

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(8): 447-449
www.biochemjournal.com
Received: 20-05-2026
Accepted: 26-06-2026

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Biometric characterization of hoof dimensions in mules

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8f.9585>

Abstract

Hoof biometry yields critical insights into hoof conformation. In the present study, biometric measurements were collected from six mules. Toe length, toe angle and quarter angles were marginally greater in hindlimb, whereas hoof length, maximum width, coronary circumference and frog length were greater in forelimb. Heel height was relatively consistent across all the limbs. Frog width exhibited only minor variation between limbs. These biometric parameters demonstrate limb-specific differences in mule hoof conformation, offering valuable baseline data for the study of hoof biomechanics, functional adaptation, and hoof management.

Keywords: Biometry, Frog, hoof, mule, toe

Introduction

The mule is a hybrid offspring from a horse (*Equus caballus*) and a donkey (*Equus asinus*)^[1]. Mules have been used as pack^[2] or draught^[3] animals in hilly terrain or on trails in mountain regions^[4], as well as in competitive sporting or gaited competitions^[5]. The hoof is an essential organ for effective locomotion of equids^[6]. It protects underlying tissue of the foot from injury and to transfer the force of locomotion to and from the limb skeleton^[7]. Mule inherits its hoof conformation from the donkey, as the mule's hoof having an almost upright inclination of hoof wall at the toe, quarter, and heel, while its hoof is smaller, longer, and narrower than for the horse^[3]. Hoof conformation has been studied in horses^[8, 9] and donkeys^[10] but there are very fewer studies for mules^[8]. Keeping this in view, the present study was planned. This study will establish reference biometric values for mule hooves, identify differences between right and left as well as forelimb and hindlimb hooves, and determine correlations among hoof parameters, thereby providing useful baseline information for hoof health, locomotor biomechanics, and management of mules.

Materials and Methods

Six (06) clinically healthy mules with no hoof lesions aged between 6 years to 15 years with wither heights ranging from 50.5 to 58.7 inches were included in the study. All hoof measurements were recorded by same person. A scale and flexible tape meter were used to measure the different parameters of hooves on each limb of each mule (Fig. 1a, 1b, 2 & 3). The toe angle and lateral quarter angles were measured using a standard plastic protractor (accuracy $\pm 1^\circ$). A ruler was used to establish the reference line along the dorsal hoof wall before angle measurement. All measurements were recorded in degrees with the mule standing squarely on a level surface. Following measurements were recorded.

1. Toe length
2. Toe height
3. Heel height
4. Toe angle
5. Hoof length
6. Hoof width at toe, quarter and heel
7. Coronary circumference
8. Frog length
9. Frog width
10. Frog length to width ratio
11. Quarter angle

Results and Discussion

Table 1 presents the mean $\pm$ standard error (SE) values for

biometric parameters of the right and left forelimb and hindlimb hooves of mule.

Table 1: Hoof biometry in mules

Parameter	Right Forelimb	Left Forelimb	Right Hindlimb	Left hindlimb
Toe length	8.75 $\pm$ 0.28	8.53 $\pm$ 0.33	8.98 $\pm$ 0.16	8.92 $\pm$ 0.23
Toe height	6.17 $\pm$ 0.21	6.42 $\pm$ 0.37	6.42 $\pm$ 0.33	6.35 $\pm$ 0.31
Heel height	2.35 $\pm$ 0.08	2.37 $\pm$ 0.05	2.37 $\pm$ 0.03	2.33 $\pm$ 0.05
Toe angle	50.83 $\pm$ 1.19	48.50 $\pm$ 0.76	51.83 $\pm$ 0.91	51.67 $\pm$ 1.02
Hoof length	11.75 $\pm$ 0.28	11.70 $\pm$ 0.19	10.90 $\pm$ 0.24	11.00 $\pm$ 0.30
Hoof width at toe	5.25 $\pm$ 0.12	5.13 $\pm$ 0.15	5.28 $\pm$ 0.17	5.17 $\pm$ 0.22
Hoof width at quarter	9.63 $\pm$ 0.17	9.45 $\pm$ 0.23	8.88 $\pm$ 0.29	8.80 $\pm$ 0.31
Hoof width at heel	4.52 $\pm$ 0.32	4.72 $\pm$ 0.25	4.82 $\pm$ 0.30	5.02 $\pm$ 0.35
Coronary circumference	32.90 $\pm$ 0.53	33.00 $\pm$ 0.59	32.43 $\pm$ 0.59	32.53 $\pm$ 0.44
Frog length	7.37 $\pm$ 0.45	7.78 $\pm$ 0.25	7.08 $\pm$ 0.43	6.58 $\pm$ 0.20
Frog width	4.23 $\pm$ 0.27	4.18 $\pm$ 0.26	4.15 $\pm$ 0.35	4.38 $\pm$ 0.38
Frog length to width ratio	1.74 $\pm$ 0.15	1.86 $\pm$ 0.13	1.71 $\pm$ 0.18	1.50 $\pm$ 0.14
Quarter angle	53.00 $\pm$ 0.37	52.83 $\pm$ 0.48	56.67 $\pm$ 0.21	56.83 $\pm$ 0.31

Toe length: The mean toe length was 8.75 $\pm$ 0.28 cm in the right forelimb and 8.53 $\pm$ 0.33 cm in the left forelimb whereas in the hindlimbs, it measured 8.98 $\pm$ 0.16 cm on the right and 8.92 $\pm$ 0.23 cm on the left. Toe length was slightly greater in the hindlimb than in the forelimb similar to the findings of Mostafa *et al.* [10] in donkey who recorded greater dorsal hoof wall length in hindlimb (6.84 $\pm$ 0.57 cm) as compared to forelimb (6.73 $\pm$ 0.46 cm). Khan *et al.* [11] in donkey recorded toe length in right (6.66 cm) and left (6.57 cm) limb which was less than the values recorded in the present study. Kawareti *et al.* [12] in equine recorded toe length which was 8.46 $\pm$ 0.22 cm for right forelimb, 8.28 $\pm$ 0.14 cm for left forelimb, 8.42 $\pm$ 0.26 cm for right hindlimb and 8.52 $\pm$ 0.18 cm for left hindlimb.

Toe height: Toe height was 6.17 $\pm$ 0.21 cm in the right forelimb and 6.42 $\pm$ 0.37 cm in the left forelimb. The corresponding values for the right and left hindlimbs were 6.42 $\pm$ 0.33 cm and 6.35 $\pm$ 0.31 cm, respectively.

Heel height: Heel height varied slightly, ranging from 2.33 to 2.37 cm. The right forelimb, left forelimb, right hindlimb and left hindlimb showed values of 2.35 $\pm$ 0.08, 2.37 $\pm$ 0.05 and 2.37 $\pm$ 0.03 cm and 2.33 $\pm$ 0.05 cm, respectively. The narrow range indicated that heel height was a comparatively consistent parameter across the four limbs.

Toe angle: Toe angle was 50.83 $\pm$ 1.19° in the right forelimb and 48.50 $\pm$ 0.76° in the left forelimb. In the hindlimbs, it was 51.83 $\pm$ 0.91° on the right and 51.67 $\pm$ 1.02° on the left. The hindlimbs showed slightly larger toe angles than the forelimbs. This difference may suggest variations in hoof orientation. The pelvic limbs tend to have somewhat less inclination than the thoracic limb [13]. Similar pattern was observed by Mostafa *et al.* [10] in donkey who recorded toe angles for forelimb (58.25 $\pm$ 5.56°) and hindlimb (59.61 $\pm$ 3.48°). Khan *et al.* [11] in donkey recorded higher toe angles in right (65.52) and left (61.41) limb. Pamela and Juan [14] recorded angle of hoof in horses which was 55.8° for forelimb and 55.4° for hindlimb without any statistical differences.

Hoof length: Hoof length was 11.75 $\pm$ 0.28 cm in the right forelimb and 11.70 $\pm$ 0.19 cm in the left forelimb. In contrast, the right and left hindlimbs showed lower values of 10.90 $\pm$ 0.24 cm and 11.00 $\pm$ 0.30 cm, respectively. The forelimb hooves were longer than the hindlimb hooves [15].

Kawareti *et al.* [12] in equine recorded solar length which was 12.31 $\pm$ 0.38 cm for right forelimb, 11.92 $\pm$ 0.26 cm for left forelimb, 11.81 $\pm$ 0.36 cm for right hindlimb and 11.57 $\pm$ 0.47 cm for left hindlimb.

Hoof width: Hoof width at the toe was 5.25 $\pm$ 0.12 cm in the right forelimb and 5.13 $\pm$ 0.15 cm in the left forelimb. The corresponding hindlimb values were 5.28 $\pm$ 0.17 cm and 5.17 $\pm$ 0.22 cm. The hindlimbs showed slightly greater toe width. Hoof width increased towards the quarters where values were 9.63 $\pm$ 0.17 cm and 9.45 $\pm$ 0.23 cm in the right and left forelimbs, respectively, compared with 8.88 $\pm$ 0.29 cm and 8.80 $\pm$ 0.31 cm in the right and left hindlimbs. The forelimb hooves were wider at the quarter than the hindlimb hooves. Kawareti *et al.* [12] in equine measured solar width at the widest part which was 11.81 $\pm$ 0.33 cm for right forelimb, 11.68 $\pm$ 0.37 cm for left forelimb, 10.77 $\pm$ 0.36 cm for right hindlimb and 10.6 $\pm$ 0.33 cm for left hindlimb. Mostafa *et al.* [10] also reported wider forelimb hooves (7.20 $\pm$ 0.51 cm) as compared to hindlimb hooves (6.33 $\pm$ 0.37 cm) in donkeys. At heel, width decreased. Hoof width at the heel was 4.52 $\pm$ 0.32 cm in the right forelimb and 4.72 $\pm$ 0.25 cm in the left forelimb. In the hindlimbs, values were 4.82 $\pm$ 0.30 cm and 5.02 $\pm$ 0.35 cm on the right and left sides, respectively. Unlike hoof width at the quarter, width at heel was greater in the hindlimbs than in the forelimbs which indicated a somewhat wider heel region in hindlimb hooves.

Coronary circumference: Coronary circumference was 32.90 $\pm$ 0.53 cm in the right forelimb and 33.00 $\pm$ 0.59 cm in the left forelimb. The same for right and left hindlimbs was 32.43 $\pm$ 0.59 cm and 32.53 $\pm$ 0.44 cm, respectively. The forelimbs showed slightly greater coronary circumference than the hindlimbs.

Frog: Frog length was 7.37 $\pm$ 0.45 cm in the right forelimb and 7.78 $\pm$ 0.25 cm in the left forelimb. In the hindlimbs, it measured 7.08 $\pm$ 0.43 cm and 6.58 $\pm$ 0.20 cm in the right and left limbs, respectively. The forelimbs had longer frog than the hindlimbs. Frog width was 4.23 $\pm$ 0.27 cm in the right forelimb and 4.18 $\pm$ 0.26 cm in the left forelimb. The corresponding hindlimb values were 4.15 $\pm$ 0.35 cm and 4.38 $\pm$ 0.38 cm. The values were relatively close across all the four limbs. Pamela and Juan [14] recorded longitudinal and transverse axis of frog in hooves of horses. Longitudinal

axis was 8.8 ± 0.7 cm for thoracic limb and 8.2 ± 0.6 cm for pelvic limb. Transverse axis was 2.1 ± 0.09 cm for thoracic limb and 2.2 ± 0.1 cm for pelvic limb Khan *et al.* [11] in donkey recorded lower values of frog length and width. Frog length was 4.89 cm for right limb and 4.74 cm for left limb. Frog width was 4.01 cm and 3.94 cm for right and left limb, respectively. The frog length was greater in show jumping animals [15].

Quarter angle: Quarter angle was $53.00 \pm 0.37^\circ$ in the right forelimb and $52.83 \pm 0.48^\circ$ in the left forelimb. In the hindlimbs, the values increased to $56.67 \pm 0.21^\circ$ on the right and $56.83 \pm 0.31^\circ$ on the left. This parameter showed a distinct forelimb and hindlimb differences, with hindlimbs having larger quarter angles by approximately $3-4^\circ$.

Conclusion

From the study it was concluded that the biometric data regarding the hoof morphology differed more between forelimbs and hindlimbs than between the right and left sides. The forelimb hooves had greater hoof length, hoof width at the quarter, coronary circumference and frog length, whereas the hindlimbs generally showed greater toe length, toe angle, hoof width at heel and quarter angle. Heel height, toe height, hoof width at toe and frog width showed comparatively small differences among the four limbs while the frog length to width ratio varied among limbs.

References

1. Brosnahan MM. Genetics, evolution, and physiology of donkeys and mules. *Veterinary Clinics of North America: Equine Practice*. 2019;35:457-467.
2. Ali A, Orion S, Tesfaye T, Zambriski JA. The prevalence of lameness and associated risk factors in cart mules in Bahir Dar, Ethiopia. *Tropical Animal Health and Production*. 2016;48:1483-1489.
3. Celani G, Robbe D, Martucci P, Petrizzi L, Stratico P, Carluccio A. "Iron and fire": History and advances of mule shoeing. *Large Animal Review*. 2021;27:215-220.
4. Watson T, Kubasiewicz LM, Nye C, Thapa S, Norris SL, Chamberlain N, et al. Not all who wander are lost: The life transitions and associated welfare of pack mules walking the trails in the mountainous Gorkha region, Nepal. *Animals*. 2022;12:3152.
5. Silva GAO, Rodrigues LM, Monteiro BS, de Souza VRC, Filho HCS, Coelho CS. Effect of a marcha field test on some blood and electrocardiographic parameters of mules. *Journal of Equine Veterinary Science*. 2018;70:42-47.
6. Phannithi T, Laikul A, Pathomsakulwong W, Rungsri P, Apichaimongkonkun T, Watcharat K, et al. External hoof measurements of untrimmed and unshod mules in Northern Thailand. *Animals*. 2024;14:1197.
7. Reilly JD. No hoof no horse? *Journal of Equine Veterinary Science*. 1995;27:166-168.
8. Souza AF, Kunz JR, Laus R, Moreira MA, Muller TR, Fontequ JH. Biometrics of hoof balance in equids. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*. 2016;68:825-831.
9. Wilson A, Agass R, Vaux S, Sherlock E, Day P, Pfau T, et al. Foot placement of the equine forelimb: Relationship between foot conformation, foot placement and movement asymmetry. *Equine Veterinary Journal*. 2016;48:90-96.
10. Mostafa MB, Abdelgalil AI, Farhat SF, Raw Z, Kubasiewicz LM. Morphometric measurements of the feet of working donkeys *Equus asinus* in Egypt. *Journal of Equine Veterinary Science*. 2020;31:17-22.
11. Khan RZU, Rosanowski SM, Parkes RSV. Hoof morphometry in a population of lame and nonlame working donkeys in Pakistan. *Equine Veterinary Journal*. 2023;55:435-445.
12. Kawareti PK, Nandeshwar NC, Banubakode SB, Ganguly S. Podometry in equine (*Equus caballus*). *Journal of Entomology and Zoology Studies*. 2017;5(5):114-116.
13. Peter U. The classic Arab horse. Reino Unido: Arab Horse Society; 1987. p.88.
14. Pamela MM, Juan GC. Morphometric description of the hoof in Pura Raza Chilena horses. *Journal of Dairy & Veterinary Sciences*. 2019;13(1):555854. doi:10.19080/JDVS.2019.13.555854.
15. Sampaio BFB, Zuccari CESN, Shiroma MYM, Bertozzo BR, Leonel ECR, Surjus RDS, et al. Biometric hoof evaluation of athletic horses of show jumping, barrel, long rope and polo modalities. *Revista Brasileira de Saúde e Produção Animal*. 2013;14(13):448-459.