Majalah Ilmiah Fisioterapi Indonesia
Indonesian Scientific Journal of Physiotherapy

Original Research Articles
ISSN (Print): 2303-1921
ISSN (Online): 2722-0443
Volume 14, Number 2, Pages 642-647 (2026)
DOI: https://doi.org/10.24843/mifi.000002077

Cross-Sectional Study on Sitting Posture, Kyphosis, and Scoliosis in Elementary Students

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Received 17 March 2025; Revised 27 March 2025; Accepted 30 March 2025; Published 31 May 2026

Background: Poor sitting posture during childhood may contribute to spinal deformities, including kyphosis and scoliosis, by altering spinal alignment and musculoskeletal development.
Objective: To determine the relationship between sitting posture and the occurrence of kyphosis and scoliosis among elementary school students.
Methods: A cross-sectional study was conducted among 90 students aged 9–13 years at SD Negeri 1 Renon, Bali. Sitting posture was assessed using the Rapid Entire Body Assessment (REBA) through ErgoFellow and Kinovea software. Kyphosis was measured using a flexible curve ruler, while scoliosis was assessed using a scoliometer. Outcomes included sitting posture risk level, kyphosis, and scoliosis. Data were analyzed using Chi-square and Spearman's rho tests.
Results: Among the participants, 62.2% had kyphosis and 12.2% presented with intermediate scoliosis. Most students demonstrated high-risk sitting postures (51.1%). Chi-square analysis showed a significant association between sitting posture and spinal deformities ($p < 0.001$). Spearman's rho analysis demonstrated a strong positive correlation between sitting posture and kyphosis ($r = 0.646$, $p < 0.001$) and a moderate positive correlation between sitting posture and scoliosis ($r = 0.400$, $p < 0.001$). Confidence intervals were not reported in the original analysis.
Conclusion: Sitting posture is significantly associated with kyphosis and scoliosis in elementary school students. Poorer sitting posture is related to greater spinal deformity severity, highlighting the importance of ergonomic education and early preventive interventions in school-aged children.

Keywords
sitting posture, spinal deformity, kyphosis, scoliosis, elementary school students

Introduction

School-aged children are in a critical period of rapid and continuous spinal growth and development, making them vulnerable to musculoskeletal disorders, including spinal deformities.[1] Spinal deformity refers to abnormalities in the vertebral column's shape, curvature, and alignment. More than 600,000 patients with spinal deformities receive treatment annually.[2] The Scoliosis Research Society classifies common spinal deformities into kyphosis, lordosis, and scoliosis.[3]

Kyphosis is characterized by an excessive forward curvature of the spine, leading to an abnormally rounded upper back. Normal kyphotic curvature in children ranges between 10° and 25°, whereas a curvature of 26° or more is considered abnormal.[4] Scoliosis is defined as an abnormal lateral curvature of the spine with a Cobb angle exceeding 10°. Children with scoliosis typically exhibit a spinal shape resembling the letter "C" or "S"[5] The incidence of scoliosis has increased from 107 per 100,000 individuals in 2015 to 161 per 100,000 in 2022. In Indonesia, particularly in Jakarta, the prevalence of scoliosis is approximately 4%–4.5%. A study conducted in Makassar on 228 students reported that 27% had kyphosis.[3]

Spinal deformities are multifactorial conditions that have become a significant public health concern, particularly among school-aged children. The progression of spinal deformities is influenced by internal factors such as body mass index (BMI), nutrition, sex, and genetics, as well as external factors like trauma or injury, physical activity, workload, and sitting posture.[7] Poor sitting posture is a major contributing factor to spinal deformities.

Sitting posture affects an individual's productivity, with proper sitting posture enhancing productivity.[8] In contrast, poor sitting posture can negatively impact spinal muscle and bone development, as the body exerts extra effort to adapt to an improper position.[9] Slouched sitting posture can lead to kyphosis in children, as the biomechanics of slouching increase anterior vertebral curvature, stretching the back extensor muscles and posterior spinal ligaments, ultimately weakening them over time.[10] Sitting asymmetrically or leaning predominantly to one side results in muscle imbalance and asymmetrical muscle tone, contributing to scoliosis. This imbalance occurs because the back muscles on one side become weaker than those on the opposite side, leading to lateral spinal curvature.[11] Understanding the relationship between sitting posture and spinal deformities can serve as a foundation for designing early intervention programs in elementary schools, such as ergonomic posture education and the development of supportive chair designs.

A study by Kolarova et al. (2019) involving 311 children aged 6–8 years found that more than 50% of the population had poor posture, with 30% experiencing spinal deformities.[12] Li et al. reported that poor sitting posture while reading and writing among 1,138 participants contributed to thoracic kyphosis.[1] In contrast, a study by de Assis et al. (2021) found no association between sitting posture and scoliosis.[13] Similarly, Drza-Grabiec et al. (2015) concluded that sitting posture reduced the thoracic kyphosis angle.[14] Differences in findings across these studies may be attributed to variations in measurement methods, study populations, and observation durations. These inconsistencies highlight the need for further research on the risk factors associated with sitting posture and spinal deformities.

Based on the discrepancies in previous studies and the lack of objective measurement approaches, this study aims to explore the relationship between sitting posture and spinal deformities in elementary school students. Specifically, the study seeks to investigate the association between sitting posture and spinal deformities, including kyphosis and scoliosis, among students at SD Negeri 1 Renon, using more objective measurement methods such as REBA and angular projection analysis with Kinovea. The research hypothesis posits a significant relationship between sitting posture, as assessed by REBA, and spinal deformities, with poor sitting posture being associated with an increased risk of kyphosis and scoliosis.

Methods

This study employed an analytical observational research design with a cross-sectional approach conducted at SD Negeri 1 Renon from January to May 2024. This design was chosen as it allows for simultaneous observation of the relationship between sitting posture and spinal deformities without intervention. The independent variable in this study was sitting posture, while the dependent variable was spinal deformities, specifically kyphosis and scoliosis. Participants were selected through purposive sampling based on inclusion and exclusion criteria. The inclusion criteria included cooperative students willing to participate, students present during the study, students who sat for a minimum of two hours daily, and both male and female students aged 9–13 years in grades IV, V, and VI. The exclusion criteria encompassed students with a history of spinal injuries, such as fractures, and those with congenital spinal deformities. Additionally, students who failed to follow instructions correctly were considered dropouts.

The sample size was determined using Lemeshow's cross-sectional formula, with a minimum of 28 participants. However, based on the selection criteria, the final sample comprised 90 students. The research began with an initial observation and coordination with SD Negeri 1 Renon to obtain research approval and inform the target population. Participant selection was facilitated by the school, where students meeting the inclusion criteria were identified through administrative data and preliminary interviews with homeroom teachers. Eligible participants were then provided with informed consent forms to be signed by their parents, confirming their willingness to participate.

The study was conducted in a designated room divided into separate booths to ensure participant privacy and optimize the measurement process. All students were asked to sit in their usual posture for five minutes before measurements were taken to ensure that the results reflected their natural sitting posture. Sitting posture was assessed using the Rapid Entire Body Assessment (REBA) on the ErgoFellow application, which evaluates body posture, including the neck, spine, upper arms, wrists, legs, force exertion, type of movement, repetition, and coupling. Postural documentation was captured at the first, third, and fifth minutes, followed by angle projection analysis using Kinovea. The REBA score interpretation was as follows: scores of 1 indicated negligible risk requiring no corrective action; scores of 2–3 suggested low risk with possible corrective measures; scores of 4–7 indicated moderate risk requiring intervention; scores of 8–10 represented high risk necessitating immediate corrective action; and scores of 11–15 denoted very high risk requiring urgent intervention.

Spinal deformities were assessed using a flexible curve ruler aligned from C7 to T12 while the participant maintained an upright standing position to measure kyphosis, and a scoliometer was used in the Adam's Forward Bending position to measure scoliosis. Kyphosis measurements for female students were conducted by a female physiotherapist and a trained female researcher responsible for recording curvature results. Male students' kyphosis measurements were taken by a trained male researcher, accompanied by a trained female researcher responsible for recording curvature results. Scoliosis measurements were carried out by a trained research team. Kyphosis was categorized as abnormal if the curvature angle exceeded 26° and normal if it ranged between 10–25°. Scoliosis was classified based on the Angle of Trunk Rotation (ATR), where ATR values of 0–3° were considered normal, 4–6° were classified as intermediate, and ATR ≥7° was considered indicative of scoliosis with a high probability.

Collected data were verified before analysis to prevent missing information, resulting in a total of 90 complete datasets. Data analysis consisted of univariate and bivariate analysis. Univariate analysis provided an overview of age, gender, sitting duration, sitting posture, and spinal deformities. Hypothesis testing was conducted through bivariate analysis to examine the relationship between sitting posture and spinal deformities using the Chi-Square test and Spearman's rho test. The Chi-Square test was employed to assess the association between variables, while Spearman's rho test determined the strength of the relationship between them. This study was approved by the Research Ethics Committee of the Faculty of Medicine, Udayana University/Sanglah General Hospital Denpasar, with ethical clearance number 1000/UN14.2.2.VII.14/LT/2024.

Results

The sample in this study comprised fourth- and fifth-grade students from SD Negeri 1 Renon, selected using a purposive sampling technique. Out of a total population of 282 students, 90 participants met the inclusion criteria and were included in the analysis. A total of 192 individuals did not meet the inclusion criteria due to reasons such as lack of parental consent, age mismatch, or a history of congenital spinal deformities. No participants experienced dropout, ensuring that all included subjects completed the research protocol as required. The sample selection process is illustrated in Figure 1.

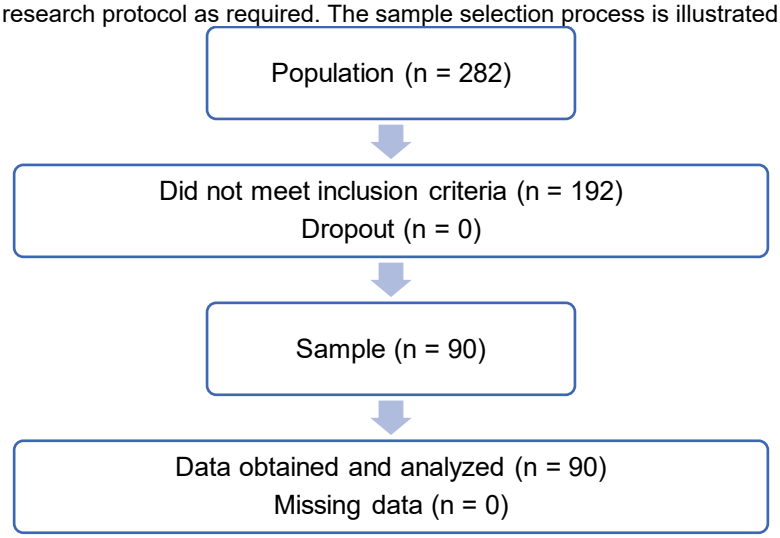

Figure 1. Research Flowchart

The characteristics of the study sample, including age, sex, sitting duration, sitting posture, kyphosis, and scoliosis, are presented in Table 1.

Table 1. Frequency Distribution of Sample Characteristics

Variable	Characteristics	Frequency (n)	Percentage (%)
Age (mean ± SD)		3.56 ± 0.996	
	9 years	1	1.1
	10 years	16	17.8
	11 years	19	21.1
	12 years	40	44.4
	13 years	14	15.6
Sex	Male	45	50
	Female	45	50
Sitting Duration	>2 hours	90	100
Sitting Posture	Moderate Risk	42	46.7
	High Risk	46	51.1
	Very High Risk	2	2.2
Kyphosis	Normal	34	37.8
	Kyphosis	56	62.2
Scoliosis	Normal	79	87.8
	Intermediate	11	12.2

Based on age characteristics in Table 1, the sample was predominantly 12 years old (44.4%), followed by 11 years old (21.1%), 10 years old (17.8%), 13 years old (15.6%), and 9 years old (1.1%). The sample was equally distributed between males and females (50% each). All participants had a sitting duration of more than two hours, which was a prerequisite for inclusion in the study. Regarding sitting posture, 46.7% exhibited moderate risk, 51.1% exhibited high risk, and 2.2% exhibited very high risk. The prevalence of kyphosis was 62.2%, while 37.8% of participants had normal spinal curvature. In terms of scoliosis, 87.8% of participants were classified as normal, while 12.2% exhibited intermediate scoliosis.

Table 2. Relationship Between Sitting Posture and Spinal Deformities (Kyphosis)

Sitting Posture	Kyphosis	Total	p-value
	Normal (%)	Kyphosis (%)	(%)
Moderate Risk	30 (33.3)	12 (13.3)	42 (46.7)
High Risk	4 (4.4)	42 (46.7)	46 (51.1)
Very High Risk	0 (0.0)	2 (2.2)	2 (2.2)
Total	34 (37.8)	56 (62.2)	90 (100.0)

Table 3. Relationship Between Sitting Posture and Spinal Deformities (Scoliosis)

Sitting Posture	Scoliosis	Total	p-value
	Normal (%)	Intermediate (%)	(%)
Moderate Risk	42 (46.7)	0 (0.0)	42 (46.7)
High Risk	37 (41.1)	9 (10.0)	46 (51.1)
Very High Risk	0 (0.0)	2 (2.2)	2 (2.2)
Total	79 (87.8)	11 (12.2)	90 (100.0)

Tables 2 and 3 indicate a significant relationship between sitting posture and spinal deformities among students at SD Negeri 1 Renon, as evidenced by a p-value of <0.001.

Table 4. Bivariate Analysis Using Spearman Rho Test: Correlation Between Sitting Posture and Kyphosis

Correlation Variables	Correlation Coefficient (r)	p-value
Sitting Posture & Kyphosis	0.646	0.000

Table 4 shows a significant and strong correlation between sitting posture and kyphosis among students at SD Negeri 1 Renon, with a p-value of 0.000 ($p < 0.05$) and a correlation coefficient of $r = 0.646$. The positive correlation indicates a direct relationship, meaning that poorer sitting posture is associated with more severe kyphosis.

Table 5. Bivariate Analysis Using Spearman Rho Test: Correlation Between Sitting Posture and Scoliosis

Correlation Variables	Correlation Coefficient (r)	p-value
Sitting Posture & Scoliosis	0.400	0.000

Table 5 demonstrates a significant moderate correlation between sitting posture and scoliosis among students at SD Negeri 1 Renon, with a p-value of 0.000 ($p < 0.05$) and a correlation coefficient of $r = 0.400$. The positive correlation signifies a direct relationship, where poorer sitting posture is linked to a greater degree of scoliosis severity.

Discussion

Characteristics of Research Subjects

This study was conducted on Saturday, May 18, 2024, at SD Negeri 1 Renon, South Denpasar District, Denpasar City, involving 90 students selected using purposive sampling. The results showed that the majority of participants were 12 years old (n = 40, 44.4%). The age range of 9 to 13 years was chosen because spinal curvature progression can be observed within this range. The Indonesian Ministry of Health recommends screening both boys and girls aged 9 to 13 years to evaluate potential spinal deformities.[14]

Regarding gender distribution, the study had an equal number of male (n = 45, 50%) and female (n = 45, 50%) participants. Both genders are susceptible to spinal deformities.[15] Concerning sitting duration, all students engaged in sitting activities for more

than two hours daily. SD Negeri 1 Renon implements a full-day school system, where prolonged sitting for six hours with poor posture can increase neck flexion, reduce lower cervical lordosis, and lead to increased thoracic kyphosis.[15] Drza-Grabiec et al. (2015) reported that prolonged sitting contributes to scoliosis in children.[16]

REBA measurements revealed that most participants had a high-risk sitting posture (n = 46, 51.1%). Utami et al. (2020) also found that 72 school-aged children had suboptimal sitting postures, with 49 exhibiting non-ergonomic postures.[17] Poor sitting posture in children negatively impacts spinal development by causing muscle imbalances and uneven pressure distribution on spinal structures.[18] This study found that 56 students (62.2%) had kyphosis, consistent with De Baranda et al. (2020), who reported kyphosis in 53.44% of 582 students from 14 different elementary schools.[19] Regarding scoliosis, most students had a normal spinal curvature (n = 79, 87.8%), aligning with Kurniawati (2017), who found that 81 students had no scoliosis, while 19 were diagnosed with scoliosis.[20]

The Relationship Between Sitting Posture and Spinal Deformities

Bivariate analysis using the chi-square test (Table 2 and Table 3) yielded p-values < 0.001, indicating a significant association between sitting posture and spinal deformities among SD Negeri 1 Renon students. Spearman's rho correlation analysis (Table 4) revealed a strong correlation between sitting posture and kyphosis ($r = 0.646$, $p = 0.000$, $p < 0.05$), while Table 5 showed a moderate correlation between sitting posture and scoliosis ($r = 0.400$, $p = 0.000$, $p < 0.05$).

A supporting study by Wen et al. (2022) also found a significant relationship between sitting posture and kyphosis. The physiological curvature of the spine is closest to its natural state in early life but is highly susceptible to pathological deviations due to prolonged incorrect posture. This study included a large sample (n = 1,138), enhancing statistical power in analyzing the relationship between sitting posture and spinal deformities. However, spinal measurements were conducted using a handheld measuring ruler, which may introduce measurement bias.[1]

Inadequate sitting posture affects sagittal spinal alignment (thoracic kyphosis) by inducing excessive trunk flexion. Persistent flexion in a seated position increases the thoracic kyphotic angle, impacting overall spinal alignment.[21] Poor sitting posture induces anterior shear stress, leading to increased pressure on the anterior vertebrae, disc flattening on the ventral side, dorsal widening, nucleus displacement, and posterior entrapment. This results in locked extension movements and ligament irritation. Additionally, ligament capsules elongate on one side and shorten on the other, potentially leading to ligament tightness.[19]

A slumped posture alters the center of gravity (COG), shifting body weight anteriorly and disrupting optimal spinal alignment. This increases thoracic kyphosis curvature due to muscle imbalances between dorsal and ventral trunk muscles, contributing to postural kyphosis development.[22] These changes occur as part of a compensatory kinematic chain mechanism to redistribute body weight according to the new posture.[23]

Zein & Permata (2024) found a significant relationship between poor sitting posture and scoliosis severity. The use of a scoliometer and Adam's Forward Bending Test provided more objective scoliosis measurements than questionnaires or visual observations. Daily asymmetrical movement habits were also linked to increased scoliosis risk, as muscle imbalances from these habits contribute to spinal deformities.[24] Poor sitting postures, such as sitting away from the desk, pelvic retroversion, and asymmetrical foot positioning, increase spinal pressure. In a non-ergonomic sitting position, weight distribution across the spine becomes unbalanced, triggering spinal curvature changes.[25] Drza-Grabiec et al. (2015) reported that prolonged sitting increases asymmetry in the pelvis, shoulders, and scapulae, leading to scoliosis progression. This posture disrupts muscle balance, particularly deactivating core stabilizer muscles during prolonged sitting.[16]

Prolonged sitting without changing position heightens musculoskeletal strain and exacerbates scoliosis risk.[26] According to Lee et al. (2016), sitting with one leg crossed induces trunk asymmetry due to asymmetric activation of the internal oblique abdominal muscles and increases spinal rotation. The spine is vulnerable to compression from rotational forces, leading to concave and convex curvatures that heighten scoliosis potential.[27]

The Hueter-Volkmann Law states that increased pressure on the epiphyseal growth plate slows growth. In scoliosis, the concave side of the curve experiences greater pressure, hindering vertebral growth, while the convex side undergoes accelerated growth. As vertebrae continue developing, this uneven pressure distribution causes vertebral wedging and facet size differences. Additionally, the spinal righting reflex compensates for primary curvature by forming secondary curves above and below the main curve to restore COG alignment.[28]

Limitations and Recommendations

A limitation of this study was students' reluctance to remove clothing during spinal deformity measurements due to embarrassment. Additionally, while REBA is practical and easy to use, it lacks the accuracy of more objective tools such as radiography (X-ray).

It is important to note that the study sample was drawn from an urban setting, where school conditions, facilities, and habits may differ from other regions or age groups, potentially affecting research outcomes. Studies from Japan, Argentina, and Poland found no significant association between sitting posture and spinal deformities, likely due to differences in daily activity levels, postural habits, and school furniture design.[29] These findings suggest that cultural and habitual contexts may influence research outcomes. Comparative studies can help identify key factors and best practices for optimal spinal development in children.

Physiotherapists play a crucial role in conducting posture assessments and educating students on proper sitting posture. Recommended exercises include core stability exercises, scrotch exercises, and thoracic spine mobility exercises. Physiotherapists can also advise schools on ergonomic desk and chair dimensions. According to the Indonesian National Standard (SNI), recommended desk heights for elementary schools range from 70.0 cm to 72.5 cm, while chair heights range from 37.0 cm to 42.0 cm.[30] Collaboration between schools and families is essential in fostering a posture-friendly environment for children. Teachers should ensure classroom ergonomics, remind students about proper sitting posture, and integrate stretching exercises into daily activities. Parents should provide ergonomic home study spaces, monitor children's sitting positions, and model good posture.

Future research recommendations include: (1) developing strategies for creating a comfortable examination environment, such as using special attire or educational approaches to improve student participation, (2) expanding research coverage across Bali for more representative data, and (3) employing high-accuracy measurement tools such as X-ray imaging for detailed spinal assessments. Implementing these suggestions will enhance research findings on the relationship between sitting posture and spinal deformities, as well as other contributing factors.

Conclusion

Based on the findings of this study and the chi-square test analysis, the results indicated a p-value of < 0.001, demonstrating a significant relationship between sitting posture and spinal deformities among students at SD Negeri 1 Renon. Furthermore, the Spearman's rho test yielded a p-value of 0.000 ($p < 0.05$), with a correlation coefficient of 0.646 for kyphosis and 0.400 for scoliosis. These findings suggest a strong correlation between sitting posture and kyphosis, as well as a moderate correlation between sitting posture and scoliosis among the students.

The results of this study highlight the importance of understanding the factors contributing to spinal deformities. This research is expected to serve as a reference for future studies and as an educational resource to raise awareness among students and educational institutions about the significance of monitoring and evaluating sitting posture to prevent spinal deformities. Additionally, these findings can serve as a foundation for physiotherapists in designing educational programs and corrective exercises for students, teachers, and parents to enhance awareness regarding proper sitting posture.

The implementation of preventive programs in schools, including health education, ergonomic modifications of desks and chairs according to children's anthropometric measurements, and stretching and postural muscle strengthening exercises, is recommended to reduce the risk of spinal deformities from an early age. Educational institutions and relevant authorities are encouraged to adopt policies that support ergonomic seating arrangements in classrooms and promote regular postural assessments as a preventive measure to maintain students' spinal health.

Author Contributions

Ni Kadek Nova Milani Dewi: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation.
I Putu Yudi Pramana Putra: Supervision, Validation, Methodology, Writing – Review and Editing.
Luh Putu Ratna Sundari: Investigation, Resources, Validation, Writing – Review and Editing.
I Made Jawi: Supervision, Validation, Writing – Review and Editing.

Acknowledgments

The authors would like to thank the principal, teachers, students, and parents of SD Negeri 1 Renon for their participation and support during this study. Appreciation is also extended to all research assistants and the Faculty of Medicine, Udayana University, for facilitating the research process.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this article.

Funding Sources

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics Statement

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Udayana University/Sanglah General Hospital Denpasar (Ethical Clearance No. 1000/UN14.2.2.VII.14/LT/2024). Written informed consent was obtained from the parents or legal guardians of all participants before enrollment in the study.

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