Preplanned Studies

Detection Rate and Risk Factors of Abnormal Spinal Curvature Among Children and Adolescents — Jiangsu Province, China, 2021–2023

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Summary

What is already known about this topic?

Spinal curvature abnormalities have emerged as a major public health challenge for children and adolescents in China, with detection rates showing a concerning upward trend in recent years.

What is added by this report?

This population-based surveillance study revealed a 2.1% detection rate of abnormal spinal curvature among children and adolescents aged 6–17 years in Jiangsu Province. The findings emphasize the critical need for early intervention programs targeting modifiable risk factors, including insufficient physical activity, inadequate sleep duration, and improper reading and writing posture.

What are the implications for public health practice?

The increasing burden of abnormal spinal curvature requires targeted attention, particularly for high school students and females during growth spurts. A comprehensive approach combining early lifestyle interventions, such as adequate outdoor activities, with appropriate referrals to public health specialists and orthopedic surgeons may enhance risk mitigation. Success in addressing this challenge requires coordinated multisectoral collaboration and active parental engagement.

ABSTRACT

Introduction: In China, the prevalence of abnormal spinal curvature in children and adolescents is high and the number of cases is increasing in recent years, which seriously threatens physical and mental health of children and adolescents. Public health surveillance of these abnormalities is crucial for developing targeted interventions.

Methods: This study evaluated detection rates and risk factors of spinal curvature abnormalities among children and adolescents in Jiangsu Province, China. This study analyzed data from the population-based "Surveillance for Common Disease and Health Risk Factors Among Students" project, implemented annually from September to November during 2021–2023. Abnormal spinal curvature was assessed using the national "Technical Guide for Prevention and Control of Abnormal Spinal Curvature in Children and Adolescents." Detection rates were calculated, and associated factors were evaluated using multivariate logistic regression.

Results: Annual detection rates were 2.6%, 1.8%, and 2.3%, respectively, among children and adolescents aged 6–17 years. Detection rates increased with age and were significantly higher among females compared to males. Adequate physical activity, sufficient sleep, and correct reading and writing postures were protective factors against spinal curvature abnormalities, while low body weight was associated with increased risk.

Conclusion: The emerging burden of abnormal spinal curvature necessitates targeted public health interventions, particularly for high school students and females. Beyond implementing early lifestyle interventions such as sufficient outdoor activities, appropriate referrals to public health specialists and orthopedic surgeons may provide additional risk mitigation. Successful outcomes require multisectoral collaboration and parental engagement to achieve sustainable public health improvements.

Abnormal spinal curvature significantly impacts both the physical and mental well-being of children and adolescents. Adolescent idiopathic scoliosis (AIS) represents the most prevalent form of abnormal spinal curvature, affecting 1%–4% of adolescents with a notable predisposition toward females (*1*). In China, spinal curvature abnormalities have emerged as a major

public health challenge, with detection rates among primary and secondary school students reaching 2.8% in 2019 (*2*). This study aimed to evaluate temporal trends in detection rates and identify risk factors associated with spinal curvature abnormalities among children and adolescents in Jiangsu Province, China. Systematic public health surveillance of spinal curvature abnormalities in this population is essential for developing targeted interventions.

This study utilized data from the "Surveillance for Common Disease and Health Risk Factors Among Students" program conducted across all 13 prefecture-level administrative regions in Jiangsu Province. The program methodology has been detailed elsewhere (*3*). The surveillance coverage expanded progressively: in 2021, a pilot study encompassed 26 districts and counties; in 2022, coverage increased to 88 districts; and by 2023, the program included all 98 districts and counties in Jiangsu. While a cohort design would have enabled incidence estimation, the current study employed cross-sectional sampling each year. Efforts to establish a longitudinal cohort for incidence rate calculations are ongoing and will be reported separately. This study implemented standardized training protocols for all field personnel and maintained rigorous quality control measures for data management. To validate temporal trends given the varying coverage, supplementary analyses were conducted using simple random sampling of two distinct districts per city annually. The questionnaire response rate achieved 97.7%.

Following the UN Convention on the Rights of the Child's definition of children as those aged 18 years and under, and considering the impact of growth spurts on spinal curvature development, this study adopted the term "children and adolescents" for this study. All variables, except abnormal spinal curvature and body mass index (BMI), were self-reported by participants. Spinal curvature abnormality was defined as spinal curvature exceeding normal physiological ranges, encompassing both scoliosis and sagittal spinal abnormalities. Screening procedures adhered to the national "Technical Guide for Prevention and Control of Abnormal Spinal Curvature in Children and Adolescents". BMI was calculated as weight in kilograms divided by height in meters squared, with measurements conducted by trained research associates using standardized equipment and protocols (height measured to 0.1 cm, weight to 0.1 kg). Detailed variable definitions are presented in corresponding table.

Statistical analyses were conducted using R Software (version 4.4.0; The R Foundation for Statistical Computing, Vienna, Austria). This study summarized categorical variables using frequencies and percentages, employing Chi-square tests to assess proportional differences. Risk factors associated with abnormal spinal curvature were evaluated using multivariate logistic regression, with variable selection informed by both lasso technique and existing literature. Statistical significance was set at $P<0.05$.

A total of 370,000 children and adolescents aged 6–17 years participated in the surveillance program during 2021–2023, comprising 47,310 participants in 2021, 150,387 in 2022, and 173,341 in 2023. The study population included 168,787 (45.5%) children aged 6–11 years and 202,251 (54.5%) adolescents aged 12–17 years, with a slight male predominance (193,518, 52.2% *vs.* 177,520, 47.8% females) and higher urban representation (197,654, 53.3% *vs.* 173,384, 46.7% rural). The annual detection rates of abnormal spinal curvature were 2.6%, 1.8%, and 2.3% for 2021, 2022, and 2023, respectively. Geographic variation in detection rates was observed across the 13 municipalities of Jiangsu Province (Table 1). Validation analyses confirmed that the temporal pattern of detection rates was consistent with the primary analysis (Supplementary Table S1, available at https://weekly.chinacdc.cn/). Age-stratified analyses revealed that detection rates increased with age, with males showing a marked increase at age 11 while females demonstrated an earlier increase at age 9 (Figure 1). Higher detection rates were observed among females compared to males (3.1% *vs.* 2.4%), senior high school students compared to primary and junior high school students (4.1% *vs.* 1.3% and 3.3%, respectively), students experiencing growth spurts compared to those who were not (2.8% *vs.* 2.0%), and students with insufficient physical activities compared to those with sufficient activities (2.8% *vs.* 1.9%) (Supplementary Table S1).

Detection rates of abnormal spinal curvature among children and adolescents in Jiangsu Province from 2021 to 2023 showed significant differences ($P<0.001$) across multiple factors, including region, district, gender, grade, BMI, growth and development period, physical activities, sleep, reading and writing posture, schoolbag habits, schoolbag weight, mattress softness, and sitting and standing posture (Table 2).

Multivariate analysis revealed protective effects associated with sufficient physical activities, adequate sleep, and correct reading and writing posture, each

TABLE 1. Detection rate of abnormal spinal curvature among children and adolescents across 13 municipalities in Jiangsu Province, 2021–2023.

Prefecture-level administrative regions	2021			2022			2023			Total		
	N	*n*	Rate (95% *CI*)	*N*	*n*	Rate (95% *CI*)	*N*	*n*	Rate (95% *CI*)	*N*	*n*	Rate (95% *CI*)
Nanjing	3,419	132	3.86 (3.21, 4.51)	13,485	196	1.45 (1.25, 1.66)	19,613	619	3.16 (2.91, 3.40)	36,517	947	2.59 (2.43, 2.76)
Wuxi	3,562	176	4.94 (4.23, 5.65)	12,776	218	1.71 (1.48, 1.93)	13,104	482	3.68 (3.36, 4.00)	29,442	876	2.98 (2.78, 3.17)
Xuzhou	3,684	54	1.47 (1.08, 1.85)	17,427	154	0.88 (0.74, 1.02)	17,862	152	0.85 (0.72, 0.99)	38,973	360	0.92 (0.83, 1.02)
Changzhou	3,669	122	3.33 (2.75, 3.91)	9,504	128	1.35 (1.12, 1.58)	12,293	311	2.53 (2.25, 2.81)	25,466	561	2.20 (2.02, 2.38)
Suzhou	3,613	66	1.83 (1.39, 2.26)	16,438	625	3.80 (3.51, 4.09)	18,880	736	3.90 (3.62, 4.17)	38,931	1,427	3.67 (3.48, 3.85)
Nantong	3,877	157	4.05 (3.43, 4.67)	9,646	537	5.57 (5.11, 6.02)	13,221	389	2.94 (2.65, 3.23)	26,744	1,083	4.05 (3.81, 4.29)
Lianyungang	3,657	67	1.83 (1.40, 2.27)	10,544	215	2.04 (1.77, 2.31)	10,884	332	3.05 (2.73, 3.37)	25,085	614	2.45 (2.26, 2.64)
Huai'an	3,702	10	0.27 (0.10, 0.44)	12,317	159	1.29 (1.09, 1.49)	12,435	382	3.07 (2.77, 3.38)	28,454	551	1.94 (1.78, 2.10)
Yancheng	3,612	23	0.64 (0.38, 0.90)	16,154	251	1.55 (1.36, 1.74)	15,393	126	0.82 (0.68, 0.96)	35,159	400	1.14 (1.03, 1.25)
Yangzhou	3,507	96	2.74 (2.20, 3.28)	8,722	39	0.45 (0.31, 0.59)	9,865	202	2.05 (1.77, 2.33)	22,094	337	1.53 (1.36, 1.69)
Zhenjiang	3,644	169	4.64 (3.95, 5.32)	10,699	119	1.11 (0.91, 1.31)	10,334	97	0.94 (0.75, 1.12)	24,677	385	1.56 (1.41, 1.71)
Taizhou	3,625	97	2.68 (2.15, 3.20)	3,662	11	0.30 (0.12, 0.48)	10,521	160	1.52 (1.29, 1.75)	17,808	268	1.50 (1.33, 1.68)
Suqian	3,739	55	1.47 (1.09, 1.86)	9,013	27	0.30 (0.19, 0.41)	8,936	79	0.88 (0.69, 1.08)	21,688	161	0.74 (0.63, 0.86)

Abbreviation: *CI*=confidence interval.

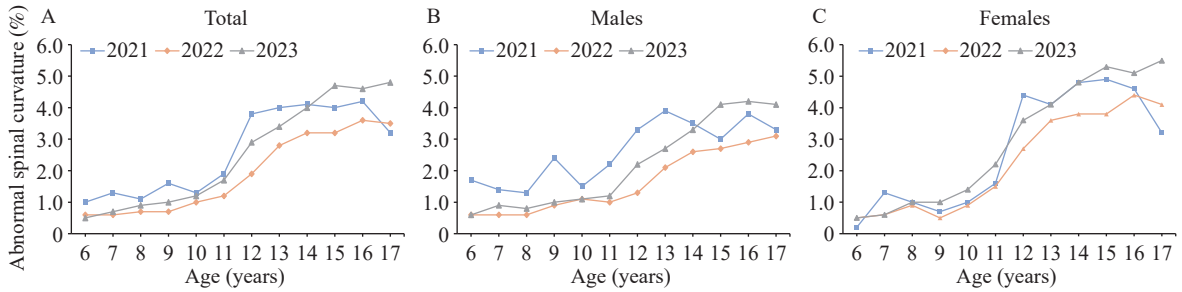

FIGURE 1. Age-specific detection rates of abnormal spinal curvature among children and adolescents aged 6–17 years in Jiangsu Province, 2021–2023. (A) All children and adolescents; (B) Males; (C) Females.

corresponding to lower odds of abnormal spinal curvature. Conversely, higher academic grades, female gender, and being underweight were associated with increased odds of abnormal spinal curvature (Figure 2).

DISCUSSION

The 3-year detection rate of spinal curvature abnormalities among children and adolescents aged 6–17 years in Jiangsu Province (2.1%) was lower than rates reported in Sichuan Province (3.4%) (*4*) and Inner Mongolia Autonomous Region (3.6%) (*5*). This regional variation may be attributed to differences in economic development levels and study sample sizes.

This study's observation of elevated detection rates of abnormal spinal curvature in higher academic grades aligns with previous findings that scoliosis prevalence in China increases with grade level (*6*). Adolescence represents a critical period for skeletal muscle development, during which persistent incorrect posture may lead to abnormal spinal curvature and scoliosis. Students in higher grades typically face increased academic workloads, potentially promoting sedentary behaviors that may contribute to spinal abnormalities.

Consistent with previous research (*7*), this study found higher detection rates of spinal curvature abnormalities in females compared to males. This gender disparity may be attributed to multiple factors,

TABLE 2. Detection rates of abnormal spinal curvature among children and adolescents in Jiangsu Province, 2021–2023.

Variables	2021				2022				2023				Total			
	N	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*
Region				<0.001				<0.001				<0.001				<0.001
Southern Jiangsu	12,934	571	4.41 (4.06, 4.77)		45,298	1,173	2.59 (2.44, 2.74)		54,188	2,067	3.81 (3.65, 3.98)		112,420	3,811	3.39 (3.28, 3.50)	
Central Jiangsu	7,940	328	4.13 (3.69, 4.57)		15,686	535	3.41 (3.13, 3.69)		24,216	680	2.81 (2.60, 3.02)		47,842	1,543	3.23 (3.07, 3.38)	
Northern Jiangsu	13,273	176	1.33 (1.13, 1.52)		46,401	692	1.49 (1.38, 1.60)		46,959	962	2.05 (1.92, 2.18)		106,633	1,830	1.72 (1.64, 1.79)	
District				<0.001				<0.001				<0.001				<0.001
Urban	19,091	383	2.01 (1.81, 2.21)		59,215	1,188	2.01 (1.89, 2.12)		67,693	2,154	3.18 (3.05, 3.31)		145,999	3,725	2.55 (2.47, 2.63)	
Rural	15,056	692	4.60 (4.26, 4.93)		48,170	1,212	2.52 (2.38, 2.66)		57,670	1,555	2.70 (2.56, 2.83)		120,896	3,459	2.86 (2.77, 2.96)	
Gender				0.153				<0.001				<0.001				<0.001
Male	17,742	535	3.02 (2.76, 3.27)		56,277	1,021	1.81 (1.70, 1.92)		65,229	1,628	2.50 (2.38, 2.62)		139,248	3,184	2.29 (2.21, 2.37)	
Female	16,405	540	3.29 (3.02, 3.56)		51,108	1,379	2.70 (2.56, 2.84)		60,134	2,081	3.46 (3.31, 3.61)		127,647	4,000	3.13 (3.04, 3.23)	
Grade				<0.001				<0.001				<0.001				<0.001
Primary school	13,161	218	1.66 (1.44, 1.87)		42,971	450	1.05 (0.95, 1.14)		47,568	649	1.36 (1.26, 1.47)		103,700	1,317	1.27 (1.20, 1.34)	
Junior High School	12,651	534	4.22 (3.87, 4.57)		40,432	1,131	2.80 (2.64, 2.96)		47,397	1,650	3.48 (3.32, 3.65)		100,480	3,315	3.30 (3.19, 3.41)	
Senior High School	8,335	323	3.88 (3.46, 4.29)		23,982	819	3.42 (3.19, 3.64)		30,398	1,410	4.64 (4.40, 4.87)		62,715	2,552	4.07 (3.91, 4.22)	
BMI*				<0.001				<0.001				<0.001				<0.001
Normal	19,946	715	3.58 (3.33, 3.84)		63,169	1,746	2.76 (2.64, 2.89)		72,390	2,691	3.72 (3.58, 3.86)		155,505	5,152	3.31 (3.22, 3.40)	
Underweight	1,220	48	3.93 (2.84, 5.03)		3,656	113	3.09 (2.53, 3.65)		5,935	296	4.99 (4.43, 5.54)		10,811	457	4.23 (3.85, 4.61)	
Overweight	6,521	172	2.64 (2.25, 3.03)		20,234	322	1.59 (1.42, 1.76)		22,558	417	1.85 (1.67, 2.02)		49,313	911	1.85 (1.73, 1.97)	
Obesity	6,460	140	2.17 (1.81, 2.52)		20,326	219	1.08 (0.94, 1.22)		24,480	305	1.25 (1.11, 1.38)		51,266	664	1.30 (1.20, 1.39)	
Growth and development period				<0.001				<0.001				<0.001				<0.001
No	17,777	415	2.33 (2.11, 2.56)		56,992	729	1.28 (1.19, 1.37)		100,871	2,851	0.62 (0.57, 0.67)		175,640	3,995	1.95 (1.86, 2.04)	
Yes	16,370	660	4.03 (3.73, 4.33)		50,393	1,671	3.32 (3.16, 3.47)		24,492	858	3.50 (3.27, 3.73)		91,255	3,189	3.49 (3.38, 3.61)	

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Variables	2021				2022				2023				Total			
	N	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*
MVPA[†]				<0.001				<0.001				<0.001				<0.001
Insufficient	29,127	959	3.30 (3.09, 3.50)		91,005	2,166	2.38 (2.28, 2.48)		106,971	3,297	3.08 (2.98, 3.19)		227,103	6,422	2.83 (2.76, 2.90)	
Sufficient	5,020	116	2.31 (1.90, 2.73)		16,380	234	1.43 (1.25, 1.61)		18,392	412	2.24 (2.03, 2.45)		39,792	762	1.91 (1.78, 2.05)	
Sleep[§]				<0.001				<0.001				<0.001				<0.001
Insufficient	26,378	872	3.31 (3.09, 3.53)		82,306	1,991	2.42 (2.31, 2.52)		97,783	3,028	3.10 (2.99, 3.21)		206,467	5,891	2.85 (2.78, 2.93)	
Sufficient	7,769	203	2.61 (2.26, 2.97)		25,079	409	1.63 (1.47, 1.79)		27,580	681	2.47 (2.29, 2.65)		60,428	1,293	2.14 (2.02, 2.26)	
Reading and writing posture				0.055				<0.001				<0.001				<0.001
Incorrect	23,124	757	3.28 (3.05, 3.51)		75,489	1,846	2.45 (2.34, 2.56)		90,572	2,826	3.12 (3.01, 3.23)		189,185	5,429	2.87 (2.79, 2.94)	
Correct	11,023	318	2.88 (2.57, 3.20)		31,896	554	1.74 (1.59, 1.88)		34,791	883	2.54 (2.37, 2.70)		77,710	1,755	2.26 (2.15, 2.36)	
Schoolbag habits				0.002				0.004				<0.001				<0.001
On the chest	2,269	45	1.98 (1.41, 2.56)		6,763	112	1.66 (1.35, 1.96)		9,215	197	2.14 (1.84, 2.43)		18,247	354	1.94 (1.74, 2.14)	
On the back	26,466	844	3.19 (2.98, 3.40)		83,457	1,878	2.25 (2.15, 2.35)		96,696	2,901	3.00 (2.89, 3.11)		206,619	5,623	2.72 (2.65, 2.79)	
On one side	2,721	108	3.97 (3.24, 4.70)		8,617	220	2.55 (2.22, 2.89)		9,866	347	3.52 (3.15, 3.88)		21,204	675	3.19 (2.95, 3.42)	
Shoulder bag	2,248	65	2.89 (2.20, 3.58)		7,252	166	2.29 (1.94, 2.63)		8,158	232	2.84 (2.48, 3.20)		17,658	463	2.62 (2.39, 2.86)	
Schoolbag with wheels	443	13	2.93 (1.36, 4.51)		1,296	24	1.85 (1.12, 2.59)		1,428	32	2.24 (1.47, 3.01)		3,167	69	2.18 (1.67, 2.69)	
Schoolbag Weight				0.028				<0.001				<0.001				<0.001
Very light	3,165	72	2.27 (1.76, 2.79)		9,561	165	1.73 (1.46, 1.99)		14,234	391	2.75 (2.48, 3.02)		26,960	628	2.33 (2.15, 2.51)	
Relatively light	5,572	184	3.30 (2.83, 3.77)		17,617	417	2.37 (2.14, 2.59)		21,342	721	3.38 (3.14, 3.62)		44,531	1,322	2.97 (2.81, 3.13)	
Medium	17,368	584	3.36 (3.09, 3.63)		55,637	1,298	2.33 (2.21, 2.46)		60,984	1,857	3.05 (2.91, 3.18)		133,989	3,739	2.79 (2.70, 2.88)	
Relatively heavy	5,435	157	2.89 (2.44, 3.33)		17,026	389	2.28 (2.06, 2.51)		19,154	497	2.59 (2.37, 2.82)		41,615	1,043	2.51 (2.36, 2.66)	
Very heavy	1,879	57	3.03 (2.26, 3.81)		5,562	97	1.74 (1.40, 2.09)		6,861	174	2.54 (2.16, 2.91)		14,302	328	2.29 (2.05, 2.54)	
Unknown	728	21	2.88 (1.67, 4.10)		1,982	34	1.72 (1.14, 2.29)		2,788	69	2.47 (1.90, 3.05)		5,498	124	2.26 (1.86, 2.65)	

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Variables	2021				2022				2023				Total			
	N	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*
Regular seat changes				0.067				0.214				0.114				0.077
No	13,052	382	2.93 (2.64, 3.22)		39,218	847	2.16 (2.02, 2.30)		52,736	1,513	2.87 (2.73, 3.01)		105,006	2,742	2.61 (2.51, 2.71)	
Yes	21,095	693	3.29 (3.04, 3.53)		68,167	1,553	2.28 (2.17, 2.39)		72,627	2,196	3.02 (2.90, 3.15)		161,889	4,442	2.74 (2.66, 2.82)	
Softness of mattress				0.125				<0.001				0.002				<0.001
Soft	4,683	125	2.67 (2.21, 3.13)		17,250	305	1.77 (1.57, 1.96)		20,322	525	2.58 (2.37, 2.80)		42,255	955	2.26 (2.12, 2.40)	
Medium	26,767	864	3.23 (3.02, 3.44)		82,861	1,927	2.33 (2.22, 2.43)		94,097	2,839	3.02 (2.91, 3.13)		203,725	5,630	2.76 (2.69, 2.84)	
Hard	2,697	86	3.19 (2.53, 3.85)		7,274	168	2.31 (1.96, 2.65)		10,944	345	3.15 (2.83, 3.48)		20,915	599	2.86 (2.64, 3.09)	
Sole wear patterns (left/right)				0.057				0.676				0.699				0.615
No difference	32,187	1,031	3.20 (3.01, 3.40)		100,740	2,256	2.24 (2.15, 2.33)		116,961	3,457	2.96 (2.86, 3.05)		249,888	6,744	2.70 (2.64, 2.76)	
Left	867	18	2.08 (1.13, 3.03)		2,964	69	2.33 (1.79, 2.87)		3,677	104	2.83 (2.29, 3.36)		7,508	191	2.54 (2.19, 2.90)	
Right	1,093	26	2.38 (1.48, 3.28)		3,681	75	2.04 (1.58, 2.49)		4,725	148	3.13 (2.64, 3.63)		9,499	249	2.62 (2.30, 2.94)	
Sole wear patterns (inside/outside)				0.922				0.839				0.1				0.266
No difference	30,596	962	3.14 (2.95, 3.34)		94,874	2,112	2.23 (2.13, 2.32)		111,363	3,276	2.94 (2.84, 3.04)		236,833	6,350	2.68 (2.62, 2.75)	
Inside	1,259	42	3.34 (2.34, 4.33)		4,384	99	2.26 (1.82, 2.70)		5,256	181	3.44 (2.95, 3.94)		10,899	322	2.95 (2.64, 3.27)	
Outside	2,292	71	3.10 (2.39, 3.81)		8,127	189	2.33 (2.00, 2.65)		8,744	252	2.88 (2.53, 3.23)		19,163	512	2.67 (2.44, 2.90)	
Sitting and standing posture				<0.001				<0.001				<0.001				<0.001
Just be comfortable	6,697	229	3.42 (2.98, 3.85)		24,439	566	2.32 (2.13, 2.50)		34,354	1,077	3.14 (2.95, 3.32)		65,490	1,872	2.86 (2.73, 2.99)	
Sometimes monitor myself	12,857	459	3.59 (3.25, 3.89)		40,268	1,068	2.65 (2.50, 2.81)		48,056	1,581	3.29 (3.13, 3.45)		101,181	3,108	3.07 (2.97, 3.18)	
Keep reminding myself	6,825	204	2.99 (2.59, 3.39)		20,539	405	1.97 (1.78, 2.16)		21,472	608	2.83 (2.61, 3.05)		48,836	1,217	2.49 (2.35, 2.63)	
Maintain good posture at all time	7,768	183	2.36 (2.02, 2.69)		22,139	361	1.63 (1.46, 1.80)		21,481	443	2.06 (1.87, 2.25)		51,388	987	1.92 (1.80, 2.04)	

Abbreviation: *CI*=confidence interval; BMI=body mass index; MVPA=Moderate to vigorous physical activity.

* BMI categorization was based on the "Screening standard for malnutrition of school-age children and adolescents" and the "Screening for overweight and obesity among school-age children and adolescents," using age-specific values.

[†]MVPA was categorized as sufficient or insufficient based on whether an individual achieved more than 60 minutes of MVPA per day.

[§] According to the 'Notice on Further Strengthening the Management of Sleep for Primary and Secondary School Students' issued by the Ministry of Education of China, insufficient sleep was defined as self-reported sleep of less than 10 hours per day for primary school students, less than 9 hours for junior high school students, and less than 8 hours for senior high school students.

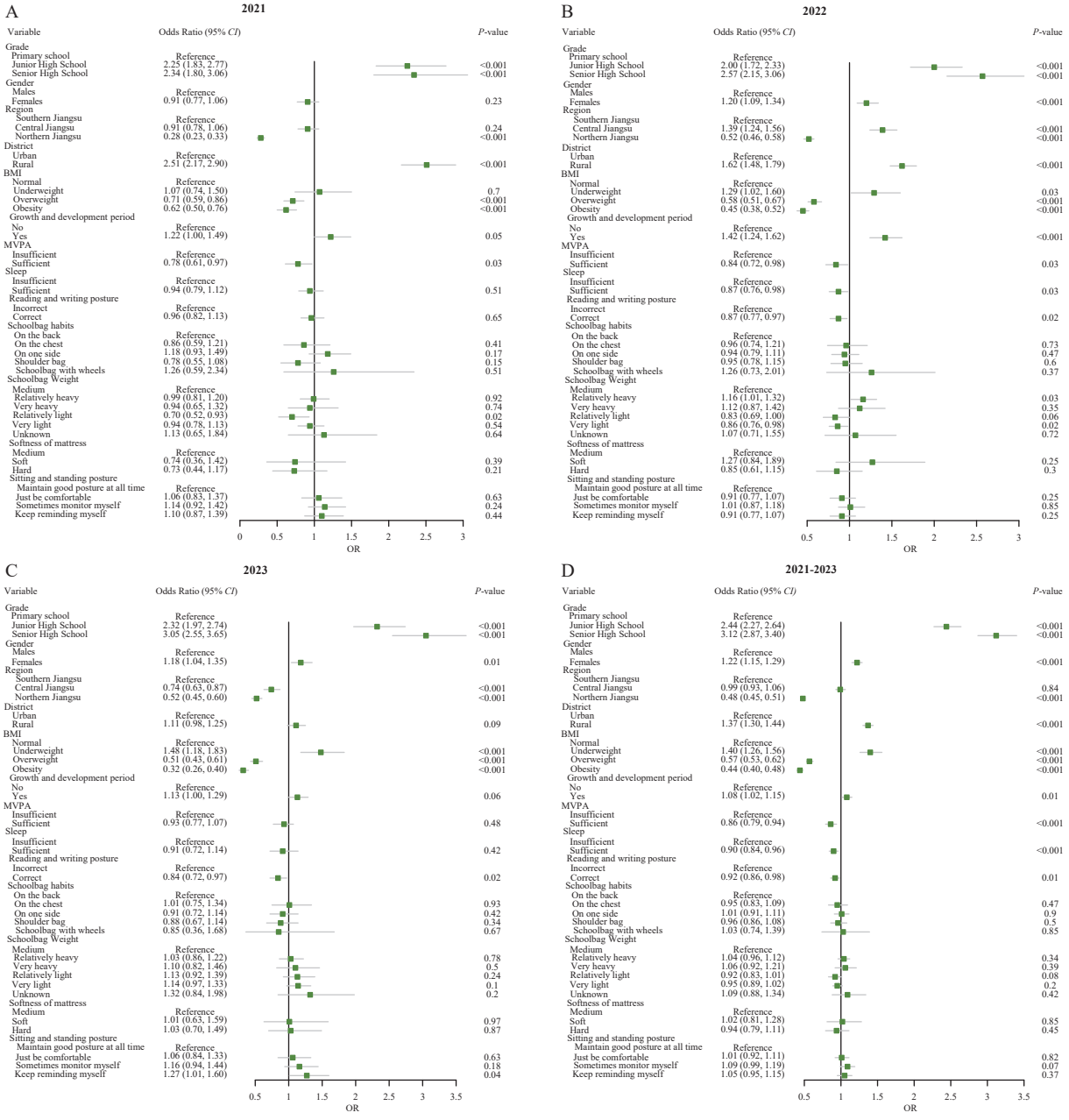

FIGURE 2. Factors associated with abnormal spinal curvature in children and adolescents in Jiangsu Province. (A) Period: 2021; (B) Period: 2022; (C) Period: 2023; (D) Period: 2021–2023.
Abbreviation: *CI*=confidence interval; BMI=body mass index; MVPA=Moderate to vigorous physical activity.

including sex-based variations in genetic heredity and the interaction between leptin production and the nervous system in females, which may trigger scoliosis development (*8*). Additionally, the differential progression of spinal curves between genders could be explained by imbalanced paraspinal muscle strength along the concave and convex sides of the spine, particularly if females engage in less moderate to vigorous physical activity than males.

Similar to previous findings demonstrating a positive correlation between low BMI and scoliosis occurrence (*9*), this study revealed that children and adolescents with low BMI exhibited a higher risk for abnormal spinal curvature. This association likely stems from biomechanical factors, where predisposed individuals lack sufficient paravertebral muscle force necessary to counteract the establishment and progression of scoliotic curves (*10*).

In alignment with existing literature (*11*–*13*), this study's identification of multiple risk factors —

including underweight status, improper reading and writing postures, insufficient sleep, and inadequate moderate to vigorous physical activity — underscores the necessity for targeted interventions. The well-documented relationship between sufficient physical activity and bone health in children and adolescents (*14*) suggests that future strategies should address the combined effects of multiple risk factors on spinal curvature abnormalities. Moreover, individuals with abnormal screening results require prompt medical evaluation and, where indicated, surgical intervention. Enhanced collaboration among families, schools, public health institutions, and hospitals is essential to protect the spinal health of children and adolescents.

Several limitations warrant consideration in this study. First, these findings from Jiangsu Province may not be generalizable to the broader Chinese population. Second, variations in detection rates between years may reflect differences in study population coverage due to the coronavirus disease 2019 (COVID-19) pandemic. Third, the cross-sectional design precludes causal inference. Finally, the reliance on self-reported questionnaires introduces potential recall bias, necessitating cautious interpretation of results. Future longitudinal studies are needed to evaluate the incidence rates of abnormal spinal curvature in this population.

In conclusion, abnormal spinal curvature emerged as a prevalent condition among children and adolescents aged 6–17 years in Jiangsu Province during 2021–2023, highlighting the urgent need for multisectoral investment in prevention and control. The Scoliosis Study Group's recommendation for annual scoliosis examinations in children aged 10–14 years (*15*) reinforces the importance of maintaining surveillance programs to facilitate service planning and ensure timely referral to public health specialists and orthopedic surgeons.

Conflicts of interest: No conflicts of interest

Ethical statement: Received ethics approval from the Institutional Ethics Committee for Clinical Research of Zhongda Hospital Affiliated with Southeast University (No. 2023ZDSYLL456-P01).

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SUPPLEMENTARY TABLE S1. Detection rate of abnormal spinal curvature in a randomized sample of adolescents in Jiangsu Province, 2021–2023.

Variables	2021				2022				2023				Total			
	N	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*	*N*	*n*	Rate (95% *CI*)	*P*
Region				<0.001				<0.001				<0.001				<0.001
Southern Jiangsu	12,934	571	4.41 (4.06–4.77)		17,491	347	1.98 (1.78–2.19)		12,810	541	4.22 (3.87–4.57)		43,235	1,459	3.37 (3.2–3.54)	
Central Jiangsu	7,940	328	4.13 (3.69–4.57)		11,218	136	1.21 (1.01–1.41)		7,554	232	3.07 (2.68–3.46)		26,712	696	2.61 (2.41–2.8)	
Northern Jiangsu	13,273	176	1.33 (1.13–1.52)		18,161	253	1.39 (1.22–1.56)		13,074	339	2.59 (2.32–2.87)		44,508	768	1.73 (1.60–1.85)	
District				<0.001				<0.001				<0.001				<0.001
Urban	19,091	383	2.01 (1.81–2.21)		25,367	528	2.08 (1.91–2.26)		18,137	758	4.18 (3.89–4.47)		62,595	1,669	2.67 (2.54–2.79)	
Rural	15,056	692	4.60 (4.26–4.93)		21,503	208	0.97 (0.84–1.10)		15,301	354	2.31 (2.08–2.55)		51,860	1,254	2.42 (2.29–2.55)	
Gender				0.153				<0.001				0.019				<0.001
Males	17,742	535	3.02 (2.76–3.27)		24,476	280	1.14 (1.01–1.28)		17,292	536	3.10 (2.84–3.36)		59,510	1,351	2.27 (2.15–2.39)	
Females	16,405	540	3.29 (3.02–3.56)		22,394	456	2.04 (1.85–2.22)		16,146	576	3.57 (3.28–3.85)		54,945	1,572	2.86 (2.72–3.00)	
Grade				<0.001				<0.001				<0.001				<0.001
Primary school	13,161	218	1.66 (1.44–1.87)		26,849	158	0.59 (0.50–0.68)		12,646	214	1.69 (1.47–1.92)		52,656	590	1.12 (1.03–1.21)	
Junior high school	12,651	534	4.22 (3.87–4.57)		12,481	278	2.23 (1.97–2.49)		12,568	517	4.11 (3.77–4.46)		37,700	1,329	3.53 (3.34–3.71)	
Senior high school	8,335	323	3.88 (3.46–4.29)		7,540	300	3.98 (3.54–4.42)		8,224	381	4.63 (4.18–5.09)		24,099	1,004	4.17 (3.91–4.42)	
BMI				<0.001				<0.001				<0.001				<0.001
Normal	19,946	715	3.58 (3.33–3.84)		27,460	543	1.98 (1.81–2.14)		19,287	797	4.13 (3.85–4.41)		66,693	2,055	3.08 (2.95–3.21)	
Underweight	1,220	48	3.93 (2.84–5.03)		1,593	41	2.57 (1.80–3.35)		1,548	81	5.23 (4.12–6.34)		4,361	170	3.90 (3.32–4.47)	
Overweight	6,521	172	2.64 (2.25–3.03)		8,673	94	1.08 (0.87–1.30)		6,153	121	1.97 (1.62–2.31)		21,347	387	1.81 (1.63–1.99)	
Obesity	6,460	140	2.17 (1.81–2.52)		9,144	58	0.63 (0.47–0.80)		6,450	113	1.75 (1.43–2.07)		22,054	311	1.41 (1.25–1.57)	
Growth and development period				<0.001				<0.001				0.056				<0.001
No	17,777	415	2.33 (2.11–2.56)		31,273	225	0.72 (0.63–0.81)		27,441	888	3.24 (3.03–3.45)		76,491	1,528	2.00 (1.90–2.10)	
Yes	16,370	660	4.03 (3.73–4.33)		15,597	511	3.28 (3.00–3.56)		5,997	224	3.74 (3.26–4.22)		37,964	1,395	3.67 (3.49–3.86)	
Total	47,310	1,224	2.59 (2.44–2.73)		46,870	736	1.57 (1.46–1.68)		33,438	1,112	3.33 (3.13–3.52)		127,618	3,072	2.41 (2.32–2.49)	

Abbreviation: *CI*=confidence interval; BMI=body mass index.