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MRI-BASED MEASUREMENT OF LUMBAR SPINAL CANAL DIMENSIONS IN THE KHYBER PAKHTUNKHWA POPULATION OF PAKISTAN: A CROSS-SECTIONAL REFERENCE STUDY

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Abstract

Background: Accurate measurement of lumbar spinal canal diameter (SCD) is essential for diagnosing lumbar canal stenosis (LCS) and for pre-surgical planning. The absence of unified radiological criteria for LCS makes knowledge of population-specific normal values critical. Magnetic resonance imaging (MRI) is the preferred modality for assessing lumbar spinal morphometry due to its superior soft-tissue contrast and absence of ionizing radiation. Objective: To establish normative MRI-based lumbar spinal canal diameter measurements at vertebral levels L1–L5 in the Khyber Pakhtunkhwa (KPK) population of Pakistan. Methods: A descriptive cross-sectional study was conducted at the MRI unit of Northwest General Hospital and Research Centre (NWGH), Peshawar, over six months. A convenience sample of 120 patients (aged 18–64 years) presenting with lower back pain and referred for lumbar MRI were enrolled. Canal diameters were measured at L1–L5 using Radiant DICOM software on a 0.35T open MRI scanner (Hitachi). Descriptive statistics and independent-samples t-tests were performed using SPSS v22. Results: Of 120 patients, 43 (35.8%) were male and 77 (64.2%) were female; mean age was 41.83 ± 11.44 years. Mean lumbar canal diameters were: L1 = 16.64 ± 1.69 mm, L2 = 14.93 ± 1.85 mm, L3 = 13.75 ± 1.78 mm, L4 = 13.36 ± 1.87 mm, L5 = 13.59 ± 2.25 mm. Overall canal diameter ranged from 11.0 to 20.4 mm. Males demonstrated wider canal dimensions at L1, L2, and L4, whereas females showed marginally wider dimensions at L3 and L5. Conclusion: This study provides population-specific normative lumbar spinal canal diameter values for the KPK region. The observed cephalocaudal narrowing pattern from L1 to L4, with slight widening at L5, is consistent with published data from other Asian populations. These reference values offer a clinically useful baseline for the diagnosis of lumbar canal stenosis in this underrepresented population.

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1. Introduction

The lumbar spinal canal (LSC) is the osseous channel bounded by the vertebral body anteriorly, pedicles laterally, and laminae posteriorly, containing the conus medullaris and cauda equina within the dural sac [1]. Lumbar canal stenosis (LCS) — narrowing of the spinal canal — is a leading cause of lower back pain, lower extremity radiculopathy, and neurogenic claudication, particularly in middle-aged and older adults [7].

Establishing accurate normative canal dimensions is fundamental to the radiological diagnosis of LCS. An anteroposterior (AP) diameter below 10 mm is generally accepted as indicating absolute stenosis, while values between 10 and 13 mm suggest relative stenosis; cross-sectional areas below 70 mm^2 have also been cited as a threshold for central stenosis [7]. However, substantial interethnic and intersex variation in spinal morphology has been documented across populations from Nigeria, India, Greece, Bangladesh, Saudi Arabia, and Korea [1, 2, 5, 6, 9, 11], highlighting the inadequacy of applying reference values derived from one population to another.

Magnetic resonance imaging (MRI) is the preferred modality for lumbar morphometry. It is non-invasive, free from ionizing radiation, and provides superior soft-tissue contrast that permits simultaneous evaluation of osseous and neural structures. Sensitivity of 87–96% and specificity of 68–75% have been reported for MRI in the diagnosis of LCS [7]. Despite its clinical utility, population-specific MRI-based reference data for the Khyber Pakhtunkhwa (KPK) province of Pakistan — a region with a distinct ethnic and demographic profile — remain largely absent from the published literature.

This study was undertaken to fill that evidence gap by measuring lumbar spinal canal diameters at levels L1–L5 using MRI in 120 patients from NWGH Peshawar, and to evaluate the influence of age and sex on these dimensions.

2. Literature Review

Published reference data on lumbar spinal canal dimensions vary substantially across ethnic groups and imaging modalities, underscoring the need for region-specific reference values.

An Indian observational MRI study (n = 100) reported a mean lumbar canal diameter range of 15–27 mm, with stenosis defined at ≤10 mm and severe stenosis at ≤8 mm [1]. A Nigerian CT-based study reported average AP diameters of approximately 16 mm and transverse diameters of 20 mm [2]. In a Greek CT study of 100 patients (aged 19–76 years), the L3 canal ranged from 15 to 32.8 mm, L4 from 13.8 to 36.6 mm, and L5 from 18.4 to 36.6 mm, demonstrating marked inter-individual variability in a non-stenotic population [5]. A Bangladeshi 128-slice CT study (n = 302) reported significant sex differences in canal dimensions and canal-body ratios (CBR) at L3–L5, with males demonstrating wider vertebral bodies and canal dimensions than females [6]. Korean MRI data indicated mean canal areas of 279.78 ± 42.36 mm^2 at L4, 301.50 ± 54.26 mm^2 at L5, and 355.10 ± 60.65 mm^2 at S1 [11]. A Saudi study reported mean canal-to-body ratios of 0.6 at L1 in males and 0.5 at L2–L5, with canal transverse width increasing progressively from L1 to L5 [9].

An Indian CT morphometry study (n = 500) observed that AP canal diameters decreased progressively from D12 to L4 before increasing at L5, with the canal transitioning from a circular to oval cross-sectional shape in the craniocaudally direction [8]. Collectively, these studies demonstrate that (i) reference values differ markedly across populations, (ii) males tend to have wider canal diameters than females at most levels, and (iii) the craniocaudally diameter pattern in the lumbar spine is not uniform. Notably, no MRI-based study has specifically characterized lumbar canal dimensions in the KPK population of Pakistan.

3. Methodology

3.1 Study Design and Setting

A descriptive cross-sectional study was conducted at the MRI Department of Northwest General Hospital and Research Centre (NWGH), Peshawar, Pakistan, from October 2025 to March 2026 — a period of six months. Ethical approval was obtained from the Institutional Research Board (IRB) of Northwest Institute of Health Sciences (NWIHS), Khyber Medical University.

3.2 Study Population and Sampling

Patients of both sexes presenting with lower back pain or associated radiculopathy and referred for lumbar spine MRI were considered for inclusion. A convenience sample of 120 patients was enrolled, calculated using the Raosoft sample size calculator.

Inclusion criteria: Adults aged 18–64 years of either sex, referred for lumbar spine MRI at NWGH

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Peshawar, with a primary complaint of lower back pain or radiculopathy.

Exclusion criteria: Patients with known spinal malignancy, prior lumbar spinal surgery, congenital spinal deformity, bone pathology obscuring canal measurement, or undergoing follow-up MRI for cancer surveillance.

3.3 MRI Protocol and Image Acquisition

All MRI examinations were performed on 0.35T open MRI scanner (Hitachi), by qualified MRI technologists. Standard lumbar spine sequences included T1-weighted (TR 700 ms, TE 20–30 ms) and T2-weighted (TR > 2000 ms, TE 60–100 ms) imaging in axial and sagittal planes. T2-weighted images, which provide the 'myelographic effect' by rendering CSF bright against neural structures, were used for canal measurement.

3.4 Measurements

From a total of 180 eligible MRI reports reviewed, 120 met inclusion criteria and were enrolled. MRI images were transferred to Radiant DICOM viewer for digital measurement. The anteroposterior (AP) sagittal diameter of the lumbar spinal canal was measured at the mid-vertebral level at each of the five lumbar vertebral levels (L1–L5) on axial T2-weighted images. All measurements were performed by trained medical imaging technology students under radiologist supervision.

3.5 Statistical Analysis

Data were entered and analyzed using Microsoft Excel and SPSS Statistics version 22 (IBM Corp.). Continuous variables are expressed as mean ± standard deviation (SD). Minimum and maximum canal diameters are reported per level. An independent-samples t-test was used to compare canal diameters between males and females. A p-value < 0.05 was considered statistically significant.

4. Results

4.1 Demographic Characteristics

A total of 120 patients (43 males [35.8%] and 77 females [64.2%]) were included. Mean age was 41.83 ± 11.44 years (range: 18–64 years). The largest age group was 33–42 years (n = 43; 35.8%), followed by 53–64 years (n = 25; 20.8%), 43–52 years (n = 24; 20.0%), 23–32 years (n = 24; 20.0%), and 18–22 years (n = 4; 3.3%).

4.2 Presenting Symptoms

Lower back pain alone was the most common presenting symptom (n = 59; 49.2%), followed by back pain radiating to the left leg (n = 24; 20.0%), back pain radiating to both lower limbs (n = 16; 13.3%), back pain radiating to the right leg (n = 13; 10.8%), back pain with right sciatica (n = 4; 3.3%), back pain with left sciatica (n = 3; 2.5%), and trauma (n = 1; 0.8%). Females reported a higher frequency of lower back pain compared to males across all symptom categories.

4.3 Lumbar Canal Diameter Measurements (L1–L5)

Mean AP lumbar spinal canal diameters at each vertebral level are summarized in Table 1. A progressive decrease in mean diameter was observed from L1 to L4, with a slight increase at L5.

Level	N	Mean (mm)	Diameter	SD (mm)	Std. Error Mean	Min (mm)	Max (mm)
L1	120	16.64		1.69	0.15	11.0	20.4
L2	120	14.93		1.85	0.17	11.0	19.6
L3	120	13.75		1.78	0.16	11.1	20.0
L4	120	13.36		1.87	0.17	11.0	19.4
L5	120	13.59		2.25	0.21	11.0	20.4

Table 1. One-sample descriptive statistics for lumbar spinal canal AP diameter at levels L1–L5 (N = 120)

4.4 Gender-Based Comparison of Canal Diameters

Gender-stratified modal canal diameters are presented in Table 2. Males showed wider canal diameters at L1, L2, and L4 compared to females, while females demonstrated marginally wider modal diameters at L3 and L5.

Lumbar Level	Male — Mean Diameter ± SD (mm)	Female — Mean Diameter ± SD (mm)
L1	16.9	16.2
L2	17.3	16.1
L3	14.2	15.3
L4	13.8	13.4
L5	12.0	12.8

Table 2. Gender-stratified modal lumbar spinal canal diameters at L1–L5

5. Discussion

This study provides MRI-based normative lumbar spinal canal diameter data from 120 patients in the KPK province of Pakistan — a population for which such region-specific reference values have been notably absent. The observed mean canal diameters ranged from 16.64 ± 1.69 mm at L1 to 13.36 ± 1.87 mm at L4, with a slight re-widening to 13.59 ± 2.25 mm at L5. This craniocaudally narrowing pattern with distal partial recovery is broadly consistent with Indian [1, 8] and Saudi [9] findings, supporting the notion of a similar lumbar canal morphometric pattern across South and Central Asian populations.

The overall canal diameter range of 11.0–20.4 mm observed in this study falls within, though at the lower end of, the 15–27 mm range reported for Indian patients [1] and the 13.8–36.6 mm range at L4 reported in a Greek CT-based study [5]. The narrower upper bound in the current study may reflect differences in imaging modality (0.35T MRI versus CT), measurement plane, or population-level morphological characteristics. Importantly, the minimum diameter of 11.0 mm observed across L1–L5 approaches the ≤10 mm absolute stenosis threshold, indicating that a subset of patients in this cohort may be at risk for symptomatic lumbar canal stenosis — a clinically significant finding.

The predominance of female patients in this sample (64.2%) is consistent with epidemiological data indicating a higher burden of low back pain in women in South Asian populations. Males demonstrated wider canal diameters at L1, L2, and L4 in this cohort — consistent with Bangladeshi [6] and Korean findings [11] reporting sex-related morphometric differences. The reversal at L3 and L5, where females showed marginally wider modal diameters, warrants further investigation with larger sex-stratified samples.

From a clinical standpoint, these reference values can guide radiologists and orthopedic/neurosurgeons in the KPK region in distinguishing incidental canal narrowing from pathological stenosis. The use of MRI, which achieved sensitivity of 87–96% for LCS in prior validation studies [7], supports the reliability of the measurements obtained. The study's use of the 0.35T MRI scanner — widely available in resource-constrained settings such as district hospitals in KPK — adds translational value.

6. Conclusion

This cross-sectional MRI morphometric study establishes normative lumbar spinal canal AP diameter values for the KPK population of Pakistan. Mean canal diameters decreased progressively from L1 (16.64 mm) to L4 (13.36 mm), with a slight widening at L5 (13.59 mm). Males generally demonstrated wider canal diameters than females. The observed diameter range of 11.0–20.4 mm provides a clinically usable reference for diagnosing lumbar canal stenosis in this underrepresented South Asian population. MRI is confirmed as a safe, sensitive modality for lumbar canal morphometry in routine clinical practice.

7. Limitations

Several limitations should be acknowledged. First, the study employed a convenience sampling method at a single tertiary center, limiting the generalizability of findings to the broader KPK population. Second, measurements were restricted to the AP (sagittal) diameter; transverse diameter and cross-sectional area data — which provide a more comprehensive morphometric profile — were not reported. Third, the use of a 0.35T scanner, while clinically accessible, offers lower spatial resolution than higher-field systems (1.5T or 3T), potentially introducing measurement variability. Fourth, the absence of age-stratified subgroup analyses limits insight into age-related canal changes. Fifth, inter-rater and intra-rater reliability of measurements was not formally assessed, though measurements were performed under radiologist supervision. Additionally, because participants were symptomatic patients referred for lumbar MRI, the findings may not represent completely asymptomatic population reference values.

8. Future Research Directions

Future studies should (i) employ multi-centre designs encompassing both urban and rural hospitals across KPK to obtain a more representative population sample; (ii) measure transverse diameter and dural sac cross-sectional area alongside AP diameter; (iii) utilise higher-field MRI systems (1.5T or 3T) to improve measurement precision; (iv) include age-stratified and body mass index (BMI)-stratified analyses; (v) formally establish inter-observer and intra-observer reliability; and (vi) compare findings with CT-based measurements to validate cross-modal equivalence. A prospective correlational study examining the relationship between canal dimensions and clinical symptom severity would further strengthen the translational impact of morphometric reference data.

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Appendix A: Suggested Article Title Alternatives

1. [PRIMARY — RECOMMENDED] MRI-Based Measurement of Lumbar Spinal Canal Dimensions in the KPK Population of Pakistan: A Cross-Sectional Normative Study
2. Reference Lumbar Spinal Canal Diameter Values on MRI in a Pakistani Population: Implications for Lumbar Canal Stenosis Diagnosis
3. MRI Morphometry of the Lumbar Spinal Canal in Khyber Pakhtunkhwa, Pakistan: A Cross-Sectional Analysis of 120 Patients
4. Sex- and Level-Specific Lumbar Spinal Canal Dimensions on MRI in Pakistani Adults: A Population-Based Reference Study
5. Establishing MRI-Based Normative Lumbar Canal Diameters in the KPK Province of Pakistan: A Foundation for Stenosis Diagnosis

Appendix B: Suggested Target Journals

Journal	Publisher	Scope	Impact / Notes
European Spine Journal	Springer	Spinal disorders, imaging, surgery	High-impact; indexed SCIE; suits morphometry/MRI studies
Journal of Back and Musculoskeletal Rehabilitation	IOS Press	Clinical spinal research, rehabilitation	Good fit for cross-sectional population studies
Spine	Wolters Kluwer / LWW	Clinical and basic spinal research	Top-tier spine journal; strongly peer-reviewed

Tip: For open-access regional reach, also consider Pakistan Journal of Medical Sciences or Journal of Ayub Medical College Abbottabad, both indexed and Pakistan-based.