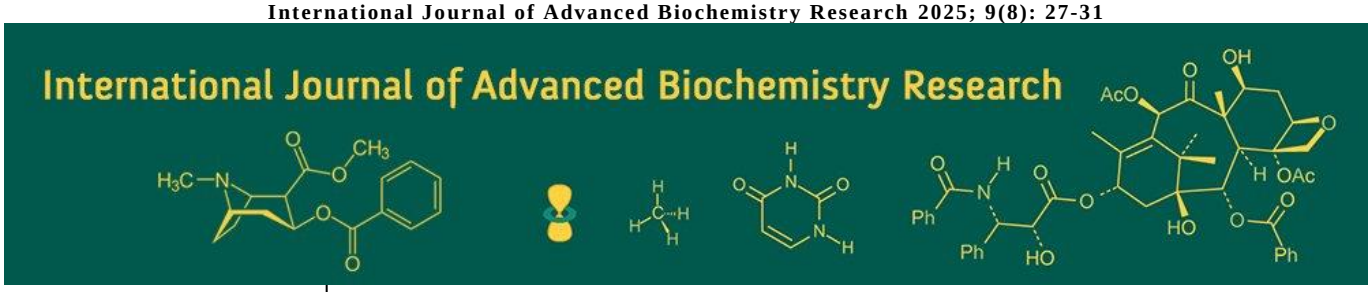

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Radiographical and gross morphometric analysis of lumbar vertebrae in domestic shorthair cats

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Abstract
This study evaluated radiographic and gross morphometry of lumbar vertebrae (L1-L7) in six adult domestic shorthair cats. Measurements included lamina, pedicle, vertebral foramen, body, spinous and transverse processes, articular, and accessory structures. Morphometric trends showed progressive enlargement from L1 to L6, with tapering at L7. Posterior features generally exceeded anterior dimensions. Bilateral symmetry and strong modality concordance were observed, with minor discrepancies due to radiographic distortion. The absence and reduction of accessory processes at L6-L7 suggest structural transition toward sacral regions. These findings offer vital anatomical reference for imaging, orthopaedic intervention, and comparative vertebral studies in small animal anatomy.

Keywords: Cat, lumbar vertebrae, morphometry, gross, radiographic

Introduction
The feline vertebral column is an intricate structure responsible for vital biomechanical functions including support, locomotion, and neurological protection. Within this system, the lumbar vertebrae (L1-L7) bear a significant portion of axial load and facilitate mobility, flexibility, and muscular attachments. Given the frequency of lumbar-related disorders in feline patients, such as fractures, disc disease, and congenital malformations, a detailed morphometric understanding of these vertebrae is paramount.
Modern imaging techniques like radiography, computed tomography (CT), and magnetic resonance imaging (MRI) allow clinicians to visualize structural abnormalities. However, their diagnostic accuracy is limited without baseline anatomical knowledge across different feline breeds (Derakshi *et al.*, 2024) [2]. Morphometric studies bridge this gap, offering precise measurements for clinical and surgical decision making.
Chang and Kim (2020) [1] reported anatomy of lumber vertebrae in cats in relation to age and body mass. As pointed out by Schmid *et al.* (2020) [6] and Kushner *et al.* (2022) [4], vertebral shape and size vary with factors such as age, body size, genetics, and evolutionary lineage. This study aimed at meticulous morphometric profile of the lumbar spine in domestic short hair cats.

Materials and Methods
The present study was conducted on six adult domestic shorthair cats. The samples were collected from cats that sustained external injuries such as those resulting from automobile accidents or falls from high-rise buildings and were either brought dead or died during treatment at the Veterinary Clinical Complex, College of Veterinary Sciences and Animal Husbandry, OUAT, Bhubaneswar. These cats were included in the study following written consent for willed body donation from their owners.
Radiographic evaluation: Left lateral view radiograph and ventrodorsal view radiographs were taken and linear measurements of vertebral parameters were recorded in centimetre using computed radiography unit. The following radiographic vertebral measurements were taken

1. **Vertebral lamina:** Length
2. **Vertebral foramen:** Vertical diameter
3. **Vertebral body:** Length and height.

4. **Spinous process:** Length and height.
5. **Transverse process:** Projection length and width.
6. **Articular process:** Projection length.

Gross morphometry: Lumbar vertebral bones from deceased cats were harvested using an entomological approach involving maggot-assisted tissue removal, which helps prevent brittleness commonly observed in dried bone specimens (Lai *et al.* 2015) [5]. Skin and visceral organs were removed. Carcass was placed in a lab animal cage, over moist gauge cloth, and kept outdoor for maggot infestation. Carcass was kept moist until bone looks clean and whitish. The lumbar vertebral morphometry from L1 to L7 was measured using digital vernier calliper (measuring range: 0-150 mm; Accuracy: ± 0.02 mm; Resolution: 0. 01 mm). Vertebral parameters were recorded in centimetre (cm).

The following measurements were taken

1. **Vertebral lamina:** Length, width and thickness.
2. **Vertebral pedicle:** Length, width and thickness.
3. **Vertebral foramen:** Transverse diameter and Vertical diameter
4. **Vertebral body:** Length, width and height.
5. **Spinous process:** Length, height and thickness.
6. **Transverse process:** Projection length, width and thickness.
7. **Articular process:** Projection length and thickness.
8. **Accessory process:** Projection length, width and thickness.

The values obtained were tabulated and all variables were expressed as Mean ± SD. Changes from L1 to L7 was analysed using SPSS software.

Results Discussions

The mean ± SD values of radiographic and gross morphometric parameters of lumbar vertebrae (L1-L7) in six adult domestic shorthair cats are presented in Tables 1-10. Analysis revealed consistent patterns of structural variation across vertebrae, highlighting both anatomical specializations and biomechanical adaptations.

Lamina and Pedicle Morphometry: Lamina dimensions (length, width, thickness) increased progressively from L1 to L5, then declined slightly at L6 and L7. Posterior laminar measurements consistently exceeded anterior values. Pedicle parameters showed gradual enlargement through L5-L6, with a notable reduction at L7. Radiographic lamina lengths were marginally lower than gross measurements, likely due to tissue compression or projection artifacts. These trends reflect transitional loading characteristics, as documented in biomechanical analyses by Fitzgerald *et al.* (2023) [3].

Vertebral Foramen and Body Morphometry: The vertical diameter of the vertebral foramen peaked at L5, while transverse diameters increased steadily caudally from L1 to L7. Vertebral body length followed a similar pattern, with a decline at L7, and body width remained consistently greater than height across all levels. These features exhibited high agreement between radiographic and gross assessments, corroborating the morphometric fidelity reported by Richter *et al.* (2024) [8].

Spinous and Transverse Processes: Spinous process metrics (height and length) increased through L1-L6, peaking at L5. Posterior regions displayed greater thickness, suggesting enhanced musculotendinous attachment. Transverse process projection lengths showed marked caudal elongation from L5 to L7. Despite minor discrepancies in lateral span, radiographic data remained strongly consistent with gross measures. Such alignment supports findings by Smith and Johnson (2018), affirming spinal variability as an adaptive mechanism for feline agility.

Articular and Accessory Processes: Anterior articular process projections peaked at L2-L3, while posterior extensions remained relatively stable. Posterior thickness exceeded anterior consistently. Radiographically, posterior lengths appeared diminished, likely due to imaging overlap. Accessory processes were absent at L7 and showed progressive decline from L1 to L6 in all measured dimensions. Schmid *et al.* (2020) [6] noted similar caudal tapering, attributing these changes to evolutionary stabilization near the sacrum.

Radiographic-Gross Concordance: Bilateral symmetry across pedicle lengths, articular projections, and laminar thicknesses was notable, supporting precise surgical and diagnostic reliability. Morphometric consistency between modalities enhances clinical confidence in preoperative planning. Kushner *et al.* (2022) [4] emphasized the relevance of such landmarks for interventions like pedicle screw placement. Minor radiographic distortions, attributable to soft tissue compression or geometric projection angles, underscore the importance of methodological awareness during imaging.

Table 1: Radiographic morphometry of lumbar vertebral lamina, foramen and vertebral body of adult domestic shorthair cats (in cm).

	Vertebral Lamina	Vertebral Foramen		Vertebral Body			
		Vertical Diameter		Length	Height		
	Length	Anterior end	Posterior end		Anterior end	Centre	Height end
L1	1.48±0.03	0.56±0.01	0.57±0.01	1.44±0.01	0.52±0.01	0.48±0.01	0.64±0.01
L2	1.52±0.03	0.59±0.01	0.57±0.01	1.62±0.01	0.63±0.01	0.49±0.01	0.59±0.01
L3	1.78±0.03	0.57±0.01	0.57±0.01	1.40±0.01	0.55±0.01	0.40±0.01	0.67±0.01
L4	1.96±0.03	0.58±0.01	0.61±0.01	1.92±0.01	0.62±0.01	0.51±0.01	0.70±0.01
L5	2.19±0.03	0.59±0.01	0.61±0.01	2.04±0.01	0.69±0.01	0.53±0.01	0.71±0.01
L6	2.07±0.03	0.53±0.01	0.49±0.01	2.11±0.01	0.69±0.01	0.57±0.01	0.72±0.01
L7	1.39±0.03	0.40±0.01	0.41±0.01	1.67±0.01	0.71±0.01	0.59±0.01	0.73±0.01

Table 2: Radiographic morphometry of lumbar vertebral processes of adult domestic shorthair cats (in cm).

	Spinous process		Transverse process				Articular process	
	Length	Height	Projection length		Width		Projection length	
			Left side	Right side	Left side	Right side	Anterior	Posterior
L1	0.96±0.01	0.80±0.01	1.47±0.02	1.90±0.01	0.63±0.01	0.60±0.01	0.69±0.01	0.42±0.01
L2	1.11±0.01	0.94±0.01	1.17±0.02	1.54±0.02	0.69±0.01	0.85±0.01	0.64±0.01	0.44±0.01
L3	1.12±0.01	1.12±0.01	1.24±0.01	1.06±0.01	0.68±0.01	1.00±0.01	0.72±0.01	0.52±0.01
L4	1.16±0.01	1.15±0.01	1.42±0.01	1.45±0.01	0.87±0.01	0.90±0.01	0.71±0.01	0.54±0.01
L5	1.51±0.01	1.18±0.01	1.67±0.01	1.69±0.01	0.94±0.01	1.14±0.01	0.63±0.01	0.43±0.01
L6	1.39±0.01	1.20±0.01	1.83±0.01	2.00±0.01	1.04±0.01	1.40±0.01	0.70±0.01	0.46±0.01
L7	0.97±0.01	1.14±0.01	1.75±0.01	1.81±0.01	0.93±0.01	1.15±0.01	0.74±0.01	0.62±0.01

Table 3: Gross morphometry of lamina of lumbar vertebrae of adult domestic shorthair cats (in cm).

	Vertebral Lamina									
		Length		Width				Thickness		
	Left side	Right side	Anterior end		Posterior end		Anterior end		Posterior end	
			Left side	Right side	Left side	Right side	Left side	Right side	Left side	Right side
L1	1.55±0.04	1.58±0.04	0.35±0.03	0.32±0.02	0.55±0.11	0.55±0.13	0.11±0.02	0.10±0.02	0.27±0.04	0.28±0.03
L2	1.65±0.04	1.63±0.03	0.39±0.02	0.40±0.01	0.61±0.18	0.59±0.15	0.11±0.03	0.11±0.02	0.26±0.06	0.28±0.06
L3	1.80±0.02	1.83±0.03	0.40±0.02	0.42±0.01	0.53±0.03	0.50±0.02	0.12±0.01	0.12±0.01	0.30±0.02	0.31±0.02
L4	2.17±0.05	2.20±0.03	0.43±0.03	0.43±0.01	0.47±0.03	0.49±0.03	0.12±0.01	0.12±0.01	0.26±0.05	0.36±0.02
L5	2.26±0.09	2.35±0.09	0.37±0.01	0.40±0.02	0.49±0.02	0.57±0.02	0.10±0.01	0.12±0.01	0.23±0.02	0.28±0.01
L6	2.06±0.06	2.12±0.04	0.48±0.03	0.49±0.03	0.54±0.02	0.58±0.01	0.11±0.02	0.10±0.01	0.26±0.02	0.25±0.02
L7	1.44±0.05	1.40±0.10	0.51±0.01	0.51±0.01	0.49±0.02	0.53±0.01	0.14±0.01	0.12±0.01	0.24±0.02	0.23±0.02

Table 4: Gross morphometry of pedicle of lumbar vertebrae of adult domestic shorthair cats (in cm).

	Vertebral Pedicle									
	Length		Width				Thickness			
	Left side	Right side	Anterior end		Posterior end		Anterior end		Posterior end	
			Left side	Right side	Left side	Right side	Left side	Right side	Left side	Right side
L1	1.25±0.03	1.27±0.04	0.38±0.01	0.38±0.01	0.55±0.12	0.57±0.13	0.16±0.01	0.16±0.02	0.21±0.01	0.21±0.01
L2	1.46±0.03	1.42±0.03	0.38±0.01	0.37±0.02	0.69±0.26	0.66±0.21	0.18±0.03	0.17±0.02	0.19±0.02	0.19±0.02
L3	1.49±0.03	1.49±0.03	0.40±0.02	0.39±0.01	0.37±0.01	0.35±0.02	0.17±0.02	0.18±0.01	0.18±0.01	0.19±0.01
L4	1.51±0.02	1.56±0.02	0.43±0.02	0.45±0.04	0.93±0.02	0.95±0.04	0.16±0.01	0.17±0.02	0.18±0.01	0.17±0.02
L5	1.62±0.06	1.60±0.02	0.47±0.04	0.46±0.02	0.93±0.03	1.02±0.03	0.14±0.02	0.13±0.01	0.16±0.01	0.18±0.01
L6	1.54±0.01	1.57±0.02	0.43±0.01	0.44±0.01	0.95±0.01	0.93±0.02	0.13±0.01	0.14±0.01	0.14±0.01	0.16±0.02
L7	1.24±0.02	1.20±0.02	0.31±0.03	0.29±0.02	0.75±0.05	0.81±0.04	0.21±0.02	0.20±0.02	0.21±0.01	0.22±0.01

Table 5: Gross morphometry of lumbar vertebral foramen of adult domestic shorthair cats (in cm).

	Vertebral Foramen			
	Transverse diameter		Vertical diameter	
	Anterior end	Posterior end	Anterior end	Posterior end
L1	0.75±0.04	0.96±0.03	0.57±0.03	0.67±0.03
L2	0.81±0.06	1.02±0.04	0.68±0.06	0.77±0.03
L3	0.81±0.02	1.22±0.04	0.66±0.05	0.59±0.03
L4	0.85±0.05	1.04±0.08	0.63±0.04	0.77±0.02
L5	0.88±0.06	1.07±0.03	0.73±0.03	0.79±0.05
L6	0.88±0.03	1.09±0.02	0.58±0.04	0.56±0.04
L7	0.89±0.03	1.10±0.09	0.46±0.03	0.43±0.01

Table 6: Gross morphometry of lumbar vertebral body of adult domestic shorthair cats (in cm).

	Vertebral body				
	Length	Width		Height	
		Anterior end	Posterior end	Anterior end	Posterior end
L1	1.48±0.03	1.09±0.02	1.17±0.03	0.59±0.02	0.62±0.02
L2	1.71±0.03	1.12±0.02	1.18±0.02	0.61±0.02	0.65±0.02
L3	1.70±0.23	1.07±0.02	1.49±0.05	0.66±0.01	1.02±0.09
L4	1.93±0.04	1.22±0.02	1.23±0.04	0.62±0.02	0.69±0.02
L5	2.08±0.02	1.24±0.01	1.22±0.01	0.70±0.01	0.68±0.01
L6	2.12±0.02	1.22±0.02	1.16±0.02	0.73±0.01	0.76±0.01
L7	1.75±0.02	1.32±0.04	1.26±0.03	0.72±0.01	0.75±0.02

Table 7: Gross morphometry of spinous process of lumbar vertebrae of adult domestic shorthair cats (in cm).

Spinous process				
	Length	Height	Thickness	
			Anterior border	Posterior border
L1	1.18±0.07	0.84±0.05	0.20±0.06	0.20±0.04
L2	1.25±0.02	0.84±0.02	0.16±0.02	0.15±0.02
L3	1.34±0.03	1.00±0.03	0.15±0.02	0.16±0.02
L4	1.35±0.02	1.08±0.04	0.15±0.01	0.19±0.02
L5	1.61±0.05	1.17±0.01	0.16±0.01	0.14±0.01
L6	1.31±0.04	1.18±0.02	0.10±0.01	0.14±0.01
L7	0.96±0.03	1.05±0.01	0.09±0.01	0.14±0.01

Table 8: Gross morphometry of transverse process of lumbar vertebrae of adult domestic shorthair cats (in cm).

Transverse process						
	Projection length		Width		Thickness	
	Left side	Right side	Left side	Right side	Left side	Right side
L1	1.22±0.49	1.04±0.29	0.53±0.06	0.53±0.06	0.33±0.24	0.33±0.25
L2	0.85±0.02	0.82±0.02	0.75±0.02	0.76±0.02	0.21±0.02	0.20±0.02
L3	1.18±0.02	1.22±0.03	0.72±0.03	0.72±0.04	0.23±0.03	0.24±0.03
L4	1.44±0.03	1.60±0.04	0.82±0.05	0.80±0.05	0.23±0.02	0.33±0.03
L5	1.58±0.03	1.59±0.02	0.91±0.04	0.85±0.02	0.29±0.01	0.31±0.01
L6	1.98±0.03	1.87±0.03	0.89±0.01	0.92±0.02	0.35±0.02	0.35±0.02
L7	2.02±0.01	2.07±0.03	0.86±0.03	0.83±0.02	0.32±0.02	0.30±0.02

Table 9: Gross morphometry of articular processes of lumbar vertebrae of adult domestic shorthair cats (in cm).

Articular processes								
	Projection length				Thickness			
	Anterior		Posterior		Anterior		Posterior	
	Left side	Right side	Left side	Right side	Left side	Right side	Left side	Right side
L1	0.76±0.01	0.72±0.02	0.60±0.04	0.63±0.03	0.18±0.01	0.19±0.01	0.30±0.03	0.31±0.06
L2	0.85±0.02	0.86±0.01	0.63±0.08	0.65±0.07	0.18±0.02	0.19±0.01	0.31±0.07	0.30±0.07
L3	0.85±0.02	0.88±0.02	0.52±0.05	0.54±0.04	0.25±0.02	0.22±0.02	0.34±0.07	0.82±1.26
L4	0.81±0.02	0.79±0.02	0.59±0.02	0.56±0.02	0.25±0.02	0.25±0.03	0.35±0.13	0.31±0.07
L5	0.75±0.02	0.74±0.02	0.52±0.05	0.54±0.04	0.23±0.03	0.22±0.02	0.23±0.06	0.23±0.05
L6	0.73±0.02	0.73±0.02	0.60±0.01	0.59±0.02	0.20±0.01	0.19±0.01	0.18±0.01	0.17±0.01
L7	0.74±0.01	1.10±0.82	0.59±0.02	0.60±0.03	0.19±0.01	0.18±0.02	0.21±0.02	0.22±0.03

Table 10: Gross morphometry of accessory process of lumbar vertebrae of adult domestic shorthair cats (in cm).

Accessory process						
	Projection length		Width		Thickness	
	Left side	Right side	Left side	Right side	Left side	Right side
L1	0.60±0.03	0.59±0.03	0.77±0.03	0.79±0.03	0.16±0.01	0.17±0.01
L2	0.55±0.03	0.56±0.03	0.68±0.02	0.66±0.03	0.16±0.01	0.15±0.01
L3	0.50±0.03	0.61±0.02	0.61±0.02	0.58±0.02	0.14±0.01	0.14±0.01
L4	0.43±0.03	0.44±0.03	0.55±0.03	0.54±0.03	0.13±0.01	0.14±0.01
L5	0.36±0.02	0.38±0.02	0.52±0.02	0.54±0.02	0.12±0.01	0.14±0.01
L6	0.33±0.02	0.30±0.02	0.43±0.03	0.40±0.03	0.10±0.01	0.10±0.01

Conclusion

The observed morphometric trends, progressive enlargement, bilateral symmetry, and caudal tapering, are emblematic of the feline lumbar spine's biomechanical specialization. The reference values derived from this study offer valuable guidance for veterinary clinicians and anatomists in contexts ranging from surgical intervention to radiological interpretation.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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