

Computed tomography and three-dimensional reconstruction of the pelvic limb anatomy in the chinchilla (*Chinchilla lanigera*)

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Summary

The chinchilla (*Chinchilla lanigera*) is an increasingly important companion and laboratory animal whose pelvic limb plays a crucial role in locomotion and jumping. Despite the availability of classical anatomical descriptions, detailed computed tomographic investigations of the pelvic limb remain limited. The aim of the present study was to investigate the osseous anatomy and muscular topography of the chinchilla pelvic limb using computed tomography (CT) and three-dimensional (3D) reconstruction techniques. Twelve clinically healthy adult chinchillas (18 months of age, body weight 0.6-0.7 kg) were examined using a 16-slice multidetector spiral CT scanner. Animals were anesthetized with intramuscular Zoletil® 50 (15 mg/kg) and scanned in dorsal recumbency. Multiplanar reconstructions and three-dimensional models were generated using dedicated imaging software. The pelvic girdle, femur, tibia, fibula, distal pelvic limb skeleton and major muscle groups were evaluated anatomically according to Nomina Anatomica Veterinaria (2017). Three-dimensional reconstruction demonstrated that the pelvic girdle consisted of paired hip bones formed by the os ilium, os pubis and os ischii. The tuberositas iliaca, elongated ala ossis ilii and prominent linea glutea were clearly visualized. The femur was characterized by a well-developed femoral neck, distinct trochanter major and trochanter minor, and absence of trochanter tertius. Two sesamoid bones associated with m. gastrocnemius were identified on the caudal aspect of the distal femur. The crus consisted of a well-developed tibia and a separate, non-fused fibula. Distally, metatarsal bones II-IV and their corresponding digits were visualized. CT images additionally enabled identification of the principal gluteal, femoral and crural muscle groups and their topographical relationships with adjacent skeletal structures. Computed tomography combined with three-dimensional reconstruction provides detailed visualization of the pelvic limb anatomy in *Chinchilla lanigera*. The technique allows reliable assessment of both skeletal structures and major muscle groups while preserving their natural anatomical relationships. The obtained findings expand the available anatomical knowledge of this species and may serve as reference data for future anatomical, orthopedic and diagnostic imaging investigations.

Keywords: *Chinchilla lanigera*, pelvic limb, computed tomography, three-dimensional reconstruction, anatomy, veterinary imaging

The long-tailed chinchilla (*Chinchilla lanigera*) is a South American hystricomorph rodent that has gained considerable importance as a companion animal, breeding species and experimental model. Originally inhabiting the rocky slopes of the Andes Mountains, the species has evolved several morphological adaptations associated with rapid locomotion, jumping ability and efficient movement in complex terrains. These locomotor adaptations are reflected in the structure of the appendicular skeleton, particularly in the pelvic limb, which plays a dominant role in propulsion and weight transmission during locomotion (6, 9).

The pelvic limb skeleton of the chinchilla has attracted the attention of veterinary anatomists because it combines features characteristics of both rodents and lagomorphs. Previous osteological investigations have shown that the os coxae is composed of the fused os ilium, os pubis and os ischii, forming a relatively lightweight but mechanically efficient pelvic girdle (2). Several anatomical peculiarities have been described, including the prominent linea glutea, the elongated ala ossis ilii, the absence of trochanter tertius and the specific arrangement of the tibia and fibula (2, 3). Comparative studies performed by Chende et al. (3) demonstrated that although the chinchilla shares numerous anatomical characteristics with the domestic rabbit, distinct species-specific differences remain evident, particularly in the morphology of the crus and distal pelvic limb.

The pelvic limb is of particular clinical importance in chinchillas because of its involvement in jumping and rapid acceleration. The considerable biomechanical loading imposed on the hindlimbs predisposes these animals to traumatic injuries. Fractures of the appendicular skeleton, especially involving the radius, ulna and tibia, are frequently encountered in veterinary practice and represent a significant proportion of orthopedic disorders reported in this species (2, 8, 10). Consequently, accurate anatomical knowledge is essential for clinical examination, radiological interpretation, fracture management and surgical planning.

Most currently available information regarding the anatomy of the chinchilla pelvic limb originates from classical anatomical studies based on skeletal preparations and dissection techniques (2, 3, 6). Although these methods provide valuable morphological information, they have inherent limitations. The preparation process may alter the natural spatial relationships between anatomical structures, while the evaluation of complex three-dimensional arrangements is often difficult when relying solely on conventional anatomical specimens. Furthermore, traditional anatomical methods cannot provide intravital visualization of the studied structures.

The introduction of advanced diagnostic imaging techniques has substantially expanded the possibilities for anatomical research. Computed tomography

(CT) has become an important tool for the evaluation of skeletal structures in both human and veterinary medicine because of its high spatial resolution and excellent contrast differentiation of mineralized tissues (8). In addition to multiplanar imaging, CT enables the generation of three-dimensional reconstructions that facilitate detailed anatomical interpretation and improve understanding of complex anatomical regions. In veterinary anatomy, CT-based studies have been successfully applied in numerous domestic and exotic species, providing valuable reference data for clinicians and researchers.

Three-dimensional reconstruction techniques offer additional advantages for anatomical investigations. By allowing segmentation and visualization of individual structures from different perspectives, these methods provide a more comprehensive understanding of anatomical relationships than conventional radiography or dissection alone. In small mammals such as the chinchilla, where many skeletal elements are relatively small and closely positioned, three-dimensional reconstruction may be particularly useful for demonstrating detailed anatomical features.

Despite the increasing application of computed tomography in exotic animal medicine, information regarding CT anatomy of the chinchilla remains limited. Most available reports have focused on clinical applications or isolated anatomical regions. Recently, Dilek et al. (5) demonstrated the usefulness of computed tomography and three-dimensional reconstruction for the anatomical investigation of the chinchilla liver, highlighting the potential of this imaging modality for anatomical studies in this species. However, comprehensive CT-based descriptions of the pelvic limb skeleton and associated muscular structures are still scarce.

Considering the clinical importance of the pelvic limb and the limited availability of tomographic anatomical data, further investigations are warranted. Detailed knowledge of normal CT anatomy is essential for distinguishing physiological anatomical features from pathological alterations and for improving the interpretation of diagnostic imaging examinations.

Therefore, the aim of the present study was to investigate the anatomy of the chinchilla pelvic limb using computed tomography and three-dimensional reconstruction techniques. Particular attention was directed toward the morphology of the pelvic girdle, femur, tibia, fibula and distal skeletal elements, as well as to the CT-based estimation of the topographical arrangement of the major muscle groups. The obtained findings are intended to expand the existing anatomical knowledge of *Chinchilla lanigera* and to provide reference data that will directly enhance diagnostic imaging accuracy and orthopedic evaluation in clinical practice.

Material and methods

Animals and ethical approval. The study was conducted on twelve clinically healthy adult chinchillas (*Chinchilla lanigera*), comprising 6 males and 6 females, aged approximately 18 months and weighing between 0.6 and 0.7 kg. The animals were maintained under standard husbandry conditions, housed individually in cages with free access to water and a commercial pelleted diet. Ambient temperature was maintained between 20 and 25°C under a 12 h light/12 h dark photoperiod.

All procedures were approved by the Local Animal Ethics Committee of Mehmet Akif Ersoy University, Burdur, Türkiye (Approval No. 1315, Approval Date: 05.06.2024) and were performed in accordance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes.

Computed tomography examination. Computed tomography examinations were performed using a 16-slice multidetector spiral CT scanner (Alexion, Toshiba Medical Systems, Japan). Prior to scanning, all animals were anesthetized by intramuscular administration of Zoletil® 50 (Virbac, France) at a dosage of 15 mg/kg body weight and positioned in dorsal recumbency.

The scanned region extended from the pelvic girdle to the distal enabling the bilateral evaluation of both the left and right pelvic limbs of each animal. Scanning parameters were standardized for all animals and included a tube voltage of 100 kV, tube current of 100 mA. A uniform slice thickness and interslice spacing of 0.5-1.0 mm were applied to all subjects without variation, as the animals were of virtually identical body size. The field of view was adjusted according to minor individual variations in animal size and image acquisition was performed using a high-resolution bone reconstruction protocol.

Prior to image acquisition, calibration of the CT system was performed according to the manufacturer's recommendations to ensure image consistency and accuracy. Image quality was optimized through the application of a standard bone reconstruction algorithm and by minimizing motion artefacts during anesthesia.

Image reconstruction and three-dimensional modeling. The acquired tomographic datasets were reconstructed in axial, sagittal and coronal planes. Three-dimensional reconstructions were generated using Vitrea software (Vital Images Inc., Minnetonka, MN, USA).

Semi-automatic segmentation procedures were applied to isolate the principal skeletal components of the pelvic limb, including the os coxae, femur, tibia, fibula, tarsal bones, metatarsal bones and phalanges. Following segmentation, volume-rendering techniques were used to generate three-dimensional anatomical models.

Image processing included calibration, noise reduction and manual refinement of segmented structures when necessary. All reconstructions were reviewed by experienced veterinary anatomists and a veterinary radiologist to ensure anatomical accuracy.

Anatomical evaluation. The anatomical assessment focused on the morphology of the pelvic girdle, femur, tibia, fibula and distal skeletal elements of the pelvic limb. Particular attention was paid to the identification of char-

acteristic anatomical landmarks, including the acetabulum, linea glutea, trochanters, tibiofibular articulations and distal limb structures.

The muscular topography of the pelvic limb was evaluated descriptively on dorsal (coronal) CT images. Major muscle groups were identified according to their anatomical location, shape and attenuation characteristics relative to adjacent osseous structures.

Anatomical terminology. All anatomical structures were identified and described according to the Nomina Anatomica Veterinaria (NAV, 6th edition, 2017) established by the International Committee on Veterinary Gross Anatomical Nomenclature.

Study limitations. Due to the small size of the distal tarsal elements and the inherent spatial resolution limits of CT imaging, identification of individual tarsal bones was based on structures that could be reliably distinguished on multiplanar and three-dimensional reconstructions. Muscular identification was performed descriptively and was not validated by anatomical dissection.

Results and discussion

Pelvic girdle. Three-dimensional reconstruction allowed detailed visualization of the pelvic girdle and its individual components. The pelvis consisted of two os coxae, each formed by the fusion of the os ilium, os pubis and os ischii. The acetabulum was clearly identified as the site of articulation with the femoral head and represented the junction of the three pelvic bones.

The os ilium was characterized by a markedly elongated ala ossis ilii. Tuberositas iliaca appeared as a distinct thickened structure located at the cranial aspect of the ilium. A prominent linea glutea extended along the lateral surface of the ilium and terminated distally in a pronounced thickening situated close to the acetabulum. Incisura ischiadica major was well developed and formed a distinct concavity at the caudal border of the ilium.

The pubic component of the pelvis consisted of a narrow ramus cranialis ossis pubis and a comparatively shorter and wider ramus caudalis ossis pubis. Caudally, the ischial portion formed a broad tabula ossis ischii terminating in a distinct tuber ischiadicum. Between the pubic and ischial components, a large oval foramen obturatum occupied most of the ventral pelvic surface (Fig. 1).

Femur. The femur represented the principal skeletal element of the proximal free pelvic limb. The caput ossis femoris articulated with the acetabulum, while a well-developed and elongated collum ossis femoris connected the head to the shaft.

The proximal femur possessed a prominent trochanter major located laterally and a distinctly developed trochanter minor situated medially. Trochanter tertius was not identified in any of the examined specimens. The shaft of the femur was elongated and terminated distally in well-developed medial and lateral condyles.

Two sesamoid bones associated with m. gastrocnemius were observed on the caudal aspect of the distal

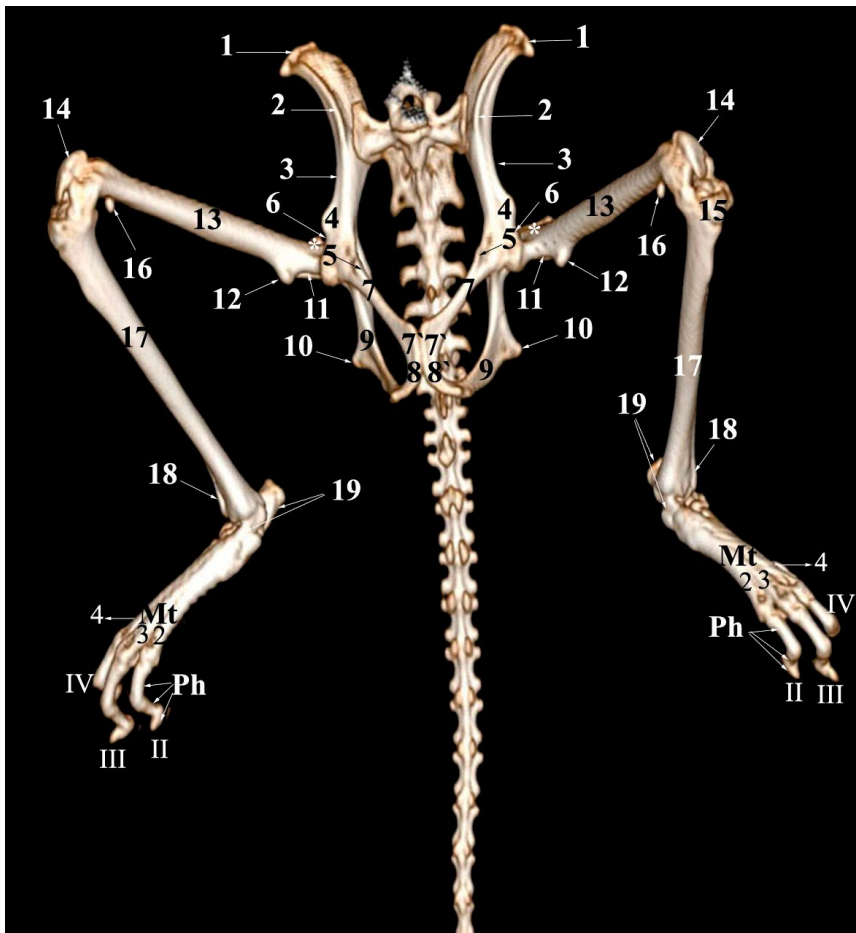


Fig. 1. 3D reconstruction of the pelvic limb in the chinchilla

Explanations: tubercle coxae (1), linea glutea (2), incisura ischiadica major (3), linea glutea (4), area medialism. Recti femoris (5), acetabulum (6), ramus cranialis ossis pubis (7), ramus caudalis ossis pubis (7'), ramus ossis ischii (8), tabula ossis ischii (9), tuber ischiadicum (10), fossa trochanterica (11), trochanter minor (12), trochanter major (*), femur (13), patella (14), tuberositas tibiae (15), ossa sesamoidea gastrocnemii (16), tibia (17), fibula (18), calcaneus (19), os metatarsale secundum (Mt 2), os metatarsale tertium (Mt 3), os metatarsale quartum (Mt 4), ossa digitorum pedis (Ph), second digit (II), third digit (III), fourth digit (IV).

femur. The patella was readily identified and exhibited a broader proximal portion and a narrower distal extremity. The cranial surface of the patella was smooth and clearly distinguishable on three-dimensional reconstructions (Fig. 1).

Crus and distal pelvic limb. The skeleton of the crus consisted of a well-developed tibia and a comparatively slender fibula. The tibia represented the dominant skeletal component of the crus. The fibula remained distinct throughout its entire length and was not fused with the tibia in any of the examined animals.

Proximally, the fibula articulated with the tibia, while distally it contributed to the formation of articulations with the tibia, talus and calcaneus. The calcaneus was the most readily identifiable tarsal element because of its size and characteristic morphology.

Precise identification of all individual tarsal bones was limited owing to their small size and close anatomical relationships. Nevertheless, the distal pelvic limb demonstrated the presence of metatarsal bones corresponding to metatarsals II, III and IV. Three

digits were clearly distinguished, each composed of a proximal, middle and distal phalanx (Fig. 1).

Computed tomographic appearance of the pelvic limb musculature. Dorsal CT images enabled visualization of the major muscle groups of the pelvic limb based on differences in soft-tissue attenuation and topographical relationships with adjacent skeletal structures. The muscular structures appeared as homogeneous to mildly heterogeneous soft-tissue formations separated by narrow hypoattenuating intermuscular septa.

The lateral pelvic region was occupied by m. gluteus superficialis, m. gluteus medius, m. gluteus profundus and m. gluteus accessorius. These muscles formed a compact muscular mass extending from the lateral surface of the pelvis toward the proximal femur. M. gluteus superficialis was positioned superficially and was closely related to m. biceps femoris.

The cranial aspect of the thigh was occupied by m. rectus femoris, m. vastus medialis and m. vastus intermedius. These muscles surrounded the femur cranially and craniomedially and displayed uniform soft-tissue attenuation. Medially, m. sartorius and m. gracilis were clearly identified, whereas m. pectineus and m. adductor occupied deeper positions. M. semimembranosus was located in the caudomedial aspect of the thigh.

The musculature of the crus was arranged into cranial and caudal groups.

The cranial group included m. tibialis cranialis, m. extensor digitorum longus and m. fibularis tertius. Caudally, m. gastrocnemius, m. flexor digitorum superficialis and m. flexor digitorum profundus formed the principal muscular mass. The digital flexor muscles demonstrated close topographical association with m. gastrocnemius and could not always be clearly separated from one another on CT images, highlighting the limitations of non-dissective evaluation.

Coronal reconstructions provided satisfactory visualization of the major muscular compartments of the thigh and crus. However, owing to the limited dimensions of the distal limb structures, individual tarsal and metatarsal bones and digital elements were less distinctly visualized on coronal images than on three-dimensional reconstructions (Fig. 2).

The present study provides a computed tomographic and three-dimensional anatomical description of the pelvic limb in the chinchilla (*Chinchilla lanigera*). The findings generally confirm previously published osteological descriptions of this species, while adding



Fig. 2. Dorsal (coronal) CT anatomical image of the muscles of the chinchilla pelvic limb

Explanations: right (R), left (L), *m. rectus femoris* (1), *m. vastus medialis* (2), *m. vastus intermedius* (3), *m. pectineus* (4), *m. adductor* (5), *m. sartorius* (6), *m. gracilis* (7), *m. gluteus profundus et m. gluteus accessorius* (8), *m. gluteus superficialis et m. gluteus medius* (9), *m. biceps femoris* (10), *m. semimembranosus* (11), *m. tibialis cranialis et m. extensor digitorum longus* (12), *m. fibularis tertius* (13), *m. gastrocnemius* (14), *m. flexor* (15)

information obtained through non-invasive imaging and 3D reconstruction. In contrast to conventional anatomical preparations, CT allows the preservation of the natural topographical relationships among the pelvic bones, free pelvic limb bones and surround-

ing soft tissues. Therefore, the present results may be useful both for anatomical reference purposes and for the interpretation of diagnostic imaging examinations in this species.

The morphology of the pelvic girdle observed in the present study corresponds largely to the descriptions of Cevik-Demirkan et al. (2) and Chende et al. (3). The os coxae was formed by os ilium, os pubis and os ischii, and the acetabulum was clearly visualized as the region of union of these three pelvic components. The well-developed tuberositas iliaca, elongated ala ossis ilii and distinct linea glutea were consistently identified. These findings support previous observations that the chinchilla pelvis possesses several characteristic osteological features that distinguish it from other small mammals.

A particularly important finding was the clear visualization of the linea glutea and its distal thickening close to the acetabulum. Cevik-Demirkan et al. (2) described the linea glutea as a prominent ridge on the ala ossis ilii, while Chende et al. (3) emphasized its comparative anatomical relevance in relation to the domestic rabbit. The present CT-based 3D reconstruction allowed this region to be appreciated in its spatial context. Functionally, the pronounced development of the gluteal region may be associated with the attachment of the gluteal musculature and the role of the pelvic limb in propulsion and jumping.

The wide oval foramen obturatum observed in the present study is also consistent with previous anatomical descriptions of the chinchilla pelvis (2, 3, 6). Its large size and position between os pubis and os ischii contribute to the characteristic morphology of the pelvic floor. Similar anatomical arrangements have been reported in other small mammals, although the proportions and spatial configuration may vary among species. In the chinchilla, the relatively wide foramen obturatum and the broad tabula ossis ischii may be regarded as important landmarks during the interpretation of pelvic CT images.

The femur showed several features typical of the species. The absence of trochanter tertius confirmed the observations of Cevik-Demirkan et al. (2) and Chende et al. (3). This finding is important from a comparative anatomical perspective, as the presence or absence of trochanter tertius varies among mammalian species. The well-developed trochanter major and trochanter minor, together with the clearly visible collum ossis femoris, correspond to the anatomical descriptions provided by Helaudais (6). These structures were clearly demonstrated on 3D reconstruction and may be useful reference points in diagnostic imaging and orthopedic assessment.

The distal part of the femur was characterized by well-defined condyles and sesamoid bones associated with *m. gastrocnemius*. The presence of ossa sesamoidea *m. gastrocnemii* has been reported in previous anatomical studies of the chinchilla (2, 3, 6). Their

visualization in the present study demonstrates that CT and 3D reconstruction are suitable for identifying not only the major long bones, but also smaller osseous elements. This may be clinically relevant because sesamoid bones can sometimes be misinterpreted as fracture fragments or pathological mineralizations if normal anatomical variation is not recognized.

The tibia and fibula demonstrated a configuration that agrees with previous descriptions of the chinchilla pelvic limb (2, 3). The tibia was the dominant and better-developed bone of the crus, whereas the fibula was thinner but clearly separated from the tibia. This finding is particularly relevant because it differs from the condition described in the rabbit, where the fibula may be partly fused with the tibia (1, 4). Therefore, the separate fibula observed in the chinchilla should be considered a normal species-specific anatomical feature and not interpreted as an abnormal separation or traumatic finding.

The distal pelvic limb was more difficult to interpret because of the small size and close spatial arrangement of the tarsal, metatarsal and digital bones. In the present study, the calcaneus was clearly identified, whereas individual differentiation of all tarsal bones was limited. This limitation is understandable in a small species such as the chinchilla and is related to the resolution of the CT images and the compact arrangement of distal skeletal elements. Nevertheless, the general configuration of the metatarsal bones and digits was visualized and corresponded broadly to previous anatomical descriptions (2, 3, 6).

The number of metatarsal bones and digits deserves careful interpretation. Previous authors have described the chinchilla as a plantigrade animal with a reduced distal pelvic limb pattern (3, 6). In the present study, metatarsals II, III and IV and the corresponding digits were clearly visualized. Because the first and fifth digits were not observed, the description of the distal limb should be formulated cautiously and based only on structures reliably identified on CT reconstruction. This cautious approach is particularly important because small distal elements may be difficult to distinguish with certainty in tomographic studies of small mammals.

The muscular topography of the pelvic limb was evaluated descriptively on CT images. The lateral pelvic muscles, cranial femoral muscles, medial femoral muscles and crural muscles were identified according to their position, shape and attenuation characteristics. The observed arrangement was generally comparable to the muscular organization described in rabbits by Barone (1) and to functional descriptions of the pelvic limb musculature in hares by Williams et al. (15). However, because the present study did not include dissection-based confirmation of each muscle, the CT-based muscular identification should be considered descriptive and topographical rather than a definitive myological analysis.

The visualization of the gluteal muscles is important because of their functional relationship with the prominent linea glutea and the pelvic girdle. The topography of the gluteal muscle group corresponded generally to the expected arrangement in small herbivorous mammals (1, 15). Their relationship with *m. biceps femoris* was also visible on the CT images. These findings indicate that CT can provide useful information not only about bone morphology but also about the spatial organization of larger muscle groups.

The cranial and medial femoral muscles were also recognizable on CT images. These muscle groups were located around the femur and medially, in accordance with the general organization of the pelvic limb musculature described in rabbits and hares (1, 15). Nevertheless, the interpretation of individual muscles on CT images should be made with caution, particularly when adjacent muscles have similar attenuation and poorly defined intermuscular borders.

The crural muscles were divided topographically into cranial and caudal groups. The observed arrangements of these cranial and caudal muscle masses were consistent with similar functional subdivisions described in lagomorphs and other small mammals (1, 15). In the chinchilla, these muscle groups are likely to be important for jumping, propulsion, and stabilization of the distal limb during plantigrade support.

Computed tomography proved to be a useful method for the anatomical evaluation of the chinchilla pelvic limb. Its value lies in the ability to visualize osseous structures in multiple planes and to generate three-dimensional reconstructions. The usefulness of CT in exotic mammals has been emphasized by Krautwald-Junghanns et al. (8), while Dilek et al. (5) demonstrated the applicability of CT and 3D reconstruction for anatomical studies in the chinchilla. The present study extends this approach to the pelvic limb and shows that CT can provide detailed anatomical information in this region.

From a clinical perspective, the present findings may be useful in the diagnosis and interpretation of orthopedic disorders of the chinchilla pelvic limb. Fractures and traumatic injuries have been reported in chinchillas and other exotic small mammals (8, 10, 12). Knowledge of normal CT anatomy is essential for distinguishing physiological anatomical features from pathological changes. The separate fibula, the sesamoid bones of *m. gastrocnemius* and the configuration of the distal pelvic limb are examples of structures that may be misinterpreted if normal species-specific anatomy is not well known. Therefore, the presented CT and 3D images provide highly valuable reference material for diagnostic imaging and orthopedic evaluation in clinical practice.

A limitation of the present study is that the analysis was mainly descriptive and did not include morphometric measurements or statistical comparison between animals. Therefore, the results should be interpreted

as anatomical reference data rather than quantitative morphometric evidence. Another limitation concerns the CT-based identification of individual muscles and small distal skeletal elements, which was restricted by image resolution and the close anatomical relationships of these structures. Future studies combining CT, dissection and morphometry would provide more comprehensive information.

In conclusion, computed tomography combined with three-dimensional reconstruction provides valuable anatomical information on the pelvic limb of *Chinchilla lanigera*. The method allows detailed visualization of the pelvic girdle, femur, tibia, fibula and major muscle groups, and confirms several characteristic anatomical features previously described by classical methods. The obtained data may serve as a useful reference for veterinary anatomists, clinicians and diagnostic imaging specialists working with chinchillas and other exotic small mammals.

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