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ASSOCIATION BETWEEN SPINAL CURVATURE ABNORMALITIES, SCREEN TIME, AND PHYSICAL INACTIVITY: A CROSS-SECTIONAL STUDY AMONG ADOLESCENTS

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ABSTRACT

Background: Abnormal spinal curvatures—scoliosis, kyphosis, and lordosis—are increasingly common among adolescents alongside sedentary lifestyles and heavy screen use. Adolescent idiopathic scoliosis affects roughly 1% of adolescents, with higher prevalence among females. This study examined the association between screen time, physical inactivity, and spinal curvature abnormalities among adolescents in Bengaluru. **Methods:** A cross-sectional study of 350 adolescents aged 10–19 years was conducted in schools and orthopaedic clinics in Bengaluru. All participants underwent the Adam's forward bend test, with scoliometer assessment and standing full-spine radiography where indicated. A structured questionnaire captured daily screen time, physical activity, sitting posture, and backpack use. Associations were assessed using chi-square tests, t-tests, and multivariable logistic regression adjusted for age, sex, and body mass index (BMI). **Results:** Trunk asymmetry was identified in 92 of 350 participants (26.3%), including 8.0% moderate and 4.3% severe. Curvature abnormality rose with screen exposure, from 16.4% (<2 h/day) to 27.7% (2–4 h/day) and 52.7% (>4 h/day) (^{2}=24.63, df=2, p<0.001). After adjustment, the odds of abnormality increased with screen time (>4 h/day: adjusted odds ratio [OR] 3.72, 95% confidence interval [CI] 2.14–6.46). Low physical activity was associated with higher musculoskeletal pain (visual analogue scale 4.8±1.9 versus 1.6±1.2, p<0.001). The combination of high screen time and physical inactivity carried the greatest risk (adjusted OR 5.47, 95% CI 3.08–9.71; interaction p=0.021). **Conclusions:** Screen-heavy, physically inactive adolescent lifestyles were associated with adverse postural and musculoskeletal outcomes. School-based screening and combined interventions addressing screen time, physical activity, and ergonomics may help reduce risk.

KEYWORDS : Adolescent idiopathic scoliosis, Ergonomics, Physical inactivity, Screen time, Spinal curvature abnormalities

INTRODUCTION

The rising incidence of spinal deformities is a growing public health concern. Curvature disorders such as scoliosis, kyphosis, and lordosis are associated with lifestyle changes including increased screen use, physical inactivity, and poor posture. The World Health Organization recommends at least one hour of physical activity per day for adolescents, yet approximately 81% of adolescents aged 11–17 years fail to meet this recommendation.[1] These deformities are linked not only to musculoskeletal disorders but also to psychological outcomes such as stress and low self-esteem, whereas an active lifestyle is associated with improved self-image, cognition, and well-being.

Adolescent idiopathic scoliosis is the most common form of scoliosis, affecting about 1% of adolescents, predominantly during the teenage years and more often among females. Alongside genetic predisposition, postural conditions are influenced by lifestyle factors including inactivity, poor ergonomics, and weak core musculature. Poorly designed desks, backpack habits, and heavy technology use contribute to the problem and can persist into adulthood.[2]

Prolonged sitting in poor ergonomic positions produces imbalanced trunk musculature that manifests as forward head posture, rounded shoulders, and thoracic kyphosis over time, while adolescents who do not meet recommended activity levels often lack adequate paraspinal and core strength to support the spine. Although idiopathic scoliosis has traditionally been attributed to genetic and neuromuscular causes, environmental factors such as backpacks, screen-based devices, and classroom seating are increasingly considered contributing or exacerbating factors. Studies of screen time point to a dose-response pattern in which greater device use is associated with reduced physical activity, sleep disruption, and poorer posture. However, most available literature addresses only one of these factors in isolation, particularly among urban South Asian adolescents. This study aimed to address that gap by investigating the extent and risk factors of spinal curvature abnormalities in relation to screen time and physical inactivity among adolescents in Bengaluru, contributing evidence to inform school-based screening and intervention programmes.

METHODS

A cross-sectional study was conducted over one year among 350 adolescents aged 10 to 19 years, recruited from schools and colleges in urban and semi-urban Bengaluru and from outpatient orthopaedic clinics affiliated with Vydehi Institute of Medical Sciences and Research Centre (VIMS & RC). Participants were selected using stratified random sampling to ensure proportional representation by age, sex, and recruitment source (school or clinic). [recruitment start and end dates]

Inclusion criteria were age 10–19 years, consent from the participant and a parent or guardian, and no history of spinal surgery or trauma. Exclusion criteria were known congenital spinal deformities, current orthopaedic treatment for spine disorders, and neurological or musculoskeletal disorders affecting posture.

Ethical clearance was obtained from the Institutional Ethics Committee of VIMS & RC, Bengaluru, prior to study initiation [approval number and date]. Informed consent and assent were obtained from each participant and their parent or legal guardian before enrolment.

Each participant underwent the Adam's forward bend test to assess spinal asymmetry. Those exceeding threshold values on scoliometer assessment of trunk rotation angle were referred for standing full-spine radiography to determine the Cobb angle and confirm scoliosis, kyphosis, or lordosis. Height, weight, and BMI were recorded to adjust for potential confounding.

A structured questionnaire captured average daily screen time, device type, physical activity (benchmarked against WHO recommendations of at least 60 minutes of moderate-to-vigorous activity per day), study sitting posture, desk ergonomics, and backpack use.

Data were analysed using SPSS version 25.0. Descriptive statistics summarised demographic and clinical variables. Chi-square tests assessed associations between categorical variables, and t-tests or analysis of variance were used for continuous-variable comparisons. Logistic regression identified predictors of spinal abnormality, adjusting for age, sex, BMI, and physical activity. A p value <0.05 was considered statistically significant.

RESULTS

Of the 350 participants, 258 (73.7%) showed no visible trunk asymmetry. The remaining 92 (26.3%) showed some degree of asymmetry: 49 (14.0%) mild, 28 (8.0%) moderate, and 15 (4.3%) severe (Table 1). Severity bands for confirmed cases were defined as mild (10–24°), moderate (25–40°), and severe (>40°) Cobb angle. Age- and sex-stratified analysis was used to assess clustering, given established evidence that early adolescence (ages 10–14) corresponds to rapid bone growth and scoliosis progression, and that females are at higher risk owing to bone-growth patterns, hormonal factors, and ligamentous laxity.[3,4]

Table 1: Findings of the Adam's forward bend test among study participants (n=350).

Finding	n	%	Clinical interpretation
Normal spinal alignment	258	73.7	No visible trunk asymmetry
Mild trunk asymmetry (suspected scoliosis)	49	14.0	Slight rib prominence or shoulder asymmetry; recommended for scoliometer assessment
Moderate trunk asymmetry	28	8.0	Noticeable rib hump; referred for standing full-spine radiography
Severe trunk asymmetry	15	4.3	Pronounced spinal deformity; immediate radiographic evaluation required
Total	350	100	—

Screen time was categorised into low (<2 h/day), moderate (2–4 h/day), and high (>4 h/day) exposure. The proportion of adolescents with curvature abnormality rose steadily across groups, from 16.4% (18/110) in the low-exposure group to 27.7% (36/130) in the moderate group and 52.7% (58/110) in the high-exposure group. This association was statistically significant ($^{2}=24.63$, df=2, $p<0.001$), indicating a clear dose-response gradient between daily screen time and spinal curvature abnormality (Table 2).

Table 2: Association between daily screen time and presence of spinal curvature abnormality (n=350).

Daily screen time	Curvature present, n (%)	Curvature absent, n (%)	Total
<2 h/day	18 (16.4)	92 (83.6)	110
2–4 h/day	36 (27.7)	94 (72.3)	130
>4 h/day	58 (52.7)	52 (47.3)	110
Total	112 (32.0)	238 (68.0)	350

$\chi^2=24.63$; df=2; $p<0.001$.

In a multivariable logistic regression adjusting for age, sex, and BMI, screen-time exposure remained an independent predictor of moderate/severe curvature abnormality. Relative to the low-exposure reference group, the adjusted odds of abnormality were 1.84-fold higher for 2–4 h/day (95% CI 1.08–3.14, p=0.025) and 3.72-fold higher for >4 h/day (95% CI 2.14–6.46, $p<0.001$). Older age (adjusted OR 1.09 per year, 95% CI 1.01–1.18, p=0.031) and higher BMI (adjusted OR 1.12 per unit, 95% CI 1.03–1.22, p=0.009) were also independently associated with abnormality, whereas female sex was not significant in the adjusted model (adjusted OR 1.41, 95% CI 0.91–2.18, p=0.120) (Table 3).

Table 3: Multivariable logistic regression for moderate/severe spinal curvature abnormality, adjusted for age, sex, and BMI.

Variable	Adjusted OR	95% CI	p value
Screen time 2–4 h/day	1.84	1.08–3.14	0.025
Screen time >4 h/day	3.72	2.14–6.46	<0.001
Female sex	1.41	0.91–2.18	0.120
Age (per year)	1.09	1.01–1.18	0.031
BMI (per unit)	1.12	1.03–1.22	0.009

Device type (mobile phone versus laptop) and body position during screen use—including lying down, which is associated with a distinct pattern of cervical and thoracic loading[5]—were considered as potential effect modifiers, given differing patterns of neck flexion and postural loading; mobile use is more commonly associated with sustained neck flexion ("text neck"), whereas laptop use at a desk is associated with a forward but comparatively straighter trunk posture.

Weekly physical activity was low (<600 metabolic equivalent [MET]-minutes/week) in 136 participants (38.9%), moderate in 142 (40.6%), and high in 72 (20.5%) (Table 4). Participants with low activity reported significantly higher pain and functional difficulty scores than those with moderate or high activity (both $p<0.001$), consistent with a dose-response relationship between physical activity and musculoskeletal symptom burden (Table 5).

Table 4: Weekly physical activity levels among study participants (n=350).

Activity level	MET-minutes/week	n (%)
Low	<600	136 (38.9)
Moderate	600–3000	142 (40.6)
High	>3000	72 (20.5)
Total	—	350 (100)

Table 5: Musculoskeletal outcomes by weekly physical activity level.

Outcome measure	Low (n=136)	Moderate (n=142)	High (n=72)	p value
Mean pain score (VAS, 0–10)	4.8±1.9	2.9±1.6	1.6±1.2	<0.001
Functional difficulty (mean score)	12.4±4.3	7.3±3.1	3.6±2.4	<0.001

A secondary comparison examined whether adolescents engaged in trunk-training sports (e.g., swimming, gymnastics) had healthier spinal outcomes than those engaged only in aerobic activity, controlling for screen time given the correlation between the two behaviours.[6] Adolescents engaged in trunk-training sports had significantly lower curvature-severity scores than those engaged only in aerobic activity (1.29±0.63 versus 1.81±0.76; t=3.41, p=0.001), suggesting that trunk-muscle engagement may be more protective for spinal alignment than aerobic activity alone.

More than a third of participants (36.6%) carried backpacks exceeding 10% of body weight, nearly half (48.9%) reported studying in a slouched posture, and the majority studied at ergonomically inappropriate desks (59.4%) without lumbar support (60.6%) (Table 6).

Table 6: Distribution of postural and ergonomic risk factors among study participants (n=350).

Risk factor	Category	n	%
Daily back pack weight	≤10% of body weight	222	63.4
	>10% of body weight	128	36.6
Backpack carrying style	Two shoulder straps	245	70.0
	Single shoulder strap	105	30.0
Study sitting posture	Upright posture	116	33.1
	Slouched posture	171	48.9
	Cross-legged/asymmetrical posture	63	18.0
Desk ergonomics	Ergonomically appropriate	142	40.6
	Ergonomically inappropriate	208	59.4
Continuous sitting duration	<30 minutes	78	22.3
	30–60 minutes	151	43.1
	>60 minutes	121	34.6
Lumbar support during study	Available	138	39.4
	Not available	212	60.6

On individual chi-square testing, slouched posture showed the strongest association with curvature abnormality (χ^2=14.87, p<0.001), followed by poor desk ergonomics (χ^2=10.58, p=0.001), backpacks exceeding 10% of body weight (χ^2=8.74, p=0.003), and absence of lumbar support (χ^2=6.42, p=0.011). Single-shoulder backpack carriage was not significantly associated with curvature findings (χ^2=2.13, p=0.144) (Table 7).

Table 7: Association of individual postural and ergonomic factors with spinal curvature abnormality.

Ergonomic/postural factor	Test statistic	p value
Slouched posture	$\dot{X}^2$=14.87	<0.001
Poor desk ergonomics	$\dot{X}^2$=10.58	0.001
Backpack >10% of body weight	$\dot{X}^2$=8.74	0.003
No lumbar support	$\dot{X}^2$=6.42	0.011
Single-shoulder backpack carriage	$\dot{X}^2$=2.13	0.144

A logistic regression model incorporating both screen time and physical inactivity with an interaction term was used to test whether their combination was associated with greater curvature risk than either factor alone. Relative to physically active adolescents with low screen time, the adjusted odds of abnormality were 1.68 for low screen time with inactivity (95% CI 0.89–3.16, p=0.110), 2.63 for high screen time with continued activity (95% CI 1.42–4.86, p=0.002), and 5.47 for both high screen time and inactivity (95% CI 3.08–9.71, p<0.001). The interaction between screen time and physical inactivity was statistically significant (interaction p=0.021), indicating that the combined burden exceeded the sum of the individual effects. Neither the age interaction (p=0.180) nor the sex interaction (p=0.290) reached significance (Table 8).

Table 8: Combined effect of screen time and physical activity on spinal curvature risk (reference: low screen time and physically active).

Exposure group	Adjusted OR	95% CI	p value
Low screen + active (reference)	1.00	—	—
Low screen + inactive	1.68	0.89–3.16	0.110
High screen + active	2.63	1.42–4.86	0.002
High screen + inactive	5.47	3.08–9.71	<0.001

Interaction p=0.021; age interaction p=0.180; sex interaction p=0.290.

DISCUSSION

The prevalence of trunk asymmetry observed in this sample (26.3%) is consistent with broader concern that postural disorders are increasingly common among adolescents in urban, screen-heavy environments. In the present sample this concern is borne out directly: curvature abnormality rose from 16.4% among low screen-time users to 52.7% among those exceeding four hours daily (χ^2=24.63, p<0.001), and each higher exposure band carried greater adjusted odds of abnormality (>4 h/day: adjusted OR 3.72, 95% CI 2.14–6.46). Most notably, the combination of high screen time and physical inactivity was associated with a more than fivefold increase in adjusted odds (OR 5.47, 95% CI 3.08–9.71), with a significant interaction term (p=0.021) indicating that the two behaviours compound one another rather than acting additively.

The strong association between low physical activity and elevated musculoskeletal pain and functional difficulty (p<0.001) supports the view that inactivity and weak paraspinal and core musculature contribute to reduced spinal support, a pattern that parallels evidence in adult populations linking higher physical activity with reduced musculoskeletal disease risk.[7] These findings are broadly consistent with prior evidence linking screen exposure and reduced outdoor activity to postural change and curve-progression risk factors in adolescents,[8] and with reviews describing associations between screen-media overuse and adverse musculoskeletal outcomes in children and adolescents.[9,10]

The high prevalence of poor ergonomic conditions—59.4% of participants studying at ergonomically inappropriate desks, 60.6% without lumbar support, and 36.6% carrying backpacks exceeding 10% of body weight—points to modifiable, school-level targets for intervention.[11] Taken together, the co-occurrence of high screen time, physical inactivity, and poor ergonomic conditions suggests that single-behaviour interventions are unlikely to be sufficient; combined, school-based programmes addressing screen time, physical activity, and classroom ergonomics together may be needed to meaningfully reduce risk.

This study has several limitations. Its cross-sectional design precludes causal inference about the direction of the relationship between screen time, physical inactivity, and spinal curvature. Screen time and physical activity were assessed by self-report questionnaire, which is subject to recall and social-desirability bias. The sample was drawn from a single city and from a mix of school and clinic populations, which may limit generalisability to community samples with lower baseline clinical concern.

In conclusion, more than a quarter of adolescents in this Bengaluru sample showed some degree of trunk asymmetry on clinical screening, and higher daily screen time was significantly and independently associated with spinal curvature abnormality (>4 h/day: adjusted OR 3.72, 95% CI 2.14–6.46; p<0.001), with the combination of high screen time and physical inactivity carrying the greatest risk (adjusted OR 5.47, 95% CI 3.08–9.71). Poor desk ergonomics and backpack practices were common and represent modifiable targets. These findings support early school-based screening combined with interventions that jointly address screen time, physical activity, and classroom ergonomics to help prevent progression toward more serious spinal deformity.

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DECLARATIONS

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