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ORIGINAL ARTICLE

Morphometric profile of the lumbar spine in the Indonesian population: vertebral body, pedicle, canal, and foramen dimensions

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ABSTRACT

Aim The lumbar spine is vital for supporting body weight and facilitating trunk mobility. Morphometric data of the lumbar spine in Southeast Asian populations, particularly the Indonesian population, remain limited. This study aimed to provide baseline morphometric parameters of the lumbar spine in Indonesia to enhance preoperative planning and surgical outcome.

Methods This descriptive study analysed 150 adult patients (ages 17-55) who underwent CT scans at Dr. Saiful Anwar General Hospital in Malang between 2021 and 2023. Lumbar spine parameters, including vertebral body dimensions, pedicle morphometry, spinal canal diameter, intervertebral foramen size, and segmental height, were measured by independent, trained observers to minimize inter-observer variability. Data were extracted from the hospital's Radiology Information System (RIS).

Results The mean vertebral body height (29.14 mm) and width (42.17 mm) were smaller than those reported in Western populations, but consistent with Indonesian data. The mean pedicle width at L3 was 10.78 mm, and the spinal canal diameter (13.9 mm) was narrower than in Western populations but similar to East Asian and Indian cohorts. These findings highlight anatomical differences that should be considered in spinal surgery, including implant sizing and preoperative planning.

Conclusion This study provides essential baseline lumbar spine morphometric data for the Indonesian population. The results emphasize the need for region-specific surgical approaches. Future studies with larger, diverse samples are recommended to refine these findings and enhance clinical applications.

Keywords: lumbar spine, pedicle screw, spinal canal, vertebral body

INTRODUCTION

The spine lies on the dorsal aspect of the body, forming the basic framework of the trunk and acting as the axis of the musculoskeletal system, supporting the torso. The lumbar spine plays a crucial role in supporting body weight, maintaining posture, and facilitating truncal mobility (1). The human spine typically comprises 33–34 bones: seven cervical, 12 thoracic, five lumbar, five sacral, and five coccygeal bones, with intervertebral discs interposed between adjacent vertebrae (2).

Morphometrics is the quantitative measurement of anatomical form capturing precise lengths, angles, areas, and volumes from clinical imaging to guide clinical decisions, especially in orthopaedic surgery (3). Morphometric characteristics of the lumbar vertebrae, including vertebral body dimensions, pedicle size, spinal canal diameter, and intervertebral foramen geometry, are fundamental for understanding spinal biomechanics (4). These parameters directly influence the diagnosis of lumbar spinal stenosis, surgical decompression techniques, and the selection or design of spinal implants (5).

Most morphometric studies have been conducted in Western populations, often using cadaveric specimens or imaging modalities such as CT and MRI. While these studies have provided invaluable insights, their applicability to Southeast Asian populations is limited due to anthropometric and anatomical

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differences (5). Southeast Asian populations generally exhibit smaller skeletal dimensions than Western counterparts, which may affect preoperative planning, particularly during pedicle screw insertion and interbody fusion procedures (6).

Evidence on lumbar morphometry in the Southeast Asian population remains limited. Prior research has typically focused on single parameters, such as pedicle width or canal diameter, without providing a comprehensive dataset that integrates multiple vertebral structures. While some studies have attempted to analyse these dimensions, they often lack generalizability due to differences in study design, population size, or the imaging techniques employed (7).

Therefore, there is a clear gap in understanding the complete morphometric profile of the lumbar spine in Indonesian individuals, particularly regarding the integration of vertebral body, pedicle, spinal canal, and intervertebral foramen dimensions.

This study aimed to bridge the gap by providing a comprehensive, CT-based analysis of the lumbar spine morphology in the Indonesian population. The goal was to provide a detailed, accurate reference for clinicians and researchers, enhancing preoperative planning for spinal surgeries and advancing understanding of spinal biomechanics in the Indonesian context.

PATIENTS AND METHODS

This descriptive study aimed to analyse the morphometric dimensions of the lumbar spine in the Indonesian population. Data were collected from patients who underwent CT scans at Dr. Saiful Anwar General Hospital in Malang between February and July 2024. The research data were extracted from the Radiology Information System (RIS). Lumbar spine anatomical parameters were measured using RIS features.

The study population consisted of adults aged 17–55 years who underwent CT scans from 2021 to 2023, during which the lumbar spine could be clearly visualized. Only patients without clinical or radiological evidence of spinal pathology were included. Inclusion criteria required the absence of any history of spinal surgery or trauma, as well as no evidence of congenital deformities, tumours, or degenerative spinal disease. Patients were excluded if they were younger than 17 or older than 55 years, showed radiographic signs of scoliosis, spondylolisthesis, or other spinal deformities, or if their imaging data were incomplete and unsuitable for further analysis. To determine the total sample size, a sample size calculation formula was applied. This sample size was selected to ensure sufficient power for accurate and reliable results. The formula used for sample size calculation was as follows:

$$n = \frac{Z^2 x\ p\ x\ (1-p)}{E^2}$$

Where, n = required sample size; Z = Z-value corresponding to the 95% confidence level (1.96); p=estimated proportion in the population (based on preliminary data, 89% = 0.89); E = margin of error (0.05).

Following the formulation, a total sample size of 150 participants was deemed adequate for the objectives of this study, ensuring that the results would be representative of the population.

For the sampling technique, a non-probability purposive sampling method was employed. In this approach, participants were selected based on specific criteria that aligned with the study objectives. This sampling method was chosen due to the availability of suitable patient data and the study's precise focus on a particular group of patients, with exact CT imaging of the lumbar spine.

Data were collected by accessing patients' electronic medical records through the hospital's RIS system.

Following institutional ethical guidelines and approval from the hospital's ethics committee, access to the data was granted.

Methods

The radiology team analysed the CT scans, and each anatomical parameter was measured twice by independent, trained observers to reduce inter-observer variability. The inter-observer variability was regularly monitored, and in cases of significant discrepancies, a third senior observer reviewed the measurements to ensure consistency. The following lumbar spine parameters were analysed:

- Vertebral body morphometric: anterior body height (ABVH), posterior body height (PBVH), vertebral width (VW), and vertebral Depth (VD);
- Pedicle morphometric: pedicle length (PL), pedicle width (PW), pedicle-to-midline distance (PMD-Ax, axial view), pedicle-to-midline distance (PMD-Sag, sagittal view);
- Parameters of the spinal canal: canal diameter at L3 (CD);
- Parameters of intervertebral foramen: intervertebral foramen at L2-L3 (IF-L23) and at L3-L4 (IF-L34) and interforaminal distance (IFD);
- Parameters of segmental length: segmental height (SH);

All morphometric measurements were performed at the L3 vertebral level, which was selected as a representative lumbar segment due to its frequent use in morphometric and surgical planning studies. Measurements were obtained using axial and sagittal CT images with standardized window settings (8). Vertebral body dimensions (anterior and posterior height, transverse width, and anteroposterior depth), pedicle dimensions (length, width, and pedicle-to-midline distance), spinal canal diameter, and intervertebral foramen dimensions were measured using high-resolution computed tomography (CT) with multiplanar reconstruction according to previously validated morphometric protocols. These measurement techniques have been validated for accuracy and reproducibility in studies comparing CT and/or MRI imaging against established anatomical and radiologic references, demonstrating high inter- and intra-rater reliability (intraclass correlation coefficients [ICC] > 0.80) and equivalence between modalities for geometric measurements of vertebral structures (9).

Statistical analysis

Descriptive statistics were used to calculate the frequency and percentage distribution for categorical variables such as gender and age groups. The morphometry data were obtained as the mean value for each lumbar spine parameter.

RESULTS

This descriptive observational study was conducted on patients undergoing lumbosacral CT scans at Dr. Saiful Anwar General

Table 1. Baseline characteristics of the sample in this study

Characteristics	No of patients (%)
Gender	
Male	90 (60)
Female	60 (40)
Age groups (years)	
17–20	15 (10)
20–30	15 (10)
31–40	20 (13)
41–50	48 (32)
51–55	52 (35)
Total	150 (100)

Table 2. Vertebral body morphometry

Parameter	Mean value (mm)
Anterior body height (ABVH)	29.14
Posterior body height (PBVH)	29.68
Transverse vertebral width (VW)	42.17
Anteroposterior vertebral depth (VD)	31.20

Hospital, Malang. The study aimed to evaluate the morphometric profile of lumbar vertebrae across different age groups in the Malang population. The study sample of 150 participants was predominantly male (60%), with the majority in the 41-55 age range (35%) (Table 1).

The vertebral body morphometric parameters reveal consistent dimensions across the various measurements. The anterior and posterior body heights were closely aligned, with only a slight difference. Notably, the transverse vertebral width (42.17 mm) was the widest measurement, followed by the anteroposterior vertebral depth (31.20 mm). Among the parameters, the posterior body height (29.68 mm) was the highest, while the anterior body height (29.14 mm) was slightly lower (Table 2).

The pedicle morphometric parameters provide essential measurements of the vertebral structure. The mean pedicle length (PL) was 17.73 mm, and the average pedicle width (PW) was 10.78 mm. The pedicle-to-midline distance at L3 measured 34.23 mm on the axial view and 29.88 mm on the sagittal view (Table 3).

Table 3. Pedicle morphometry at lumbar 3 (L3)

Parameter	Mean value (mm)
Pedicle length (PL)	17.73
Pedicle width (PW)	10.78
Pedicle-to-midline distance, axial (PMD-Ax)	34.23
Pedicle-to-midline distance, sagittal (PMD-Sag)	29.88

The spinal canal diameter, intervertebral foramen dimensions, and segmental height were assessed to better understand the anatomical structure of the lumbar spine (Table 4). The midsagittal spinal canal diameter at L3 (CSD) and the intervertebral foramen diameters at L2-L3 and L3-L4 reflect the key space requirements for spinal cord and nerve root passage. The interforaminal distance (IFD) between these levels was also measured to indicate the lateral spacing between the foramina. Additionally, the segmental height between the inferior endplate of L2 and the superior endplate of L4 was evaluated. The results showed that the CSD at L3 was 13.85 mm, while the intervertebral foramen at L2-L3 and L3-L4 were 16.19 mm and 16.44 mm, respectively. The interforaminal distance (IFD) was 47.80 mm, and the segmental height was 40.60 mm, highlighting the importance of these measurements in assessing the space for neural structures and the overall lumbar spine anatomy.

DISCUSSION

This descriptive study provides baseline morphometric parameters of the lumbar spine in the Indonesian population, including vertebral body dimensions, pedicle morphometry, spinal canal diameter, intervertebral foramen size, and segmental height. These findings are essential, as morphometric data specific to Southeast Asian populations remain limited, while most available references are derived from Western cohorts. The differences observed between Indonesian data and those of Western populations highlight the importance of tailoring surgical procedures to the specific anatomical characteristics of the population.

Pedicle and vertebral body measurements inform implant sizing and placement (10). The mean vertebral body height (29 mm) and width (42 mm) in our series provide key insights into the structural dimensions of the vertebrae, which are essential for understanding spinal biomechanics and surgical planning (11). The results were comparable to those of Indonesians (12), though still smaller than those of Greeks and Turks, where transverse widths often exceed 50 mm (13,14). These differences could be attributed to genetic factors, dietary influences, or environmental conditions that affect bone growth and development across different populations. A study in Chinese populations found similar trends in smaller vertebral body dimensions compared to their Western counterparts, suggesting that these differences may be consistent across other Asian groups (15).

Mean pedicle measurements highlight the key dimensions relevant for surgical interventions, such as screw placement and spinal fusion procedures (16). Overall, the pedicle dimensions were adequate for instrumentation, with distances increasing at lower lumbar level, reflecting the lateral orientation of caudal pedicles. These values provide a comprehensive understanding of the pedicle morphology, which is crucial for preoperative planning and ensuring the safety of spinal surgeries (17). In our results, the mean pedicle width at L3 measured approximately 10.8 mm, which aligns closely with other studies (7–9 mm) for East and Southeast Asian populations (18), and is smaller than those for American (10–13 mm) (19) and Oceanian (12–16 mm) (20) populations. Similarly, our pedicle-to-midline distances (34.2 mm axial and 29.9 mm sagittal) suggest a lateralization pattern comparable to that of other Asian cohorts (21), but smaller than those reported in Western literature, where larger values are often observed due to wider vertebral bodies (22,23). This variation is likely due to anatomical differences in the broader skeletal structures of Western populations, as observed in studies of European and North American cohorts, which reported wider pedicles on average (24,25). The smaller pedicle width in Indonesians compared to Western populations reinforces the need for careful screw selection. From a surgical standpoint, the mean pedicle width of 10.78 mm at L3 suggests that commonly used pedicle screws with diameters of 6.5–7.5 mm would be appropriate for most Indonesian patients, while larger-diameter screws designed for Western populations may increase the risk of pedicle breach or neural injury (26). These findings underscore the importance of population-specific morphometric data in minimizing implant-related complications.

The spinal canal diameter in our study (CD 13.9 mm at L3) was also narrower than that of Western populations (15–18 mm)

Table 4. Spinal canal, intervertebral foramen, and segmental length parameters

Parameter	Mean value (mm)
Midsagittal spinal canal diameter at L3 (CSD-L3)	13.85
Intervertebral foramen at L2–L3 (IF-L23)	16.19
Intervertebral foramen at L3–L4 (IF-L34)	16.44
Interforaminal distance (IFD)	47.80
Segmental height	40.60

but consistent with East Asian and Indian cohorts (13–14 mm) (27). Relatively narrow spinal canal dimensions highlight the importance of preoperative planning. Even mild hypertrophy of the ligamentum flavum or facet arthropathy can lead to clinically significant stenosis in populations with smaller baseline canal sizes (28). This has been echoed by other research that found that East Asian populations are more likely to develop symptomatic stenosis with minor spinal degeneration compared to their Western counterparts. This leads to a clinical significance where surgeons must tailor decompression techniques accordingly to avoid under- or over-resection (29).

Intervertebral foramen diameters (16 mm at L2-3 and L3-4) were comparable to those in Asian populations (30), but smaller than European values (31), which typically exceed 18–20 mm. Similarly, segmental height from L2 to L4 (40.6 mm) also reflected relatively smaller vertebral body dimensions compared to Western reports (32). This may be attributed to differences in bone structure, with Eastern populations generally exhibiting more compact, shorter vertebral segments (33). Other studies have shown similar findings in the smaller foramen sizes in Asian populations compared to European (31) and North American (34) groups. Segmental and foraminal morphometry data provide benchmarks for interbody fusion and cage placement (35). Given that Indonesian vertebral bodies are smaller than those in Western cohorts, downsizing implants or developing region-specific cage designs may be warranted to prevent complications such as cage subsidence, inadequate height restoration, or endplate violation (27). The necessity for custom implants has been suggested in other studies, emphasizing the importance of adapting spinal instrumentation to local anatomical variations to reduce the risk of surgical complications (36).

While this study provides valuable baseline morphometric data for the Indonesian population, several limitations should be acknowledged. First, the sample size, though adequate for descriptive purposes, may not fully represent the entire Indonesian population, as it was based on patients at a single hospital. Future studies should include a larger, more diverse sample from across Indonesia to account for potential regional variations in lumbar spine morphology. Additionally, this study focused on adults aged 17-55, excluding the paediatric and elderly populations, which may present different morphometric characteristics. Expanding the age range in future research would provide a more comprehensive understanding of lumbar spine anatomy across the lifespan. Furthermore, while inter-observer reliability was assessed through repeated measurements by independent observers, future studies could consider employing advanced imaging techniques (e.g., 3D CT reconstructions) to enhance measurement precision. Ultimately, longitudinal studies could investigate how these morphometric parameters evolve, particularly in relation to spinal disorders or following surgical interventions.

In conclusion, this study provides essential baseline morphometric parameters of the lumbar spine in the Indonesian population, including vertebral body dimensions, pedicle morphometry, spinal canal diameter, intervertebral foramen size, and segmental height. These findings provide valuable data for a population with limited morphometric studies and highlight the need for region-specific considerations in spinal surgery, such as implant sizing and preoperative planning, to account for anatomical differences compared to Western populations. Future research with a larger, more diverse sample could further refine these findings and enhance their clinical applications.

FUNDING

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CONFLICTS OF INTEREST

None to declare.

ETHICS STATEMENT

This study was approved by the Saiful Anwar General Hospital Ethics Commission, under approval number 400/083/K.3/102.7/2025, issued on 14 March 2025.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request and with permission of the institution.

AUTHOR CONTRIBUTIONS (CRediT)

Conceptualization: A.Y.; **Data curation:** A.Y.; **Formal analysis:** A.Y., Y.Y., H.S.; **Investigation:** R.S.D., I.K.S.; **Methodology:** R.S.D., E.M.; **Project administration:** A.Y.; **Resources:** Y.Y.; **Software:** M.A.C.; **Supervision:** R.S.D., E.M., M.A.C., H.S., I.K.S.; **Validation:** R.S.D., E.M., M.A.C., Y.Y., H.S., I.K.S.; **Visualization:** A.Y.; **Writing – original draft:** A.Y., R.S.D., E.M., M.A.C.; **Writing – review & editing:** Y.Y., H.S., I.K.S. All authors have read and agreed to the published version of the manuscript.

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