MORPHOMETRIC STUDY ON THE HOOF OF BUFFALO*

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Received: 26.04.2019
Accepted: 09.05.2019

Abstract

Morphometric study on the hoof of buffalo was undertaken in the present work. The toe length, toe height, toe angle, sole length, sole width, heel bulb length, heel bulb height and heel bulb width of lateral and medial claws of both forelimbs and hind limbs were recorded separately. There was no statistically significant correlation between the body weight and the different morphometric measurements of hooves. The average toe length of fore and hind limbs were 8.16±0.19 cm and 7.795±0.253 cm respectively. The average toe height of fore and hind limbs were 5.535±0.472 cm and 5.20±0.48 cm. Maximum sole length was recorded in the left lateral claw of hindlimb (13.45±0.833 cm) and minimum in the right lateral of forelimb (12.5±0.83 cm). Maximum sole width was recorded in the right medial claw of forelimb (6.45±0.46) and minimum in the right medial claw of hindlimb (4.75±0.592). There existed a significant difference in the mean toe length, toe height, sole length, sole width, heel bulb length, heel bulb height and heel bulb width of forelimb and hindlimb and showed greater values for forelimb.

Key words : *Morphomtery, hoof, buffalo*

The hoof is the most important part of the limbs. There are considerable variations in its shape, size, histology and blood supply in different species of animals. The optimal production and performance of the animal will be reduced when affected with hoof ailments. Lameness in dairy cattle causes crippling economic losses to the industry. Up to 52% (average 20-25%) of high producing, intensively managed dairy cows going lame each year and the loss in milk production is devastating for producers (Barker *et al*., 2010, Espejo *et al.,* 2006, Von Keiserlingk *et al.,* 2012). Feeding pattern plays an important role in the occurrence of laminitis and it has been suggested that the acidic pH of rumen contributed to its

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pathogenesis (Cook *et al.,*2004*,* Nordlund *et al.,* 2004). The incidence of foot diseases in buffaloes is very minimal or they are considered to be more resistant to hoof ailments. Basic studies aimed at gaining a better understanding of the morphology and morphometry of the hoof in buffaloes are scanty and therefore deserving the attention of researchers. Therefore the present study was undertaken to understand the structural specialities of the hoof capsule of the digits in this species and comparing this with the crossbred dairy cattle. The result of the present study can be employed to improve the hoof quality and to reduce the vulnerability to foot diseases of crossbred dairy cattle.

Materials and Methods

Morphometric studies on the hoof of buffalo were undertaken in the present work. Hooves of six adult she buffaloes collected from the animals slaughtered at Meat Technology Unit, Kerala Veterinary and Animal Sciences University, Mannuthy formed the materials for the present study. The morphometric values were determined following the method described by Nuss *et al*. (2011). The linear measurements of the hoof were recorded using a measuring tape to the scale of 0.1 cm and the angles were measured using a protractor. The following parameters were recorded- toe length, toe height, toe angle, sole length, sole width, heel bulb length, heel bulb height and heel bulb width (Figure 1). The toe length was measured from the border between the skin and the coronet to the distal end of the dorsal wall and parallel to the digital axis. The toe angle was measured between this line on the dorsal wall of the horn capsule and the sole. The length of the heel bulb will be measured between the caudal end of the sole to the highest point of the heel bulb. Heel bulb height was measured along a line perpendicular to an imaginary caudal extension of the sole to the highest point of the heel bulb. Heel bulb width was measured along a diagonal line from the axial to the abaxial borders between the horn and the haired skin. Sole width was measured along a line that intersects sole length perpendicularly and run from the axial to the abaxial border of the claw. Sole length was measured from the palmar point of heel bulb to the tip of the claw. The measurements of lateral and medial claws of both forelimbs and hind limbs were recorded separately.

The correlation was used to check the relationship between body weight of buffaloes and the different morphometric values of hooves. The independent sample t-test was performed to compare the means of different morphometric measurements of forelimb and hindlimb and the analysis were carried out using Statistical Product and Service Solutions (SPSS) software version 20.

Results and Discussion

In the present study, the mean live body weight of buffaloes were 580.1±31.74 kilograms and there was no statistically significant correlation ($p > 0.05$) between the body weight of buffaloes and the different morphometric measurements of hooves. Similar to this result Tariq *et al.,* (2013) reported that 529.5±67.5 kg was the mean body weight in Niliravi buffaloes and found a close correlation between the body weight and the morphometric variables including chest girth and body length as well as body condition score.

Toe length

In buffalo, the maximum toe length was recorded in the left lateral claw of forelimb (8.3±0.22 cm) and minimum in the right lateral claw of hindlimb (7.55±0.12 cm) in the buffalo (Table 1 & 2). The average toe length of fore and hind limbs were 8.16±0.19cm and 7.795±0.253cm, respectively and there was a significant difference in the mean toe length of forelimb and hindlimb ($t=4.46, p<0.001$) indicating that the mean toe length of forelimb is more than that of the hindlimb (Table 3).

Koluman and Goncu (2017) reported that 3.9 cm was the average toe length of forelimb in Alpine and Sannen breeds of goats where as in Boer it was 4.1 cm and the respective measurements for hindlimb was 3.7 cm for Alpine and Sannen breeds and 4.0 cm for Boer breed. Similarly in sambar deer, the average toe length of forelimb and hindlimb were 6.28±0.09 cm and 5.71±0.08 cm respectively and were significantly different

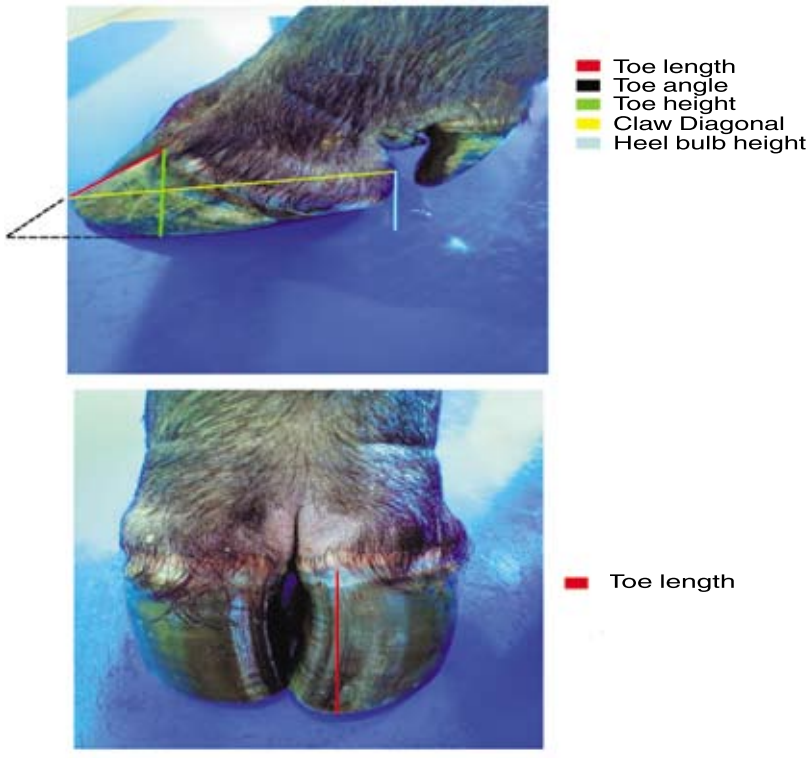

Figure 1 Morphometry of hoof in buffalo- lateral view

with the toe length of forelimb being greater than that of hindlimb (Sunilkumar *et al.,* 2018). The higher morphometric values of forelimb when compared with the hindlimb observed in these animals may be due to the fact that around 60 % of the body mass is being beared by forelimbs in ruminants.

But in horses, there was no significant difference between the toe lengths of forelimb and hindlimb. This may be due to the well developed stay apparatus in equines which assist in locomotion (Stachurska *et al.,* 2008 and Kawareti *et al.,* 2017).

Toe height

Maximum toe height was recorded in the left medial claw of forelimb (5.71±0.40) and minimum in the left lateral claw of hindlimb (5.016±0.331) (Table 1& 2). The average toe height of fore and hind limbs were 5.535±0.472 cm and 5.20±0.48 cm, respectively in the buffalo. There was a significant difference in the mean toe height of forelimb and hindlimbs in buffaloes ($t=2.206$,$p<0.05$) indicating that the mean toe height of forelimb is more than that of the hindlimb (Table 3). In sambar deer the average toe height of forelimb was 4.60±0.08 cm and of hindlimb was 4.38±0.06 cm with the hoof of forelimb being taller (Sunilkumar *et al.,* 2018) which agreed with the observations in different breeds of goats (Koluman and Goncu, 2017).These observations also explain the difference in weight bearing pattern between fore and hind limbs.

Toe angle

In buffalo, maximum toe angle was recorded in the left medial claw of hindlimb (55.16±5.307°) and minimum in the right medial claw of forelimb (47.6±7.94°) (Table 1&2). Raulkar *et al.,* (2016) observed in cattle that increase in toe length decreased the hoof angle causing shifting of weight bearing from anterior part of hoof to the posterior part. It resulted in overburdening the heel causing affection of heel or inter digital space. The average toe angle of fore and hind limb were 50.02±5.51º and 54.03±7.75º, respectively in the buffalo and the mean toe angle of hindlimb was more than that

of the forelimb (Table 3). In contradiction to this observations the toe angle did not showed any significant difference in goats (Koluman and Goncu, 2017) sambar deer (Sunilkumar *et al.,* 2018), and hog deer (Sunilkumar *et al.,* 2019). The difference in measurements observed among these species and buffaloes are may be because of the fact that the forelimb is bearing more body mass thus resulting in more wear and tear of hoof and in turn a decreased toe angle. In deer and goat because of their lighter body weight the toe angle did not varied much.

Heel bulb length

The maximum heel bulb length was recorded in the right medial claw of forelimb (5.28±0.65 cm) and minimum in the right lateral claw of hindlimb (4.25±0.33 cm) in the buffalo. In cattle the heel bulb length of medial and lateral claw of forelimb was 4.2 cm and 4.7 cm respectively where as in hind limb the measurements were 3.4 and 3.6 cm respectively (Nuss *et al*., 2011). The average heel bulb length of fore and hind limb of buffalo were 4.92±0.552cm and 4.44±0.385cm respectively and there was a significant difference in the mean heel bulb length ($t=4.124, p<0.001$) indicating that the mean heel bulb length of forelimb was more than that of the hindlimb in buffalo (Table 3). According to Clark *et al.,* 2004, in cattle the heel bulbs of the forelimbs were >10 mm longer and higher, and also the corresponding measurements at the level of the corium were almost 10 mm greater compared to the hind limbs. This may associated with a steeper foot and a larger claw volume.

As observed by Nuss *et al.,* (2011), in buffaloes also it can be assumed that the larger volume, the steeper toe angle and the higher heel bulb make the front claws more resistant to stress associated with weight-bearing.

Heel bulb height

In the present study, maximum heel bulb height was recorded in the left medial claw of forelimb (4.35±1.001 cm) and minimum in the right lateral of hindlimb (2.266±0.744 cm) (Table1 & 2). In cattle the heel bulb height of medial and lateral claw of forelimb was 2.8 cm and 2.9 cm respectively where as in hind limb the measurements were 1.8 and 2.1 cm respectively (Nuss *et al*., 2011). The average Heel bulb height of fore and hindlimbs were 4.27±0.73cm and 2.70±0.644cm, respectively in the buffalo. There was a significant difference in the mean heel bulbheight of forelimb and hindlimbs in buffaloes ($t=2.206$, $p<0.001$) indicating that the mean heel bulbheight of forelimb is more than that of the hindlimb (Table 3).

The average heal bulb height was 1.98±0.07 cm and 1.75±0.06 cm respectively for forelimb and hindlimb of sambar deer (Sunilkumar *et al.,* 2018). The heel bulb height of lateral claw was greater that of medial claw in buffalo which was in agreement to the reports in cattle (Meyer *et al.,* 2007; Schmid *et al.,* 2009). A larger heel bulb might afford better cushioning since the lateral claws of the forelimbs contact the ground first during the walk.

Heel bulb width

In the present study, maximum heel bulb width was recorded in the left lateral claw of forelimb (4±1.22 cm) and minimum in the right lateral claw of hindlimb (2.68±1.105 cm) (Table 1&2). The average Heel bulb width of fore and hindlimbs were 3.69±1.117cm and 2.84±1.099cm , respectively in the buffalo. There was a significant difference in the mean heel bulb width of forelimb and hindlimbs in buffaloes ($t=2.206$,$p<0.05$) indicating that the mean heel bulb width of forelimb is more than that of the hindlimb (Table 3). The average heal bulb width was 2.10±0.04 cm and 1.90±0.03 cm respectively for forelimb and hindlimb with forelimb being larger in sambar deer (Sunilkumar *et al.,* 2018) which was in agreement with the findings in goats (Koluman and Goncu, 2017).

Sole length

In the present study, Maximum sole length was recorded in the left lateral claw of hindlimb (13.45±0.833) and minimum in the right lateral of forelimb (12.5±0.83) (Table 1&2). In cattle the sole length of medial and lateral claw of forelimb was 11.3 cm and 10.6 cm respectively where as in hind limb the measurements were 11.0 cm and 11.4 cm respectively (Nuss *et al*., 2011). The

Table 1. Morphometric values of claws of forelimb in buffalo (Mean ± SD)

Claw	Toe Length (Cm)	Toe Height (Cm)	Toe Angle (º)	Heel Bulb Length (Cm)	Heel Bulb Height (Cm)	Heel Bulb Width (Cm)	Sole Length (Cm)	Sole Width (Cm)
Rt. Lateral	7.88±0.20	5.58±0.80	49.5±4.84	4.85±0.56	4.16±0.68	3.4±1.02	12.5±0.83	6.4±0.56
Rt. Medial	8.28±0.22	5.4±0.12	47.6±7.94	5.28±0.65	4.25±0.516	3.45±0.95	13.25±0.52	6.45±0.46
Lt. Lateral	8.3±0.22	5.45±0.57	49.16±4.99	4.5±0.37	4.35±0.73	4±1.22	13.16±0.68	6.3±0.48
Lt. Medial	8.21±0.14	5.71±0.40	53.83±4.30	5.08±0.63	4.35±1.001	3.91±1.28	12.61±0.69	6.26±0.71

Table 2. Morphometric values of claws of hindlimb in buffaloes (Mean ± SD)

Claw	Toe Length (Cm)	Toe Height (Cm)	Toe Angle (°)	Heel Bulb Length (Cm)	Heel Bulb Height (Cm)	Heel Bulb Width (Cm)	Sole Length (Cm)	Sole Width (Cm)
Rt. Lateral	7.55±0.122	5.26±0.665	55±8.36	4.25±0.33	2.26±0.744	2.68±1.105	13.28±0.248	4.96±0.28
Rt. Medial	7.8±0.209	5.05±0.612	51.83±7.111	4.35±0.314	2.63±0.524	2.81±0.908	13.43±0.382	4.75±0.592
Lt. lateral	8.08±0.40	5.016±0.331	54.16±10.225	4.53±0.372	2.76±0.643	2.8±1.086	13.45±0.833	4.95±0.50
Lt. medial	7.75±0.281	5.5±0.340	55.16±5.307	4.66±0.527	3.166±0.665	3.1±1.298	13.3±0.742	5.23±0.516

Table 3. Comparison of Mean ± SD values of different parameters between forelimb and hindlimb in buffaloes

Parameters	Forelimb	Hindlimb	t Value	p Value
Toe Length	8.16±0.19	7.795±0.253	4.462	.000
Toe Height	5.535±0.472	5.20±0.48	2.206	.032
Toe Angle	50.02±5.51	54.03±7.75	-2.058	.045
Heel Bulb Length	4.92±0.552	4.44±0.385	4.124	.000
Heel Bulb Height	4.27±0.73	2.70±0.644	7.777	.000
Heel Bulb Width	3.69±1.117	2.84±1.099	2.657	.011
Sole Length	12.88±0.68	13.36±0.551	-2.546	.014
Sole Width	6.35±0.55	4.97±0.472	9.329	.000

average sole length of fore and hindlimbs were 12.88±0.68cm and 13.36±0.551cm, respectively in the buffalo. There was a significant difference in the mean sole length of forelimb and hindlimbs in buffaloes (t= -2.546 ,p<0.05) indicating that the mean sole length of hindlimb is more than that of the forelimb (Table 3).

These findings were in agreement with morphometric values in sambar deer in which the average sole length was 6.88±0.11 cm and 6.15±0.08 cm respectively in forelimb and hindlimb. There observed significant difference in sole length and sole width between forelimb and hindlimb with forlimb being longer (Sunilkumar *et al.,* 2018). Similar observations were made by Koluman and Goncu, (2017) in different breeds of goats. But in horses, there was no significant difference in solar length between forelimb and hindlimb (Kawareti *et al.,* 2017).

Sole width

In the present study, Maximum sole width was recorded in the right medial claw of forelimb (6.45±0.46) and minimum in the right medial claw of hindlimb (4.75±0.592) (Table 1&2). The average sole width of fore and hindlimbs were 6.35±0.55cm and 4.97±0.472cm, respectively in the buffalo. There was a significant difference in the mean sole width of forelimb and hindlimbs in buffaloes (t=9.329, p<0.001) indicating that the mean sole width of forelimb is more than that of the

hindlimb (Table 3). Similar observations were made by Koluman and Goncu, (2017) in different breeds of goats and solar width measurements in horses (Kawareti *et al.,* 2017).

In buffalo, there was no significant correlation statistically between the body weight and the different morphometric measurements of hooves. There existed a significant difference in the mean toe length, toe height, sole length, sole width, heel bulb length, heel bulb height and heel bulb width of forelimb and hindlimb and showed greater values for forelimb. The higher morphometric values of forelimb when compared with the hindlimb observed in buffaloes are may be due to the fact that around 60 % of the body mass is being beared by forelimbs in ruminants. In cattle maximum pressures were normally found on the medial claw of forelimb and on lateral claw in the hindlimb and there was a significant difference in morphometric parameters of these claws indicating a correlation between these two. This remarkable difference observed between dairy cattle and buffaloes has to be further investigated with the aid of biomechanical study tools on the pressure distributions pattern and has to be compared with dairy cattle. As buffaloes are considered a species with minimal foot ailments, the analyzed morphometric parameters and the knowledge gained in this study can form the basis for the research works to cure the foot ailments in dairy cattle.

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