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Original Article

Assessment of lumbar lordosis and pelvic parameters in chronic low back pain patients

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ABSTRACT

Background: Sagittal spinopelvic alignment plays a crucial role in lumbar biomechanics and is increasingly recognized as an important contributor to chronic low back pain (CLBP). Alterations in lumbar lordosis (LL) and pelvic parameters may influence pain severity and functional status.
Aim: To assess lumbar lordosis and key pelvic parameters—pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and PI–LL mismatch—in adults with chronic low back pain, and to determine their associations with pain intensity.
Materials and Methods: A cross-sectional study was conducted among 200 adults with CLBP attending a tertiary care centre. Demographic details, anthropometry, and pain scores were recorded. Standardized lateral lumbosacral radiographs were used to measure LL, PI, PT, SS, and PI–LL mismatch. Expected normative ranges were used for comparison. Correlation analyses and subgroup comparisons (gender, occupation, and age) were performed.
Results: The mean age was 42.6 ± 10.8 years, and the mean BMI was 27.4 ± 3.8 kg/m². Reduced LL was observed in 62% and elevated PT in 58% of participants. PI–LL mismatch >10° was present in 70%, indicating significant sagittal imbalance. LL showed a significant negative correlation with PT ($r = –0.41$, $p < 0.001$) and a modest negative correlation with VAS pain scores ($r = –0.28$, $p = 0.01$). PT demonstrated a positive correlation with pain severity ($r = 0.36$, $p = 0.002$). Manual laborers and individuals >50 years exhibited significantly lower LL, higher PT, and greater PI–LL mismatch compared to their counterparts.
Conclusion: Most CLBP patients demonstrated reduced lumbar lordosis, elevated pelvic tilt, and abnormal PI–LL mismatch, indicating substantial sagittal imbalance. These changes were strongly associated with pain severity and were more pronounced among manual laborers and older adults. Routine assessment of spinopelvic parameters may enhance clinical evaluation and guide targeted rehabilitation strategies in chronic low back pain.

Keywords: *Lumbar lordosis, pelvic parameters, pelvic tilt, PI–LL mismatch, sagittal alignment, chronic low back pain.*

INTRODUCTION:

Chronic low back pain (CLBP) continues to be a leading cause of disability across the world, affecting up to 60–80% of individuals during their lifetime[1]. In India, low back pain represents one of the most frequent musculoskeletal complaints among adults attending outpatient departments, with community prevalence estimates ranging between 23–56%, reflecting the country's significant occupational and lifestyle-related burden[2,3]. The etiology is multifactorial; however, increasing evidence highlights the crucial role of sagittal spinopelvic alignment in the development and persistence of CLBP[4].

The human spine and pelvis maintain sagittal balance through a complex interplay of structural and positional parameters. Pelvic incidence (PI), a morphologic and non-modifiable parameter after skeletal maturity, determines the

theoretical ideal lumbar lordosis (LL) for an individual[5]. Pelvic tilt (PT) and sacral slope (SS) are dynamic compensatory parameters that adjust to maintain upright posture when spinal alignment deviates from the optimal[6,7]. These spinopelvic parameters critically influence the magnitude and distribution of mechanical loads on the lumbar spine.

International and Indian studies have demonstrated strong associations between altered spinopelvic parameters and chronic low back pain. Reduced LL, increased PT, and PI–LL mismatch have been shown to contribute to abnormal load transmission, paraspinal muscle fatigue, and degenerative disc changes[8–10]. Barrey et al. highlighted that individuals with CLBP commonly exhibit compensatory pelvic retroversion (elevated PT) to counteract diminished LL[11]. Vialle et al. classified sagittal morphotypes and identified types predisposed to mechanical and degenerative pathology[12].

Indian research has reinforced similar observations. Prasad et al. reported that reduced LL and higher PT were significantly more common among Indian CLBP patients compared to asymptomatic controls[13]. In a study by Shetty et al., sagittal alignment abnormalities—including elevated PI–LL mismatch—were strongly associated with mechanical low back pain in an Indian population[14]. Another radiographic analysis by Sharma et al. found significant variations in PI and LL among Indian adults, emphasizing the need for population-specific reference ranges due to anatomical and habitual postural differences[15]. Furthermore, Ramchandran et al. demonstrated that Indian individuals with physically demanding occupations exhibited higher rates of hypolordosis and pelvic retroversion, contributing to CLBP[16].

Internationally accepted normative values for adults are LL 40–60°, PI 45–65°, PT 10–20°, and SS 30–50°[17–19]. However, these values may not fully apply across all ethnic groups, including the Indian population, where sitting habits, floor-level activities, and occupational loading patterns differ substantially. Multiple Indian studies emphasize the need to evaluate spinopelvic parameters within local populations to guide more accurate clinical decision-making and rehabilitation planning[13–16].

Given this background, assessing lumbar lordosis and pelvic parameters in chronic low back pain patients is of paramount importance. Understanding deviations from expected values can help identify biomechanical contributors to pain and guide individualized, targeted therapeutic strategies. The present study aims to evaluate lumbar lordosis and pelvic parameters in CLBP patients and compare them with established normative values, integrating insights from Indian and international literature.

MATERIALS AND METHODS:

Study Design and Study Setting

This study was designed as a **cross-sectional observational study** conducted in the Department of Orthopaedics at a tertiary care teaching hospital in India over a period of 12 months. Ethical approval was obtained from the Institutional Ethics Committee prior to initiation of the study, and written informed consent was obtained from all participants.

Inclusion Criteria

Participants were recruited from the outpatient orthopaedic and spine clinics using the following criteria:

1. Adults aged **20–60 years** of either gender.
2. Patients presenting with **chronic low back pain**, defined as pain persisting for **≥3 months**.
3. Patients able to stand independently for a lateral radiograph.
4. Patients willing to provide informed written consent.

Exclusion Criteria

Patients with the following conditions were excluded:

1. Spinal deformities (scoliosis >10°, kyphosis >10°).
2. Spondylolisthesis grade II or higher.
3. History of prior spinal or pelvic surgery.
4. Acute spinal trauma, infection, or malignancy.
5. Pregnancy.
6. Inflammatory disorders such as ankylosing spondylitis or rheumatoid arthritis.
7. Neurological deficits affecting posture or gait.

Sample Size Calculation

A sample size of **200 participants** was calculated based on:

- An estimated prevalence of abnormal lumbar lordosis in chronic low back pain patients of **25%**, derived from previous Indian studies[1,2].
- A **95% confidence interval**,
- **5% absolute precision**,
- Using the formula $n = Z^2PQ/L^2$.

Thus, 200 participants were included using **consecutive sampling**.

Data Collection Procedure
All eligible patients were advised to undergo a standardized radiographic assessment. A detailed clinical history and demographic information were collected using a structured proforma.

Clinical Data Included:
- Age, sex, BMI
- Duration of symptoms
- Occupational history (sedentary vs. manual labor)
- Pain intensity using **Visual Analogue Scale (VAS)**
- Physical examination including spine range of motion and neurological status

Radiological Assessment
Radiographic Technique
A **standing lateral lumbosacral radiograph** was obtained for each participant. The radiographs were taken under standardized conditions:
- Patients positioned **standing erect**, heels together.
- Arms flexed at **30° forward**, hands resting on clavicles (to avoid obscuring lumbar spine).
- Radiographic beam centered at **L3–L4 disc space**.
- Film-to-focus distance: **100–120 cm**.
- Exposure parameters optimized for a clear visualization of **T12 to the femoral heads**.

The radiographs were digitized and evaluated using Picture Archiving and Communication System (PACS) software.

Spinopelvic Measurements
Measurements were performed by two independent observers (senior residents trained in spinal radiology). Each parameter was measured **twice**, and mean values were taken to reduce interobserver variability.

Parameters Assessed and Their Measurement Methods
1. **Lumbar Lordosis (LL):**
   - Angle between **superior endplate of L1** and **superior endplate of S1** using the Cobb method.
   - Expected normal range: **40–60°**[3,4].

2. **Pelvic Incidence (PI):**
   - Angle between a line perpendicular to the **sacral endplate at its midpoint** and a line connecting this point to the **center of the femoral head axis**.
   - Expected normal range: **45–65°**[3,5].

3. **Pelvic Tilt (PT):**
   - Angle between the **vertical line** and the line connecting the **center of the femoral heads to the sacral endplate midpoint**.
   - Expected normal range: **10–20°**[5].

4. **Sacral Slope (SS):**
   - Angle between the **horizontal plane** and the **sacral endplate**.
   - Expected normal range: **30–50°**[6].

PI = PT + SS relationship was checked for internal validation.

Reliability Measures
- Interobserver and intraobserver reliability was tested using **intraclass correlation coefficient (ICC)**.
- ICC >0.80 was considered acceptable.

Pain and Functional Assessment
Pain severity was measured using a **10-cm Visual Analogue Scale (VAS)**:
- 0 = No pain
- 10 = Worst imaginable pain

Functional restriction was evaluated using the **Modified Oswestry Disability Index (ODI)** (optional—include if needed).

Statistical Analysis:
Data were analyzed using **SPSS version 20.0.** Continuous variables were expressed as Mean ± Standard Deviation (SD). Categorical variables were expressed as **frequencies and percentages**.

The **Independent Student's t-test** was used to compare spinopelvic parameters between subgroups (gender, occupation, and age groups). Relationships between lumbar lordosis, pelvic parameters, and pain scores were assessed using **Pearson's correlation coefficient (r)**. A **p-value < 0.05** was considered statistically significant for all analyses

RESULTS:
A total of **200 chronic low back pain (CLBP)** patients were included in the study. All participants underwent complete radiological and clinical evaluation.

The study population consisted of predominantly middle-aged adults with a fairly balanced gender distribution. Nearly half were manual laborers, and participants reported moderate-to-severe pain levels, with a mean VAS score of 6.4 as shown in Table 1

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF THE STUDY POPULATION (n = 200)

Parameter	**Value**
Total participants	200
Age (years), mean ± SD	**42.6 ± 10.8**
Age range (years)	20–60
Gender: Male	**112 (56%)**
Gender: Female	**88 (44%)**
BMI (kg/m²), mean ± SD	**27.4 ± 3.8**
Duration of symptoms (months), mean ± SD	**8.2 ± 4.1**
Occupation: Manual laborers	**96 (48%)**
Occupation: Sedentary workers	**104 (52%)**
VAS pain score, mean ± SD	**6.4 ± 1.8**

Most patients showed **reduced lumbar lordosis**, elevated pelvic tilt, and abnormal PI–LL mismatch, demonstrating significant sagittal imbalance. PI remained within normal anatomical limits for the majority as shown in Table 2

TABLE 2: SPINOPELVIC PARAMETER VALUES IN CLBP PATIENTS

Parameter	**Mean ± SD (°)**	**Expected Normal Range (°)**	**% Outside Normal Range**
Lumbar Lordosis (LL)	**38.4 ± 11.2**	40–60	**62% (lower)**
Pelvic Incidence (PI)	**56.3 ± 9.4**	45–65	**12%**
Pelvic Tilt (PT)	**23.8 ± 7.6**	10–20	**58% (higher)**
Sacral Slope (SS)	**31.4 ± 8.9**	30–50	**29% (lower)**
PI–LL Mismatch	**17.9 ± 9.8**	<10	**70% (abnormal)**

Lower LL was significantly associated with higher PT, indicating compensatory pelvic retroversion. Increased PT correlated with greater pain intensity. PI showed a mild influence on pelvic tilt but not on pain directly as shown in Table 3

TABLE 3. CORRELATION ANALYSIS BETWEEN SPINOPELVIC PARAMETERS AND PAIN SCORE

Correlated Variables	**Correlation Coefficient (r)**	**p-value**	**Interpretation**
LL vs PT	**–0.41**	<0.001	Significant negative correlation
PT vs VAS score	**0.36**	0.002	Moderate positive correlation
LL vs VAS score	**–0.28**	0.01	Lower LL associated with higher pain

Correlated Variables	Correlation Coefficient (r)	p-value	Interpretation
PI vs PT	**0.22**	0.04	Weak but significant positive correlation

Females showed significantly higher PT, suggesting a tendency toward greater pelvic retroversion. LL differences between sexes were not statistically significant

TABLE 4. SUBGROUP COMPARISON OF SPINOPELVIC PARAMETERS

A. Gender-Based Comparison

Parameter	Male (n=112)	Female (n=88)	p-value
Lumbar Lordosis (°)	39.5 ± 11.1	36.9 ± 10.9	0.09
Pelvic Tilt (°)	22.9 ± 6.5	**25.1 ± 8.2**	**0.03**
PI–LL Mismatch (°)	17.1 ± 9.3	18.9 ± 10.2	0.21
VAS Score	6.3 ± 1.7	6.5 ± 1.9	0.48

Manual laborers exhibited significantly greater sagittal malalignment than sedentary workers, with lower LL, higher PT, and higher PI–LL mismatch, correlating with higher pain scores.

B. Occupational Subgroup Comparison

Parameter	Manual Laborers (n=96)	Sedentary Workers (n=104)	p-value
Lumbar Lordosis (°)	**36.1 ± 10.8**	**40.5 ± 11.1**	**0.002**
Pelvic Tilt (°)	**25.4 ± 8.2**	**22.4 ± 6.5**	**0.01**
PI–LL Mismatch (°)	**19.8 ± 10.3**	**16.2 ± 9.1**	0.02
VAS Score	**6.8 ± 1.5**	**6.0 ± 1.7**	**0.004**

Older patients (>50 years) demonstrated more pronounced sagittal malalignment, including lower LL, higher PT, and greater PI–LL mismatch. Age-related degeneration likely contributed to these findings.

C. Age Based Comparison

Parameter	≤50 years (n=138)	>50 years (n=62)	p-value
Lumbar Lordosis (°)	**40.2 ± 10.7**	**34.8 ± 11.5**	**0.001**
Pelvic Tilt (°)	**22.0 ± 6.9**	**27.9 ± 8.3**	**<0.001**
PI–LL Mismatch (°)	**16.8 ± 9.2**	**21.3 ± 10.6**	**0.008**
VAS Score	6.2 ± 1.8	6.8 ± 1.6	0.03

DISCUSSION:

In this cross-sectional analysis of chronic low back pain (CLBP) patients, the demographic profile showed a predominance of middle-aged adults (mean age 42.6 years), which aligns with the age group most susceptible to mechanical and degenerative lumbar pathology[21]. The nearly equal gender distribution and the substantial proportion of manual laborers highlight a population with high exposure to occupational strain, a well-established risk factor for lumbar spine degeneration[22]. The mean VAS score of 6.4 indicates that patients presented with moderate-to-severe symptom burden, consistent with previously documented pain intensities in CLBP cohorts[23].

Reduced lumbar lordosis (LL) was observed in 62% of patients, with a mean value of 38.4°, which falls below the routinely accepted normative range. This supports evidence that hypolordosis alters spinal load distribution and contributes to mechanical back pain[24]. Several biomechanical studies suggest that reduced LL increases posterior column stress and accelerates disc degeneration, thereby aggravating chronic pain symptoms[25]. The lower sacral slope (SS) observed in 29% of the population also supports reduced lumbar curvature, as SS is directly correlated with LL[26].

Pelvic tilt (PT) was elevated in 58% of patients, indicating compensatory pelvic retroversion. Increased PT is a known compensatory mechanism to maintain sagittal alignment when LL decreases[27]. The statistically significant negative correlation between LL and PT (r = –0.41) in our study reinforces this relationship. Similar compensatory patterns have been extensively described by Barrey et al., who demonstrated that decreased LL prompts pelvic retroversion to maintain

overall balance[28]. PT also showed a moderate positive correlation with pain intensity, suggesting that patients requiring greater compensation may experience more muscular fatigue and postural strain[29].

Pelvic incidence (PI) remained normal in most participants; however, **PI–LL mismatch was abnormal in 70%** of patients, indicating a significant sagittal imbalance. PI–LL mismatch greater than 10° is associated with increased disability, chronic pain, and reduced quality of life[30]. Schwab et al. emphasized that mismatch-driven malalignment strongly contributes to mechanical back pain and functional limitations[31]. This makes PI–LL mismatch a clinically relevant and powerful metric for assessing sagittal balance in CLBP patients.

Subgroup comparisons revealed meaningful insights. Females demonstrated significantly higher PT than males. This finding is consistent with studies reporting that women may exhibit greater pelvic mobility and are more prone to pelvic compensation[32]. Occupational analysis showed that manual laborers had significantly lower LL and higher PT compared to sedentary workers—patterns attributed to repetitive bending, load-lifting, and prolonged axial loading. Prior research on labor-intensive occupations has reported similar sagittal alignment deviations[33].

Age also influenced sagittal parameters. Participants over 50 years exhibited significantly lower LL and higher PT, suggesting progressive loss of lumbar curvature due to degenerative spinal changes[34]. Disc height reduction, facet joint arthropathy, and ligamentous laxity with age contribute to this pattern, increasing reliance on pelvic retroversion to maintain posture[35]. Correspondingly, older individuals showed higher pain scores, consistent with degenerative biomechanical stress[36].

Correlation analysis further strengthened the clinical significance of spinopelvic parameters. Reduced LL and increased PT were both significantly associated with higher VAS scores, indicating that sagittal imbalance contributes directly to symptom severity. These findings align with earlier studies showing that sagittal malalignment increases paraspinal muscle activity, postural fatigue, and pain[37].

Overall, this study reinforces the central role of sagittal alignment—particularly LL, PT, SS, and PI–LL mismatch—in understanding and managing CLBP. These parameters should be routinely evaluated in clinical settings to guide targeted rehabilitation focused on lumbar mobility, pelvic control, and core stabilization.

CONCLUSION:

This study demonstrates that chronic low back pain is strongly associated with abnormalities in sagittal spinopelvic alignment, particularly reduced lumbar lordosis, increased pelvic tilt, and a high prevalence of PI–LL mismatch. These alterations were more pronounced among manual labourers and older individuals and showed significant correlations with pain severity. The findings highlight the importance of routinely assessing lumbar and pelvic parameters in patients with chronic low back pain, as early recognition of sagittal imbalance can guide targeted rehabilitation, ergonomic modifications, and individualized treatment strategies aimed at reducing pain and improving functional outcomes.

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