Uttar Pradesh Journal of Zoology

Volume 45, Issue 17, Page 362-370, 2024; Article no.UPJOZ.3857
ISSN: 0256-971X (P)

Macro-anatomical Studies on the Pelvic Limb Skeleton of the Indian Mongoose (*Herpestes javanicus*)

Prasanth Babu. A [a*], Karunasri. V [a], Supriya. B [a] and Sai Urmila.T [a]

[a] *Department of Veterinary Anatomy, College of Veterinary Science, Proddatur, YSR Kadapa District, Andhra Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i174380

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3857

Original Research Article

Received: 04/06/2024
Accepted: 08/08/2024
Published: 21/08/2024

ABSTRACT

The aim of the study is to document the anatomical details of bones of pelvic limb of Indian mongoose (*Herpestes javanicus*). Six adult Indian mongooses are collected for the present study and which died due to natural causes. The bones are collected by fresh water maceration technique. The macro-anatomy of bones of pelvic limb is studied after fresh water maceration and cleaning. The anatomy of pelvic limb bones is found to be similar in structure to the other carnivores and some rodents that have been studied. Oscoxae, the bone of pelvic girdle is sturdy and the ilium and ischium runs parallel to the vertebral column. Pelvic symphysis is formed by the pubic symphysis only. The obturator foramen is large and oval and presents a characteristic cranio-lateral notch. Fovea capitis is indistinct in femoral head; femur consists of trochanter major and minor in

**Corresponding author: Email: prasanthankem@gmail.com;*

Cite as: *A, Prasanth Babu., Karunasri. V, Supriya. B, and Sai Urmila. T. 2024. "Macro-Anatomical Studies on the Pelvic Limb Skeleton of the Indian Mongoose (Herpestes Javanicus)". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (17):362-70. https://doi.org/10.56557/upjoz/2024/v45i174380.*

proximal epiphysis. Two sesamoid bones “febellae” embed in the tendons of the origin of gastrocnemius muscle. Patella is a shield shaped bone that glides over the trochlea of femur. Tibia and fibula are two long bones, articulate at proximal and distal extremities with a wide interosseous space. Seven tarsals are arranged in three rows, located between the tibia and fibula dorsally and metatarsals distally. Five metatarsal bones, I-V are evident of which first one is short. Five digits are present, first one contains two phalanges and the remaining digits contain three phalanges each. Total of eight proximal sesamoids and five distal sesamoids are present in digit region of each limb. Altogether, 46 bones are involved in the formation of one pelvic limb in Indian mongoose.

Keywords: Pelvic limb bones; gross anatomy; Indian mongoose (Herpestes javanicus).

1. INTRODUCTION

Mongoose is a small terrestrial carnivorous mammal belonging to the family Herpestidae. These are famous for their ability to kill venomous snakes as they are quick and agile. This allows them to effectively dart the attacks of snakes with ease. They are creative hunters with their sharp teeth and claws. Mongoose is a common name for 29 to 34 species in 14 genera of the family Herpestidae which are found in vast areas of southwestern Asia [1]. The native distribution of the small Indian mongoose (*Herpestes auropunctatus* (Hodgson 1836)) stretches from Iraq in the west to Myanmar in the east, and from northern Pakistan southwards throughout the Indian subcontinent [2]. It is a small predatory mammal capable of surviving in a variety of habitats, including deserts, forests, agricultural areas, and urban areas. The small Indian mongoose is listed under CITES Appendix III in India (as *Herpestes javanicus auropunctatus*) [3]. Mongooses are poached in India for their hairs, which are used for making paint and shaving brushes. Due to poaching, mongooses have been reclassified from Schedule IV to Schedule II of the Wildlife Protection Act in India [4]. Hence, there is no information available on the anatomical features of the skeletal system of the Indian mongoose. Anatomical and morphological studies of the pelvic limb have always been of interest to the researchers in the field of anatomy, due to its high significance in various fields of Veterinary Medicine and Zoology. As the literature on the macro-anatomical features about the pelvic limb in wild carnivores is meagre, the present study is conducted to contribute the dearth of information in Indian mongoose.

2. MATERIALS AND METHODS

The present study was conducted on pelvic limbs of six Indian mongooses which were died due to natural causes. The six dead mongooses were collected and macerated in fresh water at the department of veterinary anatomy, College of Veterinary Science, Proddatur, Andhra Pradesh. After maceration, the bones of pelvic limb were cleaned, and the gross anatomical features of the pelvic limb bones were recorded. Radiographs were captured at an exposure of 15 mAs and a voltage of 60 kV.

3. RESULTS

3.1 Oscoxae

The pelvic girdle consisted of left and right os coxae. These two bones meet at the pelvic symphysis ventrally. This bone articulated dorsally with the sacrum through ilium and runs parallel to the vertebral column. The oscoxae built with three bones viz., ilium, ischium and pubis (Fig. 1).

3.1.1 Ilium

Ilium formed the cranio-dorsal part of the oscoxae. It was the largest of the three parts. It was a wide triangular shaped bone with a wing dorsally and shaft ventrally. It was comprised of two surfaces, three borders and three angles.

Surfaces: This bone was comprised of two surfaces, lateral and medial. Lateral surface had a deeply concave area called gluteal fossa and surrounded by a rim. It was wide and concave dorsally became narrow ventrally and flat. The Medial surface was divided into a non-articular iliacus area cranially and a rough semilunar shaped sacral articular area caudally. These two areas were separated by a rough ridge. A strong Ilio-pubic line extends from this surface to the anterior border of the pubis and carried a thin psoas tubercle at its middle.

Borders: Anterior border was called as iliac crest which appeared as a thin crest. A thick ventral or cotyloid border was straight and joined

with the acetabulum caudally. In front of the acetabulum, on either side of this border consisted of a tubercle and circumscribed depression and was considered as the area for the origin of rectus femoris muscle. The dorsal border comprise of a shallow greater ischiatic notch and met the ischiatic spine caudally.

Angles: The lateral angle, coxal tuber was thick and rounded. The medial angle, tuber sacrale was pointed and thin. The ischiatic angle met with the concerned angles of the ischium and pubis at the acetabulum.

3.1.2 Ischium

Ischium was an elongated rhomboidal plate, extended cranially from the acetabular fossa, connected to other half medially by a symphyseal ligament and posteriorly by ischial tuberosity and ischial arch. It had two surfaces, four borders and four angles.

Surfaces: The dorsal or pelvic surface was concave and roughly triangular in shape. The ventral surface was flat and the ischial spine was extended from the ischial tuberosity to the acetabular fossa. Ischial groove extended on this surface, which arised from the acetabular notch.

Borders: lateral border was concave and forms the lesser ischiatic notch and separated from the ischiatic spine by a small pointed ridge. Medial or symphyseal border met with the similar border of the opposite side bone by symphyseal ligaments and didn't involve in the formation of pelvic symphysis. The anterior border was concave and forms posterior half of the obturator foramen. Cranio-lateral notch present on the obturator foramen which was relatively large and oval. Posterior border was nearly straight and diagonally extending from the ischial tuberosity to the symphyseal border. The ischial arch was formed by meeting along with the similar border of the opposite half.

Angles: Two lateral and two medial angles were present in this bone. The antero-lateral angle met the acetabular fossa and postero –lateral angle formed the rounded ischial tuberosity which was continued distally with the ischial spine. The medial angles met at the symphyseal border.

3.1.3 Pubis

The pubis appeared as L shaped bone in an anterio-posterior position. It had two surfaces, three borders and three angles. The dorsal or pelvic surface was concave and the ventral surface was convex. The anterior border was concave and thin which was continued anteriorly with the cotyloid border of the ilium. The caudal border was deeply concave and formed the anterior border of the obturator foramen. The medial border met the similar border of the other half forming the pelvic symphysis. The lateral angle joined with the similar angles of the ilium and ischium and formed the acetabular fossa. The medial angles joined with the pelvic symphysis.

Acetabulum was very deep which was formed by the contribution of the acetabular angles of the ilium, ischium and pubis. Acetabulum had an articular and deep non-articular area for the round ligament of the hip joint. The articular area was nearly circular for the head of the femur. A wide acetabular notch was present at the postero-medial aspect of the rim of the acetabular fossa.

Fig. 1. Oscoxae- Lateral View IC- Iliac Crest, A- Acetabulum, N- Notch in acetabular rim, P- Pubis, PS- Pubic Symphysis, IS- Ischium, Arrow showing cranio-lateral notch on obturator foramen

3.2 Femur

It was a long slender bone showed a shaft and two extremities. When the animal was in normal position it lies parallel to the vertebral column. The diaphysis was slightly rotated from medial to the lateral surface. The shaft had four surfaces. The lateral and posterior surfaces were flat and separated by a sharp border where as the anterior and medial surfaces were rounded and continuous with each other. The proximal epiphysis consisted of a femoral head, trochanter major, trochanter minor and fossa (Fig. 2). The femoral head was absolutely round in shape and distinctly separated from neck. It was higher in position than the trochanter major unlike in higher mammals. The fovea capitis appeared as an indistinct depression. The trochanter major was strongly bent, its lateral surface was rough and the medial surface bounded the trochanteric fossa. The trochanter minor was a distinct elevation at lower part of the posterior aspect of the proximal extremity. It was connected to the trochanter major by a trochanteric ridge and formed the lateral boundary of trochanteric fossa. The trochanteric fossa was very deep and narrow. The distal extremity was larger than the proximal extremity and slightly twisted to lateral direction. It carries a trochlea cranially and two condyles caudally. The trochlear groove was wide and margined by thick ridges. Whic articulated with the posterior surface of patella. The posterior condyles were separated by a wide intercondyloid fossa. The trochlear groove was continuous with the intercondyloid fossa and they showed ellipsoidal articular areas for articulation with the tibial condyles. Two sesamoid bones (febellae) were placed above the condyles and believed to be embedded in the tendons of gastrocnemius muscle. A lateral supracondyloid fossa was located above the lateral condyle and a blunt medial supracondyloid crest was present above the medial condyle.

3.3 Patella

Patella was a thin and appeared like a shield shaped bone. It had a wide base dorsally and a wide pointed apex below. The cranial surface was smooth and nearly flat. The caudal surface had a flat articular area for the trochlea of femur (Fig. 3).

Fig. 2. Caudal view of Femur showing H – Head, s-shaft, Tr M- Trochanter Major, Tr Mi- Trochanter Minor, Tr F- Trochanteric Fossa, M C- Medial Condyle, Lc- Lateral Condyle, ICF- Intercondyloid Fossa

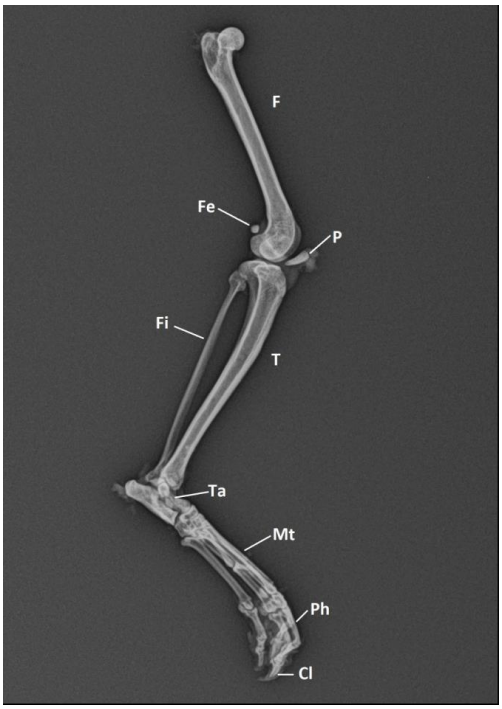

Fig. 3. Medial View of Hindlimb radiograph showing bones F- Femur, Fe-febellae, P- Patella, Fi- Fibula, T- Tibia, Ta- Tarsals, Mt- Metatarsals, Ph- Phalanges, Cl- Claw

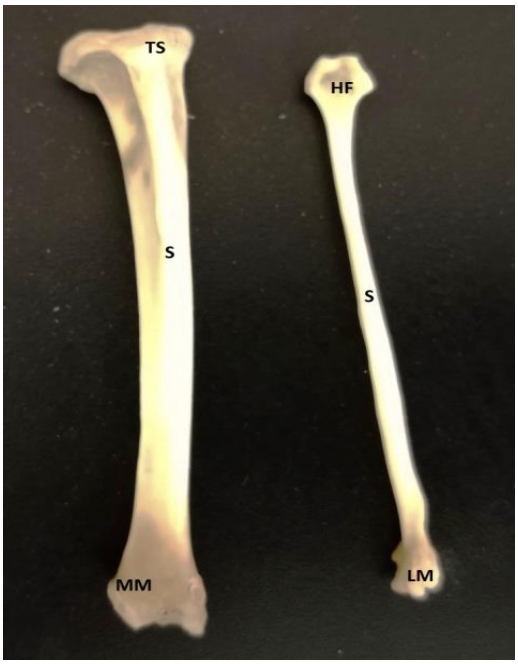

Fig. 4. Cranial view of Tibia and Fibula showing T S- Tibial Spine, s-shaft, MM- Medial Malleolus, LM- Lateral Malleolus, H F- Head of Fibula

3.4 Tibia and Fibula

These two bones were articulated at their extremities with like facets and left a wide and elongated interosseous space between them.

3.4.1 Tibia

Tibia was a long bone with a shaft and two extremities. The shaft was massive and three sided above and flattened below. The lateral

surface was grooved and concave above and became gradually inclined towards the anterior face distally. The medial surface was flat proximally and became round distally. The lateral and medial surfaces were separated by a crest called the tibial crest. The posterior surface carried a groove proximally and the groove was limited laterally by a popliteal crest. The distal half of this surface was round. The shaft had three borders viz., lateral border was concave and applied against the fibula and formed the tibio-fibular groove. The anterior border was prominent at the proximal third as the tibial crest, which joined the tibial tuberosity proximally and in the distal third it disappeared and joined with the anterior surface. The medial border was thick and blunt. The proximal extremity of tibia carried two condyles and a cranial tibial tuberosity. The condyles were medial and lateral which were slightly concave for articulation with the condyles of the femur. In between the condyles an elongated tibial spine was present that extended into the intercondyloid fossa of femur. The rough depressions were present infront and behind the tibial spine for the attachment of ligaments. The popliteal notch was present in between the condyles caudally. The lateral condyle bear an articular area for the head of fibula and the medial condyle bear a depression for the attachment of ligaments. The tibial tuberosity was present cranially which was continuous with the tibial crest distally. The distal extremity was smaller than the proximal extremity. The medial border of the distal extremity was continuous with the medial malleolus (Fig. 4). The lateral border articulated with the distal extremity of fibula. It showed articular areas for tibial tarsal distally.

3.4.2 Fibula

The fibula was a slender rod like bone. It extended from proximal to the distal extremity of tibia on its lateral border. It had a shaft and two extremities. The shaft was thin and applied against the lateral border of the tibia and formed tibio-fibular arch. The proximal extremity was wide and its medial surface articulated with the lateral surface of the lateral condyle of the tibia. The distal extremity was also expanded and forms the lateral malleolus, which articulated with the distal extremity of tibia on its lateral surface. The articular area for fibular tarsal was absent in this bone.

3.5 Tarsals

Tarsals were seven short bones arranged in three rows between the tibia proximally and metatarsals distally (Fig. 3).

Proximal row consisted of two bones viz., fibular and tibial tarsal. The fibular tarsal was placed laterally and tibial tarsal was placed medially. The middle row had a single bone, the central tarsal. The distal row consisted of four bones from medial to the lateral are I, II, III and IV.

3.5.1 Fibular tarsal

The fibular tarsal was the largest among all the tarsal bones. The fibular tarsal had a body, a proximally projected tuber calcis and medially projected sustentaculum tali. The medial surface of the body articulated with the lateral surface of the tibial tarsal and distally articulated with the fourth tarsal. The sustentaculum tali articulated with the plantar surface of the tibial tarsal.

3.5.2 Tibial tarsal

The tibial tarsal was located medially in the proximal row. It had a trochlea proximally and a rounded head distally. The trochlea articulated with the distal extremity of tibia whereas the plantar and lateral surface of the tibial tarsal articulated with the corresponding surface of body of fibular tarsal. The distal head was rounded and articulates with the proximal surface of the central tarsal.

3.5.3 Central tarsal

It was located in the central row. It had a deep concave articular surface on its dorsal surface for the head of tibial tarsal. It had a projection on its dorso-medial border of this surface. It articulated with the fibular and fourth tarsal bones partially. The distal surface articulated with the first, second and third tarsals from the medial to lateral aspect.

3.5.4 The tarsals of distal row

I, II, III and IV tarsals articulated with central and fibular tarsal dorsally and distally they facilitated articulations for the proximal heads of the respective metatarsal bones except fourth tarsal, which articulated with the fourth and fifth metatarsal bones.

3.6 Metatarsals

The pedis comprised of metatarsal bones which were longer than the metacarpal bones. Five metatarsal bones are present. The first one was short, third and fourth metatarsals were longer than remaining. First metatarsal carried two

phalanges whereas second to fourth metatarsals carried three phalanges. Each metatarsal bone was a long bone and had a shaft and two extremities.

3.7 Digits

Five digits were present, each digit had a metatarsal and three phalanges except the first digit that was comprised of two phalanges only.

3.7.1 Phalanges

Each digit had three phalanges i.e., proximal, middle and distal phalanges. First digit consisted of only proximal and distal phalanges. Proximal phalanges were larger than the middle phalanges. These two phalanges were long bones, which were constructed with a shaft and two extremities. Shaft was flat and bent towards the palmar direction. Proximal extremity of first phalanx showed two condyles separated by a groove and the distal extremity contained a distinct trochlea. The proximal extremity of the middle phalanx contained two articular areas separated by a ridge and the distal extremity of it showed two condyles with a distinct groove between them.

Distal phalanx or ungulate bone showed a concave articular area for the middle phalanx, surrounded by prominent rim/crest. In front of this articular area extensor process was present dorsally and a flexor tubercle evident on palmar surface. Below the rim/crest an ungulate process was present, which was sharp and bent in palmar direction and also bear the claws (Fig. 3).

Proximal sesamoids were 8 in number in each limb, which articulated at the ventro-palmar side of each metatarso-phalangeal joint. These bones were small and elongated. Distal sesamoids were five in number, which articulated at the distal phalangeal joints on the palmar side. These bones were small, round in shape.

4. DISCUSSION

The pelvic limb study of the Indian mongoose unveiled a lot of similarity and some differences in skeletal morphology with other species of rodents and carnivores as mongoose kept under order carnivora. In the oscoxae of mongoose, ilio-pubic line extended from medial surface of ilium to the anterior border of the pubis and carried a psoas tubercle at the middle. In contrary, the shaft of ilium presented an indistinct iliopubic eminence and psoas tubercle on ventral border in the oscoxae of Orange Rumped Agouti [5]. In the present study, dorsal border of ilium described as iliac crest which was thin but a thick and convex iliac crest and terminated in a hook like muscular projection was reported in Orange Rumped Agouti [5]. Ilium carried a shallow concave greater ischiatic notch on its dorsal border, whereas the ilium of mole rat showed a wide and deep greater sciatic notch [6].

Antero-lateral angle of ischium met the acetabular fossa and postero –lateral angle forms the rounded ischial tuberosity which was continued distally with the ischial spine in the Indian mongoose. Similarly a prominent ischial tuber with two processes was observed in Orange Rumped Agouti [5] and the ischium of African giant pouched rat also consisted of ischial tuber at its caudo-lateral aspect [7]. The pubis appeared as L shaped bone in an anterio-posterior position in Indian mongoose. Similar findings were made in the pubis of Orange Rumped Agouti [5]. The lateral angle of pubis was joined with the similar angles of the ilium and ischium and formed the acetabular fossa. The medial angles joined with the pelvic symphysis in Indian mongoose but the medial angle of pubis was slender in mole-rat [6]. A wide acetabular notch was present at the postero-medial aspect of the rim of the acetabular fossa in present study. In contrast, it was described that acetabular notch was absent in mole-rat instead a little foramen was present [6].

Femur was a long slender bone with a shaft and two extremities. The proximal epiphysis consisted of a femoral head, trochanter major, trochanter minor and fossa. The femoral head was absolutely round in shape and distinctly separated from neck. It was higher in position than the trochanter major unlike in domestic mammals. Similar findings were made in the femur of Orange Rumped Agouti [5]. In contrary to the above studies, the greater and lesser trochanters and trochanter tertius were prominent in the femur of mole-rat [6], African giant pouched rat [7] and Orange Rumped Agouti [5]. Two sesamoid bones “febellae” were also reported in canines [8] and in Orange Rumped Agouti [5] as observed in the present study. Patella was a shield shaped bone in Indian mongoose but it was a comma shaped bone in Orange Rumped Agouti [5].

Tibia and fibula of Indian mongoose were articulated at their extremities only and left a

wide elongated interosseous space between them. These results were in accordance with the tibia and fibula of Orange Rumped Agouti and this anatomical feature was believed to be responsible for limited capacity in digging of the soil [5]. In contrast to the above studies, in mole-rats [6] and in African giant pouched rats [7] the two bones were fused at their distal 1/3 portion.

Tarsals bones of Indian mongoose consisted of seven short bones arranged in three rows between the tibia proximally and metatarsals distally, as mentioned the similar observations in dog [10] and hedgehog [9,10]. But in contrast to present study, 8 tarsal bones were observed in Orange Rumped Agouti [5], mole-rat [6] and in African giant pouched rat [7].

The pedis of the Indian mongoose was comprised of five metatarsals and five digits. Similarly findings were reported in other burrowing animals like Wistar rats [11], laboratory rats [12], Rabbits [13], Minks [14], Porcupines [15] and Mole rats [6]. Whereas, Orange rumped agouti [5] and guinea pig [16] showed three metatarsals and three digits.

5. CONCLUSION

This study was conducted in the 6 Indian mongooses and described the osteology of hind limb. A thin iliac crest in ilium, and a wide acetabular notch at the postero-medial aspect acetabular fossa and a cranio-lateral obturator notch was observed. The proximal epiphysis of femur the head was higher in position than the trochanter major unlike in domestic mammals. Two sesamoid bones (febellae) of mangoose, embedded in the tendons of the origin of gastrocnemius muscle. Patella was a shield shaped bone articulated with the trochlea of femur. Tibia and fibula were the bones of the leg region which articulated at their extremities and left a wide and elongated interosseous space between them. This anatomical feature was responsible for limited capacity in digging the soil. Tarsals were seven short bones arranged in three rows between the tibia and metatarsals. The pedis was complete with five metatarsals and five digits. These anatomical features may be responsible for the ability of Indian mongoose to stand merely on hind limbs.

SUPPLEMENTARY DATA

The supplementary data is available in the following link
http://taxonomicon.taxonomy.nl/TaxonTree.aspx?src=0&id=168277

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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