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Research Article

THE RELATIONSHIP BETWEEN SPINOPELVIC PARAMETERS ON RADIOGRAPHY AND THE DEGREE OF LUMBOSACRAL INTERVERTEBRAL DISC HERNIATION ON MRI

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Abstract
Given the limited availability of lumbosacral MRI, currently the most accurate modality for assessing the severity of intervertebral disc herniation, in many hospitals in Indonesia, evaluation of spinopelvic parameters on lumbosacral radiographs is expected to serve as an alternative predictor of lumbar disc herniation grade. This study aims to analyze the relationship between spinopelvic parameters and the degree of lumbosacral intervertebral disc herniation, and to identify which parameters are most accurate in predicting the degree of the herniation in patients with low back pain. This research is a retrospective analytic observational study with a cross-sectional design that included 52 patients with low back pain who underwent lumbosacral radiography and MRI at Saiful Anwar General Hospital in 2022–2023. The degree of disc herniation was assessed on sagittal and axial lumbosacral MRI. In contrast, spinopelvic parameters, including pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK), were measured on lumbosacral radiographs. Statistical tests were conducted on four groups (normal, bulging, protrusion, and extrusion). Using Spearman's test, a correlation was found between lumbar lordosis angle and the degree of lumbosacral intervertebral disc herniation, with $p=0.011$ ($p<0.05$). One-way ANOVA showed a significant difference in lumbar lordosis across herniation grades, with $p=0.028$ ($p<0.05$). A smaller lumbar lordosis angle was associated with a higher risk of lumbosacral intervertebral disc herniation. Therefore, lumbar lordosis, as one of the spinopelvic parameters, may be considered a predictive factor for lumbosacral disc herniation.

Keywords: Disc Herniation, Low Back Pain, Spinopelvic Parameters

INTRODUCTION

Low back pain is a health problem affecting 70–90% of individuals and is a major cause of physical and functional limitations, leading to significant medical and economic burdens. One of the most common causes of low back pain is disc herniation (approximately 26.9%), a degenerative process in which the nucleus pulposus migrates beyond the physiological boundaries of the annulus fibrosus. The prevalence of low back pain is 60.9% in women and 28.8% in men, and it is higher among individuals aged >60 years compared to those aged 36–59 years (Meucci et al., 2015; Deyo & Mirza, 2016; Berra et al., 2021). Because disc pressure is greatest during spinal flexion and rotation, disc herniation may lead to substantial radicular symptoms, radiating pain, or accompanying paresthesia, weakness, and reflex disturbances (Schroeder et al., 2016; Kushchayev et al., 2018; Kim et al., 2020; Azemi et al., 2022).

For maintaining sagittal balance, the pelvis and spine act as compensatory structures between the head and lower extremities. Alterations in this alignment may lead to early degenerative changes and increased energy expenditure. Sagittal balance analysis has been associated with degenerative disc diseases such as disc herniation, spondylolisthesis, and intervertebral disc degeneration (Habibi et al., 2014; Kos et al., 2019; Scarcia et al., 2022). Magnetic resonance imaging (MRI) is the best imaging modality for evaluating intervertebral disc herniation. Axial MRI images allow for the assessment and categorization of intervertebral disc herniation into bulging, protrusion, and extrusion. However, MRI is not widely accessible in several regions due to limited facility availability and high operational costs, which may lead to delays in establishing the diagnosis of intervertebral disc herniation. (Fardon et al., 2014; Ma, 2015; Kushchayev et al., 2018; Hung et al., 2021; Çetin et al., 2023).

Delayed evaluation and diagnosis of low back pain attributable to intervertebral disc herniation may lead to worsened clinical and functional outcomes, even following surgical intervention. Evidence consistently demonstrates that a shorter duration of symptoms prior to surgery is associated with superior postoperative recovery (Koumtouzoua & Higgins, 2021; Hamawandi et al., 2022; Isa et al., 2023). Accordingly, there is a need for an accessible adjunctive assessment capable of indicating the severity of lumbar disc herniation using lumbosacral radiography, which is widely available in most Indonesian hospitals, to facilitate earlier identification and timely management of patients presenting with low back pain.

Several previous studies have analyzed the relationship between sagittal body balance and the risk of intervertebral disc alterations, including disc degeneration, disc herniation, and spondylolisthesis. Seven spinopelvic parameters obtained from lumbosacral radiographic evaluation have been shown to influence lumbosacral intervertebral disc changes: pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK) (Khodair et al., 2014; Tuncer et al., 2019; Wang & Sun, 2019; Kaur et al., 2023). Lower PI, SS, PT, and LL values have been correlated with an increased frequency of disc bulging (Chun et al., 2017; Watters et al., 2020). Decreased LSA and SK angles, along with increased STA, have been associated with intervertebral disc herniation (Habibi et al., 2014; Tuncer et al., 2019; Yamazato et al., 2021). However, in Indonesia, studies examining the association between spinopelvic angular parameters and the severity of intervertebral disc herniation remain scarce, and no research to date has evaluated which spinopelvic parameter most accurately reflects the grading of lumbosacral disc herniation. Therefore, the aim of this study is to analyze the relationship between spinopelvic parameters and the degree of lumbosacral intervertebral disc herniation, and to identify which parameters are most accurate in predicting the degree of the herniation in patients with low back pain.

RESEARCH METHOD

This study was conducted in the Radiology Department of Dr. Saiful Anwar General Hospital, Malang, East Java, from January to March 2024. It is a retrospective analytic observational study with a cross-sectional design aimed at analyzing the relationship between spinopelvic parameters on radiography and the degree of lumbosacral intervertebral disc herniation on MRI. The study population consisted of patients diagnosed with low back pain by orthopedic and traumatology specialists, who had undergone standing lateral lumbosacral radiographic examinations and lumbosacral MRI at Dr. Saiful Anwar General Hospital in Malang, using secondary data collected from January 2022 to December 2023.

The minimum sample size was 29 participants, calculated using the correlational analysis sample size formula. However, the sample size may be increased to make the study results more representative. The sample consisted of all accessible subjects who met the inclusion criteria: patients aged 18–80 years with clinical symptoms of low back pain, for whom radiographic and lumbosacral MRI examinations were requested within a time interval of less than 3 months. Exclusion criteria included a history of

previous lumbar spine surgery or interventional procedures, trauma, tumors, metastasis, spinal inflammation, congenital anomalies, or scoliosis. Sampling was performed using a purposive sampling technique.

Spinopelvic parameters, including pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK) were measured on lumbosacral radiographs, as shown in Figure 1. The degree of disc herniation was assessed on sagittal and axial lumbosacral MRI, as illustrated in Figure 2.

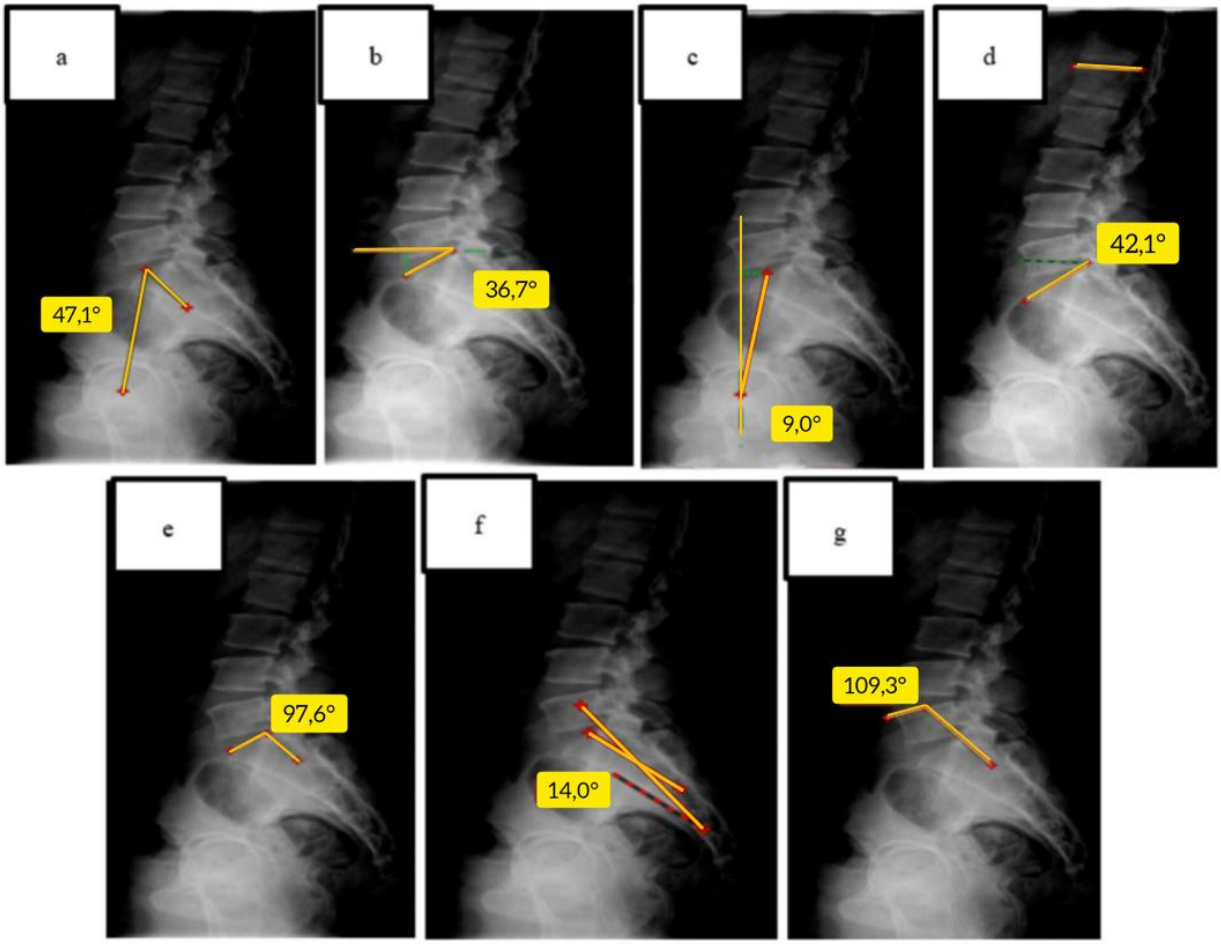

Figure 1. Measurement of spinopelvic parameters on lateral lumbosacral radiography: (a) Pelvic Incidence, (b) Sacral Slope, (c) Pelvic Tilt, (d) Lumbar Lordosis, (e) Sacral Table Angle, (f) Sacral Kyphosis, (g) Lumbosacral Angle (Ru et al., 2021; Lee et al., 2022; Jakob et al., 2023)

Figure 2. Evaluation of the degree of herniation on lumbosacral MRI examination

The study will utilize lumbosacral MRI and standing lateral lumbosacral radiography results from patients presenting to the Radiology Department at Dr. Saiful Anwar General Hospital with clinical low back pain. These imaging data will be analyzed to measure various spinopelvic parameters and assess the degree of lumbosacral intervertebral disc herniation. Lumbosacral MRI examinations were conducted using a Philips Ingenia 3-Tesla scanner, while standing lateral radiographs were obtained using a GE General X-Ray system (model E7843X). All imaging data were subsequently transferred to the PACS and evaluated by a musculoskeletal radiology subspecialist with over 10 years of clinical experience.

Prior to data analysis, numerical variables were assessed for normality using the Shapiro–Wilk test. Variables with a normal distribution were analyzed using parametric tests (Pearson correlation), whereas non-normally distributed variables were analyzed using nonparametric methods (Spearman correlation). Differences in spinopelvic parameters (pelvic incidence, sacral slope, pelvic tilt, lumbar lordosis, lumbosacral angle, sacral table angle, and sacral kyphosis) across the varying grades of intervertebral disc herniation (normal, bulging, protrusion, and extrusion) were evaluated using a one-way ANOVA for normally distributed data; if normality assumptions were not met, the Kruskal-Wallis test was applied. A post hoc test followed a significant one-way ANOVA, while the Mann-Whitney U test followed a significant Kruskal-Wallis test. All analyses were conducted at a 95% confidence level ($\alpha = 0.05$), and statistical significance was defined as $p < 0.05$. Data analysis was performed using SPSS version 20.

RESULTS AND DISCUSSION

A total of 52 samples consisting of lumbosacral radiography and MRI data from patients with low back pain who met the inclusion criteria were collected between January 2022 and December 2023 at the Radiology Department of Dr. Saiful Anwar General Hospital, Malang. Tables 1 and 2 show that the study subjects consisted of more females, 28 patients (53.8%), compared to males, 24 patients (46.2%). The three most common age groups were 51–60 years (30.76%), followed by 61–70 years (26.92%), and 41–50 years (15.38%).

Table 1. Demographic characteristics of study subjects based on sex (n=52)

Sex	Frequency	Number (%)
Male	24	46.2%
Female	28	53.8%

Table 2. Demographic characteristics of study subjects based on age (n=52)

Age	Frequency	Number (%)
18 – 20	2	3.84
21 – 30	5	9.61
31 – 40	5	9.61
41 – 50	8	15.38
51 – 60	16	30.76
61 – 70	14	26.92
71 – 80	2	3.84

Correlation Analysis of Spinopelvic Parameters on Radiography with the Degree of Lumbosacral Intervertebral Disc Herniation on MRI

Hypothesis testing was performed using Spearman's correlation to determine the relationship between various spinopelvic parameters and the degree of lumbosacral intervertebral disc herniation. A positive value indicates a direct correlation, whereas a negative value indicates an inverse correlation. The correlation coefficient (r) ranges from +1 to -1. The closer the r value is to +1 or -1, the stronger the relationship between the two variables, and vice versa. In the Spearman correlation test, the correlation value between lumbar lordosis (LL) and the degree of lumbosacral intervertebral disc herniation was –0.351, with a p-value of 0.011 (<0.05). Meanwhile, the other parameters, pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK), had p-values >0.05. This indicates that the measurement of lumbar lordosis on lumbosacral radiography is significantly associated with the degree of disc herniation on lumbosacral MRI, compared with the other spinopelvic parameters.

Table 3. Correlation Test

Variable	Spearman's rho	Sig.
Pelvic Incidence	0.177	0.208
Pelvic Tilt	0.061	0.666
Sacral Slope	0.098	0.491
Lumbar Lordosis	-0.351*	0.011*
Lumbosacral Angle	-0.052	0.716
Sacral Table Angle	0.036	0.801
Sacral Kyphosis	0.152	0.282

Analysis of Differences in Spinopelvic Parameters Across Various Degrees of Lumbosacral Intervertebral Disc Herniation

To determine whether differences exist in spinopelvic parameters across the various degrees of lumbosacral intervertebral disc herniation, tests of normality and homogeneity were first performed. Normality was assessed using the Shapiro–Wilk test, while homogeneity was evaluated using Levene's test. Subsequently, One-Way ANOVA was used for spinopelvic parameters with normally distributed data, whereas the Kruskal–Wallis test was used for parameters with non-normally distributed data.

In this study, only the sacral slope (SS) parameter was analyzed using the Kruskal–Wallis test due to its non-normal distribution, whereas pelvic incidence (PI), pelvic tilt (PT), lumbar lordosis (LL), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK) were analyzed using One-Way ANOVA.

Table 4. Analysis of differences in spinopelvic parameters across various degrees of lumbosacral intervertebral disc herniation

Degree of Herniation	PI	PT	SS	LL	LSA	STA	SK
Normal	62.33±17.4	19.6±17.0	37.15±21.2	63.8±8.1	116.75±6.3	92.65±3.1	26.7±15.3
Bulging	51.86±6.7	23.91±12.6	26.98 ±9.5	46.78±13.6	114.99±7.5	95.52±4.7	19.08±12.8
Protrusion	58.98±11.1	26.59±9.8	30.85±12.5	40.03±17.6	112.94±12.1	96.93±4.9	25.3±10.2
Extrusion	57.87±9.3	23.21±12.1	32.9±8.9	38.55±15.7	113.59±11.4	95.16±7.2	24.45±9.7
Type of Test	ANOVA	ANOVA	Kruskal Wallis	ANOVA	ANOVA	ANOVA	ANOVA
P-value	0.109	0.704	0.347	0.028*	0.886	0.518	0.352

Note: significant if $p < 0.05$

Table 4 presents the values of various spinopelvic parameters for each degree of disc herniation. For the lumbar lordosis parameter, the ANOVA analysis produced a p-value of 0.028, which is less than $\alpha = 0.05$ ($p < 0.05$). The mean lumbar lordosis angles were 63.8 ± 8.1 in the normal group, 46.78 ± 13.6 in the bulging group, 40.03 ± 17.6 in the protrusion group, and 38.55 ± 15.7 in the extrusion group. To identify which herniation-grade groups differed significantly following the One-Way ANOVA for lumbar lordosis (LL), a post hoc analysis was subsequently performed.

Table 5. Post Hoc Test

Variable		p-value
Normal	Bulging	0.053
	Protrusion	0.008*
	Extrusion	0.006*
Bulging	Normal	0.053
	Protrusion	0.202
	Extrusion	0.155
Protrusion	Normal	0.008*
	Bulging	0.202
	Extrusion	0.794
Extrusion	Normal	0.006*
	Bulging	0.155
	Protrusion	0.794

Based on Tables 4 and 5, the One-Way ANOVA for the lumbar lordosis (LL) parameter demonstrated a significant difference across the degrees of lumbosacral intervertebral disc herniation. The subsequent post hoc analysis also revealed a significant difference in lumbar lordosis angles between the normal, protrusion, and extrusion groups. This study demonstrates that, among all the spinopelvic parameters assessed, only the lumbar lordosis parameter was able to predict the degree of lumbar intervertebral disc herniation.

Spinal alignment is an essential element of postural stability in the sagittal axis, with the pelvis and spine functioning as balancing structures between the head and lower extremities (Cheung, 2020). Patterns of spinopelvic alignment in the sagittal plane vary among individuals. Alterations in this alignment may lead to early degenerative changes, increased energy expenditure, and excessive load on the spine. One of the resulting degenerative conditions is lumbosacral intervertebral disc herniation, a continuous degenerative process characterized by a reduction in proteoglycans within the nucleus pulposus, causing it to migrate beyond the physiological boundaries of the annulus fibrosus (Menezes-reis et al., 2021; Wang et al., 2023). Lumbosacral disc herniation is one of the most common causes of low back pain (approximately 26.9% of cases) and frequently occurs between the ages of 25 and 55 years. About 95% of cases occur at the L4–L5 or L5–S1 levels. The occurring disc herniation may present as bulging, protrusion, extrusion, or sequestration, which can lead to substantial radicular symptoms radiating to surrounding areas, accompanied by paresthesia, weakness, or reflex disturbances (Kushchayev et al., 2018; Fjeld et al., 2019).

In this study, 52 subjects met the inclusion criteria, consisting of 24 males (46.1%) and 28 females (53.8%). The most frequent age ranges were 51–60 years (30.7%), 61–70 years (26.9%), and 41–50 years (15.3%). These findings align with literature reporting that disc herniation in Indonesia occurs more frequently in females, predominantly among individuals aged 45–65 years (15.6%), with a peak at 50 years of age (Segita, 2020). These results are consistent with Bento et al. (2021), who found a prevalence of 60.9% in females and 28.8% in males, with higher rates among individuals older than 60 years than among those aged 36–59 years. Wang et al. (2023) further reported that the prevalence and severity of intervertebral disc space narrowing were higher in elderly women than in men, which may be associated with the diverse physiological changes influenced by estrogen, including those affecting growth and proliferation of intervertebral disc tissues.

The relationship between each spinopelvic parameter and the degree of lumbar intervertebral disc herniation

This study found a correlation between lumbar lordosis and the degree of lumbosacral intervertebral disc degeneration. The evaluation of lumbar lordosis parameters across various degrees of lumbosacral intervertebral disc herniation in this study demonstrated a significant difference between the normal group (63.8 ± 8.1°), the bulging group (46.7 ± 13.6°), the protrusion group (40.0 ± 17.6°), and the extrusion group (38.5 ± 15.7°), with a p-value of 0.028. Therefore, it can be stated that a lower lumbar lordosis angle is associated with an increased risk of lumbar intervertebral disc herniation. These findings are consistent with those reported by Amin et al. (2017) and Eren et al. (2024), who demonstrated a significant relationship between the degree of disc herniation and a decrease in the lumbar lordosis angle. The alteration in lumbar lordosis angle may be attributed to spinal flattening, which typically begins in the fourth decade of life at the lower lumbar levels and progresses to the higher lumbar levels by the sixth decade. This process may also be associated with muscular imbalance and facet angle asymmetry, in which the increasing distribution of mechanical stress across the intervertebral discs shifts lumbar pressure points in response to load magnitude and aging (Khodair et al., 2014; Liang et al., 2016). Furthermore, it has been noted that a decreased lumbar lordosis angle redirects vertical load distribution toward the disc complex, potentially compromising the mechanical integrity of the disc, thereby significantly increasing the risk of developing lumbosacral disc herniation (Chun et al., 2017; Beck et al., 2020; Ogunleye et al., 2024).

The pelvic incidence and sacral slope measurements in the normal group were 62.3±17.4° and 37.15±21.2°, respectively, which were not statistically different from the mean pelvic incidence and sacral slope values observed in the bulging, protrusion, and extrusion groups. Nonetheless, there was an apparent trend toward lower pelvic incidence and sacral slope values in the pathological disc groups compared with the normal group. In contrast, the pelvic tilt measurements showed the opposite pattern, with the normal group demonstrating a lower mean pelvic tilt angle of 19.6±17.0° than the bulging, protrusion, and extrusion groups. These findings are consistent with the existing literature, which indicates that pelvic

incidence is a relatively constant anatomical parameter, as it represents the sum of pelvic tilt and sacral slope. A smaller pelvic tilt generally compensates for a greater sacral slope, and vice versa. Pelvic incidence, sacral slope, and pelvic tilt have been shown to exhibit a stronger and more meaningful association with spondylolisthesis than with intervertebral disc herniation or lumbosacral disc degeneration (Tuncer et al., 2019; Yamazato et al., 2021). Accordingly, the present study did not identify any association between variations in pelvic incidence, sacral slope, or pelvic tilt and the degree of lumbosacral intervertebral disc herniation.

The researchers also found no association between changes in sacral table angle or sacral kyphosis and the degree of lumbar intervertebral disc herniation. This aligns with existing literature stating that sacral table angle and sacral kyphosis are anatomical parameters not affected by posture, as their angular values are largely genetically determined (Tuncer et al., 2019; Yamazato et al., 2021; Kaur et al., 2023). This is due to variations in sacral angulation points among individuals. For example, in this study, some subjects exhibited sacral angulation at the S3 or S4 levels, and some even at the coccygeal level. In contrast, sacral kyphosis is measured at the S2 level by observing the intersection of the midline of S1 and the midline of S4. A similar principle applies to the sacral table angle, which is measured at a specific region of the sacrum. Therefore, these measurement characteristics may explain why no relationship was found between these parameters and the degree of lumbar disc herniation.

The lumbosacral angle was also unable to predict the degree of lumbar disc herniation. Although previous studies have reported that a lower lumbosacral angle may reduce segmental curvature and increase compressive forces on the intervertebral discs, it is often considered to confer greater mechanical stability and, therefore, shows limited association with the severity of lumbosacral disc herniation. Individual variability in sacral morphology and segmental lumbar lordosis makes the lumbosacral angle (LSA) a less reliable and less stable indicator of disc pathology (Hosseinifar et al., 2016; Ozalp & Çolak, 2022; Napitupulu et al., 2022; Zhan et al., 2023).

CONCLUSION

This study investigated the relationship between seven lumbosacral spinopelvic angular parameters — pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), lumbosacral angle (LSA), sacral table angle (STA), and sacral kyphosis (SK) and the severity of lumbosacral intervertebral disc herniation as graded on MRI (Normal, Bulging, Protrusion, Extrusion). Statistical analysis revealed that only lumbar lordosis (LL) differed across herniation grades ($p = 0.028$). At the same time, all other parameters (PI, PT, SS, LSA, STA, SK) exhibited no significant variation ($p > 0.05$). Notably, LL values decreased progressively with increasing herniation severity, from $63.8° \pm 8.1°$ in normal cases to $38.55° \pm 15.7°$ in extrusion cases.

These findings indicate that reduced lumbar lordosis is strongly associated with more severe disc herniation, suggesting that LL may serve as a reliable, radiographically measurable biomarker for estimating herniation severity. In clinical practice particularly in regions where MRI access is limited or delayed assessment of LL on routine lumbosacral radiographs could support early triage, prompt referral, and timely intervention for patients presenting with low back pain. This approach has the potential to mitigate diagnostic delays, reduce the risk of neurological deterioration, and improve long-term functional outcomes.

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AUTHOR CONTRIBUTIONS

Nasrizarni served as the principal investigator, Irma Darinafitri as a musculoskeletal radiology specialist who reviewed the lumbosacral radiographic and MRI findings, and Abdullah Azmy measured the lumbosacral angles on radiographs.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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