



ISSN: 2456-2912

VET 2023; 8(4): 149-153

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www.veterinarypaper.com

Received: 07-03-2023

Accepted: 16-04-2023

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Gross anatomical studies on the skeleton of pelvic limb of Indian eagle owl (*Bubo bengalensis*)

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Abstract

The present study was conducted on the skeleton of hindlimb of adult Indian eagle owl. The os-coxae was made up of three bones - ilium, ischium, and pubis. Elongated os-ilium can be distinguished into pre-acetabular and post-acetabular parts. The ischium was in the form of a large bony plate which formed a large sciatic foramen with ilium and a small obturator foramen with pubis. Pubis was a thin, elongated bone situated along the ventral border of ischium where it formed the incisura puboischii. The acetabulum was in the form of a circular foramen. Femur presented a hemispherical head, a short neck, and a very large trochanter major on the proximal end, and two disto-caudally directed condyles on very large distal end. Tibiotarsus which was formed by the fusion of distal end of tibia with the proximal row of tarsals presented two grooved condyles on the proximal extremity and two symmetrical condyles which were separated by the inter-condyloid fossa anteriorly on the distal extremity. It was the longest bone. Fibula was a reduced bone. Tarsometatarsus comprised of II, III and IV metatarsal bones which were fused together and with distal tarsal bones.

Keywords: Indian eagle owl, acetabulum, os-coxae, tibiotarsus, tarsometatarsus

1. Introduction

The Indian eagle owl, also known as Bengal eagle owl is a sub-species of Eurasian eagle owl belonging to the order of Strigiformes. It is a fairly large fowl with prominent brown ear tufts and usually hunts from a perch, but will also make low foraging flights to dive on prey. It inhabits the rocky hills with bushes, wooded county with ravines, and semi-deserts with rocks and bushes throughout the Indian subcontinent. The skeleton of an owl is typical to that of birds in general i.e., lightweight and durable, it may be used for both walking and flight. The literature is available on the gross anatomy of pelvic girdle of Spot-billed pelicans (Sathyamoorthy *et al.*, 2012), femur of domestic fowl, guinea fowl, turkey, ostrich, crested serpent eagle, and brown wood owl (Venkatesan *et al.*, 2006; Choudhary *et al.*, 2021), tibiotarsus and fibula of peahen and Indian eagle-owl (Sreeranjini *et al.*, 2013; Sarma *et al.*, 2018a), tibiotarsus and tarsometatarsus of emu, cattle egret, and Indian eagle-owl (Kumar and Singh, 2014; Rezk, 2015; Sarma *et al.*, 2018a)^[14, 17, 2, 15, 11, 5, 10, 11]. Keeping in view the paucity of literature, the present study was planned with an aim to evaluate the morphological characteristics of skeleton of pelvic limb (os-coxae, femur, tibiotarsus, and tarsometatarsus) in Indian eagle owl. The results of this study will supplement the current knowledge and provide baseline data on gross morphological aspects of the pelvic limb bones in this species that might be useful in treating surgical and other clinical disorders and can function as an anatomical guide for future research.

2. Materials and Methods

The present study was conducted on the skeleton of pelvic limb of one adult Indian eagle owl obtained dead near the premises of the college, PGIVER, Jaipur and was eaten by insects. The collected bones were processed as per standard technique (Raghavan, 1964) and subsequently studied in order to observe the gross morphological features.

3. Results and Discussion

The pelvis of Indian eagle owl was comprised of two os-coxae, each of which further consisted of three fused bones-iliac, ischium and pubis (Fig. 1) as also observed by Kumar *et al.* (2016)

in Barn owl and Sarma *et al.* (2018b) in Indian eagle-owl^[4, 12]. The pelvis was fused with lumbo-sacral vertebrae thus, formed an irregular, bony cage-like structure. The ilium and ischium bones do not unite towards the ventral aspect, so pelvis was open ventrally (Fig. 2) as observed by Mehta *et al.* (2013) in emu, Sasan *et al.* (2017) in Bar-headed goose, and Sarma *et al.* (2018b) in Indian eagle-owl^[8, 13, 12].

3.1 Ilium

The elongated ilium was divided into a pre-acetabular and a post-acetabular part, which were joined to the vertebrae of the synsacrum (Fig. 1). The pre-acetabular part was completely fused with the lumbo-sacral mass cranially. Similar observations were recorded by Nickel *et al.* (1977) in domestic birds and Sarma *et al.* (2018b) in Indian eagle-owl^[9, 12]. In contrast, Lavanya *et al.* (2017) reported the absence of such fusion in pigeon^[7]. The dorsal (gluteal) surface was concave in pre-acetabular part and slightly convex in the post-acetabular part. Similar observations were reported by Nickel *et al.* (1977) in domestic birds and Kumar *et al.* (2016) in Barn owl^[9, 4]. On either side of the lumbo-sacral mass, very prominent crests were observed dorsally (Fig. 1) which were closely placed in the anterior portion but distantly placed in posterior region. The crests, which originated from the anterior portions of pre-acetabular part continued as lateral border posteriorly over the post-acetabular part which aligns with previous findings in Indian eagle-owl reported by Sarma *et al.* (2018b)^[12].

Anteriorly, the flat ventral surface of ilium was fused with transverse processes of synsacrum and presented four large foramina on either side of the median plane (Fig. 2). However, Sathyamoorthy *et al.* (2012) reported 7-8 openings on either side of the median ridge in spot-billed pelicans^[14]. Through these foramina, the spinal nerves pass. This surface was excavated posteriorly and formed the fossa renalis (Fig. 2) for the accommodation of kidneys. This was in accordance with the findings of Sarma *et al.* (2018b) in Indian eagle-owl, Sathyamoorthy *et al.* (2012) in spot-billed pelicans, and Nickel *et al.* (1977) in domestic birds^[12, 14, 9]. However, the absence of such depression on the ventral surface reported in previous studies on emu (Mehta *et al.*, 2013) and Bar-headed goose (Sasan *et al.*, 2017) contrasts with the present findings^[8, 13]. Acetabulum was in the form of a circular foramen and was formed by all the three bones. This contrasts with the findings of Nickel *et al.* (1977) in fowl and duck where the pubis was not involved^[9]. On the caudo-dorsal aspect of acetabulum, strong large anti-trochanter was observed. This prominence is for articulation with trochanter major of femur as reported in domestic birds, cattle egret, spot-billed pelicans, and Indian eagle-owl (Nickel *et al.*, 1977; Rezk, 2015; Sathyamoorthy *et al.*, 2012; Sarma *et al.*, 2018b)^[9, 10, 14, 12].

3.2 Ischium

Ischium was in the form of a long bony plate which lies below the post-acetabular part of ilium (Fig. 1). Its cranial part was involved in the formation of the acetabulum and posterior to the acetabulum, formed a large, oval elongated foramen ischiadicum with ilium. Similar findings were recorded in domestic birds, Indian eagle-owl, spot-billed pelicans, guinea fowl, and pigeon (Nickel *et al.*, 1977; Sathyamoorthy *et al.*, 2012; Sarma *et al.*, 2018b; Lavanya *et al.*, 2017)^[9, 14, 12, 7]. The caudal part fused dorsally with the lateral border of the post-acetabular part of ilium as mentioned in domestic birds by Nickel *et al.* (1977) and pelicans by Sathyamoorthy *et al.*

(2012)^[9, 14]. Anteriorly, the ventral border of ischium was joined with pubis to form obturator foramen and continued behind to form the ischio-pubic incisure which was in concurrence with previous findings in Indian eagle-owl, guinea fowl, pigeon, domestic fowl, and duck reported by Sarma *et al.* (2018b), Lavanya *et al.* (2017), and Nickel *et al.* (1977)^[12, 7, 9].

3.3 Pubis

Pubis was a thin, rib-like bone (Fig. 1) placed below the ventral border of ischium. It was extended beyond the ischium caudally and formed the ischio-pubic incisure with the ventral border of ischium. Similar observations have been noted in spot-billed pelicans by Sathyamoorthy *et al.* (2012), Bar-headed goose by Sasan *et al.* (2017), and owl by Sarma *et al.* (2018b)^[14, 13, 12]. However, in guinea fowl and pigeon, the ischio-pubic incisure was merged with the obturator foramen anteriorly (Lavanya *et al.*, 2017)^[7]. In contrast, pubis did not project beyond the ilium and ischium in emu (Mehta *et al.*, 2013)^[8]. Pubis was narrow anteriorly with absence of pectineal process and the broad posterior end was in the form of a rounded process similar with previous findings in spot-billed pelicans, emu, pigeons, and Indian eagle-owl as reported by Sathyamoorthy *et al.* (2012), Mehta *et al.* (2013), Lavanya *et al.* (2017) and Sarma *et al.* (2018b)^[14, 8, 7, 12]. However, pectineal process was rudimentary in duck and goose and was well-developed in domestic fowl (Nickel *et al.*, 1977)^[9].

3.4 Femur

Femur (Fig. 3) was tubular in outline and consisted of a curved shaft, wider proximally and distally. The anterior, medial and lateral surfaces were smooth and continuous as observed in domestic fowls, crested serpent eagle, and brown wood owl (Nickel *et al.*, 1977, Choudhary *et al.*, 2021)^[9, 2]. A thin bony ledge called linea aspera was observed on both the anterior and posterior surfaces, which aligns with previous findings in domestic fowl, guinea fowl, crested serpent eagle, and brown wood owl as reported by Nickel *et al.* (1977), Venkatesan *et al.* (2006), and Choudhary *et al.* (2021)^[9, 17, 2]. The linea aspera on the posterior surface was very prominent and it reached up to medial condyle distally. This was in corroboration with the observations of Choudhary *et al.* (2021) in serpent eagle and brown wood owl, and Sreeranjini *et al.* (2013) in peahen^[2, 15].

The proximal extremity comprised of a hemispherical head which presented a deep fovea capitis as also stated by Choudhary *et al.* (2021) in brown wood owl^[2]. However, Lakshmi *et al.* (2007) reported that the fovea capitis was absent in emu^[6]. The head was continued by a short, distinct neck. The trochanter minor was indistinct as also reported by Sreeranjini *et al.* (2013) in peahen; however, the lesser trochanter was in the form of a small tubercle in emu (Lakshmi *et al.*, 2007)^[15, 6]. The trochanter major was large and had an articular surface for the antitrochanter of the ilium bone. Similar observations were reported by Choudhary *et al.* (2021) in crested serpent eagle, brown wood owl, and Sreeranjini *et al.* (2013) in peahen^[2, 15].

The distal extremity presented a trochlea on the anterior aspect and two condyles on the posterior aspect (Fig. 4, 5) as also mentioned in domestic fowl, guinea fowl, and peahen (Nickel *et al.*, 1977; Venkatesan *et al.*, 2006; Sreeranjini *et al.*, 2013)^[9, 17, 15]. The presence of two ridges in trochlea which were separated by a wide groove was consistent with earlier findings in domestic fowl, guinea fowl, ostrich, crested

serpent eagle, and brown wood owl (Venkatesan *et al.*, 2006; Choudhary *et al.*, 2021) ^[17, 2]. The presence of condyles of which the lateral one was larger and presented a distinct groove, and an articular area on the postero-lateral aspect for the head of the fibula was similar to that mentioned in domestic birds (Nickel *et al.*, 1977) ^[9].

3.5 Tibiotarsus

Tibiotarsus was formed by the fusion of the distal end of tibia with the proximal row of tarsal bones (Fig. 3, 4, 5) as also reported in domestic fowls, cattle egret, and Indian eagle-owl (Nickel *et al.*, 1977; Rezk, 2015 and Sarma *et al.*, 2018a) ^[9, 10, 11]. The presence of three surfaces i.e., medial, lateral, and posterior on the straight shaft was consistent with earlier findings in crested serpent eagle and brown wood owl (Choudhary *et al.*, 2021) ^[2]. A well-marked fibular crest was observed just below the lateral condyle for the shaft of fibula as mentioned by Sarma *et al.* (2018a) in Indian eagle-owl and Choudhary *et al.* (2021) in crested serpent eagle and brown wood owl ^[11, 2].

The proximal end presented two condyles separated by a ridge - medial and lateral, among them, the medial one was larger which aligns with previous findings of Sreeranjini *et al.* (2013) in peahen and Sarma *et al.* (2018a) in Indian eagle-owl ^[15, 11]. Lateral condyle presented a facet towards the lateral border for the head of fibula as also stated by Choudhary *et al.* (2021) in crested serpent eagle and brown wood owl ^[2]. These two condyles were traversed by a notch caudally. Cranially, a sharp laterally curved cnemial crest was observed on the proximal end as also reported in peahen, cattle egret, Indian eagle-owl (Sreeranjini *et al.*, 2013; Rezk, 2015; Sarma *et al.*, 2018a) ^[15, 10, 11]. However, Choudhary *et al.* (2021) stated that this crest was more prominent in the crested serpent eagle than that in brown wood owl ^[2]. Also, lateral cnemial crest was observed caudo-lateral to the medial cnemial crest. Al-Sadi (2012), Rezk (2015), Sarma *et al.* (2018a), and Choudhary *et al.* (2021) also reported the presence of these two cnemial crests in turkey, cattle egret, Indian eagle-owl, crested serpent eagle, and brown wood owl, respectively ^[1, 10, 11, 2]. These two crests were separated by a wide inter-cnemial groove which was in harmony with the observations made by Rezk (2015) in cattle egret and Sarma *et al.* (2018a) in Indian eagle-owl ^[10, 11].

The distal extremity comprised of asymmetrical trochlea of which, the lateral one was larger and was placed at higher level than the medial. The extensor canal was absent in the present study which coincides with the findings in brown wood owl (Choudhary *et al.*, 2021) ^[2]. In contrast, previous studies reported the presence of extensor canal in peahen, Indian eagle-owl, and crested serpent eagle (Sreeranjini *et al.*, 2013; Sarma *et al.*, 2018a; Choudhary *et al.*, 2021) ^[15, 11, 2]. A bony bridge was observed just above the trochlea for the passage of extensor tendons as also earlier observed by Sreeranjini *et al.* (2013) in peahen ^[15]. On either side of the trochlea, depressions for the attachment of collateral ligaments of hock joint were found as seen in fowl, crested serpent eagle, and brown wood owl, respectively (Getty, 1975; Choudhary *et al.*, 2021) ^[3, 2].

3.6 Fibula

Fibula was a reduced rod-shaped bone with a prominent head and rudimentary body. Head articulated with the lateral condyle of tibiotarsus and contacted the lateral condyle of femur. Shaft was thin, tapering distally and extended up to distal third of the lateral border of the tibiotarsus (Fig. 3, 4) similar to the findings in Indian eagle-owl, crested serpent eagle, and brown wood owl (Sarma *et al.*, 2018a; Choudhary *et al.*, 2021) ^[11, 2]. Shaft presented a rough area for attachment with the bony ledge of tibiotarsus and thus, formed the proximal and distal interosseous spaces (Fig. 4) as reported in Indian eagle-owl (Sarma *et al.*, 2018a), crested serpent eagle, and brown wood owl (Choudhary *et al.*, 2021) ^[11, 2].

3.7 Tarsometatarsus

Tarsometatarsus was a long bone derived by fusion of several bones - metatarsal bones II, III and IV and the distal tarsal bones. This observation was consistent with previous reports in domestic fowls, chickens, emu, and Indian eagle-owl (Nickel *et al.*, 1977; Tahon *et al.*, 2013; Kumar and Singh, 2014; Sarma *et al.*, 2018a) ^[9, 16, 5, 11]. The shaft had longitudinal ridges on both dorsal and plantar surfaces which were more prominent on the plantar surface (Fig. 3, 4). These ridges were marked in the proximal half and became inconspicuous towards the distal aspect as also reported by Choudhary *et al.* (2021) in crested serpent eagle, and brown wood owl, respectively ^[2]. Cranially, a deep fossa was observed towards the proximal half. The anterior surface presented a distal vascular foramen just above the lateral trochlear cleft and the plantar surface presented the flexor sulcus, which was in the form of a longitudinal groove bounded by lateral and medial crests as also reported in Indian eagle-owl (Sarma *et al.*, 2018a), crested serpent eagle, and brown wood owl (Choudhary *et al.*, 2021) ^[11, 2].

The proximal end exhibited two concave articular facets for the trochlea of tibiotarsus, separated by a bony protuberance which was also present in cattle egret (Rezk, 2015), Indian eagle-owl (Sarma *et al.*, 2018a), and brown wood owl (Choudhary *et al.*, 2021) ^[10, 11, 2] whereas, the bony protuberance was not observed in emu and crested serpent eagle (Kumar and Singh, 2014; Choudhary *et al.*, 2021) ^[5, 2]. This extremity presented a deep groove on the dorsal surface and longitudinally directed ridges on the planter surface. A hypotarsus with two foramina on either side of it was observed medially on the posterior surface of proximal extremity as also reported previously in Indian eagle-owl, crested serpent eagle, and brown wood owl (Sarma *et al.*, 2018a; Choudhary *et al.*, 2021) ^[11, 2]. The distal extremity comprised of three trochlea i.e., medial, middle and lateral, separated by two deep clefts representing their origin from metatarsal bones II, III and IV. Each trochlea was divided by a groove. However, this groove was distinct in the middle trochlea as the trochlea for the third digit was the most prominent similar to the findings in domestic fowls, Indian eagle-owl, crested serpent eagle, and brown wood owl (Nickel *et al.*, 1977; Sarma *et al.*, 2018a; Choudhary *et al.*, 2021) ^[9, 11, 2].

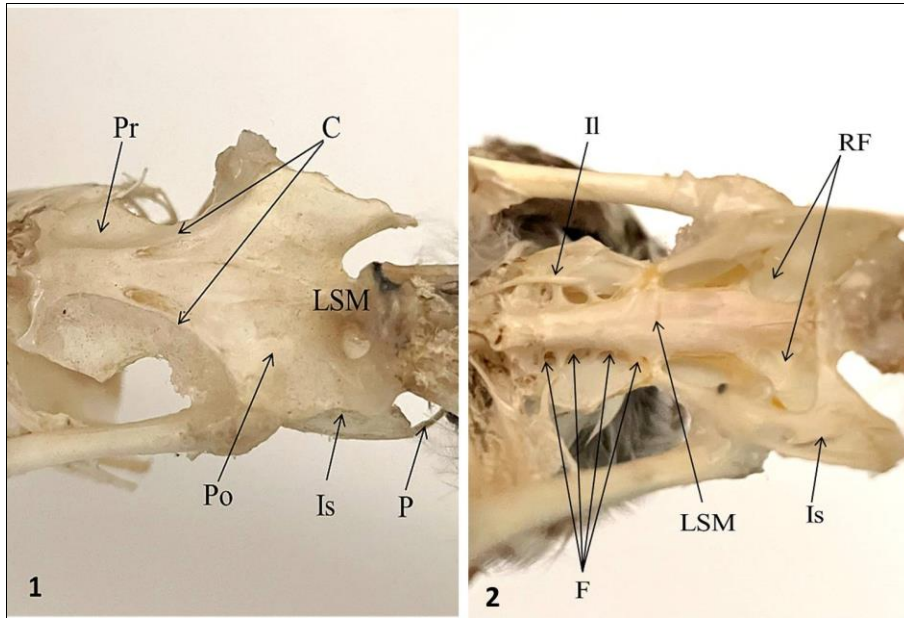


Fig 1-2: 1. Dorsal view of the os-coxae of Indian eagle owl showing pre-acetabular (Pr), post-acetabular (Po) parts of ilium, lumbo-sacral mass (LSM), posterior extremity of pubis (P), ischium (Is), dorsal iliac crest (C) and pubis (P). 2. Ventral view of the os-coxae showing lumbo-sacral mass (LSM), renal fossae (RF), ilium (Il), ischium (Is) and foramina (F).

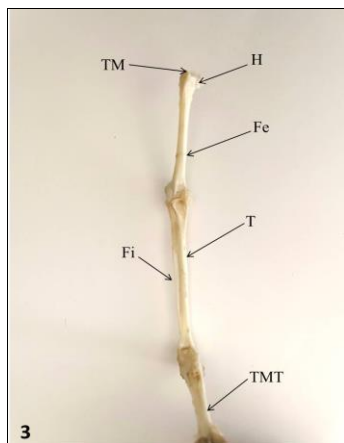


Fig 3: Postero-medial view of the long bones of pelvic limb showing femur (Fe), tibia (T), fibula (Fi), tarsometatarsus (TMT), head of femur (H), and trochanter major (TM).

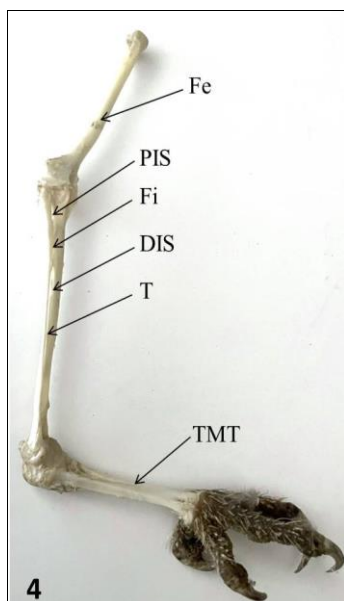


Fig 4: Lateral view of the long bones of pelvic limb showing femur (Fe), tibia (T), fibula (Fi), tarsometatarsus (TMT), proximal interosseous space (PIS) and distal interosseous space (DIS)



Fig 5: Anterior view of the long bones of pelvic limb showing femur (Fe) and tibia (T)

4. Conclusion

Hind limb is the most crucial and specialized predatory attribute of the raptor morphology and serves as the principal support structure for the body mass. The tarso-metatarsal bone was relatively short and stout, which is helpful in the efficient killing and carrying of prey and plays a vital role in withstanding functional loading. These robust hind limb bones attributes grip strength and thus, facilitating prey capture.

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