Bangladesh Journal of Veterinary and Animal Sciences
Journal home page: www.bjvas.com
pISSN 2227-6416
eISSN 2709-2542

Research article

Morphology and morphometric analysis of bones of the forelimb of giraffe *(Giraffa camelopardalis)*

Sadia Jahan[1], Md. Shahriar Hasan Sohel[2]and Mohammad Lutfur Rahman[1*]

[1]Department of Anatomy & Histology, Chattogram Veterinary and Animal Sciences University, Bangladesh.
[2]Laboratory of Veterinary Anatomy, Joint Graduate School of Veterinary Sciences, Gifu University, Japan.

A R T I C L E I N F O

Article history:

Received: 10/05/2021

Accepted: 28/06/2021

Keywords:

Morphology and morphometry, giraffe, thoracic limb, scapula, humerus, radius ulna, skeleton

[*]*Corresponding author:*

Cell: +88-01726842715
E-mail: lutfur@cvasu.ac.bd

A B S T R A C T

We studied the bones of forelimb of male giraffe *(Giraffa camelopardalis)* to record the gross anatomical and morphometrical features of the scapula, humerus, radius and ulna. We observed some unique anatomical features that will be helpful for radiographic interpretation and forensic investigations. For this purpose all the bones of thoracic limb were collected timely from the burial ground, identified by their morphological features and finally measured after processing with chemicals. The scapula was a triangular flat bone and the lateral surface of scapula was unequally divided into supraspinous (*fossa supraspinata*) and infraspinous fossa (*fossa infraspinata*) by a well-developed spine (*spina scapulae*). The humerus was a major and massive bone in the appendicular skeleton to bear the total body weight. The average length of humerus was 56.17 cm that run from the shoulder to the elbow. It possessed a cylindrical diaphysis which was somewhat compressed laterally and two enlarged epiphysis namely-proximal epiphysis and distal epiphysis. The humeral head *(coput humeri)* was long and strongly curved cranio-caudally; while the distal end had condyles *(condylus)* and epicondyles *(epicondylud laterialis)*. The radius and ulna were twin bones where radius was articulated craniolateral to the ulna proximally and craniomedial to the ulna distally. However, the ulna was the longest bone in the forelimb of giraffe. These bones were entirely fused in giraffe except two places namely- proximal and distal interosseous spaces.

To cite this paper: *S. Jahan, M. S. H. Sohel and M. L. Rahman, 2021. Morphology and morphometric analysis of bones of the forelimb of giraffe (Giraffa camelopardalis). Bangladesh Journal of Veterinary and Animal Sciences, 9(1):59-66.*

1. INTRODUCTION

In all living terrestrial animals, giraffe (*Giraffa camelopardalis)* is the tallest and largest ruminant. They are African artiodactyl mammal with nine subspecies. The giraffe maintains some specialized and unique features with it's distinguishing coat patterns, very long neck and legs. All male and female giraffes have a pair of parietal ossicones on the parietal bones of the skull which are columnar or conical skin-covered bone structures (Spinage, 1968). Giraffe is under the family of Giraffidae and the okapi is the closest extant relative of them. Giraffes typically inhabit savannas and woodlands. They are widely distributed in Africa and their ranges are from Chad in the North to South Africa in the South, and from Niger in the West to Somalia in the East. The giraffes are herbivores animal and their favourite foods are leaves, fruits and flowers of woody plants which they browse at heights most other herbivores cannot reach. The average height of adult male giraffe is 4.3-5.7 meter (14.1-18.7 ft) whereas the female one is a bit shorter (Nowak, 1999).

Similarly, the average weight is 1192 kg (2628 lb) for adult male and 828 kg (1825 lb) for adult female (Skinner and Smithers, 1990). Though it has long neck and legs, the giraffe's body is relatively short (Swaby, 2010). The forelimb and hindlimb of the giraffe are about the same length. The radius and ulna of the forelimb are articulated by the carpal bones, which structurally equivalent to the human wrist, function as a knee (MacClintock and Mochi, 1973). The suspensory ligament of the forelimb allows the animal to support it's great weight (Wood, 2014). The average diameter of the foot of giraffe is 30 cm (12 in), and the height of the hoof is 15 cm (5.9 in) in males and 10 cm (3.9 in) in females (Williams et al., 2011). The rear of each hoof is low and the fetlock is close to the ground, allowing the foot to provide additional support to the animal's weight (Dagg, 1971). There are no interdigital glands and dewclaws in giraffe. Though the pelvis of giraffe is comparatively short but it's ilium outspread at the upper ends (Dagg and Foster, 1982). Many scientists studied on the skeletal systems of large animals, for example horse and cattle, small ruminants such as sheep and goat (Getty, 1975), carnivores such as dog (Evans and de Lahunta, 2013), wild carnivores such as tiger (Pandit, 1994; Tomar et al., 2018), leopard (Podhade, 2007), Asiatic cheetah (Nazem et al., 2017), Indian wild cat (Palanisamy et al., 2018), guineapig, rat and rabbit (Özkan et al., 1997). On the other hand, only few number of literatures are available on different bones of the Asiatic lion (Pandey et al., 2004; Nzalak et al., 2010), however, the morphology and morphometrical study of skeletal system of the giraffe has not been studied yet. The aim of this study was to explore the general osteological features and osteomorphometry of scapula, humerus, radius and ulna of the forelimb and to utilize the facts during surgery and radiography.

2. MATERIALS AND METHODS

Study area

The study was conducted in the Anatomy museum of Chattogram Veterinary and Animal Sciences University, Bangladesh. The bones of the giraffe were collected from Bangladesh National Zoo, Dhaka which was buried in an isolated place of the zoo with aseptic measures.

Study period

The giraffe was over aged (more than 35 years old) and died due to neckling in February 2019. Couple of ribs at the left thorax were broken. Just after death the carcass was put under the ground for the period of 6 months. In August 2019, the bones of the giraffe were collected from the buried ground with a view to prepare a complete skeleton. The morphology and morphometrical study of the bones of forelimbs were carried out from September 2019 to February 2020.

Processing of collected bone

Total 6 months under the ground were very appropriate time for wiped out the associated muscles from the bones and the visceral organs were also wasted out at that time. On the other hand, the structure and shape of the collected bones were in very good condition for preparing a complete skeleton. The collection of bones and transportation from the Bangladesh National Zoo, Dhaka to the Anatomy museum of Chattogram Veterinary and Animal Sciences University, Bangladesh were done with fully aseptic measures. All the workers were protected with proper gown, gumboot and gloves, and all collected bones were stored in plastic containers to transport by a truck. For this study, initially the bones of forearm (scapula, humerus, radius and ulna) of giraffe were processed by removing the dirt and mud with a brush and washed under running tap water. Then the bones were soaked overnight in a soapy bath, using a degreasing detergent such as wheel powder/surf excel and then the bones were rinsed thoroughly under running water. Further, the bones were boiled (104^0C) carefully until all the fat and flesh comes away. The cleaned and cooled bones were placed in a bucket of hydrogen peroxide (5-10%) until the bones reached the desired whiteness, and again rinsed them thoroughly under running water and leave somewhere cool to dry. The whole process was done very carefully to keep the anatomical structures unchanged. The morphological parameters/features in different views of each individual bone of forelimbs were observed. For morphometrical study, the length, width, height and circumference were measured by using a metallic calibrated scale and were recorded in centimeter (cm). The weight was also measured by using a digital balance and recorded in gram (gm.).

3. RESULTS AND DISCUSSION

Scapula

It was a downward and forward directed triangular-shaped flat bone with three borders namely cranial, caudal and dorsal border. Among three borders the caudal one is the longest (average 60.2 cm) whereas the dorsal one was very short (average 27.6 cm) (Table 1). These features of giraffe's scapula were similar with cattle (McLeod, 1958), sheep, goat (Getty, 1975) and lion (Nzalak et al., 2010). The dorsal border was measured 27.4 cm in right and 27.8 cm in left scapula. The cranial border was slightly curved and the caudal border was somewhat smooth. The maximum length of dorsal border to glenoid cavity was 67.3 cm (Table 1).

Table 1. Morphometrical data for different parameters of scapula, N = 2

SL No.	Parameters	Measurements Right	Measurements Left
1.	Borders (cm)		
	• Cranial border-	56.5	56.7
	• Caudal border-	60.7	59.7
	• Dorsal border-	27.4	27.8
2.	Length of spine (cm)	45.5	46
3.	Max. length of dorsal border to glenoid cavity (cm)	67.5	67.1
4.	Height of supraspinous fossa to spine (cm)	9.9	10.1
5.	Height of infraspinous fossa to spine (cm)	9.8	9.8

The lateral surface was divided into two unequal fossae by a well-developed scapular spine (*spine scapulae*) which extended from the level of vertebrae to the neck of scapula, where it was subsided (Figure 1). Cranially there were supraspinous fossa (*fossa supraspinata*) and caudally infraspinous fossa (*fossa infraspinata*). The former one was smaller with smooth surface which was occupied by the supra-spinatus muscle, whereas infraspinous fossa was occupied by the infraspinatus muscle. The ratio between the two fossae was 1 to 3. On the other hand, in the medial surface, the serratus ventralis muscle, poorly underlined, demarcated a wide and shallow subscapular fossa (*fossa subscapularis*) which was similar with horse (Getty, 1975). The subscapular fossa was divided into a larger triangular caudal fossa and a smaller cranial fossa which provided an attachment for the subscapularis muscle (Figure 2). In the studied individual, the scapular spine raised and descended progressively, without a visible distal continuation of the scapular spine namely acromion process or processus hamatus which was dissimilar with cattle (McLeod, 1958; Getty, 1975) (Figure 1). However, a well developed acromion process was over-hanged to the glenoid notch in human (Williams and Warwick, 1980), African elephant (Smuts and Bezuidenhout, 1993) and lion (Nzalak et al., 2010). The glenoid cavity *(cavitas glenoidalis*) of scapula was ovoid in shaped, similar to that of cows (McLeod, 1958), whereas it was found elongated in elephant (Ahasan et al., 2016). The supraglenoid tubercle (*tuberculum supra-glenoidalis*) was simple and tuberous (Figure 3).

Figure 1. Lateral aspect of Scapula
1= Cranial angle, 2= Caudal Angle,3= Spine of Scapula , 4= Supraspinous fossa, 5= Infraspinous fossa ,6 = Supraglenoid Tubercle

Figure 2. (Medial aspect of scapula)
1= Cranial angle, 2= Caudal angle, 3= Caudal Ridge,4= Cranial Ridge, 5 = Dorsal Margin, 6= Cranial margin, 7= Caudal Margin, 8= Scapular notch ,

Figure 3: Distal aspect of Scapula
1= Glenoid cavity, 2= Supraglenoid tubercity

Humerus

Humerus was the major and massive bone in the appendicular skeleton of giraffe to bear the total body weight. It was a long bone (average length 56.17 cm) in the forelimb that runs from the shoulder to the elbow. Dorsally it connected with the scapula and ventrally with the two bones of the lower limb, the radius and ulna. It possessed a cylindrical shaft (diaphysis/body) and two enlarged extremities (epiphysis) such as proximal extremity and distal extremity (Figure 4 and 5). The average weight, circumference of shaft and head of humerus were 3687.5 gm, 25.75 cm and 38 cm, respectively (Table 2).

Table 2. Morphometrical data for different parameters of humerus. N = 2

SL No.	Parameters	Measurements	
		Right	Left
1	Weight (gm)	3625	3750
2	Total length (cm)	56	56.35
3	Shaft		
	• Length (cm)	40	40
	• Circumference of upper part (cm)	29.5	31
	• Circumference of middle part (cm)	24	23
	• Circumference of lower part (cm)	23	24
4	Circumference of head (cm)	38	38
5	Proximal extremity		
	• Circumference (cm)	59.8	59.8
	• Width (cm)	22	20
7	Distal extremity		
	• Circumference (cm)	46	47
	• Width (cm)	12.6	12.8

The shaft *(corpus humeri*) of humerus was spirally twisted, downward and backward directed and also somewhat compressed laterally (Figure. 4). The humeral head *(coput humeri)* was long and strongly curved cranio-caudally; the neck was distinctly marked, while the distal end had condyles *(condylus*) and epicondyles (*epicondylud laterialis*) (Figure 5). The medial condyle was larger than the lateral one. The nutrient foramen of the diaphysis was located on the caudal surface of the distal half of the humerus which was similar with sheep (Getty, 1975) and dissimilar with cattle (McLeod, 1958), while the nutrient foramen was located at distal third of the lateral surface of humerus. On the diaphysis, we have noticed a poorly developed deltoid tubercle (*tuberositas deltoidei*) (Figure 5). The spiral groove was also shallow. The general aspect of the distal epiphysis suggested an accentuated projection of the axis of the bone in the caudal direction, so that the trochlea and the condyles had a much more elongated basis compared to the axis of the bone (Figure 4 and 5).

Figure 4 Humerus (caudal view); 1= Head of humerus, 2= Olecranon fossa, 3= neck of humerus

Figure 5. Humerus (Cranial view)
1= Greater tubercle, 2= Intertubular groove, 3= Body of humerus, 4= Deltoid tubersity, 5= Radial fossa, 6= Capitulum of humerus, 7= Lateral epicondyl, 8= Medial epicondyle, 9= Trochlea of humerus. 10= Neck of humerus, 11= Lesser tubercle.

Redius and Ulna

The radius and ulna were two complete bones and were entirely fused in giraffe except proximal and distal interosseous spaces where the shafts (*corpus radii*) were separated from each other (Figure 7). The ulna's proximal end was caudal to the radius and its distal end formed the lateral styloid process, located distal to the radius and articulating with the ulnar carpal bone (Figure 7). The radius was cranio-lateral to the ulna at the cubital articulation (the humeroulnar and humeroradial articulation of the elbow joint, served by the musculo-cutaneous, radial and ulnar nerves) and cranio-medial to the ulna at the carpal articulation. The rough caudal surface of the radius was the border facing the ulna; this interosseous surface had a nutrient foramen near the proximal end of the radius (Figure 7).

Radius bone

The average length of the radius bone was 85.2 cm which was longer than humerus and the circumference of the proximal extremity (39.4 cm) was slightly larger than that of distal extremity (37.5 cm). The average circumference of the shaft was 23.48 cm (Table 3).

Table 3. Morphometrical data for different parameters of radius. N = 2

SL No.	Parameters	Range	
		Right	Left
1	Total length (cm)	85.4	85
2	Proximal extremity		
	Circumference (cm)	39.9	38.9
	Width (cm)	13.8	13.5
3	Distal extremity		
	Circumference (cm)	37.8	37.2
	Width (cm)	13.8	13.5
4	Circumference (shaft)		
	Upper (cm)	23.3	24.7
	Middle (cm)	21.4	21.4
	Lower(cm)	24.8	25.3

The proximal extremity was widened and three glenoid surfaces were sculpted on it; a very large medial one, a deep median one and a narrow lateral one. The medial one was L shaped which was different from that of the bovine (Getty, 1975). On its contour there was a well marked coronoid process, laterally flanked by a secondary coronoid process. The neck of the radius appeared polished on the medial side by a small tendon, and the bicipital tuberosity was long and faint. The body of the radius presented on the lateral edge of the volar surface synostosis with the ulna, interrupted at the level of the arcades (Figure 7). The distal extremity was obliquely cut and presented two glenoid fossae. Two inclined condyles and two small digital fossae situated in the back of the condyles. The tendinous grooves were poorly marked and the styloid process was well developed. The radius of the giraffe had an elongated linear shape, compared to its proportions in the radius of cow (McLeod, 1958).

Ulnar bone

The ulnar bone was the longest (93 cm) in all bones of forearm, contributed a lot for increasing the height of giraffe. The proximal extremity of the ulnar bone was very prominent and its circumference was larger than the distal extremity (Table 4).

Table 4. Morphometrical data for different parameters of ulna. N = 2

SL No.	Parameters	Range	
		Right	Left
1	Total length (cm)	93	93
2	Circumference (cm)		
	Upper extremity	8.3	8.8
	middle extremity	4	4
	Lower extremity	2.5	2.2
3	Proximal Extremity (cm)		
	Circumference	27.9	28.2
	Width	11.3	11.5
4	Distal Extremity (cm)		
	Circumference	4.1	4.2
	Width	2.2	2.5

The ulna articulated with the radius on all of its length, forming two radio-ulnar joints-proximal and distal, united on the lateral face through a groove (Figure 9). The olecranon was massive and long with more pronounced tuberosity, and its summit was medially deviated. The styloid process was very well marked and exceeds the length of the radius (Figure 7). The articular surface of the olecranon was similar to that of the bovine (McLeod, 1958).

Figure 6: Radius and Ulna of Giraffe; 1= Head of radius bone, 2= Neck of radius bone, 3=Shaft of Radius, 4= Olecranon tubersity of ulna, 5= Shaft of ulna, 6= Styloid process, 7= Proximal interosseous space, 8= Distal interossesous space, 9= Radio-ulnar joint

Figure 7. Radius and Ulna of Giraffe
1= olecranon tuber, 2= Trochlear notch,
3= Olecranon process, 4= Anconeal process.

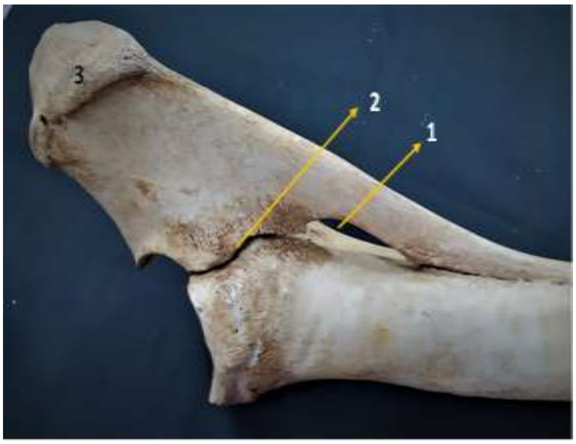

Figure 8. Radius and Ulna of Giraffe
1= Antebrachial interosseous space,
2= Radioulnar joint, 3= olecranon tuberosity of ulna (Proximal epiphysis).

4. CONCLUSIONS

This study on the gross anatomy of the forelimbs of giraffe presented the numerical and morphological information on bones of this animal highlighting specific features, similarities and differences from other domestic mammals. The mentioned information regarding some unique anatomical features and their morphometric measurements can be helpful for identification, radiographic interpretation and forensic investigation of the bones of giraffe. These will also provide the pathway and guideline for better understanding of the appropriate anatomical parameters.

ACKNOWLEDGEMENTS

We are very thankful to the authorities of Bangladesh National Zoo, Dhaka, Bangladesh for giving permission to collect the bones of Giraffe for the Anatomy museum of CVASU. The authors are also grateful to Dr. Md. Kabir Hossain, Department of Anatomy and Histology, Chattogram Veterinary and Animal Sciences University, Chattogram for his kind co-operation and help specially during taking morphometric parameters of bones to complete this research work.

REFERENCES

Ahasan, A. S. M., Quasem, M., Rahman, M. L., Hasan, R. B., Kibria, A. S. M. and Shil, S. K. 2016. Macroanatomy of the bones of thoracic limb of an Asian elephant (*Elephas maximus*). International Journal of Morphology, 34(3): 909-917.

Dagg, A. I. 1971. Giraffa camelopardalis. *Mammalian Species.* Volume **5** (5): 1–8 pp.

Dagg, A. I. and Foster J. B. 1982. The Giraffe. Its Biology, Behavior, and Ecology. Malabar, Florida, Krieger Publishing Company.

Evans, H. E. and de Lahunta, A. 2013. Miller's Anatomy of the Dog-E-Book. Elsevier Health Science.

Getty, R. 1975. Sisson and Grossman's The Anatomy of the Domestic Animals 5th edn., Philadelphia, Saunders, 2019-2066 pp.

MacClintock, D. and Mochi, U. 1973. A natural history of giraffes. Scribner. 30 p.

McLeod, W. M. 1958. Bovine Anatomy, 2nd edn., Cornell University, Burgess Publishing Company.

Nazem, M. N. Sajjadian, S. M. and Nakhaei, A. 2017. Anatomy, functional anatomy and morphometrical study of forelimb column in Asiatic cheetah *(Acinonyx jubatus venaticus).* Italian Journal of Anatomy and Embryology, 122(3): 157-172.

Nowak, R. M. 1999. Giraffe in Walker's Mammals of the World. Baltimore, USA, London, UK. The Johns Hopkins University Press, Volume 1, 1086-1089 pp.

Nzalak, J. O., Eki, M. M., Sulaiman, M. H., Umosen, A. D., SaLami, S. O., Maidawa, S. M. and Ibe, C. S. 2010. Gross anatomical studies of the bones of the thoracic limbs of the Lion *(Panthera leo).* Journal of Veterinary Anatomy, 3(2): 65-71.

Özkan, Z. E., Dync, G. and. Aydin, A. 1997. Investigations on the comparative gross anatomy of scapula, clavicula, skeleton brachii and skeleton antebrachii in rabbits (Oryctolagus cuniculus), guinea pigs *(Cavia porcellus)* and rats *(Rattus norvegicus)*. Fýrat University Journal of Health Science, 11: 171-175.

Palanisamy, D., Tomar, M. P. S., Ankem, P. B., Ullakula, R. S., Jonnalagadda, N. and Korampalli, V. 2018. Gross morphology of scapula in Indian wild cat *(Felis silvestris ornate)*. International Journal Current Micro-biology Applied Science, 7(4):2473-2477.

Pandey, S. P., Bhayani, D. M. and Vyas, Y. L. 2004. Gross anatomical study on the scapula of Asiatic lion *(Panthera persica*). Indian Journal of Veterinary Anatomy, 16(1-2): 53-56.

Pandit, R. V. 1994. Osteology of Indian tiger. Tech. Bull.No.VI., Conservator of Forest and Director, Project Tiger, Melghat, Amravati 29-57 pp.

Podhade, D. N. 2007. Studies on Characteristic Features of Appendicular Skeleton of Leopard as an Aid in Wildlife Forensic. Master of Veterinary Science and Animal Husbandry in Wildlife Health and Managmenent Thesis. Jabalpur, College of Veterinary Science and Animal Husbandry.

Spinage, C. A. 1968. Horns and other bony structures of the skull of the Giraffe, and their functional significance. African Journal of Ecology, 6 (1): 53-61.

Skinner, J. D. and Smithers, R. H. M. 1990. The mammals of the Southern African subregion, 2nd edn., Pretoria, University of Pretoria, 616-620 pp.

Smuts, M. M. and Bezuidenhout, A. J. 1993. Osteology of the thoracic limb of the African elephant *(Loxodonta africana).* Onderstepoort Journal of Veterinary Research, 60(1):1-14.

Swaby, S. 2010. "Giraffe". Harris, T. (ed.). *Mammal Anatomy: An Illustrated Guide.* Marshall Cavendish. 64-84 pp.

Tomar, M. P. S. Taluja, J. S. Vaish, R. Shrivastav, A. B. Shahi, A. and Sumbria, D. 2018. Gross Anatomy of Scapula in Tiger *(Panthera tigris)*. Indian Journal Animal Research, 52(4):547-550.

Williams, E. 2011. *Giraffe*. Reaktion Books. ISBN 978-1-86189-764-0

Williams, P. L. and Warwick, R. 1980. Gray's anatomy. 36th edn., Edinburgh, London: Churchill Livingstone.

Wood, C. 2014. "Groovy giraffes distinct bone structures keep these animals upright". Society for Experimental Biology.