32 (1.28, 1.37)*	1.32 (1.27, 1.37)*
Often work to cover a colleague	1.18 (1.15, 1.20)*	1.28 (1.24, 1.32)*	1.29 (1.24, 1.33)*	1.30 (1.25, 1.35)*

Note: Adjusted for age, sex, survey year, enterprise, city, industry, working age, education level, monthly income level, body mass index, smoking status, exercise status, and workplace risk factors (often standing at work, sitting often at work, squatting or kneeling often at work, lifting heavy loads, exerting great force on the upper limbs or hands, using vibration tools at work, working in the same postures at a high pace).

Abbreviation: MSDs=musculoskeletal disorders; *PR*=prevalence ratio.

* P<0.05.

or four-shift work systems); overtime; resuming work after rest; staff shortages; and working to cover absent colleagues. These results suggest that further cohort studies with larger populations are required to validate these findings. To reduce the impact of MSDs on the workforce in China, adjusting work organization conditions for the specific needs is warranted. This finding offers valuable recommendations for improving shiftwork systems, increasing rest time, and providing more flexibility in assigning overtime.

Conflicts of interest: No conflict of interest.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Pairwise multiple comparisons analysis of MSD pain scores.

Characteristic	Neck	Shoulders	Upper back	Lower back	Elbows	Wrists/hands	Hips/thighs	Knees	Ankles/feet
Rest break frequency (time)									
≤1 *vs.* 2	3234.0*	2484.5*	1830.3*	1367.7*	613.7*	1382.5*	1246.5*	1057.0*	428.5*
≤1 *vs.* ≥3	3829.8*	2918.8*	1889.9*	1002.8*	505.7*	602.1*	1317.3*	724.1*	−821.4*
2 *vs.* ≥3	595.8*	434.3*	59.7	−364.9	−107.9	−780.4*	70.9	−332.9	−1249.9*
Rest break duration (min)									
≤10 *vs.* >10 to 30	−868.1*	−1076.7*	−249.0	−1627.2*	285.6	460.2*	−371.7	−303.3	716.8*
≤10 *vs.* >30 to 60	31.3	25.0	580.5*	−779.2*	877.2*	1083.2*	244.3	661.1*	1194.7*
≤10 *vs.* >60	513.7	349.1	1055.7*	−190.9	1632.5*	1642.3*	958.7*	1103.3*	837.5*
>10 to 30 *vs.* >30 to 60	899.4*	1101.7*	829.5*	848.1*	591.6*	622.9*	616.0*	964.4*	477.9*
>10 to 30 *vs.* >60	1381.9*	1425.8*	1304.7*	1436.4*	1346.9*	1182.0*	1330.4*	1406.6*	120.7
>30–60 *vs.* >60	482.4	324.1	475.2	588.3*	755.3*	559.1*	714.4*	442.1	−357.2
Shift work system									
Fixed day shift *vs.* two-shift	355.4	−164.8	−713.0*	−205.0	−271.1	−1478.4*	−659.6*	−338.9	−3778.8*
Fixed day shift *vs.* three-shift	−2171.8*	−1699.0*	−2104.6*	−2477.0*	−1127.5*	−1065.5*	−3428.8*	−2712.4*	−3622.9*
Fixed day shift *vs.* four-shift	−6414.1*	−5695.4*	−5958.7*	−5704.1*	−3659.8*	−3173.8*	−4971.5*	−4930.0*	−4953.7*
Fixed day shift *vs.* other	−5413.4*	−3560.1*	−2122.7*	−1661.7*	161.7	150.5	−1467.5*	−1173.7*	−1524.4*
Two-shift *vs.* three-shift	−2527.2*	−1534.1*	−1391.6*	−2272.0*	−856.4*	412.9	−2769.2*	−2373.5*	156.0
Two-shift *vs.* four-shift	−6769.5*	−5530.5*	−5245.7*	−5499.1*	−3388.7*	−1695.4*	−4311.9*	−4591.1*	−1174.9*
Two-shift *vs.* other	−5768.8*	−3395.2*	−1409.7*	−1456.7*	432.9	1628.9*	−807.9*	−834.7*	2254.4*
Three-shift *vs.* four-shift	−4242.3*	−3996.4*	−3854.1*	−3227.1*	−2532.3*	−2108.3*	−1542.7*	−2217.6*	−1330.9*
Three-shift *vs.* other	−3241.6*	−1861.1*	−18.1	815.3	1289.3*	1215.9*	1961.3*	1538.8*	2098.5*
Four-shift *vs.* other	1000.7	2135.3*	3836.0*	4042.4*	3821.6*	3324.2*	3504.0*	3756.3*	3429.3*

Abbreviation: MSDs=musculoskeletal disorders.

* P<0.05.

SUPPLEMENTARY TABLE S2. Prevalence ratios and 95% confidence intervals of work organization for MSDs.

Characteristic	Upper back	Elbows	Wrists/hands
	PR (95% *CI*)	*PR* (95% *CI*)	*PR* (95% *CI*)
Rest break frequency (time)			
≤1	Ref	Ref	Ref
2	0.94 (0.89−0.98)*	0.95 (0.89−1.02)	0.96 (0.91−1.01)
≥3	0.97 (0.92−1.02)	1.03 (0.96−1.10)	1.02 (0.97−1.07)
Rest break duration (min)			
≤10	Ref	Ref	Ref
>10 to 30	0.98 (0.94−1.02)	0.94 (0.88−1.01)	0.95 (0.91−0.99)*
>30 to 60	0.95 (0.90−0.99)*	0.86 (0.80−0.92)*	0.89 (0.85−0.94)*
>60	0.90 (0.85−0.96)*	0.80 (0.73−0.87)*	0.89 (0.84−0.94)*
Working days per week (days)			
≤5	Ref	Ref	Ref
>5 to 7	1.15 (1.10−1.20)*	1.07 (1.01−1.14)*	1.08 (1.03−1.13)*
Working (h/day)			
≤8	Ref	Ref	Ref
>8	1.22 (1.17−1.27)*	1.17 (1.10−1.25)*	1.22 (1.17−1.28)*
Shift work system			
Fixed day shift	Ref	Ref	Ref
Two-shift	1.10 (1.04−1.16)*	1.19 (1.10−1.28)*	1.13 (1.07−1.20)*
Three-shift	1.06 (0.98−1.14)	1.13 (1.01−1.25)*	1.09 (0.99−1.18)
Four-shift	1.17 (1.07−1.28)*	1.32 (1.16−1.50)*	1.23 (1.10−1.37)*
Other	1.05 (0.97−1.13)	1.09 (0.97−1.23)	0.99 (0.91−1.09)
Overtime	1.34 (1.28−1.40)*	1.49 (1.41−1.59)*	1.37 (1.31−1.43)*
Sufficient rest	0.60 (0.57−0.62)*	0.59 (0.56−0.63)*	0.62 (0.60−0.65)*
Resumed work after rest	1.10 (1.02−1.18)*	0.98 (0.90−1.08)	1.03 (0.96−1.11)
Decide work time	1.05 (0.99−1.10)	1.19 (1.12−1.27)*	1.03 (0.98−1.08)
Decide rest time	0.96 (0.92−1.01)	1.03 (0.96−1.11)	0.97 (0.92−1.02)
Staff shortage	1.40 (1.34−1.45)*	1.60 (1.51−1.69)*	1.41 (1.35−1.46)*
Often work to cover a colleague	1.37 (1.31−1.43)*	1.61 (1.52−1.71)*	1.42 (1.36−1.49)*

Note: Adjusted for age, sex, survey year, enterprise, city, industry, working age, education level, monthly income level, body mass index, smoking status, exercise status, and workplace risk factors (often standing at work, sitting often at work, squatting or kneeling often at work, lifting heavy loads, exerting great force on the upper limbs or hands, using vibration tools at work, working in the same postures at a high pace).

Abbreviation: MSDs=musculoskeletal disorders; *PR*=prevalence ratio; *CI*=confidence interval.

* P<0.05.

SUPPLEMENTARY TABLE S3. Prevalence ratios and 95% confidence intervals of work organization for MSDs.

Characteristic	Hips/thighs *PR* (95% *CI*)	Knees *PR* (95% *CI*)	Ankles/feet *PR* (95% *CI*)
Rest break frequency (time)			
≤1	Ref	Ref	Ref
2	0.98 (0.92−1.03)	0.97 (0.92−1.03)	0.94 (0.89−0.99)*
≥3	0.99 (0.94−1.05)	1.01 (0.95−1.07)	0.99 (0.94−1.04)
Rest break duration (min)			
≤10	Ref	Ref	Ref
>10 to 30	0.95 (0.90−1.01)	0.97 (0.92−1.02)	0.99 (0.95−1.05)
>30 to 60	0.90 (0.85−0.96)*	0.99 (0.93−1.04)	0.97 (0.93−1.03)
>60	0.85 (0.79−0.91)*	0.88 (0.82−0.94)*	0.96 (0.91−1.02)
Working days per week (days)			
≤5	Ref	Ref	Ref
>5 to 7	1.16 (1.10−1.22)*	1.16 (1.10−1.22)*	1.13 (1.08−1.18)*
Working (h/day)			
≤8	Ref	Ref	Ref
>8	1.30 (1.24−1.37)*	1.23 (1.17−1.29)*	1.26 (1.21−1.32)*
Shift work system			
Fixed day shift	Ref	Ref	Ref
Two-shift	1.15 (1.08−1.23)*	1.09 (1.02−1.16)*	1.23 (1.15−1.30)*
Three-shift	1.25 (1.15−1.35)*	1.12 (1.03−1.22)*	1.19 (1.10−1.29)*
Four-shift	1.23 (1.11−1.37)*	1.10 (0.99−1.22)	1.32 (1.19−1.46)*
Other	1.01 (0.92−1.11)	0.98 (0.89−1.07)	1.03 (0.94−1.12)
Overtime	1.47 (1.40−1.54)*	1.44 (1.37−1.51)*	1.40 (1.34−1.46)*
Sufficient rest	0.57 (0.54−0.60)*	0.59 (0.57−0.62)*	0.61 (0.58−0.63)*
Resumed work after rest	1.07 (0.99−1.16)	1.14 (1.05−1.24)*	1.14 (1.06−1.24)*
Decide work time	1.02 (0.97−1.09)	1.07 (1.01−1.13)*	1.02 (0.96−1.07)
Decide rest time	0.95 (0.90−1.01)	1.03 (0.98−1.09)	0.94 (0.89−0.99)*
Staff shortage	1.52 (1.45−1.59)*	1.45 (1.38−1.51)*	1.42 (1.37−1.48)*
Often work to cover a colleague	1.43 (1.36−1.50)*	1.41 (1.34−1.48)*	1.40 (1.34−1.47)*

Note: Adjusted for age, sex, survey year, enterprise, city, industry, working age, education level, monthly income level, body mass index, smoking status, exercise status, and workplace risk factors (often standing at work, sitting often at work, squatting or kneeling often at work, lifting heavy loads, exerting great force on the upper limbs or hands, using vibration tools at work, working in the same postures at a high pace).

Abbreviation: MSDs=musculoskeletal disorders; *PR*=prevalence ratio; *CI*=confidence interval.

* P<0.05.

Preplanned Studies

Congenital Clubfoot Prevalence and Folic Acid Supplementation — Five Counties, Shanxi Province, China, 2003–2024

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Summary

What is already known about this topic?

Congenital clubfoot is a common musculoskeletal deformity and its prevalence varies across regions. In recent years, the overall prevalence of congenital clubfoot among perinatal infants has shown an upward trend in China.

What is added by this report?

This study demonstrated a significant increasing trend in isolated congenital clubfoot after 2012, whereas non-isolated cases continued to decline in the well-recognized high-prevalence region of birth defects in northern China, highlighting the distinct temporal patterns between congenital clubfoot subtypes.

What are the implications for public health practice?

Continued surveillance is needed to monitor changing patterns of congenital clubfoot subtypes and clarify factors underlying the increase in isolated congenital clubfoot.

ABSTRACT

Introduction: Congenital clubfoot is a common musculoskeletal defect that can occur as a secondary manifestation of neural tube defects (NTDs). This study estimated the prevalence and trends of congenital clubfoot in Shanxi Province, an area with a high incidence of NTDs.

Methods: Data from a population-based birth defect surveillance system covering five counties in Shanxi Province during 2003–2024 were analyzed. The cases were classified as isolated (congenital clubfoot only) or non-isolated (congenital clubfoot with additional congenital anomalies). The prevalence of congenital clubfoot was calculated and trends in prevalence were analyzed using joinpoint regression and interrupted time series (ITS) analysis.

Results: Among 296,064 births, the overall prevalence of congenital clubfoot was 0.46 per 1,000 live births, including 0.26 per 1,000 for isolated cases and 0.20 per 1,000 for non-isolated cases. Joinpoint analysis identified a 2012 inflection for isolated congenital clubfoot (annual percentage change [APC]=−11.85% pre-2012 and 11.89% post-2012). The ITS showed no immediate effect of the folic acid policy; however, isolated congenital clubfoot increased after 2012 (trend prevalence rate ratio [PRR]=1.230, $P<0.05$).

Conclusion: Isolated and non-isolated congenital clubfoot showed distinct temporal patterns. Continued surveillance is needed to clarify the increase in isolated cases after 2012.

Congenital clubfoot is one of the most common musculoskeletal deformities resulting from structural abnormalities of the foot and lower leg that cause abnormal positioning of the foot and ankle joints (*1*). Congenital clubfoot is generally classified as isolated or complex (non-isolated), with the complex type accounting for approximately 20%–25% of patients and occurring with other congenital anomalies (*2*). Genetic susceptibility and environmental exposure can contribute to the development of congenital clubfoot. Folic acid (FA) supplementation, a well-established preventive measure for neural tube defects (NTDs), is associated with reduced risk of congenital clubfoot (*3*). Congenital clubfoot frequently occurs as a secondary manifestation in infants with spina bifida, suggesting a potential developmental association between NTDs and congenital clubfoot (*4*).

Shanxi Province in northern China has historically been recognized as a region with a high incidence of NTDs. A previous study in this region showed a substantial decline in overall birth defects, particularly NTDs and orofacial clefts, whereas the incidence of congenital heart defects increased. However, the prevalence and temporal trends of congenital clubfoot in this population have not been systematically

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examined. Given the close association between congenital clubfoot and NTDs, and the potential long-term disability caused by congenital clubfoot, understanding its epidemiological patterns is important for public health. Therefore, this study aimed to estimate the birth prevalence of isolated and non-isolated congenital clubfoot in Shanxi Province from 2003 to 2024, with a particular focus on cases of spina bifida.

Data from a population-based birth defect surveillance system covering five counties in Shanxi Province from 2003 to 2024, an area with a relatively high prevalence of NTDs, were analyzed. A population-based birth defect surveillance system was introduced to the study area in October 2002 (*5*–*6*). All live births (≥28 weeks), all stillbirths (≥20 weeks), and pregnancy terminations at any gestational age following the prenatal diagnosis of birth defects were recorded. Live-born infants with birth defects were included in the surveillance system if they had a gestational age of at least 20 weeks, and a birth defect was diagnosed by 6 weeks of age. For stillbirths and pregnancy terminations, the diagnoses were established at the time of delivery or termination. Congenital clubfoot cases were coded as Q66 according to the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10), initially diagnosed by local maternal-fetal specialists and confirmed by pediatricians at Peking University. All congenital clubfoot cases were classified as isolated (congenital clubfoot without any other anomalies) or non-isolated (congenital clubfoot accompanied by additional congenital anomalies) using the categorization derived from the original reported data.

The prevalence per 1,000 live births was calculated for total, isolated, and non-isolated congenital clubfoot; the denominator was the total number of all live births, while the numerator was all cases observed in the surveillance system. Trends were assessed using the Cochran-Armitage trend tests. To reduce random year-to-year fluctuations due to small case counts, three-year centered rolling averages were calculated, smoothing short-term variability while preserving overall trends. Joinpoint regression analysis was performed to identify significant changes in the trend slopes and estimate the annual percentage change (APC) and average annual percentage change (AAPC). The maximum number of joint points was set to three. Model selection was based on the Monte Carlo permutation test with a significance level of 0.05. Based on the joinpoint results and relevant policy interventions, an interrupted time-series (ITS) analysis was conducted using generalized linear models with a quasi-Poisson distribution, including the logarithm of total live births as an offset to account for overdispersion. The models incorporated terms for baseline time trend (underlying temporal pattern), level changes at each intervention or joint point (immediate changes in prevalence), and post-intervention trend changes (changes in slope over time). Three ITS models were evaluated: 1) the 2009 FA policy, 2) the 2012 trend inflection, and 3) a combination of these. In ITS, prevalence rate ratios (PRRs) quantify the relative changes in case counts. Categorical variables are summarized as frequencies and percentages, and group differences were assessed using the chi-square test. Statistical significance was defined as a two-tailed P<0.05. Analyses were performed using SPSS (version 25.0, SPSS Inc., Chicago, IL, USA), R (version 4.5.1, R Foundation for Statistical Computing, Vienna, Austria; packages DescTools, dplyr, tidyr, zoo, and ggplot2), and JoinPoint (version 5.0.2, Statistical Research and Applications Branch, National Cancer Institute, Bethesda, MD, USA; Information Management Services, Inc., Calverton, MD, USA).

From 2003 to 2024, the Shanxi surveillance system recorded 296,064 births and 137 cases of congenital clubfoot (Supplementary Table S1, available at https://weekly.chinacdc.cn/), with 56.2% (77/137) isolated congenital clubfoot and 43.8% (60/137) non-isolated congenital clubfoot. No significant differences were observed between the two groups in terms of maternal residence, infant sex, or clubfoot laterality, whereas the gestational age differed.

The overall prevalence of congenital clubfoot was 0.46 per 1,000 live births [95% confidence interval (*CI*): 0.39, 0.55], including 0.26 per 1,000 for isolated cases (95% *CI*: 0.21, 0.32) and 0.20 per 1,000 for non-isolated cases (95% *CI*: 0.16, 0.26). From 2003 to 2024, the prevalence of total and non-isolated congenital clubfoot gradually declined, with values falling from 0.93/1,000 and 0.37/1,000 in 2003 to 0.55/1,000 (2024, total cases) and 0.07/1,000 (2022–2024, non-isolated cases), respectively, whereas isolated congenital clubfoot showed no significant downward trend. Trend analysis confirmed a statistically significant decrease in non-isolated congenital clubfoot (P<0.05) (Figure 1A–C). The incidence of non-isolated congenital clubfoot with spina bifida was 0.14/1,000 overall. It decreased from 0.31/1,000 in 2003 to 0.07/1,000 in 2022–2024 (P<0.05) with a consistent downward trend (Figure 1D).

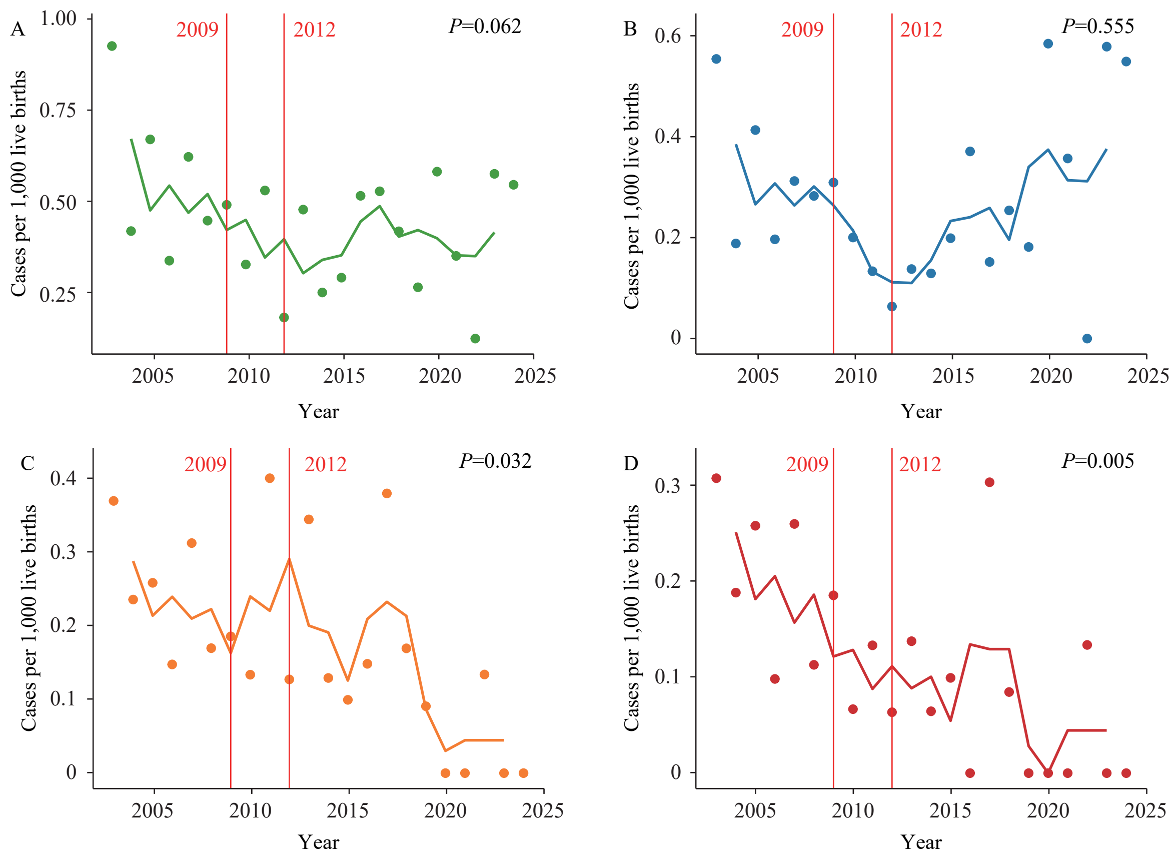

FIGURE 1. Time trends in the prevalence of congenital clubfoot in five counties, Shanxi Province, 2003–2024. (A) Total congenital clubfoot. (B) Isolated congenital clubfoot. (C) Non-isolated congenital clubfoot. (D) Non-isolated congenital clubfoot with spina bifida.
Note: Data for 2003 were available for only four counties: Zezhou, Pingding, Taigu, and Shouyang. For 2023 and 2024, data were available for Xiyang, Pingding, Taigu, and Shouyang. The data for all five counties are presented for all other years.
Abbreviation: NTDs=neural tube defects.
* *P* for Cochran-Armitage trend test.

Joinpoint regression analysis further examined temporal changes in prevalence (Table 1). No significant joinpoints were identified for total congenital clubfoot, non-isolated congenital clubfoot, or non-isolated congenital clubfoot with spina bifida, so trends were summarized using the AAPC. Total congenital clubfoot showed a modest but significant decline (AAPC=−2.62%, P=0.048), while non-isolated congenital clubfoot showed no significant overall trend (AAPC=−2.84%, P=0.129). Non-isolated congenital clubfoot with spina bifida declined significantly (AAPC=−4.21%, P=0.035). In contrast, isolated congenital clubfoot exhibited a significant joinpoint in 2012, with a decreasing trend before 2012 (APC=−11.85%, P=0.016), followed by an increasing trend thereafter (APC=11.89%, P=0.023).

Interrupted time series (ITS) models were used to assess the association between the 2009 FA supplementation policy and the 2012 statistical inflection point (Table 2). For patients with isolated congenital clubfoot, no significant immediate changes were observed after either intervention. A significant increasing trend was detected after 2012 (trend PRR=1.230, 95% *CI*: 1.074, 1.408, P<0.05). No significant trend change was observed following the FA policy (trend PRR=1.163, 95% *CI*: 0.948, 1.426). For total congenital clubfoot, non-isolated congenital clubfoot, and non-isolated congenital clubfoot with spina bifida, neither the level nor trend changes associated with the FA policy or the 2012 inflection point were statistically significant. The combined ITS models yielded similar results (Supplementary Table S2 and Supplementary Figure S1, available at https://weekly.chinacdc.cn/).

DISCUSSION

In this population-based study covering over

TABLE 1. APC and AAPC in the prevalence of congenital clubfoot in five counties, Shanxi Province, 2003–2024.

Types of cases	Period	APC (95% *CI*)	*P*
Total congenital clubfoot*			
Trend	2003–2024	−2.62 (−5.15, −0.02)	0.048
Isolated congenital clubfoot			
Trend1	2003–2012	−11.85 (−20.21, −2.60)	0.016
Trend2	2012–2024	11.89 (1.74, 23.07)	0.023
AAPC	2003–2024	1.02 (−5.26, 7.72)	0.756
Non-isolated congenital clubfoot*			
Trend	2003–2024	−2.84 (−6.46, 0.92)	0.129
Non-isolated congenital clubfoot with spina bifida*			
Trend	2003–2024	−4.21 (−7.93, −0.32)	0.035

Abbreviation: APC=annual percentage change; AAPC=average annual percentage change; *CI*=confidence interval.
* Trends were summarized using the AAPC.

TABLE 2. Changes in congenital clubfoot prevalence following folic acid supplementation and the joinpoint identified in 2012 in five counties, Shanxi Province, 2003–2024: an interrupted time series analysis.

Types of cases	Model	PRR (95% *CI*)
Total congenital clubfoot	Time	0.909 (0.799, 1.034)
	FA policy level change	1.007 (0.536, 1.893)
	FA policy trend change	1.099 (0.958, 1.261)
	Time	0.941 (0.874, 1.013)
	2012 joinpoint level change	0.871 (0.473, 1.602)
	2012 joinpoint trend change	1.091 (0.987, 1.206)
Isolated congenital clubfoot	Time	0.909 (0.751, 1.101)
	FA policy level change	0.697 (0.264, 1.838)
	FA policy trend change	1.163 (0.948, 1.426)
	Time	0.909 (0.820, 1.008)
	2012 joinpoint level change	0.732 (0.301, 1.780)
	2012 joinpoint trend change	1.230 (1.074, 1.408)
Non-isolated congenital clubfoot	Time	0.909 (0.736, 1.123)
	FA policy level change	1.543 (0.564, 4.222)
	FA policy trend change	1.015 (0.809, 1.275)
	Time	0.979 (0.870, 1.103)
	2012 joinpoint level change	1.116 (0.442, 2.821)
	2012 joinpoint trend change	0.912 (0.764, 1.088)
Non-isolated congenital clubfoot with spina bifida	Time	0.884 (0.693, 1.128)
	FA policy level change	1.095 (0.313, 3.834)
	FA policy trend change	1.048 (0.798, 1.375)
	Time	0.897 (0.774, 1.039)
	2012 joinpoint level change	1.113 (0.304, 4.082)
	2012 joinpoint trend change	1.036 (0.822, 1.306)

Note: For each intervention, two PRRs are presented: one for level change (immediate effect) and one for trend change (change in the slope over time). All the models were adjusted for the underlying time trend and included an offset term for the logarithm of total births. Only separate policy models are presented in this table; the results from the model that includes both policies simultaneously are provided in Supplementary Table S2 (available at https://weekly.chinacdc.cn/).
Abbreviation: PRR=prevalence rate ratio; FA=folic acid; *CI*=confidence interval.

290,000 births, the overall prevalence of congenital clubfoot was estimated to be 0.46 per 1,000 live births, with isolated congenital clubfoot accounting for 0.26 per 1,000 births and non-isolated congenital clubfoot for 0.20 per 1,000 births. An increasing trend in isolated congenital clubfoot prevalence was observed after the joinpoint identified in 2012, whereas no statistically significant changes were identified for the FA policy.

Compared with the global data, the prevalence of congenital clubfoot in Shanxi Province was relatively low. The reported rates range from 1.18 per 1,000 globally to 1.29 per 1,000 people in the United States (*7*). In China, the prevalence varies across regions. A cohort in Beijing from 2013 to 2018 showed a prevalence of 0.69 per 1,000 singleton infants (*3*), while lower rates were observed in Hunan and Guangxi provinces. Overall, the prevalence in Shanxi Province was slightly higher than the national average, but remained lower than that in some regions. Both isolated and non-isolated congenital clubfoot are relatively rare in Shanxi, comparable to Sweden (2016–2019), where isolated cases occurred at 1.24 per 1,000 live births and non-isolated cases comprised 8% of all cases, resulting in an overall prevalence of 1.35 per 1,000 (*8*).

Our study demonstrated a marked decline in the incidence of non-isolated congenital clubfoot accompanied by spina bifida over the past two decades. Among the NTD subtypes, spina bifida is particularly prone to coexisting musculoskeletal abnormalities, with congenital clubfoot being one of the most common. Neurological deficits caused by NTDs may impair fetal motor function, thereby reducing intrauterine movement and contributing to congenital clubfoot development (*9*). Previous evidence has reported that approximately 30% of NTD fetuses show congenital clubfoot on ultrasound before 24 weeks of gestation, with additional cases developing later in gestation, suggesting a progressive risk as pregnancy advances (*10*). Therefore, dynamic monitoring of foot morphology is crucial for fetuses with NTDs.

For isolated congenital clubfoot, the observed significant increase in prevalence after 2012 suggests a distinct temporal pattern compared to non-isolated congenital clubfoot. A population-based study of perinatal infants in China (2011–2020) also reported an increasing trend, consistent with the findings of this study on isolated congenital clubfoot (*11*). Several factors may have contributed to this change. Improved standardization of classification and reporting may have reduced under-reporting and enhanced surveillance completeness. Meanwhile, advances in prenatal screening and imaging, including better ultrasound technology and increased diagnostic expertise, may have led to a greater detection of fetal limb anomalies, particularly in milder cases. Additionally, environmental risk factors and adverse prenatal exposure may have become more prominent, potentially affecting the genetic susceptibility. Notably, the joinpoint identified in 2012 represents a data-driven temporal inflection rather than a defined intervention, and its underlying causes remain uncertain. Therefore, these interpretations should be considered as exploratory.

From a broader public health perspective, congenital clubfoot represents not only a structural deformity but also a long-term neurological impairment, repeated surgical interventions, and even amputation, leading to functional disability and imposing significant psychosocial and economic burdens on affected families and the healthcare system. Although a declining trend was observed, the persistence of isolated and non-isolated cases indicated that congenital limb deformities remain an important challenge. Future efforts should integrate strengthened prenatal surveillance, long-term monitoring of congenital anomalies and their subtypes, and continued investigations of genetic and environmental mechanisms to reduce the burden of congenital clubfoot and related congenital anomalies.

Our study has several strengths. First, it is based on a population-based surveillance system with an extended study period and involves both perinatal and pre-perinatal cases, thereby providing a more comprehensive assessment of the occurrence of congenital anomalies. Second, this study conducted a detailed analysis of the prevalence and trends of isolated and non-isolated clubfoot, which has rarely been reported in China.

The findings in this report are subject to at least two limitations. First, the surveillance data were restricted to five counties, which may have limited generalizability. Second, the absence of maternal sociodemographic and lifestyle information precluded exploration of specific risk factors.

Conflicts of interest: No conflicts of interest.

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SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. Characteristics of infants with congenital clubfoot in five counties, Shanxi Province, 2003–2024.

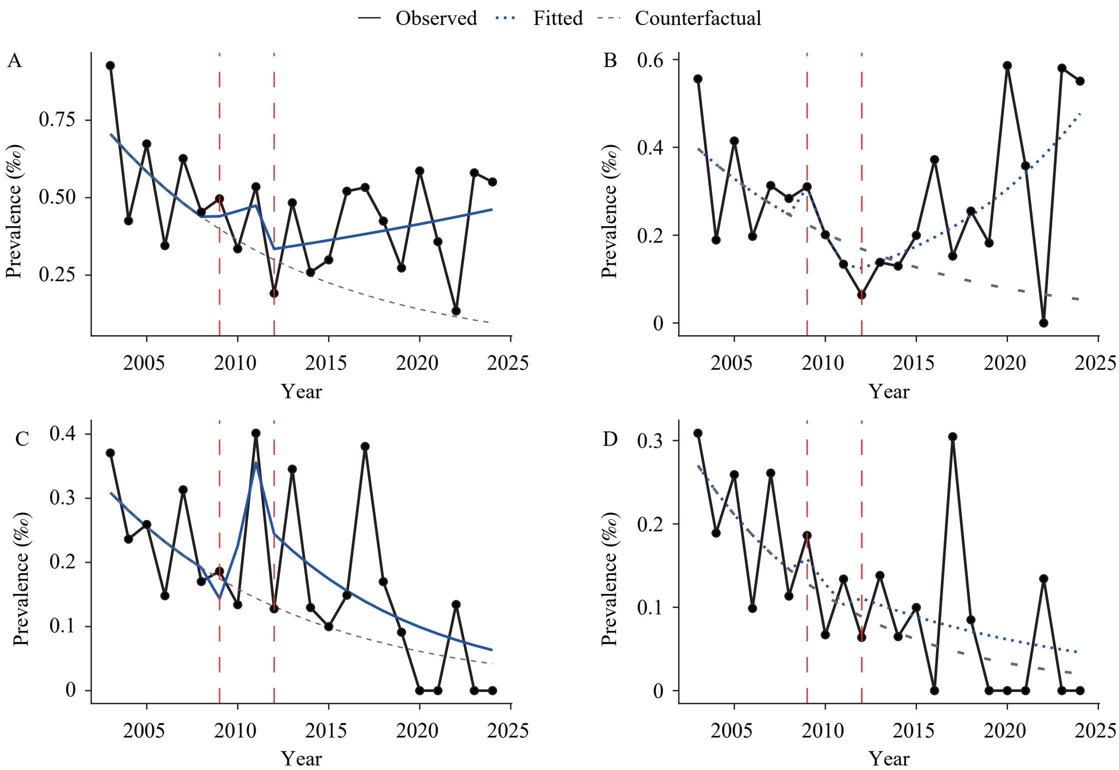
Characteristics	Isolated congenital clubfoot (*n*=77)	Non-isolated congenital clubfoot (*n*=60)	χ^2	*P*
Residence				
Rural	25 (32.5)	13 (21.7)	1.963	0.161
Urban	52 (67.5)	47 (78.3)		
Infant sex				
Male	43 (55.8)	37 (61.7)	0.866	0.352
Female	34 (44.2)	21 (35.0)		
Unknown	0 (0.0)	2 (3.3)		
Gestational weeks				
<28	8 (10.4)	19 (31.7)	9.648	0.002
≥28	69 (89.6)	41 (68.3)		
Laterality				
Bilateral	16 (20.8)	11 (18.3)	2.512	0.113
Unilateral	28 (26.3)	8 (13.4)		
Missing	33 (42.9)	41 (68.3)		
Delivery time				
Before 2009	36 (46.8)	28 (46.7)	<0.001	0.992
After 2009	41 (53.2)	32 (53.3)		

Note: Data for 2003 were available for only four counties: Zezhou, Pingding, Taigu, and Shouyang. For 2023 and 2024, data were available for Xiyang, Pingding, Taigu, and Shouyang. Data for all five counties were presented for all other years.

SUPPLEMENTARY TABLE S2. Results of interrupted time series models including both the folic acid supplementation policy and the joinpoint identified in 2012.

Types of cases	Model	PRR (95% *CI*)
Total congenital clubfoot	Time	0.909 (0.796, 1.038)
	FA policy level change	1.104 (0.493, 2.473)
	FA policy trend change	1.142 (0.706, 1.846)
	2012 joinpoint level change	0.679 (0.229, 2.012)
	2012 joinpoint trend change	0.989 (0.620, 1.578)
Isolated congenital clubfoot	Time	0.909 (0.761, 1.086)
	FA policy level change	1.380 (0.488, 3.901)
	FA policy trend change	0.721 (0.347, 1.498)
	2012 joinpoint level change	1.434 (0.229, 8.983)
	2012 joinpoint trend change	1.706 (0.834, 3.488)
Non-isolated congenital clubfoot	Time	0.909 (0.739, 1.119)
	FA policy level change	0.823 (0.216, 3.134)
	FA policy trend change	1.731 (0.842, 3.559)
	2012 joinpoint level change	0.437 (0.103, 1.845)
	2012 joinpoint trend change	0.568 (0.281, 1.146)
Non-isolated congenital clubfoot with spina bifida	Time	0.884 (0.683, 1.143)
	FA policy level change	1.228 (0.250, 6.040)
	FA policy trend change	0.916 (0.321, 2.613)
	2012 joinpoint level change	1.322 (0.104, 16.759)
	2012 joinpoint trend change	1.148 (0.408, 3.231)

Note: The full model includes both policies to evaluate their independent effects after mutual adjustments.
Abbreviation: PRR=prevalence rate ratio; FA=folic acid; *CI*=confidence interval.



SUPPLEMENTARY FIGURE S1. Fitted trends and counterfactual estimates of congenital clubfoot prevalence from interrupted time series analysis, 2003–2024. (A) Total congenital clubfoot; (B) isolated congenital clubfoot; (C) non-isolated congenital clubfoot; (D) non-isolated congenital clubfoot with spina bifida.

Note: The black solid line represents the observed prevalence of clubfoot (per 1,000 live births). The blue solid line shows the fitted values from the quasi-Poisson ITS model incorporating two temporal change points: the 2009 folic acid policy and a statistical jointpoint in 2012 identified by joinpoint regression. The grey dotted line indicates a counterfactual trend, representing the expected prevalence in the absence of these changes. The red dashed vertical lines mark the timing of the 2009 folic acid policy and the jointpoint identified in 2012.

Abbreviation: ITS=Interrupted time series.

Methods and Applications

Nomogram for Predicting Myopia Risk in Chinese Children and Adolescents Aged 5–19 Years — 10 PLADs, China 2020–2024

Keke Liu[1,2]; Ran Qin[2]; Huijuan Luo[2]; Xin Guo[1,3,#]

ABSTRACT

Introduction: This study aimed to identify the determinants of myopia in children and adolescents across 10 provincial-level administrative divisions (PLADs) and develop a predictive nomogram to aid risk identification.

Methods: From November 2020 to July 2024, 32,075 students aged 5–19 years were selected using stratified cluster random sampling across 10 PLADs. Myopia screening and questionnaires were used to collect demographic, behavioral, and environmental data. To account for the hierarchical structure of the data, multilevel logistic regression was employed to identify the independent predictors of myopia. A nomogram was constructed based on the regression coefficients, following the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) guidelines. The model performance was evaluated using receiver operating characteristic (ROC) curves, area under the curve (AUC), calibration plots, and decision curve analysis (DCA).

Results: The prevalence of myopia was 29.49% (9,460/32,075). Sex, daily frequency of school eye exercises, homework/reading and writing time after school, time spent on computers, 33-centimeter eye-to-book distance during reading and writing, 3-meter eye-to-TV distance, lying or prone position for reading/screen, parent-controlled game time, and parental myopia were identified as significant predictors. The nomogram demonstrated strong predictive ability, with AUCs of 0.80 (training) and 0.81 (validation), good calibration, and a high net clinical benefit in DCA.

Conclusion: The developed nomogram proved effective for identifying high-risk children, supporting personalized risk stratification, and targeting early intervention strategies.

The global prevalence of myopia has rapidly increased and has become a major public health concern, particularly among children and adolescents. Global myopia prevalence is projected to increase from 22.9% in 2000 to 49.8% by 2050, with 9.8% of the population expected to have high myopia (*1*). East and Southeast Asia have reported a particularly high prevalence of myopia, with China showing particularly elevated rates, affecting 53.6% of children and adolescents and over 90% of college students (*2*). Early onset myopia substantially increases the risk of sight-threatening complications, including retinal detachment, glaucoma, and myopic maculopathy, resulting in long-term health and socioeconomic burdens (*3*).

Although genetic susceptibility contributes to the development of myopia, the rapid increase in prevalence cannot be explained by genetic factors alone. Parental myopia is a well-established predictor, whereas modifiable behavioral factors, such as prolonged near work, insufficient outdoor activity, and excessive screen exposure, also play a critical role (*4*). Therefore, early identification of high-risk children is essential for implementing timely preventive and control strategies.

Nomograms provide an intuitive and practical approach for individualized risk prediction by integrating multiple predictors into a graphical model (*5*). However, the existing myopia prediction models are often complex and lack clinical applicability. This study aimed to develop and validate a concise nomogram to predict myopia risk among Chinese children and adolescents aged 5–19 years across 10 provincial-level administrative divisions (PLADs), supporting individualized risk assessment and prioritization of high-risk children for behavioral counseling.

This study is based on a national cross-sectional survey conducted by the National Disease Control and Prevention Administration of China between November 2020 and July 2024. Using a multistage stratified cluster sampling method, students were

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recruited from kindergartens and primary, middle, and high schools across 10 PLADs in China (Beijing, Shanxi, Liaoning, Zhejiang, Shandong, Henan, Hunan, Guangdong, Chongqing, and Shaanxi). The detailed survey procedures have been described previously (*6*). In total, 34,563 students participated in the survey. After excluding 2,488 participants owing to missing refractive, demographic, or behavioral data, 32,075 students aged 5–19 years were included in the final analysis. Model development and reporting adhered to the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) guidelines (*7*).

Data were collected via a structured questionnaire covering demographics (age, sex, school level, and region), behaviors (daily eye exercise frequency, homework/reading and writing time after school, time spent on computers, 33-centimeter eye-to-book distance during reading and writing, 3-meter eye-to-TV distance, lying or prone position for reading/screen, and parent-controlled game time), and family history (parental myopia). For grades 1–3, questionnaires were completed jointly by parents and students, and for higher grades, questionnaires were completed by students alone. Myopia screening included measurement of uncorrected distance visual acuity and cycloplegic autorefraction. All examiners were trained and certified by health professionals. Screening myopia was defined as an uncorrected visual acuity of <5.0 and a cycloplegic spherical equivalent (SE) of ≤−0.50 diopters (D) in at least one eye. The SE was calculated as the sphere power plus half the cylinder power.

The participants were randomly divided into training (70.00%) and validation (30.00%) sets. To account for the potential clustering effects of students within different PLADs and school grades, a multilevel logistic regression model with random intercepts for PLAD and grade was employed to identify the independent predictors of myopia. Covariates were selected based on clinical plausibility and the primary objectives of the study, including demographic, behavioral, and familial factors associated with myopia in school-aged populations. Age and school grade were highly collinear; therefore, the grade was included as a random intercept to reflect cumulative academic exposure. A nomogram was constructed based on the regression coefficients of the model. Model performance was evaluated using the area under the receiver operating characteristic curve (AUC), calibration plots with 1,000 bootstrap resamples, and decision curve analysis (DCA). Calibration plots were used to assess the agreement between the predicted and observed probabilities with ideal calibration along the 45° reference line. DCA quantifies net benefit across threshold probabilities by comparing the model against "treat-all" and "treat-none" strategies. Statistical analyses were performed using R software (version 4.4.2; R Foundation for Statistical Computing, Vienna, Austria), with a two-sided $P<0.05$ considered statistically significant.

The overall prevalence of myopia among the 32,075 students included in this analysis was 29.49% (9,460/32,075). The SE of the left and right eyes showed a strong correlation ($r=0.94$, $P<0.05$); therefore, data from the right eye were used for all subsequent analyses. Significant differences were observed between students with and without myopia in terms of age, sex, residency status, school grade, region, and SE (all $P<0.05$), whereas no significant differences in ethnicity were observed ($P>0.05$) (Table 1).

Univariate analyses revealed significant differences in the daily frequency of school eye exercises, homework/reading, and writing time after school, computer use time, 33-centimeter eye-to-book distance during reading and writing, 3-meter eye-to-TV distance, reading or screen use in lying or prone positions, parental control of game time, and parental myopia status between students with and without myopia (all $P<0.05$) (Supplementary Table S1, available at https://weekly.chinacdc.cn/). The multilevel logistic regression analysis identified several factors associated with myopia in both children and adolescents (Supplementary Table S2, available at https://weekly.chinacdc.cn/). The intraclass correlation coefficient for the null multilevel model was 0.42, suggesting that a substantial proportion of the total variance in myopia risk was attributable to differences across PLADs and school grades. Female sex [odds ratio (OR)=1.12, 95% confidence interval (CI): 1.05, 1.20], homework/reading and writing time ≥2 h per day (OR=1.25, 95% CI: 1.14, 1.37), often/always lying or prone position during reading or screen use (OR=1.22, 95% CI: 1.10, 1.35), lack of parental control of game time (OR=1.16, 95% CI: 1.06, 1.27), and parental myopia (unilateral: OR=1.68, 95% CI: 1.55, 1.81; bilateral: OR=2.49, 95% CI: 2.27, 2.74) were associated with higher odds of myopia. Maintaining an eye-to-book distance of ≥33 cm (OR=0.86, 95% CI: 0.80, 0.92) and an eye-to-TV distance ≥3 m (OR=0.84, 95% CI: 0.79, 0.90) were associated with lower odds of myopia.

TABLE 1. Baseline characteristics of participants from 10 PLADs, China, 2020–2024 (*n*=32,075).

Variables	Without myopia (*n*=22,615)	With myopia (*n*=9,460)	χ^2/*t**	*P*
Age (years)	7.87±1.82	10.66±2.99	−84.29	<0.001
Spherical equivalent (Diopter)	0.70±0.88	−2.29±1.76	156.71	<0.001
Sex			25.99	<0.001
Male	11,712 (51.79)	4,604 (48.67)		
Female	10,903 (48.21)	4,856 (51.33)		
Ethnicity			0.25	0.621
Han Chinese	21,507 (95.10)	8,984 (94.96)		
Others	1,108 (4.90)	476 (5.03)		
Whether live in school			1,005.69	<0.001
Yes	756 (38.77)	1,194 (61.23)		
No	21,859 (72.56)	8,266 (27.44)		
School level			7,306.56	<0.001
Lower primary (Grades 1–3)	18,153 (80.27)	3,259 (34.45)		
Upper elementary (Grades 4–6)	3,841 (16.98)	3,751 (39.65)		
Middle school	432 (1.91)	1,386 (14.65)		
High school	189 (0.84)	1,064 (11.25)		
Area			679.84	<0.001
Northeastern	1,428 (6.31)	1,327 (14.03)		
Eastern	7,658 (33.86)	2,844 (30.06)		
Central	11,054 (48.88)	3,860 (40.80)		
West	2,475 (10.94)	1,429 (15.11)		

* Continuous variables (Age, Spherical equivalent) were analyzed using independent samples t-test and presented as mean±standard deviation, with test statistic reported as *t*; categorical variables (Sex, Ethnicity, Whether live in school, School level, Area) were analyzed using Chi-square test and presented as *n* (%), with test statistic reported as χ^2.

Based on the independent predictors identified, a nomogram was constructed incorporating sex, daily frequency of school eye exercises, homework/reading and writing time after school, time spent on computers, 33-centimeter eye-to-book distance during reading and writing, 3-meter eye-to-TV distance, lying or prone position for reading/screen, parent-controlled game time, and parental myopia to estimate the individual myopia risk (Figure 1). To facilitate practical application of the nomogram, two representative case examples (high-risk and low-risk profiles) are provided to demonstrate the step-by-step procedure for calculating individual myopia risk (Supplementary Figure S1, available at https://weekly.chinacdc.cn/).

The nomogram demonstrated good discriminative performance, with an area under the ROC curve (AUC) of 0.80 (95% *CI*: 0.80, 0.81) in the training cohort (Figure 2A) and 0.81 (95% *CI*: 0.80, 0.82) in the validation cohort (Figure 2B). Calibration curves showed good agreement between the predicted and observed probabilities in both cohorts (Figure 2C–D). Decision curve analysis indicated that the nomogram provided a positive net clinical benefit across a wide range of threshold probabilities (0.10–0.80) in both the training and validation cohorts (Figure 3A–B), supporting its potential clinical applicability.

DISCUSSION

Predicting the risk of myopia is a major public health priority. Using data from children and adolescents aged 5–19 years across 10 PLADs, this study integrated key demographic, behavioral, and familial factors to develop a nomogram for individualized myopia risk prediction. The model demonstrated good discrimination, calibration, and clinical utility, providing a practical tool for early identification of high-risk populations to inform targeted behavioral recommendations.

Consistent with previous studies, myopia prevalence increased with age and school level, with secondary school students showing a higher prevalence than

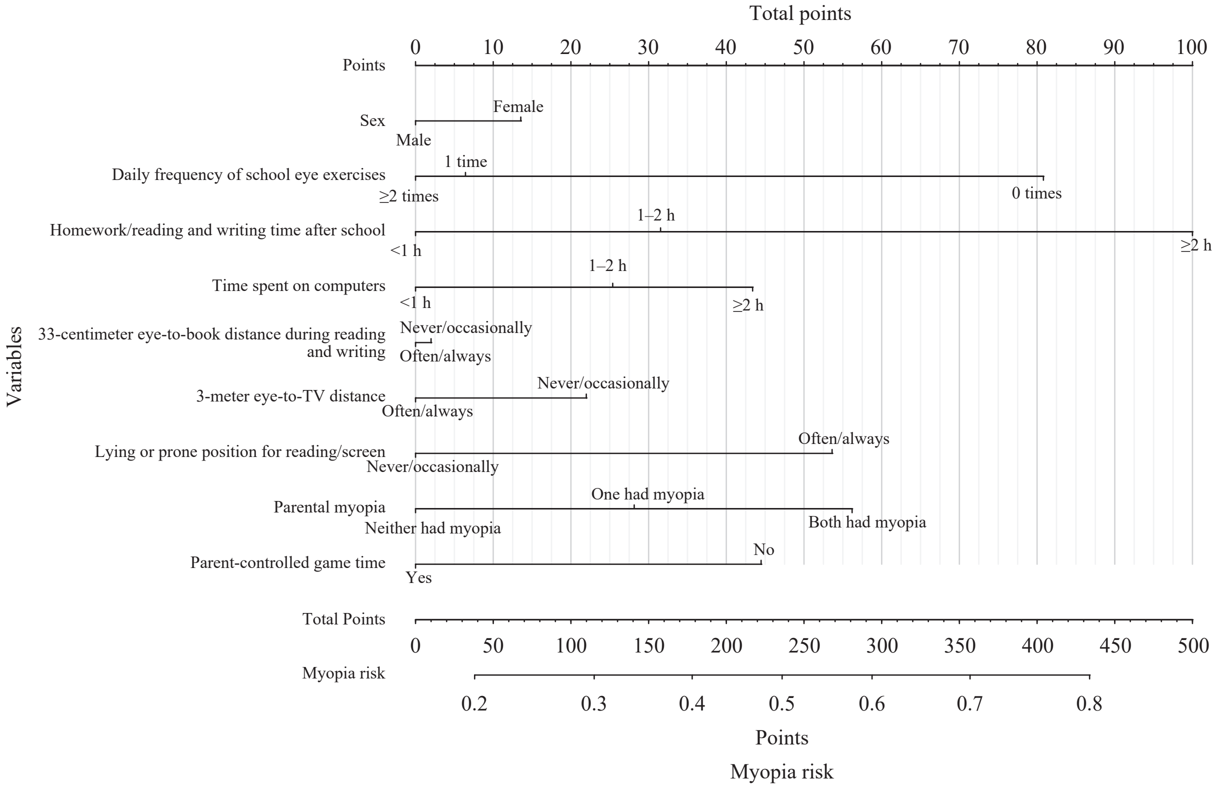

FIGURE 1. Nomogram for predicting myopia risk in children and adolescents aged 5–19 years from 10 PLADs, China, 2020–2024.

primary school students, likely reflecting increasing academic demands and prolonged near-work exposure (*8*). A slightly higher prevalence was observed among women, in line with previous international findings (*9*), which is possibly related to sex-specific physiological changes during adolescence. In addition, resident students generally had a higher prevalence of myopia, which may be associated with less regular daily routines and limited opportunities for rest and outdoor activities.

Behavioral factors related to near-work are strongly associated with myopia. Longer homework and reading times after school, prolonged computer use, inappropriate reading postures (lying or prone positions), and shorter eye-to-book or eye-to-screen distances were all linked to an increased risk of myopia, consistent with earlier evidence (*10–11*). These behaviors may contribute to sustained accommodative stress and visual fatigue, thereby promoting the progression of myopia. Conversely, maintaining appropriate reading distance (≥33 cm) and screen distance (≥3 m) was associated with a lower myopia prevalence, highlighting the importance of proper visual habits in daily life. Frequent school eye exercises were associated with a reduced risk of myopia, particularly when performed two or more times per day. This finding aligns with previous reports suggesting that massage-based eye exercises may improve accommodation and visual function (*12*). As expected, parental myopia remained a strong risk factor, underscoring the combined influence of genetic susceptibility and shared environmental exposure on the development of childhood myopia (*13*). Children with two parents with myopia had the highest risk. For these high-risk children, healthy visual habits may be particularly beneficial, and our nomogram can help identify those who require early behavioral interventions.

Compared with conventional risk scores or "black-box" machine learning approaches, the nomogram developed in this study offers greater transparency and clinical interpretability. Visual integration of multiple risk factors allows clinicians and public health practitioners to estimate individual myopia risk without complex calculations (*14*). Internal and external validations demonstrated stable performance, supporting its potential application in school-based screening and risk-based intervention planning.

This study has some limitations. First, the cross-sectional design precludes causal inferences between

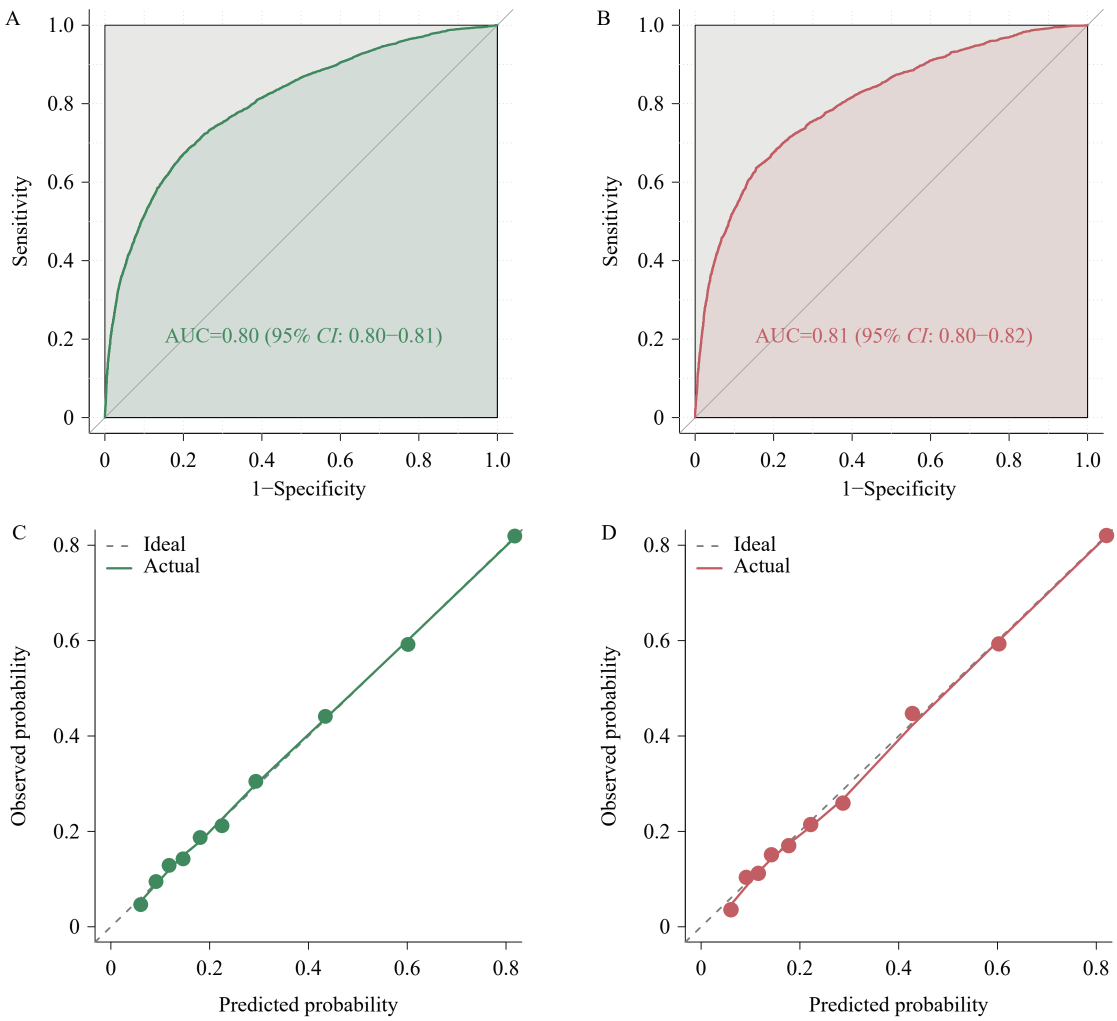

FIGURE 2. Performance of the nomogram for predicting myopia among children and adolescents from 10 PLADs, China, 2020–2024. (A) Receiver operating characteristic (ROC) curve in the training cohort; (B) ROC curve in the validation cohort. The x-axis represents 1-specificity and the y-axis represents sensitivity; (C) Calibration curve in the training cohort; (D) Calibration curve in the validation cohort.

Abbreviation: ROC=receiver operating characteristic; AUC=area under the curve; *CI*=confidence interval.

the risk factors and myopia development. Longitudinal studies are needed to validate the predictive value of these nomograms over time. Second, the behavioral variables were self-reported and may have been subject to recall or social desirability bias. Future studies that incorporate objective measures are warranted. Finally, the inclusion of additional socioeconomic and environmental factors may further improve the generalizability and predictive accuracy of the model.

In conclusion, a nomogram integrating school level, sex, key visual behaviors, and parental myopia effectively predicted the risk of myopia among Chinese children and adolescents. This model provides a simple and practical tool to support individualized risk assessment and early targeted intervention by identifying children with the highest probability of myopia.

Conflicts of interest: No conflicts of interest.

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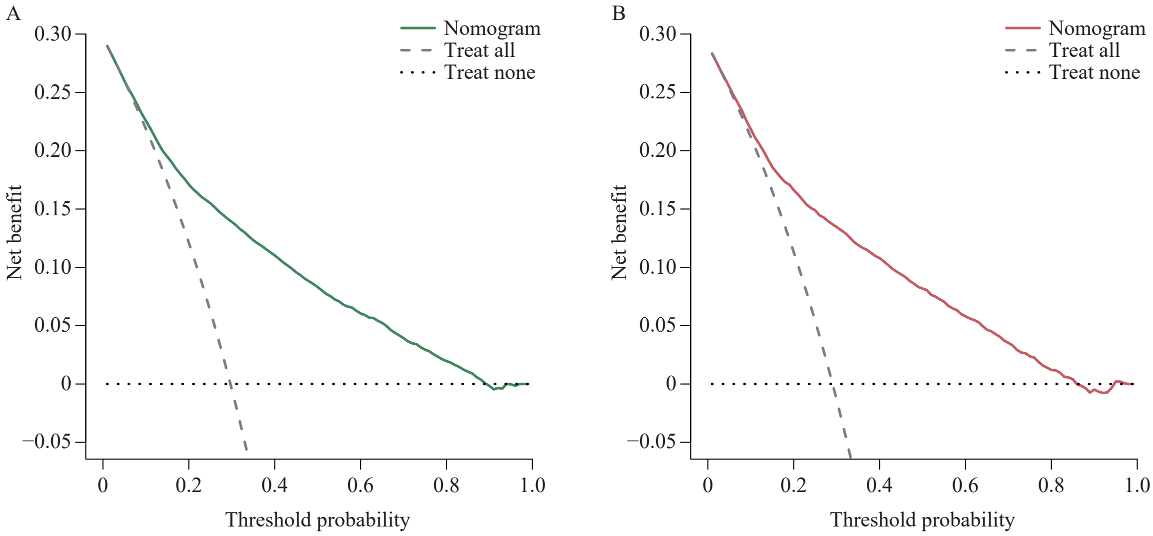

FIGURE 3. Clinical utility of the nomogram evaluated by decision curve analysis (DCA) among children and adolescents from 10 PLADs, China, 2020–2024. (A) Decision curve in the training cohort; (B) Decision curve in the validation cohort.
Abbreviation: DCA=decision curve analysis.

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SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. Univariate analysis of factors associated with myopia among children and adolescents from 10 PLADs, China, 2020–2024.

Variables	Without myopia (*n*=22,615)	With myopia (*n*=9,460)	χ^2	*P*
Daily frequency of school eye exercises			315.15	<0.001
0 times	1,018 (4.50)	915 (9.67)		
1 time	8,016 (35.45)	3,198 (33.81)		
≥2 times	13,581 (60.05)	5,347 (56.52)		
Homework/reading and writing time after school			859.29	<0.001
<1 h	7,996 (35.36)	2,319 (24.51)		
1–2 h	9,589 (42.40)	3,590 (37.95)		
≥2 h	5,030 (22.24)	3,551 (37.54)		
Time spent on computers			328.40	<0.001
<1 h	19,241 (85.08)	7,321 (77.39)		
1–2 h	2,113 (9.34)	1,145 (12.10)		
≥2 h	1,261 (5.58)	994 (10.51)		
33-centimeter eye-to-book distance during reading and writing			44.52	<0.001
Never/occasionally	13,324 (58.92)	5,952 (62.92)		
Often/always	9,291 (41.08)	3,508 (37.08)		
3-meter eye-to-TV distance			52.14	<0.001
Never/occasionally	10,674 (47.20)	4,883 (51.62)		
Often/always	11,941 (52.80)	4,577 (48.38)		
Lying or prone position for reading/screen			314.99	<0.001
Never/occasionally	20,201 (89.33)	7,763 (82.06)		
Often/always	2,414 (10.67)	1,697 (17.94)		
Parent-controlled game time			285.15	<0.001
Yes	18,684 (82.62)	7,036 (74.38)		
No	3,931 (17.38)	2,424 (25.62)		
Parental myopia			147.73	<0.001
Neither had myopia	10,277 (45.44)	3,741 (39.55)		
One parent had myopia	8,636 (38.19)	3,698 (39.09)		
Both had myopia	3,702 (16.37)	2,021 (21.36)		

Abbreviation: TV=television.

PRACTICAL APPLICATION OF THE NOMOGRAM WITH CASE EXAMPLES

To facilitate the clinical and public use of the developed nomogram, we provided two representative scenarios (cases A and B) to demonstrate how to calculate individual myopia risk.

Calculation Procedure

Locate levels: For each risk factor, identify the specific level of the student on the corresponding axis.

Assign points: Draw a vertical line upward from that level to the "points" axis at the top to read the score.

Sum total points: Add the points from all factors to obtain the "total points."

Predict risk: Locate the calculated sum on the "total points" axis and draw a vertical line downward to the "myopia risk" axis to read the predicted probability.

SUPPLEMENTARY TABLE S2. Multilevel logistic regression analysis of factors associated with myopia among children and adolescents from 10 PLADs, China, 2020–2024.

Variables	Parameter estimate (95% *CI*)	*P*	*OR* (95% *CI*)
Sex			
Male			1
Female	0.12 (0.05, 0.18)	<0.001	1.12 (1.05, 1.20)
Daily frequency of school eye exercises			
0 times			1
1 time	0.03 (−0.13, 0.19)	0.673	1.03 (0.88, 1.21)
≥2 times	0.02 (−0.15, 0.18)	0.852	1.02 (0.87, 1.19)
Homework/reading and writing time after school			
<1 h			1
1–2 h	0.05 (−0.03, 0.13)	0.250	1.05 (0.97, 1.14)
≥2 h	0.22 (0.13, 0.31)	<0.001	1.25 (1.14, 1.37)
Time spent on computers			
<1 h			1
1–2 h	−0.05 (−0.16, 0.06)	0.388	0.95 (0.85, 1.06)
≥2 h	0.09 (−0.05, 0.22)	0.204	1.09 (0.95, 1.25)
33-centimeter eye-to-book distance during reading and writing			
Never/occasionally			1
Often/always	−0.16 (−0.23, 0.08)	<0.001	0.86 (0.8, 0.92)
3-meter eye-to-TV distance			
Never/occasionally			1
Often/always	−0.17 (−0.24, 0.10)	<0.001	0.84 (0.79, 0.90)
Lying or prone position for reading/screen			
Never/occasionally			1
Often/always	0.20 (0.10, 0.30)	<0.001	1.22 (1.1, 1.35)
Parent-controlled game time			
Yes			1
No	0.15 (0.06, 0.24)	<0.001	1.16 (1.06, 1.27)
Parental myopia			
Neither had myopia			1
One had myopia	0.52 (0.44, 0.59)	<0.001	1.68 (1.55, 1.81)
Both had myopia	0.91 (0.82, 1.01)	<0.001	2.49 (2.27, 2.74)

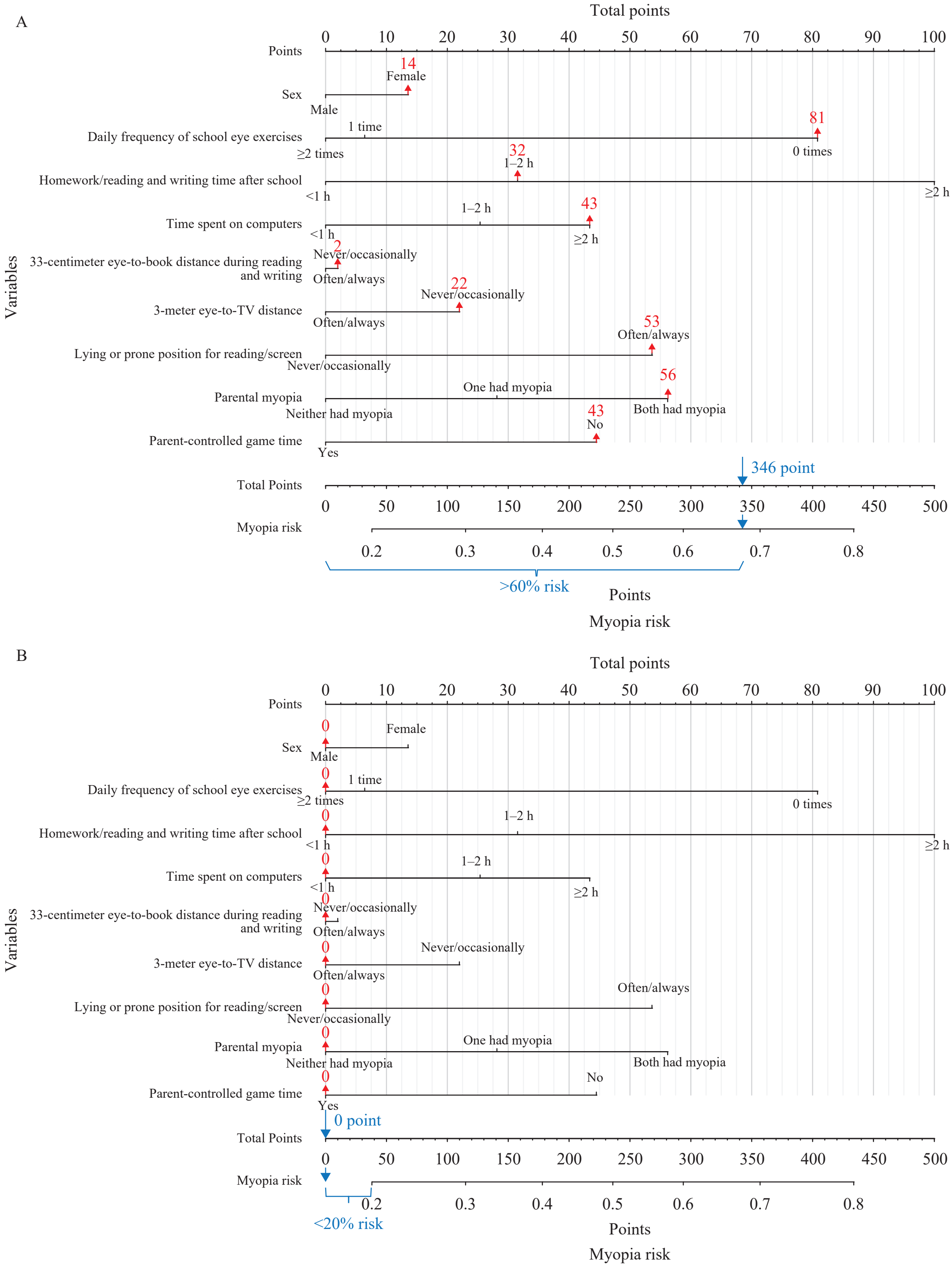
Abbreviation: TV=television; *OR*=odds ratio; *CI*=confidence interval.

High-risk Case Demonstration (case A) — Refer to Supplementary Figure S1A

(A) High myopia risk student (Case A): A female student who never performs school eye exercises, spends 1–2 h on homework and ≥2 h on computers after school. She never maintains a 33-centimeter eye-to-book distance during reading and writing or a 3-meter eye-to-TV distance and often reads or uses screens in a lying or prone position. Both her parents had myopia, and her game time was not controlled by her parents.

Point Calculation

Sex (Female): 14 pts
Daily frequency of school eye exercises (0 times): 81 pts
Homework/reading and writing time after school (1–2 h): 32 pts.



SUPPLEMENTARY FIGURE S1. Demonstration of the myopia risk nomogram's practical application with case examples among children and adolescents from 10 PLADs, China, 2020–2024. (A) High myopia risk student (case A); (B) Low myopia risk profile (case B).

Abbreviation: TV=television.

Time spent on computers (≥2 h): 43 pts
33-centimeter eye-to-book distance during reading and writing (never/occasionally): 2 pts
3-meter eye-to-TV distance (never/occasionally): 22 pts
Lying or prone position for reading/screen (often): 53 pts
Parental myopia (both): 56 pts
Parent-controlled game time (no): 43 pts
Total points: 14 + 81 + 32 + 43+ 2 + 22 + 53 + 56 + 43=346
Predicted risk: Mapping 346 points on the total points axis downward resulted in a risk of 0.68 (68%).
Interpretation: This student had a 68% absolute probability of developing myopia.

Low-risk Case Demonstration (Case B) — Refer to Supplementary Figure S1B

(B) Low myopia risk profile (Case B):This example demonstrates the nomogram application for a male student exhibiting predominantly protective visual behaviors: daily frequency of school eye exercises ≥2 times, homework/reading and writing time after school <1 h, time spent on computers <1 h, often/always maintenance of ≥33-centimeter eye-to-book distance during reading and writing and ≥3-meter eye-to-TV distance, never/occasionally using a lying or prone position for reading/screen presence of parental game time control, and no parental myopia.

Point calculation: All factors map to 0 points.
Total points: 0
Predicted risk: Mapping 0 on the total points axis downward resulted in a risk of <0.20 (20%).
Interpretation: The students had a low absolute probability (<20%) of developing myopia.

Clarification of Risk Values

The values on the "myopia risk" axis (e.g., 0.20, 0.50, and 0.80) represent the predicted absolute probability. For instance, a risk of 0.6 indicates a 60% chance of myopia in a student with a specific combination of risk factors. This probability was derived using a logistic link function, incorporating the intercept of the model to reflect the baseline risk of the population.

Commentary Commemoration

Commemorating the Centenary of Fangzhou Gu

Qifan Song[1,2]; Yufan Liang[2]; Jingyu Shi[3]; Yue Wang[2,#]

Fangzhou Gu (1926–2019) (Figure 1) was a preeminent medical scientist, virologist, and medical educator in 20th-century China, and 2026 marks the 100th anniversary of his birth. In December 2025, to commemorate the outstanding contributions of the Chinese scientist Fangzhou Gu to global public health, the 43rd General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) formally adopted a resolution to include the centenary of his birth in its list of internationally observed annual events. Fangzhou Gu devoted 42 years of research to the prevention and control of poliomyelitis and was one of the pioneers of tissue culture-based oral live vaccines in China. In 1957, Fangzhou Gu voluntarily assumed responsibility for leading a research team in the critical fight against polioviruses. In the early 1960s, he successfully developed two forms of live vaccine — liquid oral and sugar-pill vaccines — saving hundreds of thousands of children from paralysis. He also proposed eliminating polio through live vaccine technology, immunization programs, and strategies suited to China's national conditions.

FIGURE 1. Professor Fangzhou Gu (1926–2019).

A Public Health Awakening at Peking University and Advanced Studies in the Union of Soviet Socialist Republics (USSR)

In 1944, Fangzhou Gu was admitted to the Peking University School of Medicine. During his studies, the public health course taught by Jingqing Yan (1905–2005) left the deepest impression on him. Closely addressing the pressing realities of public health challenges in China, Yan's lectures deeply moved Fangzhou Gu and inspired him to devote himself to public health, determined to help the broader population live free from disease and in better health. In 1951, Fangzhou Gu pursued his studies in the USSR. He attended the Institute of Virology of the USSR Academy of Medical Sciences for his postgraduate education, which was one of the top institutions for medical scientific research and organizational management in the USSR at that time. Gu's supervisor was Professor E. N. Levkovich, a renowned expert in encephalitis virology in the USSR. This interdisciplinary knowledge base enabled him to combine basic scientific research with national epidemic prevention needs, a core prerequisite for China's localized polio control model.

Initiating China's National Polio Prevention Campaign

Polio emerged as a severe public health threat in China in the 1950s. The first local outbreak was recorded in Nantong in 1953, followed by a devastating nationwide epidemic in 1955, with an incidence rate of 32.1 per 100,000 people. In vulnerable children, the virus causes widespread paralysis and fatal respiratory failure, creating an urgent demand for localized prevention technologies and systematic control strategies. In response to the national epidemic crisis, Gu launched China's systematic polio etiology research and prevention

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program in 1957, initiating a long-term polio elimination campaign. He said, "This was a mission entrusted to me by the government," and overcoming poliomyelitis became the work of his lifetime.

Fangzhou Gu's first major breakthrough in controlling poliomyelitis was the isolation and typing of polioviruses. In 1957, he led a research team at the Academy of Military Medical Sciences of the Chinese People's Liberation Army. After investigating fecal specimens from patients with poliomyelitis in several domestic regions, the team isolated and successfully typed poliovirus from the feces of patients from 12 locations, including Beijing, Shanghai, Tianjin, and Qingdao. In 1958, Fangzhou Gu et al. (*1*) reported *Isolation and Identification of Poliomyelitis Viruses in Shanghai* in the *Chinese Journal of Parasitic and Infectious Diseases*. This study was the first to report the isolation of poliovirus using rhesus monkey kidney tissue culture technology, and to confirm the predominance of type I poliovirus in epidemics through etiological and serological methods in China. Thus, it provided essential epidemiological data to prevent further transmission of poliomyelitis.

Gu's vaccine development strategy reflected the typical Chinese public health decision-making logic of prioritizing national affordability and practical applicability over imported technical standards. In 1959, he verified that an imported inactivated polio vaccine (IPV) was economically unaffordable for universal national vaccination under China's socioeconomic conditions. Accordingly, he strategically shifted his research focus to low-cost oral attenuated live vaccines (OPV) and launched independent domestic vaccine research. This adaptive technological choice laid the foundation for large-scale population immunization and became a classic model for the localized transformation of foreign public health technologies in China.

Groundbreaking Clinical Trials for OPV

Rigorous clinical verification constitutes another key experience in China's vaccine-driven epidemic control. Gu designed a standardized research system that integrates animal experiments and three-phase clinical trials. To validate vaccine safety for children, the core vaccination population, he conducted self-testing in Phase I trials and enrolled his newborn child as a trial participant, with team members volunteering their own children. These actions, undertaken in the specific context of the early 1960s, reflect the researchers' willingness to assume personal risk before promoting broader vaccination. Large-scale population-based trials confirmed the public health value of OPV control models. In 1960, sequential Phase II and Phase III trials covering 2 million children nationwide systematically verified vaccine safety and real-world protective efficacy. Epidemiological surveillance has shown a sharp decline in polio incidence among vaccinated populations, providing solid evidence for the nationwide promotion of immunization (*2*). The momentum of the epidemic spread was significantly curbed, and Chinese children gained reliable immunological protection against poliomyelitis.

Development and Popularization of Sugar-pill Polio Vaccine

Sugar-pill vaccine innovation solved the bottleneck of grassroots epidemic prevention by optimizing China's rural disease control model. Early liquid OPV required strict low-temperature storage and had a short shelf life, which was incompatible with China's vast rural and remote mountainous areas with limited logistics and medical infrastructure. Gu et al. developed a solid sugar-pill OPV in 1962 (*3*) featuring a longer shelf life, convenient transportation and administration, and stable immunogenicity.

Its nationwide popularization in 1964 and subsequent trivalent vaccine optimization in 1986 further improved China's polio prevention system. The successful development of the trivalent sugar-pill vaccine not only resolved the supply issue of semi-finished poliovirus vaccine liquid but also improved production efficiency, reduced manufacturing costs, and made administration more convenient. The sustained iteration of vaccine technology and promotional strategies has driven a steady annual decline in national polio cases, forming a complete prevention system that covers etiological monitoring, vaccine research and development, and full-population immunization.

In October 2000, the Western Pacific Regional Certification Commission for the Eradication of Poliomyelitis of the World Health Organization (WHO) confirmed that the transmission of indigenous wild poliovirus in China was interrupted. This milestone achievement validates the effectiveness of China's localized polio prevention model, which integrates independent technological innovation, adaptive strategy adjustment, full-population coverage, and standardized grassroots implementation.

Scientific Spirit and Global Public Health Legacy

China's polio elimination practices, led by Fangzhou Gu, summarize three core public health experiences. First, precise epidemic research serves as the premise for scientific prevention and control. Second, localized technological innovation adapts public health tools to national grassroots conditions. Third, population-oriented full-coverage immunization strategies can eliminate epidemic transmission risks. These practices address the core challenges of infectious disease control in developing countries, including limited medical resources, unbalanced regional medical development, and large populations.

Gu's modest dedication and successful polio control model offer profound global public health lessons. Beyond protecting hundreds of millions of children, China's polio elimination experience provides a replicable paradigm for developing countries to respond to major childhood infectious diseases. UNESCO's global commemoration further highlights the international value of China's grassroots public health strategies, technological independence, and people-centered prevention concepts, offering lasting guidance for global infectious disease prevention and control cooperation.

Conflicts of interest: No conflicts of interest.

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