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Morphology of the Sternum, Pectoral Girdle and Wing of West African Black-Crowned Crane (*Balearica pavonina pavonina*)

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ABSTRACT

The present work was undertaken to study the gross morphological features of the sternum, pectoral girdle and wing bones of adult black-crowned crane. The bones were processed using standard techniques to highlight structural details. The sternum was triangular shaped, comprised of three borders and two surfaces. The dorsal border was slightly shallow medially having linearly arranged pneumatic foramina. The basal border was strongly convex and bears a prominent sternal crest. The cranial border was broad and transversely convex with shallow grooves on the lateral edges for articulation with the coracoid bones. There were seven pairs of ribs that articulated with corresponding sterno-costal bones. The shoulder girdle comprised of the blade-like scapula, coracoid, and the clavicles which fused proximally to form the foramen triosseum. The humerus was pneumatic tubular bone with flat expanded proximal ends and small rounded distal ends. The ulna and radius were of comparatively equal length, separated along their long axis by extended interosseous space. The carpus consisted of the ulnar carpal bone and radial carpal bone. Whereas, the carpo-metacarpal comprised of three primary bones that articulated distally with corresponding rays of digits.

Keywords: Black-crowned Crane; Osteomorphology; Pectoral Girdle; Sternum; Wing bones.

INTRODUCTION

The skeletal system in birds comprised of pleomorphic individual bones, whose shape is determined by their function and exhibit species-specific characteristics (Nickel *et al*., 1977). The avian skeleton is highly adapted for flight characterized by a prominent sternum, a pelvis that is open ventrally, a forelimb modified to form a wing, and considerable fusion of the vertebrae (Dyce *et al*., 2010). Crane birds are described as omnivorous, large, long-legged, and long-necked members of the order *Gruiformes* (Del Hoyo *et al*., 1994). A case report on fracture management of long bone in Sandhill crane (Klein and Thompson, 1997) and musculoskeletal disorders (Hartup *et al*., 2018) on captive crane species have been reported. Similarly, Hiragi *et al*. (2014) described vertebral formula in Red-Crowned and hooded Crane. Edet *et al*. (2018), reported on the conservation status of the Cranes in the wetlands of Northern Nigeria. However, to the best of our knowledge, little is known about of the gross morphology of the skeleton of the West African black-crowned crane. The present study aimed to document some aspects of the skeleton of the West African black-crowned crane.

MATERIALS AND METHODS

An adult crane bird (*Belearica pavonina paonina*) died while on admission at the avian unit of Veterinary Teaching Hospital, University of Maiduguri was presented to the Department of Veterinary Pathology of the same institution for post-mortem examination. The cadaver of the bird was collected for anatomical study. The bones of the sternum, pectoral girdle, and wing were macerated using technique described by Kumar and Singh (2014). The macerated bones were cleaned with aid of brush, forceps, and dissecting needle to remove soft tissue remnants and were re-washed with 10% hydrogen peroxide for bleaching and sun-dried. The gross morphological features of each bone were carefully observed and documented. Photographs of the bones were taken in different anatomical planes using a digital camera (Nikon D-90). Metrical dimensions of the long bones were measured in centimeters (cm) using a plastic ruler.

RESULTS

Sternum and Ribs

The sternum in black-crowned crane bird was relatively large and when viewed laterally presented an elongated triangular bony plate, whereas on a dorsal view it presented a rectangular outlined with surfaces and borders (Figure. 1A-B). It has two surfaces and three borders. The dorsal surface was concave, whereas the ventral surface presented a strongly convex ventral bony plate. The sternal crest slightly projected ventrally from the ventral surface of the plate. The sharp cranial end of the sternal crest was concave. The cranial border was thick and convex transversely with shallow grooves on the lateral edges of the border for articulation with the coracoid bones. The lateral edges of the cranial border presented short blunt processes, whereas the median region of this border presented the less prominent manubrial spine (Figure. 1C). The caudal surface of the cranial border presented a small bony ridge that possessed two smalls caudally directed folds. Immediately behind the ridge were several median pneumatic foramina arranged linearly on the midline for communication with air sacs. The thickened lateral borders of the sternum presented seven facets on either side for articulation with the corresponding sterno-costal ribs. The caudal border has broad lateral ends with a median shallow groove (Figure. 1A-C).

There are seven pairs of sternal ribs in the black-crowned crane. Each rib consisted of a shaft and two extremities, two surfaces, and two borders. The lateral surface was convex while the medial surface was concave. The cranial border was thin and the caudal border was slightly thick. The uncinate process was approximately at the middle half of the shaft, which was a bony projection on the caudal border of each rib and directed caudodorsally toward the cranial border of the succeeding ribs. There was a pneumatic foramen which existed at the bifurcation of the head and tubercle medially. The proximal extremities presented the head, neck, and tubercle. The head articulated with the corresponding thoracic vertebrae. The tubercle articulates with the transverse process of the thoracic vertebra via the articular facet. The sternal ribs joined proximally with the distal extremity of the respective vertebral rib and formed a gliding joint and the sternal extremity articulated with the costal facet on the lateral border of the sternum (Figure. 1 D).

Bones of the pectoral girdle

The pectoral girdle comprised of three primary bones; the scapula, coracoids, and clavicles. These bones established the link between the trunk and the wing, whereas the space created by their union formed the triosseal canal (foramen triosseum). The scapula was blade-like, long with sharp borders. It lies against the upper part of the thoracic wall, its caudal narrow extremity extended to the level of the ilium while the cranial extremity was large and articulates with the clavicle, coracoids, and the head of the humerus (Figure. 2A). The coracoid bone was small, elongated and articulated with the sternum via its spatula-shaped distal extremities. The coracoid extended in an oblique direction to the shoulder joint. The proximal extremity was irregular having proximal and lateral processes, whereas the distal extremity possessed the glenoid process which formed the glenoid cavity medially for articulation with the sternum (Figure. 2A). The slender right and left clavicles slightly curved along it shaft where it fused ventrally pointing at the dorsal portion of the cranial border of the sternum. The proximal end of the clavicles articulated with the scapula and the coracoid bones respectively. The fused distal end of the clavicles presented an arch (Figure. 2B).

Bones of the wing

Humerus

The humerus was the strongest of the wing bones. It was pneumatic tubular bones, with flat expanded proximal ends and small rounded distal ends. The maximum length of the humerus was 19 centimeters (cm). The proximal extremity was flat and consisted of indistinct head. Lateral to the head at the same plane was the lateral tubercle which extended towards the shaft as the prominent lateral tubercular crest. The medial tubercle was slightly larger and presented a curved rounded tuberosity. Distal to the medial tubercle was shallow curvature that blends with the shaft of the humerus. The distal extremity presented the flexor process on its caudal surface and comprised the larger ulnar condyle and smaller radial condyle for articulation with the ulna, and both radius and ulna respectively forming the elbow joint. The two condyles were separated by the intercondylar notch. The ulnar epicondyle and radial epicondyle lie peripheral to the corresponding condyles. In addition, the caudal aspect of the humeral distal end presented a relatively wide and shallow olecranon fossa (Figure. 3A-B).

Ulna and radius

The ulna was thicker in width than the radius. However, both bones were comparatively of equal length, separated along their long axis by relatively wide interosseous space. The maximum length of ulna and radius was 21.3 and 19.7 centimeters (cm) respectively. The proximal end of the shaft of the ulna presented a small rounded protuberance that bears concave articular surfaces for articulation with the ulnar condyles of the humerus. The distal end of the ulna was trochlear in shape and presented condyles for articulation with ulnar carpal and radial carpal bones respectively. The radius was slender and articulated with the humerus and the ulna proximally. The distal end of the radius presented an articular surface for articulation with radial carpal bone. There existed a rounded mass of bony callus of a healed fracture toward the distal end of the left radius (Figure. 4A).

Carpus

The carpus comprised of the ulnar carpal bone and radial carpal bone respectively. The ulnar carpal bone articulated proximally with the ulna and distally with the carpometacarpal bone. The radial carpal bone was irregular in shape, situated on the cranially. It articulated proximally with the distal end of the radius and the ulna, and distally with the carpo-metacarpal. The distal row of carpal bones fused with the proximal end of the metacarpus forming the carpometacarpal bones. The proximal end of these compound bones bears the cranial and the caudal carpal fossae, the carpal trochlea as well as a strong fusiform process projected from the palmar surface of the proximal end of the carpo-metacarpal (Figure. 4).

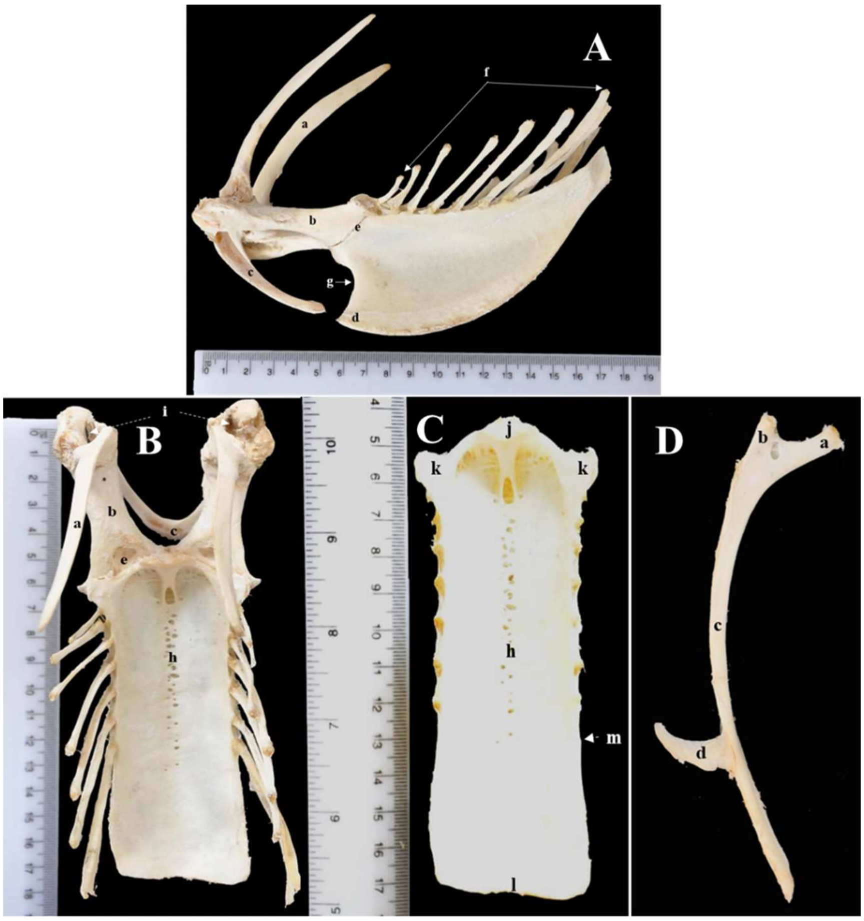

Figure 1A. Pectoral girdle of black-crowned crane (lateral view) showing: a- Scapula, b- Coracoid, c- Clavicle, d- Sternal crest, e- Coraco-sternal articulation, f-Sterno-costal bones, g-cranial border, **Figure 1B.** Pectoral girdle of black-crowned crane (dorsal view) showing: a-Scapula, b- Coracoid, c- Clavicle, e- Coraco-sternal articulation, i- Foramen triosseum, h- Pneumatic foramina, **Figure 1C.** Pectoral girdle of black-crowned crane (dorsal view) showing: j- manubrial spine, k- cranio-lateral processes, h- Pneumatic foramina, l- caudal border, m-lateral border, **Figure 1D** A rib of black-crowned crane (longitudinal view) showing: a- Head, b- Costal tubercle, c- Shaft, d- Uncinate process.

Figure 2A-B. A coracoid of black-crowned crane (dorsal view) showing: a- shaft, b-proximal extremity having processes, c- distal extremity, d- glenoid process, e-medial process, f- glenoid circumference for coraco-sternal articulation B. Fused clavicles of black-crowned crane showing: a-shaft, point of fusion (broken line) (longitudinal view).

Figure 3A-B. Right Humerus of black-crowned crane (caudal and cranial view) showing: a- Head, b- Medial tubercle, c- Lateral tubercle crest, d- Shaft, e- Lateral trochlea, f- Medial trochlea, g- Lateral epicondyle.

Carpo-metacarpal

The carpo-metacarpal consisted of three primary bones that fused with the distal carpal bone. The second (II) carpometacarpal bone was the largest. A small projection directed ventrally from the proximal end of the second carpometacarpal represents the first (I) carpometacarpal bone. The third (III) carpo-metacarpal was thin and the shaft was slightly arched along its long axis. It fused proximally and distally with the second (II) carpo-metacarpal separated along their shaft by a large interosseous space (Figure. 4A-B).

Digits

There were three rays of digits in the wing which articulated proximally with the corresponding carpo-metacarpal bones. These include; the first (I) digit which presented a sharp-pointed phalanx and articulated proximally with the first (I) carpo-metacarpal. The most developed second (II) digit articulates proximally with the distal ends of both the second and third (II and III) carpo-metacarpal and consists of two phalanges. The first (I) phalanx (proximal) was larger and has a thick cranial border with a sharp curved edge. The distal phalanx (second) was in the form of a pointed claw. The third (III) digit was the smallest and articulated with the distal end of the third (III) carpo-metacarpal (Figure. 4A-B).

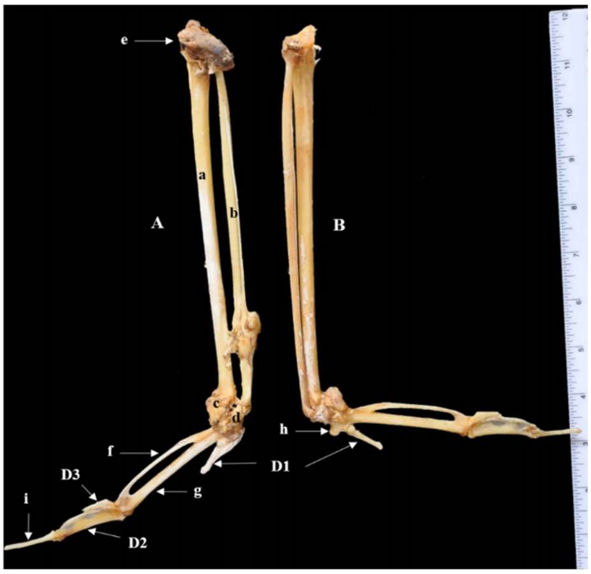

Figure 4 A-B. Ulna and radius of black-crowned crane (lateral and cranio-medial view) showing: a- Ulnar, b- Radius, c- Ulnar carpal bone, d- Radial carpal bone, e- Olecranon-ulnar, f- Carpo-metacarpal bone-III, g- Carpo-metacarpal bone-II, h- Carpo-metacarpal bone I, D1- First digit, D2- Second digit, D3- Third digit, i- Second Phalanx of second digit.

DISCUSSION

The sternum in the carinate carries a prominent ventral median keel (King and Mclelland, 1975), which is particularly prominent in birds with well-developed powers of flight and provided attachment to the important strong flight muscles (McLelland, 1990). The shape of the sternum was triangular on lateral view similar to that of domestic fowl (Nickel *et al*., 1977; Dyce *et al*., 2010) and white-rumped vultures (Sathyamoorthy *et al*., 2012b). The cranial end of the sternal crest was concave as reported in the fowl (Nickel *et al*., 1977; Dyce *et al*., 2010) and Cattle Egret (Rezk, 2015a). However unlike in the fowl, the sternal crest was at the same level with the cranial border. The ventral border was convex as reported in Cattle Egret (Rezk, 2015a), concave in the fowl, whereas makes a steep caudally directed arch in the pigeon (Nickel *et al*., 1977). The manubrial spine was rudimentary in the black-crowned crane, whereas in spot-billed pelican a triangular process was observed (Sathyamoorthy *et al*., 2012a). In addition, a thick, short and prismatic process was reported in the white rumped vulture (Sathyamoorthy *et al*., 2012b). The cranio-lateral process of the sternum was short with blunt rounded processes in black-crowned crane as observed in the white rumped vulture (Sathyamoorthy *et al*., 2012b) this process was very large in the fowl (Nickel *et al*., 1977; Dyce *et al*., 2010). In addition, a caudolaterally directed clasp-like process was present in the fowl, duck, and geese giving rise to an oval notch in these species (Nickel *et al*., 1977) providing support to the lateral and ventral body wall (Dyce *et al*., 2010). The caudal border of the sternum sloped medially to formed a shallow groove, whereas in spot-billed pelican it was triangular, thick, and presented a short process at the center (Sathyamoorthy *et al*., 2012a). It has been stated that cartilaginous caudal end of the sternum in young birds serves as age indicator (Dyce *et al*., 2010).

Seven articular facets were observed on the lateral border of the sternum in black-crowned crane, whereas six facets were reported in white rumped vulture (Sathyamoorthy *et al*., 2012b), five in spot-billed pelican (Sathyamoorthy *et al*., 2012) and four in Cattle egret (Rezk, 2015a). The linearly arranged pneumatic foramen on the dorsal surface of the sternum observed in the present study, was earlier reported in white rumped vulture (Sathyamoorthy *et al*., 2012b) and the spot-billed pelican (Sathyamoorthy *et al*., 2012a). It has been mentioned that these pneumatic foramina communicate with clavicular air sac and help lower the wing load without loss of strength (Sreeranjini *et al*., 2015). There were seven pairs of ribs in black-crowned crane similar to findings in Cattle egret (Rezk, 2015a) and white rumped vulture (Sathyamoorthy *et al*., 2012b). Whereas in duck and geese (Nickel *et al*., 1977) nine pairs of ribs were documented. The position of the uncinate processes on the ribs shaft in black-crowned crane was similar to that of white rumped vulture (Sathyamoorthy *et al*., 2012b). the uncinate processes was absent on the first rib in all domestic birds and from the last two ribs in the fowl and pigeon and the last three in the duck and geese (Nickel *et al*., 1977). Codd, (2010) specified that uncinated processes were integral to the mechanics of ventilation being active during locomotion and respiratory function. In addition, these processes give attachment to muscles and ligaments and strengthen the thoracic wall (Dyce *et al*., 2010). The morphology of the scapula of black-crowned crane and their relative position to the vertebral column was similar to findings in Cattle egrets (Rezk, 2015b). The scapula and coracoid and clavicle bones of the crane formed the foramen (*canalis triosseus*) a feature of avian species (Nickel *et al*., 1977), that transmits the tendon of the supracoracoid muscle (Dyce *et al*., 2010). The proximal end of the coracoid in black-crowned crane was irregular having processes as reported crested serpent eagle (Keneisenuo *et al*., 2019). The Paired clavicles commonly called furcula formed a broad U shape outlined as reported in crested eagle (Keneisenuo *et al*., 2019). However, numerous pneumatic foramina were observed in the proximolateral extremity of the clavicle in crested eagle which were absent in our findings. The furcular acts as a bony strut to maintain distance between two shoulders (Frandson *et al*., 2009), and helps to brace the girdle against axial skeleton (Dyce *et al*., 2010).

A small pneumatic foramen presents on caudal surface of the humerus in the present study was inconstant in position and size. Ilgun, (2019) observed the presence of two-three pneumatic foramen on the proximal part of the humerus in Dalmatian Pelican. The proximal extremity of the humerus of the crowned-crane, bears prominent lateral tubercular crest that extends towards the shaft whereas in the cassowary, a long curved humeral process towards the mid-shaft of the humerus was observed (Saber and Hassanin, 2014). The comparable length of the ulna and radius in the black-crowned crane was similar to that of fowl (Dyce *et al*., 2010). However, the ulna was distinctly curved in the fowl and pigeon (Nickel *et al*., 1977), but straight in the black crane. The autopodium was comparably shorter than the arm and forearm in black-crowned crane, whereas in the pigeon it was longer than the upper arm and about the equal length to the lower arm (Nickel *et al*., 1977). These are adaptive features for long-distance fliers and aids in maneuvers through the wetland and shrub vegetation of the Sahel. The autopodium exceeded the length of both upper and lower arms in the duck and goose the (Nickel *et al*., 1977). The morphological presentation of the rays of digits of black-crowned crane was similar to that of fowl (Nickel *et al*., 1977) and the cassowary (Saber and Hassanin, 2014).

Conclusion

The study highlighted structural details of different bones of the trunk, pectoral gridle and bones of the wings in West African Black-Crowned Crane. The osteological features observed are adaptive characteristics typical of long distant fliers. Moreover, gross anatomy of the musculoskeletal system has been documented which could aid in designing clinically oriented orthopedic models for management of fracture frequently seen in captive crane birds.

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

IAG designed and interpreted findings from the study, ISN collected and processed the specimen, MMK reviewed and proofread the manuscript.

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