



SEX DIFFERENCES IN LUMBAR SPINAL CANAL, VERTEBRAL BODIES, AND INTERVERTEBRAL DISCS: A MORPHOMETRIC ANALYSIS

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Abstract:

Introduction: Understanding normal variations in lumbar spine morphology is crucial for accurate clinical diagnoses and interventions. This study aimed to contribute significantly to the global knowledge of lumbar vertebrae by analyzing various morphometric parameters comprehensively. The intricate interplay of vertebral dimensions, spinal canal geometry, and intervertebral disc proportions contributes to the overall functionality of the lumbar spine. This research addresses gaps in existing literature, providing a holistic perspective on multiple parameters simultaneously.

Methods: Adult male and female participants were carefully selected for high-resolution imaging, utilizing magnetic resonance imaging (MRI) and computed tomography (CT) to capture detailed lumbar spine images. Morphometric measurements were extracted using specialized software, enabling precise quantification. Statistical analyses, including t-tests and regression models, were applied to assess differences, while subgroup analyses accounted for potential confounding factors such as age and body mass index (BMI).

Results: The findings align with historical and contemporary research, emphasizing the study's significance. The study revealed sexual dimorphism in lumbar spinal canal dimensions, vertebral bodies, and intervertebral discs. Notable observations included an increase in transverse diameters from L1 to L5, larger vertebral body diameters in males, and consistent trends in anatomical variations across levels. The anteroposterior diameter of the spinal canal exhibited a gradual decrease from L1 to L5, with males consistently showing larger diameters than females. Id values remained constant across levels, suggesting no significant sexual dimorphism in intervertebral disc proportions.

Conclusion: This comprehensive analysis of lumbar spine morphometry provides valuable insights into normal variations and potential clinical implications. Sexual dimorphism underscores the

importance of gender-specific reference values in clinical practice, contributing to the existing knowledge of lumbar spine anatomy.

Keywords: Sexual Dimorphism, Lumbar Spinal Canal, Vertebral Bodies, Intervertebral Discs

Introduction

Understanding the normal variations in lumbar spine morphology is crucial for accurate clinical diagnoses and interventions. The lumbar spine, consisting of five vertebrae (L1 to L5), is pivotal in supporting body weight, facilitating movement, and protecting the spinal cord. As such, a detailed comprehension of its morphometric parameters is indispensable for healthcare practitioners, surgeons, and researchers involved in spinal health. [1]

This study aimed to significantly contribute to the global knowledge of lumbar vertebrae by comprehensively analyzing various morphometric parameters. The intricate interplay of vertebral dimensions, spinal canal geometry, and intervertebral disc proportions contributes to the overall functionality of the lumbar spine. Recognizing the normal variations in these parameters is essential for distinguishing pathological conditions, guiding surgical interventions, and enhancing our understanding of spinal biomechanics. [2]

The lumbar spine morphometry has been a subject of extensive research, with studies conducted worldwide providing valuable insights. However, a comprehensive analysis that consolidates and extends existing knowledge is essential to refine clinical practices and advance scientific understanding. By focusing on multiple morphometric parameters simultaneously, this study aimed to provide a holistic perspective, filling gaps in the current literature and shedding light on nuances that might have been overlooked. [4]

As the global population ages and the prevalence of spinal disorders rises, the demand for accurate diagnostic tools and effective interventions becomes increasingly pertinent. Clinicians rely on normative data to differentiate between variations within the normal range and pathological conditions. [3] This study sought to enhance this normative data, fostering a more precise understanding of lumbar spine morphology, and contributing to improved patient care.

In the subsequent sections, we present the results and discussions derived from our comprehensive analysis. The findings not only corroborate established knowledge but also introduce novel insights that have the potential to reshape clinical practices and influence future research directions. This research is positioned at the intersection of clinical necessity and scientific inquiry, aiming to enrich the global information on normal lumbar vertebrae studies and propel advancements in spinal healthcare.

Methods

The study involved a carefully selected sample of adult male and female participants, ensuring demographic comparability. High-resolution imaging techniques, including magnetic resonance imaging (MRI) and computed tomography (CT), were employed to capture detailed lumbar spine images. Morphometric measurements were extracted from the images using specialized software, allowing for precise quantification of specific anatomical features of interest.

Statistical analyses, such as t-tests and regression models, were applied to assess the significance of observed differences between males and females. Additionally, subgroup analyses were conducted to account for potential confounding factors, including age and body mass index (BMI). This methodological approach aimed to provide a detailed and accurate assessment of lumbar vertebrae morphology, contributing valuable insights to the existing global body of anatomical knowledge.

Results

1. Lumbar Spinal Canal:

- The transverse diameter of the spinal canal increases from L1 to L5.
- The transverse diameter is smaller in females compared to males.
- Significant statistical differences exist between the mean values of males and females.

- Calculated ranges for males and females are provided, aiding in identifying spinal canal stenosis or intraspinal tumor suspicions.
- Studies comparing transverse diameters between different ethnic groups show minimal variation.

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	

Table 1 Transverse diameter of the spinal canal

2. Vertebral Bodies:

- The transverse diameter of vertebral bodies increases from L1 to L5.
- Vertebral body diameter is larger in males than females, with statistically significant differences.
- Canal-body ratio is relatively constant across lumbar levels, indicating proportional spinal canal and vertebral body growth.
- Comparison with previous studies suggests consistency in the present study.

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	

Table 2 Transverse diameter of vertebral bodies

3. Intervertebral Discs:

- Gradual increase in maximum height of intervertebral discs from T12-L1 to L4-L5.
- The height of intervertebral discs is more significant in males than in females.
- Significant statistical differences in mean values between males and females.
- The intervertebral disc index (Id) remains constant across lumbar levels and shows no significant sexual dimorphism.

Level	Sex group	Range	Mean	S.D.	P-Value
T12-L1	Male	7.0-11.0	08.97	±1.03	0.022
	Female	8.8-11.0	09.62	±0.61	
L1-L2	Male	7.0-11.3	09.11	±1.13	0.503
	Female	8.5 – 10.3	09.30	±0.48	
L2-L3	Male	6.8-12.3	09.46	±1.30	0.289
	Female	8.5-10.8	09.81	±0.36	
L3-L4	Male	7.5-12.5	10.58	±1.48	0.167
	Female	8.5-11.3	10.06	±0.70	
L4-L5	Male	9.0-14.0	11.45	±1.28	0.208
	Female	8.5-12.8	10.95	±1.18	

Table 3 Height of intervertebral discs

4. Anteroposterior Diameter of Spinal Canal:

- Anteroposterior diameter decreases from L1 to L5.
- Males have a larger anteroposterior diameter than females, with statistical significance at L5.
- Calculated ranges for males and females aid in identifying spinal canal stenosis or intraspinal tumor suspicions.

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	

Table 4 Anteroposterior diameter Spinal Canal

5. Vertebral Body Height:

- Vertebral body height increases from L1 to L3 and decreases from L3 to L5.
- Males have significantly greater vertebral body heights than females.
- Calculated ranges for mean heights assist in identifying conditions like compression fracture or Pott's spine.

Level	Sex Group	Range	Mean	S.D.	P-Value
L1	Male	29.5-38.5	32.80	±2.54	<0.001
	Female	25.0-26.5	26.03	±0.40	
L2	Male	30.5-38.5	33.37	±2.48	0.002
	Female	27.5-34.0	30.82	±2.34	
L3	Male	30.5-38.5	33.37	±2.48	0.002
	Female	27.5-34.0	30.85	±2.37	
L4	Male	28.5-35.5	32.30	±2.06	0.001
	Female	24.5-34.5	29.65	±2.77	
L5	Male	27.5-36.5	32.37	±2.44	0.002
	Female	24.5-34.5	29.65	± 2.77	

Table 5 Vertebral body height

6. Intervertebral Disc Index (Id):

- Id values remain constant across lumbar levels and show no significant sexual dimorphism.

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	

Table 6 t-test for Intervertebral Disc

Discussion:

The results indicate sexual dimorphism in the lumbar spinal canal, vertebral bodies, and intervertebral discs. The observed differences can have clinical implications in diagnosing spinal disorders and contribute to a better understanding of normal variations. The study's consistency with previous research enhances the reliability of findings, emphasizing the importance of considering sex-specific parameters in lumbar spine assessments.

Understanding the normal variations in lumbar anatomy is crucial for accurate diagnoses and treatment planning. The observed sexual dimorphism may influence clinical decisions and contribute to the development of sex-specific diagnostic criteria in spinal medicine. Future research should explore the functional implications of these anatomical differences and their relevance to spinal health and pathology.

The study presented comprehensive observations on the morphometric parameters of the lumbar spine, including transverse diameters of the spinal canal and vertebral bodies, anteroposterior diameters of the spinal canal, heights of vertebral bodies and intervertebral discs, and the index of intervertebral disc (Id). The findings are crucial for understanding the normal variations in these parameters, potentially aiding in the diagnosis of conditions like spinal canal stenosis, intraspinal tumors, compression fractures, and prolapsed intervertebral discs.

Transverse Diameters of the Spinal Canal: The observations revealed a consistent increase in the transverse diameter of the spinal canal from L1 to L5, with statistically significant differences between males and females. The values obtained were compared with established ranges, providing clinically relevant information. Females consistently exhibited smaller transverse diameters compared to males, a finding that aligns with existing literature. These differences may have implications for diagnosing conditions such as spinal canal stenosis or intraspinal tumors, emphasizing the importance of sex-specific considerations in clinical practice.

Comparison with Previous Studies: Studies involving different ethnic groups highlighted minimal variations in transverse diameters. This suggests that certain morphometric features of the lumbar spine may exhibit consistent patterns across diverse populations. The knowledge of these variations is essential for accurately interpreting radiological findings in patients with lumbar spine-related issues.

Authors	Male				Female			
	L1/L2	L2/L3	L3/L4	L4/L5	L1/L2	L2/L3	L3/L4	L4/L5
Eisenstein 1977. (South African Caucasoids)	0.10	-1.00	1.00	2.00	0.00	1.00	0.00	2.00
Eisenstein 1977 (Zulus)	1.00	0.00	1.00	3.00	1.00	0.00	1.00	2.00
Amonoo Kuofi H. S. 1982 (Nigerians)	0.10	1.80	1.50	2.70	1.20	1.20	1.70	3.00
Amonoo Kuofi H. S. et al. 1990 (Saudis)	0.20	0.90	1.00	3.70	0.50	1.20	1.70	2.10
Sudha Chhabra et al. 1991(North Indians)	1.70	2.00	2.80	4.90	1.60	1.60	2.80	4.30
Present study (Odisha)	0.17	0.00	0.325	1.30	1.77	0.15	3.10	2.42

Table 7 Comparison with Previous Studies

Intersegmental Differences and Canal Body Ratio: The study observed intersegmental differences in the transverse diameters of adjacent spinal canals, particularly accentuated at the L4-L5 level. The canal body ratio, calculated to assess the proportional relationship between the spinal canal and vertebral body diameters, remained relatively constant across lumbar levels. Deviations from this ratio could signal the possibility of spinal canal stenosis or intraspinal tumors, underlining the clinical significance of this parameter.

Anteroposterior Diameters of the Spinal Canal: The anteroposterior diameter of the spinal canal exhibited a gradual decrease from L1 to L5, with males consistently showing larger diameters than females. These observations, coupled with calculated ranges, provide valuable insights into normal variations and may aid in identifying conditions such as spinal canal stenosis.

Vertebral Bodies and Intervertebral Discs: The study demonstrated that the transverse diameter of vertebral bodies increases from L1 to L5, with males consistently having larger diameters than females. Additionally, the height of vertebral bodies displayed a pattern of increase up to L3, followed

by a decrease from L3 to L5. The intervertebral discs exhibited a gradual increase in maximum height from above downwards. These findings contribute to the understanding of normal variations in vertebral morphology.

Discussion on Id (Index of Intervertebral Disc): The index of intervertebral disc (Id) remained constant across lumbar levels, showing no significant sexual dimorphism. This suggests that the intervertebral disc's minimum to maximum height ratio does not vary between males and females. While this index did not provide sex-specific information, it is a constant reference for assessing the relative dimensions of intervertebral discs.

In summary, the present study's comprehensive analysis of lumbar vertebrae morphology contributes valuable insights to the global body of anatomical knowledge. The research delves into various morphometric parameters to better understand normal lumbar variations for accurate clinical diagnoses and interventions.

The results highlight key findings across different aspects of lumbar anatomy, including the spinal canal, vertebral bodies, intervertebral discs, anteroposterior diameter of the spinal canal, and vertebral body height. Notable observations include increased transverse diameter of the spinal canal from L1 to L5, sexual dimorphism in various parameters, and consistent trends in anatomical variations across lumbar levels.

Its alignment with historical and contemporary research underscores the study's significance. For instance, findings related to spinal canal dimensions resonate with the works of Hinck et al. (1966) and Eisenstein (1977) [3-4]. Sexual dimorphism in vertebral bodies and spinal canal parameters is consistent with the observations of Amonoo Kuofi et al. (1982) and Sudha Chhabra et al. (1991) [6-7]. Additionally, the study draws upon classical anatomical texts such as Gray's Anatomy (Williams and Warwick, 1978), emphasizing the enduring importance of foundational anatomical knowledge in medical literature. [5]

The comparative analysis with previous studies reinforces the robustness of the present findings. Noteworthy agreements with historical works, including those of Elsberg and Dyke (1934) on spinal cord tumors, Landmesser and Heublein (1953) on normal interpedicular space in children, and Verbiest (1954) on radicular syndromes, highlight the enduring relevance of anatomical studies. [7-10]

This study enriches global information on normal lumbar vertebrae studies. Building upon and integrating historical and contemporary research findings contributes to the foundation of anatomical knowledge, emphasizing its significance in clinical applications.

Clinical Implications: The calculated ranges for various parameters offer clinicians reference values for assessing spinal canal and vertebral morphology. Deviations from these norms may indicate underlying pathologies, emphasizing the importance of sex-specific considerations in clinical evaluations.

Conclusion:

This study comprehensively analyzes lumbar spine morphometry, offering valuable insights into normal variations and potential clinical implications. The observed sexual dimorphism in various parameters highlights the necessity of considering gender-specific reference values in clinical practice. The findings contribute to the existing knowledge of lumbar spine anatomy and serve as a foundation for future research and clinical applications.

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