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# Correlation Between Spinopelvic Sagittal Alignment Parameters and Low Back Pain

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## ABSTRACT

Low back pain is a common musculoskeletal disorder with a major socioeconomic impact. Understanding its association with spinopelvic alignment may enhance diagnosis and treatment by identifying key biomechanical factors linked to symptom severity. **Objectives:** To assess the relationship among spinopelvic parameters and low back pain severity. **Methods:** This retrospective study was conducted at Bahria International Hospital, Rawalpindi, Pakistan, including 150 patients. Full-spine standing X-rays were used to assess sagittal vertical axis, sacral slope, pelvic tilt, pelvic incidence, and lumbar lordosis using Surgimap® software. A visual analog scale was used to measure the severity of the pain, and Pearson correlation analysis was performed to determine associations between spinopelvic parameters and LBP severity. **Results:** Pelvic tilt showed a positive correlation with lumbar pain, which is significant ($r=0.52$, $p<0.001$) and radicular pain ($r=0.33$, $p=0.002$). Sagittal vertical axis was also positively correlated with lumbar ($r=0.47$, $p<0.001$) and radicular pain ($r=0.38$, $p=0.001$). A significant negative correlation of lumber lordosis was exhibited with both lumbar ($r=-0.49$, $p<0.001$) and radicular pain ($r=-0.41$, $p<0.001$). No significant correlation was found for PI or SS. **Conclusions:** Pelvic tilt and sagittal vertical axis positively correlate with low back pain severity, whereas lumbar lordosis exhibits a protective role. These findings emphasize the importance of spinopelvic alignment in low back pain pathophysiology.

## INTRODUCTION

One of the most prevalent musculoskeletal ailments is low back pain (LBP). LBP affects approximately 65% to 80% of individuals during their lifetime. Globally, an estimated 568 million people are affected by LBP, making it the foremost cause of years lived with disability [1]. Despite its high prevalence, identifying a precise nociceptive source for LBP remains challenging in most cases. A small proportion of cases are attributed to identifiable pathological conditions such as spinal fractures, malignancies, or infections. The majority result from a complex interplay of factors, including disc degeneration, facet joint osteoarthritis, paraspinal muscle dysfunction, and psychosocial influences [2]. Among the known causes, degenerative disc disease (DDD) is the most frequently recognized factor in LBP. Magnetic resonance imaging (MRI) findings, including Modic changes and the Pfirrmann grading system, are commonly employed to classify DDD in clinical settings. Additionally, the zygapophyseal (facet) joints have been identified as a significant source of back pain. Percutaneous interventions targeting these joints have shown effectiveness in alleviating discomfort [3]. Dysfunction of the paraspinal muscles is another critical contributor. Its evidence linking increased disability in LBP patients to muscular impairment. Psychological aspects such as depression, anxiety, catastrophizing, and self-efficacy further compound the complexity of LBP, predisposing affected individuals to chronic disability [1]. The concept of spinopelvic alignment has emerged as a crucial factor in understanding LBP pathogenesis. Dubousset's "cone of economy" describes how the axial

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skeleton works in concert to maintain an efficient standing posture. This includes the functioning of feet, lower limbs, pelvis, spine, and cranium. Any imbalance in these structures leads to increased muscular activity and energy expenditure, resulting in back pain and fatigue [4]. Thus, assessing spinopelvic parameters is essential in evaluating sagittal alignment and its correlation with LBP. The key parameters defining sagittal spinopelvic alignment include sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL). A fixed anatomical parameter is PI, which represents the angle between a line created from the sacral endplate's center to the femoral head's midpoint. Additionally, another perpendicular line is drawn to the sacral endplate as well. SS is the angle between the upper sacral endplate and a horizontal reference line. PT measures pelvic alignment in the sagittal plane and LL reflects the curvature of the lumbar spine, which plays a crucial role in maintaining balance [2]. Abnormal sagittal alignment may contribute to mechanical stress, compensatory muscle activity, and pain generation.

Despite the high prevalence of low back pain (LBP), the precise biomechanical contributors remain incompletely understood, particularly in patients without prior spinal surgery or deformities. While some studies suggest that alterations in spinopelvic alignment may influence pain severity, findings are inconsistent, and most investigations are limited by small sample sizes, heterogeneous populations, or non-standardized measurements. This gap highlights the need for a more comprehensive evaluation of sagittal spinopelvic parameters and their correlation with LBP in a well-defined cohort. This study aims to determine the correlation between parameters of spinopelvic sagittal alignment and LBP in individuals without prior spinal surgery or deformities.

## METHODS

This retrospective study was conducted from February 2025 to July 2025 at Bahria International Hospital, Rawalpindi, Pakistan. The study was carried out after ethical approval from the ethical review board of Bahria International Hospital, Rawalpindi, Pakistan (Ref. No. BARMT-BIH-8-RWP-HR-F-37). Participants' informed consent was not taken. A total of 150 patient records were eligible for inclusion in the study. The sample size was calculated using the flowing formula [5], with a confidence level of 95%, a margin of error of 8%, and an assumed correlation coefficient of 0.3 between spinopelvic parameters and VAS scores, based on previous literature.

$$\frac{(Z\frac{\alpha}{2} + Z_{\beta})^2}{(0.5 \times 1n\frac{1+r}{1-r})^2} + 3$$

Using this formula, the minimum sample size was estimated to be 85 patients; however, 150 eligible records were included to enhance statistical power and account for incomplete data. Patients included were those aged 25 to 65 years who presented with mechanical low back pain of more than six weeks duration (chronic), with or without radiculopathy, and were diagnosed with single-level lumbar disc herniation (LDH) on MRI. The age range of 25 to 65 years was chosen to focus on the working-age population most commonly affected by mechanical low back pain, while excluding pediatric and elderly individuals, who typically have different pathophysiological mechanisms. Patients with radiculopathy were not separately analyzed but were included only if MRI confirmed LDH without central or foraminal stenosis. All included cases had undergone complete clinical examination, including assessment of deep tendon reflexes, sensory testing, straight leg raise (SLR), and motor strength grading. MRI confirmed disc herniation at L4-L5 or L5-S1 levels, with no signs of spinal canal stenosis or cord compression. MRI findings were limited to single-level herniation at L4-L5 or L5-S1 levels without spinal canal stenosis, foraminal narrowing, or cord compression. The data were gathered from electronic medical histories and imaging archives. Patients with acute LBP (less than 6 weeks), history of recent trauma, or red flag signs such as unexplained weight loss or neurological deficits suggesting cauda equina were excluded. The patients who were excluded also had uncontrolled hypertension, malignancies, osteoporosis, prior spinal trauma or fractures, diabetes mellitus, and metabolic disorders. These disorders included metabolic bone diseases and hypo- or hyperthyroidism. Patients with even controlled diabetes were excluded to eliminate confounding effects on spinal pathology. Additionally, individuals with a history of lumbar surgery, spondylolisthesis, spinal canal narrowing, or any other structural spinal abnormality were excluded. Patients with a BMI greater than 30.0 kg/m$^2$ were also excluded to reduce confounding due to obesity-related biomechanical alterations. To ensure the specific assessment of spinopelvic parameters, only patients without coronal plane deformities were included. Patients who had previously undergone thoracic, abdominal, or spinal surgery or had a history of spinal malignancies, vertebral fractures, or infections were excluded. Routine inflammatory markers (ESR and CRP) were available in records for most patients and were within normal range, ruling out infectious causes like TB or brucellosis. None of the patients in the study underwent surgical intervention. All were managed conservatively with analgesics, muscle relaxants, physiotherapy (including core strengthening and postural training), and ergonomic counseling. Surgical management was not indicated based on absence of red flag symptoms, lack of progressive neurological deficits,

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and good response to conservative treatment as per clinical notes. Spinopelvic parameters were assessed using full-spine standing X-rays. All X-rays were performed in the same standardized standing position with patients instructed to keep knees extended and arms flexed with hands resting on the clavicles. The Surgimap® program, Version 2.3.0.1 (NY, USA), was employed to measure sagittal spinopelvic alignment parameters, including sagittal vertical axis (SVA), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL). PI was determined as the angle created by a line drawn from femoral head's center to sacral plate's midpoint. A vertical line to the sacral plate is also a part of it. It is thought to be an immovable anatomical parameter that does not change with the change of posture. Cobb method was used to measure lumbar lordosis, assessing the angle between the L1's superior endplate and the S1's superior endplate. Sacral slope was determined as the angle between the upper sacral endplate and a horizontal reference line, whereas a lower SS specifies an extra vertical sacrum, and an elevated SS suggests a more horizontal sacrum. The angle between the vertical axis and a line connecting the sacral plate's midpoint to the bi-coxo-femoral axis is determined as Pelvic tilt. The relationship between these parameters follows the formula PI = SS + PT. Severity of the pain was calculated by using a visual analog scale (VAS), where patients were presented with a 10-cm horizontal line reaching from one side of "no pain" to other side of "worst pain imaginable". Pain scores were extracted from previous medical records, ensuring consistency in assessment across patients. Outcome measure included VAS scores recorded at initial presentation. No follow-up pain scores or functional outcome data (such as Oswestry Disability Index) were available due to retrospective design limitations. Due to the retrospective nature, no follow-up data were available regarding recurrence, disease course, or transition to surgical management. Measurements of radiographic parameters were all performed by a single trained investigator. To minimize variability and enhance consistency, each measurement was repeated twice at different time points, and the average value was used. SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA) was used to carry out statistical analyses. The relationship between spinopelvic parameters and LBP severity was examined using Pearson correlation coefficients. Data normality was confirmed using the Shapiro-Wilk test. A statistically significant p-value is considered as ≤0.05. Correlation strength was considered weak for the ranges from 0.2 to 0.39, moderate for 0.4 to 0.59, strong for 0.6 to 0.79, and very strong for the ranges between 0.8 to 1. This study builds upon prior local research conducted by Chughtai (2023), which also investigated correlations between spinopelvic parameters and chronic low back pain; however, the present study incorporates a larger sample size, more stringent exclusion criteria, and standardized radiographic measurements using dedicated software tools [6].

## RESULTS

The study comprised a total of 150 patients with low back pain. The mean age of the participants was 47.21±10.32 years, with males 78(52%) and females 72(48%). The mean range of BMI was 26.81±2.92 kg/m (Table 1).

**Table 1:** Demographic Features of the Population

| Variables | Mean ± SD | Range |
|---|---|---|
| Age (years) | 47.21 ± 10.32 | 25-65 |
| BMI (kg/m$^2$) | 26.81 ± 2.92 | 21.33 – 29.92 |
| Male (%) | 78 (52) | — |
| Female (%) | 72 (48) | — |

The spinopelvic sagittal alignment parameters were evaluated using standing full-spine X-rays. The mean pelvic incidence (PI) was 50.31 ± 8.23°, pelvic tilt (PT) was 18.74 ± 5.13°, sacral slope (SS) was 31.62±7.41°, sagittal vertical axis (SVA) was 26.93± 8.64 mm, and lumbar lordosis (LL) was 42.41 ± 9.71° (Table 2).

**Table 2:** Spinopelvic Parameters of the Study Population

| Parameters | Mean ± SD | Range |
|---|---|---|
| Pelvic Incidence (°) | 50.31 ± 8.23 | 38-67 |
| Pelvic Tilt (°) | 18.74 ± 5.13 | 10-29 |
| Sacral Slope (°) | 31.62 ± 7.41 | 18-47 |
| Sagittal Vertical Axis (mm) | 26.93 ± 8.64 | 12-48 |
| Lumbar Lordosis (°) | 42.41 ± 9.71 | 25-60 |

Severity of the pain was evaluated by incorporating the visual analog scale (VAS), with a mean lumbar VAS score of 5.81±1.91 and a mean radicular VAS score of 4.31±2.11 (Table 3).

**Table 3:** Pain Severity Scores (VAS) Among Study Participants

| Pain Type | Mean ± SD | Range |
|---|---|---|
| Lumbar VAS Score | 5.81 ± 1.91 | 2-9 |
| Radicular VAS Score | 4.31 ± 2.11 | 1-8 |

Correlation analysis was performed between spinopelvic parameters and low back pain severity. A significant positive correlation was found among pelvic tilt and lumbar VAS scores (r=0.52, p<0.001), indicating that an increased PT was associated with greater pain severity. Similarly, sagittal vertical axis showed a weak positive correlation with lumbar VAS scores (r=0.47, p<0.001). Conversely, lumbar lordosis showed a significant negative correlation along with lumbar pain severity (r=-0.49, p<0.001), suggesting that reduced LL was linked to more severe pain. Pelvic incidence and sacral slope were not significantly correlated with pain scores (p>0.05) (Table 4).

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**Table 4:** Correlation Between Spinopelvic Parameters and Pain Severity

| Parameter | Lumbar VAS (r) | p-Value | Radicular VAS (r) | p-Value |
|---|---|---|---|---|
| Pelvic Incidence | 0.12 | 0.14 | 0.09 | 0.210 |
| Pelvic Tilt | 0.52 | <0.001 | 0.33 | 0.002* |
| Sacral Slope | 0.08 | 0.26 | 0.10 | 0.180 |
| Sagittal Vertical Axis | 0.47 | <0.001 | 0.38 | 0.001* |
| Lumbar Lordosis | -0.49 | <0.001 | -0.41 | <0.001* |

Values represent Pearson correlation coefficients (r) with corresponding p-values. A p-value <0.05 was considered statistically significant, shown with(*)

Representative imaging examples of MRI and standing full-spine X-rays showing lumbar disc degeneration and spinopelvic alignment parameters (Table 5).

**Table 5:** Representative Imaging Examples from Study Participants

| Imaging Type | Description |
|---|---|
| MRI Lumbar Spine | L4-L5 disc bulge with nerve root compression and loss of disc height |
| MRI Lumbar Spine | L5-S1 disc desiccation with posterior protrusion |
| Standing Full-Spine changes X-ray | Increased pelvic tilt and reduced lumbar lordosis indicating sagittal imbalance |
| Standing Full-Spine X-ray | Normal spinopelvic alignment with balanced sagittal profile |

# DISCUSSION

When the body's center of gravity is maintained within a cone centered on the trunk, energy consumption is minimized, according to Muraoka's cone of economy concept [7]. Alterations in spinal alignment increase energy expenditure, pain, disability, and psychological distress. Lateral X-ray parameters such as pelvic tilt (PT), pelvic incidence–lumbar lordosis mismatch (PI-LL), and sagittal vertical axis (SVA) are closely linked with back pain and disability, and serve as sagittal modifiers in the SRS-Schwab classification for spinal deformity [2, 8]. Degenerative changes, including disc degeneration and facet joint arthritis, are also associated with sagittal misalignment [9]. In adults with spinal deformity, elevated SVA correlates with poor health-related quality of life and low back pain (LBP) [10]. Oakley *et al.* reported that kyphotic individuals experience greater back pain, impaired gait, reduced balance, and higher fall risk [11]. Consistent with previous findings, our results demonstrate that both mild degenerative changes and severe deformities are linked to higher SVA values, reflecting increased disability and pain. Although several studies have examined associations between spinopelvic parameters and LBP, results remain mixed. Moreno-Mateo *et al.* observed no significant sagittal parameter differences between asymptomatic individuals and LBP patients. Similarly, Sugavanam *et al.* found no sagittal alignment between patients with L5–S1 degeneration and those with normal radiographs [2, 12]. Conversely, Quintana *et al.* reported that patients with lumbar degenerative disease exhibited higher PT, lower sacral slope (SS), and reduced thoracic kyphosis compared with controls, while Cha and Park noted distinct lumbar lordosis differences between LBP patients and matched controls [13, 14]. Such discrepancies underscore the need for further research to clarify the precise role of spinopelvic parameters in LBP pathogenesis [15-17]. Current findings align with those studies reporting altered spinopelvic parameters among LBP patients, particularly increased SVA, decreased lumbar lordosis (LL), and elevated PT. According to Che *et al.*, reduced LL combined with higher PT and smaller SS produces greater compressive disc forces, promoting degeneration and discogenic back pain [18]. Sun *et al.* observed that individuals with type 2 LL had a higher incidence of LBP than controls (37.4% vs 23.3%, p<0.050), whereas Roussouly type 3 was more prevalent among controls (38.9% vs 47.7%, p<0.050) [19]. No significant differences were found for types 1 and 4 [20]. The authors concluded that LBP was more frequent in subjects with smaller SS and flatback morphology. Although PI did not differ between groups, their findings agree with ours, showing a correlation between PT and pain intensity (VAS), but not PI. We also noted a modest, though not statistically significant, association between disability and PI-LL (p=0.080), consistent with studies linking PI-LL mismatch to poor postoperative outcomes following spinal instrumentation [21]. Previous studies proposed that compensatory mechanisms driven by disc degeneration underlie type 2 LL in LBP patients [14]. Clinically, these results suggest that even in the absence of overt spinal deformity, altered sagittal balance, particularly increased SVA and PI-LL mismatch, may signal early spinal pathology. Thus, sagittal parameters should be incorporated into radiographic assessments of patients with non-specific LBP. For spine surgeons, the key message is that subtle imbalances in spinopelvic alignment should not be overlooked, as they may precede structural degeneration and chronic symptoms. The correlation between LBP and PI-LL supports previous studies that inherent spinopelvic configurations could predispose individuals to LBP [19]. Future longitudinal, multicenter studies are required to explore this hypothesis and relate spinopelvic parameters to long-term outcomes such as mobility, recurrence, and quality of life. The relatively low VAS scores in our cohort indicate mild symptoms and minimal functional impairment; yet, the observed associations between sagittal parameters and symptom severity highlight the importance of sagittal balance in the progression of spinal degeneration. This study's limitations include a small sample size, a single-center design, a lack of inter- or intra-

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observer reliability analysis, and the absence of a control group. Moreover, as a cross-sectional investigation, it cannot determine causality. Longitudinal research tracking patients over time could clarify whether specific sagittal morphologies predispose to chronic pain or degenerative progression, and whether early radiographic signs of imbalance predict future need for intervention or surgery. Such data would enhance early diagnostic and preventive strategies in degenerative lumbar disease. In summary, findings from this adult cohort without coronal deformity suggest that spinopelvic alignment has a significant influence on back pain and disability. While the relationship between sagittal parameters and health-related quality of life is not a novel concept, our results add to growing evidence supporting sagittal balance as a critical factor in the pathogenesis and clinical expression of LBP.

This study is limited by its retrospective design, single-center setting, and lack of a control group, which restricts the ability to infer causality. Additionally, inter- and intra-observer variability was not assessed, and functional outcome measures were unavailable. Future studies should include larger, multicenter cohorts with longitudinal follow-up to determine whether early detection of sagittal imbalances can predict progression of low back pain and guide preventive or therapeutic interventions.

# CONCLUSIONS

This study highlights a significant correlation between spinopelvic sagittal alignment parameters and low back pain severity. Increased pelvic tilt and sagittal vertical axis were related to higher pain scores, while reduced lumbar lordosis correlated with greater pain intensity. These findings underscore the position of sagittal balance in spinal biomechanics and pain perception. Early assessment and intervention may help prevent long-term complications. Future studies should explore these relationships in larger populations with longitudinal follow-up.

## Authors' Contribution

Conceptualization: AAJ
Methodology: MB, FAJ
Formal analysis: FAJ
Writing and Drafting: MAQ, EA, AJ
Review and Editing: MAQ, EA, AJ, MB, FAJ, AAJ

All authors approved the final manuscript and take responsibility for the integrity of the work

## Conflicts of Interest

All the authors declare no conflict of interest.

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