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Measurement of radiographic parameters of front feet hooves in Caspian horses

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Abstract A correct diagnosis of lameness necessitates the accurate interpretation of both the clinical examination and the radiological findings. The objective of this study was to identify the typical radiographic characteristics of the distal phalanx in a mature, healthy Caspian horse. The study population consisted of 10 mature Caspian horses. The samples consisted of five mares and five stallions of a similar size and weight, and they underwent the same training and management procedures. Radiographic imaging of the distal phalanx and associated soft-tissue structures of the front feet of horses was conducted. Subsequently, latero-medial (LM) radiographic views of each front distal phalanx were employed to ascertain pertinent distances, angles, and ratios pertaining to the hoof wall. To obtain the actual distances, the measurements from the latero-medial radiographs were multiplied by the magnification correction factor. The mean ± SD thickness of the soft tissues dorsal to the proximal and distal aspects of the distal phalanx was 12.55 ± 0.39 and 11.73 ± 0.71 mm, respectively. The average D-founder measurement was 8.17 mm. No statistically significant difference was observed between the right and left digits. In conclusion, the results of this study indicate that the normal parameters of the Caspian horse were obtained and compared with those of ponies and warm-blooded horses. The parameters obtained from the Caspian horse were found to be lower than those observed in warm-blooded horses and ponies, which may be attributed to the smaller size of their feet. These differences underscore the significance of investigating morphometric variables across diverse breeds.

Introduction

The Caspian horse is one of the oldest breeds of horses in Iran and is widely regarded as one of the most esteemed breeds in the global equine community. With an average height of 107-120 cm, this breed is considered a miniature horse. The Caspian horse is distinguished from other equine breeds by its small head and proportional body. The Caspian horse was considered extinct for several decades until 1965, when Louise Firouz discovered a few individuals in the southern region of the Caspian Sea [1].

The Caspian Sea is the largest inland body of water in the world. It washes five countries: Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan, a significant part of it is located in Caucasus shared by Azerbaijan and Dagestan. [2]

Caspian horses are renowned for their intelligence and kindness, which makes them an excellent choice for teaching children horse riding [1]. Currently, this breed is employed in a multitude of disciplines, including equestrian, carriage, and circus. The genome of the Caspian horse does not directly fall into the four ancestral types, which has led to this breed being

considered one of the rarest and unique in the *Equidae* family [3].

One of the primary causes of lameness in horses is hoof-related issues, which arise due to poor hoof structure [4]. A diagnosis of lameness necessitates the accurate interpretation of both clinical examination and radiographic findings, as well as a comprehensive understanding of the normal radiographic anatomy of the equine foot and the relationship between the distal phalanx and the hoof capsule [5].

One of the most significant causes of lameness in horses is laminitis. This disease is caused by the inflammation of the sensitive laminae along the dorsal aspect of the foot. If not diagnosed in the early stages, the local ischemia and necrosis of the laminae will result in the rotation and sinking of the distal phalanx, which is an extremely painful complication for the horse. Furthermore, the disease will significantly affect the horse's future performances [6].

Acute laminitis is more prevalent in the forelimbs, and in the majority of cases, the clinical manifestations of the disease are a delayed response to the inciting factor. Therefore, early diagnosis is crucial to prevent extensive laminar damage [5]. In cases where laminitis is suspected, radiographs are an indispensable tool, offering invaluable insight into the presence and chronicity of the disease. Additionally, radiography can be utilized to assess the severity and progressive nature of the disease [7]. It is imperative to obtain radiographic images at the earliest indication of laminitis in order to confirm the diagnosis and establish a baseline for subsequent radiographic examinations. Furthermore, this study is essential to elucidate the distinctions between the alterations that occur during the disease process in the distal phalanx and the surrounding soft tissue [5].

In order to diagnose limb lesions, it is essential to have a comprehensive understanding of the anatomical condition of the structures involved. The typical anatomy of the horse's digits has been elucidated in the radiographic examination [8].

In 1993, Linford et al. conducted a study to ascertain the morphometric factors of the third phalanx in the forelimb of Thoroughbred horses. The mean distance between the dorsal surface of the hoof wall and the dorsal surface of the distal phalanx in horses with no observable pathology was 14.6 mm. It was indicated that horses exhibiting this characteristic with a distance exceeding 16.6 mm are considered to be at risk for developing laminitis [9].

In 1999, Crips and Eustace proposed a novel definition of D-founder for the first time. In accordance with this definition, the vertical distance between the coronary band and the proximal part of the extensor process of the third phalanx was established as a criterion for diagnosing laminitis. Given the potential for rotation of the third phalanx within the hoof and subsequent sinking towards the ground surface, an increase in D founder is an unequivocal indicator of the presence of this complication within the hoof. Cripps posited that the dimensions of the equine subject and the nature of its exercise regimen influence the radiological measurements [10].

As posited by Masoudifard et al., the CF-Founder and S-Founder criteria were introduced as a means of more accurately measuring the occurrence of sinking [11]. The significance of these criteria has been substantiated by other researchers, as evidenced by Baxter and Cripps in two distinct studies. The D-Founder, C-Founder, and S_Founder criteria are employed to assess the sinking phenomenon in laminitis. The C-Founder and S_Founder criteria exhibit greater precision [5, 10]

In addition to the Thoroughbred, these criteria have been measured in the Hanoverian, the Akhal-Teke, the purebred Arabian horse, and ponies [9, 10, 11, 12, 13].

Because Miniature Caspian Horses have shorter arms for their body size, using data from other breeds to diagnose limb disease would not be reliable. There has been no radiographic study of Caspian horse hooves. In this study, the morphometric factors of the third phalanx of the forelimbs were measured and compared to other breeds.

Materials and Methods

Case selection

A total of 10 pure Caspian horses were selected from one of the stables in the north of Kerman. The average weight of the studied horses was 205±20 and the average height was 125±10. They included 5 mares and 5 stallions, ranging in age from 2 to 5 years. All horses had normal hooves that were trimmed regularly. The horses were clinically examined to rule out any orthopedic disease. There was no history of lameness or limb abnormalities for at least one year prior to the study.

Case preparation

Prior to each radiograph, the sulci of the frog and the plantar surface of the digits were cleaned. A 5 cm wire marker was attached to the dorsal aspect of the hoof wall, extending distally from the coronary band (where the last hair leaves the skin). It was used to determine the amount of radiographic magnification and to mark the coronary band on the lateromedial radiograph (Figure 1- A). Another metal marker was placed on the palmar surface of the hoof to determine the area of the coronary band (Figure 1- B). An appropriate concentration of barium sulfate contrast was applied to the sole surface and frog sulci for better visualization of these areas on lateromedial radiographs (Figure 1- C) [11, 13].

Radiography

Radiography was performed with a MeX+20 portable X-ray generator. The exposure factors were 60 kV, 8 mAs, and the focal distance was 80 cm [17]. Radiographs were digitally stored using a digital radiography (DR) system. Horses were positioned with both forelimbs simultaneously on a wooden block, standing squarely with the limbs equally weighted. Care was taken to ensure that the third metacarpal was perpendicular to the ground. The hoof was also placed on a thick wooden block for all radiographs.

All measurements from the lateromedial radiographs were multiplied by the magnification correction factor (MCF) to obtain the actual distances. The MCF was determined by dividing the actual length of the metal marker by the length of the radiographic image of the marker.

Morphometric analysis of the radiographs

In each obtained radiograph, 7 distances, 6 angles, and 3 ratios of the distal phalanx and the hoof wall were measured.

The morphometric assessments were made as follows:

1. The hoof wall and its soft tissue thickness included 3 regions:

a) STTD: Total soft tissue thickness dorsal to the distal aspect of the DP (Figure 2- C).

b) STTM: Total soft tissue thickness dorsal to the mid aspect of the DP (Figure 2- B).

c) STTP: Total soft tissue thickness dorsal to the proximal aspect of the DP (Figure 2- A).

They were the shortest distance between the dorsal surface of the hoof wall and the dorsal cortex of the DP.

2. Palmarocortical length (PCL) of the DP: The distance from the tip of the solar margin to the midpoint of the articulation between the phalanx and the navicular bone (Figure 2).

3. The ratios of wall thickness to PCL: These ratios are assessed by the correct thickness of STTD, STTM, and STTP expressed as a percentage.

4. D-Founder: The perpendicular distance from the horizontal line through the extensor process to the horizontal line through the coronary band (Figure 2).

5. S-Founder: The perpendicular distance from the horizontal line through the highest point of the barium sulfate contrast depleted sole surface anterior to the frog to the tip of the DP (Figure 2).

6. CF founder: The perpendicular distance from the horizontal line through the highest point of the frog corium to the extensor process (Figure 2).

7. Hoof Wall Axis (S-Angle): The caudal angle formed between a line along the dorsal surface of the hoof wall and a line along the plantar surface of the hoof (Figure 2).

8. Distal Phalanx Axis (T-Angle): The caudal angle formed between a line along the dorsal cortex of the phalanx and a line along the bearing surface of the hoof wall (Figure 2).

9. H Angle: The difference between the S and T angles.
10. Middle Phalanx Axis (U Angle): The caudal angle formed between a line through the center axis of the middle phalanx and a line along the bearing surface of the hoof wall (Figure 2).
11. R Angle: The difference between the U and T angles.
12. P Angle: A caudal angle formed between a line through the palmarocortical and a line through the dorsal surface of the DP (Figure 2) [11].

Statistical Analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26. The mean, standard deviation, and minimum and maximum values were identified as the primary measurements in Caspian horses. The paired t-test was employed to compare the measurements between males and females, as well as between the right and left front feet. The level of significance was set at $P < 0.05$.

Results

The results of the measurements of the distances, ratios, and angles of morphometric variables of the distal phalanx and hoof in lateral radiographs of the total, left, and right front feet, and male and female Caspian horses are presented in Tables 1 and 2.

The results of this study indicate that there is no statistically significant difference ($p < 0.05$) in the measured parameters between the left and right forelimb lateral radiographs. A comparison of the data pertaining to the distal phalanx and hoof in male and female horses revealed the absence of any statistically significant differences with respect to the parameters under consideration.

Table 1. Mean ± Standard Deviation (SD) measurements of the distances of morphometric variables of distal phalanx and hoof in lateral radiographs of front feet of total, left and right, and male and female in sound Caspian horses

	Mean$_{(sd)}$ of total	**Mean$_{(sd)}$ of left & right**	**Mean$_{(sd)}$ of male & female**
STTD(mm)	11.73(.71)	L:11.87(0.9) R:11.6(0.52)	M:11.63(0.25) F:12.04(0.43)
STTM(mm)	12.13(0.39)	L:12.12(0.26) R:12.15(0.53)	M:12.03(0.38) F:12.44(0.43)
STTP(mm)	12.55(0.39)	L:12.35(0.22) R:12.75(0.57)	M:12.46(0.46) F:12.8(0.35)
PCL(mm)	41.56(1.19)	L:42(1.41) R:41.13(0.98)	M:42.43(1.56) F:43.6(1.26)
STTD/PCL%	28.23(0.75)	L:28.26(1.00) R:28.20(0.55)	M:27.42(0.38) F:27.4(0.42)
STTM/PCL%	29.19(0.72)	L:28.85(0.72) R:29.54(0.72)	M:28.43(0.81) F:28.58(0.16)
STTP/PCL%	29.97(0.65)	L:29.40(0.79) R:30.54(0.52)	M:29.06(0.43) F:29.27(0.19)
DF(mm)	8.17(1.61)	L:7.65(0.92) R:8.7(2.31)	M:8.43(1.56) F:7.38(1.11)
SF(mm)	7.66(0.4)	L:8.1(0.27) R:7.22(0.54)	M:7.68(0.21) F:7.6(0.7)
CF(mm)	41.15(2.39)	L:40.97(2.78) R:41.30(2.00)	M:41.08(1.81) F:41.6(2.94)

Table 2. Mean ± Standard Deviation (SD) measurements of the angles of morphometric variables of distal phalanx and hoof in lateral radiographs of front feet of total, left and right, and male and female in sound Caspian horses.

	Mean$_{(SD)}$ of total	**Mean$_{(sd)}$ of left & right**	**Mean$_{(sd)}$ of male & female**
S angle	55.3(2.35)	L:55.2(2.82) R:55.4(1.89)	M:56.33(2.94) F:53.5(2.12)
T angle	54.67(2.09)	L:55.5(2.67) R:53.85(1.52)	M:56.33(2.80) F:53(2.82)
H angle	0.72(1.70)	L: -0.1(1.85) R:1.35(1.56)	M:0.1(1.6) F:0.5(0.7)
U angle	53.4(2.23)	L:55.3(2.83) R:53.5(1.64)	M:56.16(2.78) F:52.5(3.53)
R angle	0.27(1.16)	L: -0.2(0.63) R:-0.35(1.7)	M:0.16(0.75) F: 0.5(0.7)
P angle	32.1(2.18)	L:33(2.44) R:31.2(1.93)	M:33.5(2.94) F:31.5(2.12)

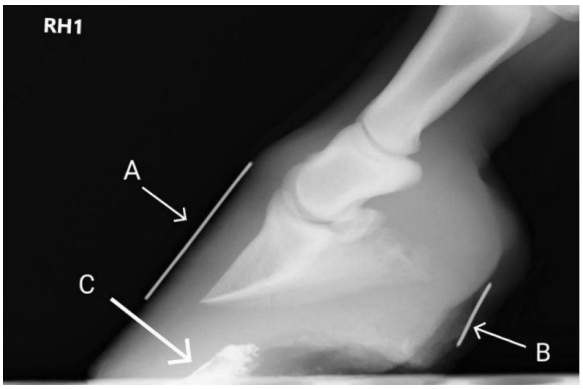

Fig 1. Latero-medial radiograph of the third phalanx of front foot of sound Caspian horse. A: metal marker on the dorsal of the hoof wall, B: metal marker on the palmar aspect of the hoof, C: sole surface

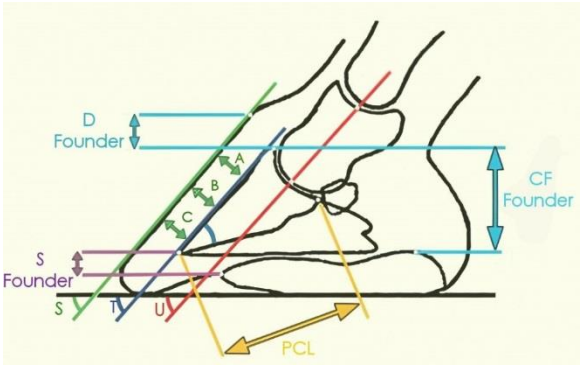

Fig 2. The schematic appearance of the leg represents angles and distances on latero-medial radiograph mentioned in the table.

Discussion

Linford (1987) posited that hoof wall thickness is contingent upon foot size. The study of Caspian horses revealed that the mean foot length was 54.75 mm, the mean foot width was 87.62 mm, and the mean hoof wall thickness was 11.7 mm. These values are lower than those observed in ponies and warm-blooded horses [10, 13, 14]. In the context of acute laminitis, the thickness of the hoof wall is increased as a consequence of inflammation of the hoof lamina [5]. In their 1993 study, Linford and colleagues asserted that a hoof wall thickness exceeding 17 mm is indicative of laminitis in horses. The authors reported that the mean thickness in the Thoroughbred breed was 14.6 mm [9]. In Caspian horses, the distance in question was found to be 12mm, with a maximum of 13.6mm. This is less than the average and maximum distance observed in ponies and warm-blooded horses. The mean distance was 14 mm in the case of the ponies [10, 11, 12, 13]. This phenomenon can be attributed to the smaller size of the Caspian horse foot in proportion to its body size. It can be reasonably inferred that the indicating distance for laminitis in Caspian should be considered to be less than 17mm.

As stated by Peloso et al. (1996), the thickness of the hoof wall should be less than 30% of the palmarocortical length of the coffin bone. An increase in this percentage is indicative of laminitis [15]. In this breed, the distance

between the poll and the center of the eye (PCL) was measured at 46 mm, which is clearly lower than in warm-blooded breeds, as well as the average distance in ponies [10,11,12,13].

In all cases in which the ratio was measured, it was less than 30% of the palmarocortical length, with the exception of two right hands that exhibited no evidence of laminitis. In a lateral radiograph of the hoof, the surface of the hoof wall and the third phalanx should be parallel [16]. The aforementioned principle was investigated by Linford in 1993 using the H angle, which is, in fact, the difference between the S angle and the T angle [9]. In thoroughbreds, the mean value of this angle was 0.5 + 1.3, with no individual value exceeding 4 degrees. In Caspian horses, the mean value of the H angle was -0.25, with no individual value exceeding 4 degrees. The DF index, which plays a pivotal role in the investigation of chronic laminitis and the occurrence of sinking, was measured between 0-15 mm in a significant number of horses. In this particular breed, the measurements ranged from 4.3-14 mm, with an average of 7.6 mm. The mean distance is 9.1 mm in ponies, 5.2 mm in Thoroughbreds, and 3.3 mm in Hanoverians [10, 17].

The rationale for employing the S-Founder and CF-Founder criteria in this investigation is that it is challenging to discern the coronary band in instances of inflammation or sinking [11]. These differences illustrate the significance of investigating morphometric variables across diverse breeds. In lateral view radiographs, the surface of the hoof wall should be entirely smooth and devoid of any evidence of erosion. It is not uncommon for sound horses to display mild convexity or concavity [16]. The radiographic examination of the Caspian horses revealed a completely straight and bone-deposit-free hoof surface. The findings of the present study may serve as a point of reference for future investigations into laminitis in Caspian horses.

Conclusion

As the preceding studies and the present study demonstrate that the parameters of the legs vary according to the type of animal and its breed, this study can serve as a valuable resource for investigating any type of change in the hoof and front feet of the Caspian horse.

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Conflict of interest

The authors declare that they have no competing interests.

Ethical approval

The trial convention was endorsed by the animal welfare committee of the Faculty of Veterinary Medicine at Shahid Bahonar University of Kerman, Kerman, Iran.

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