# PREVALENCE OF SCOLIOSIS AND LIMB LENGTH DISCREPANCY AMONG ADOLESCENTS : A CROSS-SECTIONAL STUDY IN SURABAYA

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## ABSTRAK

Skoliosis merupakan kelainan bentuk tulang belakang yang dapat terjadi pada remaja dan berhubungan dengan ketidakseimbangan panjang tungkai bawah. Gangguan ini dapat menyebabkan adaptasi postural yang berpotensi memicu keluhan muskuloskeletal jangka panjang. Penelitian potong lintang ini bertujuan untuk mengetahui proporsi skoliosis dan hubungannya dengan ketidakseimbangan panjang tungkai bawah pada remaja sekolah menengah atas di Surabaya. Sebanyak 276 siswa berusia 14–19 tahun menjalani skrining menggunakan *Adam's Forward Bending Test* untuk mendeteksi skoliosis. Responden yang menunjukkan hasil positif kemudian menjalani pemeriksaan lanjutan menggunakan *Tes Galeazzi* untuk menilai ketidakseimbangan panjang femur dan tibia, serta dilakukan pengukuran panjang tungkai sebenarnya dan semu guna membedakan kelainan struktural dan fungsional. Hasil penelitian menunjukkan prevalensi skoliosis sebesar 17,4%, dengan proporsi tertinggi pada kelompok usia 17 tahun. Pemeriksaan *Galeazzi* menunjukkan adanya ketidakseimbangan tibia pada 29,2% dan femur pada 22,9% dari kasus skoliosis. Pengukuran panjang tungkai semu menunjukkan derajat asimetri yang lebih besar dibandingkan pengukuran panjang sebenarnya, yang mengindikasikan bahwa ketidakseimbangan postural memberikan pengaruh lebih besar dibandingkan perbedaan struktural tulang. Temuan ini menunjukkan bahwa skoliosis pada masa remaja berkaitan erat dengan adaptasi fungsional ekstremitas bawah akibat gangguan postur. Oleh karena itu, diperlukan pemeriksaan yang mencakup evaluasi tulang belakang dan tungkai bawah untuk deteksi secara dini pada populasi remaja.

**Kata kunci :** panjang tungkai, postur tubuh, remaja, skoliosis

## *ABSTRACT*

*Scoliosis is a spinal deformity during adolescence and associated with lower limb length discrepancy. This condition can result in postural adaptations that potentially contribute to long-term musculoskeletal issues. This cross-sectional study aimed to determine the proportion of scoliosis and its association with lower limb length discrepancy among high school adolescents in Surabaya. A total of 276 students aged 14–19 years were screened using the Adam's Forward Bending Test to identify scoliosis. Participants with positive findings underwent further evaluation using the Galeazzi test to assess femoral and tibial length discrepancies, along with true and apparent leg length measurements to differentiate structural from functional abnormalities. The prevalence of scoliosis was 17.4%, with the highest proportion found in the 17-year-old age group. The Galeazzi test indicated tibial discrepancies in 29.2% and femoral discrepancies in 22.9% of scoliosis cases. Apparent leg length measurements demonstrated greater asymmetry compared to true measurements, suggesting that postural imbalance exerts a stronger influence than structural bone differences. These findings indicate that adolescent scoliosis is closely associated with functional adaptations in the lower extremities as a consequence of postural disturbances. Therefore, comprehensive evaluation involving both spinal and lower limb assessments is essential for early detection in adolescents.*

***Keywords** : scoliosis, adolescents, leg length, posture*

## INTRODUCTION

Scoliosis is a three-dimensional spinal deformity marked by lateral curvature and vertebral rotation, commonly emerging during adolescence when skeletal growth accelerates. During

this phase, spinal elongation may outpace the adaptive capacity of surrounding musculature, leading to mechanical imbalances (Ridderbusch et al., 2018; Singh et al., 2022; Yang et al., 2014). Epidemiological data estimate a global prevalence between 0.5% and 6% in school-aged populations. Without early detection, scoliosis may result in postural asymmetry, gait disturbances, and musculoskeletal complications (Ramadhani et al., 2024; Ameri et al., 2015). Asymmetrical growth of the vertebral column can disrupt biomechanical equilibrium, often manifesting as lower limb length discrepancy. This discrepancy may be structural, due to variations in femoral or tibial length, or functional, related to pelvic tilt and compensatory spinal alignment (Adolescent idiopathic scoliosis, 2022; Singh et al., 2022; Buyukaslan et al., 2022).

These imbalances can amplify spinal curvature and destabilize posture. Understanding their interaction may clarify pathophysiological mechanisms contributing to scoliosis progression (Fadzan & Bettany-Saltikov, 2017; Zhu et al., 2023; Adolescent idiopathic scoliosis, 2022). Physical screening methods such as the Adam's Forward Bending Test and Galeazzi test provide accessible means for early scoliosis detection and assessment of limb length asymmetry (Adolescent idiopathic scoliosis, 2022; Lo & Huang, 2017; Buyukaslan et al., 2022). These tests remain practical in school settings due to their simplicity and reliability. However, population-based data correlating spinal deformity with limb length differences remain scarce, particularly among adolescents in Indonesia (Adolescent idiopathic scoliosis, 2022; Fadzan & Bettany-Saltikov, 2017; Weiss et al., 2016).

This study aims to evaluate the prevalence of scoliosis in high school adolescents in Surabaya and explore its association with lower limb length discrepancy. Findings may guide early biomechanical assessments and inform targeted interventions within adolescent musculoskeletal health programs. Genetic and environmental factors have been widely studied to understand the etiology of adolescent idiopathic scoliosis (AIS). Although the exact cause remains unknown, recent studies suggest a multifactorial origin involving genetic predisposition, neuromuscular dysfunction, and biomechanical factors (Wise et al., 2008; Fadzan & Bettany-Saltikov, 2017; de Sèze & Cugy, 2012). Neural crest cell anomalies have also been proposed as contributing factors, highlighting the complexity of the pathogenesis of scoliosis (Zaydman et al., 2018). Understanding these mechanisms is crucial for developing preventive strategies and personalized treatment plans.

Physical activity levels and lifestyle habits during adolescence also appear to influence scoliosis progression. Some evidence suggests that reduced physical activity and increased screen time may exacerbate spinal deformities by weakening postural muscles and limiting spinal flexibility (Zhu et al., 2023; Glavaš et al., 2023). Conversely, targeted exercise programs and postural rehabilitation have shown promise in mitigating curve progression and improving quality of life for adolescents with scoliosis (Weiss et al., 2016; Lo & Huang, 2017). These findings underscore the importance of integrating physical activity assessments into scoliosis screening protocols. Radiological evaluation remains the gold standard for diagnosing and monitoring scoliosis. However, concerns about cumulative radiation exposure have prompted investigations into alternative imaging methods and clinical screening tools to minimize risks, especially in growing adolescents (Cool et al., 2023).

Early clinical screening using non-invasive tests such as the Adam's Forward Bending Test can facilitate timely referral for radiographic confirmation, balancing diagnostic accuracy with safety (Adolescent idiopathic scoliosis, 2022). This approach is particularly relevant in resource-limited settings like many regions in Indonesia. Finally, addressing limb length discrepancy (LLD) as part of scoliosis management may provide additional benefits in correcting postural imbalances. Studies have shown that both structural and functional LLD can influence spinal biomechanics, potentially aggravating scoliotic curvature (Buyukaslan et al., 2022; Singh et al., 2022). Interventions such as orthotic insoles, physical therapy, and

corrective exercises targeting pelvic alignment and limb length asymmetry could complement scoliosis treatment and improve overall musculoskeletal health in adolescents (Adolescent idiopathic scoliosis, 2022; Weiss et al., 2016). Future research is needed to establish standardized protocols for combined management of scoliosis and LLD.

## METHODS

This cross-sectional descriptive study examined the prevalence of scoliosis and its association with lower limb length discrepancy among 276 high school students in Surabaya in October 2024. Participants aged 14–19 years were selected through total sampling from grades 10 to 12 based on active enrollment, parental consent, and school approval. Scoliosis was identified using the Adam's Forward Bending Test, and those with positive results underwent Galeazzi testing as well as true and apparent leg length measurements. All examinations were performed by trained personnel using standardized and calibrated instruments. Data were processed using a statistical analyzer program, and presented descriptively in the form of frequencies, percentages, means, and standard deviations.

## RESULT

This study involved 276 high school students in Surabaya, consisting of 136 males (49.3%) and 140 females (50.7%), indicating a near-equal gender distribution. Most participants were aged 15 years (44.6%) and 16 years (46.7%), aligning with the rapid skeletal growth phase of adolescence. The remaining age groups included 14 years (2.2%), 17 years (6.2%), and 19 years (0.4%).

**Table 1. Distribution of Participants by Sex and Age**

| Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| **Sex** | | |
| Male | 136 | 49.3 |
| Female | 140 | 50.7 |
| **Age (years)** | | |
| 14 | 6 | 2.2 |
| 15 | 123 | 44.6 |
| 16 | 129 | 46.7 |
| 17 | 17 | 6.2 |
| 19 | 1 | 0.4 |

Screening using the Adam's Forward Bending Test identified 48 participants (17.4%) with positive scoliosis findings. The remaining 228 participants (82.6%) tested negative.

**Table 2. Adam's Forward Bending Test Results**

| Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| Positive | 48 | 17.4 |
| Negative | 228 | 82.6 |

Age-stratified analysis showed the highest proportion of scoliosis among 17-year-olds (35.3%), followed by 16-year-olds (20.2%) and 15-year-olds (13%). No cases were identified in the 14- and 19-year-old groups.

Gender distribution among scoliosis cases was nearly identical. Among males, 24 (17.6%) tested positive, as did 24 females (17.7%).

**Table 3. Age Distribution by Adam's Forward Bending Test**

| Age Group | Adam's Result | Frequency (n) | Percentage (%) |
|---|---|---|---|
| 14 | Positive | 0 | 0.0 |
| | Negative | 6 | 100.0 |
| 15 | Positive | 16 | 13.0 |
| | Negative | 107 | 87.0 |
| 16 | Positive | 26 | 20.2 |
| | Negative | 103 | 79.8 |
| 17 | Positive | 6 | 35.3 |
| | Negative | 11 | 64.7 |
| 19 | Positive | 0 | 0.0 |
| | Negative | 1 | 100.0 |

**Table 4. Gender Distribution by Adam's Forward Bending Test**

| Gender | Adam's Result | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Male | Positive | 24 | 17.6 |
| | Negative | 112 | 82.4 |
| Female | Positive | 24 | 17.7 |
| | Negative | 116 | 82.9 |

Among the 48 participants with scoliosis, Galeazzi testing revealed femoral length discrepancies in 11 (22.9%) and tibial discrepancies in 14 (29.2%). Tibial differences were more common than femoral.

**Table 5. Galeazzi Test Results Among Scoliosis Cases**

| Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| Femur Positive | 11 | 22.9 |
| Femur Negative | 37 | 77.1 |
| Tibia Positive | 14 | 29.2 |
| Tibia Negative | 34 | 70.8 |

True leg length measurements among participants with femoral discrepancies showed a mean of 85.00 cm (left) and 84.18 cm (right). For tibial differences, the left measured 86.50 cm and the right 85.36 cm.

**Table 6. True Leg Length Based on Galeazzi Test**

| Variable | Left Leg Mean (cm) | SD | Right Leg Mean (cm) | SD |
|---|---|---|---|---|
| Femur | 85.00 | 3.63 | 84.18 | 3.48 |
| Tibia | 86.50 | 3.08 | 85.36 | 3.07 |

Apparent measurements showed larger discrepancies. For femoral cases, left leg averaged 93.09 cm and right 91.91 cm. For tibial cases, the means were 93.93 cm (left) and 92.42 cm (right).

**Table 7. Apparent Leg Length Based on Galeazzi Test**

| Variable | Left Leg Mean (cm) | SD | Right Leg Mean (cm) | SD |
|---|---|---|---|---|
| Femur | 93.09 | 5.04 | 91.91 | 4.03 |
| Tibia | 93.93 | 3.97 | 92.42 | 3.85 |

## DISCUSSION

The scoliosis prevalence of 17.4% found among adolescents in this study reflects a musculoskeletal adaptation that commonly emerges during the phase of accelerated skeletal growth. The increased occurrence in the 16- and 17-year age groups supports the theory that

disproportionate vertebral elongation relative to neuromuscular adaptation leads to mechanical imbalance along the axial skeleton. During this phase, growth is often not matched by symmetrical development of postural support structures, which contributes to lateral deviation and vertebral rotation (Ameri et al., 2015; Buyukaslan et al., 2022; Alman, 2009). This relationship between growth velocity and spinal alignment explains why scoliosis often becomes more evident as adolescents approach the late stages of puberty (Yang et al., 2014; Adolescent idiopathic scoliosis, 2022; Asher & Burton, 2006).

Analysis of lower limb asymmetry using the Galeazzi test demonstrated a higher frequency of tibial length discrepancies compared to femoral. This pattern indicates that structural or functional adaptation occurs more dominantly in the distal segment of the lower extremity in response to axial misalignment (Weiss et al., 2016; Alman, 2009; Columbia Orthopedics, 2024). Biomechanically, scoliosis induces an uneven distribution of mechanical load across the pelvis, which then propagates through the lower limbs (Glavaš et al., 2023; de Sèze & Cugy, 2012). As a result, the tibia, being the more distal and weight-bearing segment, may reflect the body's attempt to compensate for pelvic tilt and spinal deviation. The lower limb thus serves not only as a support structure but also as a dynamic participant in the postural compensation mechanism (Glavaš et al., 2023; Wise et al., 2008).

Apparent leg length measurements consistently showed greater discrepancies than true structural measurements. This suggests that postural shifts, including pelvic rotation and tilt, play a greater role in observed asymmetry than actual differences in bone length (Singh et al., 2022; Yang et al., 2014; Asher & Burton, 2006). The body's attempt to maintain upright balance in the presence of spinal curvature can result in functional shortening or lengthening of one limb. Such adaptations, while not structurally fixed, may still alter gait dynamics and predispose the individual to further musculoskeletal imbalance (Ameri et al., 2015; Weiss et al., 2016; Gashaw et al., 2021). These findings emphasize that functional assessments provide additional diagnostic value beyond skeletal measurement alone.

The combination of spinal curvature and limb asymmetry in adolescents indicates an interconnected pattern of musculoskeletal adjustment rather than isolated deformity. The consistency of scoliosis prevalence across sexes and the pattern of compensatory changes in the lower limbs suggest that growth-related mechanical stress affects the entire axial-appendicular system (Columbia Orthopedics, 2024; Cool et al., 2023; Zaydman et al., 2018). Recognizing these interactions reinforces the importance of early physical screening in adolescent populations, not only to detect spinal misalignment but also to identify related biomechanical adaptations (Glavaš et al., 2023; Cool et al., 2023; Zaydman et al., 2018).

## CONCLUSION

This study indicate a close relationship between spinal curvature and lower limb asymmetry, particularly in the tibia, suggesting postural compensation during rapid growth. Apparent leg length discrepancies were more prominent than structural differences, highlighting the role of functional adaptation. The results emphasize that scoliosis during adolescence involves both axial and appendicular components. Comprehensive musculoskeletal screening that includes spinal and limb assessments is essential for early detection and management of biomechanical imbalances in the growing adolescent population.

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