B-5084
[1-6]

RESEARCH ARTICLE Indian Journal of Animal Research

Morphological and Morphometrical Studies on the Radius and Ulna of Indian Elephant (*Elephas maximus indicus*)

P.J. Kapadnis[1], S.K. Gupta[1], S.K. Karmore[1], G.P. Jatav[1], B.P. Shukla[1]

10.18805/IJAR.B-5084

ABSTRACT

Background: The fore and hind limbs of the elephant are arranged in an almost vertical position under the body, similar to a pillar or leg of a table rather than being in the angular position seen in many other quadruped mammals to support great weight. The aim of this study was to elucidate the morphological and morphometrical outline on the radius and ulna in Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field.

Methods: For the present study, the materials from three Indian elephants were used. Some of the specimens were available at the Department of Veterinary Anatomy, Mhow. Few skeletons were dug out from the ground which was buried from the last 5-10 years in the premises of college.

Result: The radius was situated obliquely in the anterior aspect of forearm region. Radius had two extremities proximal and distal extremity and a shaft. The distal end of the radius was thick, flattened and slightly prismatic in shape. The ulna was more massive than radius. It had two extremities and a body.

Key words: Indian Elephant, Morphology, Morphometry, Radius, Ulna.

INTRODUCTION

The elephant under the order of Proboscidea is a non-ruminant herbivore, belonging to the family Elephantidae with two living genera and species of elephants, Elephas maximus of Southern Asia and Loxodonta Africana of Africa (Nowak, 1999). The Asian elephants are subdivided into three different subspecies: *Elephasmaximusmaximus* of Sri Lanka, *Elephas maximus indicus* of India and *Elephas maximus sumatranus* of Sumatra (Shoshani and Eisenberg, 1982). As the elephant is the largest living terrestrial mammal, the feet have to carry an enormous weight and hence feet are probably one of the most important parts of its body. Many numbers of captive Asian elephants suffer from numerous foot ailments as a result of being tethered in unhygienic surroundings and these conditions often aggravate due to negligence and lack of awareness regarding proper care and treatment among elephant keepers. Hence an observational study of the elephants of this region was warranted.

The purpose of this work was to enhance the knowledge on elephant skeleton and the study on radius and ulna of Indian elephant will overcome the gap of knowledge in the comparative anatomy also. This study provides a baseline data for further vetero-legal, archaeological and clinical cases.

MATERIALS AND METHODS

For the present study material from three Indian elephants irrespective of sex were used. The permission for the specimen collection has been obtained from the Principal Chief conservator of forest and wildlife warden, Government of Madhya Pradesh, vide letter no 239/6998261 on dated 29.12.2020.

[1]Cattle Breeding Farm and Dangi Cow Research Station, Igatpuri-422 402, Mumbai Veterinary College, Maharashtra Animal and Fishery Science University, Nagpur, Maharashtra, India.

Corresponding Author: P.J. Kapadnis, Cattle Breeding Farm and Dangi Cow Research Station, Igatpuri, Mumbai Veterinary College, Parel, Maharashtra Animal and Fishery Science University, Nagpur-400 012, Maharashtra, India. Email: pj1kapadnis@rediffmail.com

How to cite this article: Kapadnis, P.J., Gupta, S.K., Karmore, S.K., Jatav, G.P. and Shukla, B.P. (2023). Morphological and Morphometrical Studies on the Radius and Ulna of Indian Elephant (*Elephas maximus indicus*). Indian Journal of Animal Research. doi:10.18805/IJAR.B-5084.

Submitted: 17-01-2023 **Accepted:** 07-06-2023 **Online:** 19-07-2023

Some of the specimens were available at the Department of Veterinary Anatomy, Mhow. The skeletons were dug out from the grounds which were buried from the last 5-10 years in the premises of college. Subsequently, the specimens were sort out and cleaned in running tap water.

After collection and sorting of all the bones, desired bones were kept in separate boxes. Various osteological features of radius and ulna found in right and left forelimb were recorded. The present work was carried out at Department of Veterinary Anatomy, College of veterinary science and Animal Husbandry, NDVSU, Mhow (M.P.) during the Jan 2021 to Jan 2022.

RESULTS AND DISCUSSION

Radius

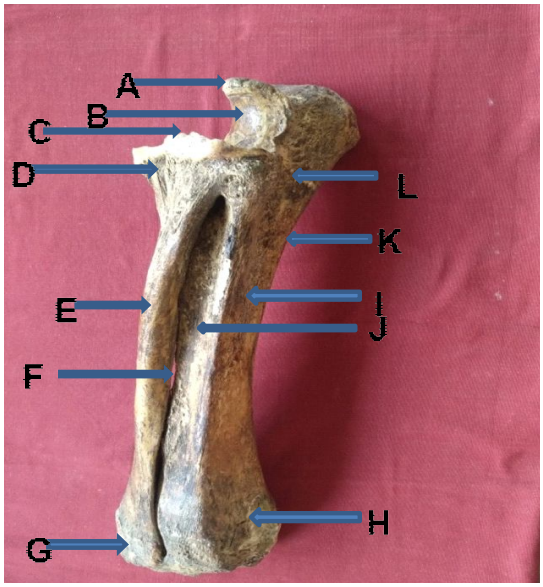
The radius was situated obliquely in the anterior aspect of forearm region (Plate 1) same as reported by Ahasan *et al*.

(2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Gupta *et al.* (2015) in camel, Onwuama *et al*. (2021) in West African giraffe and Budras and Robert (2003) in bovines. The radius articulates proximally with humerus as described by Konig and Liebich (2006) in domestic animals and with the lateral aspect of anterior surface of ulna (Plate 1 and 2). Distally, it articulates with the radial and intermediate carpal bones and distal part of the medial surface of ulna. Radius has two extremities proximal and distal extremity and a shaft (Plate 1) in toto agreement with Ahasan *et al*. (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Gupta *et al*. (2015) in camel, Onwuama *et al*. (2021) in West African giraffe, Getty (1975) in horse and Konig and Liebich (2006) in domestic animals.

The proximal extremity was smaller than the distal extremity as noted by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. Talukdar *et al*. (2008) and Smuts and Bezuidenhout (1993) in African elephant, reviewed that the proximal extremity was triangular in shape and Choudhary *et al.* (2013) in chital observed it as an irregularly oval in outline. Damian *et al*. (2012) reported that the proximo-caudal articular surface was L shaped in the giraffe, while in the cow it was crescent shaped.

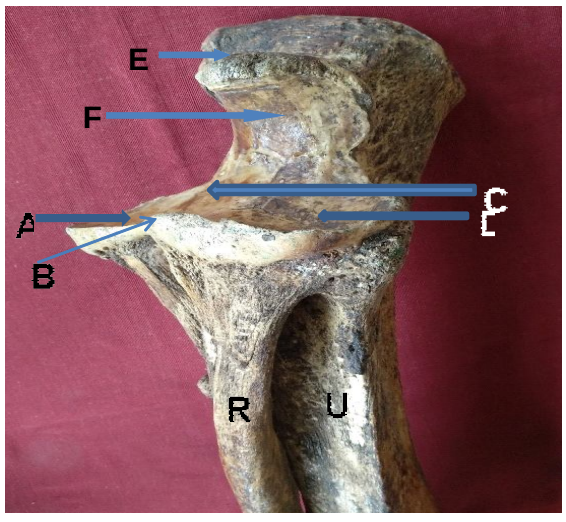
It was attached to the lateral aspect of anterior surface of the ulna in the prone position so that its proximal end was directed outward, and the distal end was directed inward (Plate 1) as reported by Mariappa (1986) in elephant calf. The proximal part of the radius was fused with the ulna but having a narrow articular facet towards the medial side. France (2009) reported that in antelope radius and ulna were fused. The articular surface of the proximal extremity was slightly saddle shaped which was crossed by sagittal ridge (Plate 2) while Damian *et al*. (2012) in giraffe reported widened proximal extremity with three glenoid surfaces sculpted on it. Onwuama *et al*. (2021) in West African giraffe noted a concave articular surface that blended with the notch. Gupta *et al.* (2015) in camel described that articular area was divided into a smaller medial and larger lateral part by a sagittal ridge. A prominent lip like projection the coronoid process was present on the anterior side (Plate 1) as reported by Getty (1975) in horse. The posterior part of proximal end was fused with the cranial surface of ulna, and it was extended upto the lateral aspect of the ulna at proximal end. The upper articular area of radius took part in the formation of both the concave articular areas with the ulna for articulation with the trochlea of humerus. Only the lateral part of proximal of radius was fused with the ulna, while the medial part was free. However, in one case the medial part was also fused with the ulnar part.

The distal end of the radius was thick, flattened same as reported by Smuts and Bezuidenhout (1993) in African elephant and slightly prismatic in shape and it was extended upto the lower extremity to form styloid process of radius on the medial side (Plate 1). Ahasan *et al*. (2016) reported that the processes styloideus radii was represented by two rough convexities separated from each other by a straight depression. Akers and Denbow (2008) mentioned that in ruminants the styloid process was at the distal extremity of the radius. The distal end was situated on the medial aspect of the ulna and forming the antero-medial part of this twin



Showing, Anconeus process. (A), Semilunar notch (B), coronoid process (C), Proximal extremity of radius (D), Shaft (E), Interosseous space (F), Distal extremity of radius (G), Distal extremity of ulna (H), Lateral surface of ulna (I), Anterior surface of ulna (J), Posterior border of ulna (K) and Proximal extremity of ulna (L).

Plate 1: Left radius and ulna antero-lateral view.



Medial articular area. (A), Coronoid process (B), Sagital ridge (C) and Lateral articular area (D),Anconeus process (E) andSemilunar notch (F).

Plate 2: Left radius (R) and ulna (U) antero-lateral view.

bone. The articular area of distal extremity was not fused with the articular area of ulna (Plate 1).Gupta *et al.* (2015) in camel noted that the ulna was completely fused with the radius in the distal extremity. Talukdar *et al*. (2008) in elephant reviewed that the distal extremity of the radius articulated with radial carpal.

The distal articular area was divided into two parts by a ridge for articulation with the radial and intermediate carpal bones (Plate 4). The smaller medial articular area was slightly convex and oval in shape which was articulating the radial carpal bone. The larger articular area was present on its lateral side for articulation with the major part of intermediate carpal. It was convexo concave in shape (Plate 3 and 4). However, three oblique articular facets on the distal extremity of radius was noted by Ingole *et al.* (2017) in sahiwal cows and Gupta *et al.* (2015) in camel.

The body was less developed and cylindrical in shape but Gupta *et al*. (2015) in camel noted that the slightly curved shaft was somewhat flattened cranio-caudally, Onwuama *et al*. (2021)in West African giraffe noted elongated linear shape. Konig and Liebich (2006) explained that in bovines radius was a rod-shaped bone which was relatively strong. The upper 1/3rd part was quadrilateral in shape while the distal 1/3rd part was prismatic in shape. Cranially it was slightly convex and smooth while caudally it was concave and rough. In the middle 1/3rd part the lateral, cranial and medial surfaces were continuous. In the middle 1/3rd part of medial surface of body a crest was present. Budras and Robert (2003) noted that in bovines the radius was flattened and relatively short.

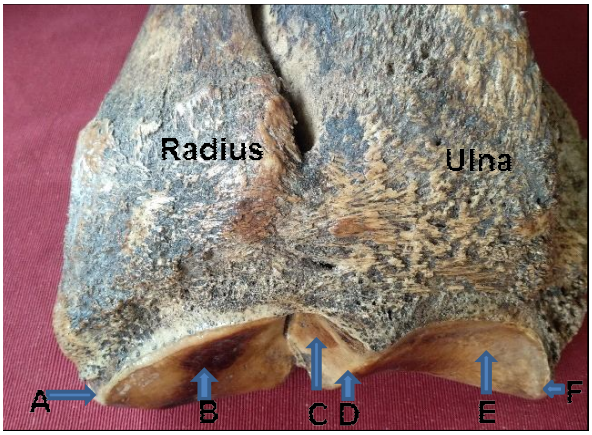
In the present study, no significant difference was recorded in between right and left forearm bones of same animal as reported by Gupta *et al.* (2015) in camel.In the present study weight of radius and ulna was 13.43±0.49 kg (Table 1). Sasan *et al.* (2016) in buffalo recorded this as 553.00±7.02 g.

In the present study, length of radius was 73.3±0.85 cm, same as Ahasan *et al*. (2016) in Asian elephant recorded as 55 cm and Lucy *et al*. (2018) recorded this as 67 cm in elephant. However, the length of the radius was 52.5±0.73 cm in camel (Gupta *et al.*, 2015), 33.52±0.07 cm in blue bull (Bharti *et al*., 2020), 28.60±0.57 cm in buffalo (Sasan *et al.,* 2016), 18.73±0.04 cm in chital (Choudhary *et al.*, 2013), 11.12±0.23 cm in black Bengal goat (Siddiqui *et al*., 2008), 24.8 cm in bear and 22.2 cm in deer (Ladukar *et al*., 1998).The circumference of the radius at proximal end, distal end and at the mid of the shaft was 13.73±0.45 cm, 38.53±0.62 cm and 14.22±0.26 cm, respectively, same Ahasan *et al*. (2016) in Asian elephant recorded this as 21 cm, 32 cm and 14.5 cm. The width of proximal end and distal end was 8.97±0.47 cm and 14.22±0.26 cm, respectively (Table 1), however Ahasan*et al.* (2016) recorded these in Asian elephant as 13 cm and 23 cm, respectively.

Ulna

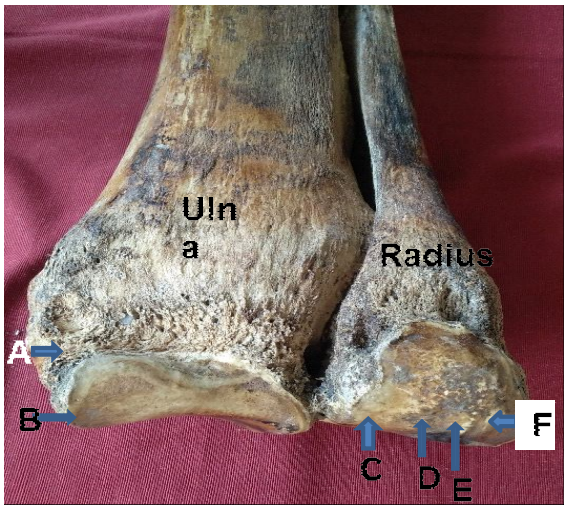
The ulna was more massive i.e., heavier, larger and longer than radius (Plate 1) same as mentioned by Ahasan *et al*. (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Gupta *et al*. (2015) in camel and Nurhidayat *et al.* (2015) in Sumatran rhino. However, Siddiqui *et al*., (2008) in black Bengal goat reported that it was ill developed and Onwuama *et al*. (2021) in west African giraffe noted it slimmer of the two bones. It was the important weight bearing bone of the forearm region same as reported by Lucy *et al*. (2018) in elephant. It had two extremities and a body same as reported by Ahasan *et al*. (2016) in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Onwuama *et al*. (2021) in west African giraffe, Choudhary *et al.* (2013) in chital, Choudhary *et al.* (2015) in black buck and Bharti *et al.* (2020) in blue bull.

The olecranon process was reached beyond the radius proximally (Plate 1 and 2) as noted by Ahasan *et al*., (2016)



Styloid process of radius. (A), Articular area of radius (B), Medial articular area of ulna (C), Ridge (D), Lateral articular area of ulna (E) and Styloid process of ulna (F).

Plate 3: Left radius and ulna (Anterior view).



Articular area for accessory carpal. (A), Styloid process of ulna (B), Lateral articular area (C), Ridge (D), Medial articular area (E) and.

Plate 4: Posterior view of distal extremity of left radius and ulna.

in Asian elephant, Smuts and Bezuidenhout (1993) in African elephant, Budras *et al*. (2003) in bovines, Budras *et al*. (2009) in horse. The ulna was extended upto the distal extremity of the radius (Plate 1, 3 and 4), which was in agreement with the findings in cattle (Getty, 1975), camel (Gupta *et al*., 2015), west African giraffe (Onwuama *et al*., 2021)and ox (Frandson *et al*., 2009) and in disagreement with the findings of Getty (1975) and Frandson *et al*. (2009) in horse, where the ulna was fused with the proximal third of radius. Nurhidayat *et al.* (2015) in Sumatran rhino noted that the ulna was fused with radius, however still forming interosseus antebrachia proximal and distal spaces.

The proximal end of the ulna was well developed. It was prismatic in shape and forming the olecranon process of ulna (Plate 1 and 2), however Muhammad and Shahid (2000) noted quadrangular shaped olecranon in buffalo and Pawan and Suraj (1999) noted tuberous in Neel gai but Smuts and Bezuidenhout (1987) in dromedary noted a well-developed tuber olecrani which was slightly bifid and Budras and Robert (2008) in bovines noted that olecranon tuber was a crest with two tubercles. In the upper part of this process medial and lateral tuberosities were present. The posterior border was concaved and continued with the same border of the shaft of ulna (Plate 1). The medial surface was slightly convex while the lateral surface was slightly concave in contrast to Getty (1975) in cattle and horse, Siddiqui *et al*. (2008) in black Bengal goat and Choudhary *et al.* (2013) in chital. Rajani *et al*. (2019) in Indian Muntjac described that olecranon of ulna was grooved transversely and consisted of two prominences, the caudal one was being larger than cranial.

In the proximal extremity olecranon process was less developed in comparison to other large domestic animals (cattle, horse) and was extended slightly above the level of anconeal process, however Lucy *et al*. (2018) in elephant mentioned that olecranon tuberosity and anconaeus process were in the same level. The tuber olecrani was massive caudolaterally same as noted by Lucy *et al*. (2018) in elephant, Choudhary *et al.* (2013) in chital, Choudhary *et al.* (2015) in black buck and Bharti *et al.* (2020) blue bull. However, Nurhidayat *et al.* (2015) in Sumatran rhino noted that olecranon protrude to caudodorsal with large olecranon tuber widened to lateral and medial. Below the tuber olecrani the bone compressed bilaterally, and it continues a narrow caudal (margin) of the shaft border same as reported by Ahasan *et al*. (2016) in Asian elephant.

On both side of olecranon process the tuberosities were present. The tuberosity present on lateral side was thick but medial tuberosity was thin and much extended giving a deeper concave area with the body. Similarly, Ahasan *et al*. (2016) in Asian elephant reported that tuber olecrani was massive, especially caudolaterally. The olecranon was wide above and rough on its posterior aspect for muscular attachment was in agreement with Mariappa (1986) in elephant calf. A broad arched dorsal border of the olecranon process narrowed as described by Ahasan *et al*. (2016) in Asian elephant. The number of foramina were present on the anterior surface of the olecranon process same as described by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant.

Anconeal process was present with a small, semi-circular shape articular notch (Plate 1 and 2) which was less extensive same as reported by Ahasan *et al*. (2016) in Asian elephant and Getty (1975) in cattle. However, in horses this notch was more extensive (Getty, 1975). The semilunar notch was roughly triangular in shape (outline) which was concave from above downward and slightly convex transversely (Plate 1 and 2). Two articular areas (concavities) for articulation with the condyle of humerus were formed mainly by the proximal end of ulna. The part of lateral articular area formed by ulna was smaller than the medial one (Plate 2). However, in the overall proximal articular area, the lateral one was bigger than the medial one. On the upper part of the lateral and medial borders of the ulna well developed tuberosities were present.

Table 1: Various gross parameters of radius and ulna of fore limb in Indian elephant.

Parameters of radius and ulna	Average±SE (Range)
Weight of radius and ulna (kg)	13.43±0.49 (12.32-14.68)
Length of radius (cm)	73.3±0.85 (71.9-76)
Circumference at proximal end of radius (cm)	13.73±0.45 (12.9-15.2)
Width at neck at proximal end of radius (cm)	8.97±0.47 (7.5-10.2)
Circumference at distal end of radius (cm)	38.53±0.62 (36.5-40)
Width at distal end of radius (cm)	16.43±1.31 (11.9-19.1)
Circumference at the mid of the shaft of radius (cm)	14.22±0.26 (13.5-15)
Length of ulna (cm)	82.5±0.48 (81-83.5)
Circumference of proximal end of ulna (cm)	54.62±0.20 (53.9-55
Circumference of distal end of ulna (cm)	40.05±0.25 (39.1-40.9)
Length of olecranon process of ulna (cm)	18.93±0.35 (17.9-19.9)
Circumference of olecranon process of ulna (cm)	47.45±0.22 (46.9-48.1)
Length of articular surface of ulna (cm)	11.9±0.61 (10-13.1
Width of articular surface of ulna (cm)	8.17±0.26 (7.9-8.9)

The shaft was thick plate as it runs entire length of radius before ending distally as the lateral styloid process (Plate 3 and 4) which was in agreement with Ahasan *et al*. (2016) in Asian elephant, Siddiqui *et al*. (2008) in black Bengal goat, and disagreement with the Getty (1975) in horse. Cranially the shaft was flattened, it was triangular in shape proximally and was quadrilateral in shaped distally.

The upper half part of the body of ulna was three sided *i.e*., prismatic in shape as elucidated in horse (Getty, 1975), chital (Choudhary *et al.*, 2013), black buck (Choudhary *et al.*, 2015) and blue bull (Bharti *et al.*, 2020), having cranial, lateral and medial surfaces with lateral, medial and posterior borders.

The nutrient foramen was present in the medial border of the ulna at the place of proximal 1/3rd but Smuts and Bezuidenhout (1993) in African elephant mentioned that the position of this foramen was variable. However, it was located on the cranial surface in horse Getty (1975) and it was not recorded in blue bull (Bharti *et al.,* 2020), black buck (Choudhary *et al.*, 2015). The medial surface was smooth and flattened, while the lateral surface was rough and slightly concave, and the anterior surface was more concave towards upper side and rough (Plate 1). The lower half part of the body was quadrilateral in shape having cranial, caudal, lateral and medial surfaces. The lateral, medial and caudal surfaces were smooth, while the cranial surface was rough.

The thin interosseous space was present lengthwise between radius and ulna (Plate 1). Ahasan *et al*. (2016) in contrast to the findings of Smuts and Bezuidenhout (1993) in African elephant in which this interosseous space was absent. However, proximal and distal interosseous spaces were noted in cattle (Getty, 1975) and camel (Gupta *et al*., 2015) but in the horse, only one proximal interosseous space was noted (Getty, 1975). Muhammad and Shahid (2000) noted that the groove present between two inter-osseous spaces of radius was deeper in buffalo in comparison with cow. Mahmud and Mussa (2016) noted that in black Bengal goat radius and ulna were in contact with each other by their ends but fused in most part and the interosseous space was narrow.

The distal extremity of ulna had articular facets for small part of intermediate, ulnar and accessory carpal bones (Plate 3) same as reported by Smuts and Bezuidenhout (1993) in African elephant.

The quadrilateral shaped distal extremity of the ulna was thick and more developed (Plate 3). The medial part of this end was articulated with the distal end of radius. This distal articular area was divided into two unequal parts by a prominent ridge. The medial part was smaller and fused with lateral articular part of radius and form a deep concave area for articulation with the intermediate carpal bone (Plate 3). On the lateral side a large concave articular area was present for articulation with the ulnar carpal bone (Plate 4). On the postero-lateral aspect a small articular area was present for articulation with the accessory carpal bone. This small articular area was separated by a faint ridge from the large lateral articular area on the postero-lateral aspect (Plate 4).

Styloid process got a shape of lateral prominence (Plate 3 and 4) same as reported by Ahasan *et al*. (2016) in Asian elephant, Choudhary *et al.* (2013) in chital and Bharti *et al.* (2020) in blue bull and it was more prominent than the processus styloideus radiae. Similarly, Pawan and Suraj (1999) studied radius and ulna of neel gai and noted that the styloid process of ulna was more pronounced. In the distal part of ulna numerous foramina were present on just above the articular area in this bone.

In the present study length of ulna was 82.5±0.49 cm (Table 1) however Ahasan *et al*. (2016) in Asian elephant noted this as 64 cm and Lucy *et al*. (2018) noted this as 75 cm in elephant. However, the length of ulna was 58.5±0.91 cm in camel (Gupta *et al.*, 2015),36.00±0.64 cm in buffalo (Sassan *et al.,* 2016), 24.30±0.05 cmin chital (Choudhary *et al.*, 2013), 14.20 ± 0.20 cm in black Bengal goat (Siddiqui *et al*., 2008), 30.2 cm in bear and 27.4 cm in deer (Ladukar *et al*., 1998).

The circumference at proximal end and distal end was 54.62±0.20 cm, 40.05±0.25 cm respectively same asAhasan *et al*. (2016) in Asian elephant noted this as 53 cm and 35 cm, respectively.

The length of olecranon and circumference of olecranon process was 18.93±0.35 cm and 47.45±22 cm, respectively (Table 1). Ahasan *et al*. (2016) in Asian elephant noted this as 11 cm and 42 cm, respectively. Gupta *et al.* (2015) in camel reported this as 10±0.36 cm and 17.5±0.54 cm, respectively. The length and width of articular surface of proximal part of ulna was 11.9±0.0.61 cm and 8.17±0.26 cm, (Table 1) respectively. Similar parameters reported by Ahasan *et al*. (2016) in Asian elephant were 9 cm and 16.5 cm, respectively. However Gupta *et al.* (2015) in camel reported that the width of articular surface was 7.5±0.17 cm.

CONCLUSION

The ulna was more massive *i.e*., heavier, larger and longer than radius It was the important weight bearing bone of the forearm region. On both side of olecranon process the tuberosities were present. Styloid process got a shape of lateral prominence, and it was more prominent than the processus styloideus radiae.

Conflict of interest: None.

REFERENCES

Ahasan, A.S.M.L., Md. Abul Quasem, A.S.M., Rahman, M.R., Hasan, R.B., Golam 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.

Akers, R.M. and Denbow, M. (2008). Anatomy and Physiology of Domestic Animals. 1st Edn. , Blackwell Publishing, Ames, Iowa, pp: 152-160.

Bharti, S.K., Singh, I. and Choudhary, O.P. (2020a). Arm and forearm bones of the adult blue bull *(Boselaphus tragocamelus)*: A morphological and morphometrical study. Indian Journal of Animal Research. DOI: 10.18805/IJAR.B4278.

Budras, K.D. and Robert, E. (2003). Bovine Anatomy: An Illustrated Text, First Edition Schlutersche. pp: 2-3.

Budras, K.D., Sack, W.O and Rock, S. (2009). Anatomy of the Horse: An Illustrated Text, Fifth Edition Schlutersche. pp: 4.

Choudhary, O.P., Singh, I. and Kumar, N. (2015). Morphometric characterization of radius and ulna of Indian blackbuck (*Antelope cervicapra*).Ruminant Science. 4(1):7-9.

Choudhary, O.P., Mathur, R., Joshi, S. and Yadav, S. (2013). Gross and biometrical studies on humerus and radius ulna of chital (*Axis Axis*). Indian Journal of Veterinary Anatomy. 25(1): 23-24.

Damian, A., Gudea, Al., Irimescu, I., Blendea A., Chirilean, I., Stan, F., Crisan, M., Dezdrobitu, C.and Ciama, I. (2012). Comparative studies of the thoracic appendicular skeleton in the giraffe and in the cow. Iucrari Stiintifice Medicina Veterinara. 14(1): 5-12.

France, D.L. (2009). Human and Nonhuman Bone Identification, A Colour Atlas, CRC Press, Tyler and Francis Group, Boca Raton, Florida. pp: 188-331.

Frandson, R.D. Wilke, W.L. and Fails, A.D. (2009). Anatomy and Physiology of Farm Animals. 7th Edn., Wiley-Blackwell, Philadelphia. pp 71-74.

Getty, R. (1975). Equine and Ruminant Osteology In: Sisson and Grossman's. The Anatomy of the Domestic Animals. (R. Getty Edn.) 5th Edn. W.B. Saunders Company, Philadelphia. Vol. I, pp. 273-317, 318-348, 1231-1252.

Gupta, S.K., Deshmukh, S.K., and Karmore, S.K. (2015). Gross morphometrical study on the forearm bones of camel (*Camelus dromedarius*). Veterinary Practitioner. 16(2): 286-287.

Ingole, S.P., Chaurasia, D. and Deshmukh, S.K. (2017). Gross morphometrical study on the skeleton of forelimb of Sahiwal cows. In: XXXII Annual Convention and National Symposium on Advances and Applications of Veterinary Anatomy in Livestock, Pet, Poultry, Lab. Animal and wildlife, Bhubaneswar. December Indian Association of Veterinary Anatomists. (21): 21-23.

Jangir, D.K. (2010). Gross studies on the bones of the forelimb in Indian gazelle (*Gazella gazella bennettii*). M.V.Sc thesis (Veterinary Anatomy and Histology), Rajasthan University of Veterinary and Animal Sciences. Bikaner.

Konig, H.E. and Liebich, H.G. (2006). Veterinary Anatomy of Domestic Animals, 3rd Edn., Schattauer, Stuttgart Germany. pp: 49-104, 145-164, 215-236.

Ladukar, O.N., Bhamburkar, V.R., Dalvi, R.S. and Banubakode, S.B. (1998). Comparative morphometric evaluation of radius and ulna in deer and bear. Tech. Bul. XII Convention and National Symposium of IAVA, pp: 6.

Lucy, K.M., Indu, V.R., Patki, H.S., Leena, C., Surjith, K.P., Fathima, R. and Ashok, N. (2018). Comparative anatomy of wild mammals. Narendra Publishing House, New Delhi. pp: 36-37.

Mahmud, A.A. Md. and Mussa, T. Md. (2016). Comparative macro anatomy of forelimb bones of black Bengal goat and indigenous dog: An over View. American. Journal of Agricultural Science, Engineering and Technology. 3(1): 45-55.

Mariappa, D. (1986). Anatomy and histology of the Indian elephant. Indira publishing house P.O.Box 37256, Oak Park, Michigan U.S.A pp17-21.

Muhammad, F. and Shahid, R. (2000). Comparative gross anatomy of the appendicular skeleton of buffaloes and cows. Pakistan Veterinary Journal. 20(3): 159-160.

Nowak, R.M. (1999). Walker's Mammals of the World. 6th Edn. Baltimore, Johns Hopkins University Press.

Nurhidayat, Lestari, E.P., Nisa, C., Cahyadi, D.D. and Supratikno (2015). Anatomical characteristic of forelimb skeleton of Sumatran rhino *(Dicerorhinus sumatrensis).* In: 5th Congress of Asian Association of Veterinary Anatomists, Bali-INDONESIA, 12-13th, February. pp: 23-24.

Onwuama, K.T., Kigir, E.S., Jaji, A.Z. and Salami, S.O. (2021). Gross anatomical studies on the fore limb of the West African giraffe (Giraffa Camelopardalis Peralta). Journal of Veterinary Anatomy. 14(1): 13-23.

Pawan, K. and Suraj, K. (1999). Morphology of the bones of a Neel gai (*Boselaphus tragocamelus*). Indian Journal of Veterinary Anatomy. 11(2): 103-114.

Rajani, C.V., Chandy, G., Sankunny, M., Surjith, K., Patki, H.S. and Ashok, N. (2019). Morphological identification of pectoral limb bones of Indian Muntjac *(Muntiacus muntjak)* from domestic ruminants. Indian Journal of Animal Research. 53(2): 218-221.

Sasan, J.S., Sarma, K., Suri, S. and Malik, M.R. (2016).Osteometry of the appendicular skeleton in buffalo (*Bubalus bubalis*). Indian Journal of veterinary Anatomy. 28(2): 46-47.

Shoshani, J. and Eisenberg, J.F. (1982). Elephas maximus. Mammalian Species. (182): 1-8. doi:10.2307/3504045. JSTOR 3504 045.

Siddiqui, M.S.I., Khan, M.Z.I., Sarma, M., Islam, M.N. and Jahan, M.R. (2008). Macro-anatomy of the bones of the limb of Black Bengal goat *(Capra hircus*). Bangladesh Journal of Veterinary Medicine. 6(1): 59-66.

Smuts, 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.

Smuts, M. and Bezuidenhout, A.J. (1987). Anatomy of the Dromedary. Clarendon Press, Oxford, UK. pp: 24-47.

Talukdar, S.R. Kalita, S.N. and Baishya, G. (2008). Gross anatomical study on the radius of adult Indian elephant *(Elephus maximus*), Souvenir and Abstract, Silver Jubilee National Symposium on Advancement in Veterinary Anatomy Teaching and Research with Special Reference to Their Clinical Application and XII Annual Convention of Indian Association of Veterinary Anatomists, pp: 62.