Chen et al.
Journal of Orthopaedic Surgery and Research (2025) 20:372
https://doi.org/10.1186/s13018-025-05760-w

Journal of Orthopaedic Surgery and Research

RESEARCH

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Correlation between abnormal posture, screen time, physical activity, and suspected scoliosis: a cross-sectional study

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Abstract

Background Scoliosis considerably affects adolescents' physical well-being and quality of life. Current research offers scant data concerning the correlation between abnormal posture, screen time, physical activity, and adolescent scoliosis. This study aimed to investigate their potential correlations with suspected scoliosis in teenagers aged 10–13 years.

Methods This is a cross-sectional study. School scoliosis screening was conducted on adolescents aged 10–13 years from nine schools in Guangzhou, China. The survey encompassed demographic attributes, postural traits, and daily lifestyles. Logistic regression analysis was performed to analyze the correlations between various variables and the occurrence of suspected scoliosis.

Results A total of 1297 questionnaires were distributed, and 1231 (94.9%) valid responses were received. All participants with valid responses underwent scoliosis screening. The overall prevalence of suspected scoliosis was 5.1%, with the highest prevalence observed in 11-year-old students, primarily affecting the thoracic spine. Significant correlations were found between suspected scoliosis and right-sided flatfoot, flat upper back, positive forward bend test (FBT), After-school screen time, weekend outdoor time, and weekend TV time.

Conclusions The results show a substantial correlation between the incidence of suspected scoliosis and abnormal posture. Moreover, a marked correlation exists between distinct activity patterns, particularly extended usage of electronic devices and television, and the incidence of suspected scoliosis. Screening for abnormal posture and performing the FBT can help detect suspected scoliosis, which requires further clinical assessment to differentiate between postural deviations and scoliosis. We advise middle and primary school kids to modify their daily routines by decreasing sedentary behavior and enhancing physical activity to mitigate the potential occurrence of trunk asymmetries.

Keywords Suspected scoliosis, Abnormal posture, Screen time, Physical activity, Influencing factors

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Introduction

Idiopathic scoliosis (IS) is a three-dimensional spinal deformity manifesting in the coronal, sagittal, and axial planes [1, 2]. The predominant form is adolescent idiopathic scoliosis (AIS), characterized by spinal curvature that manifests between the ages of 10 and skeletal maturity [3]. The worldwide prevalence of AIS varies from 0.98 to 1.70% [4], with the highest rates found in the 13–14-year-old demographic [5, 6]. According to Lonstein's [7] research, the gender ratio in scoliosis varies with disease severity. In mild scoliosis (Cobb angle > 10°), females slightly exceed males (1.4:1–2:1); however, in moderate and severe instances, predominance increases dramatically to 5.4:1 and 10:1, respectively. A thorough analysis reveals that the frequency of AIS among primary and middle school students in mainland China typically ranges from 0.85 to 1.18% [8]. However, age range and screening methods may affect prevalence across studies. School scoliosis screening (SSS) and hospital diagnoses in Wuxi estimated the prevalence of IS at 2.4% among adolescents aged 10–16 [9]. In Shanghai, suspected scoliosis was noted in 6.9% of teenagers aged 12–16, while the prevalence was 8.6% in the remote inland region of Gansu [10]. The incidence of scoliosis among individuals in Guangdong province aged 10–19 was 5.14% [11]. Age coverage and screening specificity may explain these differences; studies covering a wider age range usually indicate lower prevalence rates due to less targeted screening [8, 9, 12–14].

Estimates suggest that IS affects 0.5–4.2% of teenagers [15], potentially leading to abnormal posture, muscular imbalance, and an elevated risk of back discomfort, thereby diminishing quality of life [12, 13, 16]. Numerous studies indicate that AIS normally has a benign long-term progression, especially in mild to moderate cases, which usually do not substantially compromise cardiac function or joint integrity [17–19]. AIS patients may encounter diminished self-esteem and psychological health challenges, with the effects differing according to characteristics such as the visibility of spinal curvature, brace wear, and individual self-perception [17]. Current research shows a strong relationship between AIS and lower body mass index (BMI) [9, 20, 21], with genetic factors likely influencing its growth [13, 22]. Additional risk factors encompass visual impairments [20] and inadequate sleep [13]. A study found that carrying an overweight bag on one shoulder tilts the spine towards the weight-bearing side over extended periods, which may cause scoliosis in schoolchildren [23]. However, there is currently no clear evidence to support a direct causal relationship with AIS [24]. The guideline study has shown that genetic predisposition and growth patterns play a more significant role in AIS development [25].

Notably, accumulating data reveals a connection between abnormal posture, personal daily behaviors, and AIS. And physical activity levels may also affect the occurrence of AIS [3, 8, 14]. Reduced physical activity could increase the risk of developing AIS, potentially through impaired neuromuscular coordination or muscle development [3]. Additionally, prolonged use of computers or electronic devices might increases the prevalence of AIS [26, 27]. Extended periods of sitting can result in postural deformities [28], especially during adolescent growth spurts, potentially exacerbating scoliosis. Furthermore, incorrect posture may impede vision, resulting in enforced positions that aggravate the progression of scoliosis [13, 29]. However, the specific health implications of these factors on AIS remain underexplored, and existing evidence is inconsistent [13]. Understanding AIS causes is crucial to developing preventative and intervention strategies. The SSS represents an effective method for detecting suspected scoliosis and high-risk children [30]. Even though SSS has been criticized [31–33], it is still a useful method for evaluating posture and finding undiagnosed scoliosis early.

In terms of modern treatment approaches, brace therapy is the primary treatment for AIS, with specific scoliosis exercises as adjunctive therapy to improve mild to moderate curvature and quality of life [25, 34, 35]. As a non-fusion therapy approach, vertebral body tethering is ideal for adolescents, preserving spinal flexibility. However, its long-term safety needs further study [36].

Consequently, we examined 10–13-year-old students in Guangzhou identified through the SSS program. Students with an angle of trunk rotation (ATR) ≥ 5°, as measured by a scoliometer, and evident postural asymmetries, were classified as suspected scoliosis and considered part of the high-risk population due to their age and the presence of both ATR and abnormal postural findings without radiographic confirmation [19, 25]. This study explores the correlation between suspected scoliosis, abnormal posture, and lifestyle factors (e.g., screen time and physical activity), with the goal of providing evidence-based recommendations for preventing adolescent scoliosis in populations with early postural deviations in coastal areas.

Methods

Study design and sample

This prospective cross-sectional epidemiological study was carried out in Guangzhou, China, from January 2023 to June 2024. The subjects comprised elementary and middle school students aged 10–13 years who underwent SSS and completed a questionnaire regarding their daily lifestyle habits, specifically screen time and physical activity. The study excluded those with physical or mental problems, orthopedic, traumatic, or rheumatic disorders affecting posture, past spinal correction surgeries, and those who refused to participate.

All methods were performed in accordance with the principles of the Declaration of Helsinki. The research received approval from the Ethics Committee of the Fifth Affiliated Hospital of Guangzhou Medical University (GZMU) (Ethics Approval No. GYWY-L2024-04) and complied with the principles and procedures of the Declaration of Helsinki. The registration number for the clinical trial is ChiCTR2200066684. We gained informed consent from students and parents.

Survey questionnaire

A self-constructed questionnaire comprised two sections. The demographic part comprised four elements: height, weight, gender, and age. The section on daily lifestyle habits consisted of 12 items. Outdoor sports frequency (OSF), physical education class frequency (PECF), after-school outdoor time (ASOT), weekend outdoor time (WOT), after-school study time (ASST), weekend study time (WST), after-school screen time (ASCT), weekend screen time (WCT), After-School Television Time (ASTT), Weekend Television Time (WTT), after-school near-vision time (ASNT), weekend near-vision time (WNT). We scored ASOT, WOT, ASST, WST, ASCT, WCT, ASTT, WTT, ASNT, and WNT as follows: 0–30 min/day (1 point), 30–60 min/day (2 points), 1–2 h/day (3 points), 2–3 h/day (4 points), and exceeding 3 h/day (5 points).

SSS

After obtaining parental informed consent and completing student questionnaires, a team from the Fifth Affiliated Hospital of GZMU executed scoliosis screenings in educational institutions. The team independently inspected males and girls, instructing males to remove their shirts and females to wear back-exposing clothes. Students were evaluated from the front, rear, and side using expert physical therapy observation procedures. To ensure screening accuracy, the evaluators supplemented the visual inspection with palpation [37]. The SSS was conducted by a single team of professional physical therapists and doctors.

We used a comprehensive assessment protocol that included standardized visual inspection, palpation, FBT, ATR measurement, and evaluation with plumb lines. During the screening process, each student was collaboratively evaluated by two physical therapists who had completed standardized training consisting of three sessions totaling over 9 h. In cases of inconsistent assessment results, a consensus was reached through discussion between an orthopedic surgeon and a physical therapist, both with more than 15 years of extensive clinical experience, to ensure diagnostic accuracy. During the ATR measurement or FBT, students were asked to perform simple spinal movements in various directions before being retested. Furthermore, students were directed to slightly flex one knee to ensure the lower edges of the posterior superior iliac spines (PSIS) remained approximately level, followed by repeated observation, palpation, and ATR measurement to mitigate the potential impact of lower limb asymmetry on our findings.

Forward head posture [38]

Students stood shoulder-width apart, barefoot, and facing forward. To assess forward head posture, the examiner used a plumb line to check if the earlobe was vertically aligned with the acromion from the side. Forward head posture was characterized by the earlobe being positioned more than 1 cm anterior to the vertical plumb line [39].

Trunk alignment [40–42]

The examiner checked earlobe symmetry, shoulder height asymmetry, rounded shoulders, thoracic rotation, pelvic tilt and rotation, lumbar curvature, flat back, and leg alignment when the subjects stood naturally.

Visual inspection and comparative back palpation were used to check for rib prominence/depression and chest asymmetry (unilateral anterior/posterior displacement). Palpation during trunk flexion assessed rib alignment. Finally, the acromion alignment was evaluated from above to determine horizontal thoracic vertebrae rotation.

The thoracic curvature was laterally examined. A normal mild kyphotic curve was defined as physiological; reduced curvature indicated a flat back, while kyphosis (hunchback) was characterized by excessive posterior convexity with associated forward head posture and shoulder protraction.

Lumbar curvature was observed laterally. A smooth anterior convexity showed physiological lordosis. Hypolordosis was identified by reduced or nonexistent curvature and hyperlordosis by increased convexity.

We assessed bilateral anterior superior iliac spine (ASIS) and PSIS for coronal alignment through visual inspection and palpation. Unilateral elevation or considerable anterior/posterior displacement of the ASIS and PSIS suggested pelvic tilt or horizontal rotation.

The examiner examined the front while the subject brought their knees together and aligned their feet. We identified genu varum (bowlegs) if knee contact occurred with ankle separation, and diagnosed genu valgum (knock-knees) if ankle contact coexisted with knee separation.

Spine alignment was assessed with a plumb line. The examiner suspended the plumb line at the student's C7 cervical vertebra. In individuals suspected of having scoliosis, the plumb line did not pass through the center of the hips but instead deviated to the left or right.

Scapular winging [43]

The examiner assessed the student's back for scapula symmetry. They detected off-center alignments such the medial scapular boundary bulging, the superior medial angle presenting lateral deviation, or the inferior angle extending outward or upward.

Foot arc [44]

Students, barefoot and with damp feet, created footprints on paper to assess foot type. Foot arch index (I) < 0.21 denotes high arch, I > 0.26 implies flatfoot, and 0.21–0.26 represents normal arch. I = midfoot area/total footprint area (excluding toe prints).

Suboptimal sitting posture [28]

We provided students photos of different sitting positions and told them to pick the one that best reflected their daily posture.

FBT [45]

Students stood barefoot shoulder-width apart during FBT. The examiner asked them to gradually bend forward until their back was almost horizontal with their arms fully extended and relaxed to assess spine and back symmetry from behind. A positive test suggested scoliosis. This test is deemed highly accurate, with a sensitivity range of 74–100% and a specificity range of 60–99% [28].

ATR

The examiner used a scoliometer (Orthopedic Systems Inc., Union City, California, USA) to measure the maximum ATR in the thoracic, thoracolumbar, and lumbar areas behind the student at eye level with the deformity. A positive ATR of ≥ 5° indicates suspected scoliosis [25].

Statistical analysis

We conducted all statistical analyses using SPSS 25.0 (IBM Corporation, USA). Continuous variables following a normal distribution were described as mean ± SD. For categorical variables, Pearson's chi-square or Fisher's exact tests were used, while independent sample t-tests or Mann–Whitney U tests were used for continuous data. A p value < 0.05 indicated statistical significance for univariate analysis. All demographic, postural, screen time, and physical activity variables with p value ≤ 0.25 in univariate analysis were included in the multivariate logistic regression model for a more conservative approach [28]. Significant p values were less than 0.05, and 95% confidence intervals (CIs) were provided.

Results

In the analysis of 1231 students, 63 (5.12%) were suspected scoliosis cases and 1168 (94.88%) were normal. Gender distribution was not statistically different between normal and suspected scoliosis groups. (52.38% men, 47.62% women, P = 0.945). Among the suspected scoliosis group, 11-year-old students accounted for the highest proportion at 29/63 (46.03%). The prevalence of suspected scoliosis among 11-year-olds was 29/393 (7.38%). Additionally, students in the suspected scoliosis group had significantly lower weight and BMI compared to the normal group (P < 0.001).

In addition, the suspected scoliosis group had significantly higher rates of pelvic rotation, scapular inferior angle abnormalities, and PSIS (P < 0.05) compared to the normal group. Significant differences in thoracic rotation and positive FBT outcomes were also seen in the suspected scoliosis group (P < 0.001). However, the prevalence of flat back was significantly higher in the normal group compared to the suspected scoliosis group (P < 0.05) (Table 1).

Figure 1 clearly illustrates the distribution of ATR values across the thoracic, thoracolumbar, and lumbar regions. The thoracic region showed a higher prevalence of suspected scoliosis than the thoracolumbar or lumbar regions, highlighting its distinct role in suspected spinal deformities. Notably, 40–65% of suspected scoliosis cases showed ATR < 5° in some spinal segments, as students were classified based on having ATR ≥ 5° in at least one region, while data from all three measured regions (thoracic, thoracolumbar, and lumbar) were included in the analysis.

Univariate analysis revealed significant associations between suspected scoliosis and factors such as weight, BMI, right-sided flatfoot, thoracic/pelvic rotation, flat upper back, scapular inferior angle abnormalities, PSIS abnormalities, and positive FBT (P < 0.05). To further investigate these associations, multivariable logistic regression analysis, including covariates with P < 0.25 from the univariate analysis, was subsequently conducted. Significant correlations were observed with right-sided flatfoot (OR = 3.20, 95% CI 1.15–8.92), thoracic right rotation (OR = 2.27, 95% CI 1.06–4.87), and positive FBT (OR = 23.13, 95% CI 10.95–48.87). Interestingly, a flat upper back was negatively associated with suspected scoliosis (OR = 0.37, 95% CI 0.14–0.96) (Table 2).

Table 3 shows that the suspected scoliosis group had a median outdoor sports frequency (OSF) of 2 times per week compared to 3 times in the normal group. Analyses of after-school activities and weekend lifestyle patterns

Table 1 Demographic characteristics and the prevalence of abnormal posture stratified by suspected scoliosis

Variables	Study sample, n	Normal group (P_{25}, P_{75})/n (%)	Suspected scoliosis group (P_{25}, P_{75})/n (%)	Z/χ^2	*P*
Total	1231 (100)	1168 (94.88)	63 (5.12)		
Height	1231	155.00 (149.00, 161.00)	154.00 (145.00, 160.00)	− 1.843	0.065
Weight	1231	44.00 (39.00, 50.00)	39.00 (33.00, 45.00)	− 4.672	< 0.001
BMI	1231	18.21 (16.53, 20.69)	15.23 (15.00, 19.09)	− 4.860	< 0.001
Sex					
Man	650	617 (52.83)	33 (52.38)	0.005	0.945
Woman	581	551 (47.17)	30 (47.62)		
Age					
10 years old	220	214 (18.32)	6 (9.52)	7.216	0.065
11 years old	393	364 (31.16)	29 (46.03)		
12 years old	410	392 (33.56)	18 (28.57)		
13 years old	208	198 (16.95)	10 (15.87)		
Earlobe				1.398	0.497
Normal	324	311 (26.63)	13 (20.63)		
Left low	395	375 (32.11)	20 (31.75)		
Right low	512	482 (41.27)	30 (47.62)		
Shoulder height	1231	1168 (100)	63 (100)	0.882	0.643
Normal	503	477 (40.84)	26 (41.27)		
Left low	330	316 (27.05)	14 (22.22)		
Right low	398	375 (32.11)	23 (36.51)		
ASIS	1231	1168 (100)	63 (100)	0.855	0.652
Normal	264	253 (21.66)	11 (17.46)		
Left low	361	340 (29.11)	21 (33.33)		
Right low	606	575 (49.23)	31 (49.21)		
Leg alignment	1231	1168 (100)	63 (100)	3.087	0.214
Normal	351	327 (28.00)	24 (38.10)		
Knock knees	361	346 (29.62)	15 (23.81)		
Bowlegs	519	495 (42.38)	24 (38.10)		
Flatfoot	1231	1168 (100)	63 (100)	6.547	0.088
No	548	524 (44.86)	24 (38.10)		
Left side	350	226 (19.35)	10 (15.87)		
Right side	121	53 (4.54)	7 (11.11)		
Left = right	212	365 (31.25)	22 (34.92)		
High arch	1231	1168 (100)	63 (100)	0.066	0.798
No	1206	1144 (97.95)	62 (98.41)		
Yes	25	24 (2.05)	1 (1.59)		
Forward head posture	1231	1168 (100)	63 (100)	0.629	0.428
No	646	616 (52.74)	30 (47.62)		
Yes	585	552 (47.26)	33 (52.38)		
Thoracic Kyphosis	1231	1168 (100)	63 (100)	0.074	0.786
No	1163	1103 (94.43)	60 (95.24)		
Yes	68	65 (5.57)	3 (4.76)		
Thoracic rotation	1231	1168 (100)	63 (100)	18.706	< 0.001
Normal	690	671 (57.45)	19 (30.16)		
Left side	271	251 (21.49)	20 (31.75)		
Right side	270	246 (21.06)	24 (38.10)		
Lumbar curvature	1231	1168 (100)	63 (100)	0.653	0.721
Normal	826	784 (67.12)	42 (66.67)		
Increase	319	301 (25.77)	18 (28.57)		

Table 1 (continued)

Variables	Study sample, n	Normal group (P_{25}, P_{75})/n (%)	Suspected scoliosis group (P_{25}, P_{75})/n (%)	Z/χ^2	*P*
Reduce	86	83 (7.11)	3 (4.76)		
Pelvic rotation	1231	1168 (100)	63 (100)	8.712	0.013
Normal	632	611 (52.31)	21 (33.33)		
Left side	302	280 (23.97)	22 (34.92)		
Right side	297	277 (23.72)	20 (31.75)		
Flat upper back	1231	1168 (100)	63 (100)	6.286	0.012
No	956	899 (76.97)	57 (90.48)		
Yes	275	269 (23.03)	6 (9.52)		
Scapular winging	1231	1168 (100)	63 (100)	2.740	0.434
Normal	886	845 (72.35)	41 (65.08)		
left side	113	107 (9.16)	6 (9.52)		
Right side	81	74 (6.34)	7 (11.11)		
Bilateral	151	142 (12.16)	9 (14.29)		
Inferior angle of scapular	1231	1168 (100)	63 (100)	7.400	0.025
Normal	332	324 (27.74)	8 (12.70)		
Left low	349	330 (28.25)	19 (30.16)		
Right low	550	514 (44.01)	36 (57.14)		
PSIS	1231	1168 (100)	63 (100)	9.505	0.009
Normal	539	523 (44.78)	16 (25.4)		
Left low	365	342 (29.28)	23 (36.51)		
Right low	327	303 (25.94)	24 (38.10)		
Positive FBT	1231	1168 (100)	63 (100)	162.260	< 0.001
No	1181	1140 (97.60)	41 (65.08)		
Yes	50	28 (2.40)	22 (34.92)		
Poor sitting posture	1231	1168 (100)	63 (100)	0.823	0.364
No	774	731 (62.59)	43 (68.25)		
Yes	457	437 (37.41)	20 (31.75)		

BMI: body mass index; ASIS: anterior superior iliac spine; PSIS: posterior superior iliac spine; FBT: adam's forward bend test

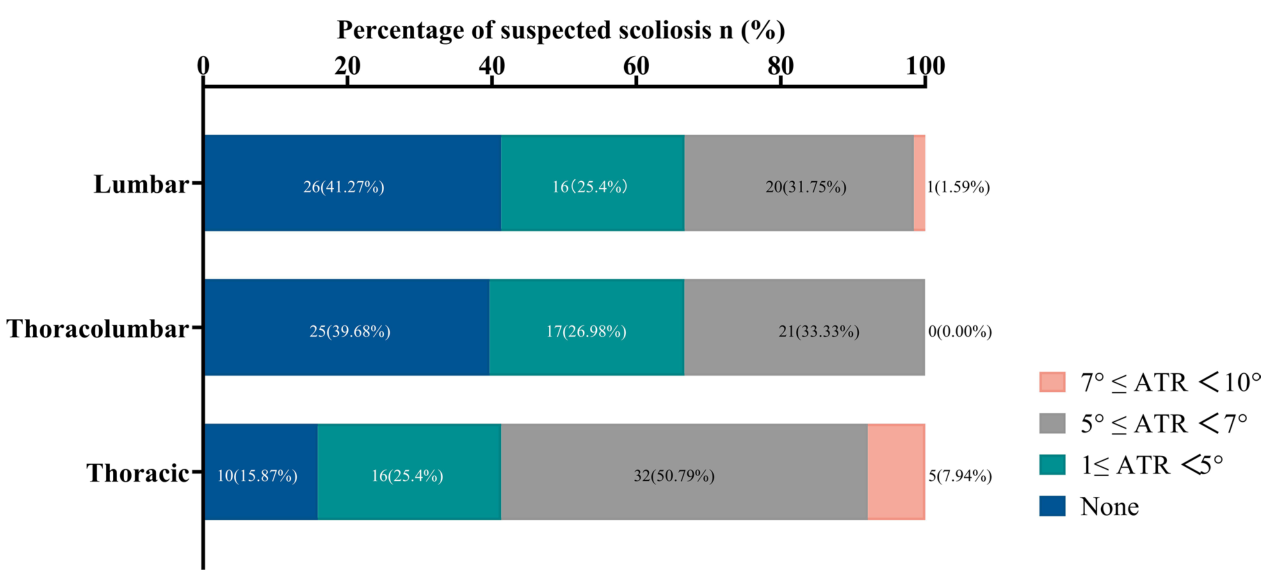

Fig. 1 Distribution of suspected scoliosis cases across thoracic, thoracolumbar, and lumbar regions

Table 2 Variables (demographics, posture) associated with suspected scoliosis

Variables	Groups	Univariate analysis		Multivariable analysis	
		P	OR (95% CI)	*P*	OR (95% CI)
Height		0.053	0.97 (0.95–1.00)	0.719	0.97 (0.81–1.15)
Weight		< 0.001	0.92 (0.89–0.95)	0.947	1.01 (0.73–1.41)
BMI		< 0.001	0.80 (0.72–0.88)	0.654	0.84 (0.38–1.83)
Age		0.896	1.02 (0.78–1.32)	–	–
Sex	Man		1		1
	Woman	0.945	1.02 (0.61–1.69)	–	–
Earlobe	Normal		1		1
	Left low	0.504	1.28 (0.63–2.61)	–	–
	Right low	0.242	1.49 (0.77–2.90)	0.996	1.00 (0.43–2.30)
Shoulder height	Normal		1		1
	Left low	0.541	0.81 (0.42–1.58)	–	–
	Right low	0.689	1.13 (0.63–2.00)	–	–
ASIS	Normal		1		1
	Left low	0.357	1.42 (0.67–3.00)	–	–
	Right low	0.549	1.24 (0.61–2.51)	–	–
Leg alignment	Normal		1		1
	Knock knees	0.119	0.59 (0.31–1.15)	0.001	0.24 (0.11–0.55)
	Bowlegs	0.163	0.66 (0.37–1.18)	0.001	0.29 (0.14–0.61)
Flatfoot	No		1		1
	Left side	0.929	0.97 (0.46–2.05)	–	–
	Right side	0.019	2.88 (1.19–7.01)	0.026	3.20 (1.15–8.92)
	Left = right	0.365	1.32 (0.73–2.38)	–	-
High arch	No		1		1
	Yes	0.798	0.77 (0.10–5.78)	–	–
Forward head posture	No		1		1
	Yes	0.429	1.23 (0.74–2.04)	–	–
Thoracic Kyphosis	No		1		1
	Yes	0.786	0.85 (0.26–2.78)	–	–
Thoracic rotation	Normal		1		1
	Left side	0.002	2.81 (1.48–5.36)	0.054	2.17 (0.99–4.76)
	Right side	< 0.001	3.45 (1.86–6.40)	0.035	2.27 (1.06–4.87)
Lumbar curvature	Normal		1		1
	Increase	0.704	1.12 (0.63–1.97)	–	–
	Reduce	0.518	0.68(0.21–2.22)	–	–
Pelvic rotation	Normal		1		1
	Left side	0.008	2.29 (1.24–4.23)	0.301	1.50 (0.70–3.23)
	Right side	0.21	2.10 (1.12–3.94)	0.289	1.52 (0.70–3.30)
Flat upper back	No		1		1
	Yes	0.016	0.35(0.15–0.83)	0.04	0.37 (0.14–0.96)
Scapular winging	Normal		1		1
	left side	0.747	1.16 (0.48–2.79)	–	–
	Right side	0.118	1.95 (0.85–4.50)	0.405	1.52 (0.57–4.09)
	Bilateral	0.481	1.31 (0.62–2.75)	–	–
Inferior angle of Scapular	Normal		1		1
	Left low	0.048	2.33 (1.01–5.40)	0.156	2.10 (0.75–5.83)
	Right low	0.009	2.84 (1.30–6.18)	0.204	1.90 (0.71–5.08)

Table 2 (continued)

Variables	Groups	Univariate analysis		Multivariable analysis	
		P	OR (95% CI)	*P*	OR (95% CI)
PSIS	Normal		1		1
	Left low	0.018	2.20 (1.15–4.22)	0.485	1.35 (0.58–3.12)
	Right low	0.004	2.59 (1.35–4.95)	0.390	1.44 (0.63–3.34)
Positive FBT	No		1		1
	Yes	< 0.001	21.85 (11.53–41.41)	< 0.001	23.13 (10.95–48.87)
Poor sitting posture	No		1		1
	Yes	0.365	0.78 (0.45–1.34)	–	–

ASIS: anterior superior iliac spine; PSIS: posterior superior iliac spine; FBT: adam's forward bend test; OR: odds ratios; CI: confidence intervals

Table 3 The prevalence of lifestyle habits (screen time, physical activity) stratified by suspected scoliosis

Variables	Study sample, n	Normal group (P25, P75)/n (%)	Suspected scoliosis group (P25, P75)/n (%)	Z/χ^2	*P*
Total	1231 (100)	1168 (94.88)	63 (5.12)		
Outdoor sports frequency (OSF)	1231	3.00 (2.00, 4.00)	2.00 (1.00, 4.00)	− 1.759	0.079
Physical education class frequency (PECF)	1231	3.00 (2.00, 3.00)	3.00 (2.00, 3.00)	− 0.199	0.842
After-school outdoor time (ASOT)					
0–30 min/day	481	454 (94.39)	27 (5.61)	3.428	0.489
30–60 min/day	403	379 (94.04)	24 (5.96)		
1–2 h/day	217	210 (96.77)	7 (3.23)		
2–3 h/day	80	76 (95.00)	4 (5.00)		
More than 3 h/day	50	49 (98.00)	1 (2.00)		
After-school study time (ASST)					
0–30 min/day	154	142 (92.21)	12 (7.79)	3.676	0.452
30–60 min/day	299	283 (94.65)	16 (5.35)		
1–2 h/day	425	405 (95.29)	20 (4.71)		
2–3 h/day	220	209 (95.00)	11 (5.00)		
More than 3 h/day	133	129 (96.99)	4 (3.01)		
After-school screen time (ASCT)					
0–30 min/day	668	639 (95.66)	29 (4.34)	4.727	0.316
30–60 min/day	305	288 (94.43)	17 (5.57)		
1–2 h/day	139	127 (91.37)	12 (8.63)		
2–3 h/day	67	64 (95.52)	3 (4.48)		
More than 3 h/day	52	50 (96.15)	2 (3.85)		
After-school TV time (ASTT)					
0–30 min/day	860	819 (95.23)	41 (4.77)	3.669	0.453
30–60 min/day	204	190 (93.14)	14 (6.86)		
1–2 h/day	90	84 (93.33)	6 (6.67)		
2–3 h/day	46	44 (95.65)	2 (4.35)		
More than 3 h/day	31	31 (100.00)	0 (0)		
After-school near-vision time (ASNT)					

Table 3 (continued)

Variables	Study sample, n	Normal group (P25, P75)/n (%)	Suspected scoliosis group (P25, P75)/n (%)	Z/χ^2	P
0–30 min/day	407	388 (95.33)	19 (4.67)	1.901	0.754
30–60 min/day	366	343 (93.72)	23 (6.28)		
1–2 h/day	230	221 (96.09)	9 (3.91)		
2–3 h/day	117	111 (94.87)	6 (5.13)		
More than 3 h/day	111	105 (94.59)	6 (5.41)		
Weekend screen time (WCT)					
0–30 min/day	344	326 (94.77)	18 (5.23)	2.497	0.645
30–60 min/day	366	344 (93.99)	22 (6.01)		
1–2 h/day	273	261 (95.60)	12 (4.40)		
2–3 h/day	135	127 (94.07)	8 (5.93)		
More than 3 h/day	113	110 (97.35)	3 (2.65)		
Weekend outdoor time (WOT)					
0–30 min/day	263	242 (92.02)	21 (7.98)	7.982	0.092
30–60 min/day	347	327 (94.24)	20 (5.76)		
1–2 h/day	320	309 (96.56)	11 (3.44)		
2–3 h/day	175	169 (96.57)	6 (3.43)		
More than 3 h/day	126	121 (96.03)	5 (3.97)		
Weekend study time (WST)					
0–30 min/day	137	130 (94.89)	7 (5.11)	6.688	0.153
30–60 min/day	312	293 (93.91)	19 (6.09)		
1–2 h/day	363	343 (94.49)	20 (5.51)		
2–3 h/day	221	207 (93.67)	14 (6.33)		
More than 3 h/day	198	195 (98.48)	3 (1.52)		
Weekend TV time (WTT)					
0–30 min/day	674	632 (93.77)	42(6.23)	5.770	0.217
30–60 min/day	295	287 (97.29)	8(2.71)		
1–2 h/day	164	155 (94.51)	9(5.49)		
2–3 h/day	60	57 (95.00)	3(5.00)		
More than 3 h/day	38	37 (97.37)	1(2.63)		
Weekend near-vision time (WNT)					
0–30 min/day	421	397 (94.30)	24(5.70)	3.649	0.456
30–60 min/day	369	355 (96.21)	14(3.79)		
1–2 h/day	214	199 (92.99)	15(7.01)		
2–3 h/day	119	113 (94.96)	6(5.04)		
More than 3 h/day	108	104 (96.30)	4(3.70)		

revealed no statistically significant differences between the suspected scoliosis group and the normal group ($P > 0.05$).

Univariate analysis also revealed significant associations between suspected scoliosis and ASCT, WOT, and WTT ($P < 0.05$). In the subsequent multivariable analysis, students reporting 1–2 h/day of ASCT had a 2.17-fold increased risk of suspected scoliosis than those reporting 0–30 min/day (OR = 2.17, 95% CI 1.02–4.64). Similarly, students with 30–60 min of ASTT had a 2.83-fold increased risk of suspected scoliosis (OR = 2.83, 95% CI 1.27–6.29). Outdoor activities for 1–2 h/day on weekends reduced the risk of suspected scoliosis (OR = 0.36, 95% CI 0.16–0.82). However, watching television for 30–60 min/day on weekends was associated with a 71% reduced risk of suspected scoliosis (OR = 0.29, 95% CI 0.12–0.71) (Table 4).

Table 4 Variables (screen time, physical activity) associated with suspected scoliosis

Variables	Groups	Univariate analysis		Multivariable analysis	
		P	OR (95% CI)	*P*	OR (95% CI)
Outdoor sports frequency (OSF)		0.104	0.87 (0.73–1.03)	0.284	0.9 (0.75–1.09)
Physical education class frequency (PECF)		0.662	0.94 (0.70–1.25)	–	–
After-school outdoor time (ASOT)	0–30 min/day		1		
	30–60 min/day	0.828	1.07 (0.60–1.88)	–	–
	1–2 h/day	0.18	0.56 (0.24–1.31)	0.804	0.89 (0.35–2.26)
	2–3 h/day	0.824	0.89 0.30–2.60)	–	–
	More than 3 h/day	0.299	0.34 (0.05–2.58)	–	–
After-school study time (ASST)	0–30 min/day		1		1
	30–60 min/day	0.309	0.67 (0.31–1.45)	–	–
	1–2 h/day	0.155	0.58 (0.28–1.23)	0.182	0.58 (0.26–1.30)
	2–3 h/day	0.272	0.62 (0.27–1.45)	–	–
	More than 3 h/day	0.089	0.37 (0.12–1.17)	0.498	0.64 (0.18–2.30)
After-school screen time (ASCT)	0–30 min/day		1		1
	30–60 min/day	0.402	1.30 (0.70–2.41)	–	–
	1–2 h/day	0.04	2.08 (1.04–4.19)	0.046	2.17 (1.02–4.64)
	2–3 h/day	0.958	1.03 (0.31–3.49)	–	–
	More than 3 h/day	0.866	0.88 (0.20–3.80)	–	–
After-school TV time (ASTT)	0–30 min/day		1		1
	30–60 min/day	0.227	1.47 (0.79–2.76)	0.011	2.83 (1.27–6.29)
	1–2 h/day	0.431	1.43 (0.59–3.46)	–	–
	2–3 h/day	0.896	0.91 (0.21–3.88)	–	–
	More than 3 h/day	0.998		–	–
After-school near-vision time (ASNT)	0–30 min/day		1		1
	30–60 min/day	0.324	1.37 (0.73–2.56)	–	–
	1–2 h/day	0.656	0.83 (0.37–1.87)	–	–
	2–3 h/day	0.837	1.10 (0.43–2.83)	–	–
	More than 3 h/day	0.748	1.17 (0.46–3.00)	–	–
Weekend screen time (WCT)	0–30 min/day		1		1
	30–60 min/day	0.653	1.16 (0.62–2.20)	–	–
	1–2 h/day	0.632	0.83 (0.39–1.76)	–	–
	2–3 h/day	0.763	1.14 (0.48–2.69)	–	–
	More than 3 h/day	0.265	0.49 (0.14–1.71)	–	–
Weekend outdoor time (WOT)	0–30 min/day		1		1
	30–60 min/day	0.28	0.71 (0.37–1.33)	–	–
	1–2 h/day	0.02	0.41 (0.19–0.87)	0.015	0.36 (0.16–0.82)
	2–3 h/day	0.059	0.41 (0.16–1.04)	0.064	0.38 (0.14–1.06)
	More than 3 h/day	0.146	0.48 (0.18–1.29)	0.228	0.52 (0.18–1.51)
Weekend study time (WST)	0–30 min/day		1		1
	30–60 min/day	0.683	1.20 (0.49–2.94)	–	–
	1–2 h/day	0.86	1.08 (0.45–2.61)	–	–
	2–3 h/day	0.632	1.26 (0.49–3.19)	–	–
	More than 3 h/day	0.073	0.29 (0.07–1.13)	0.134	0.32 (0.07–1.42)
Weekend TV time (WTT)	0–30 min/day		1		
	30–60 min/day	0.027	0.42 (0.19–0.91)	0.007	0.29 (0.12–0.71)
	1–2 h/day	0.721	0.87 (0.42–1.83)	–	–
	2–3 h/day	0.704	0.79 (0.24–3.64)	–	–
	More than 3 h/day	0.38	0.41 (0.05–3.04)	–	–

Table 4 (continued)

Variables	Groups	Univariate analysis		Multivariable analysis	
		P	OR (95% CI)	*P*	OR (95% CI)
Weekend Near-Vision Time (WNT)	0–30 min/day		1		1
	30–60 min/day	0.214	0.65 (0.33–1.28)	0.259	0.66 (0.32–1.36)
	1–2 h/day	0.517	1.25 (0.64–2.43)	–	–
	2–3 h/day	0.782	0.88 (0.35–2.20)	–	–
	More than 3 h/day	0.412	0.64 (0.22–1.87)	–	–

OR: odds ratios; CI: confidence intervals

Discussion

The study found 5.1% of adolescents had suspected scoliosis, with the highest rate in 11-year-olds, notably in the thoracic region. The incidence was 5.08% among males and 5.16% among females. The research demonstrated a significant link between suspected scoliosis and several postural traits, notably thoracic right rotation, right-side flatfoot, and a positive FBT ($P<0.05$). Long-term electronic device use and limited physical activity were linked to suspected scoliosis ($P<0.05$). The detected incidence of suspected scoliosis exceeds the overall prevalence of under 1.5% of AIS in China [8]. A significant explanation for this discrepancy is that suspected scoliosis (ATR > 5°) does not directly correspond to a Cobb angle over 10° for spinal scoliosis. Regional differences, variances in the age range studied, environmental and socio-economic factors, as well as differences in students' activity levels and homework loads between urban and rural areas, may also contribute to this mismatch.

Correlation between postural anomalies and suspected scoliosis

Research demonstrates that shoulder asymmetry is the predominant postural anomaly in Chinese children and adolescents [29]. Postural problems may be related to the occurrence and progression of AIS [46, 47]. The study found both parallels and differences in postural changes between students with suspected scoliosis and those without. Lower right shoulder, ASIS, and forward head position were comparable. Lifestyle factors including inactivity and sedentary behavior may explain these similarities. Chinese elementary and secondary school children are known to carry large school bags and suffer high academic pressure, which can worsen trunk and pelvic asymmetry and cause compensatory adjustments and postural abnormalities [46, 48, 49]. The study revealed that 37 students with suspected scoliosis had a thoracic ATR ≥ 5°, substantially higher than in the thoracolumbar and lumbar areas. This finding is consistent with an earlier meta-analysis that found thoracic scoliosis to have the highest prevalence, at 3.89% [50].

Nonetheless, several postural traits, such as weight, BMI, right-sided flatfoot, thoracic rotation (left or right), left pelvic rotation, flat back, scapular inferior angle asymmetry (lower on the left or right), PSIS asymmetry (lower on the left or right), and a positive FBT, exhibited significant correlations with suspected scoliosis ($P<0.05$). This aligns with some studies, further confirming the inverse relationship between scoliosis and BMI [9, 13, 20]. A low BMI may indicate malnutrition or physical weakness, potentially hindering the growth and maintenance of bones and muscles, thereby increasing the risk of spinal curvature [46, 51]. Students with suspected scoliosis demonstrated increased thoracic and pelvic rotation relative to their non-scoliotic peers, with thoracic rotation mostly occurring to the right and pelvic rotation primarily to the left. This aligns with the Postural Restoration Institute's (PRI) hypothesis of inherent asymmetry in human anatomy. PRI indicates that typical persons generally display a pattern of right pelvic rotation and left thoracic rotation, known as the Left Anterior Interior Chain (LAIC) and the Right Brachial Chain (RBC) [52]. Alteration of this typical asymmetrical pattern, exemplified by excessive thoracic right rotation and pelvic left rotation noted in our study, may elevate the risk of scoliosis. The predominant form of AIS, characterized by a right thoracic and left lumbar convex curvature [53, 54], causes scapular angle asymmetry and thoracic vertebral rotation primarily in the transverse plane [55], leading to a primary right rotation of the thoracic spine. Our investigation, however, revealed that excessive left thoracic rotation may also contribute to suspected scoliosis, underscoring the significance of spinal postural equilibrium. Left pelvic rotation may signify the body's effort to achieve and sustain spinal equilibrium, possibly influencing the right lower PSIS [48, 56]. Consequently, the height of the PSIS may serve as a possible predictor of suspected scoliosis. In contrast to certain studies, we noted a reduced prevalence of flat back in students with suspected scoliosis. This mismatch could be caused by different screening methods, pubertal development spurts, sagittal pelvic morphology, or differences in how the spine and pelvis are aligned [57, 58]. Overall, Prolonged postural asymmetry may influence biomechanics, potentially affecting the progression of spinal scoliosis [59, 60].

Multivariable logistic regression analysis confirmed a substantial connection between excessive thoracic right rotation and suspected scoliosis (OR = 2.27, 95% CI 1.06–4.87). A positive FBT was associated with an increased risk of suspected scoliosis (OR = 23.13, 95% CI 10.95–48.87), suggesting that postural abnormalities may accelerate scoliosis progression.

Correlation between lifestyle habits and suspected scoliosis

The World Health Organization (WHO) standards stipulate that children and adolescents should participate in a minimum of 60 min of moderate-to-vigorous physical activity each day, incorporating exercises that enhance muscular and skeletal strength [61, 62]. Research has demonstrated that adequate physical exercise reduces the incidence of AIS [63]. Outdoor activities, specifically, enhance the absorption of vitamin D and calcium, which are essential for the management of AIS [64].

Students often have sedentary lifestyles, including excessive screen time, and insufficient physical activity. Research indicates that adolescents who engage in daily screen time over 2 h are at an increased risk of developing scoliosis ($P < 0.001$) [46]. Our research identified a positive connection between ASCT (OR = 2.17, 95% CI 1.02–4.64) and ASTT (OR = 2.83, 95% CI 1.27–6.29) with the incidence of suspected scoliosis. Prolonged screen time is frequently linked to sedentary behavior and insufficient physical activity, adversely affecting teenagers' muscular and skeletal health [61]. This coincides with Zhu et al. [26], who reported that persons with daily screen time exceeding 2 h had a 3.40-fold greater risk of AIS compared to those with less screen time. Extended use of electronic devices entails repetitive upper limb motions and anterior head positioning, which may intensify musculoskeletal strain and elevate the risk of AIS [26]. Conversely, a 2020 study indicated comparable electronic device usage trends between AIS patients and healthy individuals [65]. Variations in sample characteristics and study methodologies may account for these inconsistencies.

Substituting screen time with physical activities is essential. A prospective cohort research study found inadequate physical activity as a novel risk factor for scoliosis [64]. Cai et al. [13] established strong correlations between diminished physical activity and AIS, indicating that prolonged exercise duration mitigates scoliosis risk, with individuals who exercised less than 1 h per day having a 7.29 times higher risk compared to those who exercised 3 h. Scaturro et al. [22] observed a greater prevalence of AIS among students who exercised less than 3 h per week, whereas Tobias et al. [3] indicated a 53% and 30% decrease in scoliosis risk for children participating in intense activity at ages 10 and 11, respectively.

Our findings showed that increasing outdoor activity duration significantly reduced suspected scoliosis risk. Weekend outdoor activity protected students from suspected scoliosis (OR = 0.36, 95% CI 0.16–0.82) compared to less than 30 min of daily physical activity. A further study indicated that teenagers engaging in less than 60 min of moderate physical exercise daily faced a 1.76-fold increased risk of developing AIS compared to those adhering to the 60-min recommendation [26]. Our study indicated that weekend TV viewers had a 71% lower incidence of suspected scoliosis (OR = 0.29, 95% CI 0.12–0.71). Moderate television consumption may help preserve healthy sitting posture, reflecting a more balanced weekend lifestyle. This equilibrium encompasses sufficient rest, participation in various physical activities, and support for mental wellness, all of which aid in preserving spine health and mitigating the risk of scoliosis [66].

Study limitations

Despite noteworthy findings, this study has limitations. As a cross-sectional design, it lacks longitudinal follow-up to assess suspected scoliosis progression. Since progression is typically monitored through radiological measurements, future studies should combine periodic ATR measurements (e.g., every 6 months for mild cases) and radiographic confirmation for high-risk cases, with a 2–3 year observation period to capture peak growth. Second, sample restrictions and self-reported data may skew results. Subsequent research could mitigate these limitations by increasing sample numbers and employing more rigorous data collection techniques. Furthermore, this study did not exclude functional scoliosis caused by disc herniation, pelvic tilt, or external forces, potentially biasing the screening results.

Strengths of the study

This study presents several strengths. First, integrating the standardized SSS with detailed postural assessments and comprehensive lifestyle questionnaires enhanced the accuracy and reliability of scoliosis detection in coastal adolescents aged 10–13. Second, by analyzing multiple lifestyle factors, such as screen time and physical activity, we provided a holistic understanding of adolescent spinal health risk factors. Lastly, the use of robust statistical methods, including multivariable logistic regression, confirmed reported correlations. These strengths provide essential insights for creating targeted early intervention and adolescent scoliosis prevention programs.

Conclusions

This study identified significant associations between suspected scoliosis and postural abnormalities, including thoracic rotation, pelvic rotation, and a positive FBT. Additionally, lifestyle factors like prolonged screen time and insufficient physical activity were linked to a higher prevalence of suspected scoliosis, while weekend outdoor activities appeared to have a protective effect. These findings underscore the importance of routine school-based SSS program, particularly the FBT, for early detection. Based on these findings, we recommend encouraging adolescents to engage in at least 30–60 min of daily physical activity that promotes spinal health, such as swimming and running, while reducing sedentary behaviors. Students with an ATR $\geq 5°$ and evident postural abnormalities should be referred for radiographic examination, while those with mild clinical signs could benefit from regular monitoring every 6 months.

Abbreviations

IS	Idiopathic scoliosis
AIS	Adolescent idiopathic scoliosis
SSS	School scoliosis screening
OR	Odds ratios
CIs	Confidence intervals
FBT	Adams forward bend test
BMI	Body mass index
GZMU	Guangzhou Medical University
OSF	Outdoor sports frequency
PECF	Physical education class frequency
ASOT	After-school outdoor time
WOT	Weekend outdoor time
ASST	After-school study time
WST	Weekend study time
ASCT	After-school screen time
WCT	Weekend screen time
ASTT	After-school TV time
WTT	Weekend TV time
ASNT	After-school near-vision time
WNT	Weekend near-vision time
ATR	Angle of trunk rotation
SD	Standard deviation
PSIS	Posterior superior iliac spine
ASIS	Anterior superior iliac spine

Acknowledgements

Not applicable.

Author contributions

H.X.C. and L.Y.W. had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. They also contributed to the drafting of the manuscript. J.Y.L., R.H., J.Y.X., K.M.Y., and Z.F.G. were responsible for data acquisition, analysis, and interpretation, as well as drafting the manuscript. T.H., Y.Y.B., C.L.C., and X.X.H. participated in manuscript writing. Y.Z. was responsible for figure preparation and statistical analysis. Z.P.Z. and R.K.Z. contributed to study design, data analysis, and interpretation, and revised the manuscript. All authors reviewed and approved the final manuscript.

Funding

This work was funded by 2022 Guangzhou Medical University-Level Student Labor Education Practice Base Project (Grant No. 02-408-2203-3016), 2023 Guangdong Provincial Higher Education Ideological and Political Education Project (Grant No. 2023GXSZ055), 2023 Guangzhou Teaching Achievement Cultivation Project (Achievement No. 2023128383), 2025 Guangzhou Educational Science Planning Project (Grant No. 2024111264), and the Key Laboratory of Guangdong Higher Education Institutes (2021KSYS009).

Data availability

The data analyzed for the current study are available on reasonable request to the corresponding author.

Declarations

Ethics approval and informed consent

This study was conducted in accordance with the Declaration of Helsinki. The research protocol was approved by the Ethics Committee of the Fifth Affiliated Hospital of Guangzhou Medical University. Written informed consent was obtained from the parents or guardians of participants under 18 years old, permitting the use of their data and images in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 24 January 2025 Accepted: 26 March 2025
Published online: 13 April 2025

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