

## MORPHOMETRIC STUDY ON THE HOOF OF INDIAN HOG DEER (*HYELAPHUS PORCINUS*)\*

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### ABSTRACT

In the present study, the morphometric aspects of the hoof of Indian hog deer (*Hyelaphus porcinus*), a small sized ungulate was investigated. Toe length, toe height, toe angle, sole length, sole width, heelbulb height and heel bulb width were the morphometric parameters observed in the study. Above parameters of lateral and medial claws of both forelimbs and hindlimbs were recorded separately. There is a statistically significant correlation between the body weight of hog deer and the different morphometric measurements of hooves. The average toe length of forelimb was  $3.09 \pm 0.23$  cm and hindlimb was  $2.815 \pm 0.127$  cm. The average toe height of forelimbs and hind limbs were  $1.84 \pm 0.14$  cm and  $1.747 \pm 0.15$  cm respectively. Toe angle was maximum in right lateral claw of hindlimb ( $40.8 \pm 2.48^\circ$ ) and minimum in right medial claw of forelimb ( $37.5 \pm 1.76^\circ$ ).

Maximum sole length was recorded in the left lateral claw of forelimb ( $3.48 \pm 0.09$  cm) and minimum in the right medial claw of hindlimb ( $3.18 \pm 0.17$  cm). Maximum sole width was recorded in left lateral claw of forelimb ( $1.53 \pm 0.16$  cm) and minimum in the left medial claw of hindlimb ( $1.4 \pm 0.20$  cm). Toe length, toe height, heelbulb length, sole length, sole width of forelimb measured higher values than that of hind limb. Toe angle, heel bulb height and heel bulb width of hind limb exhibited higher values than forelimb.

**Keywords:** Morphometry, hoof, Indian hog deer.

### INTRODUCTION

Hooves are one of the most important organs in an animal's body and perform many functions including supporting the weight of the animal, dissipating the energy impact as hooves strike the ground or surface and protecting the tissue and

bone within the hoof capsule. According to Miller *et al.*, (1986) the hoof growth varied seasonally and reported maximum hoof growth during the late summer and the minimum hoof growth during the winter season. The quality and integrity of the hoof epidermis primarily depends on the normal keratinization process. Keratinization is a complex process of differentiation of epidermal cells. These epidermal cells are capable of synthesis high rate of keratin proteins as well as intercellular cementing substances and finalized by the programmed death of the living epidermal cells (Budras *et al.*, 1996). The quality of hooves is the important aspects of hoof health. The desired hoof quality provides structural strength to animals. The captive wild ungulates are generally fed with commercially available concentrate feed and roughages, which is different from their natural diet. These variations in feeding pattern could lead to low rumen pH and subsequent hoof affections in captive wild ruminants. Laminitis and other hoof related ailments are one of the major clinical challenges faced by a zoo veterinarian while handling with Cervidae family. Basic studies aimed at gaining a better understanding of the morphology and morphometry of the hoof in Indian hog deer (*Hyelaphus porcinus*) are scanty and therefore deserving the attention of researchers.

## MATERIALS AND METHODS

Morphological and morphometric study on the hoof of Indian hog deer was undertaken in the present work. Hooves of six Indian hog deer of either sex were collected from the State Museum and Zoo, Thrissur. 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 was 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 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 R Core Team (2020), a language and environment for statistical computing Foundation for Statistical computing, Vienna, Austria.

## RESULTS AND DISCUSSION

In the present study, the mean body weights of Indian hog deer were  $21.4 \pm 3.65$  kilograms. There was a statistically significant correlation ( $p < 0.05$ ) between the body weight of hog deer and the morphometric measurements of hooves such as toe height, heel bulb length, sole length and sole width (Table 1). Koluman and Goncu (2016) reported that the claw length, hoof height, diagonal diameter of hoof and bulb height of goat were significantly correlated with body weight. Anju *et al.* (2019) reported that the mean live body weight of buffaloes

were  $580.1 \pm 31.74$  kilograms and there was no statistically significant correlation between the body weight of buffaloes and the different morphometric measurements probably because of the increased body weight in these species when compared to small ruminants and animals of Cervidae family.

### Toe length

The maximum toe length was recorded in the right lateral claw of forelimb ( $3.15 \pm 0.28$  cm) and minimum in the left lateral claw of hind limb ( $2.75 \pm 0.13$  cm) in the hog deer (Table 2&3). In hog deer the average toe length of fore and hind limbs were  $3.09 \pm 0.234$  cm and  $2.815 \pm 0.125$  cm, respectively. There was no significant difference in the mean toe length of forelimb and hind limb in hog deer ( $t = -1.265, p > 0.05$ ) (Table 4).

According to Stachurska *et al.*, (2008) and Kawareti *et al.* (2017) in horses, there was no significant dissimilarity between the toe lengths of forelimb and hindlimb since in equines the components of stay apparatus is better developed assisting in locomotion. In buffaloes, the average toe length of fore and hind limbs were  $8.16 \pm 0.19$  cm and  $7.795 \pm 0.253$  cm, respectively and there was a significant difference in the mean toe length of forelimb and hindlimb indicating

**Table 1.** Correlation between body weight and morphometric parameters of hoof in the buffalo

		Correlations							
		Toe Length	Toe Height	Toe Angle	Heel bulb Length	Heel bulb Height	Heel bulb Width	Sole Length	Sole Width
Body Weight	Pearson Correlation	-0.793	0.761	-0.098	-0.138	-0.394	-0.408	-0.069	0.152
	Sig.	0.060	0.079	0.853	0.794	0.440	0.422	0.896	0.774
	N	6	6	6	6	6	6	6	6

**Table 2.** Morphometric values of hoof of forelimb in Hog deer (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	3.15±0.28	1.91±0.21	40±0.63	1.66±0.10	1.56±0.18	1.26±0.13	3.31±0.34	1.46±0.13
Rt. Medial	3.15±0.187	1.85±0.15	37.5±1.76	1.76±0.22	1.61±0.21	1.31±0.11	3.35±0.26	1.45±0.16
Lt. Lateral	3.06±0.24	1.85±0.10	37.5±4.03	1.86±0.16	1.53±0.26	1.46±0.15	3.48±0.09	1.53±0.16
Lt. Medial	3.01±0.23	1.75±0.10	39.9±4.36	1.85±0.12	1.6±0.31	1.48±0.14	3.46±0.13	1.48±0.09

that the mean toe length of forelimb is more than that of the hindlimb (Anju *et al.*, 2019). In sambar deer, the average toe length of forelimb was 5.71±0.08 and in hind limb was 6.28±0.09 cm. There was no significant difference between the toe length of forelimb and hind limb and the measurements 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 hog deer may be due to the fact that around 60 % of the body mass is being beared by forelimbs in ruminants.

**Toe height**

In the present study, maximum toe height was recorded in the right lateral claw

of forelimb (1.91±0.21 cm) and minimum in the left medial claw of hindlimb (1.68±0.16 cm), (Table 2 & 3). The average toe height of fore and hind limbs were 1.84±0.14cm and 1.74±0.15cm, respectively in the hog deer. There was a significant difference in the mean toe height of forelimb and hindlimbs in hog deer (  $t=2.839, p<0.05$ ) indicating that the mean toe height of forelimb is more than that of the hindlimb (Table 4). Similar finding were reported in sambar deer and buffaloes (Sunilkumar *et al.*, 2018 and Anju *et al.*, 2019).

**Toe angle**

The maximum toe angle was recorded in the right lateral claw of hindlimb (40.8±2.48°) and minimum in the

right medial claw of forelimb ( $37.5 \pm 1.76^\circ$ ), (Table 2 & 3). The average toe angle of fore and hind limb were  $38.72 \pm 2.69^\circ$  and  $40.1 \pm 1.537^\circ$ , respectively in the hog deer. There was a significant difference in the mean toe angle of forelimb and hindlimb in hog deer ( $t = -2.464$ ,  $p < 0.05$ ) indicating that the mean toe angle of hindlimb is more than that of the forelimb (Table 4). Anju et al. (2019) reported similar results in buffalo.

Famarzi et al. (2020) reported that variations in hoof conformation lead to the alteration of stress distribution. Several

anatomical variables showed correlations with biomechanical variables. Toe angle was negatively correlated with contact area.

**Heel bulb length**

The maximum heel bulb length was recorded in the left lateral claw of forelimb ( $1.86 \pm 0.16$  cm) and minimum in the right lateral claw of forelimb ( $1.66 \pm 0.10$  cm) in Indian hog deer. The average heel bulb length of fore and hind limb were  $1.78 \pm 0.15$  cm and  $1.68 \pm 0.14$  cm,

**Table 3.** Morphometric values of hoof of hind limb in Hog deer (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	2.83±0.10	1.76±0.13	40.8±2.48	1.66±0.15	1.61±0.16	1.41±0.19	3.2±0.14	1.43±0.21
Rt. Medial	2.83±0.13	1.75±0.19	40.3±1.75	1.7±0.08	1.6±0.15	1.45±0.25	3.18±0.17	1.48±0.14
Lt. lateral	2.75±0.13	1.8±0.12	39.3±0.51	1.68±0.23	1.63±0.19	1.51±0.29	3.21±0.19	1.48±0.21
Lt. medial	2.85±0.15	1.68±0.16	40±1.41	1.7±0.12	1.61±0.11	1.38±0.22	3.26±0.19	1.4±0.20

**Table 4.** Comparison of Mean ± SD values of different parameters between forelimb and hindlimb in Hog deer

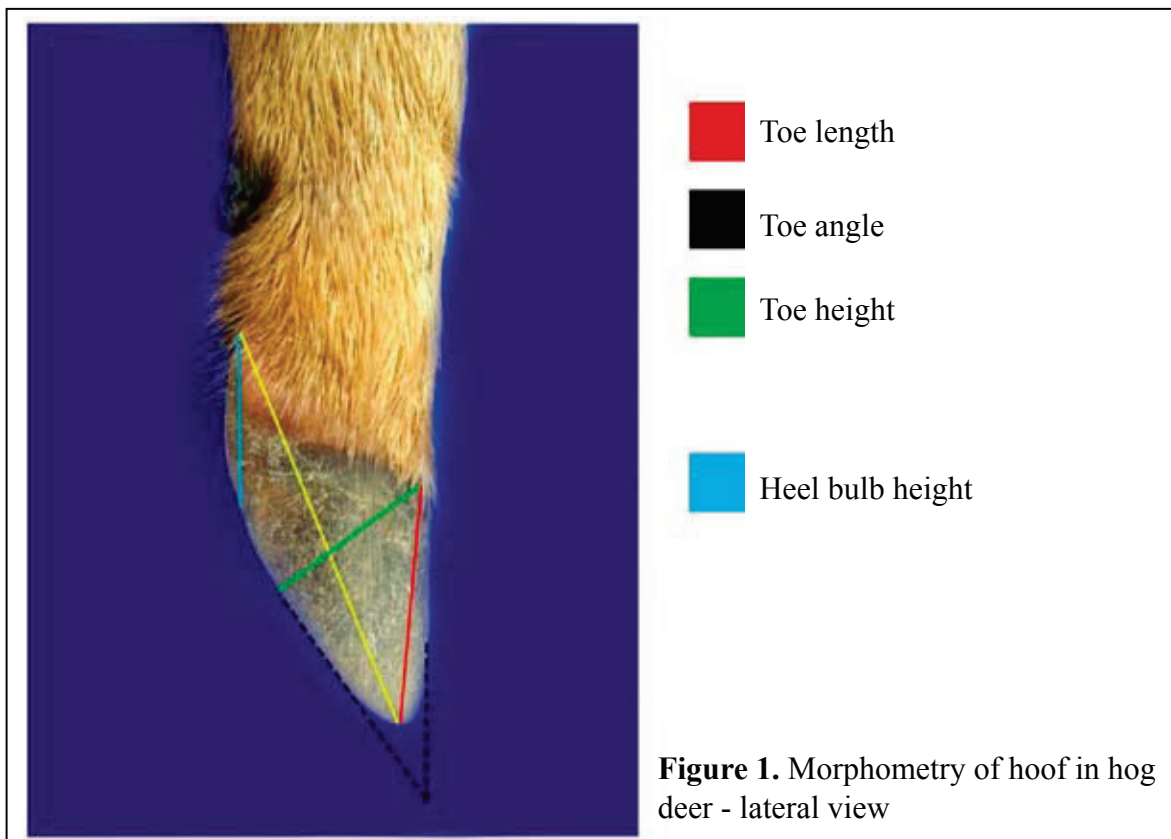
Parameters	Forelimb	Hindlimb	t Value	p Value
Toe Length	3.09±0.234	2.815±0.127	-1.265	0.218
Toe Height	1.84±0.14	1.747±0.15	2.839	0.009
Toe Angle	38.72±2.69	40.1±1.537	-2.464	0.021
Heel Bulb Length	1.78±0.15	1.685±0.145	1.742	0.094
Heel Bulb Height	1.575±0.24	1.612±0.152	-1.328	0.197
Heel Bulb Width	1.37±0.132	1.437±0.23	1.797	0.085
Sole Length	3.4±0.205	3.21±0.172	3.043	0.005
Sole Width	1.48±0.135	1.44±0.19	-1.248	0.224

respectively. There was no significant difference in the mean heel bulb length of forelimb and hindlimb in hog deer ( $t=1.742$ ,  $p>0.05$ ). Anju *et al.* (2019) reported that, the average heel bulb length of fore and hind limb were  $4.92\pm 0.552$ cm and  $4.44\pm 0.385$ cm, respectively in the buffalo.

**Heel bulb height**

In the present study, maximum heel bulb height was recorded in the left lateral claw of hindlimb ( $1.63\pm 0.19$ ) and minimum in the left lateral claw of forelimb  $1.53\pm .26$ . The average Heel bulb height of fore and hindlimbs were  $1.575\pm 0.24$ cm and  $1.612\pm 0.152$  cm, respectively. There was no

significant difference in the mean heel bulb height of forelimb and hindlimbs in hog deer ( $t=-1.328$ ,  $p>0.05$ ). Anju *et al.* (2019) observed in buffaloes that the maximum heel bulb height was recorded in the left medial claw of forelimb ( $4.35\pm 1.001$ cm) and minimum in the right lateral of hindlimb ( $2.266\pm 0.744$  cm). According to Nuss *et al.* (2011) 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 which were in agreement with the observations on the difference in measurements between forelimb and hind limb. In sambar deer the average heel bulb



height of forelimb was  $4.60\pm 0.08$  cm and of hindlimb was  $4.38\pm 0.06$  cm. The heel bulb height was greater than that of hind limb (Sunilkumar *et al.*, 2018).

### Heel bulb width

The maximum heel bulb width was recorded in the left lateral claw of hindlimb ( $1.51\pm 0.29$  cm) and minimum in the right lateral claw of forelimb ( $1.26\pm 0.13$  cm) (Table 2 and 3). The average heel bulb width of fore and hindlimbs were  $1.37\pm 0.13$  cm and  $1.437\pm 0.23$  cm, respectively. There was no significant difference in the mean heel bulb width of forelimb and hindlimbs in the hog deer. Nuss *et al.* (2011) reported similar results. Whereas Sunilkumar *et al.* (2018) reported that the average heel bulb width in forelimb was more than that of hind limb as the forelimb was larger in sambar deer.

### Sole length

In the hog deer maximum sole length was recorded in the left lateral of fore limb ( $3.48\pm 0.09$  cm) and minimum in the right medial of hind limb ( $3.18\pm 0.17$  cm). The average sole length of fore and hindlimbs were  $3.4\pm 0.20$  cm and  $3.21\pm 0.17$  cm, respectively. There was a significant difference in the mean sole length of forelimb and hindlimbs in hog deer ( $t=3.043, p<0.05$ ). Similar findings were reported in sambar deer and buffaloes

(Sunilkumar *et al.*, 2018 and Anju *et al.*, 2019).

### Sole width

In the hog deer, maximum sole width was recorded in the lateral claw of forelimb ( $1.53\pm 0.16$ ) and minimum in the left medial claw of hindlimb ( $1.4\pm 0.20$ ) (Table 2 & 3). The average sole width of fore and hind limbs were  $1.48\pm 0.135$  cm and  $1.44\pm 0.19$  cm, respectively in the hog deer. There was no significant difference in the mean sole width of forelimb and hind limbs in hog deer ( $t=-1.248, p>0.05$ ) (Table 4). Similar observations were made by Kawareti *et al.* (2017) in horses and goats and Koluman and Goncu (2017) in different breeds of goats. But there observed significant difference in sole width between forelimb and hindlimb with forelimb being longer in sambar deer (Sunilkumar *et al.*, 2018).

### CONCLUSION

In hog deer, there is a statistically significant correlation between the body weight and the different morphometric measurements of hooves such as toe height, heel bulb length, sole length and sole width. Generally the morphometric values were higher in forelimbs than hindlimbs. Toe length, toe height, heel bulb length, sole length, sole width of forelimb showed greater values than hindlimb. Toe

angle, heel bulb height and heel bulb width of hindlimb exhibited higher values than forelimb.

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