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Risk factors, lifestyle and prevention among adolescents with spinal curvature abnormality: a cross-sectional study in twenty-four primary and secondary schools in Hangzhou, Zhejiang Province, China

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Abstract

Background Spinal Curvature Abnormality (SCA) is a general term for abnormal curvature of the spine that can have long-term negative consequences in adolescents. Research into its aetiology is important for identifying high-risk populations and formulating tailored prevention strategies. This study aimed to evaluate the association between school-related factors and daily lifestyle habits and SCA.

Methods In this population-based cross-sectional study, 5652 primary and secondary school students were recruited in Hangzhou, eastern China. All selected students underwent spinal health screenings, as well as height and weight assessments. The influencing factors were gathered through self-report questionnaires completed by the students themselves. We used logistic regression models to estimate the relative risk of SCA prevalence for each variable in the analysis.

Results The overall prevalence of SCA was found to be 2.23% (126/5652), with the SCA rates observed among students in primary school, junior high school, and senior high school, at 0.06%, 1.88%, and 4.61%, respectively. After adjustment for potential confounders, multivariable logistic regression models showed that live on campus was significantly increased the risk of SCA in children and adolescents (OR = 2.68, 95% CI:183 – 3.92; $P < 0.001$), However, attending a suburban school (OR = 0.18, 95% CI:0.11–0.31; $P < 0.001$), spending ≥ 2 h per day outdoors (OR = 0.56, 95% CI:0.34–0.93; $P = 0.026$), being overweight (OR = 0.54, 95% CI:0.31–0.95; $P = 0.032$) and maintaining correct sitting and standing postures (OR = 0.60, 95% CI:0.37–0.97; $P = 0.036$) were protective factors for SCA in children and adolescents.

Conclusions In conclusion, academic-related factors, outdoor activity time, weight status and daily lifestyle habits were significantly associated with SCA in Chinese children and adolescents. It is recommended that schools, families,

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hospitals and society should jointly take measures to encourage adolescent students to cultivate good academic-related behaviours and healthy lifestyles to maintain and promote spinal health.

Keywords Spinal curvature abnormality, Scoliosis, Risk factors, Child, Adolescent, Preventive strategies

Background

Spinal Curvature Abnormality (SCA) is a complex three-dimensional deformity involving mainly asymmetric changes in the spine and trunk. It is typically accompanied by structural and biomechanical changes in the vertebrae and is a general term for abnormal spinal curvature, comprises mainly scoliosis and anterior-posterior spinal curvature abnormality [1–3]. It represents a significant health risk for children and adolescents, with a prevalence of approximately 2%~4% of children and adolescents worldwide [4–6] and 1.02% ~7.90% of children and adolescents in China, and showing an upward trend [7–9]. Given the adverse effects of SCA on cardiopulmonary function, activity, weight status, mental health, self-image, and quality of life in adolescents [10–14], as well as its potential to contribute to absenteeism from school and work in adolescents [15], and its propensity to become chronic into adulthood [16, 17], it is critical to identify and understand the potential risk factors associated with SCA presence and severity.

At present, there is no consensus among the scientific community regarding the causes of SCA in children and adolescents. SCA may be congenital and genetically predisposed, but in most cases, it is an acquired condition that arises as a consequence of other underlying conditions, including trauma, infection, neuromuscular disorders, or prolonged poor posture, among others [1, 18]. In approximately 90% of cases, the acquired form does not permit the precise of the aetiology [19]. To date, there is a consensus agreement that SCA has a multifactorial aetiology. A number of potential risk factors for the onset of SCA have been studied in the literature, such as growth alterations, postural disorders, the use of heavy backpacks, environmental factors, participation in sports activities, and visual and dental disorders [19–22]. Nevertheless, the current evidence is insufficient to substantiate a causal relationship between SCA and the adoption of poor postures, weight status, sleep state, or the carrying of heavy backpacks [23, 24]. Further investigation may yield more conclusive results.

The objective of the present study was, therefore, to elucidate the potential role of modifiable influence factors associated with SCA in order to enhance knowledge of the disease and to propose tailored preventive strategies for high-risk groups, such as the large-scale organisation of screening campaigns and the implementation of educational interventions on risk factors for adolescents directly at school.

Methods

Study population

This is a school-based cross-sectional study that employs a stratified whole cluster random sampling method. The study was conducted in four districts and counties (two urban and two suburban) in Hangzhou city between September and November 2021. Hangzhou, located in the southeastern coastal region of China, boasts well-developed transportation. The prevalence of SCA among primary and secondary students has garnered significant attention from local government and education authorities. The city hosts top medical institutions and orthopedic hospitals with rich experience in spinal-related diseases care. A total of six educational institutions were selected from each district and suburban area, comprising two primary schools (grades four, five, six), two junior high schools (grades one, two, three), and two senior high schools (grades one, two, three). The surveys were conducted on a class-by-class basis, with a total of three classes of students randomly selected from each grade to participate in this study. Individuals diagnosed with any known skeletal anomalies or pathological SCA from other causes were excluded from the study. This dataset represents the original data collected by the research team.

Ethical clearance

The study adhered to the tenets of the Declaration of Helsinki, and was approved by the Medical Ethics Committee of Hangzhou Centre for Disease Control and Prevention (approval no. Declared 2019-17). A comprehensive review of the study's subject design, research protocol, informed consent procedures, and associated materials was also undertaken. Spinal health screening formally submits a written request for approval, outlining the study objectives and procedures in detail, and securing consent from the local education board to carry out the research within schools. Prior to the commencement of the study, verbal informed consent was obtained from all participants and their parents. In the case of a child under 12 years of age, the consent form was signed by the child's parents. In the case of children aged 13 and above, the consent form was signed by both the child and their parents. The participants and their parents were provided with a comprehensive explanation of the study's objectives and methodology. At any point, participants were permitted to withdraw from the research without providing justification to the investigators. The confidentiality of individual research data has been maintained by the

investigators, and the data have been de-identified prior to analysis.

Methodology and criteria for the identification of SCA

The primary outcome of this study was screening SCA. All selected students underwent examination for SCA in accordance with the Screening of spinal curvature abnormality of children and adolescents (GB/T 16133 – 2014) [25] and the Technical Guidelines for Prevention and Control of Spinal Curvature Abnormality in Children and Adolescents [3]. Each student was subjected to both a scoliosis screening, which comprised a general examination, an Adam's test, a Trunk Rotation Measurement Instrument (TRMI) examination and a Spinal Motion Test, and an anterior-posterior spinal curvature abnormality screening, which included a general examination and a prone test. Refer to flow chart of screening for spinal curvature abnormality in primary and secondary school students for the specific screening process (Supplementary Fig. 1). The TRMI examination measurements were obtained using the scoliosis tester, as demonstrated in supplementary Figs. 4 and 5. For detailed individual projects screening procedures, please refer to the Guidelines for screening for spinal curvature abnormality (Supplementary annex 1). The screening results indicated the presence of scoliosis and anterior-posterior spinal curvature abnormality. The results of the scoliosis screening were classified as follows: no scoliosis, poor posture, and scoliosis (of the thoracic, thoracolumbar, or lumbar type). Any of the three abnormalities of the abnormal general examination or a positive Adam's test or an Apical Trunk Rotation (ATR) ≥ 5 degrees, plus ATR ≥ 5 degrees after spinal motion test was determined to be positive for scoliosis. The results of the screening for anterior-posterior spinal curvature abnormality were classified as follows: no anterior-posterior spinal abnormality, poor posture, and anterior-posterior spinal abnormality. The criteria for evaluation are presented in Supplementary Tables 1 and the results are recorded in the Screening Results Record Form (Supplementary Table 2).

Questionnaire surveys

Using literature evidence and the 2021 National programme [20–22, 26], we designed an SCA risk factors questionnaire. To test it, 120 students (not previously studied) from grades 4–6 of primary school, grades 1–3 of middle school, and grades 1–3 of high school were selected. These students provided feedback on understanding and ease of completion. The final questionnaire was also determined by combining expert and parental opinions. The questionnaire encompassed 19 items across four dimensions, including essential information (gender, grade, live on campus, ethnic group), read and write posture (posture in reading and writing, supervision by parents and teachers), outdoor activities and sleep conditions, and behaviour related to SCA (backpack habits, weight of schoolbag, seat switching, adjusting the height of desks and chairs, softness of mattress, wear and tear of shoe soles, standing and sitting posture). The administration of the questionnaire was organised and guided for independent completion by the teacher in collaboration with the investigator towards the mid to late of the semester (penultimate third to fourth week). The original questionnaire is provided in Supplementary annex 2 for further examination.

Criteria for obesity and sleep duration

In accordance with the stipulations set forth in the "Health requirements of daily learning time for secondary and elementary school students (GB/T 17223 – 2012)", insufficient sleep is defined as less than 10 h for primary school students, less than 9 h for junior high school students, and less than 8 h for high school students [27]. The Body Mass Index (BMI) of students was calculated based on measured height and weight and was judged according to the screening standard for malnutrition, overweight and obesity among school-aged children and adolescents (WS/T 456–2014 and WS/T 586–2018) [28, 29]. The aforementioned criteria are age- and sex-specific ranges of values between the ages of 6 and 18 years, with one criterion for each half year of age. The detailed criteria are presented in Supplementary Tables 3 and 4.

Quality control

The questionnaire survey was carried out by the investigators with the cooperation of the teachers. Questionnaires were double-entered, and any discrepancies or inaccuracies in the data entered by the two individuals were resolved through calibration and correction based on the questionnaires. Questionnaires with more than 5% missing content were excluded when analysing the data. Medical examiners are clinical surgeons. In order to facilitate a comprehensive understanding of the process of spinal health screening and the criteria for SCA diagnosis, a uniform training was delivered prior to the medical examination by experts invited by Hangzhou Center for Disease Control and Prevention. All instruments and equipment were calibrated before use. In addition, 5% of the population was randomly selected for on-site medical examinations to ensure the homogeneity and reliability of the results.

Statistical analysis

Statistical description and analyses were conducted using MS Excel and SPPS version 25. Single factor statistical analysis method: enumeration data were described by rate and composition ratio, and the comparison was

performed by chi-square test or Fisher probabilities method. Univariate or multivariate logistic regression was used to analyze the occurrence of SCA between different groups. The odds ratio (OR) and 95% confidence interval (CI) were used to describe and compare the associations between factors at different levels. Statistical tests were declared significant for a two-tailed *P* value not exceeding 0.05, except where otherwise specified.

Results

Distribution characteristics of SCA

The study population comprised 5652 individuals with both complete spinal examinations data and questionnaire data, comprising 1813 primary school students, 1910 junior high school students, and 1929 senior high school students. The overall prevalence of SCA was found to be 2.23% (126/5652), with the SCA rates observed among students in primary school, junior high school, and senior high school, at 0.06%, 1.88%, and 4.61%, respectively (Table 1). The overwhelming majority (99.2%) of SCA were scoliosis cases, with the types being thoracic, thoracolumbar, and lumbar, representing 55.2%, 42.4%, and 49.6%, respectively. The overall SCA prevalence among students was observed to increase as the academic year progressed ($\chi^2 = 90.679$, $P < 0.001$). The overall prevalence of SCA was found to be higher in urban areas (3.49%) than in suburban areas (0.70%), with a statistically significant difference ($\chi^2 = 49.954$, $P < 0.001$). Meanwhile, Fig. 1 illustrates that the prevalence of SCA among urban students was consistently higher than that of rural students across all age groups. The prevalence of SCA among boy and girl students is 2.36% and 2.08%, respectively. No statistically significant differences in the prevalence of SCA were identified between children of different genders ($\chi^2 = 0.507$, $P = 0.477$). As age increased, the prevalence of SCA reached three peaks at 12.5, 15 and 17.5 years old, which was observed in both stratified analyses conducted across gender and across regions (Fig. 1).

Univariate analysis of related factors of SCA

The univariate analysis indicated that live on campus (OR = 2.12, 95% CI:1.49–3.02; $P < 0.001$) and class seat swap left and right (OR = 1.78, 95% CI:1.06–2.97; $P = 0.027$) were associated with an increased risk of SCA. While the distance between the chest and the edge of the table is more than one fist while reading or writing, the distance between the eyes and the book is more than one foot (33 cm) while reading or writing, outdoor activity time ≥ 2 h per day in the past week, overweight or obesity, and always maintain correct posture may reduce the risk of SCA among students (all $P < 0.05$). The univariate analysis of related factors of SCA are summarized in Table 2.

Table 1 Classification of SCA in children and adolescents

Variables	*N*	SCA (%)	Univariate analysis	Scoliosis			Abnormal anteroposterior curvature of spine (%)
				Thoracic scoliosis (%)	Thoracolumbar scoliosis (%)	lumbar scoliosis (%)	
Academic stage							
Primary school	1813	1 (0.06)	$\chi^2 = 90.679$, $P < 0.001$	1 (0.06)	0	0	0
Junior high school	1910	36 (1.88)		18 (0.94)	19 (0.99)	16 (0.84)	1 (0.05)
Senior high school	1929	89 (4.61)		50 (2.59)	34 (1.76)	46 (2.38)	0
Gender							
Boy	2963	70 (2.36)	$\chi^2 = 0.507$, $P = 0.477$	37 (1.25)	35 (1.18)	34 (1.15)	1 (0.03)
Girl	2689	56 (2.08)		32 (1.19)	18 (0.67)	28 (1.04)	0
Total	5652	126 (2.23)		69 (1.22)	53 (0.94)	62 (1.10)	1 (0.02)

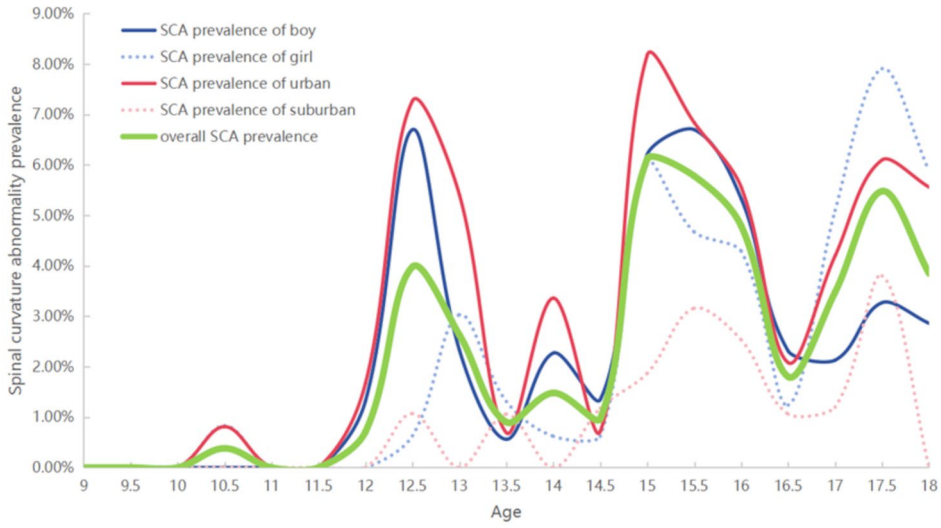

Fig. 1 Trends of SCA prevalence with age among children and adolescents by gender and by region

Multiple logistic regression analysis of related factors of SCA

Taking SCA as dependent variable, the statistically significant factors in the univariate analysis as independent variables into the binary logistic regression model. The results showed that, live on campus significantly increased the risk of SCA in students (OR = 2.68, 95% CI:183 – 3.92; $P < 0.001$). However, school in suburban, outdoor activity time ≥ 2 h per day in the past week, overweight, always maintain correct sitting and standing posture were protective factors for SCA in children and adolescents (all $P < 0.05$). The multiple logistic regression analysis of related factors are summarized in Table 3.

Discussion

The overall SCA rate observed in this study among children and adolescents was 2.23%, which is comparable to that documented in developed countries worldwide [4–6], but lower than the national average (2.80%) in 2019 [3]. There was considerable variation in the prevalence of SCA in many parts of the country, which may be related to factors such as the study population, the time, the number of samples, and the screening method [19–22]. The relatively developed area of Hangzhou exhibits a relatively low prevalence of SCA, which can be attributed to the strong health-related beliefs and good life habits of their parents.

The overall SCA prevalence among students showed an obvious upward trend with the advancement of the academic stage, reaching its peak during puberty and exhibiting the highest prevalence between the ages of 12 and 16 years. This finding is consistent with the results of previous studies [30–32]. The increased academic load, prolonged periods of sedentary behaviour and reduced time spent engaging in outdoor activities, coupled with the neglect of sitting, standing, reading and writing postures among students during this period, may be the underlying causes [7, 31, 33, 34]. Additionally, excessive height growth during puberty, high organic content in the bones and relatively insufficient calcium and phosphorus content, and immature development of the muscles and ligaments around the spine may also be causal factors [35–38]. It is worthy of note that the trend graph illustrates a nadir in the prevalence of SCA at the age of 13.5–14.5 years. This may be attributed to the fact that students have had an extended period of summer holidays and have recently commenced their studies in junior secondary school, where they are not required to contend with the heightened pressure of promotion examinations [39]. Therefore, it is imperative that the mode of study at the junior and senior high school level be adjusted in order to reduce students' academic load and to pay attention to children's nutrition during adolescence.

The present study did not find any differences in the prevalence of SCA between genders. Live on campus was associated with an elevated risk of SCA.This association may be attributable to a number of factors, including the suboptimal design of school beds and the absence of adequate parental supervision [40]. This study also found that the prevalence of SCA screening positive among students in urban areas was higher than that in suburban areas. This phenomenon may be attributed to a lesser degree of academic stress and a greater proportion of time spent outdoors in the suburbs. Given the relatively low health literacy levels of suburbans' residents, it is also important to focus on and promote healthcare in suburban areas [41, 42]. It was discovered that overweight (higher BMI) served as a protective factor for SCA. BMI was an important indicator of pulmonary function in patients with scoliosis [43]. This is consistent with

Table 2 Univariate analysis of related factors of SCA in children and adolescents

Influencing factors	Number of students	Number of SCA (%)	Univariate analysis	Unadjusted OR (95% CI)
Region				
Urban	3093	108 (3.49)	$\chi^2=49.954$, $P<0.001$	1
Suburban	2559	18 (0.70)		0.20 (0.12–0.32)*
Live on campus				
No	3657	59 (1.61)	$\chi^2=18.035$, $P<0.001$	1
Yes	1995	67 (3.36)		2.12 (1.49–3.02)*
Body Mass Index (BMI)				
Normal	3704	97 (2.62)	$\chi^2=8.414$, $P=0.038$	1
Wasting	327	7 (2.14)		0.81 (0.38–1.77)
Overweight	943	14 (1.48)		0.75 (0.56–0.99)*
Obesity	678	8 (1.18)		0.76 (0.60–0.97)*
The distance between chest and the edge of the table is more than one fist while reading or writing				
Never or occasionally	2451	66 (2.69)	$\chi^2=4.265$, $P=0.039$	1
Often or always	3201	60 (1.87)		0.69 (0.49–0.98)*
The distance between the eyes and book is more than one foot (33 cm) while reading or writing				
Never or occasionally	2368	65 (2.74)	$\chi^2=4.971$, $P=0.026$	1
Often or always	3284	61 (1.86)		0.67 (0.47–0.96)*
The distance between the finger and the tip is more than 3 cm while reading or writing				
Never or occasionally	2051	50 (2.44)	$\chi^2=0.642$, $P=0.423$	1
Often or always	3601	76 (2.11)		0.86 (0.60–1.24)
Teacher reminds the reading and writing posture to be incorrect				
Never or occasionally	2870	73 (2.54)	$\chi^2=2.642$, $P=0.104$	1
Often or always	2782	53 (1.91)		0.74 (0.52–1.06)
Parents reminds the reading and writing posture to be incorrect				
Never or occasionally	2009	51 (2.54)	$\chi^2=1.368$, $P=0.242$	1
Often or always	3643	75 (2.06)		0.81 (0.56–1.16)
Outdoor activity time per day in the past week				
<2 h	3906	105 (2.69)	$\chi^2=12.215$, $P<0.001$	1
≥ 2 h	1746	21 (1.20)		0.44 (0.28–0.71)*
Sleeping time per day				
Adequate	1890	39 (2.06)	$\chi^2=0.358$, $P=0.550$	1
Insufficient	3762	87 (2.31)		0.89 (0.61–1.30)
Habit of endorsement package				
On the back	4991	115 (2.30)	$\chi^2=1.097$, $P=0.295$	1
On one side/chest	661	11 (1.66)		0.72 (0.38–1.34)
Bag weight				
Light	1377	27 (1.96)	$\chi^2=4.031$, $P=0.133$	1
Medium	3147	65 (2.07)		1.06 (0.67–1.66)
Heavy	1128	34 (3.01)		1.55 (0.93–2.59)
Class seat swap left and right				
No	1216	17 (1.40)	$\chi^2=4.912$, $P=0.027$	1
Yes	4436	109 (2.46)		1.78 (1.06–2.97)*
Adjusted the height of desks and chairs according to the height of students				
Never	1139	33 (2.90)	$\chi^2=2.920$, $P=0.087$	1
Regularly	4513	93 (2.06)		0.71 (0.47–1.06)
Mattress softness				
Moderate	4541	97 (2.14)	$\chi^2=1.462$, $P=0.481$	1
Soft	529	12 (2.27)		1.06 (0.58–1.95)
Hard	582	17 (2.92)		1.38 (0.82–2.33)
Situation of left and right sole wear				
No difference	5279	119 (2.25)	$\chi^2=0.228$, $P=0.633$	1
Severely worn on one side	373	7 (1.88)		0.83 (0.38–1.79)

Table 2 (continued)

Influencing factors	Number of students	Number of SCA (%)	Univariate analysis	Unadjusted OR (95% CI)
Situation of inside and outside sole wear				
No difference	4809	109 (2.27)	$\chi^2=0.206$, $P=0.650$	1
Severely worn on one side	843	17 (2.02)		0.89 (0.53–1.49)
Requirements for your sitting and standing posture				
No requirement, just be comfortable	3562	101 (2.84)	$\chi^2=16.240$, $P<0.001$	1
Always maintain correct posture	2090	25 (1.20)		0.42 (0.27–0.65)*

Note: OR, odds ratio; CI, confidence interval; *, $P<0.05$

Table 3 Multiple logistic regression analysis of influencing factors of SCA in students

Influencing factors	Wald χ^2 value	*P*	Adjusted OR (95% CI)
School in suburban	40.955	<0.001	0.18 (0.11–0.31)*
Live on campus	25.917	<0.001	2.68 (1.83–3.92)*
The distance between chest and the edge of the table is more than one fist while reading or writing	0.150	0.698	0.91 (0.56–1.47)
The distance between the eyes and book is more than one foot (33 cm) while reading or writing	0.046	0.830	1.05 (0.65–1.70)
Outdoor activity time ≥ 2 h per day in the past week	4.987	0.026	0.56 (0.34–0.93)*
Body Mass Index (overweight)	4.580	0.032	0.54 (0.31–0.95)*
Body Mass Index (obesity)	3.701	0.054	0.49 (0.24–1.01)
Class seat swap left and right	2.329	0.127	1.52 (0.89–2.61)
Always maintain correct sitting and standing posture	4.383	0.036	0.60 (0.37–0.97)*

Note: OR, odds ratio; CI, confidence interval; *, $P<0.05$

the findings of Matusik et al. [44]. Further research is required to establish the relationship between nutritional status and SCA. Numerous studies have demonstrated a strong association between a lower BMI and an elevated risk of developing scoliosis [21, 45, 46]. Therefore, the nutritional status and accommodation of children should also be given priority attention.

This study demonstrated that always maintaining proper postures for reading, writing, sitting, and standing serves as protective factors against SCA, aligning with the findings of previous research [31, 33, 34]. The findings indicate that participation in suitable physical activities is a protective factor for SCA. Low-intensity sports such as Pilates have been shown to enhance rib cage expansion and trunk flexibility [47]. Conversely, high-intensity sports such as football and basketball, through their emphasis on neuromotor control, contribute to the strengthening of the trunk and pelvis, thereby preventing spinal deformities [48]. However, it is important to note that excessive asymmetries in activities, such as those seen in dance and rhythmic gymnastics, may lead to increased deformability and vertebral rotation [49]. We also did not find an association between sleep state, or the carrying of heavy backpacks and SCA in children and adolescents.

A study was conducted to investigate the prevalence and risk factors for SCA among children and adolescents in eastern China. One advantage of the current study is that a large sample size of students at all grade levels was selected, thereby allowing for an assessment of the relationship between SCA and age, grade level and gender. However, there are some limitations. First, the cross-sectional design of this study does not permit the establishment of causal relationships. Second, most risk factors were obtained through the completion of questionnaires. It should be noted that the assessment of time spent or feelings may vary to some extent between individuals, which could potentially introduce a degree of confounding bias and recall bias. Third, several significant risk factors for SCA, including environmental, dietary, familial economic status, and genetic factors such as inherited gene polymorphisms, were not subjected to analysis.

SCA has a considerable detrimental effect on the health of children and adolescents. In light of the findings of the present survey, it is recommended that comprehensive measures be taken with regard to the prevention and control of SCA [49, 50]. It is recommended that schools and families consider the selection of appropriate mattresses for children, with a focus on children nutrition, along with the importance of encouraging and monitoring children to maintain correct posture during reading, writing, sitting and standing, and to choose conforming desk and chair. It is recommended that children and adolescents consciously maintain correct posture when sitting, standing and when reading or writing. Moreover, it is advised that children engage in more outdoor physical activity. In subsequent studies, there is a need to extend the scope to encompass a more diverse range of sectors, including but not limited to communities and

hospitals. It is expected that the construction of a comprehensive prevention and control intervention model for SCA in children and adolescents, based on collaboration between society, hospitals, schools, families and individual students, will contribute to the alleviation of the ongoing rise in the prevalence of SCA.

Conclusions

In conclusion, academic-related factors, outdoor activity time, weight status and daily lifestyle habits were significantly associated with SCA in Chinese children and adolescents. It is recommended that schools, families, hospitals and society should jointly take measures to encourage adolescent students to cultivate good academic-related behaviours and healthy lifestyles to maintain and promote spinal health. However, longitudinal studies are needed in the future to explore the causal relationship between these lifestyle-related factors and SCA.

Abbreviations

BMI	Body Mass Index
SCA	Spinal Curvature Abnormality
TRMI	Trunk Rotation Measurement Instrument

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22883-1.

Supplementary Material 1

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Author contributions

All authors listed have made substantial contributions to the work. LJZ, BZ, HX and XJJ contributed to the conception or design of the work. LJZ, XJJ, WHZ, LH, YYZ and SXW contributed to the acquisition, analysis or interpretation of data for the work. LJZ and BZ drafted the manuscript. BZ, HX and XJJ critically revised the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analysed during the current study are not publicly available due contains a wealth of data on adolescent health but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of Hangzhou Centre for Disease Control and Prevention (approval no. Declared 2019-17). we certify that the study was performed in accordance with the 1964 declaration of HELSINKI and later amendments. Written informed consent was obtained from all participants themselves and their guardians prior to the enrollment of this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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