B-4886
[1-5]

RESEARCH ARTICLE Indian Journal of Animal Research

Osteological Study on the Humerus of Indian Elephant (*Elephas maximus indicus*)

P.J. Kapadnis, S.K. Gupta, S.K. Karmore, G.P. Jatav, B.P. Shukla, A. Suman

10.18805/IJAR.B-4886

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 is to elucidate the osteological outline on the humerus of Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field.

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

Result: Humerus has a proximal and a distal extremity and a shaft. The shaft was consisted of four surfaces. The cylindrical shaped shaft of humerus was consisted of four surfaces. The Musculo spiral groove was limited by the lateral epicondyloid crest at the posterior surface of the shaft. The deltoid tuberosity was present in the proximal third of the shaft. The proximal extremity was consisted of the head, neck, two tuberosities and the intertubular groove. Distal extremity consisted of two condyles which were unequal in size and separated by a ridge.

Key words: Elephant, Gross, Humerus.

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: Elephas *maximus maximus* of Sri Lanka, *Elephas maximus indicus* of India and *Elephas maximus sumatranus* of Sumatra (Shoshoni and Eisenberg, 1982).

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.

Elephant can move slowly to quite fast and elephants can run out most humans and can remain standing for long periods with the support of bones and limbs. Both in structure and in kinematic patterns (Weissengruber *et al.,* 2006) the limbs of elephants reveal many peculiarities.

The aim of this study is to elucidate the osteological outline on the humerus in Elephants, thereby making more contribution in filling the gap of knowledge and skills framework in this field. This study provides a baseline data for further ventro-legal, archaeological and clinical cases.

MATERIALS AND METHODS

For the present study material from three Indian elephants of either 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 / Prabandh / 239 / 699, Bhopal dated 29.12.2020 and Page No/ Prabandh/ 239/ 8261Bhopal, dated 29.12.2020 The skeletons were dug out from the grounds which were buried from last 5-10 years in the premises of College of Veterinary Science and Animal Husbandry, Mhow. These bones were washed out with bleaching powder to get rid of the offensive odour, dust and then sun dried afterwards for one week.

After collection and sorting of all the bones, desire bones were kept in separate boxes. The gross study was carried out in Osteology laboratory, Department of Veterinary Anatomy, College of Veterinary Science and Animal Husbandry, Mhow. Various osteological features of humerus were recorded. The weight of humerus was taken by

Department of Veterinary Anatomy and Histology, College of Veterinary Science and Animal Husbandry, Nanaji Deshmukh Veterinary Science University, Mhow-453 446, Madhya Pradesh, India.

Corresponding Author: P.J. Kapadnis, Department of Veterinary Anatomy and Histology, College of Veterinary Science and Animal Husbandry, Nanaji Deshmukh Veterinary Science University, Mhow-453 446, Madhya Pradesh, India.
Email: padmakarkapadnis@gmail.com

How to cite this article: Kapadnis, P.J., Gupta, S.K., Karmore, S.K., Jatav, G.P., Shukla, B.P. and Suman, A. (2022). Osteological Study on the Humerus of Indian Elephant (*Elephas maximus indicus*). Indian Journal of Animal Research. DOI: 10.18805/IJAR.B-4886.

Submitted: 11-02-2022 **Accepted:** 04-06-2022 **Online:** 16-06-2022

weighing machine and the length, width and circumference of humerus was taken with the help of inelastic thread and measuring tape and data was subjected to routine statistical analysis as per sedecor and cochran (1994). 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

In the present study humerus was the largest, longest and heaviest bone of the forelimb same as reported by Smuts and Bezuidenhout (1993) in African elephant and Mariappa (1986) and Lakshmishree *et al*. (2021) in Indian elephant. It has a proximal and a distal extremity and a shaft. Smuts and Bezuidenhout (1987) found that the humerus was massive, particularly proximally in dromedary. Talukdar *et al*. (2002) revealed that humerus of mithun was short but very strong and stout in comparison to that of the other domesticated animals. Nurhidayat *et al*. (2015) recorded that the humerus of Sumatran Rhino was relatively big and short bone.

The cylindrical shaped shaft was twisted in appearance as noted by Lakshmishree *et al*. (2021) in Indian elephant, Gupta and Deshmukh (2014) in camel, Getty (1975) in horse, Sarma *et al*. (2008), Bharti *et al*. (2021) and (Pawan and Suraj 1999 Rohlan *et al*. 2018) in Nilgai/ blue bull, Bordoloi *et al*. (1991) in Indian one -horned rhinoceros, Jangir (2010) in chinkara, Choudhary and Singh (2016) in blackbuck, Sarma *et al*. (2019) in adult Indian barking deer. However, it was spirally twisted in the African elephant (Tefera, 2012) and flattened cranio-caudally in Indian one-horned rhinoceros (Bordoloi *et al*., 1991). The shaft was consisted of four surfaces. The lateral surface was smooth. The deeper musculo-spiral groove was present in the lateral portion of the shaft of this surface same as elucidated by Ahasan *et al*. (2016) in Asian elephant, Tefera, (2012) in the African elephant and Bordoloi *et al*. (1991) in Indian one-horned rhinoceros, while Lakshmishree *et al*. (2021) in Indian elephant and Muhammad and Shahid (2000) in buffalo noted a shallow musculo-spiral groove. The Musculo spiral groove was limited by the lateral epicondyloid crest at the posterior surface of the shaft. This Musculo-spiral groove was continuous with the posterior surface above in agreement with Getty (1975) in horse.

The deltoid tuberosity was present in the proximal third of the shaft same as reported by Bordoloi *et al*. (1991) in Indian one -horned rhinoceros and Rajani *et al*. (2019) in Indian Muntjac. It was slightly distinct rough elevated and elongated area same as reported by Ahasan *et al*. (2016) in Asian elephant however, Mahmud and Mussa (2016) sin black Bengal goat noted in the form of a faint impression and Onwuama *et al*. (2021) reviewed that in West African giraffe the deltoid tuberosity was absent. Getty (1975) mentioned that the deltoid tuberosity was well developed in the horses.

The anterior surface was separated from lateral surface with a ridge. A well-developed deltoid ridge was present in proximal third part of the shaft of humerus. This ridge was separating the anterior surface with the lateral surface in proximal third as mentioned by Lucy *et al*. (2018) in elephant. A well- developed vertical ridge was also present medial to deltoid ridge and deltoid tuberosity (Plate 2) on the anterior surface of the shaft. Similar observations were noted by Mariappa (1986) and Lakshmishree *et al*. (2021) in Indian elephant and Choudhary and Singh (2016) in blackbuck.

A prominent structure of the crest of major tubercle was observed cranially and becomes indistinct at the middle of shaft as reported by Smuts and Bezuidenhout (1993) in African elephant. The crest of major tubercle was in the form of rough line which was present on medial surface as reported in Indian elephant Lakshmishree *et al*. (2021). However, it was well developed in Mithun (Talukdar *et al*, 2002).The nutrient foramen was located distally at posterior surface as reported by Lakshmishree *et al*. (2021) In Indian elephant, Sarma and Kalita (2008) in Asian elephant and Bordoloi *et al*. (1991) in Indian one-horned rhinoceros. However, it was in distal third of medial surface in horse (Getty, 1975), whereas it was observed at distal third of lateral surface in black Bengal goat (Siddiqui *et al*., 2008) and in the distal third of cranial surface in camel (Smuts and Bezuidenhout, 1987 and Gupta and Deshmukh, 2014).

The proximal extremity was consisted of the head, neck, two tuberosites and the intertubular groove (Plate 1) as recorded by Lakshmishree *et al*. (2021) In Indian elephant, Gupta and Deshmukh (2014) in camel, Bordoloi *et al*. (1991) in Indian one-horned rhinoceros and Getty (1975) in horse.

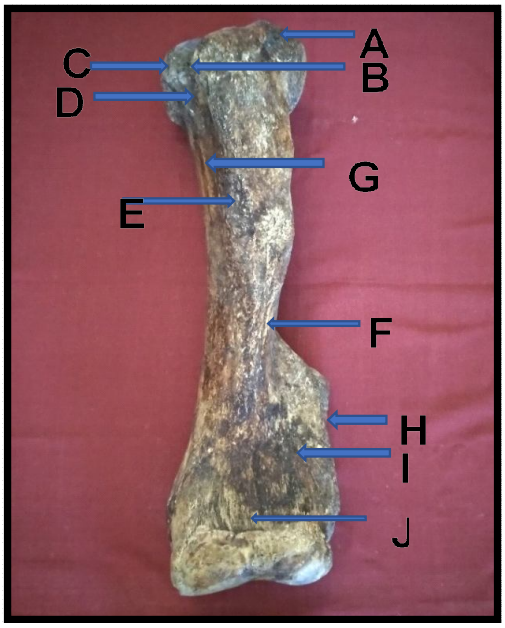

Plate 1: Left humerus anterior view showing, Convex part of lateral tuberosity (A), Summit of lateral tuberosity (B), Medial tuberosity (C), bicipital groove(D), Deltoid tuberosity (E), Musculospiral groove (F), Vertical ridge parallel to deltoid ridge (G), Lateral epicondyloid crest (H), Flat part (I) and Radial fossa (J).

The head was elongated ovoid in shape. However, Lakshmishree *et al*. (2021) in Indian elephant noted it as roughly spherical shape and Gupta and Deshmukh (2014) in camel noted circular shape. The elongated flattened articular area was laterally marked by a rough faint border and forming the rounded surface of the head same as reported by Smuts and Bezuidenhout (1993) in African elephant. It was located in the caudo-medial aspect of the proximal extremity same as in camel Gupta and Deshmukh (2014) and was directed in cranio- caudal plane as observed by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. It was about twice extensive as the glenoid cavity of scapula, but the articular area of the head was equal to the glenoid cavity.

The tuberosites present on proximal extremity were, lateral tuberosity and medial tuberosity. While Budras *et al*. (2003) in bovines and Budras *et al*. (2009) in equines mentioned these tuberosites as the lateral major tubercle and the medial minor tubercle. The lateral tuberosity was well developed and placed laterally to the head and extends cranially to it as mentioned by Ahasan *et al*. (2016) and Lucy *et al*. (2018) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant and Gupta and Deshmukh (2014) in camel. Lateral tuberosity was consisted of two parts, *i.e*. anterior and posterior part same as in camel (Gupta and Deshmukh, 2014) and bovine (Budras *et al*., 2003).

The medial tuberosity was very small and tuberous in shape in agreement with Lucy *et al.* (2018) in elephant. However, Budras *et al*. (2009) recorded that in equine the greater and lesser tubercles on the lateral and medial sides, respectively, of the proximal extremity were nearly equally well developed. In bovines these tubercles were divided into cranial and caudal parts (Budras *et al*., 2003).

In between the lateral and medial tuberosites an intertubular groove (bicipital groove) (Plate 3) was present same as reported in Indian elephant by Lakshmishree *et al*. (2021) and in camel by Gupta and Deshmukh (2014). Damian *et al*. (2012) concluded that in giraffe the bicipital groove was less evident. Pawan and Suraj (1999) recorded that in Neel gai bicipital groove was shallow. The bicipital groove was present lateral to the cranial extremity of medial tuberosity and medial to the cranial part of lateral tuberosity as elucidated by Smuts and Bezuidenhout (1993) in African elephant. However, the bicipital groove was subdivided by a prominent ridge in horse (Konig and Liebich, 2006) and camel (Gupta and Deshmukh, 2014). Gupta and Deshmukh (2014) in camel noted that it was present between the lateral tuberosity and intermediate tubercle and a less developed in between intermediate tubercle and medial tuberosity.

The distal extremity was consisted of two condyles which were unequal in size and separated by a ridge as noted by Lakshmishree *et al*. (2021) in Indian elephant, Onwuama *et al*. (2021) in West African giraffe and Getty (1975) in horse.

The lateral epicondyle was massive in size and was present just above the condyle which showed many minute foramina as elucidated by Ahasan *et al*. (2016) in Asian elephant, In the lateral epicondyle a big tuberosity was present. The medial epicondyle was much smaller than the lateral epicondyle and lies caudally in the upper part of the condyle as described by Smuts and Bezuidenhout (1993) in African elephant and Smuts and Bezuidenhout (1987) in dromedary.

Just above the condyle on the anterior surface a well-developed radial fossa was present. While in one animal it

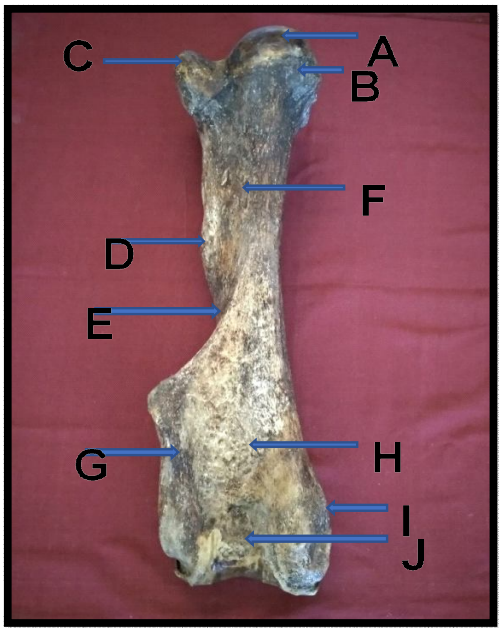

Plate 2: Left humerus posterior view showing, Head (A), Neck (B), Lateral tuberosity (C), Deltoid tuberosity (D), Musculo spiral groove (E), Posterior surface (F), Lateral epicondyloid crest (G), Flat part (H), Medial epicondyle (I) and Olecranon fossa (J).

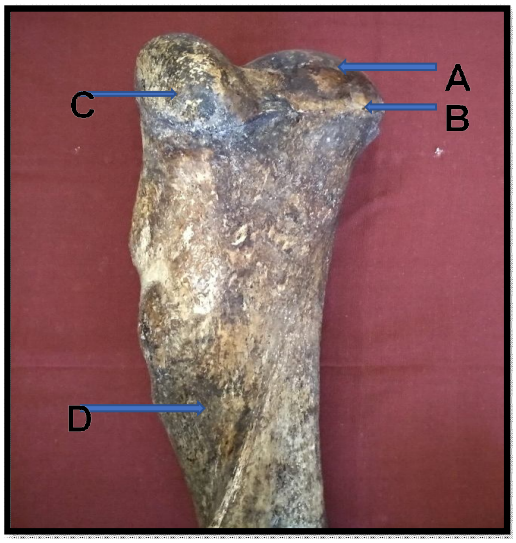

Plate 3: Left humerus (posterior view) showing, Head (A), Neck (B), Rough part of lateral tuberosity (C) and Musculospiral groove (D).

Table 1: Showing various gross parameters of humerus of forelimb in indian elephant.

Parameters	Average±SE (Range)
Weight of humerus (in kg)	17.16±0.76 kg (14.68-19.34)
Length of humerus (cm)	84.07±1.81 (79.1-89)
Circumference of proximal end (cm)	73.33±1.47 (68.5-76.2)
Circumference of distal end (cm)	64.12±0.60 (62.0-65.1)
Circumference proximal part of shaft (cm)	59.02±1.65 (53.2-61.9)
Circumference at mid part of shaft (cm)	37.55±0.62 (35.4-38.9)
Circumference of distal part of shaft (cm)	64.1±0.88 (61.2-65.9)
Curvature of proximal articular surface (cm)	26.72±0.63 (24.5-27.9)
Width of proximal articular surface (cm)	17.38±1.55 (14.5-22.5)
Length of proximal articular surface (cm)	21.31±0.55 (21-22)
Length of distal articular surface (cm)	20.92±0.41 (20-22).
Width of distal articular surface (cm)	19.52±0.38 (17.9-20.2)
Length of shaft (cm)	67.82±1.87 (61.9-71.1)
Position of nutrient foramen (cm)	42.62±1.43 (38.3-42.5)
Position of deltoid tuberosity (cm)	16±0.25 (15-16.9)
Position of terece tubercle (cm)	22.1±0.60 (20.1-23.9)
width of medial condyle (cm)	7.5±0.37 (5.9-8.3)
Width of lateral condyle (cm)	8.68±0.25 (8.1-9.5)
Circumference of head (cm)	58.02±0.95 (54.4-60.5)
Maximum breadth of shaft (cm)	19.32±0.37 (18.2-20.5

was deep and elongated in shape. The radial fossa was present on the cranial aspect as observed by Ahasan *et al*. (2016) in Asian elephant and Smuts and Bezuidenhout (1993) in African elephant. Just lateral to radial fossa a somewhat smaller deep rounded fossa was present.

The olecranon fossa was formed by two epicondyles caudally. The olecranon fossa and radial fossa were not communicated with each other same as reported by Lakshmishree *et al*. (2021) in Indian elephant. However, Choudhary and Singh (2016) in black buck reported that the olecranon fossa and radial fossa communicated with each other and form supratrochlear foramen in contrast with the present finding. Both radial and olecranon fossa were deep same was recorded by Lakshmishree *et al*. (2021) in Indian elephant and Smuts and Bezuidenhout (1987) in dromedary.

There was no significant difference in between the right and left humerus of same animal same as described by Gupta and Deshmukh (2014) in camel. In the present study weight of humerus was 17.16±0.76 kg (Table1) nearly same weight was recorded by Lakshmishree *et al*. (2021) in Indian elephant, which was 17.7 kg. In the present study the length of humerus was 84.07±1.81 cm (Table 1).

CONCLUSION

In the present study humerus was the largest, longest and heaviest bone of the forelimb. The deltoid tuberosity was present in the proximal third of the shaft. It was slightly distinct rough elevated and elongated area. The head of humerus was about twice extensive as the glenoid cavity of scapula.

Conflict of interest: None.

REFERENCES

Ahasan, A.S.M.L., Md. Abul Quasem, A.S.M., Lutfur Rahman, M., Hasan, R.B., Golam Kibria, A.S.M. and Subrata Kumar Shil. (2016). Macroanatomy of the bones of thoracic limb of an Asian elephant (*Elephas maximus*). Int. J. Morphol. 34(3): 909-917.

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.B 4278.

Bordoloi, C.C., Kalita, S.N., Kalita, H. and Baishya, G. (1991). Anatomical study on the humerus of Indian one-horned rhinoceros (*Rhinoceros Unicornis*). Indian Journal of Veterinary Anatomy. 3(2): 69-71.

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. and Singh, I. (2016). Morphometrical studies on humerus of Indian blackbuck (*Antilope cervicapra*) Journal of Wildlife Research. 4(1): 06-09.

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

Gupta, S.K. and Deshmukh, S.K. (2014). Gross morphometrical Study on the Humerus of camel (*Camelus dromedarius*) Indian Vet. J., 91 (10): 26-28.

Jangir, D.K. (2010). Thesis entitled "Gross Studies on the Bones of the forelimb in Indian gazelle (*Gazella gazella bennettii*). College of Veterinary and Animal Science, Rajasthan University of Veterinary and Animal Sciences. Bikaner. pp: 78-91.

Kalita, S.N and. Sarma M. (2003). Anatomy of Elephant: Some Important Features. In Health care, breeding and Management of Asian Elephants, [Das D, (ed)]. Assam: College of Veterinary Science, Assam Agricultural University.

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.

Lakshmishree, K.T., Dhoolappa, M., Ganganaik, S., Mutturaj, R.P. and Yuvaraj. (2021). Osteomorphometry of Humerus of Indian elephant (*Elephas maximus indicus*). Indian Journal of Veterinary Anatomy. 33(1): 67-69.

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.36-37.

Mariappa, D. (1986) Anatomy and Histology of the Indian Elephant. Indira Publishing House P.O.Box 37256,Oak park, Michigan U.S.App17-21.

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. AJASET, ISSN: 2158-8104 (Online), 2164-0920 (Print): 3(1): 45-55

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 ed. 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 2015. 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*). J. Vet. Anat. 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 J. Anim. Res. 53(2): 218-221.

Rohlan, K., Mathur, R., Dangi, A., Shringi ,N., Ganguly, S. and Vikas Kumar (2018). Morphometrical studies on humerus of blue bull (*Boselaphus tragocamelus*). International Journal of Livestock Research. 8(06): 177-184.

Sarma, K. Singh, J., Sasan and Suri, S. (2019). Gross and morphometrical studies on the humerus of Indian Barking deer (*Muntiacus muntjak*). Journal of Entomology and Zoology Studies. 7(6): 278-282.

Sarma, K., Kalita, S.N. and Kumar, P. (2008). Anatomy of the humerus of Nilgai (*Boselaphus tragocamalus*). Indian J. Ani. Sci. 78(1): 24-27.

Sarma, M. and Kalita, S.N. (2008). Passive Locomotor System of the Arm of Adult Asian Elephant; A Gross Study, 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: 58.

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

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 J. Vet. Med. 6(1): 59-66.

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

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

Talukdar, M., Kalita, A. and Baishya, G. (2002). Gross anatomical study on the humerus of Mithun. Indian Vet. J. 79(6): 585-587.

Tefera, M. (2012). Kinematics and Comparative Anatomy of Some Limb Bones of the African Elephant (*Loxodonta africana*) and Large Domestic Animals. Journal of Veterinary Anatomy. l5(2): 15-31.

Weissengruber, G.E., Fuss, F.K., Egger, G., Stanek, G., Hittmair, K.M. and Forstenpointner, G. (2006). The elephant knee joint: Morphological and biomechanical considerations. J. Anat. 208(1): 59-72.