



HINDLIMB SKELETAL MORPHOLOGY OF THE HELMETED GUINEA FOWL (*NUMIDA MELEAGRIDIS*)

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ABSTRACT

The Guinea fowl (*Numida meleagris*) is a semi-domestic bird whose commercial popularity is on the increase. The gross anatomy of the hindlimbs of 8 helmeted Guinea fowls of equal sexes were studied. The pubic shafts were free, thus they did not fuse ventrally to form a symphysis. The ilium had a quadrilateral and roughly triangular pre and post acetabular wings, respectively. A conspicuous renal fossa was observed in the post acetabular wing. An incomplete concentric obturator foramen, lacking a caudal margin, was formed by the ventral border of the ischium and dorsal border of the cranial pubic shaft, while a prominent ischiopubic fissure was formed by the same bones, caudally. The incomplete concentric nature of the obturator foramen created a common space between it and the ischiopubic fissure. The femoral major trochanter was more proximal than the head, while the minor trochanter and the head were on the same horizontal level. The femur lacked a visible pneumatic foramen. The tibiotarsus had a prominent cranial cnemial crest. The fibular spine terminated at the tibia mid-shaft, leaving one interosseous space. An intertarsal sesamoid bone was identified, indicative of an adult skeleton. Crests and channels depicted the hypotarsus. Vascular foramen was identified in the distal extremity of the tibiotarsus. Digit I was oriented to the planter direction.

These results, and others, were compared with those of other birds in the available literature, and some morpho-functional paradigm of the Guinea fowl hindlimb skeleton was established.

Key words: femur; Guinea fowl; *os coxae*; tarsometatarsus; tibiotarsus

INTRODUCTION

The evolution of the avian skeleton is geared towards adaptation to flight and egg production. To this end, an array of unique features most especially the pneumatic sacs of the avian skeleton, in comparison to mammalian skeleton, has been identified. Some of these include the pneumatization of the femur and humerus, to reduce bone weight, necessary for flight, and the fusion and resultant reduction in number of bones such as the vertebrae (resulting in bones such as notarium, synsacrum and pygostyle), tibiotarsus and tarsometatarsus, to achieve maximum skeletal rigidity and minimal body weight, necessary for flight [16]. Others are the extensive keel, necessary to provide large surface area for attachment of flight muscles [16] and the absence of pubic symphysis, necessary for development and contact incubation of eggs [10]. Despite these general unique features of avian skeleton, a wide range of differences still exists in the skeletal morphology within

the different members of the avian class, including their hindlimbs. For example, the ostrich is the only extant avian specie with a pubic symphysis [8, 40]. The obturator foramen is a complete concentric foramen in the owl [32] but incomplete in the emu [8, 38]. The Digit I and IV of parrots, such as budgerigar have planter orientation, while Digits II and III have dorsal orientation, known as zygodactyly [6], while only Digit I has planter orientation in the domestic fowl, known as anisodactyly [21]. These unique features of avian skeleton sequels the need to explore the skeletal anatomy of different birds, and compare results with existing data of other birds to provide more insight on avian skeletal anatomy.

The subject of this study is the helmeted Guinea fowl. It is a member of the order Galliformes, and family Numididae. It is native to Africa, named after Guinea, a country on the sub-Saharan Africa. It is a ground feeding bird, characterized by a very wide crown, filled with grey-blue bare skin topped by a prominent horn coloured bony casque (helmet) in red brown colour, a feature which is unique in the guinea fowl [45]. The commercial popularity of the Guinea fowl is on the increase; they are used as ornamental birds [26], pest control in crop farms [36], and dietary source of high protein [26, 27]. Studies have also shown that the guinea fowl is relatively more resistant to endemic poultry diseases than the domestic fowl [17, 35].

The anatomy of some body systems of the helmeted Guinea fowl is available in the literature. These include: the digestive system [14, 31], reproductive system [2, 11], respiratory system [5, 15], integuments [29, 41, 45], nervous system [3], muscular system [9] and forelimb skeleton [1]. Generally, studies on forelimb anatomy of avian species abound, probably due to the relevance of the forelimb to flight. However, the anatomy of avian hindlimb, especially that of the helmeted Guinea fowl, is dearth in available literature. Apart from the comparative anatomy of the femur of some birds including the Guinea fowl [44], comparative anatomy of the *os coxae* of the Guinea fowl and the pigeon [20] and comparative morphometry of the tibiotarsus of the turkey and Guinea fowl [1], there is no comprehensive anatomical report on the entire bones of the hindlimb of the Guinea fowl available in the literature, hence, this research.

This study will make available a comprehensive anatomical report on the entire bones of the helmeted Guinea fowl hindlimb. Such information is necessary for compar-

ative avian anatomy; it will serve as a reference aid for radiographic interpretation and surgical intervention of hindlimb abnormalities in the specie and a baseline for management of other pathologies of the Guinea fowl hindlimb. Consequently, the research was aimed at biological maceration of the Guinea fowl hindlimb, assembling the entire bones of the hindlimb, studying and reporting their gross anatomy, comparing the results with reports of other birds in the available literature, and establishing some morpho-functional paradigm of the Guinea fowl hindlimb skeleton.

MATERIALS AND METHODS

Eight (8) adult helmeted Guinea fowls (*Numida meleagris*), comprising of 4 females and 4 males, with an average weight of 3.0 kg, were used for the research. They were purchased from a local market at Ilorin, Kwara State, Nigeria, and housed in the Gross Anatomy Laboratory of the Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Ilorin, Nigeria. Prior to commencement of the study, they were fed with grains and water *ad libitum*. During the acclimatization period, they were clinically examined and ascertained to be apparently healthy and without any skeletal deformity.

The birds were sacrificed by severing the jugular vein. They were dissected using a surgical blade to remove feathers, skin, thoracic, abdominal and pelvic viscera while the muscles were teased away leaving the bones with minimal soft tissue attachments. The carcasses were placed in a bowl (after being sprinkled with water) and allowed to stay for 3 days in an open space outside of the laboratory. This was to allow flies to perch on them, and lay eggs. After 3 days, they were taken back into the laboratory and kept at room temperature for 5 months. This was to allow for larva appearance, growth and feeding on the soft tissues.

The recovered bones were disarticulated, washed, rinsed and sun-dried for 3 days. Their morphological features were noted and described. Lastly, their photographs were taken using a digital camera.

Ethical approval

Ethical approval was obtained from the Animal Ethics Committee of the University of Ilorin, Nigeria.

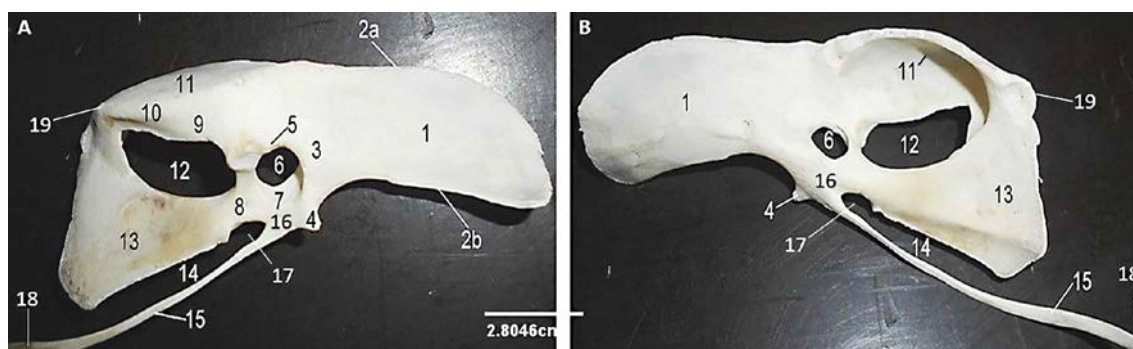


Fig. 1. Dorsolateral (A) and medial (B) surfaces of the Guinea fowl pelvic girdle

1–Pre acetabular wing of ilium; 2a–Dorsal iliac crest; 2b–Lateral iliac crest; 3–Body of ilium; 4–Acetabular tubercle; 5–Antitrochanter; 6– Acetabular foramen; 7–Acetabulum; 8–Body of Ischium; 9–Lateral surface of post-acetabular wing; 10–Dorsolateral iliac crest; 11–Dorsal surface of post acetabular wing; 11'–Ventral surface of post acetabular wing (renal fossa); 12–ilioischadic foramen; 13–Wing of ischium; 14–Ischiopubic fissure; 15–Shaft of pubis; 16–Body of pubis; 17–Obturator foramen; 18–Apex of pubis; 19–Caudal iliac spine

Table 1. Morphometric data of bones of the Guinea fowl (*Numida meleagris*) hindlimb

Bones	Range [cm]	Mean $\pm$ SEM [cm]
<i>Ossa coxarum</i>	1.8	10.49 $\pm$ 2.34
Femur	0.8	7.95 $\pm$ 1.88
Tibiotarsus	0.9	11.91 $\pm$ 1.78
Fibula	1.3	7.15 $\pm$ 0.87
Tarsometatarsus	0.5	7.24 $\pm$ 0.75

RESULTS

The hind limb comprised the bones of the pelvic girdle, femur, fibula, tibiotarsus, tarsometatarsus and phalanges. Table 1 presents the morphometric data obtained from the study.

The pelvic girdle comprised of the paired ilium, ischium and pubis. Each pair was fused to form the *os coxae*. The two *ossa coxarum* did not fuse ventrally; thus, there was no pubic symphysis. The pelvic girdle was located on the caudodorsal aspect of the skeleton. Each *os coxae* articulated medially with the synsacrum and laterally with the femoral head at the acetabulum.

The *os ilium* (Figure 1) presented a flat bone, the largest of the three bones of the pelvic girdle. It laid dorsal to the last 3 ribs and caudal to the caudal extremity of the scapula. It was composed of a cranioventral pre acetabular wing, a body and a dorsal post acetabular wing. The pre acetabular wing was quadrilateral in shape; it had a concave lateral and convex medial surfaces bounded by dorsal and lateral iliac crests. The dorsal iliac crest articulated

with the fused spinous processes of the synsacrum. The body formed the dorsal and cranial parts of the acetabulum which was placed caudolateral to the pre acetabular wing. The acetabulum was perforated within the articular socket to form the acetabular foramen. Caudal to the body and dorsal to the acetabulum was the less prominent antitrochanter. The post acetabular wing was roughly triangular in shape; it presented three surfaces: ventral, dorsal and lateral. The lateral was separated from the dorsal by a dorsolateral iliac crest. The ventral surface was concave, forming the renal fossa, to lodge the caudal extremity of the kidney. The dorsal surface was smooth and slightly convex. It ended caudally as a small process, the caudal iliac spine. The lateral surface presented a ventral border that formed the dorsal margin of the ilioischadic foramen.

The *os ischii* (Figure 1) presented a flat, roughly triangular bone with a cranial body, a caudal wing with lateral and ventral surfaces. The body formed the caudal margin of the acetabulum, the cranioventral margin of the ilioischadic foramen and the craniodorsal margin of the obturator foramen. The dorsal border of the wing formed the caudoventral margin of the ilioischadic foramen. The ilioischadic foramen is the largest of the three foramina on the *os coxae*. It was oblong in shape.

The *os pubis* (Figure 1) presented a thin, slender bone that extended caudoventrally. It was comprised of a body, shaft and apex. The body formed the ventral margin of the acetabulum. It gave off an acetabular tubercle (pectineal process) that extended cranioventrally. The shaft extended from the body cranially, to the apex caudally, projecting beyond the level of the *os ischii*. The dorsal border of the cranial part of the shaft did not fuse with the ventral border



Fig. 2. Cranial (A) and caudal (B) views of the left femur of the Guinea fowl

1–Head; 2–Neck; 3–Minor trochanter; 4–Shaft; 5–Labium; 6–Lateral epicondyle; 7–Medial epicondyle; 8–Medial condyle; 9–Intercondylar groove; 10–Lateral condyle; 11–Fibula trochlea; 12–Major trochanter; 13–Trochanteric crest; 14–Patella groove

of the *os ischii*. This resulted to an incomplete obturator foramen where the dorsal border of the cranial part of the pubic shaft contributed as the ventral margin of the foramen. Caudally, a wide and long ischiopubic fissure was created between the ventral border of the ischium and the dorsal border of the pubic shaft. The incomplete concentric nature of the obturator foramen created a common space between the obturator foramen and the ischiopubic fissure. The apex was the caudal end of the *os pubis*.

The femur (Figure 2) presented a somewhat cylindrical shaped bone having a shaft and two extremities, the proximal and distal. The proximal extremity presented a medially directed round head, a cranio-lateral major trochanter and a caudo-lateral minor trochanter. The major trochanter was more proximal than the head, while the minor trochanter and the head were on the same horizontal level. The head bore a small shallow notch, the *fovea capitis*, and was connected to the shaft by a distinct neck.

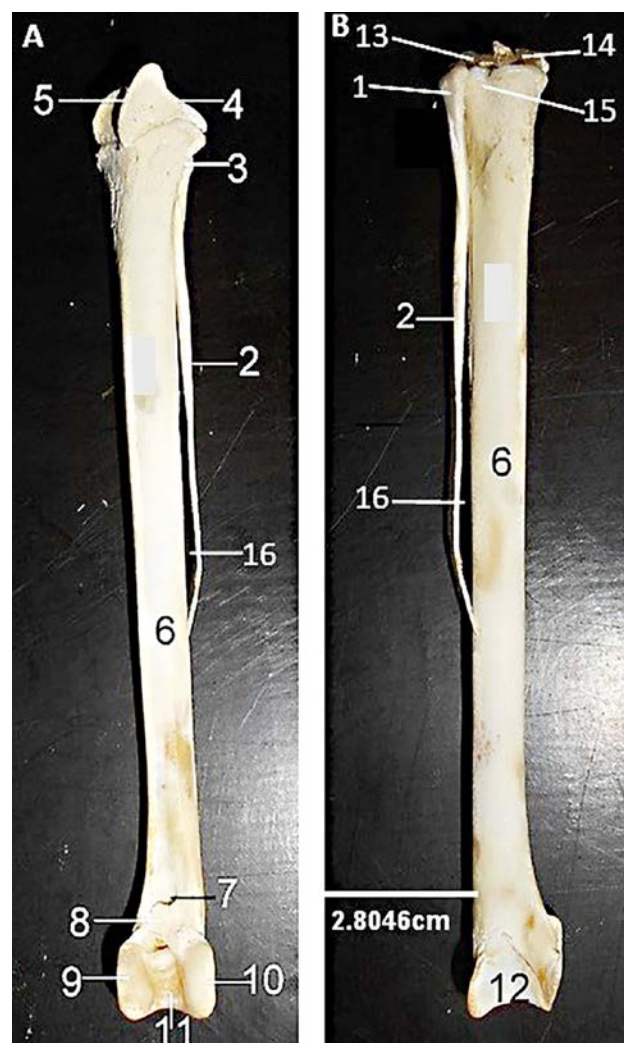


Fig. 3. Cranial (A) and caudal (B) views of the Guinea fowl left tibiotarsus and fibula

1–Head of fibula; 2–Spine of fibula; 3–Lateral cnemial crest; 4–Patella crest; 5–Cranial cnemial crest; 6–Shaft of tibiotarsus; 7–Extensor groove; 8–Supratendinal bridge; 9–Medial condyle; 10–Lateral condyle; 11–Intercondylar incisure; 12–Trochlea for tibial cartilage; 13–Lateral articular surface; 14–Medial articular surface; 15–Flexor fossa; 16–Interosseous space

A rough ridge, the trochanteric crest extended distally in an oblique fashion, from the major trochanter to a short distance on the cranial surface of the femoral shaft. Two muscular lines (lateral and medial labium) also extended distally on the caudal surface of the shaft from the minor trochanter and ended on the distal extremities. The distal extremity bore the medial and lateral condyles separated by an intercondylar groove. Caudally, the fibula trochlea was formed lateral to the lateral condyle creating a sulcus between them. Also on this caudal surface, the medial and lateral epicondyles were located proximal to the respective condyles with the popliteal fossa between them. The cranial surface of the intercondylar groove formed the pa-



Fig. 4. Dorsal (A) and plantar (B) surfaces of Guinea fowl tarsometatarsus

1–Intertarsal sesamoid bone; 2–Intercondylar eminence; 3–Lateral cotyla; 4–Medial cotyla; 5–Tendinous grooves; 6–Shaft; 7–Metatarsal I; 8–Medial trochlea (trochlear of metatarsal II); 9–Middle trochlea (trochlear of metatarsal III); 10–Lateral trochlea (trochlear of metatarsal IV); 11–Vascular foramen; 12–Hypotarsus (channel); 12'–Hypotarsus (crests); 13–Medial intertrochlear incisure; 14–Lateral intertrochlear incisure

tellar groove for articulation with the patella. The patella was a large irregularly shaped sesamoid bone with straight roughened external surface and concave internal surface.

The tibiotarsus (Figure 3) presented a straight cylindrical shaft with an expanded proximal extremity, a narrow distal extremity, cranial and lateral surfaces. At its expanded proximal extremity, a small lateral and large medial articular surface for articulation with the femoral condyles were separated by an interarticular area. The cranial surface of the proximal extremity consisted of an elevated patella crest that extended transversely from the medial articular surface ending laterally and perpendicularly to form a small lateral cnemial crest. The prominent cranial cnemial crest extended from the middle summit of the transverse patella crest downwards. Between the cnemial crests was the intercnemial groove for muscular attachment. On the caudal surface of the proximal extremity, the flexor fossa was located below the articular surfaces. The distal extremity bore the medial and lateral condyles separated by the intercondylar incisure. The articular surfaces of the condyles coalesced caudally, forming the trochlea for articulation with the tibial cartilage. An extensor groove was located cranially, just proximal to the condyles and spanned or bridged by the delicate supratendinal bridge.

The fibula (Figure 3) presented a head and a slender body. The head presented a medial articular facet, for the tibiotarsus and a lateral articular facet for the lateral condyle of the femur. The thin rod-like body tapered to a pointed spine. The fibular spine terminated at the mid-shaft of

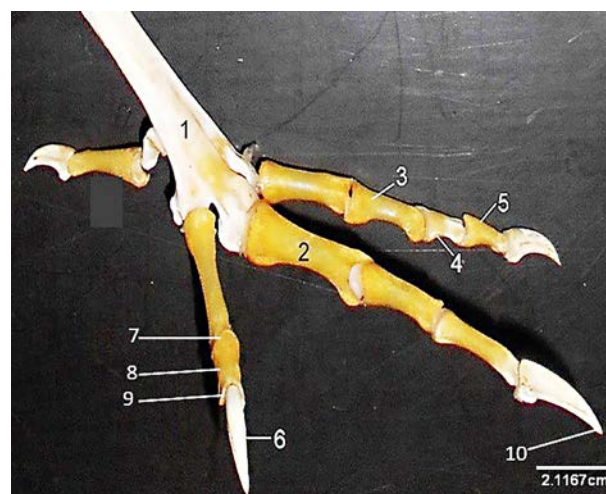


Fig. 5. Dorso-lateral view of the Guinea fowl hindlimb digits

1–Tarsometatarsus; 2–Proximal phalanx of digit III; 3–First intermediate (second) phalanx of digit IV; 4–Second intermediate (third) phalanx of digit IV; 5–Third intermediate (fourth) phalanx of digit IV; 6–Distal phalanx of digit II; 7–Base of phalanx; 8–Body of phalanx; 9–Capitulum of phalanx; 10–Apex of distal phalanx

the tibia, leaving only one interosseous space. The Guinea fowl presented an irregularly shaped intertarsal sesamoid bone which lodged in the trochlear of tibial cartilage at the distal extremity of the tibiotarsus.

The tarsometatarsus (Figure 4) presented a long straight somewhat flattened shaft having proximal and distal extremities, as well as planter and dorsal surfaces. The proximal extremity bore the medial and lateral condyle with articular surfaces for articulation with the respective condyles of the tibiotarsus. They were separated by the intercotylar eminence. On the plantar surface of the proximal extremity, a hypotarsus extended longitudinally as crests, separated by shallow channels. The channels were not enclosed by the crests to form canals. The shaft presented shallow tendinous grooves on its dorsal and plantar surfaces. Metatarsal I articulated on the medial surface of the distal third of the shaft. The distal extremity presented three trochleae (medial, middle and lateral) of the metatarsal II to IV, respectively. Trochlear of metatarsal III was the longest as it distended more than others. The trochleae were separated by the intertrochlear incisures. A vascular foramen was present between the middle and lateral trochlea.

The digits (Figure 5) were made up of 2, 3, 4 and 5 phalanges for digits I, II, III and IV respectively. Digit I was oriented to the planter direction, while digits II to IV were oriented dorsally. With the exception of the distal phalanx of each digit, the phalanges (proximal and intermediate) presented a base with a concave articular surface, a body, and a capitulum incorporating a trochlear articular surface. The base articulated with either the trochlear of metatarsal (for proximal phalanges) or with the trochlear of the capitulum of a preceding phalanx (for intermediate phalanges). The capitulum was distal, articulating with the base of a succeeding phalanx by its trochlear. The distal phalanx consisted of a base and a pointed apex; its base articulating with the penultimate phalanx.

DISCUSSION

The gross anatomical features of the hindlimb bones of the Guinea fowl (*Numida meleagris*) presented similarities and differences when compared to previously studied avian species such as the domestic fowl, cattle egret, and the barn owl. The *os coxae* was formed by the fusion of the ilium, ischium and pubis. This finding is in agreement with

findings reported by D y c e et al. [12] and T a h o n et al. [39] in chicken, and R e z k [28] in cattle egret. The pubic shafts were free, thus did not fuse ventrally to form a pubic symphysis. This absence of pubic symphysis has been reported in many extant birds as an evolutionary adaptation to allow for contact incubation of eggs and to evade physical constraint on egg size [10]. It is also indicated in the protection of underlying visceral organs [18, 30]. The ostrich (*Struthio camelus*) is the only extant bird with a pubic symphysis [8, 45], an adaptation that is detrimental to their egg size, but supportive to bear the weight of their large visceral organs. In our study, the dorsal iliac crest articulated with the fused spinous processes of the synsacrum. This was also reported in the same specie by L a v a n y a et al. [20], Indian-eagle owl by S a r m a et al. [32] and duck by C h u k k a t h et al. [8]. In contrast, there is no such fusion in the pigeon [20], rather a canal is left between the dorsal iliac crest and the fused spinous processes of the synsacrum.

The quadrilateral and roughly triangular shapes of the pre and post acetabular parts of the Guinea fowl ilium, respectively, as reported in our study, is consistent with those of the ostrich and emu [8, 38]. However, N i c k e l et al. [25] recorded that the post acetabular part of the ilium in the duck and turkey is quadrilateral in shape (not roughly triangular). While the dorsal iliac crest fused with the synsacrum in our study, the fusion of the synsacrum in the ostrich and emu is with both the dorsal iliac crest and the medial surface of the pre acetabular wing of the ilium [8]. This broad surface area of fusion of the *os coxae* and synsacrum in the ostrich and emu, necessary to bear the heavy weight of these birds, is not necessary in the much lighter Guinea fowl. Furthermore, the antitrochanter observed in the Guinea fowl ilium from our study was not prominent. S r i d e v i et al. [38] reported that it is very prominent in the emu, with a conspicuous facet for articulation with the trochanter major of the femur. S a t h y m o r t h y et al., [34], R e s k [28] and S a r m a et al. [32] also reported that it is prominent in the pelicans, cattle egret and owl, respectively. Since the joint formed by the antitrochanter and the trochanter major of the femur inhibits excessive movement of the coxofemoral joint [21], it may imply that this inhibitory effect is less indicative in the Guinea fowl than in the emu, owl, pelicans and cattle egret. The dorsally placed caudal iliac spine observed in our study has been reported in the pelicans [34]. In the pigeon, it is presented

more laterally than in the Guinea fowl due to the wider lumbosacral mass wedged between the two pelvic bones [20]. Similar lateral presentation was reported in the domestic fowl by M a i e r l et al. [21] who referred to it as the dorsolateral iliac spine of the chicken. It is completely absent in the emu [38]. The conspicuous renal fossa observed in this study is also lacking in the emu [8, 18, 38], goose [33] and ostrich [8] because of the attachment of the bodies of the vertebrae to the ventral surface of the post acetabular wing in these species. V e n k a t e s a n et al. [43] had earlier reported that the kidneys of the emu reside ventral to the synsacrum, exposing them to traumatic insults. The presence of renal fossa confers better protection to the kidneys of the helmeted Guinea fowls than those of the emu, goose and ostrich.

The flat, roughly triangular shape of the ischium in our study has also been reported in the Indian-eagle owl by S a r m a et al. [32], duck and domestic fowl by C h u k k a t h et al. [8]. Contrarily, C h u k k a t h et al. [8] and S r i d e v i et al. [38] described the ischium of the emu as a long and broad rod-like bone. It is also a long, but narrow bone in the ostrich [40]. The ilium, ischium and pubis contributed in forming the acetabular foramen, but only the ilium and ischium formed the ilioischadic foramen in the Guinea fowl from our research. This is similar with the domestic fowl [12], pigeon [20] and owl [32].

The acetabular tubercle that exited from the body of the pubis in our study is the same as in the emu [38]. It differed from the domestic fowl as M a i e r l et al. [21] reported that the tubercle exited from the ilium, thus, referred to as pre-acetabular tubercle. It is completely absent in the Japanese quail [23], pigeon [20] and owl [32]. This tubercle, also called the pectineal process, provides attachment for the pectineus muscle. The incomplete concentric obturator foramen observed in this work has been reported by L a v a n y a et al. [20] in the same Guinea fowl. It has also been reported in the ostrich by T a m i l s e l v a n et al. [40], pigeon by L a v a n y a et al. [20], emu by C h u k k a t h et al. [8] and S r i d e v i et al. [38] and the duck by C h u k k a t h et al. [8]. In fact, C h u k k a t h et al. [8] concluded that the caudal border of obturator foramen was formed by connective tissue in emu and duck, instead of the pubis. This may be the case in the Guinea fowl, although the connective tissue may have been lost during maceration, leaving an incomplete concentric obturator foramen that communicated caudally with the ischi-

opubic fissure. A complete concentric obturator foramen has been observed in the domestic fowl [21] and owl [32]. The obturator foramen creates passage for the obturator nerve and obturator medialis muscle [21]. The ischiopubic fissure observed in the Guinea fowl exists as a large foramen in the ostrich due to the cartilaginous joint between the caudal end of the ischium and the ipsilateral pubis in the ostrich [8, 40]. C h u k k a t h et al. [8] also demonstrated that it exists as a notch in the emu (ilioischadic notch) because there is no such fusion between the caudal end of the ischium and the ipsilateral pubis. In an earlier study by V e n k a t e s a n et al. [43] had reported an absence of joint between the caudal end of the ischium and the pubis in the emu. The pubic shaft extended beyond the level of the ischium in our study, similar to the ostrich [40], domestic fowl [21], pigeon [20], goose [33] and owl [32]. Conversely, it did not project beyond the level of the ischium in the emu [24, 38].

The morphological features of the long cylindrical shaped femur are largely similar to findings in the cattle egret [28] and the barn owl [42]. However, the major trochanter observed to be more proximal than the femoral head in this study is absent in birds like the *Parus major*, *sitta europaea* and *passer domesticus*. In the turkey, the major trochanter is present, but, unlike the Guinea fowl, is on the same horizontal level with the femoral head; in the ostrich, the femoral head is more proximal than the major trochanter, unlike in the Guinea fowl [44]. Furthermore, C h o u d h a r y et al. [7] observed that the femoral head and major trochanter are on the same level in the serpent eagle and the brown wood owl, unlike in the Guinea fowl. The shallow notch of the *fovea capitis* observed in the Guinea fowl is similar to those of near-same size adult birds like the domestic fowl [8, 21] and duck [8]. In the ostrich, the *fovea capitis* is a large and deep notch surrounded by boney ridges [44], while in the emu, it is indistinct [8, 19]. The muscular lines observed on the caudal surface of the Guinea fowl femur has been observed in the same specie by V a n k a t e s a n et al. [44]. However, the authors observed that the lines are indistinct in the turkey, but well developed in the ostrich. They have also been reported in the peahen [37], serpent eagle and brown wood owl [7]. One unique feature of the Guinea fowl femur from this study is the absence of a vascular/nutrient foramen. This foramen has been reported on the caudal surface of the femur of many other birds including

the quail [13], turkey and ostrich [44], emu, duck and domestic fowl [8]. Furthermore, pneumatic foramen reported on the femur, below the greater trochanter in the crested serpent eagle by Choudhary et al. [7], in the ostrich by Venkatesan et al. [44] and emu by Chukkath et al. [8], is lacking in the Guinea fowl from this study. Choudhary et al. [7] did not observe it in the brown wood owl, Chukkath et al. [8] did not observe it in the domestic fowl and duck, while Venkatesan et al. [44] did not observe it in the turkey. According to Chukkath et al. [8], pneumatic foramen is indicated in the femur of large birds to reduce the body weight while accommodating their large body size. This is not necessary in the Guinea fowl, domestic fowl, duck, owl and turkey, as they are smaller birds compared to ostrich and emu. The roughness of the external surface of the patella is for attachment of tendon of the ambient muscle [21].

The tibiotarsus was formed by the fusion of the tibia and the proximal row of tarsal bones. The tibiotarsus in our study, was the longest bone. This is similar to the findings in the chicken [25], cattle egret [28], barn owl [42], emu and ostrich [8], serpent eagle and brown wood owl [7]. The lateral cnemial crest observed in our study is not as extensive as that reported in the ostrich by Chukkath et al. [8], who described it as a large tuberosity in the ostrich. The prominent nature of the cranial cnemial crest of the Guinea fowl is comparable to those of the peahen [37], cattle egret [28], Indian eagle-owl [32], serpent eagle and brown wood owl [7]. It serves as the point of origin of extensor muscles of the stifle joint [22]. The conspicuous intercnemial groove observed in our study serves as the point of origin for the long digital extensor muscle, which inserts on the extensor groove on the same cranial surface, just proximal to the tibial condyles; also, the flexor fossa is for origin of the long digital flexor muscle [21]. The fibular spine terminated at the mid-shaft of the tibia in this study, similar to that of the duck [8], but unlike that of the domestic fowl that extended to the distal extremity of the tibia [8]. Also, contrary to the findings in the Guinea fowl, the fibula reached up to distal third of the lateral border of the tibiotarsus in the serpent eagle and brown wood owl [7]. Only one interosseous space, without a distinct fibular crest, was observed between the tibia shaft and fibular spine in this study. Conversely, Choudhary et al. [7] observed both proximal and distal interosseous spaces, created by distinct fibular crests in both the serpent eagle

and brown wood owl. Two interosseous spaces were also reported in the Indian eagle-owl by Sarma et al. [32]. The extensor groove observed in this study was reported in the same location in the crested serpent eagle, as an extensor canal, by Choudhary et al. [7] who did not observe it in the brown wood owl. This groove guides the distal tendons of the extensors of the toes [21]. The intertarsal sesamoid bone identified in our study is indicative of an adult skeleton. It was consistent in all the birds used for the study. It is a product of ossification of the tibial cartilage, and it provides a gliding surface for tendons of the gastrocnemius and digital flexor muscles [21].

The tarsometatarsus was formed by the fusion of the middle and distal rows of tarsal bones with metatarsus II-IV, and had similar presentation to that of the chicken [39] and cattle egret [28]. The hypotarsus is a component of the distal tarsal bones. Chukkath et al. [8] reported that the hypotarsus enclosed a bony canal for guiding flexor tendons in domestic fowl and duck, which were lacking in ostrich and emu. These canals were also lacking in the Guinea fowl hypotarsus, from our study, rather crests and channels depicted the Guinea fowl hypotarsus. Also, the tendinous grooves observed on the shaft of the tarsometatarsus in the Guinea fowl were shallow, but in the emu, Chukkath et al. [8] reported that they were deep. The vascular foramen identified between the middle and lateral trochlea in the Guinea fowl was identified above the lateral trochlear on the same cranial surface of the tarsometatarsus in the crested serpent eagle and brown wood owl by Choudhary et al. [7].

The number and arrangement of metatarsal trochlear and digital phalanges in the Guinea fowl presented seems to be the normal presentations in most birds as similarity was noted in the chicken [4], cattle egret [28], barn owl [42], serpent eagle and brown wood owl [7]. However, Chukkath et al. [8] reported that the ostrich has only two trochlear (medial and middle) and two digits (digits III and IV) while the emu has three trochlear (like the Guinea fowl), but only three digits (digits II-IV). Zhang et al. [46] and Chukkath et al. [8] further observed that the digit IV of the ostrich is devoid of the 5th phalanx. This is unlike the digit IV of the Guinea fowl from this study, which has 5 phalanges, just like most other birds in the literature. Based on the planter orientation of only digit I, the Guinea fowl foot is anisodactyl. This is the same as most extant birds. Conversely digits I and IV of the budgerigars

orient to the planter direction, while digits II and III remain in the dorsal orientation [6]. Thus, the budgerigar foot is zygodactyl.

CONCLUSIONS

This study on the hindlimb of the Helmeted Guinea fowl (*Numida meleagris*) has been able to elucidate the morphological features of the bones of the hindlimb while comparing their similarities with documented literature on some other birds.

CONFLICT OF INTEREST

Authors declare that no conflict of interest is associated with this work.

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