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Gross and morphometrical studies on the sacrum of blue bull (*Boselaphus tragocamelus*)

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Abstract

The present study was carried out on the sacrum of adult Blue bull (*Boselaphus tragocamelus*) of either sex. It was found that the sacrum was almost triangular in shape and consisted of five segments. The lateral borders were thin, sharp, concave and irregular. Cranially, the centrum of S1 was flattened from above downwards and had a transversely elongated convex surface known as the promontory for articulation with the caudal extremity of the body of the sixth lumbar vertebra. The apex was formed by the caudal end of the fifth sacral vertebra. The neural canal gradually decreased in depth and width caudally and the posterior opening was found to be approximately half the size of the anterior one. The cranial articular processes were reported to be large, concave medially and convex laterally. The dorsal supraspinous processes of the sacral segments were fused with each other that extended to the summits forming the median sacral crest. Further, the two lateral sacral crests were located on either side of the median sacral crest on the dorsal surface of the sacrum that represented the fusion of the articular processes of all the sacral segments. The ventral or pelvic surface was concave and presented a ventral groove throughout its length. There were presence of four pairs of dorsal and ventral sacral foramina on the respective dorsal and ventral surfaces of sacrum. Biometrical observations on different parameters reflected significance ($P < 0.05$) differences between the sexes of this species.

Keywords: Blue bull, sacrum, sacral crest, sacral foramina

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. Blue bull is considered sacred as per Hindu religion since Vedic period (1500-500 BC) and it is considered as religious. The Blue bull belongs to the family Bovidae and comes under the genus *Boselaphus*. The German Zoologist Scientist Peter Simon Pallas explained this species for the first time in 1766. English Zoologist Scientist Philips for the first time in 1833 narrated the binomial combination of the Blue bull. 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 adult male appears like ox and so called as Blue bull. They are usually seen in day times in the meadow pasture, timberland areas and agricultural land area. It prefers mostly plain or grassy plain and low hilly areas with shrubs, small bushes, scrub forests with scattered trees and does not usually found in dense forest areas, dense compact wood, etc. The Blue bulls are safeguarded beneath the IUCN since 2003 and also under safeguard of 'Schedule III' of the Indian Wildlife Protection Act, 1972^[1]. The Blue bull is safeguarded in various parts of India such as Gir National Park (Gujarat), Kumbhalgarh Sanctuary (Rajasthan) and Panchamarahi Biosphere Reserve, India. 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 developed a baseline data on the sacrum 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 no previous work has been done in this field on the Blue bull.

Materials and methods

The present study was carried out on the sacrum 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 vide letter no. F, 3(04) Tech-II/CCF/2013/2077, dated 12.12.2014, Chief Conservator of Forest (CCF) vide letter no. F, 3(04) Tech-11/CCF/2013/2326, dated 12.01.2015 and subsequently from the Deputy Conservator of Forest (Wildlife), Jodhpur s.n./sam/388-90, dated 22.01.2015. 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 [3]. The gross study was conducted under the supervision of the Zoo Authority, Jodhpur, India. The different parameters of sacrum were measured and subjected to routine statistical analysis [18] and independent samples t-Test with Systat Software Inc, USA and SPSS 16.0 version software.

Results and discussion

In the present study, the sacrum of the adult Blue bull was found to be almost triangular in shape and consisted of five segments. The present finding was concurrent with the reports given by [8] in horse and ox, [14] and [5] in ox, [7] in horse, [17] in camel and [10] in Calamian deer, whereas it disagreed with [2] in cat, [12] and [4] in dog and [20] in otters, where three numbers of sacral vertebrae were fused, [6] in sheep, [19] in porcupine and [13] in mole-rats, where four numbers of sacral vertebrae were fused, [9] in horse and [16] in mule and ass, where the sacrum comprised of the fusion of four to six usually five numbers of sacral vertebrae. Biometrical observations revealed that the average weight of the sacrum was found to be 324.87 ± 1.56 gm in adult Blue bull. Further, the average weight was measured as 321.29 ± 0.52 gm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 328.44 ± 1.22 gm (Table 1). The sacral openings were triangular in shape at the base and apex of sacrum in Blue bull (Fig. 1 and Fig. 2). The average vertical diameter of sacral canal at the base was found to be 1.22 ± 0.02 cm in adult Blue bull. Further, it was measured to be 1.19 ± 0.02 cm and 1.25 ± 0.03 cm in females and males respectively. Similarly, the average vertical diameter of the sacral canal at the apex was found to be 2.72 ± 0.03 cm in adult Blue bull. Further, it was measured to be 2.67 ± 0.04 cm and 2.77 ± 0.01 cm in females and males respectively. The average transverse diameter of the sacral canal at the base was found to be 1.25 ± 0.02 cm in adult Blue bull. Further, it was measured as 1.20 ± 0.01 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.30 ± 0.02 cm (Table 1). The average transverse diameter of the sacral canal at the apex was found to be 2.94 ± 0.02 cm in adult Blue bull. Further, it was measured to be 2.93 ± 0.03 cm and 2.94 ± 0.04 cm in females and males respectively [15]. reported the breadth of the sacral canal at the base and apex as 3.5 cm and 1.1 cm in Indian muntjac (*Muntiacus muntjac*) respectively.

The centrum of S1 was very wide and the entrance to the sacral canal was correspondingly wide and low. The average length of the body of the sacrum was found to be 24.92 ± 0.32 cm in adult Blue bull. Further, it was measured as 24.23 ± 0.24 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 25.60 ± 0.32 cm (Table 1) [15]. Reported the length of the sacral body as 10.2 cm in Indian muntjac (*Muntiacus muntjac*). The width of the body of the sacrum at the base was found to be 17.07 ± 0.11 cm in adult Blue bull. Further, it was measured to be 16.87 ± 0.15 cm

and 17.27 ± 0.12 cm in females and males respectively. Similarly, the width of the body of the sacrum at the apex was found to be 6.07 ± 0.18 cm in adult Blue bull. Further, it was measured to be 5.80 ± 0.29 cm and 6.33 ± 0.19 cm in females and males respectively (Table 1) [15]. Reported the breadth of the sacrum at the base and apex was 3.8 cm and 1.2 cm in Indian muntjac (*Muntiacus muntjac*) respectively [3]. Reported that the greatest length of the sacrum was found to be 8.62 ± 0.0579 cm in Black buck.

The cranial articular processes were reported to be large, concave medially and convex laterally. They were widely separated from each other. The present observations agreed with the findings made by [6] in the ox and horse, [14] in ox and [17] in camel. Biometrical observations confirmed that the average distance between the two cranialmost articular processes at the dorsal aspect of the first sacral vertebra or sacrum was found to be 4.52 ± 0.10 cm in adult Blue bull. Further, it was measured to be 4.33 ± 0.07 cm and 4.70 ± 0.12 cm in females and males respectively. The average distance between the two cranialmost articular processes in the middle of the first sacral vertebra or sacrum was found to be 6.18 ± 0.12 cm in adult Blue bull. Further, it was measured to be 5.97 ± 0.09 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 6.40 ± 0.12 cm. However, the average distance between the two cranialmost articular processes at the ventral aspect of the first sacral vertebra or sacrum was found to be 4.65 ± 0.13 cm in adult Blue bull. Further, it was measured to be 4.43 ± 0.15 cm and 4.87 ± 0.15 cm in females and males respectively (Table 1).

The dorsal supraspinous processes of the sacral segments were fused with each other. The fusion extended to the summits forming the median sacral crest or the Crista sacralis media, which was similar to the findings of [6] and [14] in ox and [13] in mole-rats and was dissimilar with the findings of the [17] in camel, [20] in otters, [9] in horse, where fusion was not complete, Getty *et al.* (1930) observed the absence of fusion in horse and that of S1 and S2 were fused in sheep [10]. investigated that the dorsal supraspinous process of S1 was not completely fused with the other sacral segments in Calamian deer [8]. Found that the free ends of the dorsal supraspinous processes were separate, but their bases were fused in carnivores and horse, whereas an indistinct crest was present in pig [4]. Reported that the dorsal supraspinous processes might be much reduced or even absent in pig, but when present they preserved their independence in horse and dog.

The margin of the median sacral crest was thick, rough and convex. The caudal end of the median sacral crest formed a pointed projection over the opening of the sacral canal. Biometrical observations revealed that the average length of the median sacral crest was found to be 20.33 ± 0.26 cm in adult Blue bull. Further, it was measured as 19.87 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 20.80 ± 0.32 cm (Table 1). The height of the median sacral crest at the base was found to be 5.70 ± 0.19 cm in adult Blue bull. Further, it was measured to be 5.37 ± 0.24 cm and 6.03 ± 0.12 cm in females and males respectively. Similarly, the height at the middle was found to be 4.73 ± 0.16 cm in adult Blue bull. Further, it was measured to be 4.50 ± 0.23 cm and 4.97 ± 0.12 cm in females and males respectively. The height at the apex was found to be 1.75 ± 0.09 cm in adult Blue bull. Further, it was measured to be 1.67 ± 0.12 cm and 1.83 ± 0.15 cm in females and males respectively (Table 1). The thickness of the median sacral

crest at the base was found to be 0.50 ± 0.04 cm in adult Blue bull. Further, it was measured as 0.42 ± 0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.57 ± 0.03 cm. Similarly, the thickness at the middle was found to be 2.13 ± 0.05 cm in adult Blue bull. Further, it was measured as 2.03 ± 0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.23 ± 0.04 cm (Table 1).

The two lateral sacral crests were situated on either side of the median sacral crest on the dorsal surface of the sacrum in Blue bull (Fig. 3). The lateral sacral crests were thick, low and represented the fusion of the articular processes of all the sacral segments in Blue bull that simulated with the findings of [6, 9, 14] in the ox and [8] in ruminants. But in horse, the lateral sacral crest was formed by a series of tubercles according to [6], in the form of low projections in dog according to [12]. Biometrical observations revealed that the average length of the lateral sacral crest was found to be 19.09 ± 0.38 cm in adult Blue bull. Further, it was measured as 18.17 ± 0.25 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 20.02 ± 0.49 cm (Table 1). The average distance between the lateral and median crests at the base was found to be 6.65 ± 0.08 cm in adult Blue bull. Further, it was measured as 6.47 ± 0.10 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 6.83 ± 0.09 cm. Similarly, the distance at the apex was found to be 1.83 ± 0.10 cm in adult Blue bull. Further, it was measured as 1.63 ± 0.11 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.03 ± 0.11 cm (Table 1).

There were four dorsal sacral foramina on either side of the sacrum that were arranged in two rows (Fig. 4). The first two were present medial to the lateral sacral crest, whereas the last two were situated lateral to the lateral sacral crest. The average diameter of the first dorsal sacral foramen was found to be 0.47 ± 0.02 cm in adult Blue bull. Further, it was measured as 0.43 ± 0.02 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.51 ± 0.03 cm. The average diameter of the second dorsal sacral foramen was found to be 0.05 ± 0.01 cm in adult Blue bull. Further, it was measured as 0.29 ± 0.01 cm and 0.33 ± 0.02 cm in females and males respectively. The average diameter of the third dorsal sacral foramen was found to be 0.05 ± 0.01 cm in adult Blue bull. Further, it was measured as 0.41 ± 0.01 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.48 ± 0.01 cm. The average diameter of the fourth dorsal sacral foramen was found to be 1.19 ± 0.07 cm in adult Blue bull. Further, it was measured as 1.16 ± 0.11 cm and 1.23 ± 0.11 cm in females and males respectively (Table 1). The average distance between the first and second dorsal sacral foramina was found to be 4.02 ± 0.07 cm in adult Blue bull. Further, it was measured as 3.83 ± 0.06 cm in females that was significantly lesser ($P<0.05$) than that of males, where they were found to be 4.20 ± 0.07 cm apart. The average distance between the second and third dorsal sacral foramina was found to be 4.79 ± 0.08 cm in adult Blue bull. Further, it was measured as 4.65 ± 0.09 cm and 4.93 ± 0.11 cm in females and males respectively. The average distance between the third and fourth dorsal sacral foramina was found to be 4.85 ± 0.10 cm in adult Blue bull. Further, it was measured as 4.65 ± 0.13 cm in females that was significantly lesser ($P<0.05$) than that of males, where they were found to be 5.05 ± 0.09 cm apart. The average distance of 1st dorsal sacral foramen from the base of the sacrum was found to be

3.23 ± 0.11 cm in adult Blue bull. Further, it was measured as 3.10 ± 0.13 cm and 3.37 ± 0.16 cm in females and males respectively. The average distance of 4th dorsal sacral foramen from the apex of the sacrum was found to be 3.77 ± 0.11 cm in adult Blue bull. Further, it was measured as 3.52 ± 0.11 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 4.02 ± 0.11 cm (Table 1).

The average distance between the first right dorsal sacral foramen from right lateral border of sacrum was found to be 1.42 ± 0.08 cm in adult Blue bull. Further, it was measured as 1.27 ± 0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.57 ± 0.03 cm. The average distance between the second right dorsal sacral foramen from right lateral border of sacrum was found to be 2.30 ± 0.09 cm in adult Blue bull. Further, it was measured as 2.17 ± 0.09 cm and 2.43 ± 0.12 cm in females and males respectively. The average distance between the third right dorsal sacral foramen from the right lateral border of the sacrum was found to be 1.95 ± 0.10 cm in adult Blue bull. Further, it was measured as 1.77 ± 0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.13 ± 0.09 cm. The average distance between the fourth right dorsal sacral foramen from right lateral border of the sacrum was found to be 1.97 ± 0.07 cm in adult Blue bull. Further, it was measured as 1.87 ± 0.09 cm and 2.07 ± 0.09 cm in females and males respectively (Table 1). The average distance between the first left dorsal sacral foramen from the left lateral border of sacrum was found to be 1.65 ± 0.10 cm in adult Blue bull. Further, it was measured as 1.47 ± 0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.83 ± 0.09 cm. The average distance between the second left dorsal sacral foramen from the left lateral border of sacrum was found to be 1.82 ± 0.08 cm in adult Blue bull. Further, it was measured as 1.67 ± 0.09 cm and 1.97 ± 0.07 cm in females and males respectively. Similarly, the average distance between the third left dorsal sacral foramen from the left lateral border of the sacrum was found to be 2.07 ± 0.06 cm in adult Blue bull. Further, it was measured as 2.00 ± 0.06 cm and 2.13 ± 0.09 cm in females and males respectively. The average distance between the fourth left dorsal sacral foramen from the left lateral border of the sacrum was found to be 1.73 ± 0.06 cm in adult Blue bull. Further, it was measured as 1.70 ± 0.10 cm and 1.77 ± 0.09 cm in females and males respectively (Table 1).

There were four large ventral sacral foramina present on either side of the ventral or pelvic surface of sacrum (Fig. 5). They opened into the neural canal in Blue bull and corresponded to the intervertebral foramen of the other vertebrae. The present findings were in agreement with the reports given by [5, 14] in ox, [6, 9] in horse and [17] in camel, but according to [2] in cat and [12] in a dog, there were two pairs of dorsal and two pairs of ventral sacral foramina, while [13] found that there were only one pair of dorsal sacral foramina and three pairs of ventral sacral foramina in mole-rats. The ventral or pelvic surface of the sacrum was arched and concave in both directions. There were transverse lines known as *Linea transverse* that indicated the fusion of sacral segments in Blue bull. The present investigation was in agreement with the findings in the ox and horse [6], in dog [4, 12], in horse [9], in camel [17] and in mole-rats [13].

Biometrical observations revealed that the average diameter of the first ventral sacral foramen was found to be 1.17 ± 0.04 cm in adult Blue bull. Further, it was measured as 1.15 ± 0.06 cm and 1.20 ± 0.05 cm in females and males respectively. Similarly, the average diameter of the second ventral sacral

foramen was found to be 1.45 ± 0.06 cm in adult Blue bull. Further, it was measured as 1.41 ± 0.08 cm and 1.50 ± 0.08 cm in females and males respectively. The average diameter of the third ventral sacral foramen was found to be 1.29 ± 0.02 cm in adult Blue bull. Further, it was measured as 1.26 ± 0.01 cm that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.32 ± 0.02 cm. The average diameter of the fourth ventral sacral foramen was found to be 1.27 ± 0.04 cm in adult Blue bull. Further, it was measured as 1.23 ± 0.05 cm and 1.31 ± 0.06 cm in females and males respectively (Table 1). The average distance between the first and second ventral sacral foramina was found to be 2.35 ± 0.06 cm in adult Blue bull. Further, it was measured as 2.22 ± 0.06 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 2.48 ± 0.05 cm apart. Similarly, the average distance between the second and third ventral sacral foramina was found to be 3.63 ± 0.07 cm in adult Blue bull. Further, it was measured as 3.47 ± 0.06 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 3.80 ± 0.09 cm apart. The average distance between the third and fourth ventral sacral foramina was found to be 3.82 ± 0.06 cm in adult Blue bull. Further, it was measured as 3.68 ± 0.09 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 3.95 ± 0.06 cm apart (Table 1). The average distance of first ventral sacral foramen from the base of the sacrum was found to be 3.18 ± 0.08 cm in adult Blue bull. Further, it was measured as 3.03 ± 0.09 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 3.33 ± 0.10 cm apart. The average distance between the 4th ventral sacral foramen from the apex of the sacrum was found to be 3.58 ± 0.08 cm in adult Blue bull. Further, it was measured as 3.38 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 3.78 ± 0.08 cm apart (Table 1). The average distance between the two ventral sacral foramina of the first sacral vertebra was found to be 3.08 ± 0.06 cm in adult Blue bull. Further, it was measured as 2.97 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 3.20 ± 0.06 cm apart. The average distance between the two ventral sacral foramina of second sacral vertebra was found to be 2.27 ± 0.06 cm in adult Blue bull. Further, it was measured as 2.17 ± 0.03 cm and 2.37 ± 0.09 cm in females and males respectively. The average distance between the two ventral sacral foramina of third sacral vertebra was found to be 1.70 ± 0.09 cm in adult Blue bull. Further, it was measured as 1.53 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where they were found to be 1.87 ± 0.09 cm apart. The average distance between the two ventral sacral foramina of fourth sacral vertebra was found to be 1.20 ± 0.08 cm in adult Blue bull. Further, it was measured as 1.07 ± 0.09 cm and 1.33 ± 0.09 cm in females and males respectively (Table 1). The average distance between the first right ventral sacral foramen from the right lateral border of the sacrum was found to be 1.92 ± 0.07 cm in adult Blue bull. Further, it was measured as 1.77 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.07 ± 0.03 cm. The average distance between the second right ventral sacral foramen from the right lateral border of the sacrum was found to be 1.00 ± 0.07 cm in adult Blue bull. Further, it was measured as 0.90 ± 0.12 cm and 1.10 ± 0.06 cm in females and males respectively. Similarly, the average distance between the third right ventral sacral foramen from the right lateral border of the sacrum was found to be

1.52 ± 0.06 cm in adult Blue bull. Further, it was measured as 1.43 ± 0.09 cm and 1.60 ± 0.06 cm in females and males respectively. The average distance between the fourth right ventral sacral foramen from the right lateral border of sacrum was found to be 1.28 ± 0.06 cm in adult Blue bull. Further, it was measured as 1.17 ± 0.03 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 1.40 ± 0.06 cm (Table 1). The average distance between the first left ventral sacral foramen from left lateral border of sacrum was found to be 1.95 ± 0.10 cm in adult Blue bull. Further, it was measured as 1.77 ± 0.09 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 2.13 ± 0.09 cm. The average distance between the second left ventral sacral foramen from the left lateral border of sacrum was found to be 0.85 ± 0.11 cm in adult Blue bull. Further, it was measured as 0.67 ± 0.12 cm and 1.03 ± 0.12 cm in females and males respectively. Similarly, the average distance between the third left ventral sacral foramen from left lateral border of sacrum was found to be 1.67 ± 0.08 cm in adult Blue bull. Further, it was measured as 1.53 ± 0.09 cm and 1.80 ± 0.06 cm in females and males respectively. The average distance between the fourth left ventral sacral foramen from left lateral border of sacrum was found to be 1.43 ± 0.11 cm in adult Blue bull. Further, it was measured as 1.27 ± 0.12 cm and 1.60 ± 0.12 cm in females and males respectively (Table 1).

The lateral borders of the sacrum were found to be thin, sharp, concave and irregular in Blue bull which was same as reported by ^[14] in ox and ^[11] in chital, but according to ^[6] the lateral borders were rough, thick anteriorly and thin posteriorly in horse. The base of the sacrum was formed by the cranial extremity of S1. Cranially, the centrum of S1 was flattened from above downwards and had a transversely elongated convex surface known as the promontory for articulation with the caudal extremity of the body of L6. The promontory of the sacrum is used as one of the reference points for measuring the diameters of pelvic cavity that can be useful in differentiation of sex and ascertaining the prognosis of parturition. Further, the neural ring was triangular in sacrum with its lower angles were rounded off in Blue bull that were similar to the findings of ^[6] in horse and ox, ^[14] in ox, ^[12] in dog, ^[17] in camel, ^[8] in ruminants and ^[11] in chital. The pelvic or ventral surface of the sacrum was concave in both directions and was marked by a central groove known as Sulcus vasculosus. This groove provided the passage for the middle sacral artery. The average length of the central ventral groove was found to be 20.47 ± 0.53 cm in adult Blue bull. Further, it was measured as 19.47 ± 0.43 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 21.47 ± 0.47 cm (Table 1).

The lateral parts of the base of sacrum were known as the alae or wings. They were curved downward and forward. The wings were quadrangular, short, compressed from before backward and high dorso-ventrally. They presented an extensive cranial surface that was non-articular and concave from side to side, whereas the caudal surface was rough and there was a triangular area at its lower part that articulated with the ilium of Os coxae in Blue bull. The present findings were similar to the observations of ^[6, 14] in ox, ^[17] in camel and ^[20] in otters, but were dissimilar with ^[12] who stated that the auricular surfaces were large, rough and presented semi-lunar facet in dogs, with ^[6] who observed that the wing had a large, oval, slightly convex surface cranially for articulation with the transverse process of L6 in horse, whereas there was no articulation in Blue bull ^[8]. Reported that S2 contributed to the formation of the sacral wings in carnivores, pigs and small

ruminants, but this was not found in Blue bull. Biometrical observations revealed that the average width of the wings of sacrum was found to be 4.88 ± 0.06 cm in adult Blue bull. Further, it was measured as 4.77 ± 0.07 cm in females that was significantly lesser ($P < 0.05$) than that of males, where it was found to be 5.00 ± 0.07 cm (Table 1).

The apex of the sacrum was formed by the caudal end of S5. The neural canal gradually decreased in depth and width

caudally and the posterior opening was found to be approximately half the size of the anterior one. It presented a small triangular neural ring centrally above which was a pointed projection of the caudal end of the median sacral crest. The apex was usually a little wider than the part just posterior to the wings in Blue bull. The present findings were similar to the reports of [14] in the ox and [12] in dog, but dissimilar to the observations of [17] in camel.

Table 1: The measurements of sacrum of Blue bull in cm.

Parameters		Mean	SD	SE	Female (Mean±SE)	Male (Mean±SE)	
Weight (gm)		324.87	3.81	1.56	321.29*±0.52	328.44±1.22	
Body	Length	24.92	0.79	0.32	24.23*±0.24	25.60±0.32	
	Width	Base	17.07	0.27	0.11	16.87±0.15	17.27±0.12
		Apex	6.07	0.43	0.18	5.80±0.29	6.33±0.19
Diameter of sacral canal	Vertical	Base	1.22	0.05	0.02	1.19±0.02	1.25±0.03
		Apex	2.72	0.07	0.03	2.67±0.04	2.77±0.01
	Transverse	Base	1.25	0.06	0.02	1.20*±0.01	1.30±0.02
		Apex	2.94	0.05	0.02	2.93±0.03	2.94±0.04
	Diameter of dorsal sacral foramen	First	0.47	0.07	0.02	0.43*±0.02	0.51±0.03
Second		0.31	0.05	0.01	0.29±0.01	0.33±0.02	
Third		0.44	0.05	0.01	0.41*±0.01	0.48±0.01	
Fourth		1.19	0.26	0.07	1.16±0.11	1.23±0.11	
Distance between the adjacent dorsal sacral foramina	First-second	4.02	0.25	0.07	3.83*±0.06	4.20±0.07	
	Second-third	4.79	0.28	0.08	4.65±0.09	4.93±0.11	
	Third-fourth	4.85	0.33	0.10	4.65*±0.13	5.05±0.09	
Diameter of ventral sacral foramen	First	1.17	0.13	0.04	1.15±0.06	1.20±0.05	
	Second	1.45	0.19	0.06	1.41±0.08	1.50±0.08	
	Third	1.29	0.05	0.02	1.26*±0.01	1.32±0.02	
	Fourth	1.27	0.13	0.04	1.23±0.05	1.31±0.06	
Distance between the adjacent ventral sacral foramina	First-second	2.35	0.19	0.06	2.22*±0.06	2.48±0.05	
	Second-third	3.63	0.25	0.07	3.47*±0.06	3.80±0.09	
	Third-fourth	3.82	0.22	0.06	3.68*±0.09	3.95±0.06	
Width of wings of sacrum		4.88	0.20	0.06	4.77*±0.07	5.00±0.07	
Thickness of median sacral crest	Base	0.50	0.09	0.04	0.42*±0.03	0.57±0.03	
	Middle	2.13	0.12	0.05	2.03*±0.03	2.23±0.04	
Median sacral crest	Length	20.33	0.63	0.26	19.87*±0.07	20.80±0.32	
	Height	Base	5.70	0.47	0.19	5.37±0.24	6.03±0.12
		Middle	4.73	0.38	0.16	4.50±0.23	4.97±0.12
		Apex	1.75	0.23	0.09	1.67±0.12	1.83±0.15
Length of lateral sacral crest		19.09	1.33	0.38	18.17*±0.25	20.02±0.49	
Distance between lateral and medial sacral crests	Base	6.65	0.29	0.08	6.47*±0.10	6.83±0.09	
	Apex	1.83	0.33	0.10	1.63*±0.11	2.03±0.11	
Distance of 4 th sacral foramina from apex	Dorsal	3.77	0.37	0.11	3.52*±0.11	4.02±0.11	
	Ventral	3.58	0.27	0.08	3.38*±0.07	3.78±0.08	
Distance of 1 st sacral foramina from base	Dorsal	3.23	0.37	0.11	3.10±0.13	3.37±0.16	
	Ventral	3.18	0.27	0.08	3.03*±0.09	3.33±0.10	
Distance between two ventral sacral foramina of same sacral segment	S1	3.08	0.15	0.06	2.97*±0.03	3.20±0.06	
	S2	2.27	0.15	0.06	2.17±0.03	2.37±0.09	
	S3	1.70	0.22	0.09	1.53*±0.07	1.87±0.09	
	S4	1.20	0.20	0.08	1.07±0.09	1.33±0.09	
Distance between two cranial articular processes (of S1)	Dorsal	4.52	0.25	0.10	4.33±0.07	4.70±0.12	
	Middle	6.18	0.29	0.12	5.97*±0.09	6.40±0.12	
	Ventral	4.65	0.33	0.13	4.43±0.15	4.87±0.15	
Length of ventral groove		20.47	1.30	0.53	19.47*±0.43	21.47±0.47	
Distance between right sacral foramen from right lateral border	Dorsal	1 st	1.42	0.19	0.08	1.27*±0.09	1.57±0.03
		2 nd	2.30	0.22	0.09	2.17±0.09	2.43±0.12
		3 rd	1.95	0.24	0.10	1.77*±0.09	2.13±0.09
		4 th	1.97	0.18	0.07	1.87±0.09	2.07±0.09
	Ventral	1 st	1.92	0.18	0.07	1.77*±0.07	2.07±0.03
		2 nd	1.00	0.18	0.07	0.90±0.12	1.10±0.06
		3 rd	1.52	0.15	0.06	1.43±0.09	1.60±0.06
		4 th	1.28	0.15	0.06	1.17*±0.03	1.40±0.06
Distance between left sacral foramen from left lateral border	Dorsal	1 st	1.65	0.24	0.10	1.47*±0.09	1.83±0.09
		2 nd	1.82	0.20	0.08	1.67±0.09	1.97±0.07
		3 rd	2.07	0.14	0.06	2.00±0.06	2.13±0.09
		4 th	1.73	0.15	0.06	1.70±0.10	1.77±0.09
	Ventral	1 st	1.95	0.24	0.10	1.77*±0.09	2.13±0.09
		2 nd	0.85	0.27	0.11	0.67±0.12	1.03±0.12
		3 rd	1.67	0.19	0.08	1.53±0.09	1.80±0.06
		4 th	1.43	0.26	0.11	1.27±0.12	1.60±0.12

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

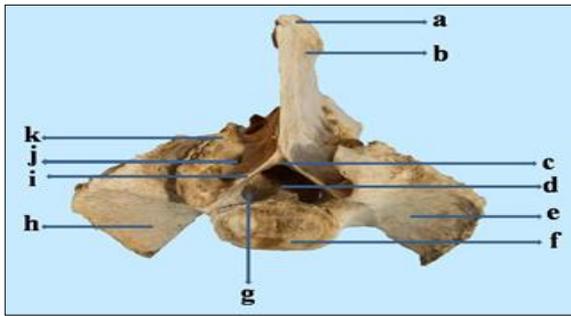


Fig 1: Cranial view of Sacrum (S₁ – S₅) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Median sacral crest, b) Dorsal supraspinous process of S₃, c) Laminae, d) Sacral vertebral foramen, e) Wing, f) Anterior surface of body or base, g) First ventral sacral foramen, h) Articular surface for ilium, i) Pedicle, j) Second dorsal sacral foramen and k) Lateral sacral crest.

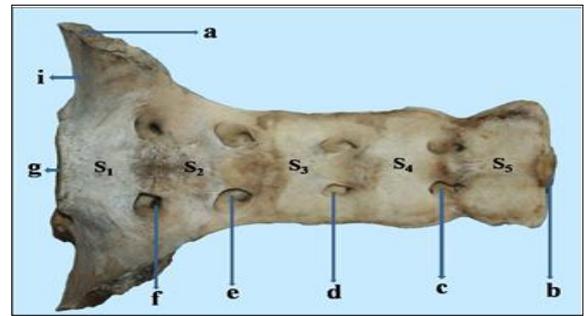


Fig. 5: Ventral view of Sacrum (S₁ – S₅) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Wing, b) Apex, c) Fourth ventral sacral foramen, d) Third ventral sacral foramen, e) Second ventral sacral foramen, f) First ventral sacral foramen, g) Base and i) Articular surface for ilium.

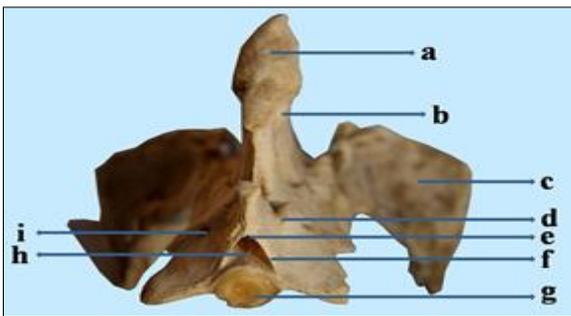


Fig 2: Caudal view of Sacrum (S₁ – S₅) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Median sacral crest, b) Dorsal supraspinous process of S₃, c) Wing, d) Lateral sacral crest, e) Laminae, f) Pedicle, g) Apex, h) Sacral vertebral foramen and i) Fourth dorsal sacral foramen.

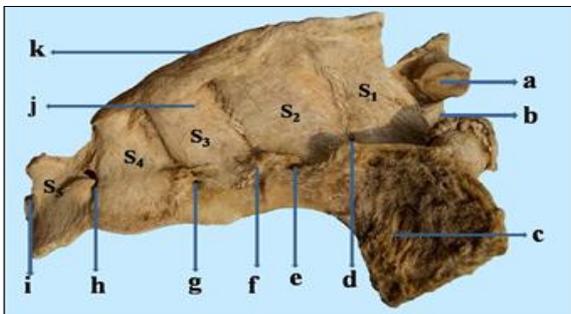


Fig. 3: Lateral view of Sacrum (S₁ – S₅) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Anterior articular process, b) Base, c) Wing, d) First dorsal sacral foramen, e) Second dorsal sacral foramen, f) Lateral sacral crest, g) Third dorsal sacral foramen, h) Fourth dorsal sacral foramen, i) Apex, j) Dorsal supraspinous process of S₃ and k) Median sacral crest.

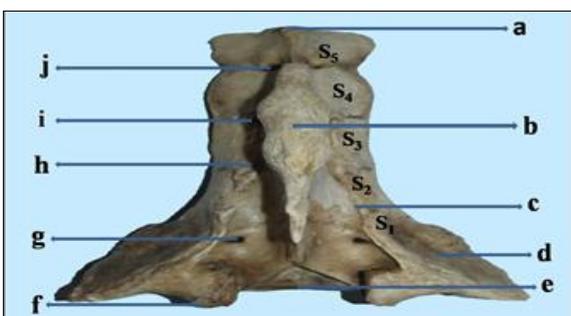


Fig. 4: Dorsal view of Sacrum (S₁ – S₅) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Apex, b) Median sacral crest, c) Lateral sacral crest, d) Wing, e) Base, f) Anterior articular process, g) First dorsal sacral foramen, h) Second dorsal sacral foramen, i) Third dorsal sacral foramen and j) Fourth dorsal sacral foramen.

Conclusions

The present gross and morphometrical study on the sacrum of adult Blue bull revealed that the sacrum was almost triangular in shape and consisted of five segments. The lateral borders were thin, sharp, concave and irregular. The base was formed by the cranial extremity of first sacral vertebra. The wings were quadrangular, short, compressed from before backward and high dorso-ventrally. The apex was formed by the caudal end of the fifth sacral vertebra. The cranial and caudal openings of sacral canal were triangular. The cranial articular processes were reported to be large, concave medially and convex laterally. The dorsal supraspinous processes of the sacral segments were fused with each other that extended to the summits forming the median sacral crest. Further, the two lateral sacral crests were located on either sides of the median sacral crest on the dorsal surface of the sacrum. The ventral or pelvic surface was concave and presented a ventral groove throughout its length. Four pairs of dorsal and ventral sacral foramina were found on the respective dorsal and ventral surfaces of the sacrum. Biometrical observations reflected that the measured parameters were more in males that differed significantly ($P < 0.05$) from the females. There is no previous information on these parameters in the sacrum of Blue bull, nor in any other domestic animals in India with which comparisons could be made. We therefore believe 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.

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