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The Impact of Lower Lumbar Spine Rotation on Pelvic Parameters and Sagittal Spinal Curvature in Patients with Disc Prolapse (MRI Study)

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Abstract

Preventing degenerative changes and preserving biomechanical stability influenced significantly on pelvic orientation and spinal alignment. This study examines how trunk rotation affects sacral slope and lumbar lordosis in patients with lumbar disc prolapse. Mid-sagittal MRI scans were performed on 30 patients in three different positions: neutral, right rotation, and left rotation. MATLAB was used to obtain the angular measurements of sacral slope and lumbar lordosis, and Pearson's correlation and paired t-tests were used for statistical analysis. When comparing trunk rotation to the neutral position, the results showed a statistically significant increase in both parameters ($p < 0.01$). All rotational positions showed strong positive correlations between sacral slope and lumbar lordosis ($r > 0.8$), suggesting that even small trunk rotation changes pelvic parameters. Pelvic tilt and incidence were not evaluated because of the limitations of sagittal imaging. Therefore, to fully assess spinopelvic alignment and improve the clinical relevance of these findings, future research using standing lateral radiographs or coronal MRI is advised.

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Keywords: Lumbar disc prolapse, Spinopelvic alignment, Trunk rotation, Lumbar lordosis, Sacral slope, Sagittal MRI, Biomechanics, Pelvic parameters, Axial rotation, Spine stability

Introduction

The spinal complex exhibits three primary curvatures within the sagittal plane, and each is essential to biomechanical stability. Lumbar curvature specifically transitions from kyphotic at birth to lordotic with the development of upright posture, stabilizing around the age of twelve. This lumbar lordosis functions fundamentally to balance axial loads while enabling mobility and flexibility [1]. Alterations in these curves significantly impact the spine's mechanical stability and can predispose individuals to spinal disorders [2].

Spinal stability is maintained by three integrated systems: passive structures (vertebrae, intervertebral discs, ligaments, joint capsules, and facet joints), active musculotendinous components, and the neuromuscular control subsystem [3,6]. Disruption or abnormal loading within these subsystems, notably through postural deviations or buckling under compressive loads, has been frequently identified as a major mechanical contributor to lower back pain [4,5].

The pelvis plays a pivotal role in supporting spinal alignment. Specifically, anterior pelvic tilt—forward rotation of the pelvis—is frequently associated with increased lumbar lordosis, potentially exacerbating lower back pain due to elevated biomechanical stress on the lumbar spine [7]. The sacrum, upon which the lumbar spine articulates, is naturally tilted forward. This forward tilt requires lumbar lordosis to keep an upright posture, a feature evident in radiographic measurements where lumbar lordosis angles typically range from 20º to over 60º, averaging approximately 50º [8] (Figure 1). Consequently, this inclination predisposes the lumbar spine to anterior displacement, particularly under load-bearing conditions, emphasizing the criticality of maintaining proper pelvic orientation for spinal stability.

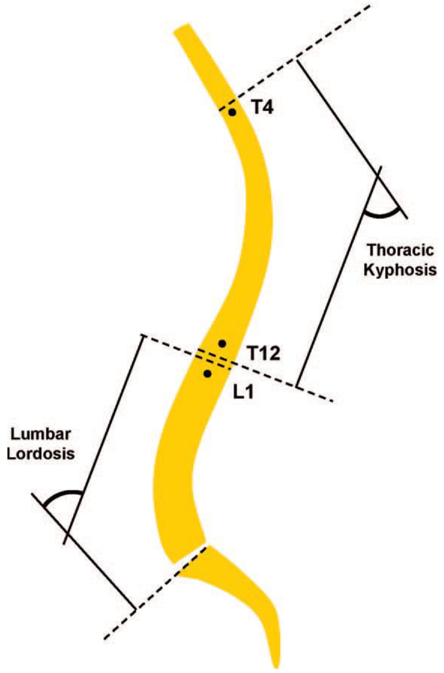

Fig 1: Lumbar lordosis was measured from the superior endplate of L1 to the superior end plate of S1 [6]

Pelvic parameters, including pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS), have been identified as crucial determinants of sagittal spinal alignment and balance. Studies have demonstrated that PI, an anatomical constant, serves as a fundamental axis for spinal equilibrium and strongly correlates with lumbar lordosis (LL), affecting spinal curvature and load distribution across the spine [9,10]. Furthermore, positional changes, such as transitioning from standing to supine, significantly alter SS but not PI, indicating the complex adaptability and importance of these parameters in maintaining spinal balance [11-13] (Figure 2).

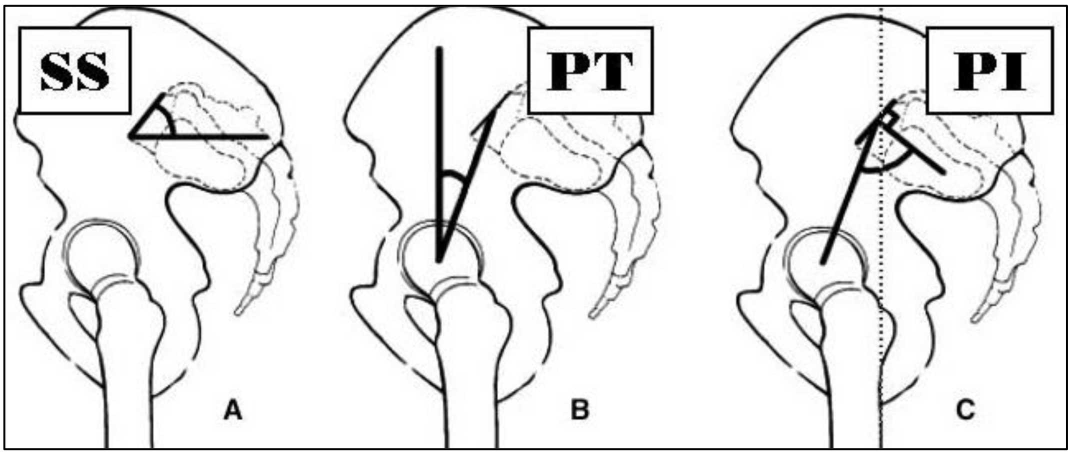

Fig 2: The illustration of the sacral slope, pelvic tilt and pelvic incidence angles measurements [15]

While previous research extensively explored pelvic parameters and their relationship with sagittal spinal alignment in static positions, relatively limited literature exists on the influence of axial trunk rotation on these parameters, particularly among patients suffering from lumbar disc prolapse.

It's important to understand this link since little rotational motions could have a big effect on the location of the pelvis, the curvature of the spine, and maybe even the advancement of disc degeneration.

This study, therefore, aims to fill this crucial previous studies gap by investigating how axial trunk rotation effects lumbar lordosis and sacral slope in patients with lumbar disc prolapse using sagittal MRI imaging. By elucidating this dynamic interplay, the results may improve therapeutic methods for identifying, treating, and rehabilitating spinal diseases linked to lumbar disc prolapse by clarifying this dynamic interaction.

Materials and methods

Thirty patients with a clinical diagnosis of lumbar disc prolapse were included in this study. Patients with a clinical and radiological diagnosis of lumbar disc prolapse and low back pain, with or without radiating symptoms, were eligible to participate. Individuals with severe spinal deformities, spinal tumours, inflammatory spinal diseases, prior spinal surgery, or spinal fractures were not included.

Imaging Process

A typical 1.5 Tesla MRI scanner was used to obtain the MRI scans. Patients were placed in three different positions for sagittal T2-weighted MR imaging: neutral (standard supine), right axial trunk rotation, and left axial trunk rotation. Patients were stabilised with standardised supports to guarantee consistency while in rotational positions, which involved gently rotating the lower trunk to 20 degrees on each side.

Spinal Angle Measurement Lumbar lordosis (LL) was measured between the superior endplates of the L1 and S1 vertebrae. The angle formed by the superior endplate of S1 and the horizontal reference line was known as the sacral slope (SS). A validated measurement technique previously described by Vaz *et al*. (2002) [16] was followed for all digital measurements using MATLAB software (version R2022b, MathWorks, Natick, MA, USA). The mean value was utilised for additional analysis after each measurement was completed three times as shown in figures (3,4 and 5).

statistical analysis

We used SPSS software (version 24, IBM Corp., Armonk, NY, USA) to do the statistical analysis. We conducted the Shapiro-Wilk test to make sure the data was normal. We used descriptive statistics like averages and standard deviations to find the LL and SS at each position. We utilised paired t-tests to see if there were any big changes in LL and SS between the left and right rotating positions and the neutral position. We used Pearson's correlation coefficient (r) to look to determine how the angles of the sacral slope and the lumbar lordosis were related in every position studied. A p-value of less than 0.05 meant that the result was statistically significant.

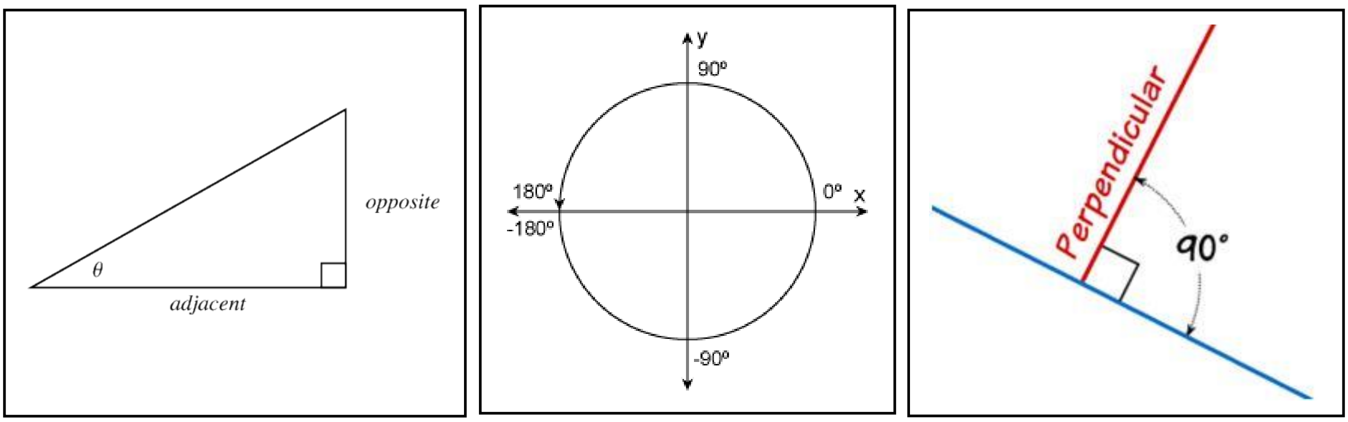

Fig 3 : shows the procedure of the measurements for the lumbar lordosis and sacral slope angles

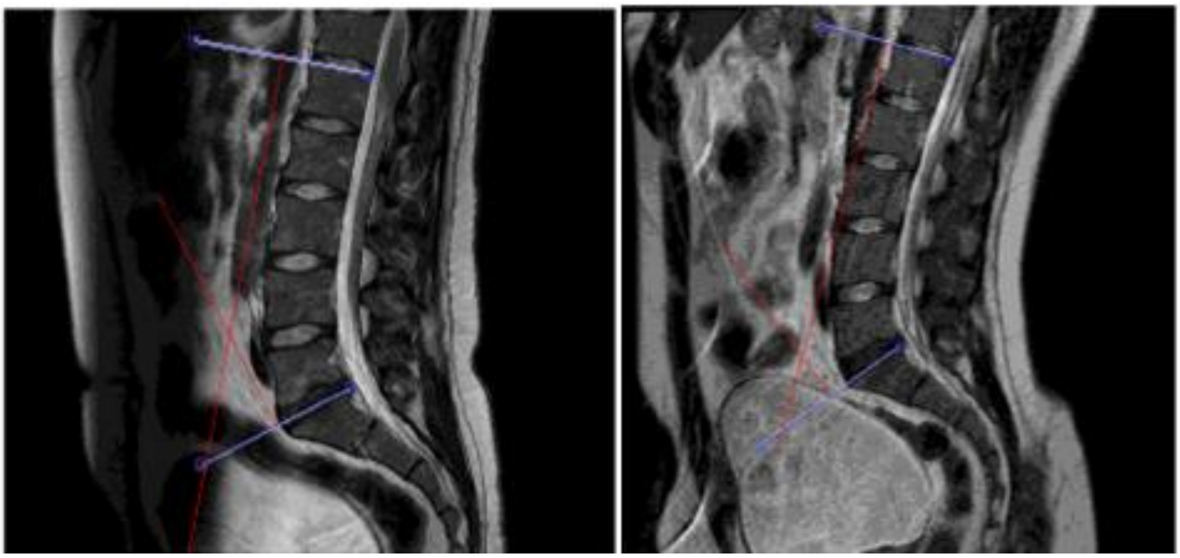

Fig 4: The lumbar lordosis angle at the neutral position (right image) and at right rotation (left image)

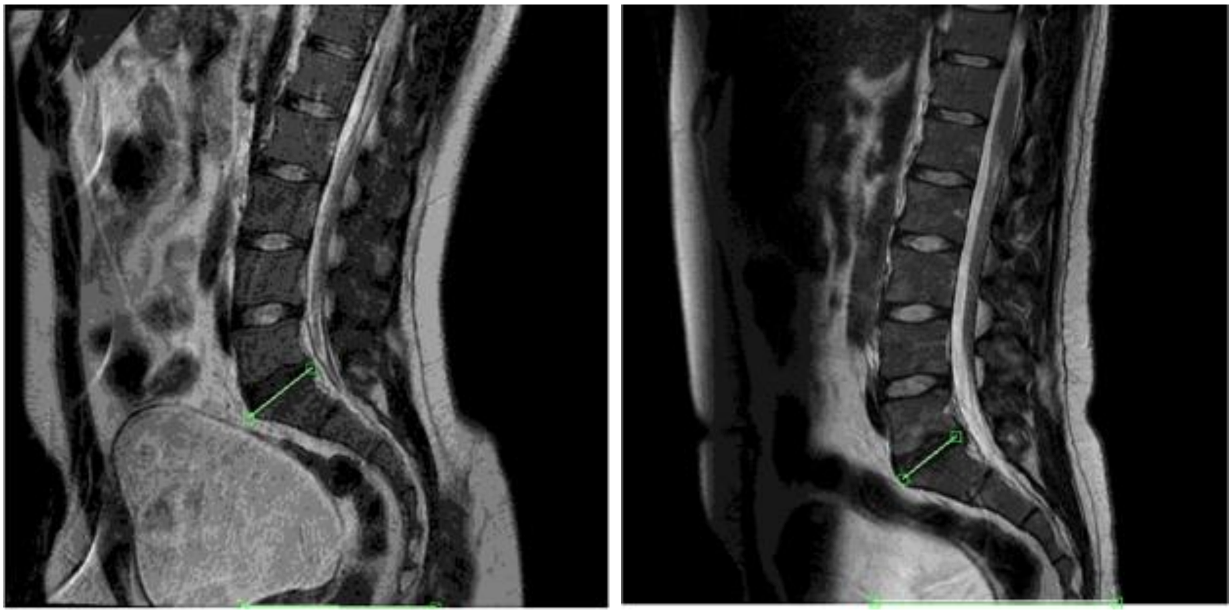

Fig 5: The sacral slope angle at the neutral position (right image) and right rotation (left image).

Results

Neutral, right trunk rotation, and left trunk rotation sagittal MRI imaging were performed on thirty patients with radiologically and clinically confirmed lumbar disc prolapse. Table 1 displays the measured values for sacral slope (SS) and lumbar lordosis (LL) across these positions.

In the neutral position, the mean lumbar lordosis (LL) angle was 43.1° ± 4.8; however, it increased significantly during the left rotation (54.0° ± 4.7) and right rotation (52.3° ± 4.2). In a similar vein, the mean sacral slope (SS) increased from 39.2° ± 3.5 in the neutral position to 42.4° ± 3.6 in the right rotation and 44.0° ± 3.2 in the left. Statistical analysis with paired t-tests ($p < 0.01$ for all comparisons) showed that there were big differences between the neutral position and both rotating positions for LL and SS as shown in the (Table 2,3, 4 and Figure 6).

Pearson's correlation study showed that LL and SS were strongly positively correlated in all positions: Neutral: r = 0.84, Rotation to the right: r = 0.82, Rotation to the left: r = 0.83.

These results suggest that even a small amount of axial trunk rotation can greatly modify sagittal spinopelvic alignment, making lumbar lordosis and sacral slope higher in those with lumbar disc prolapse.

Table 1: The lumbar lordosis and sacral slop angles according to the changing from the neutral to the right, and left rotation.

Position	Lumbar lordosis angle		Sacral slop angle	
	M(degree) (SD) (°)	Mean Difference(°)	M(degree) (SD) (°)	Mean Difference(°)
N	43.1 (2.4)		39.2(2.1)	
RR	52.3(2.4)	-9.2**	42.4(1.8)	-3.2**
LR	54(2.4)	-10.9**	44(1.7)	-4.8**

Table 2: Correlation of lumbar lordosis angles according to the changing from the neutral to the right, and left rotation.

Position	Lumbar lordosis angle
N	1
RR	.93**
LR	.90**

Table3: Correlation of sacral slope angles according to the changing from the neutral to the right, and left rotation.

Position	Sacral slop angle
N	1
RR	.915**
LR	.805**

Table 4: Correlation between lumbar lordosis and sacral slope angles according to the changing from the neutral to the right, and left rotation.

Position	Correlation between Lumbar lordosis and Sacral Slop angles
N	.84**
RR	.82**
LR	.83**

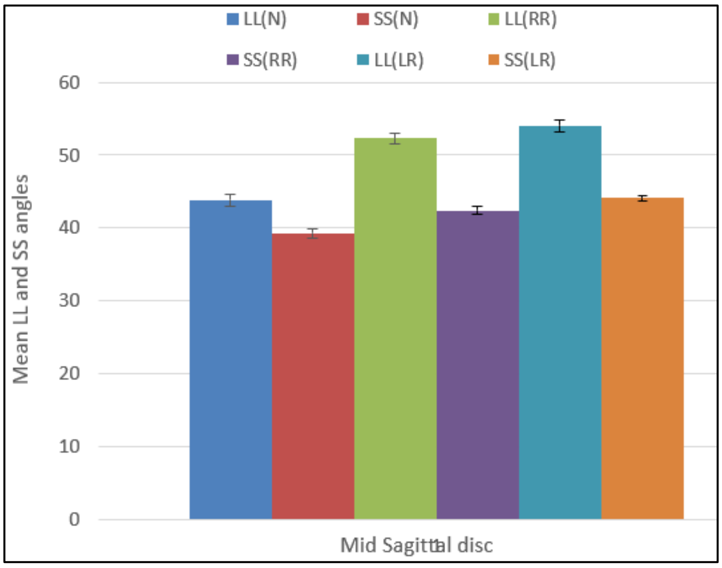

Fig 6: The relation between the lumbar lordosis curve and the sacral slope angles at neutral position and right and left rotation

Discussions

Many studies have investigated the relationship between pelvic parameters and sagittal spinal curvature. Researchers like Wei *et al*. (2018) [17], Barrey *et al*. (2007) [18], Mardare *et al*. (2016) [19], Roussouly *et al*. (2011) [20], Wang *et al*. (2019) [21], Han *et al*. (2017) [22], Yang *et al*. (2024) [34], Jain *et al*. (2024) [24], Sebaaly *et al*. (2024) [25], and Huang *et al*. (2024) [26] demonstrated a significant correlation between lumbar disc degeneration in neutral positions and sagittal plane parameters of the spine and pelvis [16–25]. However, studies by Christensen *et al*. (2008), Vrtovec *et al*. (2012), Bao *et al*. (2024), and Weng *et al*. (2015) [26–29] have found no correlation has been observed between sagittal spinal curves and overall spinal health or distress. These conflicting results are most likely due to differences in the measurement techniques, intervertebral disc levels analysed, and degrees of lumbar disc degeneration.

In particular, pelvic incidence (PI) is a pivotal factor in determining the progression and region of lumbar disc degeneration. Similar to Wei *et al*. (2018) [17], patients with PI ≤ 50° were more likely to develop degeneration at L4/5 and L5/S1 levels, whereas the patients with PI > 50° were more likely to develop degeneration at L3/4 and L4/5. Furthermore, Han *et al*. (2017) [22] found that patients with degenerative lumbar scoliosis were more likely to have degenerative lumbar spondylolisthesis when their PI values were higher. Additionally, Sebaaly *et al*. (2024) [25] and Huang *et al*. (2024) [26] highlighted that PI is directly correlated with the sagittal orientation of facet joints, especially at the L5-S1 level, indicating a biomechanical propensity for segmental instability and possibly spondylolisthesis [24,25]. These results suggest that more research is required to ascertain whether therapeutic interventions are beneficial for patients with elevated PI values.

However, recent research by Huang *et al*. (2024) [26], Yang *et al*. (2024) [23], and Tateiwa (2023) [31] have been revealed that severe hip osteoarthritis may change the sagittal alignment of the spine-pelvis-leg complex without necessarily resulting in low back pain [22,25,30]. In particular, patients with impaired compensatory mechanisms showed markedly unbalanced spinopelvic alignment, leading to more functional limitations [23].

Epidemiological research have found ambiguous correlations between sagittal spinal curvature and spinal health outcomes, particularly pain [26, 27]. The practical application of sagittal pelvic measures for prognostic purposes is hindered by the lack of normative values due to individual heterogeneity. Bao *et al*. (2024) [29] reported no significant differences in pelvic inclination (PI) between individuals with and without lumbar disc herniation, suggesting that lumbar disease minimally influenced PI variations [28]. Incorrect spinopelvic alignment can result in functional impairment; thus, the interrelation of spine, pelvis, and leg parameters necessitates comprehensive examinations to inform therapeutic decisions efficiently.

During trunk rotation to the left and right, lumbar lordosis and sacral slope angles in our study increased significantly, showing strong positive correlations (Tables 2, 3, and 4). These findings highlight the biomechanical impact of even small trunk rotations on pelvic orientation and spinal curvature. However, direct comparative analyses are complicated by methodological differences between our study and previous research such as the applied positions and the degree of lower trunk rotation [32, 33, 34,35,36].

Due to sagittal MRI imaging limitations, specifically the lack of distinct femoral head landmarks, our study is limited in its ability to measure pelvic tilt (PT) and pelvic incidence (PI). To improve the clinical applicability of findings pertaining to trunk rotation and spinopelvic alignment, future studies should use standing lateral radiographs or coronal MRI to acquire these crucial pelvic measurements (Figure 6).

Conclusion

This study showed that trunk rotation impacted substantial on lumbar lordosis and sacral slope in patients with lumbar disc prolapse. The biomechanical link between pelvic orientation and spinal curvature is shown by the positive correlations obtained, even with slight rotational motions. Furthermore investigations utilizing coronal MRI or scanning lateraly are required because important factors like pelvic tilt and pelvic incidence could not be evaluated as a result of imaging limitations. This type of study will help to more learn more understanding about how the spinopelvic system works, which could lead to better ways to diagnose, treat, and rehabilitate spinal diseases caused by lumbar disc prolapse.

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