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Analysis of Lumbosacral Sagittal Spinal Alignment in Adolescent Idiopathic Scoliosis: A 10-Year Retrospective Data Review

Adolesan İdiopatik Skolyozda Lumbosakral Sagittal Omurga Diziliminin Analizi: 10 Yıllık Retrospektif Veri İncelemesi

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Abstract: This study aimed to investigate lumbosacral sagittal alignment in patients with adolescent idiopathic scoliosis (AIS). The study included data of patients with AIS aged 10-18 years from a ten-year period (between January 2013 and January 2023). Using digitized radiographies, sagittal and coronal spinal parameters including Cobb angle, Risser staging, intervertebral disc angles, lumbar lordosis angle, lumbosacral lordosis angle, lumbosacral angle, sacral tilt and disc heights were measured and analyzed. Patients were categorized based on the Cobb angle into high (≥23.8°) and low (<23.8°) angle groups. Results: A total of 1102 scoliosis x-rays have been evaluated for eligibility. Of those, 122 patients (73% female) were included in the analyses. The median age and Cobb angle were 14 (4) years and 23.8 (13.9) degrees, respectively. Majority of the patients (43.4%) had thoracic curvature. The most frequently observed Risser grade was 4 (n=48). Patients with a Cobb angle ≥23.8° exhibited significantly lower L5-S1 intervertebral disc heights when compared to those with a Cobb angle <23.8° (p=0.014). No significant differences were observed in other sagittal parameters between high and low Cobb angle groups. In patients with AIS, those with high Cobb angle have lower L5-S1 intervertebral disc heights compared to the low Cobb angle group. Since reduced disc height may serve as an early indicator of potential disc degeneration or herniation, high-angle AIS patients would require closer monitoring. The study emphasizes the importance of early assessment to prevent future musculoskeletal risks in AIS patients with higher curvature angles

Keywords: Adolescent; Scoliosis; Intervertebral disc; Intervertebral disc degeneration; Disc herniation; Lumbosacral region

Özet: Bu çalışmanın amacı adölesan idiyopatik skolyozlu (AİS) hastalarda lumbosakral sagittal dizilimi araştırmaktır. Çalışmaya on yıllık bir dönemdeki (Ocak 2013 ile Ocak 2023 arası) 10-18 yaş arası AIS hastalarının verileri dahil edilmiştir. Dijitalleştirilmiş radyografiler kullanılarak, Cobb açısı, Risser evrelemesi, intervertebral disk açıları, lomber lordoz açısı, lumbosakral lordoz açısı, lumbosakral açı, sakral tilt ve disk yükseklikleri dahil olmak üzere sagital ve koronal spinal parametreler ölçülmüş ve analiz edilmiştir. Hastalar Cobb açısına göre yüksek (≥23,8°) ve düşük (<23,8°) açı gruplarına ayrılmıştır. Toplam 1102 skolyoz radyografi uygunluk açısından değerlendirilmiştir. Bunlardan 122 hasta (%73'ü kadın) analizlere dahil edilmiştir. Ortanca yaş ve Cobb açısı sırasıyla 14 (4) yıl ve 23,8 (13,9) derece idi. Hastaların büyük çoğunluğunda (%43,4) torasik eğrilik vardı. En sık gözlenen Risser evresi 4 (n=48) idi. Cobb açısı ≥23,8° olan hastalarda, Cobb açısı <23,8° olanlara kıyasla L5-S1 intervertebral disk yükseklikleri anlamlı derecede düşüktü (p=0,014). Diğer sagital parametrelerde, yüksek ve düşük Cobb açısı grupları arasında anlamlı bir fark gözlenmemiştir. AİS hastalarında, yüksek Cobb açısına sahip olanlar düşük Cobb açılı gruba kıyasla daha düşük L5-S1 intervertebral disk yüksekliğine sahiptir. Disk yüksekliğinin azalması potansiyel disk dejenerasyonu veya herniasyonunun erken bir göstergesi olabileceğinden, yüksek açılı AİS hastalarının daha yakından izlenmesi gerekecektir. Bu çalışma, yüksek eğrilik açısına sahip AİS hastalarında gelecekteki kas-iskelet sistemi risklerini önlemek için erken değerlendirmenin önemini vurgulamaktadır.

Anahtar Kelimeler: Adolesan, skolyoz, intervertebral disk, intervertebral disk dejenerasyonu, disk hernisi

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1. Introduction

Adolescent idiopathic scoliosis is a common disorder with a prevalence of 0.47-5.2%. There is a close relationship between the distribution of adolescent idiopathic scoliosis and gender. While the female to male ratio is 1.5:1 at younger ages, this ratio increases to 3:1 at older ages. Thoracic curvatures are most common in adolescent idiopathic scoliosis. This is followed by thoracolumbar and lumbar curves. Double curves are observed more rarely. Thoracolumbar and lumbar curves are more common in males. Thoracic and double curvatures are more common in females.[1] There is no definite accepted theory about the pathogenesis of adolescent idiopathic scoliosis. Although many different pathogenetic processes have been emphasized, the view that the disease is multifactorial comes to the forefront.

There have been numerous small-scale studies that have examined the interaction between various sagittal parameters in patients with scoliosis. Nevertheless, no conclusions have been reached concerning the correlation between coronal and sagittal plane abnormalities. Moreover, the relationship of sagittal spino-pelvic parameters with different coronal curve patterns has not been fully understood in adolescent idiopathic scoliosis.[2-4] There is also some negative evidence revealing no correlation between sagittal spinal alignment and the coronal curve models. Newton et al. reported that lumbosacral lordosis, pelvic incidence, sacral slope, and pelvic tilt were significantly greater in adolescent idiopathic scoliosis compared to normal adolescents.[4] A recent study revealed that the identification of prominent morphologic features in the apical disc by quantitative disc analysis reveals its importance in predicting surgical intervention in adolescent idiopathic scoliosis.[2] Especially, data on lumbar intervertebral disk height and angles in adolescent idiopathic scoliosis is limited. Given the inconsistency and undetermined points in the literature, the aim of this study was to evaluate the potential relationship between coronal curves and lumbosacral sagittal spinal alignment in patients with adolescent idiopathic scoliosis.

2. Materials and Methods

The study included patients who were diagnosed with adolescent idiopathic scoliosis between January 2013 and January 2023, aged 10-18 years, and whose scoliosis imaging studies were available in the hospital system. Regarding the inclusion of radiographs, scoliosis x-rays taken while patients standing and without orthoses were included in the evaluation. Exclusion criteria were: i) neurological scoliosis, ii) infantile scoliosis, iii) structural scoliosis, iv) history of spinal surgery/major trauma, v) severe spondylolisthesis, vi) spondylodiscitis, and vii) severe vertebral fracture, or ix) spinal tumor.

A total of 1102 scoliosis x-rays between January 2013 and January 2023 have been evaluated for eligibility. Of the x-rays, 629, belonging to adult/infant/congenital scoliosis patients, were excluded. Of the remaining patients, these were excluded due to several reasons as follows: Cobb angle<10 degrees (n=189), spinal tumor (n=6), spondylodiscitis (n=10), vertebral osteonecrosis (n=9), spinal surgery (n=16), vertebral fracture (n=4), neuromuscular scoliosis (n=40), structural scoliosis (n=27), and inappropriate image quality (n=50). After the exclusion of 980 individuals, 122 patients were incorporated in the analyses (Figure 1).

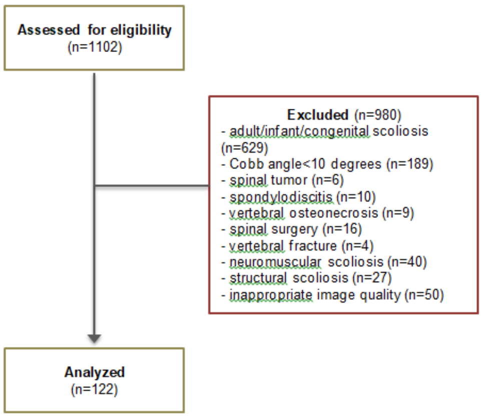

Figure 1. Flowchart of the study.

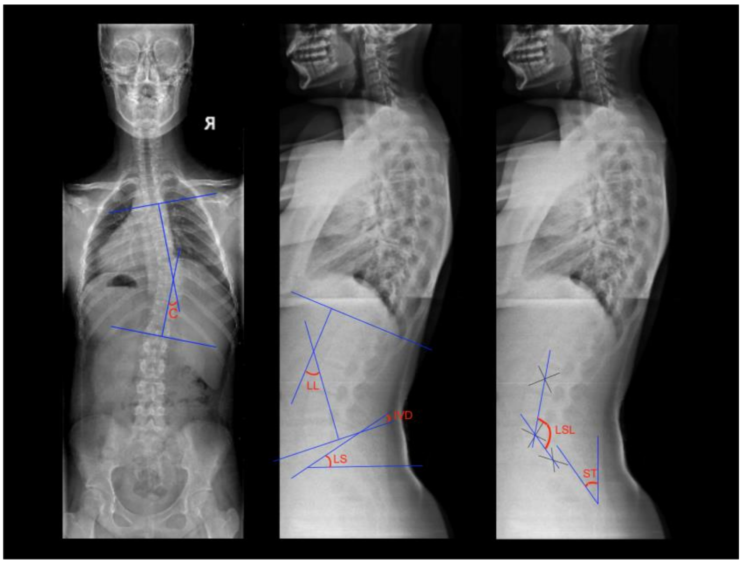

Figure 2. Angles measured on digitized radiographs. C: Cobb angle, LL: lumbar lordosis angle, IVD: intervertebral disc angle, LS: lumbosacral angle, LSL: lumbosacral lordosis angle, ST: sacral tilt.

Demographic and radiographic data of the patients were obtained retrospectively from the abstraction of digitalized medical records. The analysis was based on the initial radiographs available in the hospital's digital archive system for each patient. The region of curvature (thoracic, thoracolumbar, lumbar), Cobb angle, Risser staging, intervertebral disc angles, lumbar lordosis angle, lumbosacral lordosis angle, lumbosacral angle, sacral tilt and disc heights were measured and recorded. Spinal skeletal maturity was assessed by the Risser Staging system.[5-8]

All measurements were performed by a single researcher experienced in radiographic evaluation. Computerized measurement of the specified angles was performed on digitized radiographic images using Enlil PACS System software version 2.5 (Enlil PACS Viewer, Eroglu Yazılım, Eskişehir, Türkiye) as follows (Figure 2):

Cobb angle (angle of curvature): The angle between the line drawn from the upper edge of the vertebra where the curvature of the spine begins and the line drawn from the lower edge of the vertebra where the curvature of the spine ends. Cobb angle was recorded in degrees.[5] In patients presenting with double curves, the curve with the higher Cobb angle was selected for analysis.

Intervertebral disc angle: The angle between the superior and inferior endplates of two neighboring vertebra. Intervertebral disc angle was recorded in degrees.

Intervertebral disc height: The average of the disc heights measured from the anterior, middle and posterior disc regions. Intervertebral disc height was recorded in millimeters.

Lumbar lordosis angle: The angle generated by the lines perpendicular to the superior endplate of the L1 vertebra and the inferior endplate of the L5 vertebra. Lumbar lordosis angle was recorded in degrees.

Lumbosacral lordosis angle: The angle formed by the line through the center of the L3 and L5 vertebras and the line through the center of the L5 and S1. Lumbosacral lordosis angle was recorded in degrees.

Sacral tilt: The angle between the line tangent to the posterior aspect of the S1 vertebra and the vertical line. Sacral tilt was recorded in degrees.

Lumbosacral angle: The angle between the line drawn parallel to the superior endplate of the S1 vertebra and the horizontal line. Lumbosacral angle was recorded in degrees.[8]

The study was approved by the Ethics Committee of Cukurova University Faculty of Medicine (Date: 8-March-2024, Number: 142/32).

Statistical analyses

The normal distribution of data was evaluated by Kolmogorov-Smirnov test. According to the mean Cobb angle the patient sample was divided into two groups: i) high angle group and ii) low angle group.

For comparative analyses, Student's t-test, Mann-Whitney U test, and Pearson's chi-squared/Fisher's exact test were used for normally distributed continuous data, abnormally distributed continuous data, and categorical data, respectively. P values were regarded as statistically significant when they were less than 0.05.

3. Results

Of 1102 scoliosis x-rays, 122 which met the inclusion criteria were incorporated in the analyses. Of the patients, 89 (73%) were female. The median Cobb angle of the study participants was 23.8 (13.9) degrees. Majority of the patients (43.4%) had thoracic curvature. The most frequently observed Risser grade was 4 (n=48). Table 1 shows the characteristics of the study sample.

The cut-off value of 23.8° for the Cobb angle was selected based on the median Cobb angle observed in the study population. According to the median Cobb angle, the sample was divided into two: patients with Cobb angle ≥23.8° and patients with Cobb angle <23.8°. The comparative analysis between groups is depicted in Table 2. Accordingly, intervertebral disc heights and angles, as well as lumbosacral angle, lumbosacral lordosis angle, and sacral tilt did not differ between groups (p>0.05). On the other hand, L5-S1 intervertebral disc height was significantly lower in patients with a Cobb angle ≥23.8° than those with a Cobb angle <23.8° (p=0.01).

Table 1. Characteristics of the study population (n=122)

Age (years)	14 (4)
Gender [n (%)]	
Female	89 (73%)
Male	33 (27%)
Risser grade [n (%)]	
1	0
2	22 (18%)
3	38 (31.1%)
4	48 (39.3%)
5	14 (11.5%)
Region of curvature [n (%)]	
Thoracic	53 (43.4%)
Thoracolumbar	39 (32%)
Lumbar	30 (24.6%)
Cobb angle (°)	23.8 (13.9)
L4-L5 IVD angle (°)	11.1 (2.9)
L5-S1 IVD angle (°)	13.2 (3.4)
L4-L5 IVD height (mm)	10.1±1.5
L5-S1 IVD height (mm)	11.5±1.6
Lumbar lordosis angle (°)	41.9±10.8
Lumbosacral lordosis angle (°)	132.0±10.7
Sacral tilt (°)	44.5±8.2
Lumbosacral angle (°)	31.8±7.6

IVD: intervertebral disc

Table 2. Comparison of the study variables according to the median Cobb angle

	Cobb angle ≥23.8° (n=62)	Cobb angle <23.8° (n=60)	*P* value
Age (years)	15 (3)	14 (4)	0.163
L4-L5 IVD angle (°)	11.2 (3.0)	10.9 (2.8)	0.752
L5-S1 IVD angle (°)	12.6 (3.3)	13.7 (3.3)	0.222
L4-L5 IVD height (mm)	10.0±1.5	10.2±1.5	0.484
L5-S1 IVD height (mm)	11.2±1.5	11.9±1.6	**0.014**
Lumbar lordosis angle (°)	42.1±12.9	41.8±8.4	0.911
Lumbosacral lordosis angle (°)	132.7±11.0	131.3±10.4	0.467
Sacral tilt (°)	44.1±7.9	44.8±8.6	0.642
Lumbosacral angle (°)	30.7±7.4	32.8±7.8	0.119
IVD: intervertebral disc			

4. Discussion

The current study on patients with adolescent idiopathic scoliosis revealed an important finding to be discussed in detail. Patients with a higher scoliosis angle (≥23.8°) showed lower L5-S1 intervertebral disk height. Such a finding should be considered meticulously, since significantly lower disk heights at the early period of life (the adolescent period) might put the individual at risk for several musculoskeletal conditions.

The potential sagittal plane alterations in patients with scoliosis have been studied by several researchers so far. Most of those studies evaluated the sagittal profile and pelvic parameters in scoliosis.[4,9-14] Nevertheless, data on lumbar intervertebral disk height and angles in adolescent idiopathic scoliosis is limited. A study by Mak et al.[9] investigated the relationship between coronal and sagittal alignment and their effects on quality of life scores in adolescent idiopathic scoliosis. They found no correlation with the coronal curve model. In addition, the researchers reported that the thoracic kyphosis angle of all patients was similar regardless of the coronal curve type, yet coronal deformity had a greater impact on quality of life outcomes, especially in those with > 40°.[9] Zhang et al., in their case-control study, found higher lumbar 5-slope angle, and smaller pelvic incidence and pelvic tilt in patients with adolescent idiopathic scoliosis compared to healthy adolescents.[10] In a retrospective study, patients were classified based on the coronal curve type. Sagittal parameters (pelvic tilt, sacral slope, and pelvic incidence) were similar for all the groups.[11] On the other hand, Schlösser et al.[12] determined increased pelvic incidence, sacral slope, and pelvic tilt in adolescent idiopathic scoliosis patients than those in controls. Nevertheless, none of the mentioned studies evaluated intervertebral parameters such as disc high and angle.

Although lumbar/lumbosacral lordosis did not differ between high (Cobb angle ≥23.8°) and low (Cobb angle <23.8°) curvature groups, we found a lesser L5-S1 intervertebral disk height in patients with a Cobb angle of 23.8° and higher compared to the patients with lower Cobb angles. The importance of this finding should be discussed in detail. A decrease in intervertebral angle can lead to disc degeneration, disc hernia, radiculopathy and/or myelopathy.[15] Degenerative spinal changes can be observed in patients with scoliosis. Bisson et al. found that facet joint degeneration was closely associated with intervertebral axial rotation. Moreover, the kyphotic intervertebral segments in the sagittal plane predicted greater facet joint degeneration and back pain.[16] Yet, they did not evaluate intervertebral disc degeneration or related parameters such as intervertebral disc heights and angles. On the other hand, Boylan et al., in their retrospective chart review study determined that 9.6% of the patients with adolescent idiopathic scoliosis had evidence of degenerative disc disease, which was Pfirrmann grade ≥ 3 in 2.9%. Additionally, they reported that the most commonly affected level by degenerative disc disease was L5-S1.[17]

Intervertebral disc height has been evaluated by a limited number of studies so far.[18-20] Ponrartana et al. identified greater values for intervertebral disc heights in patients with adolescent idiopathic scoliosis. Moreover, intervertebral disc height showed positive correlation with the presence of scoliosis.[18] Smit suggested that higher intervertebral disc height in patients with adolescent idiopathic scoliosis might indicate high intradiscal pressure, encouraging the synthesis of proteoglycans and, consequently, osmotic pressure. Intradiscal pressure can over-stretch the annulus fibrosus and longitudinal ligaments, preventing them from remodeling and growing, thus leading to differential growth.[21, 22] Patients with scoliosis exhibit disparities in the wedging of the vertebral body and disc in the thoracic and lumbar regions. The thoracic region exhibits a more severe vertebral body wedging. Conversely, the extent of disc wedging is more severe in the lumbar region.[23] This finding could be related to an asymmetric loading to spine.[23, 24]

In the current study, we compared intervertebral disc height between high and low Cobb angle groups. Patients with higher Cobb angles revealed lower intervertebral disc height in the L5-S1 level. Such as finding may probably be regarded as an early sign of disc degeneration and herniation in patients with higher Cobb angles. Therefore, those children should be monitored meticulously in terms of the development of intervertebral disc disorders. Nevertheless, longitudinal studies are required to confirm the results of the present study. A study on adult scoliosis showed that the asymmetric degree of bony construction was correlated with intervertebral disc-endplate degeneration, which was positively correlated with Cobb's angle.[25]

Altered load distribution at the lumbosacral junction and compensatory mechanisms along the sagittal axis may influence intervertebral disc morphology. Additionally, brace treatment might impact disc height and shape due to altered mechanical loading or immobilization. These aspects need further exploration. In addition to sagittal alignment, other factors such as pelvic parameters, vertebral rotation, curve type and location, paraspinal muscle asymmetries, and body mass index may also affect intervertebral disc angles. These factors could not be comprehensively analyzed in this study and should be considered in future research.

Morphological alterations in intervertebral discs can be observed in adolescent idiopathic scoliosis.[26,27] Those in the lumbosacral (L5-S1) level can lead to conditions such as degeneration, spondylolisthesis, and herniation. As the main limitation of the current study, we were not able to understand such a causative relation. Longitudinal studies would be required to clarify this point. Another important limitation relates to the retrospective data review: we could not verify measurement consistency, control for imaging conditions or account for potential changes in radiographic technology or protocols over time. Due to incomplete clinical records, information regarding brace usage was not available for all patients. This may have influenced disc morphology and should be considered as a limitation. Other pelvic parameters such as pelvic tilt and pelvic incidence were not evaluated in this study. This represents a limitation. Another limitation of this study is that intra- and inter-observer reliability assessments were not conducted, as all measurements were performed by a single researcher. This may affect the generalizability of the measurement consistency.

5. Conclusion

The current study highlighted the difference in L5-S1 intervertebral disc height in adolescent idiopathic scoliosis patients with high (≥23.8°) and low (<23.8°) Cobb angles. The potential association of decreased L5-S1 disc height with and increased risk of disc pathologies (e.g., disc degeneration and herniation) should be evaluated by longitudinal studies. Meanwhile, particular attention should be directed to patients with high Cobb angles to prevent potential problems associated to decreased disc height at the lumbosacral junction.

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