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Original Research Article

PELVIC INCIDENCE AND LUMBAR DISC DEGENERATION: A RETROSPECTIVE STUDY

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ABSTRACT

Background: Sagittal spinopelvic alignment influences biomechanical load distribution across the lumbosacral spine. Data correlating these parameters with graded intervertebral disc degeneration in the Indian population remain limited. **Objectives:** To compare spinopelvic parameters between patients with intervertebral disc degeneration (IDD) and asymptomatic controls and assess their association with MRI-based Pfirrmann grades.

Materials and Methods: This retrospective cross-sectional study included 70 patients with MRI-confirmed IDD and 70 asymptomatic controls. Standing lateral radiographs were used to measure pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), lumbosacral angle (LSA), and sacral inclination angle (SIA). Disc degeneration was graded on MRI using the Pfirrmann classification. Group comparisons, correlation analysis, multivariable regression, and receiver operating characteristic (ROC) analysis were performed.

Results: Mean PI was higher in cases than controls (50.35° ± 5.48° vs 46.72° ± 5.62°, p=0.0002). SS was also higher in cases (38.19° vs 37.17°, p=0.031). PI increased with Pfirrmann grade and showed a positive correlation with degeneration severity (r=0.287, p=0.0158). ROC analysis showed the highest discriminative performance for PI (AUC 0.684; cutoff >48.5°). In multivariable analysis, PI was the only independent predictor of degeneration severity (β=0.284, p=0.0017) and was independently associated with IDD presence (OR 1.062 per degree, p=0.0032).

Conclusions: Higher PI is associated with the presence and severity of lumbar intervertebral disc degeneration. Its modest discriminative performance supports an adjunctive role in radiographic risk stratification, not standalone diagnosis.

Keywords: Pelvic Incidence; Intervertebral Disc Degeneration; Spine; Magnetic Resonance Imaging; Low Back Pain.

INTRODUCTION

Intervertebral disc degeneration (IDD) is a common structural abnormality of the lumbar spine and an important contributor to chronic low-back pain and disability. Although degeneration is often interpreted primarily from magnetic resonance imaging (MRI) morphology, the mechanical environment in which the lumbar discs function is also relevant. The pelvis and lumbar spine form an integrated sagittal system in which pelvic morphology, pelvic orientation and lumbar curvature interact to maintain an economical upright posture.[1-4]

Pelvic incidence (PI) is a morphological parameter defined by the geometry between the sacral endplate and the centre of the femoral heads. Unlike positional parameters such as sacral slope (SS) and pelvic tilt (PT), PI is considered relatively fixed after skeletal maturity.[1,2] This distinction is important when interpreting degenerative disease: an elevated PI is more appropriately considered a pre-existing anatomical configuration that may influence mechanical loading, rather than a

parameter that simply changes as a consequence of disc degeneration.

The relationship between sagittal alignment and degenerative spinal disease has been examined in asymptomatic populations, lumbar disc lesions, degenerative spondylolisthesis and adult spinal deformity.[3-10] A larger PI is generally accompanied by greater lumbar lordosis and an altered sacral orientation to preserve sagittal balance.[5,9,10] In pathological states, compensatory changes in PT and other alignment variables may develop as the spine adapts to altered disc height and curvature.[7-11] These relationships are clinically relevant because the same parameters are routinely considered during radiographic assessment and, in selected patients, during planning of spinal surgery.

MRI remains the principal modality for characterising disc degeneration because it directly demonstrates changes in disc signal, structure and height. The Pfirrmann classification provides a widely used five-grade morphological system based on disc signal intensity, structure, distinction between nucleus pulposus and annulus fibrosus, and disc height.[13,10] However, degenerative MRI findings can also be present in asymptomatic individuals, making the clinical interpretation of morphology dependent on the wider clinical and biomechanical context.[16]

Several studies have reported differences in spinopelvic parameters between patients with degenerative lumbar conditions and asymptomatic subjects, but findings are not uniform across populations or disease phenotypes.[3,5,14,18-22] Indian data remain comparatively limited, and there is particular value in establishing locally derived reference measurements because pelvic morphology and sagittal alignment can vary among populations.[11,19,22]

The practical question is whether a parameter that can be measured on a routine standing lateral radiograph is associated not only with the presence of IDD but also with its MRI-assessed severity. A simple radiographic association would not replace MRI, but could provide additional risk stratification in patients with chronic low-back pain and could help contextualise degenerative findings. The present study therefore compared six spinopelvic parameters—PI, SS, PT, lumbar lordosis (LL), lumbosacral angle (LSA) and sacral inclination angle (SIA)—between patients with MRI-confirmed IDD and asymptomatic controls, assessed their relationship with Pfirrmann grade, and evaluated their diagnostic performance.

MATERIALS AND METHODS

Study design and setting

This was a hospital-based retrospective cross-sectional observational study conducted in the Department of Radiodiagnosis, Dr. Kamakshi Institute of Medical Sciences and Research Centre, Chennai, Tamil Nadu, over 12 months from January to December 2024. Imaging examinations had been performed as part of routine clinical care and were subsequently reviewed from the hospital picture archiving and communication system. No additional imaging or radiation exposure was undertaken solely for the study.

Participants

The study included 140 adults: 70 cases with chronic low-back pain of at least three months and MRI-confirmed intervertebral disc degeneration, and 70 asymptomatic controls. Controls had no history of chronic low-back pain and had undergone MRI for another clinical indication, with no disc degeneration identified on the reviewed examination. Participants were aged 18 years or older. Subjects were excluded if they had spinal trauma, spinal infection, spondylolisthesis, congenital or acquired spinal deformity, previous spinal surgery, seronegative spondyloarthropathy or pregnancy-related spinal problems. The sample size of 70 participants per group was derived using p=3%, absolute error=4% and Zα/2=1.96.

Radiographic assessment

Standing lateral lumbosacral radiographs were reviewed for measurement of PI, SS, PT, LL, LSA and SIA. Measurements were performed digitally using Surgimap or dedicated spine-measurement software to standardise landmark placement and angle calculation. PI was defined as the angle between a line perpendicular to the midpoint of the superior S1 endplate and a line joining that point to the centre of the femoral heads. SS was measured as the angle between the superior S1 endplate and the horizontal reference. PT was calculated from PI and SS. LL was measured as the Cobb angle between the superior endplate of L1 and the inferior endplate of L5. LSA was defined by the relationship of the L5 inferior and S1 superior endplates, while SIA represented the orientation of the posterior S1 border relative to the vertical reference.[1,2,10]

MRI assessment and Pfirrmann grading

Lumbar MRI examinations had been acquired at 1.5-T or 3-T field strength using sagittal T1- and T2-weighted sequences and axial T2-weighted sequences, with slice thickness of 3 mm or less. Disc degeneration was graded on sagittal T2-weighted images using the Pfirrmann five-grade classification.[13] Grade I represents a homogeneous bright disc with preserved structure and height, whereas progressively higher grades reflect increasing heterogeneity, loss of distinction between the nucleus pulposus and annulus fibrosus, and disc-space narrowing, with Grade V representing advanced collapse. The analysed cases comprised symptomatic degenerative discs graded III–V. Because degeneration was assessed at individual disc levels and patients could have multilevel involvement, disc-level counts are reported separately from the patient-level case-control analysis.

Ethical considerations

The study was approved by the Institutional Ethics Committee. Although the imaging examinations had already been performed for clinical care, informed consent for use of identifiable imaging data was obtained in accordance with the institutional protocol. Data were anonymised before analysis, and no additional imaging was performed for research purposes.

Statistical analysis

Statistical analysis was performed using SPSS version 24.0. Continuous variables were summarised as mean ± standard deviation or median with interquartile range, as appropriate; categorical variables were expressed as frequencies and percentages. Distributional assumptions were assessed using the Shapiro–Wilk test. Independent-samples t-tests or Mann–Whitney U tests were used for two-group comparisons, while one-way analysis of variance (ANOVA) or Kruskal–Wallis testing was used for comparisons across Pfirrmann grades. Pearson or Spearman correlation was used to assess associations between spinopelvic parameters and Pfirrmann grade. Multiple linear regression was used to identify independent predictors of degeneration severity, and binary logistic regression was used to evaluate associations with the presence of IDD. Receiver operating characteristic (ROC) analysis was performed to estimate discriminative performance and identify optimal thresholds. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), area under the curve (AUC) and Youden index were calculated where applicable. All tests were two-tailed and $p<0.05$ was considered statistically significant.

RESULTS

Demographic characteristics

The study comprised 70 cases and 70 controls. Mean age was 45.3 ± 15.2 years among cases and 40.7 ± 14.8 years among controls; the difference was not statistically significant (p=0.068). Each group contained 35 men and 35 women. Mean age did not differ significantly between male and female participants within either group.

Table 1:Comparison of demographic characteristics and spinopelvic parameters between cases and controls

Variable	Cases (n=70)	Controls (n=70)	p-value
Age, mean ± SD (years)	45.3 ± 15.2	40.7 ± 14.8	0.068
Male:Female	35:35	35:35	—
PI (°)	50.35 ± 5.48	46.72 ± 5.62	0.0002*
SS (°)	38.19 ± 2.89	37.17 ± 3.12	0.0314*
PT (°)	12.16 ± 6.12	10.52 ± 6.54	0.1169
LL (°)	47.51 ± 7.58	45.08 ± 7.02	0.0570
SIA (°)	44.56 ± 7.38	46.41 ± 8.71	0.1869
LSA (°)	14.27 ± 6.98	14.19 ± 7.29	0.9474

*Statistically significant at p<0.05. SD, standard deviation; PI, pelvic incidence; SS, sacral slope; PT, pelvic tilt; LL, lumbar lordosis; SIA, sacral inclination angle; LSA, lumbosacral angle.

Case-control comparison of spinopelvic parameters

PI was significantly higher in cases than controls, with a mean difference of 3.63° (50.35 ± 5.48° vs 46.72 ± 5.62°, p=0.0002). SS was also higher in cases (38.19 ± 2.89° vs 37.17 ± 3.12°, p=0.0314). PT was higher in cases but did not reach statistical significance (12.16 ± 6.12° vs 10.52 ± 6.54°, p=0.1169). LL showed a higher mean in cases with a borderline difference (47.51 ± 7.58° vs 45.08 ± 7.02°, p=0.0570). SIA and LSA did not differ significantly between groups.

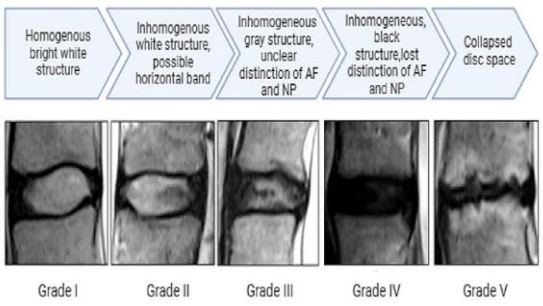


Figure 1

Pfirrmann Grades I–V on sagittal T2-weighted MRI, illustrating progressive loss of signal homogeneity, internal disc structure and disc height.

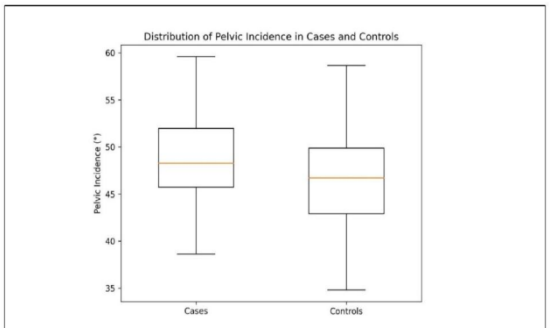


Figure 2

Box-and-whisker plot showing higher pelvic incidence values among patients with intervertebral disc degeneration than among asymptomatic controls.

Distribution across Pfirrmann grades

Across the evaluated L4–L5 and L5–S1 disc levels, 37 disc-level observations were Grade III, 59 were Grade IV and 44 were Grade V. Grade I and II discs were not represented among the symptomatic

degenerative cases because the study population was restricted to clinically relevant IDD of Grade III or above. The grade counts are disc-level observations; individual patients could contribute more than one degenerated level.

Table 2: Spinopelvic parameters across Pfirrmann grades III–V

Parameter	Grade III	Grade IV	Grade V	p-value
PI (°)	48.36 ± 5.21	50.82 ± 5.34	51.24 ± 5.68	0.0156*
SS (°)	38.41 ± 2.75	38.05 ± 3.02	38.11 ± 2.96	0.6734
PT (°)	9.96 ± 5.38	12.77 ± 6.14	13.13 ± 6.48	0.0289*
LL (°)	47.16 ± 7.42	47.65 ± 7.68	47.59 ± 7.64	0.8901
SIA (°)	44.27 ± 7.31	44.73 ± 7.45	44.68 ± 7.41	0.9156
LSA (°)	13.92 ± 6.71	14.48 ± 7.08	14.36 ± 7.19	0.8434

*p<0.05 by one-way ANOVA. Values are mean ± SD. Grade categories refer to disc-level observations.

PI increased progressively from Grade III to Grade V (48.36 ± 5.21°, 50.82 ± 5.34° and 51.24 ± 5.68°, respectively; p=0.0156). PT also increased across the same grades (9.96 ± 5.38°, 12.77 ± 6.14° and 13.13 ± 6.48°; p=0.0289). SS, LL, SIA and LSA did not show statistically significant differences across grades.

Table 3: Correlation and diagnostic performance of selected spinopelvic parameters

Parameter	Correlation r	p-value	AUC	Optimal cut-off
PI	0.287	0.0158*	0.684	>48.5°
PT	0.253	0.0340*	0.608	>11.5°
SS	−0.052	0.6673	0.575	>37.8°
LL	0.031	0.7874	0.571	>46.2°

*Statistically significant at p<0.05. AUC, area under the receiver operating characteristic curve.

Correlation, ROC and regression analyses

PI showed a weak positive correlation with Pfirrmann grade (r=0.287, p=0.0158). PT also showed a weak positive correlation (r=0.253, p=0.0340), whereas SS and LL were not significantly correlated with grade. PI demonstrated the highest discriminative performance in ROC analysis (AUC 0.684; 95% CI 0.583–0.785) with an optimal threshold of >48.5°. At this threshold, sensitivity was 72.9%, specificity 65.7%, PPV 68.4% and NPV 70.4%. The corresponding AUCs for PT, SS and LL were 0.608, 0.575 and 0.571, respectively.

The spinopelvic variables also demonstrated expected internal relationships. PI and PT were positively correlated (r=0.614, p<0.0001), while SS and PT were inversely correlated (r=−0.714, p<0.0001), consistent with the relationship PT=PI−SS used in the measurement framework. PI and SS were positively correlated (r=0.312, p=0.0082). No statistically significant gender-based difference was identified for any measured parameter in either cases or controls.

Table 4: Multivariable regression analyses for IDD severity and presence

Model / parameter	Effect estimate	95% CI	p-value
Linear regression: PI	β=0.284	0.108–0.460	0.0017*
Linear regression: SS	β=0.216	−0.064–0.496	0.1283
Linear regression: PT	β=0.102	−0.019–0.223	0.0980
Linear regression: LL	β=0.085	−0.020–0.190	0.1120
Logistic regression: PI (per 1°)	OR=1.062	1.020–1.106	0.0032*
Logistic regression: SS (per 1°)	OR=1.041	0.982–1.103	0.1843
Logistic regression: PT (per 1°)	OR=1.038	1.005–1.072	0.0224*
Logistic regression: LL (per 1°)	OR=1.031	1.000–1.062	0.0496*

*Statistically significant. CI, confidence interval; OR, odds ratio. PI was the only independent predictor retained in the linear model for degeneration severity; PI, PT and LL were associated with the binary presence of IDD in logistic regression.

In multiple linear regression, PI was the only parameter that independently predicted degeneration severity (β=0.284, 95% CI 0.108–0.460, p=0.0017), with the model reported to explain approximately 28.7% of the variance in severity. In binary logistic regression assessing the presence of IDD, PI was associated with increased odds per degree (OR 1.062, 95% CI 1.020–1.106, p=0.0032); PT (OR 1.038, p=0.0224) and LL (OR 1.031, p=0.0496) also showed statistically significant associations, whereas SS did not (p=0.1843).

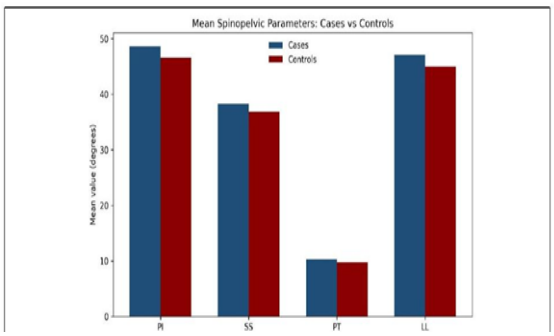


Figure 3

Mean pelvic incidence, sacral slope, pelvic tilt and lumbar lordosis were higher in cases than controls, with the clearest between-group differences for PI and SS.

DISCUSSION

The principal finding of this study was that PI was consistently associated with lumbar intervertebral disc degeneration across several analytical approaches. Cases had a significantly higher mean PI than asymptomatic controls, PI increased across Pfirrmann grades III–V, PI correlated positively with degeneration severity, and PI remained independently associated with both severity and the binary presence of IDD in multivariable models. Among the six evaluated spinopelvic parameters, PI therefore showed the most reproducible relationship with degenerative disease.

This finding is biologically plausible because PI represents an anatomical feature of the pelvis that remains relatively constant after skeletal maturity.[1,2] A larger PI alters the geometry required to maintain an upright sagittal posture and is generally associated with a greater requirement for lumbar lordosis and an altered orientation of the sacrum.[5,7,9,10] The resulting distribution of shear and compressive forces across the lumbosacral junction may increase mechanical demand on the lower lumbar motion segments. Previous work has linked spinopelvic morphology, including PI, with lumbar disc lesions and degenerative lumbar disorders, supporting the interpretation of PI as a marker of biomechanical predisposition rather than a purely secondary change.[3,5,14,21,22]

The grade-wise results provide an additional dimension to the case-control comparison. PI rose from 48.36° in Grade III to 51.24° in Grade V, with a statistically significant trend across the analysed disc-level observations. This pattern suggests that higher PI is not merely associated with the presence of degeneration but is also related to increasing morphological severity. Nevertheless, the magnitude of the correlation was modest (r=0.287). The association should therefore be interpreted as one component of a multifactorial degenerative process rather than evidence that PI alone determines disease progression.

PT showed a different but complementary pattern. PT increased across Pfirrmann grades and had a weak positive correlation with grade, but the case-control comparison did not reach statistical significance. PT is a positional parameter that reflects pelvic retroversion and can change in response to sagittal imbalance.[7,8,11] Its increase with more advanced degeneration may therefore represent a compensatory response to altered spinal mechanics rather than a fixed anatomical predisposition. The strong positive relationship between PI and PT and the inverse relationship between SS and PT in the present dataset are consistent with the established geometrical relationship among these parameters.

SS was significantly higher in cases than controls, but it did not show a meaningful association with Pfirrmann grade. Similarly, LL was higher in cases with a borderline case-control difference and was not correlated with grade. These findings emphasise the distinction between parameters that describe fixed morphology and those that are influenced by posture and compensatory mechanisms. Because SS, PT and LL interact with PI to maintain sagittal balance, their isolated associations may be weaker or less consistent than the association of PI itself.[5,7,9,10]

LSA and SIA showed no significant case-control difference or meaningful grade-wise relationship. These parameters describe more local aspects of lumbosacral orientation and may be more informative in selected pathologies, such as spondylolisthesis or focal segmental deformity, than in generalized degenerative disc disease. The absence of a strong association in this cohort should not be interpreted as evidence that these parameters are clinically irrelevant in other disorders.

The asymptomatic control values provide a useful internal reference for this cohort. Mean PI, SS, PT and LL were 46.72°, 37.17°, 10.52° and 45.08°, respectively. These values are broadly comparable with published radiographic studies of asymptomatic adults and Indian populations.[4,6,11,19] The use of an asymptomatic hospital-based control group is a strength in that measurements were obtained within the same institutional imaging environment, but it also limits generalisability to a community population.

ROC analysis demonstrated that PI had the highest AUC among the evaluated parameters, but the value of 0.684 indicates only modest or fair discrimination. The threshold of >48.5° yielded a sensitivity of 72.9% and specificity of 65.7% in this sample. These figures are insufficient to support PI as a standalone diagnostic test. Instead, PI may be considered an adjunctive radiographic risk-stratification parameter. In settings where standing radiographs are readily available but MRI access is constrained, such information may be useful in deciding which patients warrant further imaging, but clinical assessment and MRI remain necessary for diagnosis and characterisation of IDD.

The regression findings reinforce this cautious interpretation. PI was the only independent predictor in the linear model of severity, whereas PI, PT and LL were associated with the binary presence of IDD. The difference between the two models is not contradictory: they address different outcomes. A parameter can contribute to separating degenerative from non-degenerative subjects while not independently explaining variation in severity after adjustment for correlated variables. The reported odds ratio for PI corresponds to a 6.2% increase in the odds of IDD for each one-degree increase in PI, within the model and study population; this should not be interpreted as a causal effect.

The study also highlights an important methodological consideration in research on degenerative disc disease. Pfirrmann grading is performed at the disc level, whereas the principal case-control comparison is patient based. Multilevel degeneration is common, and individual patients may therefore contribute more than one degenerated disc. The present study reports the available disc-level grade counts and patient-level spinopelvic comparisons separately. Future studies should prespecify the patient-level method used to derive a single severity outcome from multilevel disc findings—for example, a predefined index level, maximum grade, or composite score—and should account statistically for clustering when multiple discs per patient are analysed.

Taken together, the findings support a biomechanical association between pelvic morphology and lumbar disc degeneration but do not establish temporal sequence or causality. PI is unlikely to be a modifiable cause of degeneration; rather, it may identify an anatomical configuration associated with increased mechanical susceptibility. Prospective longitudinal studies integrating PI with age, body mass index, occupational loading, physical activity, smoking, clinical pain scores, disability indices and segment-specific MRI findings would better determine the independent contribution of spinopelvic morphology to disease onset and progression.

Limitations

This study has several limitations. First, its retrospective, single-centre and cross-sectional design prevents determination of whether the observed alignment differences precede degeneration or develop concurrently with it. Second, the controls were hospital-based rather than community-based, which may introduce selection bias. Third, formal interobserver and intraobserver reliability analysis for the Surgimap measurements was not performed. Fourth, potentially important confounders such as body mass index, occupation, physical activity, smoking and comorbidities were not systematically available for analysis. Fifth, pain intensity and functional disability scores were not incorporated, so the relationship between radiographic parameters and patient-reported clinical severity cannot be assessed. Finally, the use of disc-level Pfirrmann grades in a cohort with possible multilevel involvement requires careful specification of the patient-level severity outcome in future analyses.

CONCLUSION

Pelvic incidence was significantly higher in patients with MRI-confirmed lumbar intervertebral disc degeneration than in asymptomatic controls and increased across Pfirrmann grades III–V. PI showed the strongest correlation and the highest discriminative performance among the evaluated spinopelvic parameters and remained independently associated with IDD in multivariable analysis. However, its AUC of 0.684 demonstrates only modest diagnostic discrimination. PI should therefore be regarded as an adjunctive radiographic risk-stratification parameter rather than a standalone diagnostic test. Larger prospective multicentre studies incorporating clinical outcomes and standardised patient-level severity definitions are warranted.

Declarations

Ethics approval and consent to participate: The study was approved by the Institutional Ethics Committee. Informed consent for use of identifiable imaging data was obtained in accordance with the institutional protocol, and all data were anonymised before analysis.

Consent for publication: Not applicable to anonymised retrospective aggregate data.

Competing interests: None declared.

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Authors' contributions: The authors contributed to the study conception, imaging review, analysis, interpretation and manuscript preparation.

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