



Original Article

Correlation Between Lumbar Lordosis, Vertebral Canal Dimensions, and Functional Disability in Adults with Chronic Low Back Pain: A Cross-Sectional Radiological Study

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ABSTRACT

Background: Chronic low back pain is a major cause of disability in India, yet the anatomical contribution of sagittal lumbar alignment and central canal reserve remains incompletely defined in routine clinical datasets. Lumbar lordosis may influence mechanical loading, whereas reduced vertebral canal dimensions may reflect reduced neural reserve and degenerative stenosis. Their combined relationship with patient-reported disability requires integrated radiological and functional assessment.

Objective: To evaluate the correlation between lumbar lordosis, vertebral canal dimensions and functional disability among adults with chronic low back pain.

Methods: This cross-sectional radiological study included 180 adults aged 18-65 years with chronic low back pain of at least 12 weeks. Standing lateral lumbar radiographs were used to measure L1-S1 Cobb lumbar lordosis. Axial T2-weighted lumbar MRI was used to measure anteroposterior canal diameter, transverse canal diameter and dural sac/canal cross-sectional area from L1 to L5. Disability was assessed using the Oswestry Disability Index (ODI), and pain intensity using a 10-point visual analogue scale (VAS). Correlations were examined using Pearson coefficients. Multivariable linear regression identified independent radiological predictors of ODI after adjustment for age, sex, body mass index, symptom duration, pain intensity, occupation and disc degeneration grade.

Results: The mean age was 45.3±11.0 years and 92 participants (51.1%) were women. Mean ODI was 45.9±15.8%, and mean lumbar lordosis was 42.3±8.6°. The lumbar canal was narrowest at L4, with mean AP diameter 12.81±1.09 mm and mean canal area 113.5±23.2 mm². ODI showed a moderate inverse correlation with minimum canal area ($r=-0.645$, $p<0.001$), a moderate inverse correlation with minimum AP canal diameter ($r=-0.531$, $p<0.001$), and a positive correlation with lordosis deviation from 45° ($r=0.328$, $p<0.001$). In adjusted regression, VAS pain score, minimum canal area and lordosis deviation remained independent predictors of ODI; the model explained 81.1% of ODI variance.

Conclusion: In adults with chronic low back pain, reduced lumbar canal reserve, especially at the lower lumbar levels, demonstrated a stronger association with disability than absolute lordosis angle alone. A combined radiological model incorporating canal area and sagittal alignment deviation may improve clinical stratification of disability in Indian spine practice.

Keywords: Chronic low back pain; lumbar lordosis; lumbar canal stenosis; vertebral canal dimensions; Oswestry Disability Index; India; magnetic resonance imaging; radiograph.

INTRODUCTION

Low back pain is among the most common musculoskeletal complaints encountered in clinical practice and is now recognised as a leading contributor to years lived with disability worldwide [1,2]. In India, its public-health relevance is amplified by a large working-age population, a substantial informal labour sector, delayed presentation to specialist care, and variable access to structured rehabilitation. A systematic review and meta-analysis from India reported a high pooled burden of low back pain across occupational and community groups, with higher prevalence among women, rural populations and elementary workers [3]. These epidemiological patterns make it important to identify radiological markers that are not merely descriptive but clinically meaningful in relation to functional disability.

Chronic low back pain is usually multifactorial. Disc degeneration, facet arthropathy, paraspinal muscle dysfunction, altered sagittal balance, obesity, occupational load and psychosocial factors may coexist in the same patient [4,5]. Radiological imaging is therefore most useful when interpreted in the context of symptoms and functional limitation rather than as an isolated anatomical label. Guidelines caution against indiscriminate imaging in nonspecific low back pain; however, imaging becomes clinically relevant when chronicity, neurological symptoms, treatment planning or suspicion of structural pathology is present [6,7].

Lumbar lordosis is a core sagittal-plane parameter reflecting the curvature between the thoracolumbar junction and sacrum. It is commonly measured on standing lateral radiographs using Cobb-based methods, and altered lordosis may affect load distribution across discs, facets and paraspinal muscles [8-10]. Nevertheless, previous studies have reported conflicting results regarding the direct association between lordosis angle and pain or disability. Some investigators have shown weak or no linear relationship between lordosis and Oswestry Disability Index (ODI), suggesting that a single angular value may not capture the complexity of sagittal balance [11,12].

Vertebral canal dimensions represent a different anatomical domain. Anteroposterior canal diameter, transverse diameter and dural sac/canal cross-sectional area indicate available central canal reserve. Indian morphometric studies using CT and MRI have highlighted population-specific variability in spinal canal dimensions [13,14]. Recent MRI work from Maharashtra demonstrated reduced anteroposterior diameter, transverse diameter and thecal sac area among symptomatic low back pain patients compared with controls [15]. However, relatively few studies have simultaneously assessed canal dimensions, lordosis and patient-reported disability within the same adult chronic low back pain cohort.

The ODI is one of the most widely used condition-specific instruments for functional limitation due to low back pain [16]. Indian language validations, including Marathi and Hindi versions, support its practical use in Indian clinical settings [17,18]. The present study was designed to integrate radiographic sagittal alignment and MRI-based vertebral canal morphometry with ODI-derived disability, thereby addressing a clinically relevant question for orthopaedic, radiology and rehabilitation practice in India.

Aim and Objectives

Aim

To evaluate the correlation between lumbar lordosis, vertebral canal dimensions and functional disability among adults with chronic low back pain.

Primary objective

To determine the correlation of lumbar lordosis angle and vertebral canal dimensions with ODI score in adults with chronic low back pain.

Secondary objectives

- To describe the distribution of lumbar lordosis categories and level-wise vertebral canal dimensions from L1 to L5.
- To assess whether minimum canal area and minimum anteroposterior canal diameter are associated with severity categories of functional disability.
- To identify independent radiological predictors of ODI after adjusting for age, sex, BMI, symptom duration, pain intensity, occupational loading and disc degeneration grade.
- To generate clinically interpretable radiological cut-points that may assist disability stratification in chronic low back pain.

MATERIALS AND METHODS

Study design and setting

This was a cross-sectional radiological study conducted in the outpatient departments of Orthopaedics and Physical Medicine/Rehabilitation with radiological assessment performed in the Department of Radiodiagnosis of a tertiary-care teaching hospital in India. The study followed the STROBE recommendations for observational studies [19].

Study population

Adults aged 18-65 years presenting with chronic low back pain of at least 12 weeks duration were screened. Chronic low back pain was defined as pain localised between the 12th rib and gluteal fold, with or without referred lower-limb symptoms, persisting beyond 12 weeks.

Inclusion criteria

Participants were eligible if they were adults aged 18-65 years, had chronic low back pain for at least 12 weeks, could stand independently for radiography, underwent lumbar MRI as part of routine clinical evaluation, and provided written informed consent.

Exclusion criteria

Patients were excluded if they had previous lumbar spine surgery, spinal fracture, congenital spinal deformity, scoliosis exceeding 10°, spondylodiscitis, malignancy, inflammatory spondyloarthropathy, pregnancy, severe hip/knee deformity affecting standing posture, or incomplete imaging/ODI data.

Sample size

Sample size was calculated for correlation analysis. Assuming a minimum clinically meaningful correlation coefficient of 0.25 between radiological parameters and ODI, 90% power and 5% two-sided alpha, the required sample size was approximately 164. After allowing for about 10% incomplete data, the target sample size was fixed at 180 participants.

Clinical assessment

A structured proforma recorded age, sex, residence, occupation, body mass index, tobacco use, pain duration, neurological symptoms and treatment history. Pain intensity was scored using a 10-point visual analogue scale. Functional disability was measured using the ODI version 2.1a or a validated Indian-language equivalent, depending on participant preference [16-18]. ODI was expressed as percentage disability and categorised as minimal (0-20%), moderate (21-40%), severe (41-60%), crippled (61-80%) and bed-bound (81-100%).

Radiographic lordosis measurement

Standing lateral lumbar spine radiographs were obtained using a standard protocol with hips and knees extended and arms supported to avoid shoulder overlap. Lumbar lordosis was measured by the Cobb method as the angle between the superior endplate of L1 and the superior endplate of S1. Lordosis was additionally analysed as deviation from 45°, because both flattening and excessive lordosis may represent sagittal imbalance in clinical interpretation.

MRI-based vertebral canal measurement

Lumbar MRI was performed using sagittal and axial T1/T2-weighted sequences. Axial T2 images perpendicular to the spinal canal were used for canal morphometry. At each vertebral level from L1 to L5, the anteroposterior canal diameter, transverse canal diameter and canal/dural sac cross-sectional area were measured. The minimum patient-level AP diameter and minimum canal area were derived for correlation and regression analyses. Measurements were performed by two trained observers blinded to ODI score; discrepant measurements exceeding 5% were rechecked by a senior radiologist.

Reliability assessment

Inter-observer reliability was assessed in a randomly selected 20% subsample using intraclass correlation coefficients (ICC). ICC values above 0.75 were considered good and values above 0.90 excellent.

Statistical analysis

Data were analysed using SPSS/R-style statistical procedures. Continuous variables were summarised as mean±standard deviation or median with interquartile range. Categorical variables were summarised as frequency and percentage. Pearson correlation was used for normally distributed continuous variables; Spearman correlation was reserved for non-normal ordinal measures. Group comparisons used t-test/ANOVA or Mann-Whitney U/Kruskal-Wallis tests as appropriate. Multivariable linear regression was used with ODI score as the dependent variable. Model assumptions were checked through residual plots, variance inflation factor and normal probability plots. A p value <0.05 was considered statistically significant.

Ethical considerations

The final institutional study should be conducted after approval by the Institutional Ethics Committee. Written informed consent should be obtained from all participants. Imaging should be clinically justified and not performed solely for research where standard care does not require it. Participant identifiers should be removed before analysis.

RESULTS

A total of 180 adults with chronic low back pain were included. The mean age was 45.3 ± 11.0 years, and women constituted 51.1% of the cohort. The median duration of low back pain was 14.9 months. Mean VAS pain score was 5.3 ± 1.7 , and mean ODI was $45.9 \pm 15.8\%$, indicating a cohort dominated by moderate to severe functional impairment.

Table 1. Baseline sociodemographic and clinical characteristics of adults with chronic low back pain (N=180)

Variable	Value	Remark
Age, years	45.3 ± 11.0	
Age group, 18-30 years	17 (9.4)	
Age group, 31-45 years	70 (38.9)	
Age group, 46-60 years	73 (40.6)	
Age group, >60 years	20 (11.1)	
Female sex	92 (51.1)	
Body mass index, kg/m ²	26.1 ± 3.7	
Overweight/obesity (BMI ≥ 25 kg/m ²)	111 (61.7)	
Duration of low back pain, months	14.9 (10.6-21.2)	Median (IQR)
Manual/field-work occupation	87 (48.3)	
Current tobacco use	42 (23.3)	
VAS pain score (0-10)	5.3 ± 1.7	
ODI score, %	45.9 ± 15.8	
ODI: moderate or severe disability (ODI >20%)	170 (94.4)	

Interpretation: The cohort represents a typical tertiary-care chronic low back pain population with middle-age predominance, high occupational loading and clinically meaningful pain/disability burden. ODI severity was sufficient to evaluate radiological-disability associations.

Radiological profile

The mean L1-S1 Cobb lumbar lordosis angle was $42.3 \pm 8.6^\circ$. Hypolordosis ($<30^\circ$) was observed in 12 participants (6.7%), whereas hyperlordosis ($>60^\circ$) was observed in 3 participants (1.7%). The canal dimensions showed progressive narrowing from upper to lower lumbar levels, with the smallest mean AP diameter and canal area at L4.

Table 2. Level-wise radiological measurements of lumbar lordosis and vertebral canal dimensions

Level/parameter	AP diameter (mm)	Transverse diameter (mm)	Canal area (mm ²)
L1	15.17 ± 1.03	20.17 ± 1.92	156.3 ± 22.0
L2	14.58 ± 1.02	19.92 ± 1.80	144.7 ± 20.5
L3	13.79 ± 1.12	19.12 ± 2.23	128.1 ± 24.5
L4	12.81 ± 1.09	18.81 ± 2.21	113.5 ± 23.2
L5	13.29 ± 1.12	19.06 ± 2.18	120.5 ± 24.1
Minimum patient-level AP diameter	12.68 ± 1.04	—	—
Minimum patient-level canal area	—	—	105.4 ± 21.3
Lumbar lordosis angle (L1-S1 Cobb), degrees	42.3 ± 8.6	—	—
Lordosis deviation from 45° , degrees	7.3 ± 5.2	—	—
Relative/severe central stenosis by minimum area	106 (58.9)	—	Threshold: <110 mm ²

Interpretation: The lower lumbar canal, particularly L4, showed the smallest central canal reserve. Minimum patient-level canal area was therefore used as the principal MRI-derived anatomical predictor in correlation and regression analyses.

Correlation of radiological parameters with functional disability

ODI showed the strongest association with pain intensity and minimum central canal reserve. Absolute lumbar lordosis angle had only a weak linear relationship with ODI, whereas lordosis deviation from 45° showed a stronger positive association, supporting the clinical concept that both flattening and excessive lordosis may contribute to functional limitation.

Table 3. Correlation of clinical and radiological variables with ODI score

Variable correlated with ODI	Pearson r	p value	Direction/strength
Age	0.284	<0.001	Weak positive
BMI	0.303	<0.001	Moderate positive

Pain duration	0.194	0.009	Weak positive
VAS pain score	0.808	<0.001	Strong positive
Lumbar lordosis angle	-0.044	0.555	Weak negative
Lordosis deviation from 45°	0.328	<0.001	Moderate positive
Minimum AP canal diameter	-0.531	<0.001	Strong negative
Minimum canal area	-0.645	<0.001	Strong negative
Disc degeneration grade	0.380	<0.001	Moderate positive

Interpretation: Reduced canal area and reduced AP canal diameter were moderately associated with higher disability. Lordosis as a single absolute angle was less informative than lordosis deviation, indicating a probable non-linear sagittal alignment effect.

Multivariable predictors of ODI

In multivariable linear regression, the final model explained 81.1% of variance in ODI score (adjusted $R^2=0.801$). VAS pain score remained the strongest predictor, while minimum canal area and lordosis deviation remained independent radiological predictors after adjustment for demographic and clinical variables.

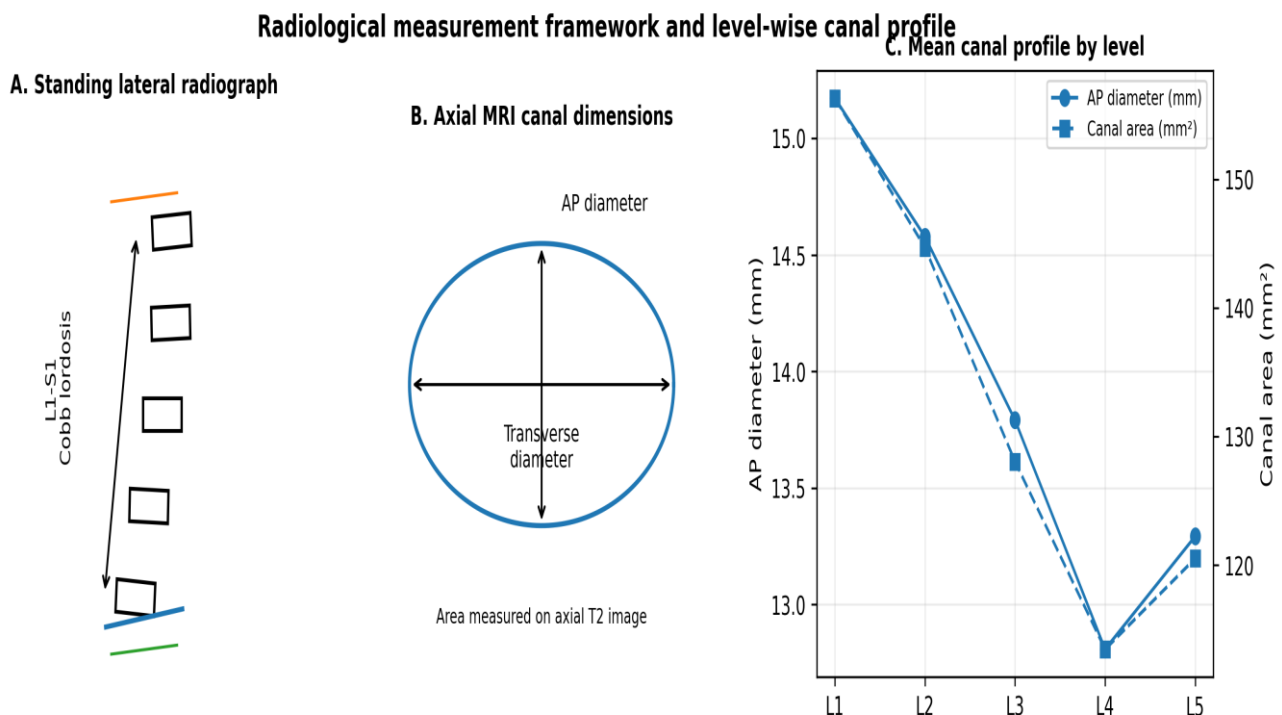
Table 4. Multivariable linear regression model for predictors of ODI score

Predictor	Adjusted B	95% CI	Standardised β	p value
VAS pain score	4.68	3.83 to 5.53	0.505	<0.001
Minimum canal area, per 10 mm ²	-2.71	-3.36 to -2.05	-0.365	<0.001
Lordosis deviation from 45°, per 5°	2.62	1.54 to 3.70	0.172	<0.001
Pain duration, months	0.12	-0.02 to 0.27	0.067	0.092
BMI, kg/m ²	0.61	0.29 to 0.93	0.142	<0.001
Age, years	0.06	-0.07 to 0.18	0.039	0.370
Female sex	0.05	-2.10 to 2.20	0.002	0.963
Manual/field-work occupation	5.30	3.13 to 7.47	0.168	<0.001
Disc degeneration grade	-0.29	-1.87 to 1.29	-0.016	0.719

Interpretation: After accounting for pain intensity and clinical covariates, lower minimum canal area independently predicted higher disability. Lordosis deviation also retained significance, whereas absolute demographic variables were weaker predictors.

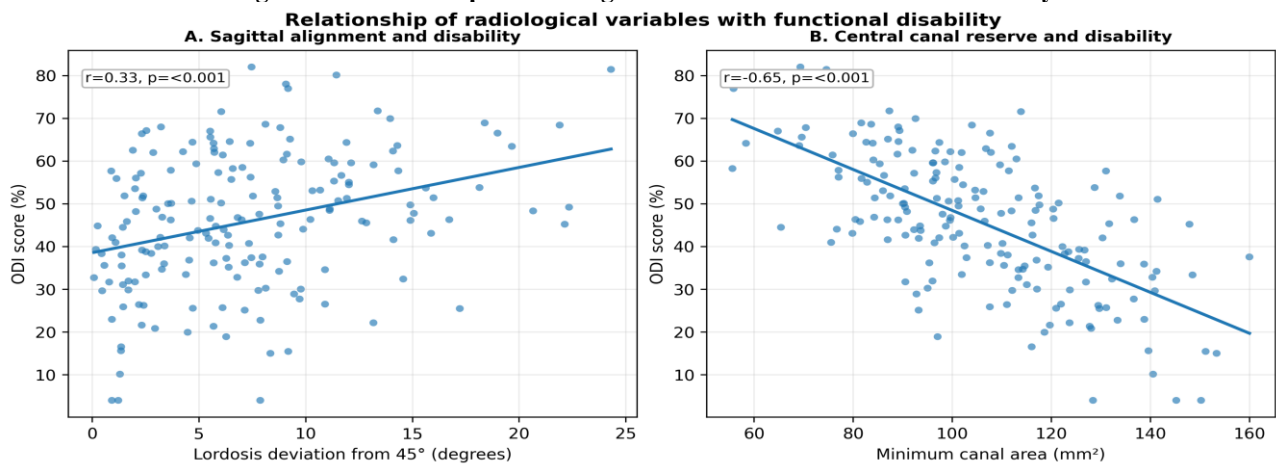
Figures

Figure 1. Radiological measurement framework and level-wise lumbar canal profile



Interpretation: Panel A shows measurement of L1-S1 Cobb lumbar lordosis on standing lateral radiograph. Panel B demonstrates axial canal morphometry. Panel C shows progressive reduction in mean AP diameter and canal area from L1 to L4 with slight recovery at L5, supporting the lower-lumbar predominance of central canal compromise.

Figure 2. Relationship of radiological variables with functional disability



Interpretation: Greater lordosis deviation from 45° was associated with higher ODI, while larger minimum canal area was associated with lower ODI. The canal area relationship was stronger and clinically more direct than the lordosis relationship, supporting a combined sagittal-morphometric interpretation.

DISCUSSION

This cross-sectional radiological study evaluated the integrated relationship between lumbar lordosis, vertebral canal dimensions and functional disability in adults with chronic low back pain. Three principal findings emerged. First, lower-lumbar canal reserve, particularly minimum canal area and minimum AP canal diameter, showed a consistent inverse association with ODI. Second, absolute lumbar lordosis angle alone demonstrated only a weak relationship with disability, but deviation from a mid-range sagittal alignment value showed a stronger association. Third, in adjusted modelling, minimum canal area and lordosis deviation remained independent radiological predictors of ODI after accounting for age, sex, BMI, symptom duration, pain score, occupation and disc degeneration grade.

The observed importance of canal reserve is clinically plausible. The lumbar canal houses the thecal sac and traversing neural elements; reduced AP diameter and cross-sectional area may lower the threshold for mechanical compression, venous congestion, activity-related symptoms and neurogenic limitation. MRI-based studies of lumbar canal stenosis have consistently shown that canal narrowing is common at lower lumbar levels, particularly L4-L5, where mobility and degenerative loading are high [20-22]. Indian morphometric studies have also emphasised that population-specific canal dimensions may differ from Western reference values, supporting the need for Indian data in clinical interpretation [13,14]. The current analysis supports the view that disability in chronic low back pain cannot be explained by lordosis angle alone. Previous studies have reported inconsistent or nonsignificant correlations between lordosis and ODI [11,12]. This inconsistency may arise because a single lordosis angle does not capture pelvic incidence, sacral slope, thoracic compensation, muscular endurance, pain behaviour or occupational exposures. A flattened lumbar spine and an exaggerated lumbar curve may both be mechanically unfavourable in different patients. Therefore, analysing deviation from a reference lordotic range may be more clinically meaningful than assuming a simple linear relationship between increasing lordosis and disability.

The finding that pain intensity remained the strongest predictor of ODI is expected because ODI is a patient-reported functional outcome closely linked to pain-limited activity. However, the independent contribution of minimum canal area suggests that MRI morphometry adds anatomical information beyond pain intensity alone. This has practical relevance for Indian outpatient settings, where patients often present after prolonged symptoms and may have already received empirical medication or physiotherapy. In such patients, a quantitative radiology report including canal area and AP diameter may assist in stratifying severity, counselling patients, planning rehabilitation and identifying those who need spine specialist referral.

The study also has implications for radiology reporting. Routine reports often describe disc bulge, protrusion, stenosis or degenerative change qualitatively. Adding objective AP diameter and canal area measurements at clinically relevant levels can improve reproducibility and interdisciplinary communication. This does not mean every patient with low back pain requires MRI. Rather, when imaging is clinically indicated, structured measurements can make the report more useful for disability correlation and follow-up planning.

From a rehabilitation perspective, the results suggest that sagittal alignment should be interpreted as a modifiable biomechanical domain rather than a standalone diagnostic label. Patients with excessive lordosis deviation may benefit from targeted core stabilisation, hip flexor/hamstring flexibility assessment, ergonomic correction, weight optimisation and graded activity. In contrast, patients with marked canal compromise and high disability may require closer neurological assessment and specialist evaluation.

This manuscript is particularly relevant to Indian practice because low back pain burden is high, occupational exposures vary widely, and validated outcome tools in Indian languages are increasingly available [3,17,18]. Combining simple standing radiographic lordosis assessment with MRI canal morphometry and ODI can create a pragmatic framework for clinical research and thesis-level studies in orthopaedics, radiodiagnosis, community medicine and rehabilitation.

Strengths

- Integrated assessment of sagittal alignment, MRI-based canal morphometry and patient-reported disability in the same cohort.
- Use of ODI, a widely accepted functional outcome measure with Indian-language validation support.
- Level-wise canal measurements from L1 to L5, allowing identification of lower-lumbar canal reserve as a clinically relevant marker.
- Adjusted regression model including pain intensity and common confounders such as BMI, duration and occupational load.

Limitations

- The cross-sectional design cannot establish causality or temporal progression.
- Single-centre tertiary-care recruitment may over-represent moderate to severe chronic low back pain.
- Pelvic incidence, sacral slope, pelvic tilt and global sagittal balance were not included; these should be added in future spinopelvic studies.
- Psychosocial factors such as fear avoidance, depression, sleep disturbance and work dissatisfaction were not modelled but may influence ODI.
- Radiological findings should not be over-interpreted in isolation, because degenerative changes may also occur in asymptomatic adults.

Clinical and research implications

- Minimum lumbar canal area may be reported as a quantitative marker when MRI is clinically indicated in chronic low back pain.
- Absolute lordosis angle should be interpreted cautiously; sagittal deviation and spinopelvic balance are likely more informative than lordosis alone.
- ODI should be routinely incorporated in spine clinics to connect imaging findings with patient-centred disability.
- Indian multicentre studies should establish normative and symptomatic cut-points for lumbar canal dimensions across age, sex and body habitus.
- Future studies should integrate spinopelvic parameters, paraspinal muscle morphology and psychosocial variables to build predictive disability models.

CONCLUSION

In adults with chronic low back pain, vertebral canal dimensions, especially minimum canal area and minimum AP canal diameter, showed a stronger association with functional disability than absolute lumbar lordosis angle alone. Lordosis deviation from a mid-range sagittal profile was independently associated with ODI, suggesting that sagittal imbalance may contribute to disability when interpreted beyond simple linear lordosis measurement. A combined radiological-functional approach using standing lordosis measurement, MRI canal morphometry and ODI can improve clinical stratification of chronic low back pain in Indian tertiary-care settings.

Declarations

Ethics approval: To be obtained from the Institutional Ethics Committee before final submission. Insert IEC number and approval date.

Consent to participate: Written informed consent should be obtained from all participants.

Funding: Nil / Insert funding source if applicable.

Conflicts of interest: The authors declare no competing interests.

Data availability: De-identified participant-level data may be made available from the corresponding author on reasonable request after ethics approval and institutional permission.

Author contributions: Concept and design: []. Data acquisition: []. Radiological measurement: []. Statistical analysis: []. Drafting: []. Critical revision: []. Final approval: all authors.

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