RESEARCH ARTICLE Indian Journal of Animal Research, Volume 55 Issue 9: 1027-1033 (September 2021)

Sex Wise Morphometrical Studies on Orbital Cavity and Foramina of Skull of Adult Blue Bull (*Boselaphus tragocamelus*)

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10.18805/IJAR.B-4169

ABSTRACT

Background: The Blue bull (*Boselaphus tragocamelus*) is one of the biggest antelopes in Asia and is widely distributed in both the forests and adjoining villages with enough green grass.

Methods: The present study was carried out on the orbital cavity and foramina of skull of six specimens of adult Blue bull (*Boselaphus tragocamelus*) of either sex. The biometrical parameters were measured by scale, graduated tape and digital Vernier's caliper.

Result: The average left cranio-caudal orbital diameter was found to be 5.7±0.11 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 5.3±0.08 cm. Similarly, the average left orbital depth was found to be 5.7±0.08 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 5.3±0.06 cm. The average length of left orbital process of frontal bone was found to be 5.1±0.05 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 5.3±0.07 cm. The average diameter of left supraorbital foramen was found to be 0.31±0.001 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 0.7±0.003 cm. Similarly, the average maximum distance between two cranial palatine foramina was found to be 1.8±0.05 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 3.3±0.12 cm.

Conclusion: Most of the biometrical observations on different parameters of orbital cavity and different foramina of skull of Blue bull were having significantly ($p<0.05$) more values in males than females. The present gross and biometrical studies would be useful to the wild life professionals for determination of sex of this animal and solving vetero-legal cases related with this species.

Key words: Blue bull, Foramina of skull, Morphometry, Orbital cavity.

INTRODUCTION

The Blue bull (*Boselaphus tragocamelus*) is regarded as one of the biggest antelopes in Asia and is widely found in both the forests and adjoining villages with enough green grass (Sathapathy *et al*., 2017, Sathapathy *et al*., 2018a and Sathapathy *et al*., 2018b). It belongs to the family Bovidae and comes under the genus *Boselaphus* (Sathapathy *et al*., 2018c, Sathapathy *et al*., 2018d and Sathapathy *et al*., 2018e). The Blue bull 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 (Sathapathy *et al*., 2019a, Sathapathy *et al*., 2019b and Sathapathy *et al*., 2019c). The adult male of the Blue bull appears like ox and so called as Blue bull (Sathapathy *et al*., 2019d and Sathapathy *et al*., 2019e). They are generally seen in day times in the meadow pasture, timberland areas and agricultural land area (Sathapathy *et al*., 2019f, Sathapathy *et al*., 2019g and Sathapathy *et al*., 2019h). The Blue bulls are safeguarded beneath the IUCN since 2003 and also under safeguard of 'Schedule III' of the Indian Wildlife Protection Act, 1972 (Bagchi *et al*., 2004). The massive body of this animal can be attributed to the large skeleton of the antelope (Sathapathy *et al*., 2019i and Sathapathy *et al*., 2019j). Further, the skeleton of the Blue bull 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 (Sathapathy *et al*., 2020a and Sathapathy *et al*., 2020b). The present study developed a baseline data on the sex wise morphometrical differences in the orbital cavity and foramina of skull of adult Blue bull that would immensely help the wild life anatomists and Veterinarians in species identification and solving forensic

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How to cite this article: Sathapathy, S., Dhote, B.S., Singh, I., Mrigesh, M., Joshi, S.K., Biswal, S.S., Sahu, S.K. and Ali, I. (2021). Sex Wise Morphometrical Studies on Orbital Cavity and Foramina of Skull of Adult Blue Bull (*Boselaphus tragocamelus*), Indian Journal of Animal Research. 55(9): 1027-1033. DOI: 10.18805/IJAR.B-4169.

Submitted: 09-05-2020 **Accepted:** 12-09-2020 **Online:** 21-12-2020

and vetero-legal cases as no previous work has been done in this field on the Blue bull.

MATERIALS AND METHODS

The present morphometrical study was carried out on the orbital cavity and foramina of skull of six specimens of adult Blue bulls (*Boselaphus tragocamelus*) of either sex. The permission for the collection of skull bones was acquired from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan. 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 boiled in an aluminium vat for about one hour. They were taken out from the vat and air dried for 3-5 days (Choudhary *et al*., 2013). The morphometrical study was conducted under the supervision of the Zoo Authority, Jodhpur, India. The different biometrical parameters of orbital cavity and foramina of skull were measured and subjected to routine statistical analysis as per standard technique given by Snedecor and Cochran (1994) and independent samples t-Test with Systat Software Inc, USA and SPSS 16.0 version software.

RESULTS AND DISCUSSION

The skull of adult Blue bull formed the skeleton of head and face of the animal and comprised of cranial and facial bones. The cranial bones consisted of paired frontal, interparietal, parietal and temporal bones and single sphenoid, occipital and ethmoid bones. The facial bones comprised of paired lacrimal, malar, maxilla, pre-maxilla, palatine, nasal, pterygoid and turbinate bones and single vomar bone. The present findings were in line with the reports of Getty *et al*. (1930) in cattle, sheep, goat, Grossman (1960) in camel, Frandson and Spurgeon (1992) in cattle, Sebastiani and Fishbeck (2005) in cattle and Dyce *et al*. (2006) in dog.

Biometrical observations of orbital cavity

The biometrical observations of orbital cavity of Blue bull revealed characteristic differences between the sexes. The average left cranio-caudal orbital diameter was found to be 5.7±0.11 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 5.3±0.08 cm. The average left dorso-ventral orbital diameter was measured as 5.4±0.16 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 6.1±0.19 cm. The average right cranio-caudal orbital diameter was found to be 5.9±0.12 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 5.6±0.10 cm Table 1.

The average left orbital depth was measured as 5.7±0.08 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 5.3±0.06 cm.

Table 1: Measurements of orbit of Blue bull in cm.

Parameters			Female (Mean±SE)	Male (Mean±SE)
Orbital diameter	Left cranio-caudal		5.7*±0.11	5.3±0.08
	Left dorso-ventral		5.4*±0.16	6.1±0.19
	Right cranio-caudal		5.9*±0.12	5.6±0.10
	Right dorso-ventral		5.9±0.14	5.7±0.12
Orbital depth	Left		5.7*±0.08	5.3±0.06
	Right		5.9±0.11	5.9±0.07
Orbital circumference	Left		19.2*±0.21	16.6±0.17
	Right		15.9±0.16	16.1±0.12
Interorbital distance	Cranial		10.1*±0.13	14.1±0.07
	Middle		10.9*±0.12	13.2±0.17
	Caudal		16.5*±0.14	21.1±0.12
Contribution of skull bones forming the orbit	Frontal bone	Left	6.5*±0.06	7.1±0.08
		Right	6.2*±0.11	8.3±0.13
	Lacrimal bone	Left	4.2*±0.15	2.7±0.09
		Right	4.9*±0.13	3.1±0.08
	Zygomatic bone	Left	6.1*±0.11	6.6±0.19
		Right	5.6*±0.16	6.4±0.12
Orbital process of frontal bone	Length	Left	5.1*±0.05	5.3±0.07
		Right	3.9*±0.04	4.2±0.07
	Width	Left	1.1±0.002	1.0±0.001
		Right	1.3±0.06	1.3±0.04
Orbital process of malar bone	Length	Left	5.1±0.10	5.3±0.12
		Right	3.2±0.11	3.3±0.13
	Width	Left	1.2*±0.001	1.0±0.001
		Right	0.9±0.002	0.7±0.001

Values bearing superscript (*) differ significantly in column $p<0.05$.

Table 2: Measurements of foramina of skull of Blue bull in cm.

Parameters			Female (Mean±SE)	Male (Mean±SE)
Diameter	Supraorbital foramen	Left	0.31*±0.001	0.7±0.003
		Right	0.27*±0.002	0.9±0.002
	Infraorbital foramen	Left	0.53*±0.002	1.1±0.005
		Right	0.56±0.003	0.8±0.01
	Optic foramen	Left	0.37*±0.002	1.1±0.006
		Right	0.35*±0.002	1.1±0.003
	Foramen orbitorotandum	Left	0.24*±0.001	0.5±0.001
		Right	0.25*±0.001	0.5±0.001
	Foramen ovale	Left	0.8*±0.002	1.5±0.005
		Right	0.9*±0.002	1.5±0.008
	Foramen lacerum	Left	0.40*±0.001	1.2±0.008
		Right	0.43*±0.002	1.4±0.006
	Posterior glenoid foramen	Left	0.40*±0.002	0.9±0.005
		Right	0.38*±0.002	1.1±0.004
	Stylomastoid foramen	Left	0.31*±0.001	0.7±0.002
		Right	0.36*±0.002	1.1±0.005
	Cranial palatine foramen	Left	0.249*±0.001	0.20±0.001
		Right	0.246±0.002	0.20±0.001
	Caudal palatine foramen	Left	0.354*±0.002	0.50±0.002
		Right	0.356*±0.001	0.50±0.002
	Foramen magnum Vertical		3.5*±0.12	2.68±0.10
	Foramen magnum Transverse		3.2*±0.15	2.97±0.08
Circumference of foramen magnum			11.8*±0.22	11.1±0.17
Distance between foramina	Left and right supraorbital foramina		5.1*±0.15	6.1±0.20
	Left and right infraorbital foramina	Dorsal	6.9*±0.21	8.1±0.16
		Ventral	5.7*±0.13	6.1±0.15
	Between optic foramen and foramen orbitorotandum	Left	5.8±0.12	5.9±0.17
		Right	5.1*±0.23	5.6±0.26
	Between foramen orbitorotandum and foramen ovale	Left	2.3±0.11	2.1±0.08
		Right	0.9*±0.002	2.1±0.04
	Between supraorbital an d infraorbital foramina	Left	12.3*±0.13	14.1±0.10
		Right	12.5*±0.17	13.9±0.19
	Between cranial palatine foramina	Maximum	1.8*±0.05	3.3±0.12
		Minimum	1.3*±0.03	2.2±0.06
	Between caudal palatine foramina		3.1±0.01	4.1±0.01
	Between cranial and caudal palatine foramina	Left	4.4*±0.18	5.5±0.12
		Right	4.7*±0.13	6.1±0.15
	Between stylomastoid and posterior glenoid foramina	Left	3.1±0.17	2.9±0.11
		Right	2.9±0.09	2.8±0.06
	Between left and right foramen lacerum		2.8*±0.12	3.9±0.14
Distance of foramen orbitorotandum from orbit		Left	6.6*±0.10	7.4±0.13
		Right	6.8*±0.12	8.5±0.17
Distance of foramen ovale from orbit		Left	8.9*±0.11	10.1±0.14
		Right	8.1*±0.10	10.2±0.12
Distance between facial tuberosity and infraorbital foramen		Left	5.6*±0.07	6.1±0.08
		Right	6.0*±0.16	7.9±0.19
Distance between infraorbital foramen and rostral part of incisive bone		Left	8.1*±0.20	13.7±0.24
		Right	7.8*±0.11	13.6±0.13
Distance between cranial palatine foramen and interpalatine suture		Left	1.2±0.001	1.3±0.002
		Right	1.2±0.002	1.3±0.003

Values bearing superscript (*) differ significantly in column $p<0.05$.

The average left orbital circumference was found to be 19.2±0.21 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 16.6±0.17 cm. The average left interorbital distance at the cranial aspect was found to be 10.1±0.13 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 14.1±0.07 cm. Similarly, the average left interorbital distance at the middle was measured as 10.9±0.12 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 13.2±0.17 cm. The average left interorbital distance at the caudal aspect was found to be 16.5±0.14 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 21.1±0.12 cm.

The average contribution of frontal bone forming the left orbit was measured as 6.5±0.06 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 7.1±0.08 cm. Similarly, the average contribution of frontal bone forming the right orbit was found to be 6.2±0.11 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 8.3±0.13 cm. The average contribution of lacrimal bone forming the left orbit was measured as 4.2±0.15 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 2.7±0.09 cm. Similarly, the average contribution of lacrimal bone forming the right orbit was measured as 4.9±0.13 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 3.1±0.08 cm. The average contribution of zygomatic bone forming the left orbit was measured as 6.1±0.11 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 6.6±0.19 cm. Similarly, the average contribution of zygomatic bone forming the right orbit was found to be 5.6±0.16 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 6.4±0.12 cm.

The average length of left orbital process of frontal bone was measured as 5.1±0.05 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 5.3±0.07 cm. Similarly, the average length of right orbital process of frontal bone (Fig 1) was found to be 3.9±0.04 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 4.2±0.07 cm. The average width of left orbital process of malar bone was measured as 1.2±0.001 cm in female, which was significantly more ($p<0.05$) than that of males, where it was recorded as 1.0±0.001 cm.

Biometrical observations of foramina of skull

The biometrical observations of different foramina of skull of Blue bull revealed characteristic differences between the sexes. The average diameter of left supraorbital foramen was measured as 0.31±0.001 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 0.7±0.003 cm. Similarly, the average diameter of right supraorbital foramen was found to be 0.27±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 0.9±0.002 cm. The average diameter of left infaorbital foramen was measured as 0.53±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 1.1±0.005 cm. The average diameter of left optic foramen (Fig 2) was measured as 0.37±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 1.1±0.006 cm. Similarly, the average diameter of right optic foramen was found to be 0.35±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 1.1±0.003 cm Table 2.

The average diameter of left foramen orbitorotandum was measured as 0.24±0.001 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 0.5±0.001 cm. Similarly, the average diameter of right foramen orbitorotandum was found to be 0.25±0.001 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 0.5±0.001 cm. The average diameter of left foramen ovale (Fig 3) was measured as 0.8±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 1.5±0.005 cm. Similarly, the average diameter of right foramen ovale was found to be 0.9±0.002 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 1.5±0.008 cm. The average diameter of left foramen lacerum was measured as

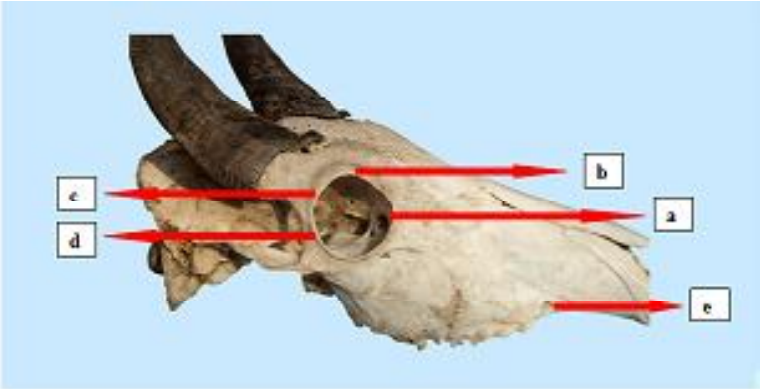

Fig 1: Right lateral view of skull of adult male Blue bull (*Boselaphus tragocamelus*) showing a) Anterior wall of orbit b) Roof of orbit c) Orbital process of frontal bone d) Orbital process of malar bone e) Infraorbital foramen.

0.40±0.001 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 1.2±0.008 cm. Similarly, the average diameter of right foramen lacerum was found to be 0.43±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 1.4±0.006 cm.

The average diameter of left posterior glenoid foramen was measured as 0.40±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 0.9±0.005 cm. Similarly, the average diameter of right posterior glenoid foramen was found to be 0.38±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 1.1±0.004 cm. The average diameter of left stylomastoid foramen was measured as 0.31±0.001 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 0.7±0.002 cm. Similarly, the average diameter of right stylomastoid foramen was found to be 0.36±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 1.1±0.005 cm. The average diameter of left cranial palatine foramen was measured as 0.249±0.001 cm in female, which was significantly more (p<0.05) than that of males, where it was recorded as 0.20±0.001 cm. The average diameter of left caudal palatine foramen was measured as 0.354±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 0.50±0.002 cm. Similarly, the average diameter of right caudal palatine foramen was found to be 0.356±0.001 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 0.50±0.002 cm.

The average vertical diameter of foramen magnum was measured as 3.5±0.12 cm in female, which was significantly more (p<0.05) than that of males, where it was recorded as 2.68±0.10 cm. Similarly, the average transverse diameter of foramen magnum was found to be 3.2±0.15 cm in female, which was significantly more (p<0.05) than that of males, where it was recorded as 2.97±0.08 cm. The average circumference of foramen magnum was found to be 11.8±0.22 cm in female, which was significantly more (p<0.05) than that of males, where it was recorded as 11.1±0.17 cm.

The average distance between left and right supraorbital foramina was measured as 5.1±0.15 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 6.1±0.20 cm. The average dorsal distance between left and right infraorbital foramina was measured as 6.9±0.21 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 8.1±0.16 cm. Similarly, the average ventral distance between left and right infraorbital foramina was found to be 5.7±0.13 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 6.1±0.15 cm.

The average distance between right optic foramen and right foramen orbitorotandum was measured as 5.1±0.23 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 5.6±0.26 cm. Similarly, the average distance between right foramen orbitorotandum and right foramen ovale was found to be 0.9±0.002 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 2.1±0.04 cm. The average distance between left supraorbital and infraorbital foramina was measured as 12.3±0.13 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 14.1±0.10 cm. Similarly, the average distance between right supraorbital and infraorbital foramina was found to be 12.5±0.17 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 13.9±0.19 cm.

The average maximum distance between two cranial palatine foramina was measured as 1.8±0.05 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 3.3±0.12 cm. Similarly, the average minimum distance between two cranial palatine foramina was found to be 1.3±0.03 cm in female, which was significantly less (p<0.05) than that of males, where it was recorded as 2.2±0.06 cm. The average distance between

Fig 2: Orbital cavity of adult female Blue bull (*Boselaphus tragocamelus*) showing optic foramen (Red arrow).

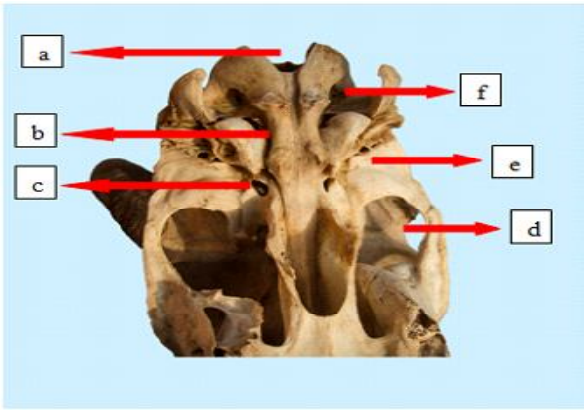

Fig 3: Ventral view of skull of adult male Blue bull (*Boselaphus tragocamelus*) showing a) Foramen magnum b) Foramen lacerum c) Foramen ovale d) Orbital cavity e) Posterior glenoid foramen f) Hypoglossal foramen.

left cranial and caudal palatine foramina was measured as 4.4±0.18 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 5.5±0.12 cm. Similarly, average distance between right cranial and caudal palatine foramina was found to be 4.7±0.13 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 6.1±0.15 cm. The average distance between the two foramen lacerum was found to be 2.8±0.12 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 3.9±0.14 cm.

The average distance of left foramen orbitorotandum from left orbit was measured as 6.6±0.10 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 7.4±0.13 cm. Similarly, the average distance of right foramen orbitorotandum from right orbit was found to be 6.8±0.12 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 8.5±0.17 cm. The average distance of left foramen ovale from left orbit was measured as 8.9±0.11 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 10.1±0.14 cm. Similarly, the average distance of right foramen ovale from right orbit was found to be 8.1±0.10 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 10.2±0.12 cm.

The average distance between left facial tuberosity and left infraorbital foramen was measured as 5.6±0.07 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 6.1±0.08 cm. Similarly, the average distance between right facial tuberosity and right infraorbital foramen was found to be 6.0±0.16 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 7.9±0.19 cm. The average distance between left infraorbital foramen and rostral part of incisive bone was measured as 8.1±0.20 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 13.7±0.24 cm. Similarly, the average distance between right infraorbital foramen and rostral part of incisive bone was found to be 7.8±0.11 cm in female, which was significantly less ($p<0.05$) than that of males, where it was recorded as 13.6±0.13 cm.

CONCLUSION

The various parameters of orbital cavity and skull such as orbital diameters, orbital depth, orbital circumference, interorbital distance, length and width of orbital processes of frontal and malar bones, diameters of foramina of skull and distance between individual foramina, showed characteristic sexual variations. There is no previous information on these parameters in orbital cavity and foramina of skull of Blue bull, nor in any other domestic animals with which comparisons could be made. It is believed that the data presented above would form a baseline for further work especially comparability and compatibility are now desirable traits as efforts are geared up towards massive improvement in the livestock sector of the international economy.

ACKNOWLEDGEMENT

The authors are grateful to the Dean, CVASc., GBPUA and T, Pantnagar, Ministry of Environment of Forests (MoEF), New Delhi and Jodhpur Zoo, Rajasthan, India for providing official permission, necessary facilities and support for carrying out the research on the skull bones of Blue bull. Funding was provided by Department of Science and Technology, New Delhi and Indian Council of Agricultural research, New Delhi, India as Ph.D. grant (DST-INSPIRE Fellowship and ICAR-SRF (PGS) to the first author. The first author is very much grateful to the co-authors Dr. S.K. Joshi, S.S. Biswal, S.K. Sahu and I. Ali for their necessary inputs and statistical analysis of the data in preparation of this manuscript.

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