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Enriching Global Understanding: Comprehensive Analysis of Lumbar Spine Morphometry

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ABSTRACT
Introduction: *Understanding the morphometric properties of the lumbar spine is crucial for accurate clinical assessments and treatments. Previous studies have explored relationships between lumbar shape and sagittal parameters, contributing to our knowledge. However, a comprehensive analysis of various morphometric characteristics is assumed to be lacking. This study aims to address this gap, providing radiological anatomic features and morphometryof the lumbar spine, incorporating transverse and anteroposterior diameters of the spinal canal, vertebral body dimensions, vertebral and intervertebral disc heights, and the index of the intervertebral disc (Id).*
Methods: *Advanced imaging techniques were employed to evaluate these parameters in a diverse sample population, ensuring demographic-inclusive parameters.*
Results: *The study reveals consistent increases in transverse and anteroposterior diameters of the spinal canal from L1 to L5. Sex-specific differences are observed, with males having larger transverse diameters. Vertebral bodies show a gradual augmentation, with males consistently displaying larger dimensions. Anteroposterior spinal canal diameters exhibit predictable increases withsexual dimorphism. Females consistently exhibit slightly smaller vertebral body heights and intervertebral discs. The index of the intervertebral disc (Id)(result) remains remarkably constant across lumbar levels, challenging past scientific research work on the same.*
Conclusion: *This comprehensive analysis enhances our understanding of normal lumbar vertebrae studies, providing valuable insights for clinicians in the diseased stage and researchers in the primary stage. The observed sexual dimorphism emphasizes the importance of tailored approaches in spinal assessments, paving the way for future biomechanical investigations. The study's findings serve as a foundation for refining diagnostic and therapeutic strategies in spinal healthcare.*

Keywords:*Lumbar spine morphometry, vertebral body dimensions, spinal canal diameters, intervertebral disc proportions, gender-specific norms, clinical implications.*

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I. Introduction

Comprehending the typical deviations in the lumbar spine shape is essential for precise clinical assessments and treatments. The lumbar spine, with five vertebrae (L1 to L5), plays a crucial role in bearing body weight, enabling movement, and safeguarding the spinal cord. Therefore, a thorough understanding of its morphometric properties is essential for healthcare practitioners, surgeons, and researchers engaged in spinal health. Several studies have been conducted to investigate the relationship between lumbar shape and sagittal parameters, including lumbar lordosis (LL) and pelvic incidence (PI)(1, 2, 3). These studies have found correlations between PI and proximal lumbar lordosis (pLL), distal lumbar lordosis (dLL), and thoracic kyphosis (T1-T12)(4, 5). Additionally, the position of the lumbar apex has been observed to migrate proximally with increasing PI. Understanding the lumbar spine's relationships and morphometric characteristics can contribute to a worldwide understanding of lumbar vertebrae and aid in clinical assessments and treatments.

The size and shape of the vertebrae, the geometry of the spinal canal, and the proportions of the intervertebral discs all contribute to the function of the lumbar spine. Understanding these parameters is essential for differentiating between pathological states, guiding surgical procedures, and improving our

understanding of spine biomechanics. Several studies have investigated lumbar spine morphometry, providing valuable insights. For example, a study by Džidić-Krivić et al. found that gender significantly affects the dimensions of the lumbar vertebrae and spinal canal (6). Another study by Shalini et al. examined typical and atypical lumbar vertebrae in the South Indian population, identifying differences in various dimensions (7). Borshchenko and Baskov conducted an MRI analysis of the lumbar intervertebral foramen, highlighting the vulnerability of the exiting spinal nerve during transforaminal interventions (8). Additionally, Thakar et al. investigated whole lumbar spine morphometry as a predictor of recurrent lumbar disc herniation, identifying specific morphometric variables that can help predict the occurrence of rLDH (9). These studies contribute to understanding lumbar spine morphometry and its clinical implications.

By focusing on numerous morphometric characteristics simultaneously, this study aims to provide a holistic picture, address gaps in the present literature, and shed light on details that might have been overlooked. With the aging of the world population and the increasing occurrence of spinal illnesses, there is a growing need for precise diagnostic tools and effective treatments. Clinicians rely on normative data to discern between deviations within the normal range and abnormal disorders. This study is intended to enrich this normative data, enable a more precise understanding of lumbar spine shape, and contribute to improved patient treatment. The findings support current information and bring unique insights that can modify clinical practices and affect future research directions.

This research aimed to enrich global information on normal lumbar vertebrae studies and provide a reference dataset for doctors and researchers worldwide. The study focused on detailed observations of various factors including the transverse and anteroposterior diameters of the spinal canal, transverse diameters of vertebral bodies, heights of vertebral bodies and intervertebral discs, and the index of the intervertebral disc (Id) (2). By rigorously assessing these factors, the study aimed to create a robust dataset that can serve as a reference for spinal healthcare professionals and drive breakthroughs in spinal healthcare (10).

II. Methods:

The study used advanced imaging techniques, including magnetic resonance imaging (MRI) and computed tomography (CT), to assess morphometric parameters of the lumbar spine. High-resolution MRI scans were used to measure the transverse and anteroposterior diameters of the spinal canal at each lumbar level, while CT scans captured transverse diameters of vertebral bodies at different lumbar levels. Both MRI and CT scans allowed for three-dimensional reconstructions, ensuring precise measurements of height variations along the lumbar spine. The study also calculated the index of the intervertebral disc (Id), measuring the minimum height of the disc relative to the maximum height of the vertebral body. A diverse sample population was examined to capture the intricacies and potential variations in lumbar spine morphometry across different population groups. The combination of advanced imaging techniques and a diverse study population enhances the reliability and applicability of the study results.

Ethical Guidelines:

The study followed strict ethical guidelines, obtaining approvals from institutional review boards and obtaining informed consent from participants. Privacy and confidentiality were prioritized, and personal information was anonymized.

Statistical analyses:

Statistical analyses were conducted using descriptive and inferential statistics to derive meaningful insights from the data. Appropriate tests like t-tests or ANOVA were used to assess the significance of observed differences, particularly in gender-specific variations. These rigorous statistical methods ensured the reliability and validity of the findings, contributing to the overall scientific rigor of the research.

III. Results:

The transverse diameter of the spinal canal exhibited a consistent increase from L1 to L5, aligning with established anatomical knowledge. Sex-specific differences were evident, with males displaying slightly larger transverse diameters than females across all lumbar levels. This finding emphasizes the necessity of considering gender-specific norms in clinical assessments and surgical interventions involving the lumbar spine.

Table 1 Mean transverse diameter of the spinal canal (mm) in both sexes.

LEVEL	SEX GROUP	RANGE	MEAN	S.D.	P-VALUE
L1	Male	20.5-28.5	25.02	±2.14	<0.001
	Female	15.5-25.5	20.30	±2.82	

L2	Male	20.5-30.5	25.20	±2.53	<0.001
	Female	20.0-25.5	22.07	±1.61	
L3	Male	20.5-29.5	25.20	±2.35	0.601
	Female	20.5-26.5	22.22	±1.76	
L4	Male	22.5-31.5	25.52	±2.27	0.439
	Female	22.5-28.5	25.32	±1.86	
L5	MALE	24.0-40.5	29.82	±6.08	0.119
	FEMALE	24.0-35.5	27.75	±3.58	

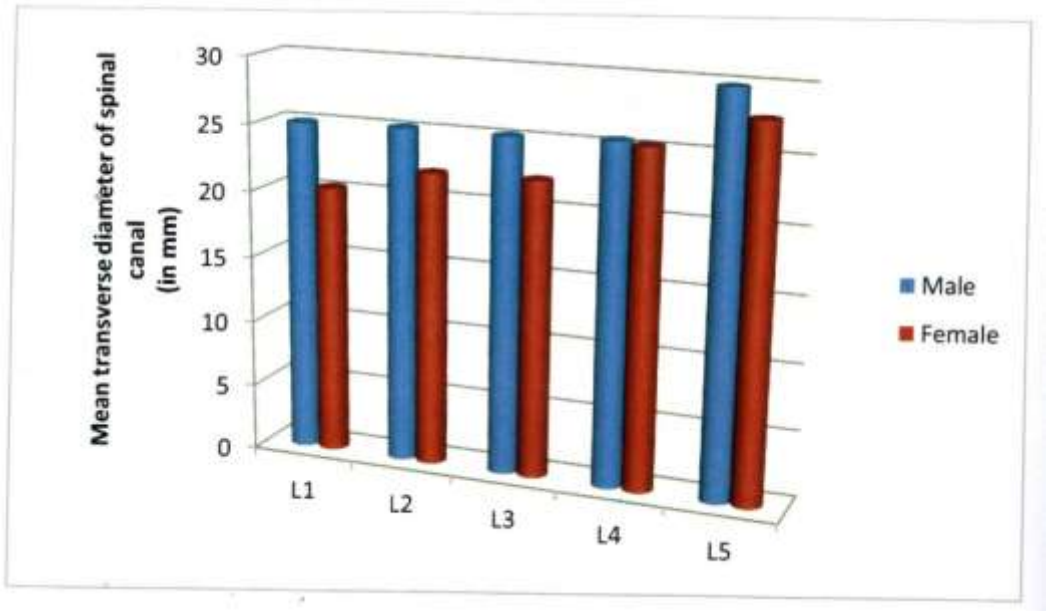

Figure 1 Mean transverse diameter of the spinal canal (mm)

A gradual augmentation from L1 to L5 was observed in examining the transverse diameters of vertebral bodies. The variations between adjacent levels were generally consistent, but individual differences were notable, hinting at the intricacies of lumbar spine morphometry. The study's findings corroborate existing literature while offering a more nuanced perspective on these variations.

Table 2 Mean transverse diameters (mm) of vertebral bodies in both sexes.

LEVEL	SEX GROUP	RANGE	MEAN	S. D.	P-VALUE
L1	Male	35.5-50.5	40.80	±4.66	0.469
	Female	34.5-46.5	39.82	±3.72	
L2	Male	37.5-49.5	42.65	±3.85	0.002
	Female	34.5-48.5	38.90	±3.06	
L3	Male	41.0-58.5	45.42	±4.02	0.052
	Female	37.5-49.5	42.85	±4.10	
L4	Male	44.5-58.5	47.60	±2.96	0.001
	Female	40.5-50.5	43.95	±3.20	
L5	Male	48.5-62.5	53.12	±4.37	0.020
	Female	46.5-54.5	50.42	±2.17	

The anteroposterior diameter of the spinal canal also exhibited a predictable increase from L1 to L5. However, the study identified subtle variations between sexes, with males displaying marginally larger anteroposterior diameters. This insight is crucial for clinicians, especially when surgical interventions or diagnostic assessments necessitate a precise understanding of spinal canal dimensions.

Table 3 Mean anteroposterior diameters (mm) of spinal canals in both sexes.

LEVEL	SEX GROUP	RANGE	MEAN	S. D.	P-VALUE
L1	Male	15.5-23.5	19.47	±2.51	0.039
	Female	15.5-20.5	18.05	±1.56	
L2	Male	15.5-21.5	18.15	±1.64	0.449

	Female	15.5-20.0	17.77	±1.46	
L3	Male	14.5-23.5	19.37	±2.60	0.601
	Female	14.5-23.0	18.95	±2.49	
L4	Male	14.5-23.0	18.95	±2.49	0.439
	Female	13.5-20.5	18.40	±1.92	
L5	Male	14.5-19.5	17.02	±1.66	1.00
	Female	14.5-19.5	17.02	±1.66	

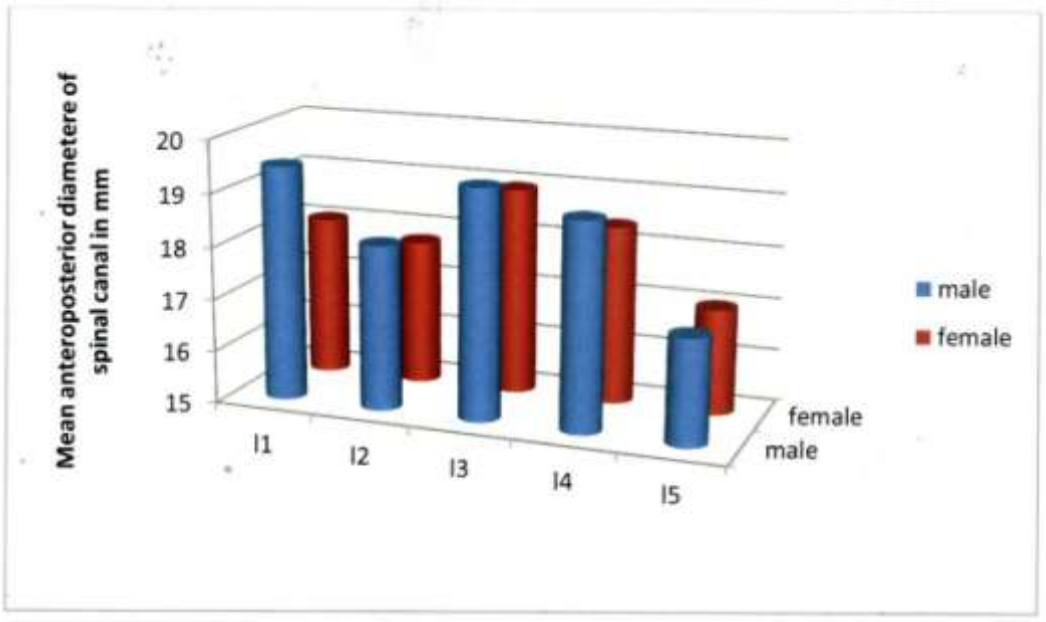

Figure 1 Mean anteroposterior diameters (mm) of spinal canals in mm.

Examining the heights of vertebral bodies and intervertebral discs revealed intriguing patterns. While heights increased progressively from L1 to L5, indicating the natural curvature of the lumbar spine, sex-specific differences emerged. Females consistently exhibited slightly smaller heights, shedding light on potential biomechanical implications that could influence clinical decision-making in spinal interventions.

Table 4 Mean height of the vertebral bodies in both sexes.

LEVEL	SEX GROUP	RANGE	MEAN	S.D.	P-VALUE
L1	MALE	27.5-34.5	31.22	±1.89	0.0002
	FEMALE	25.0-27.8	26.65	±0.80	
L2	MALE	29.0-36.3	31.71	±2.01	<0.001
	FEMALE	26.0-31.5	29.05	±1.84	
L3	MALE	29.0-36.3	31.71	±2.01	<0.001
	FEMALE	26.5-31.5	29.08	±1.81	
L4	MALE	28.0-34.8	31.17	±1.56	<0.001
	FEMALE	23.5-32.8	28.51	±2.13	
L5	MALE	26.5-35.3	31.01	±2.15	0.001
	FEMALE	23.2-31.8	28.55	±2.13	

The index of intervertebral disc (Id) remained remarkably constant across lumbar levels, highlighting a consistent ratio of minimum to maximum intervertebral disc height.

Table 5 Index of intervertebral disc (Id) in both sexes

LEVEL	SEX GROUP	RANGE	MEAN	S.D.	P-VALUE
T_{12}-L_1	Male	0.18-0.36	0.264	±0.061	<0.001
	Female	0.32-0.44	0.370	±0.040	
L_1-L_2	Male	0.16-0.35	0.259	±0.060	0.031
	Female	0.25-0.33	0.293	±0.027	
$L_2 - L_3$	Male	0.20-0.37	0.270	±0.056	0.109
	Female	0.25-0.34	0.292	±0.025	
L_3-L_4	Male	0.21-0.39	0.288	±0.047	0.006
	Female	0.26-0.39	0.326	±0.352	
L_4-L_5	Male	0.29-0.46	0.363	±0.046	0.957
	Female	0.26-0.45	0.362	±0.059	

Id = Minimum height of intervertebral disc / Maximum height of the vertebral body

This observation table shows that values of intervertebral disc index (Id) in both sexes are constant from L1 to L5. There is no significant difference in the values of ID of males and females, so this index is not conclusive as far as sexual dimorphism is concerned.

This finding contributes valuable information for researchers and clinicians involved in spinal biomechanics, as it establishes a baseline understanding of the relative proportions within the lumbar intervertebral discs.

IV. Discussion:

*Transverse Diameter of the Spinal Canal:*The transverse diameter of the spinal canal increases consistently from L1 to L5, as observed in multiple studies(11, 12, 13). However, there are sex-specific differences, with males having slightly larger transverse diameters than females (**Error! Reference source not found.**) at all lumbar levels, as shown in

Table *1*(14). This sexual dimorphism highlights the importance of considering gender-specific norms in clinical assessments and surgical interventions involving the lumbar spine(15). Previous researchers, such as Eisenstein (1977) and AmonooKuofi et al. (1982),(16, 17) have also noted variations in spinal canal dimensions based on sex, further emphasizing the relevance of anatomical studies in shaping clinical considerations.

*Vertebral Bodies:*The study found that there is a gradual increase in the transverse diameters of vertebral bodies from L1 to L5 as shown in

Table *2*, which is consistent with existing literature. However, there were notable individual differences, indicating the complexity of lumbar spine morphometry. Males consistently had larger vertebral body diameters than females, which is in line with previous studies by AmonooKuofi et al. (1982)(17) and Sudha Chhabra et al. (1991)(18). These findings provide valuable insights into the variations in vertebral morphology and contribute to a better understanding of lumbar anatomy(19, 20).

*Anteroposterior Diameter of the Spinal Canal:*The anteroposterior diameter of the spinal canal was found to increase predictably from L1 to L5, with males having slightly larger diameters than females as shown in

Table *3* and (**Figure 1**). This finding is consistent with the observations of Eisenstein (1977)(21) and highlights the importance of considering sex-specific factors in lumbar spine assessments(22, 23). Clinicians involved in surgical interventions or diagnostic assessments should have a precise understanding of these differences to ensure accurate treatment and diagnosis (24).

*Vertebral Bodies and Intervertebral Discs:*The examination of vertebral body and intervertebral disc heights revealed intriguing patterns as shown in

Table *4*, indicating a natural curvature of the lumbar spine. Females consistently exhibited slightly smaller heights, suggesting potential biomechanical implications. These findings resonate with established anatomical knowledge and may influence clinical decision-making in spinal interventions. The observed sexual dimorphism aligns with studies by AmonooKuofi et al. (1982)(17) and Sudha Chhabra et al. (1991),(18) emphasizing the consistent nature of these anatomical variations.(25, 26)

*Index of Intervertebral Disc (Id):*The index of intervertebral disc (Id) remained remarkably constant across lumbar levels

Table 5, suggesting a consistent ratio of minimum to maximum intervertebral disc height (27). These finding challenges previous assumptions and provides a baseline for understanding lumbar intervertebral disc proportions. While not showing significant sexual dimorphism, the Id values contribute valuable information for researchers and clinicians involved in spinal biomechanics (28). This uniformity challenges previous assumptions about potential variations in disc proportions along the lumbar spine and opens avenues for biomechanical investigations (29).

Clinical Implications: The subtle but significant sexual dimorphism observed in various parameters underscores the importance of tailored approaches in spinal assessments, particularly in surgical procedures. Gender-specific considerations can optimize outcomes and minimize complications, aligning with the evolving trend toward personalized medicine. Additionally, the uniformity in the index of intervertebral disc (Id) challenges previous assumptions, emphasizing the need for a standardized approach in lumbar spine morphometric assessments for precise diagnostic and therapeutic strategies.

Comparisons with Existing Studies: Comparisons with existing studies reveal both congruencies and disparities, emphasizing the need for a standardized approach to lumbar spine morphometric assessments. The study contributes a robust dataset to the evolving global understanding of normal lumbar vertebrae studies. The observed variations documented in this comprehensive analysis provide a basis for refining diagnostic and therapeutic strategies, ensuring patient-centered and evidence-based care.

V. Conclusion:

In conclusion, the comprehensive analysis of lumbar spine morphometry in this study contributes valuable insights into normal variations and potential clinical implications. The observed sexual dimorphism in various parameters emphasizes the importance of gender-specific reference values in clinical practice. The study not only reinforces established anatomical knowledge but also challenges assumptions, opening new avenues for biomechanical investigations. The findings serve as a foundation for future research and enhance our understanding of spinal healthcare.

Conflict of Interest:

The authors declare no conflicts of interest that could affect the objectivity or integrity of their research, focusing on lumbar spine morphometry advancement without external influences. They maintain transparency in disclosing potential conflicts of interest to uphold ethical standards and ensure the credibility of the findings.

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