



Original Research

Gross Morphometrical Study on the Atypical (6th and 7th) Cervical Vertebrae of Blue bull (*Boselaphus tragocamelus*) with Special Reference to Sexual Dimorphism

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Abstract

The present study was carried out on the atypical cervical vertebrae, especially sixth (C₆) and seventh (C₇) cervical vertebrae of six specimens of adult Blue bull (*Boselaphus tragocamelus*) of either sex after collection of macerated bones. It was found that these vertebrae were comprised of body, arch and processes. The arch had laminae and pedicles. The processes were dorsal supraspinous, transverse, cranial and caudal articular processes. The ventral division of transverse process of C₆ was quadrilateral plate like. The transverse foramina were absent in C₇ and also the transverse process was single in C₇. There was a pair of costal facets one on either side of caudal surface of body of C₇. The supraspinous process of C₇ was very well developed and almost resembled with that of the thoracic vertebrae. Biometrical observations on different parameters of C₆ and C₇ reflected significance ($P < 0.05$) differences between the sexes of this species which would help the wild life Veterinarians in identification of species and differentiation of sex in this animal.

Key words: Blue Bull, Cervical Vertebrae, Gross Morphometry

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Introduction

The Blue bull (*Boselaphus tragocamelus*) is known to be one of the biggest antelopes in Asia and is widely found in both the forests and adjoining villages with enough green grass. It is quite prevalent in northern and central parts of India especially in the foothills of Himalayas, eastern part of Pakistan and southern part of Nepal, but has vanished from Bangladesh. The massive body of the Blue bull can be attributed to the large skeleton of the antelope. Further, the skeleton comprises of large and massive bones of axial and



appendicular skeleton that not only protects the viscera, but also provides shape and support to the heavy musculature of the Blue bull. The present osteo-morphological study was undertaken to develop a baseline data on the atypical cervical vertebrae, especially on C₆ and C₇ of adult Blue bull that would immensely help the wild life anatomists and Veterinarians in species identification and solving forensic and vetero-legal cases as the literature in this field is lacking.

Materials and Methods

The present study was carried out on the atypical cervical vertebrae, especially on C₆ and C₇ of six specimens of adult Blue bulls (*Boselaphus tragocamelus*) of either sex. The permission for the collection of bones was acquired from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan. The bones were possessed from the Jodhpur zoo, Rajasthan getting authentic confirmation from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan and subsequently from the Deputy Conservator of Forest (Wildlife), Jodhpur. The skeletons were taken out from the burial ground that was located in the premises of the office of the Deputy Conservator of Forest Wildlife (WL), Jodhpur. Afterwards, the specimens were processed as per standard technique given by Choudhary *et al.* (2015). The gross study was conducted under the supervision of the Zoo Authority, Jodhpur, India. The different biometrical parameters like weight of the vertebra, the average length and width of the body, the diameters of vertebral canal, the average height and width of supraspinous process, the length and width of the transverse processes, the diameters of transverse foramen, etc. of C₆ and C₇ were measured and subjected to routine statistical analysis (Snedecor and Cochran, 1994) and independent samples t-Test with Systat Software Inc, USA and SPSS 16.0 version software.

Result and Discussion

Sixth Cervical Vertebra

Gross Morphology

In the present study, the sixth cervical (C₆) vertebra of Blue bull was found to be atypical type. The lower part of the transverse process of C₆ was large, thick, quadrilateral plate like and directed ventrally (Fig. 1). The supraspinous process was well developed and summit of the process was found to be tuberos and inclined cranially. The infraspinous process was not present which was in accordance with the findings of Getty *et al.* (1930a) and Raghavan (1964) in ox, Miller *et al.* (1964) in dog, Smuts and Bezuidenhout (1987) in camel, Ozkan (2007) in mole-rats and Meena (2012) in chital. The articular processes were reported to be large and connected by a bony plate of same side which simulated with the findings of Getty *et al.* (1930a) and Raghavan (1964) in ox, Konig and Liebich (2005) in ruminants and Meena (2012) in chital.

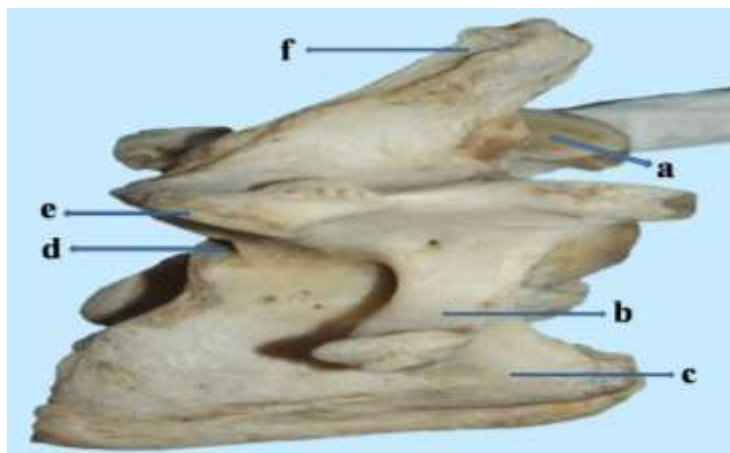


Fig. 1: Lateral view of sixth cervical vertebra of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Cranial articular process, b) Dorsal division of transverse process, c) Ventral division of transverse process, d) Transverse foramen, e) Caudal articular process and f) Supraspinous process

The lower part of the transverse process descended from the ventro-lateral aspect of the body and was modified to form a large thick quadrilateral plate. Its lateral surface was concave and the medial surface was convex. The upper part of the transverse process projected laterally and posteriorly. The transverse foramen of C₆ in Blue bull was found to be largest in the series. These findings resembled those reported by the aforesaid workers.

Biometrical Observation

The biometrical observations revealed that the average weight of C₆ was found to be 244.84±3.14 gm in adult Blue bull. Further, it was measured to be 238.67±2.48 gm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 251.01±2.29 gm. The average length of the body was found to be 3.93±0.06 cm in adult Blue bull. Further, it was measured to be 3.87±0.09 cm and 4.00±0.06 cm in females and males respectively. The average width of the body at the cranial aspect was found to be 2.37±0.02 cm in adult Blue bull. Further, it was measured to be 2.32±0.01 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.42±0.02 cm. Similarly, the average width of the body at the middle was found to be 3.04±0.02 cm in adult Blue bull. Further, it was measured to be 2.99±0.02 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 3.09±0.01 cm. The average width of the body at the caudal aspect was found to be 2.72±0.07cm in adult Blue bull. Further, it was measured to be 2.59±0.08 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.86±0.04 cm. The average vertical diameter of vertebral canal at the cranial aspect was found to be 1.88±0.04 cm in adult Blue bull. Further, it was measured to be 1.80±0.04cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 1.95±0.02 cm. The average vertical diameter of vertebral canal at the caudal aspect

was found to be 2.40 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.34 ± 0.05 cm and 2.46 ± 0.02 cm in females and males respectively. The average transverse diameter of vertebral canal at the cranial aspect was found to be 2.12 ± 0.03 cm in adult Blue bull. Further, it was measured to be 2.06 ± 0.04 cm and 2.17 ± 0.03 cm in females and males respectively. The average transverse diameter of vertebral canal at the caudal aspect was found to be 2.88 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.81 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.96 ± 0.02 cm. The average height of supraspinous process was found to be 4.62 ± 0.08 cm in adult Blue bull. Further, it was measured to be 4.49 ± 0.11 cm and 4.75 ± 0.06 cm in females and males respectively. The average width of supraspinous process at the summit was found to be 1.63 ± 0.05 cm in adult Blue bull. Further, it was measured to be 1.58 ± 0.08 cm and 1.68 ± 0.05 cm in females and males respectively. The average width of supraspinous process at the middle was found to be 1.88 ± 0.04 cm in adult Blue bull. Further, it was measured to be 1.80 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.95 ± 0.03 cm. Similarly, the average width of supraspinous process at the base was found to be 3.19 ± 0.05 cm in adult Blue bull. Further, it was measured to be 3.10 ± 0.05 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 3.27 ± 0.05 cm.

The average length of dorsal division of transverse process was found to be 2.70 ± 0.06 cm in adult Blue bull. Further, it was measured to be 2.57 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.83 ± 0.04 cm. Similarly, the average width of dorsal division of transverse process was found to be 1.55 ± 0.03 cm in adult Blue bull. Further, it was measured to be 1.47 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.63 ± 0.02 cm. The average length of ventral division of transverse process was found to be 8.20 ± 0.10 cm in adult Blue bull. Further, it was measured to be 8.08 ± 0.13 cm and 8.32 ± 0.14 cm in females and males respectively. The average width of ventral division of transverse process was found to be 2.81 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.73 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.90 ± 0.03 cm. The average distance between the two ventral divisions of transverse process was found to be 5.48 ± 0.05 cm in adult Blue bull. Further, it was measured to be 5.43 ± 0.07 cm and 5.53 ± 0.09 cm in females and males respectively. The average transverse diameter of cranial transverse foramen was found to be 1.08 ± 0.02 cm in adult Blue bull. Further, it was measured to be 1.03 ± 0.02 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.14 ± 0.02 cm. The average vertical diameter of cranial transverse foramen was found to be 1.48 ± 0.07 cm in adult Blue bull. Further, it was measured to be 1.42 ± 0.12 cm and 1.53 ± 0.09 cm in females and males respectively. The average transverse diameter of caudal transverse foramen was found to be 1.05 ± 0.04 cm in adult Blue bull. Further, it was measured to be 1.00 ± 0.05 cm and 1.10 ± 0.07 cm in females and males respectively. The average vertical diameter of caudal transverse foramen was found to

be 1.50 ± 0.03 cm in adult Blue bull. Further, it was measured to be 1.43 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.57 ± 0.04 cm. The average distance between the cranial and caudal transverse foramen was found to be 1.38 ± 0.05 cm in adult Blue bull. Further, it was measured to be 1.27 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.48 ± 0.05 cm.

The average length of cranial articular process was found to be 2.75 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.68 ± 0.06 cm and 2.82 ± 0.05 cm in females and males respectively. Similarly, the average width of cranial articular process was found to be 2.48 ± 0.03 cm in adult Blue bull. Further, it was measured to be 2.44 ± 0.05 cm and 2.53 ± 0.03 cm in females and males respectively. The average length of caudal articular process was found to be 2.78 ± 0.02 cm in adult Blue bull. Further, it was measured to be 2.73 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.83 ± 0.02 cm. Similarly, the average width of caudal articular process was found to be 2.62 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.53 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.71 ± 0.05 cm. The average distance between two cranial articular processes was found to be 4.25 ± 0.08 cm in adult Blue bull. Further, it was measured to be 4.10 ± 0.06 cm and 4.40 ± 0.06 cm in females and males respectively. Similarly, the average distance between two caudal articular processes was found to be 2.52 ± 0.07 cm in adult Blue bull. Further, it was measured to be 2.40 ± 0.06 cm and 2.63 ± 0.09 cm in females and males respectively. The average distance between the cranial and caudal articular processes was found to be 3.30 ± 0.06 cm in adult Blue bull. Further, it was measured to be 3.17 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 3.43 ± 0.06 cm.

Seventh Cervical Vertebra

Gross Morphology

It was also atypical type in Blue bull. The transverse process of C_7 was single, i.e. not bifid, short, and thick (Fig. 2). The transverse foramen was absent. The ventral spines were absent. The supraspinous process was found to be thin, flat and highest in the series which resembled the thoracic spines. Its cranial border was sharp and inclined caudally. The supraspinous process was found to be wider below and narrower above. The present findings were concurrent to the findings of Raghavan (1964) in ox and Dyce *et al.* (2006) in dog, whereas disagreed to Getty *et al.* (1930a) in horse, where it was nearly reported to be vertical and to Ozkan (2007) in mole-rats where it was antero-dorsally directed. The cranial and caudal articular processes were present. The right caudal articular process was bicycle seat like.

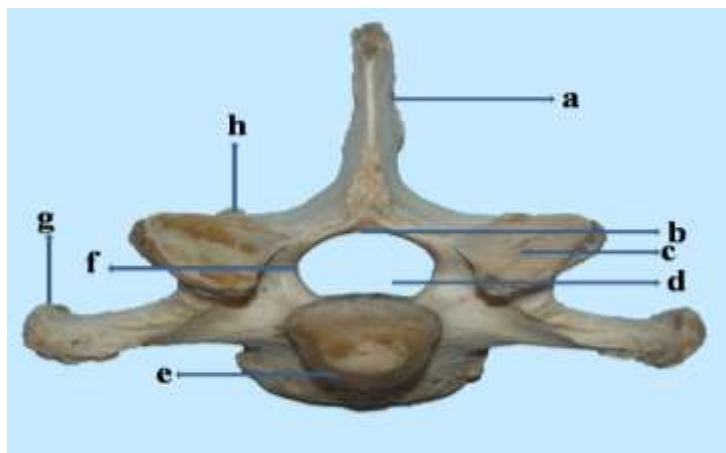


Fig. 2: Cranial view of seventh cervical vertebra of adult male Blue bull (*Boselaphus tragocamelus*) showing a) supraspinous process, b) Laminae, c) Cranial articular process, d) Cervical vertebral foramen, e) Cranial surface of body, f) Pedicle, g) Transverse process and h) Caudal articular process

The infraspinous process and transverse foramen were absent in C₇ of Blue bull. The transverse process was found to be single, i.e. not bifid like C₆. It was projected laterally and slightly posteriorly that represented the upper tubercular portion. The neural ring was found to be very large and a ridge was located in the ventral surface of the ring. The cranial articular surface of vertebral body was strongly convex, wider dorsally than ventrally and the caudal was concave and presented a thick dorsal arch in Blue bull. The posterior costal facets were saddle shaped situated on either side of the centrum (Fig. 3) that articulated with the head of first pair of ribs. The present findings were similar to those reported by Getty *et al.* (1930a) in horse, Raghavan (1964) in ox, Miller *et al.* (1964), Smuts and Bezuidenhout (1987) in camel, Yilmaz *et al.* (2000) in otters, Konig and Liebich (2005) in horse, carnivores, ruminants and pig, Dyce *et al.* (2006) in dog, Ozkan (2007) in mole-rats and Meena (2012) in chital.

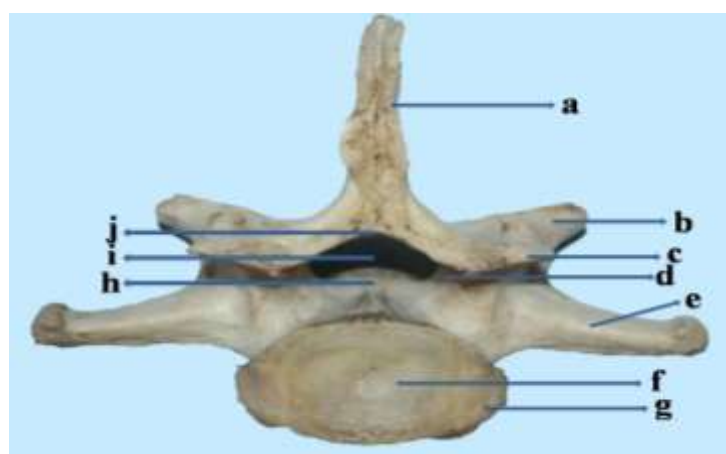


Fig. 3: Caudal view of seventh cervical vertebra of adult male Blue bull (*Boselaphus tragocamelus*) showing a) supraspinous process, b) Cranial articular process, c) Caudal articular process, d) Pedicle, e) Transverse process, f) Caudal surface of body, g) Facet on caudal surface of body for head of first rib, h) Floor of neural canal, i) Neural foramen and j) Laminae

Biometrical Observation

The biometrical observations revealed that the average weight of C₇ was found to be 183.27±2.19 gm in adult Blue bull. Further, it was measured to be 179.37±1.30 gm and 187.17±2.67 gm in females and males respectively. The average length of the body was found to be 3.40±0.11 cm in adult Blue bull. Further, it was measured to be 3.20±0.06 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 3.60±0.12 cm. The average width of the body at the cranial aspect was found to be 1.47±0.08 cm in adult Blue bull. Further, it was measured to be 1.33±0.09 cm and 1.60±0.06 cm in females and males respectively. The average width of the body at the middle was found to be 2.41±0.06 cm in adult Blue bull. Further, it was measured to be 2.28±0.05 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.53±0.04 cm. The average width of the body at the caudal aspect was found to be 2.20±0.05 cm in adult Blue bull. Further, it was measured to be 2.11±0.05 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.29±0.03 cm. The average vertical diameter of vertebral canal at the cranial aspect was found to be 2.18±0.05 cm in adult Blue bull. Further, it was measured to be 2.08±0.05 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.28±0.03 cm. Similarly, the average vertical diameter of vertebral canal at the caudal aspect was found to be 2.60±0.07 cm in adult Blue bull. Further, it was measured to be 2.46±0.04 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.75±0.07 cm. The average transverse diameter of vertebral canal at the cranial aspect was found to be 2.12±0.03 cm in adult Blue bull. Further, it was measured to be 2.05±0.04 cm and 2.18±0.01 cm in females and males respectively. The average transverse diameter of vertebral canal at the caudal aspect was found to be 2.77±0.07 cm in adult Blue bull. Further, it was measured to be 2.64±0.07 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.90±0.04 cm. The average height of supraspinous process was found to be 5.95±0.10 cm in adult Blue bull. Further, it was measured to be 5.77±0.09 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 6.13±0.09 cm. Similarly, the average width of supraspinous process at the summit was found to be 2.08±0.07 cm in adult Blue bull. Further, it was measured to be 1.94±0.04 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.22±0.07 cm. The average width of supraspinous process at the middle was found to be 2.83±0.01 cm in adult Blue bull. Further, it was measured to be 2.66±0.14 cm and 3.00±0.04 cm in females and males respectively. The average width of supraspinous process at the base was found to be 3.08±0.05 cm in adult Blue bull. Further, it was measured to be 2.98±0.05 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 3.17±0.04 cm. The average length of transverse process was found to be 3.51±0.06 cm in adult Blue bull. Further, it was measured to be 3.36±0.07 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 3.67±0.05 cm.

Similarly, the average width of transverse process was found to be 1.82 ± 0.05 cm in adult Blue bull. Further, it was measured to be 1.66 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.97 ± 0.04 cm. Kumar *et al.* (2000) reported that the upper cervical spine had shorter transverse processes (C_2 : 9.0 ± 1.23 mm) which gradually increased to C_7 (22.0 ± 2.2 mm) in red deer (*Cervus elaphus elaphus*).

The average length of cranial articular process was found to be 2.75 ± 0.06 cm in adult Blue bull. Further, it was measured to be 2.63 ± 0.08 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.87 ± 0.06 cm. Similarly, the average width of cranial articular process was found to be 2.43 ± 0.05 cm in adult Blue bull. Further, it was measured to be 2.34 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.52 ± 0.03 cm. The average length of caudal articular process was found to be 2.20 ± 0.04 cm in adult Blue bull. Further, it was measured to be 2.10 ± 0.05 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.29 ± 0.04 cm. Similarly, the average width of caudal articular process was found to be 1.77 ± 0.05 cm in adult Blue bull. Further, it was measured to be 1.62 ± 0.05 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.92 ± 0.03 cm. The average distance between two cranial articular processes was found to be 4.23 ± 0.01 cm in adult Blue bull. Further, it was measured to be 4.03 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 4.43 ± 0.09 cm. The average distance between two caudal articular processes was found to be 3.15 ± 0.18 cm in adult Blue bull. Further, it was measured to be 2.83 ± 0.15 cm and 3.47 ± 0.20 cm in females and males respectively. The average distance between the cranial and caudal articular processes was found to be 3.10 ± 0.12 cm in adult Blue bull. Further, it was measured to be 2.78 ± 0.12 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 3.42 ± 0.10 cm.

The average length of the caudal costal facet was found to be 1.42 ± 0.05 cm in adult Blue bull. Further, it was measured to be 1.35 ± 0.08 cm and 1.48 ± 0.07 cm in females and males respectively. The average width of the caudal costal facet was found to be 1.07 ± 0.05 cm in adult Blue bull. Further, it was measured to be 0.96 ± 0.05 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.19 ± 0.05 cm. The average distance between two caudal costal facets at the dorsal aspect was found to be 3.21 ± 0.11 cm in adult Blue bull. Further, it was measured to be 3.03 ± 0.04 cm and 3.39 ± 0.17 cm in females and males respectively. The average distance between two caudal costal facets at the middle was found to be 2.77 ± 0.06 cm in adult Blue bull. Further, it was measured to be 2.65 ± 0.04 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.88 ± 0.05 cm. The average distance between two caudal costal facets at the ventral aspect was found to be 2.47 ± 0.06 cm in adult Blue bull. Further, it was measured to be 2.36 ± 0.04 cm and 2.58 ± 0.07 cm in females and males respectively. Meena

(2012) in chital (*Axis axis*) reported that the rostral end plate depth (EPDr) in cervical vertebrae was largest in C₆ (2.433 ± 0.071 cm) whereas it was lowest in C₇ (2.183 ± 0.07 cm).

Conclusions

The sixth (C₆) and seventh (C₇) cervical vertebrae were considered as atypical cervical vertebrae in Blue bull. It was revealed that the various parameters of C₆ and C₇ such as weight of the vertebra, the average length and width of the body, the diameters of vertebral canal, the average height and width of supraspinous process, the length and width of the transverse processes, the diameters of transverse foramen in C₆ and the average length and width of cranial and caudal articular processes were significantly more (P<0.05) in adult males than females. This biometrical study would form a sex wise baseline data on the various gross parameters of sixth and seventh cervical vertebrae of Blue bull that in turn would help the wild life Veterinarians in identification of species and differentiation of sex in this animal.

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Conflict of Interest

There is no conflict of interest among the Authors.

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