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Gross Morphometrical Study on the Sternum of Guinea fowl (*Numida meleagris*)

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ABSTRACT

The present study was conducted to evaluate the gross morphometry of the sternum in the guinea fowl, with the aim of documenting its anatomical features and establishing baseline biometric data relevant to avian skeletal biology. The body of sternum was concave dorsally and convex ventrally. The cranio-lateral process was elongated and directed cranially. Caudo-lateral process started as a single process which bifurcated into a smaller dorsal and a longer ventral process. Median pneumatic foramen was present. An oval to round foramen was observed towards the cranial-most aspect of sternum just caudal to rostrum. The cranial border presented transversely elongated grooves separated by rostrum to articulate with the distal extremity of coracoid bone. Cranially, the lateral border presented four facets for sternal ribs. The rostrum was roughly triangular plate-like structure in outline. A foramen was observed between the rostrum and cranial border of sternum. The ventral surface presented triangular shaped keel (carina) with concave cranial border. The apex of the keel was in level with the origin of cranio-lateral process. Length of sternum was 12.01 cm. Width of sternum was maximum at the level of facets (2.41 cm). The cranio-lateral processes were shortest and caudo-ventral processes were the longest. The height of keel was maximum at its apex. This study provides foundational data on the sternal morphology of guinea fowl, which may serve as a useful reference in comparative anatomy, veterinary medicine, and functional morphology of avian species.

Keywords: Biometry, Guinea fowl, Keel, Pneumatic foramen, Sternum

INTRODUCTION

The guinea fowl (*Numida meleagris*) is an important avian species, both economically (as a source of meat and eggs) and ecologically (Araujo *et al*., 2023). Avian skeleton is highly adapted for flight characterized by a prominent sternum, pelvis that is opened ventrally, forelimb modified to wing and fusion of vertebrae (Dyce *et al*., 2010). Sternum is an extensive bone forming the floor of thoracic cavity and part of abdominal cavity of fowl (Pathak *et al*., 2017). The sternum plays an important role in flight mechanism as it provides attachment area for pectoralis and supra-coracoideus muscles that function in wing flapping (Altshuler *et al*.,2015). Sternal crest is most developed in sophisticated fliers like swifts and hummingbirds and least developed in the flightless ratites, which have a flat and raft-like sternum (Bezuidenhout,1999).The morphological variation, depending upon the species, may exist in the development of keel, processes, sternal spine and in the presence or absence of pneumatic foramen (John *et al*., 2014a). Literature is available on the gross anatomy and biometry of sternum of avian species (Duzler *et al*., 2006), pigeon, crow and owl (John *et al*., 2014b), emu, turkey and duck(Jayachitra *et al*., 2015), peacock, turkey, duck and waterhen (Pathak *et al*., 2017), moorhen (Wani *et al*., 2017), Japanese domestic fowls (Kudo *et al*., 2017), owl (Choudhary *et al*., 2018), crow (Sunil kumar *et al*., 2019), crane (Girgiri *et al*., 2022) and domestic fowl (Jones *et al*., 2023).There is positive correlation between flight capability and height of the sternal crest to which flight muscles insert (Dursun *et al*.,2002). Keeping in view the functional aspect of sternum, the present study was planned to focus on the gross morphology and biometry of sternum in guinea fowl which further help document species-specific skeletal features that distinguish it from other domestic and wild birds. Documenting the gross anatomy of the sternum further enriches anatomical databases and

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will be valuable for teaching in veterinary and zoological sciences.

MATERIALS AND METHODS

The present study was conducted on the sternum (N=01) of guinea fowl. Carcass was obtained from Division of Livestock Farm Complex, F.V.Sc & A.H., SKUAST-Jammu. Immediately after collection, the bones were processed as per the standard techniques (Raghavan, 1964) and used for recording various morphological characteristics and biometrical parameters.

RESULTS AND DISCUSSION

Gross morphology

The sternum was a well-developed single bone in guinea fowl and formed major supportive element along the ventral body wall. Shape of sternum varied with species (Konig *et al.*, 2016). It was located on the antero-ventral aspect of body cavity and gives attachment to coracoid and sternal ribs (Jayachitra *et al.*, 2015). The dorsal aspect of the sternum was roughly pyramidal with base facing cranially and apex direct caudally which was at par with the findings of Wani *et al.* (2017) in moorhen. Wani *et al.* (2018) divided the sternum of crow into three parts namely body, rostrum and keel. Wani *et al.* (2017) divided the body of sternum of moorhen into anterior and posterior parts with the origin of caudo-lateral process as the demarcation point.

The body was elongated, concave dorsally and convex ventrally which gives attachment to breast muscles (Jayachitra *et al.*, 2015). A roughly quadrilateral body was observed in peacock and turkey (Pathak *et al.*, 2017) and crow (Wani *et al.*, 2018). Cranio- lateral process was elongated and directed cranially (Fig. 1) and represents the limit of the cranial opening of the ribcage (Konig *et al.*, 2016). This process extended up to rostrum unlike in peacock, where this process did not extend up to rostrum (Pathak *et al.*, 2017). The process was highly developed in owl, moderately in crow and highly reduced in pigeon (John *et al.*, 2014b). Caudo-lateral process started as a single process which bifurcated into a smaller dorsal and a longer lateral processes in moorhen unlike in crow and owl, where caudo-lateral process was single (John *et al.*, 2014b). In this study, the caudo - dorsal process was much wider at its terminal end as compared to caudo-ventral process (Fig. 1). Caudo-ventral process and lateral border of the body delineates the medial incisure whereas dorsal and ventral processes formed the boundary of lateral incisure (Fig. 1, 2). In live bird, both these incisures were closed by connective tissue membranes (Konig *et al.*, 2016). Caudo-lateral process was absent in emu (Jagapathi *et al.*, 2007). John *et al.* (2014b) reported double lateral notch in pigeon and single notch in crow. In moorhen, the caudo- lateral processes terminated well behind the caudal end of the body.

In the present study, the median pneumatic foramen was present (Fig. 2) as also reported by John *et al.*(2014b) in pigeon. Additional lateral foramen was observed in sternum of crow, owl and pigeon hawk (John *et al.*, 2014b). Wani *et al.* (2017) reported elongated pneumatic foramen that communicated with the ventral surface of the body in moorhen. Two large median pneumatic foramina were observed by Pathak *et al* (2017) in peacock. Sternum of duck presented distinct median pneumatic foramen towards the anterior border (Pathak *et al.*, 2017). Sunil kumar *et al.* (2019) in crow reported several pneumatic foramina arranged linearly in midline for ventral process, both directed caudally (Fig. 1). Wani *et al.* (2017) also reported two caudo communication with air sacs. In duck, there was only single foramen located at cranial border of midline of the basal plate (Sumena and Lucy, 2015). Pneumatization is derived from diverticulae originating from the clavicular air sac (Konig *et al.*, 2016).In the present study, a single oval to round foramen was observed on the cranial aspect of the dorsal surface of the sternum, located just caudal to the rostrum (Fig. 2). This foramen was positioned along the midline and extended ventrally, opening toward the ventral surface. It is hypothesized that this foramen may serve as a passage for blood vessels and/or nerves. To the best of our knowledge, such an opening has not been previously described in other avian species in the available literature.

Cranial border was thick, convex and triangular in outline as also reported by Tomar *et al*. (2011) in pariah kite. It presented transversely elongated groove to articulate with the distal extremity of coracoid bone just below the cranial border (Fig. 3). This acts as a base for the shoulder (Yasuda, 2002). The groove was bordered by dorsal and ventral lip as observed by Wani *et al*. (2018) in crow and Choudhary *et al*. (2018) in owl. Grooves were separated by a plate-like rostrum in the middle (Fig. 3). The caudal border was in the form of a pointed projection. In crow, caudal border was deeply notched (Wani *et al.,* 2018). Anteriorly, the lateral border was thick and presented four facets for sternal ribs (Fig. 2). These facets were located between the origin of cranio-lateral and caudo-lateral processes. The lateral border on either side presented four articular facets in black drongo (Sumena and Lucy, 2015), peacock and turkey (Pathak *et al*., 2017), five facets in owl (Choudhary *et al*., 2018) and crow (Sunil kumar *et al*., 2019), six facets in duck (Sumena and Lucy, 2015), seven in Black- crowned crane (Girgiri *et al*., 2022).Posteriorly, the lateral border was concave similar to the findings of Wani *et al*. (2018) in crow.

The rostrum was roughly triangular plate-likein outline (Fig. 4) whereas Pathak *et al*. (2017) in peacock and Sathyamoorthy *et al*. (2021) in Asian koel reported quadrilateral shaped rostrum. However, the rostrum was typically Y shaped in crow (John *et al*., 2014b) and hook shaped in green winged macaw (Sreeranjini *et al*., 2015). Sternum of pariah kite was devoid of rostrum (Tomar *et al*., 2011). Choudhary *et al*. (2018) reported triangular shaped rostrum in owl.

The ventral surface was convex and presented triangular shaped keel (carina) in midline (Fig. 1) as earlier reported by Sunilkumar *et al*. (2019) in crow.In contrast, the sternum of ostrich was devoid of keel (Sathyamoorthy and Ramesh, 2006). In the present study, the cranial border of keel was deeply concave. It's cranial projection formed the apex of the keel. Konig *et al*. (2016) categorized birds on the basis of development of carina sterni into ratites with poorly developed carina or carinate birds with well-developed carina. Khamas and Rutllant (2024) reported that the keel bone was the main attachment site for the flight muscles (supracoracoideus and pectoralis) in chicken. In guinea fowl, the height of keel was recorded to be maximum cranially which decreased caudally as also observed by Wani *et al*. (2018) in crow. The cranial border was concave and the apex was at the level with the origin of caudo-lateral process. However, in black drongo, the apex was at the level with the manubrium (Sumena and Lucy, 2015). The dorsal border fused with the ventral surface of the body of sternum whereas the ventral border was convex. In crow, the ventral border of keel bifurcated caudally and each ridge joined caudo- lateral angles of body of sternum (Sunil kumar *et al*., 2019). The height of keel alone should not be considered as the index for flying abilities because in chicken, keel is deep but it is a poor flier (Dyce *et al*., 2010).

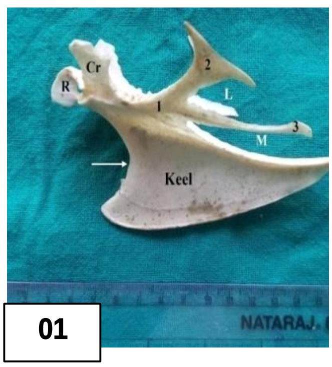
Biometry

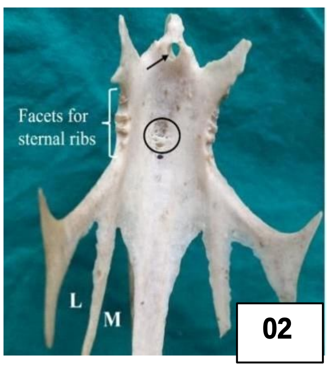
In the present study, the length of sternum was recorded as 12.01 cm which was longer than the sternum of other avian species such as moorhen (4.2 cm) (Wani *et al*., 2017), pigeon (6.73 cm), crow (6.02 cm) and owl (4.69 cm) (John *et al*., 2014b) and Brown wood owl (5.6 cm) (Choudhary *et al*., 2018). In domestic fowl, the length of sternum was 15 cm (Sumena and Lucy 2015). Width of sternum was found to be maximum at the level of facets (2.41 cm) followed by width caudal to caudo-lateral process (1.41 cm) and least at the caudal extremity (0.91 cm). The percent decrease in the width of sternum from the level of facets to caudal part of caudo-lateral process was

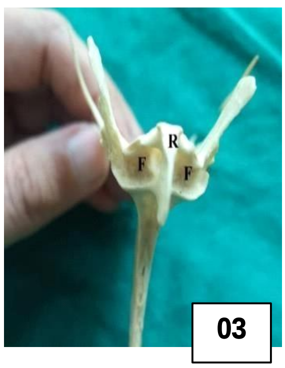
41.49% and thereafter the width decreased by 35.46%. However, the overall decrease of width from cranial to caudal extremity was 62.24%. In domestic fowl, width of sternum was 3 cm (Sumena and Lucy, 2015). Sunil kumar *et al.* (2019) also reported maximum width of sternum at cranial part (2.65 ± 0.11 cm) in crow. The width of sternum ranged between 24 to 65 mm in flying birds (Duzler *et al.*, 2006). A wide sternum would produce an attractive appearance for a fighting cock (Kudo *et al.*, 2017).

Length of keel at its attached border was measured as 8.91 cm whereas the curved length of keel was 11.3 cm which was greater than in pigeon (7.15 ± 0.04 cm), crow (5.54 ± 0.03 cm) and owl (4.81 ± 0.03 cm) (John *et al.*, 2014b). In the present study, curved length of keel was 26.81% greater than its length at its attached border. The height of keel was maximum at its apex (3.72 cm). The height of keel decreased caudally which was in accordance to the findings of John *et al.* (2014a) in pigeon hawk. Dursun *et al.* (2002) documented a positive correlation between flight capability and height of keel.Keel height was 3.03 ± 0.06 cm in pigeon, 2.25 ± 0.04 cm in crow and 2.26 ± 0.04 cm in owl (John *et al.*, 2014b).Distance between right and left cranio-lateral process (A) was 3.21 cm. This distance was 3.7 ± 0.04 cm in pigeon, 3.38 ± 0.04 cm in crow and 3.57 ± 0.03 cm in owl (John *et al.*, 2014b). Distance between mid- point of cranial border of sternum and apex of keel (B) was 5.06 cm. Average A/B value was 0.64. Duzler *et al.* (2006) recorded this value as 1.56 to 1.95 mm in swimming group, 0.96 to 1.35 mm in flying group and 0.50 to 0.68 mm in walking group of birds. Distance between lateral ends of two articular coracoid grooves (C) was 1.62 cm. The same was 1.83 ± 0.04 cm in pigeon, 1.22 ± 0.03 cm in crow and 1.4 ± 0.01 cm in owl (John *et al.*, 2014b). Average C/B value was 0.32. Duzler *et al.* (2006) recorded this value as 1.21 to 1.43 mm in swimming group, 0.63 to 1.04 mm in flying group and 0.41 to 0.50 mm in walking group of birds, which was comparable to our present findings.

In conclusion, this study presented a detailed gross morphometric assessment of the sternum in guinea fowl, emphasizing its distinct anatomical characteristics and dimensional attributes relevant to avian skeletal biology. The observed morphometric features reflect structural adaptations for flight and provide important anatomical reference points for future veterinary, anatomical, and zoological research involving this species.







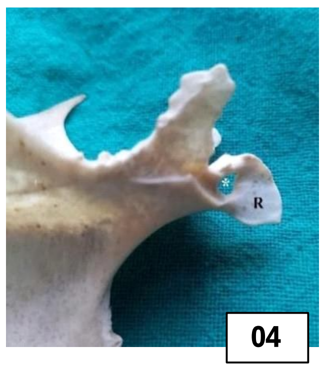


Fig. 1 Photograph showing lateral aspect of sternum of guinea fowl showing rostrum (R), cranio-lateral process (Cr), caudo-lateral process (1) which started as a single process and then divided into caudo-dorsal (2) and caudo-ventral (3) process. Ventrally, keel was present with concave anterior border (arrow). Medial incisure (M) and lateral incisure (L) are also evident. **Fig. 2** Photograph showing dorsal aspect of sternum of guinea fowl showing median pneumatic foramen (encircled). Medial incisure (M) and lateral incisure (L) are also evident. An oval to round opening (arrow) was prominent towards cranial border just caudal to rostrum. Four facets are present for sternal ribs, **Fig. 3** Photograph showing cranial aspect of sternum of guinea fowl transversely elongated facets (F) for coracoid bone separated by rostrum (R), **Fig. 4** Photograph showing roughly triangular plate-like rostrum (R). An opening (*) was observed between rostrum and cranial border of sternum

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