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ORIGINAL RESEARCH

Assessing the Role of MRI-Based Angle Measurements in Diagnosing Lumbosacral Transitional Vertebrae

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ABSTRACT
Background: Lumbosacral transitional vertebrae (LSTV) are anatomical variations in the lumbosacral region, often implicated in chronic lower back pain. Accurate diagnosis of LSTV is critical for appropriate clinical management. This study aimed to assess the utility of Sacral Inclination and Lumbosacral Angle measurements in predicting LSTV using magnetic resonance imaging (MRI**). Methods:** A comparative cross-sectional study was conducted, including 100 cases with confirmed LSTV and 100 controls without LSTV. Sacral Inclination and Lumbosacral Angle were measured on sagittal MRI images. Receiver operating characteristic (ROC) analysis was performed to determine the diagnostic performance of these angle measurements in predicting LSTV. **Results:** The mean Sacral Inclination and Lumbosacral Angle were significantly higher in cases compared to controls ($p < 0.001$). ROC analysis revealed that Sacral Inclination had a moderate ability to predict LSTV, with an area under the curve (AUC) of 0.62. The optimal cut-off value for Sacral Inclination was 37.2°, yielding a sensitivity of 85.2% and a specificity of 59%. Lumbosacral Angle demonstrated better predictive capability, with an AUC of 0.85. The optimal cut-off value of 42.8° provided a sensitivity of 83% and a specificity of 81%. **Conclusion:**Lumbosacral Angle is a more reliable predictor of LSTV compared to Sacral Inclination, demonstrating better diagnostic performance. These angle measurements could be valuable in enhancing the accuracy of LSTV diagnosis, aiding in the clinical management of patients with low back pain. Further studies are needed to validate these findings across diverse populations.
Keywords: Lumbosacral transitional vertebra (LSTV), Sacral Inclination, Lumbosacral Angle, Magnetic resonance imaging (MRI), Low back pain, ROC analysis, Diagnostic accuracy, Anatomical variations

INTRODUCTION

Transitional lumbosacral anatomy refers to a congenital variation in the spine, commonly identified as lumbosacral transitional vertebra (LSTV), where the last lumbar vertebra (L5) may partially or fully fuse with the sacrum.[1-3] This condition is clinically significant due to its potential to affect spinal mechanics, leading to an increased risk of lower back pain and complicating diagnostic and surgical approaches.[4-6] LSTV is a common anatomical anomaly, affecting 4% to 35% of the population, and plays a notable role in degenerative spinal diseases.[7,8] The presence of LSTV influences spinal biomechanics by altering the normal load-bearing dynamics at the lumbosacral junction. This altered biomechanics can lead to accelerated degeneration of adjacent intervertebral discs and facet joints, increasing susceptibility to conditions such as disc herniation, early degenerative changes, and radicular pain due to nerve root compression. Studies have consistently shown that individuals with LSTV are more prone to developing chronic lower back pain and exhibit a higher incidence of lumbar disc herniation, particularly in younger adults.[4,9] The association between LSTV and radicular symptoms has also been highlighted, as the abnormal vertebral structure that can contribute to changes in nerve root orientation, further exacerbating neurological symptoms .

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Accurate radiologic identification and reporting of lumbosacral transitional vertebra (LSTV) are essential for clinicians, as they may reveal a potential cause for the patient's symptoms, such as low back pain, and prevent misidentification of vertebral levels. This is particularly important in cases where spinal surgery is being considered, as improper numbering of the lumbar vertebrae could lead to surgical errors, with significant clinical consequences. While the anteroposterior (AP) radiograph of the lumbar spine remains the gold standard for detecting LSTV, MRI readers may not always have access to these radiographs.[6,10] This can create diagnostic challenges, particularly given the importance of correctly identifying vertebral anomalies to ensure proper treatment planning and intervention.Magnetic Resonance Imaging (MRI) is a preferred imaging modality for detecting and characterizing LSTV due to its high-resolution soft tissue contrast and ability to provide multi-planar visualization of the lumbosacral spine.[11] On MRI studies of the lumbar spine, lumbosacral transitional vertebrae (LSTVs) can typically be identified on either coronal or axial images. Coronal images are especially useful for highlighting the complex transitional lumbosacral anatomy, showing the spatial relationship and alignment between the lumbar vertebrae and sacrum. Axial images of the lumbosacral junction, on the other hand, allow for a detailed depiction of pseudoarthrosis or the fusion between the last lumbar vertebra and the sacrum.[6]Despite the value of coronal images in detecting LSTVs, they are not routinely acquired in standard MRI protocols for the lumbar spine. This omission increases the likelihood of missing important anatomical details, especially when combined with potential errors in identifying the correct lumbosacral level on sagittal scout images.

In patients with lumbosacral transitional vertebra (LSTV), the lumbosacral junction may be mistakenly identified at the L4-L5 level on sagittal scout images. This misidentification can result in incomplete axial coverage, potentially overlooking the true transitional anatomy during MRI scans, which may lead to missed diagnoses.To address these challenges, various studies have explored alternative detection methods for LSTVs, focusing on the structural changes in the lumbosacral curvature that may signal the presence of these anatomical variations.Chalian et al. proposed that transitional lumbosacral anatomy is associated with notable changes in the curvature of the lumbosacral spine.[6]Specifically, they suggested that an increased curvature, as measured on sagittal MRI images, could serve as an indicator of LSTV. Their findings indicated that heightened curvature should alert radiologists to the possibility of a transitional vertebra. However, due to the limited sample size in their study, the authors recommended that larger, more comprehensive prospective studies be conducted to confirm these results and improve the accuracy of MRI-based predictions.The present study aims to comprehensively evaluate two simple angle measurements for predicting LSTV using MRI in a Kashmiri population. By assessing these measurements, we seek to enhance early detection and improve the diagnostic accuracy for LSTV in routine clinical practice, ultimately reducing the risk of missed diagnoses and improper treatment planning.

METHODOLOGY

This case-control study was conducted over one year at the Department of Anatomy in collaboration with the Department of Radiology, focusing on patients with and without lumbosacral transitional vertebra (LSTV). A total of 200 patients, 100 with LSTV and 100 without, were included in the study. These participants were selected based on lumbar spine MRI findings, which were primarily taken for complaints of chronic lower back pain. The objective was to evaluate the predictive ability of two simple angle measurements for identifying LSTV on MRI. Patients were recruited prospectively and divided into two groups based on their MRI results: the case group, comprising patients with LSTV, and the control group, consisting of patients without any transitional anatomy. The inclusion criteria for the study were adults aged 18 and older with chronic lower back pain, while exclusion criteria included individuals with a history of spinal surgery, significant trauma, or severe spinal deformities like scoliosis. A balanced number of participants in both the case and control groups allowed for comparative analysis.

Each participant underwent lumbar spine MRI on a 1.5-Tesla machine, utilizing standard sagittal T1-weighted and T2-weighted images along with axial T2-weighted sequences. The main focus was on capturing the lumbosacral junction to assess potential transitional vertebrae. Although coronal images were not routinely acquired, a subset of patients underwent coronal imaging to enhance the visualization of lumbosacral anatomy. To ensure accurate identification, radiologists independently reviewed the MRIs, focusing on two specific measurements: the lumbosacral angle (LSA) and the lumbosacral disc angle (LSDA). The LSA measured the angle between the last lumbar vertebra and the sacrum's endplate, while the LSDA assessed the angle at the lumbosacral disc space. These measurements were hypothesized to be altered in patients with LSTV.All MRI scans were evaluated by two radiologists who were blinded to the patients' clinical information. This approach minimized potential biases. The radiologists measured both the LSA and LSDA, and disagreements were resolved through a consensus process. In addition to the angle measurements, any presence of fusion or pseudoarthrosis at the lumbosacral junction was documented, providing a more comprehensive understanding of the patients' anatomy.

The statistical analysis involved comparing the LSA and LSDA between the case and control groups using independent t-tests. Additionally, a receiver operating

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characteristic (ROC) curve was used to evaluate the sensitivity and specificity of these angles in predicting LSTV. A p-value of less than 0.05 was considered statistically significant. This analysis aimed to determine whether alterations in the lumbosacral curvature, as reflected by the angle measurements, could reliably predict the presence of LSTV.

RESULTS

In this section, the results of the study will be described

Table 1: Demographic and Clinical Characteristics of Cases and Controls

Variable		Cases (n=100)	Controls (n=100)	P-value
Age (years)		45.6 ± 12.3	44.8 ± 11.9	0.643
Sex	Male	55 (55%)	52 (52%)	0.67
	Female	45 (45%)	48 (48%)	
Clinical Symptoms	Present	72 (72%)	68 (68%)	0.537
	Absent	28 (28%)	32 (32%)	
History of Lower Back Pain	Yes	80 (80%)	77 (77%)	0.605
	No	20 (20%)	23 (23%)	

Table 3 provides a comparison of demographic and clinical characteristics between cases and controls. The mean age was similar in both groups, with cases averaging 45.6 ± 12.3 years and controls 44.8 ± 11.9 years (p=0.643). Sex distribution was nearly equal, with 55% of the cases being male compared to 52% of the controls (p=0.67). Clinical symptoms were present in 72% of the cases and 68% of the controls, with no statistically significant difference (p=0.537). Similarly, a history of lower back pain was reported by 80% of the cases and 77% of the controls (p=0.605), with no significant difference between the groups. These findings suggest no major demographic or clinical differences between the two groups.

Table 2: Comparison of Angle Measurements between Cases and Controls

Variable	Cases (n=100)	Controls (n=100)	p-value
Sacral Inclination (°)	46.01 ± 6.1	40.2 ± 4.9	<0.001*
Lumbosacral Angle (°)	45.8 ± 5.3	37.2 ± 5.4	<0.0001*

Table 2 presents a comparison of angle measurements between the case group, consisting of 100 subjects with lumbosacral transitional vertebrae (LSTV), and a control group of 100 subjects without LSTV. The mean Sacral Inclination was significantly higher in the case group, measured at 46.01 ± 6.1°, compared to 40.2 ± 4.9° in the control group, with a highly statistically significant p-value of less than 0.001. Similarly, the mean Lumbosacral Angle was also elevated in the case group at 45.8 ± 5.3° versus 37.2 ± 5.4° in the controls, yielding an equally significant p-value of less than 0.0001. These results indicate that both angle measurements are substantially greater in individuals with LSTV, highlighting their potential utility as indicators for this anatomical variation.

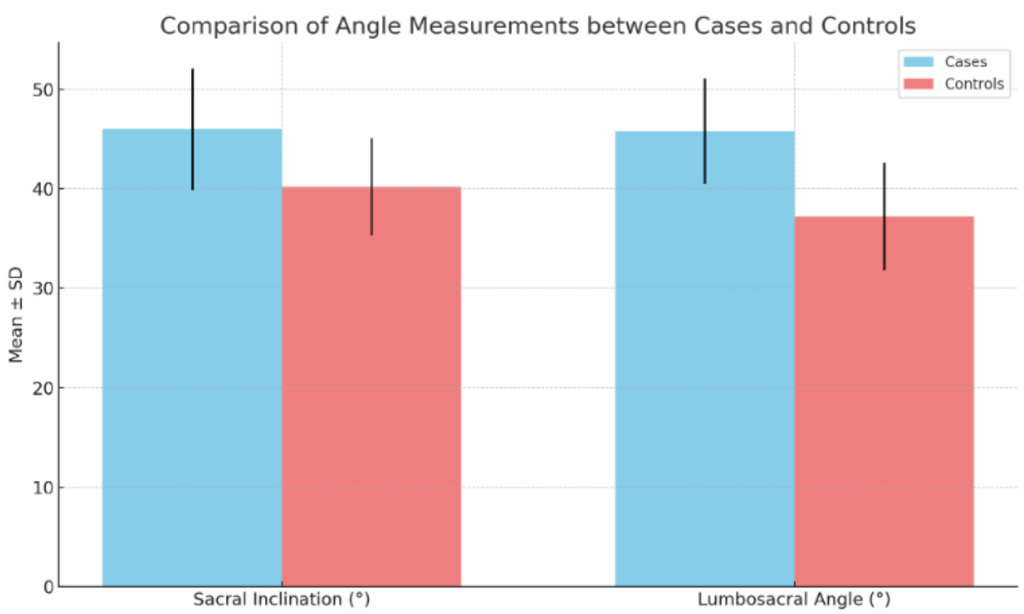

Fig 1: Showing comparison of (mean±sd) for sacral inclination and lumbosacral angle

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Table 3: Performance metrics for Sacral Inclination and Lumbosacral Angle in predicting LSTV

Parameter	Sacral Inclination	Lumbosacral Angle
Cut-off	37.2°	42.8°
Sensitivity	85.2%	83%
Specificity	59%	81%
AUC	0.62	0.85
Confidence Interval	0.428 - 0.626	0.709 - 0.821
P-value	0.0001	0.0001

Table 3 presents the performance metrics for Sacral Inclination and Lumbosacral Angle in predicting the presence of lumbosacral transitional vertebrae (LSTV). For Sacral Inclination, the optimal cut-off was determined to be 37.2°, which yielded a sensitivity of 85.2% and a specificity of 59%. The area under the curve (AUC) for this measurement was 0.62, indicating moderate discrimination in identifying LSTV. In contrast, the Lumbosacral Angle had a cut-off value of 42.8°, resulting in a sensitivity of 83% and a higher specificity of 81%. The AUC for the Lumbosacral Angle was 0.85, reflecting good discrimination capabilities for predicting LSTV. These ROC curves illustrate the trade-offs between sensitivity and specificity in predicting LSTV based on these angles.

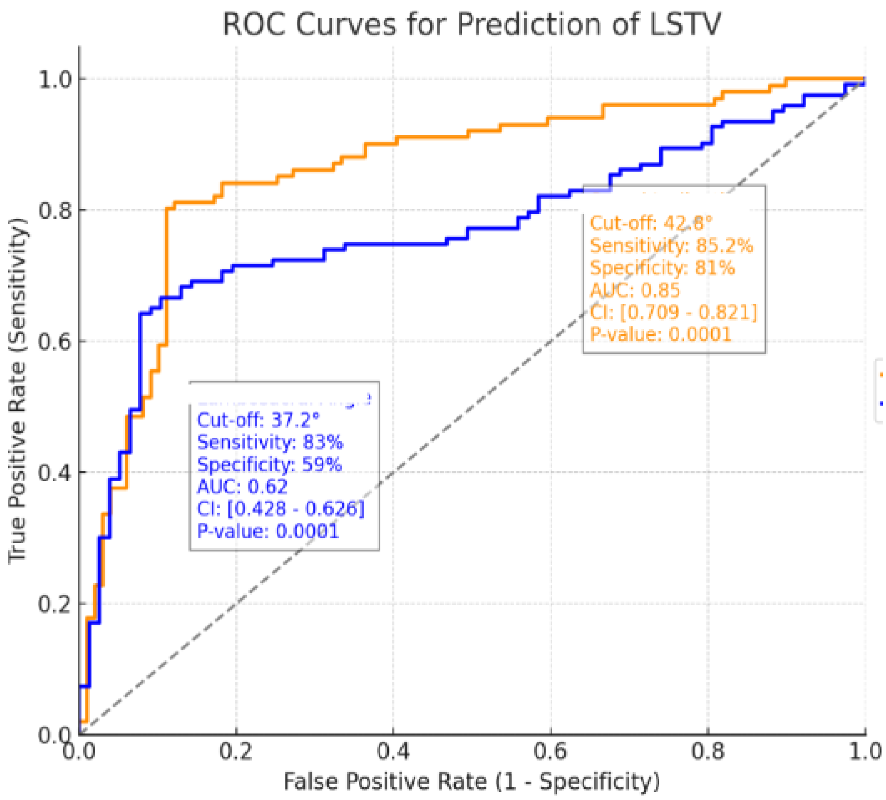

Fig 2: ROC curves illustrate the trade-offs between sensitivity and specificity in predicting LSTV based on these angles

DISCUSSION

The present study aimed to evaluate the utility of two simple angle measurements, the Lumbosacral Angle and Sacral Inclination, in predicting lumbosacral transitional vertebra (LSTV) using MRI. The results demonstrated no significant demographic or clinical differences between the case and control groups, with both age and sex distributions being comparable (p=0.643 and p=0.67, respectively). Additionally, there were no significant differences in clinical symptoms or history of lower back pain between the two groups, as indicated by p-values of 0.537 and 0.605, respectively. These findings are consistent with previous studies suggesting that demographic factors like age and sex, and common clinical symptoms such as lower back pain, are not necessarily reliable indicators of LSTV. In North America, Savage et al. (2005) reported a prevalence of LSTV of 7.5% in the African-American cohort and 6.7% in the White cohort, with a higher prevalence in females than in males. However, no statistically significant differences were found between population groups or between sexes.[12] Similarly, Challan M et al. (2012) found no significant correlation between the presence

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of LSTV and variables such as age, sex, or clinical symptoms in their study of patients with chronic low back pain.[6] These findings reinforce the notion that demographic and clinical factors may not be reliable predictors of LSTV.

In individuals with LSTV, low back pain can arise from several anatomical and biomechanical abnormalities. These include pseudoarthrosis, which creates abnormal joint movement; resultant instability and degeneration at the level above the LSTV; compression of the nerve root by an enlarged transverse process; and strain on the contralateral facet joint, particularly when the articulation is unilateral. Clinicians, who recognize LSTV as a potential cause of low back pain, as well as physicians involved in interventional lumbar procedures, can benefit significantly from MRI reports that describe the presence of this anatomical variation and provide precise numbering of the lumbar vertebrae. Accurate identification is crucial because LSTV can influence both the origin of symptoms and procedural planning. Although MRI is a key tool for diagnosing lumbar spine issues, it lacks the panoramic perspective offered by radiography and the high spatial resolution of computed tomography (CT). This limitation can result in missed diagnoses if the radiologist does not specifically look for LSTV. In our clinical experience, patients with LSTV often exhibit exaggerated lumbar lordosis and a diminished sharp angulation at the lumbosacral junction on mid-sagittal MRI images. These distinctive characteristics prompted us to employ two straightforward angle measurements that quantify lumbosacral angulation and sacral inclination on sagittal MRI images. These measurements provide a practical and efficient means of detecting anatomical deviations associated with LSTV, ensuring that this variation is not overlooked during routine MRI assessments.In the present study, the mean Sacral Inclination for the cases was measured at 46.01 ± 6.1 degrees, while the controls exhibited a significantly lower mean of 40.2 ± 4.9 degrees, with a highly significant p-value of less than 0.001. Similarly, the mean Lumbosacral Angle for the cases was 45.8 ± 5.3 degrees, compared to 37.2 ± 5.4 degrees in the control group, which also yielded a statistically significant p-value of less than 0.0001. These results indicate that both the Sacral Inclination and Lumbosacral Angle measurements are significantly greater in cases compared to controls, suggesting that these angles may play a role in the assessment of lumbosacral transitional vertebrae (LSTV).These findings align with previous literature on the relationship between anatomical variations at the lumbosacral junction and the development of lumbosacral transitional vertebrae (LSTV). Notably, Konin and Walz (2010) proposed that such anatomical variations can lead to altered biomechanics at the lumbosacral junction, potentially contributing to lower back pain and other spinal disorders.[3] This biomechanical alteration is further supported by the work of Bron et al. (2007), who suggested that variations in lumbosacral morphology could predispose individuals to LSTV.[13] These studies underscore the notion that changes in spinal alignment can significantly impact transitional anatomy, highlighting the importance of understanding these variations in clinical practice. In relation to our findings, Chalian M et al. (2012) also reported elevated angle measurements in their case group, with a mean A-angle (lumbosacral angle) of 46.3 ± 7.8° and a mean B-angle (sacral inclination) of 46.7 ± 8.4°.[6] These values were significantly higher than those observed in their control group, which had a mean A-angle of 35.9 ± 7.7° and a B-angle of 41.6 ± 10.0° ($p < 0.0001$ for A-angle and $p = 0.0035$ for B-angle). The similarities between our results and those of Chalian et al. emphasize the consistent association between increased lumbosacral angle and sacral inclination in individuals with LSTV. The elevation of these angles in both our study and previous literature may be attributed to altered loading patterns and stress distribution across the lumbosacral junction, which could lead to compensatory changes in spinal alignment. As a result, the increased angles might serve as critical indicators of LSTV presence, reinforcing the necessity for precise anatomical evaluation during imaging studies.

In this study, we evaluated the predictive performance of two angular measurements, Sacral Inclination and Lumbosacral Angle, in identifying lumbosacral transitional vertebrae (LSTV) using receiver operating characteristic (ROC) analysis. For Sacral Inclination, the established cut-off of 37.2° yielded a sensitivity of 85.2% and a specificity of 59%, with an area under the curve (AUC) of 0.62, indicating moderate discrimination. In contrast, the Lumbosacral Angle demonstrated a cut-off of 42.8° with a sensitivity of 83% and a markedly higher specificity of 81%, resulting in an AUC of 0.85, which signifies good discrimination in predicting LSTV. The confidence intervals for both metrics were statistically significant, with p-values of 0.0001.These results align with the literature on the diagnostic efficacy of angle measurements in assessing LSTV. For instance, Chalian M et al. (2012) reported that the optimal cut-off values for A-angle (Lumbosacral Angle) and B-angle (Sacral Inclination) were 39.8° and 35.9°, respectively. Their findings indicated a sensitivity of 80% and specificity of 80% for the lumbosacral angle, while the sacral inclination showed a sensitivity of 80% with lower specificity at 54% and an AUC of 0.687.[6]The higher specificity and AUC of the Lumbosacral Angle in our study suggest its superiority as a predictive measure for LSTV.Furthermore, numerous authors have suggested various predictive signs that can indicate the presence of LSTV in lumbar spine MRIs, however, they lack predictive performance.O'Driscoll et al. described two distinct types of intervertebral discs at the lumbosacral junction in subjects with LSTV. They reported that"type I" disc is smaller than the superior disc,

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maintains high T2 signal intensity, and exhibits no intranuclear cleft while extending across the anteroposterior space without fusion between adjacent endplates.[14]While this type of disc is considered indicative of LSTV, its specificity is questionable since transitional discs may appear normal in cases of pseudoarthrosis.Similarly, the "type II" disc is characterized as a rudimentary disc, smaller than the transitional disc, and associated with fusion of the anterior endplates.[14] However, the non-specificity of these signs is emphasized by the finding that residual discs can be present at the S1-S2 level in up to 58% of cases, leading to potential over-diagnosis of LSTV.[1] Additionally, the identification of iliolumbar ligaments from the L5 vertebra on axial images aids in detecting LSTV accurately; however, segmentation anomalies in the thoracolumbar spine may complicate this identification.Moreover, other studies have noted that LSTVs often present a "squared" appearance in lateral radiographs, with a specific ratio of the anteroposterior diameter of the superior endplate to the inferior endplate being less than 1.37.[15] These findings suggest that while anatomical variations and disc morphology can provide valuable diagnostic information, they may not reliably predict the presence of LSTV without correlating measurements like the Lumbosacral Angle and Sacral Inclination.The observed differences in performance metrics of the two angles observed in the present study can be attributed to variations in study populations, methodologies, and the specific anatomical and functional implications of these angles. The Lumbosacral Angle, reflecting the alignment of the lumbar spine relative to the sacrum, may provide more relevant information regarding biomechanical stability and stress distribution in the lumbosacral region. Conversely, the Sacral Inclination may be influenced by additional anatomical variations or compensatory mechanisms, which could explain its lower specificity and moderate AUC in our findings.The importance of these metrics in clinical practice cannot be overstated. Clinicians evaluating patients with low back pain and potential LSTV would benefit from incorporating these angle measurements into their diagnostic protocols. Given the significance of the Lumbosacral Angle's efficient predictive ability, it may serve as a valuable tool in identifying patients at risk for LSTV-related complications, guiding more targeted therapeutic interventions. Overall, the study underscores the utility of simple radiographic measurements in enhancing the diagnostic accuracy for LSTV, supporting their incorporation into routine imaging assessments.

CONCLUSION

The findings of this study highlighted the significant differences in Sacral Inclination and Lumbosacral Angle measurements between cases and controls, suggesting their potential utility in predicting the presence of lumbosacral transitional vertebrae (LSTV). The elevated mean angles observed in the case group, along with the strong statistical significance of these results, underscore the relevance of these measurements in clinical practice. These metrics may aid clinicians in accurately diagnosing LSTV, facilitating appropriate management strategies for patients presenting with low back pain and related symptoms. The findings further suggest that while both angles provide valuable insights, the Lumbosacral Angle offers superior discrimination capabilities compared to Sacral Inclination. Given the moderate discrimination of Sacral Inclination and the strong performance of the Lumbosacral Angle, these measurements can serve as important tools for clinicians. They may enhance diagnostic accuracy and inform clinical decision-making for patients with low back pain associated with LSTV. Nevertheless, further investigation is warranted to corroborate these results and refine the clinical application of these angle measurements in diverse patient populations.

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