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Research article

Gross morphometric studies on scapula, humerus, radius, and ulna of the Royal Bengal Tiger (*Panthera tigris*)

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A B S T R A C T

The study was carried out to know the gross anatomy and morphometry of scapula, humerus, radius, and ulnar bones of forelimb of an adult Royal Bengal Tiger. The bones were collected from Bangladesh National Zoo, Dhaka, and processed scientifically in The Veterinary Anatomy Laboratory of Chattogram Veterinary and Animal Sciences University (CVASU). The scapula was somewhat a quadrangular shape having two surfaces, three borders, and three angles. Its lateral surface was unequally divided into supraspinous and infraspinous fossa by a well-developed spine which gradually diminished towards the proximal extremity. The acromion process was subdivided into thick triangular shaped suprahamate process and hamate process which was over hanged the glenoid cavity. The humerus of The Royal Bengal Tiger was a long bone with a spirally twisted shape. The body of the humerus was somewhat compressed laterally. The radius was a slightly twisted bone with an anteroposteriorly flattened shaft and two extremities. The proximal extremity had a concave facet and the distal extremity was expanded and was about twice the size of the proximal extremity. The ulna was longer than the radius and was flattened mediolaterally. The proximal extremity had an olecranon process, anconeus process, and facet for the humerus. The olecranon process possessed three tubercles. Some osteo-morphometrical features in the bones of forelimb specified unique discrepancies for this species which were the key factors for interpretation in the field of radiology and forensic studies.

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1. INTRODUCTION

The Royal Bengal Tiger, one of the biggest living wild cats alive today, belongs to the family Felidae and a specific population of the *Panthera tigris tigris* subspecies (Kitchener et al., 2017; Sunquist and Sunquist, 2002). It is considered to belong to the world's charismatic megafauna (Sankhala, 1978) and documented as the national animal of Bangladesh (Lytton, 1841). Forelimb strength is a crucial element of the prey capturing apparatus in feline. Moreover, morphology and morphometric data of the bones of the forelimbs indicate hunting behavior of an animal belongs to Felidae family (Salesa et al., 2010).

For the adaptation of any animal, locomotion shows a critical role. The Royal Bengal Tigers move in their home ranges to forage for food resources, to search for the mating partner, to avoid the unfavorable environment, to hunt their prey, or to protect from possible threats like a human being or other animals (Biewener, 2003). Skeletal systems of large animals, for example, horses, cattle, small ruminants such as sheep, goats (Sisson et al., 1975), carnivores such as a dog (Evans et al., 2013), wild carnivores such as leopard (Podhade et al., 2007), Asiatic cheetah (Nazem et al., 2017), Indian wild cat (Palanisamy et al., 2018) and Asiatic lion (Nzalak et al., 2010) were studied in detail. There is a paucity of literature on systematic information of anatomical features of bones of forelimb of the Royal Bengal Tiger although some scientists have been studied the skeletal system of the Royal Bengal Tiger (Mazák, 1981; Heptner and Sludskij, 1992). Although the muscular anatomy of the forelimb of the tiger (Dunn et al., 2020) was studied, the morphometrical study of the bones of the forelimb of the Royal Bengal Tiger has not been studied in detail. Besides, in the field of radiology and forensic studies, the osteo-morphometrical features of the scapula, humerus, radius, and ulna are very important. Therefore, we investigated the morphometrical characteristics of the bones of the forelimb of the Royal Bengal Tiger.

2. MATERIALS AND METHODS

The bones (scapula, humerus, radius, and ulna) of the forelimb of the adult Royal Bengal Tiger were examined at the Anatomy Museum of Chittagong Veterinary and Animal Sciences University, Bangladesh. Recently a Royal Bengal Tiger was died in the Bangladesh National Zoo, Dhaka, and buried in an isolated place of the zoo with aseptic measures. Subsequently, the bones were collected, processed by removing the mud, and boiled with water and hydrogen peroxide (H_2O_2) for one hour to remove the remaining muscular structures and other tissues from the bones. After removing the extra structures with a knife, all the bones were properly washed with fresh water and finally, all the bones were dried under sunlight for a week. The whole processing was done carefully to keep the anatomical structures unchanged. To get the gross anatomical parameters different views of the scapula, humerus, radius, and ulna were photographed and documented. For the gross morphometric study, the length, width, height, and circumference were measured by using a calibrated scale and were recorded in centimeters (cm). The weight was also measured by using a digital balance (Sunrise Technology, Ahmedabad, India) and recorded in gram (gm). The morphometrical measurements of scapula, humerus, radius and ulna of the Royal Bengal Tiger compared with the previous findings of related animals including ruminant, canine, feline, etc.

3. RESULTS AND DISCUSSION

Scapula

The scapula of the Royal Bengal Tiger was quadrangular in shape (Figure1, 2) which was similar to the Indian wild cat (Palanisamy et al., 2018) and in Civet cat (Sarma et al., 2017). The scapula of the Royal Bengal Tiger possessed two surfaces, three borders, and three angles (Figure 1, 2) which were found to be homologous to those of the horse, cattle, sheep, and dog (Gretty, 1975). The lateral surface of the scapula was divided by a well-developed spine into two unequal fossae, i.e. supraspinous fossa and infraspinous fossa (Figure 1) were similar to lions (Nzalak et al., 2010). However, equal fossae were found in dogs and Indian wild cats (Palanisamy et al., 2018). The height of the spine gradually decreased towards the proximal extremity (Figure 1) which was similar to the findings of the lion (Pandey et al., 2004). The distal continuation of the spine was known as the acromion process, composed of the hamate process and suprahamate process; however, they are also called as acromion and metacromion process (Figure 3). The hamate process was triangular with thick blunted ends that over-hanged the glenoid cavity (Figure 3). The findings were consistent within lion (Nzalak et al., 2010) although it was not over-hanged to the glenoid cavity in cattle, sheep, and goats (Gretty, 1975). The dorsal border was measured 26.5 cm both in right and left scapula (Table 1). The cranial border was slightly convex which extended from scapular notch to cranial angle. The outline of the border was circular and smooth as mentioned previously in lion. Its length was measured 22.5 cm (right) and 21.4 cm (left). The caudal border was found straight with a thick and smooth outline and extended from the caudal angle to the glenoid cavity which was reported in the Indian lion (Nzalak et al., 2010), leopard and Indian wild cat (Palanisamy et al., 2018). The length of this border in right and left scapula was measured 18.3 cm and 18 cm, respectively (Table 1). The glenoid cavity was somewhat oval in shape (Figure 3) which was almost similar to Indian lion (Nzalak et al., 2010) and elongated in elephants (Ahasan et al., 2016). Its length was 5.2 cm and 5.4 cm in right and left, respectively and the width was 3.7 cm and 3.6 cm, respectively (Table 1).

Humerus

The humerus was one of the major bones in the appendicular skeleton of the Royal Bengal Tiger to bear the total body weight. It was a long bone with a spirally twisted shaft, which was located obliquely downward and backward directed. It formed a shoulder joint between its head and the glenoid cavity of scapula and elbow joint below by its condyles with the proximal extremities of radius and ulna (Figure 4, 5). The morpho-metrical data for different parameters of the humerus of the Royal Bengal Tiger were presented in the table (Table 2).

Figure 1. Lateral view of the left scapula of tiger showing cranial angle (1), caudal angle (2), cranial margin (3), caudal margin (4), supraspinous fossa (5), infraspinous fossa (6), scapular spine (7), tuberosity of spine (8), suprahamate process (9), hamate process (10), scapular notch (11) and coracoid process (12).

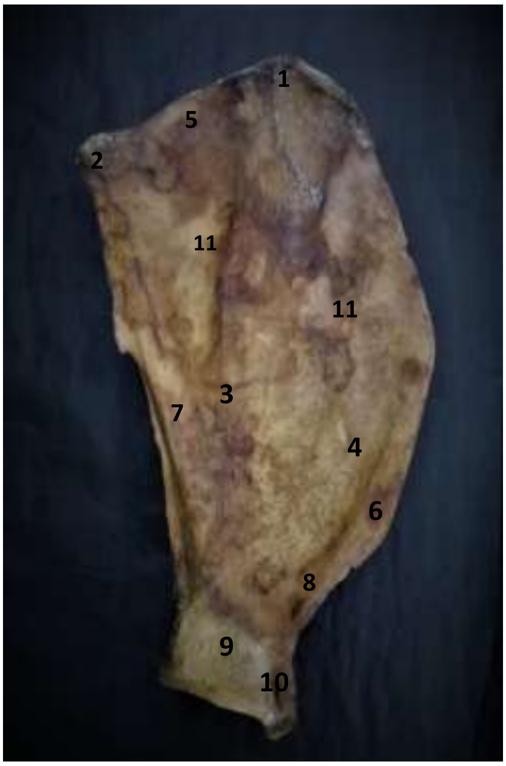

Figure 2. Medial view of left scapula of tiger showing cranial angle (1), caudal angle (2), caudal ridge (3), cranial ridge (4), dorsal margin (5), cranial margin (6), caudal margin (7), scapular notch (8), glenoid cavity (9) and coracoid process (10).

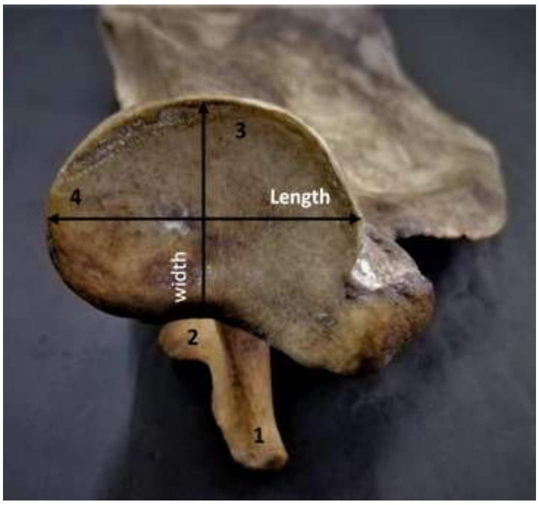

Figure 3. Ventral view of the left scapula of tiger displaying hamate process (1), suprahamate process (2), glenoid cavity (3) and coracoid process (4).

Table 1. The morphometrical data of different parameters of the scapula

Serial no	Parameter	Right(cm)	Left (cm)
1	Maximum length (Dorsal border to glenoid cavity)	26.5	26.5
2	Maximum width (Cranial border to caudal angle)	20	17.2
3	Length of cranial border	22.5	21.4
4	Length of caudal border	18.3	18
5	Length of dorsal border	20	19.9
6	Length of scapular spine	22.7	22.4
7	Height of scapula spine from supraspinous fossa	3.8	3.9
8	Height of scapula spine from infraspinous fossa	4	4
9	Maximum width of supraspinous fossa	6.9	6.8
10	Maximum width of infraspinous fossa	7.4	7.5
11	Length of glenoid cavity	5.2	5.4
12	Width of glenoid cavity	3.7	3.6
13	Distance between glenoid cavity and acromion process	3.6	3.9

Table 2. The morphometrical data for different parameters of the humerus

Serialno		Parameters	Right (cm)	Left(cm)
1		Total length	28	27.9
2	Shaft	Length	20	20.1
		Circumference of upper part	12.1	12
		Circumference of middle part	10.5	10.3
		Circumference of lower part	10.6	10.4
		Circumference of head	19.4	19.6
4	Proximal extremity	Circumference	22	21.8
		Width	8	7.9
5	Distal extremity	Circumference	20	19.8
		Width	4.7	4.5
6		Depth of olecranon fossa	17.5	17.6

It possessed a cylindrical shaft (diaphysis or body) and two enlarged extremities (epiphysis) such as proximal extremity and distal extremity. The head was rounded. The greater tubercle was large and prominent on the cranial and lateral surface of the proximal end of the bone, whereas the latter one was smaller, dorsally extended, non-articulated just under the head on the medial surface (Figure 4, 5). Similar findings were observed in the Asiatic cheetah (Nazem et al., 2017) but the most prominent major tubercle was found in the dog (Ahasan et al., 2016). The shaft was compressed craniocaudally in the proximal part, rounded to oval in the middle part, and compressed mediolaterally in the distal part (Figure 4, 5) as described in the lion (Kirberger et al., 2005). The humerus bones possess four surfaces; cranial, caudal, lateral and medial, however merely lateral and medial surfaces were reported in the Asiatic cheetah (Nazem et al., 2017). The lateral surface was curvedly bent and smooth, while the medial one was condensed in the proximal and nearly round in the distal part. A shallow, convex musculospiral groove (also known as a brachial groove) was present on the lateral surface, which continued until the proximal half of this bone (Figure 4, 5). The less-developed deltoid tuberosity was noticed at the edge between the lateral and medial surfaces, whereas well-developed deltoid tuberosity was noticed in the dog (Sarma et al., 2017). Lateral surface possess another oblique crest-like erection recognized as the tricipital line or deltoid crest, which ended in the deltoid tuberosity. On the cranio-lateral aspect of the humerus, another crest-like structure was started from the distal part of the lateral (greater) tuberosity, continued as a slightly oblique line, and finally terminated at teres major tuberosity. On the distal part of the shaft, a supracondyloid ridge started just above the lateral epicondyle, continued obliquely, and then ended on its caudal surface (Figure 4, 5). The nutrient foramen was observed on the caudal surface of the proximal to the middle of the shaft but (Nzalak et al., 2010) observed this foramen on the distal half of the shaft. In contrast, two nutrient foramina were observed in the Asiatic cheetah (Nazem et al., 2017). The distal extremity of the humerus had two condyles, two epicondyles, one supracondyloid foramen, radial and olecranon fossae. A long, narrow supracondyloid foramen was found on the medial surface of the distal extremity just above the medial epicondyle (Figure 4 and 5). This foramen didn't connect the radial fossa with the olecranon fossa as found in the dog (Sarma et al., 2017).

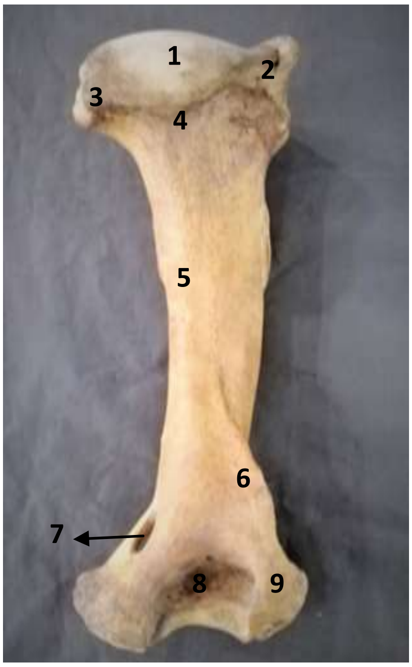

Figure 4. Caudal view of humerus of tiger showing head of humerus (1), greater of major tubercle (2), lesser tubercle (3), neck of humerus (4), deltoid tuberosity (5), supracondyloid crest or ridge (6), supracondyloid foramen (7), olecranon fossa (8), lateral epicondyle (9) and medial epicondyle (10).

Figure 5. Medial view of humerus of the tiger presenting lesser tubercle (1), head of humerus (2), neck of humerus (3), crest of lesser tubercle (4), shaft of humerus (5) and medial epicondyle (6)

Radius and Ulna

The radius had a long shaft or body and two extremities- the proximal one was smaller and the distal one was larger and expanded. The head of the radius was very well defined. On the proximal surface of the head, the concave fovea capitis radii- a triangular articular surface was seen which articulated with the lateral condyle of the humerus (Figure 7). Similar observation was reported by (Nzalaket al., 2010). Immediately below the head, the neck had an irregular surface for the articulation with ulna in its caudal part. A rough, prominent eminence- the radial tuberosity was present on the medial surface of the proximal extremity. The shaft of the radius was craniocaudally compressed, which was similar to the Asiatic cheetah (Nazem et al., 2017) but dissimilar with Asian elephants (Ahasan al., 2016). It had four surfaces- anterior, posterior, lateral, and medial. The anterior surface was rough for the attachment of tendons of muscles, while the posterior surface was somewhat concave as reported in dogs and cats (Gretty, 1975). The lateral and medial surfaces were a bit rounded and comparatively smooth.

The distal extremity was the largest part of this bone. It had a medial elongated projection called the medial (radial) styloid process. An articular surface-ulnar notch for the attachment of radius with ulna was also present.

Table 3. The morphometric data for different parameters of radius.

Serial no	Parameters		Right (cm)	Left (cm)
1	Total length		28	27
2	Proximal extremity	Circumference Width	11.4 3.5	11.5 3.7
3	Distal extremity	Circumference Width	15.9 4.9	15.4 4.8
4	Circumference at midshaft	Circumference of upper part Circumference of middle part Circumference of lower part	7.6 8.6 9.2	7.8 8.5 9.1

The ulna was the longest bone in the forelimb of the Royal Bengal Tiger. The olecranon of the ulna was projected further than the radius at the proximal extremity (Figure 6), which was similar with the cattle (Budras et al., 2011) and sheep (Sisson et al., 1975) but not similar with the horse (Sisson et al., 1975). The free end of this olecranon was extended caudolaterally to form olecranon tuberosity (Figure 6) as observed in the dog (Getty, 1975) and Asiatic cheetah (Nazem et al., 2017). It had three prominences- two were cranial and the caudal one was large and rounded as reported in the dog (Getty, 1975). The trochlear (semilunar) notch was large and articulated with the trochlea of the humerus. It was extended distally by the lateral and medial coronoid processes which form a concave area for joint, while proximally it was extended with the anconeal process. As like a radius, the shaft of the ulna was triangular in section and slightly convex cranially (Figure 6). These findings were also observed similar in Asiatic cheetah (Nazem et al., 2017). The proximal half of the shaft was thick as resembling the distal part at caudal view. At the distal extremity, a distally projected lateral styloid process was seen which articulated with the carpal bones as observed previously by (Nzalak et al., 2010). Medially, it had a convex facet that articulated with the radius.

Figure 6. Lateral view of ulnar bone of tiger showing olecranon tuber (1), olecranon process (2), anconeal process (3), trochlear notch (4), styloid process (5).

Table 4. The morphometric data for different parameters of the ulna.

Serial no		**Parameters**	**Right** (cm)	**Left** (cm)
1		Total length (cm)	35	35
2	Proximal extremity	Circumference Width	13.2 4	13.1 5
3	Distal extremity	Circumference Width	8.2 4.2	8.8 4.5
4	Circumference at midshaft	Circumference of upper part Circumference of middle part Circumference of lower part	11.3 7.5 6.1	11.2 7.9 5.7

Figure 7. Lateral view of radius bone of tiger presenting capitular fovea of radius (1) radial tuberosity (2), shaft of radius (3), styloid process of radius (4)

4. CONCLUSION

The scapula of the Royal Bengal Tiger was somewhat quadrangular shape with two surfaces, three borders, and three angles. Its lateral surface was unequally divided into supraspinous and infraspinous fossa by a well-developed spine which gradually decreased towards the proximal extremity. The acromion process was subdivided into thick triangular shape suprahamate process and hamate process which was over hanged the glenoid cavity. The humerus of the Royal Bengal Tiger was a long bone with a spirally twisted shape. The body of the humerus was somewhat compressed laterally. Radius was slightly twisted bone with an anteroposteriorly flattened shaft and two extremities. The proximal extremity had a concave facet and the distal extremity was expanded and was about twice the size of the proximal extremity. The ulnar bone was longer than the radius and was flattened mediolaterally. The proximal extremity had an olecranon process, anconeus, process, and facet for the humerus. The gross anatomical features and morphometric parameters of different bones of the forelimb will be indicating tools for comparative studies and radiographic interpretations.

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