

Radiographic assessment of normal parameters of forelimb distal phalanx in Turkmen horses

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Abstract

The Turkmen horse is one of the oldest breeds in the world with unique characteristics in agility, endurance and jump, being publicly acclaimed. Laminitis affects the limbs and decreases athletic performance. Radiographic evaluation is essential to confirm the sinking diagnosis in every breed of a horse suffering from laminitis. Since no information about distal phalanx radiographic measurements in this breed has been reported, the current study was designed and conducted. In the present study, 24 clinically sound registered Turkmen horses of both sexes (15 mares and nine stallions) were selected. Lateromedial radiographic views of both front distal phalanges were taken, focusing on the distal phalanx. After magnification correction, images were used to measure founder distances (FD) and other distal phalanx radiographic measurements using an image processing program. There was no significant difference between radiographic measurements of the left and right front feet. The FD had a significant positive correlation with weight. The horses under 3 years of age had a significantly greater U angle than the horses over the age of three. Also, palmarocortical length (PCL) in the Turkmen stallions was significantly higher than mares. In this investigation, PCL in horses under the age of three was significantly lower than horses over 3 years of age. The values determined in this study can be used as baseline data of front feet in Turkmen horses.

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Introduction

Turkmen horse is one of the oldest breeds in the world. Due to unique characteristics and versatile skills for athletic performance, Turkmen horses join wide varieties of equestrians, including racing, endurance, jumping, dressage and polo competitions.¹⁻³ Laminitis is one of the most common causes of lameness^{4,5} and as a painful condition, it can affect any horse breed or performance.⁶ Laminitis disrupts the distal phalanx balance, leading to a change in the hoof shape.⁵

Identifying the changes happening at the early stage of laminitis is highly important. It is well-known that radiography is still the most common diagnostic tool to assess the position of the distal phalanx within the hoof capsule. A latero-medial radiograph is a gold standard for diagnosing this positional change.⁷ Different radiographic indicators are used as the prognostic factors for laminitis in horses. Founder distance (FD), a vertical distance from the top of the dorsal hoof wall to the top of the extensor

process of the pedal bone, is the most important diagnostic criterion for evaluating distal displacement or sinking of the distal phalanx.^{7,8} The reported founder values are variable and may depend on individual differences, including horse breed or size.⁷ So, in order to measure the amount of positional change of the distal phalanx alignment, the knowledge of normality should be given. Previous studies have been performed on different breeds of horses, such as Thoroughbred,⁹ Hanoverian,⁹ Arab^{10,11} and Pony.⁹ In this study, some normal radiographic measurements in forelimbs of Turkmen horses were evaluated to assess hoof balance in this breed.

Materials and Methods

This study was approved by the ethics committee of the Faculty of Veterinary Medicine of Ferdowsi University in Mashhad, Iran (IR.UM.REC.1400.205). Measurements were performed on the forelimbs of pure Turkmen horses selected from one of the free horse herds in Jargalan area

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of North Khorasan province, Iran. Twenty-four horses, including nine stallions and 15 mares with a mean age of 4.50 years and average body weight of 307.25 kg were selected. Until the beginning of the study, these horses had been only trimmed but not shod. These horses were determined to be free of lameness with clinical examinations. After standard foot preparation, a 70.00 mm metal marker was placed on the hoof wall at the midsagittal plane at the level of the coronary band to the tip of the hoof to locate the outer surface of the hoof wall on the radiograph images. The lateromedial radiographs were taken from each forelimb on the wooden positioning block with an embedded metal bar on its top surface (71.00 mm high). Radiographs were obtained using a portable X-ray device (Soyee SY-HF-110; Soyee Product Inc., Seoul, South Korea). The X-ray beam was aligned at a right angle to the sagittal plane of the foot centered midway between the heel and the toe.

Radiological measurements. Radiographs were fixed onto a horizontal viewing box and then, photographs were taken by a digital camera (A710 IS; Canon, Nagasaki, Japan) at a constant distance from the radiographs. Ten measurements were made by ImageJ software (National Institutes of Health, Bethesda, USA) from each lateromedial radiograph (Fig. 1). Ten radiographic parameters were measured as follows:¹²

1. The vertical distance or FD is measured between the coronary band and the proximal edge of the extensor process.
2. Sole depth (SD) is the perpendicular distance between the solar margin and the highest point of the sole surface.
3. Corium of frog (CF)-founder (CFF) is the perpendicular distance from the horizontal line through the top point of the frog corium to the extensor process.
4. The palmarocortical length (PCL) of the distal phalanx is measured from the solar margin at the distal toe to the palmar articular edge between the distal phalanx and the distal sesamoid bone.
5. Distance P is the thickness of the dorsal soft tissues measured 5.00 mm distal to the junction of the extensor process to the dorsal cortex.
6. Distance D is the thickness of the dorsal soft tissues measured 6.00 mm proximal to the most distal point of the dorsal cortex.
7. Length of the middle phalanx (MP).
8. S angle is the angle between the dorsal hoof wall and the ground.
9. T angle is the angle between the dorsal cortex of the distal phalanx and the ground.
10. U angle is the angle between a line connecting the centers of curvature of the proximal and distal inter-phalangeal joints and the ground.

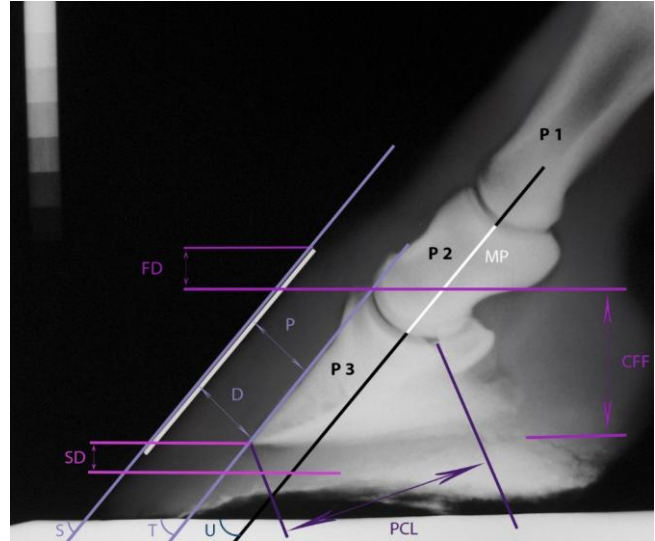


Fig. 1. Lateral radiograph of 3rd phalanx (P3) and calculated radiographic measurements. FD: Founder distance; SD: Sole depth; CFF: Corium of frog-founder; PCL: Palmarocortical length; MP: Middle phalanx length; P1: 1st phalanx; P2: 2nd phalanx; P: Thickness of the dorsal soft tissues measured 5.00 mm distal to the junction of the extensor process with the dorsal cortex; D: Thickness of the dorsal soft tissues measured 6 mm proximal to the most distal point of the dorsal cortex; Angle S: Angle between the dorsal hoof wall and the ground; Angle T: Angle between the dorsal cortex of the distal phalanx and the ground; Angle U: Angle between a line connecting the centers of curvature of the proximal and distal inter-phalangeal joints and the ground.

The magnification correction factor was used to obtain the actual distance. For this purpose, the actual length of the metal marker was divided into its radiographic lengths and multiplied by each measurement.

Statistical analyses. The normality of radiology data was assessed. To determine the normal ranges for radiographic indices, the MedCalc statistical software (version 13.0; MedCalc Software bvba, Ostend, Belgium) was used. Whereas the sample size was relatively small, lower and upper limits (90.00% confidence interval) were calculated using a robust approach. Comparison of the left and right limb indices was carried out using pair sample *t*-test. Additionally, a linear regression technique was used to evaluate the relationship between age, sex and weight with radiographic indices. The SPSS Software (version 23.0; IBM Corp., Armonk, USA) was used for the mentioned statistical analyses.

Results

Forty-eight forelimbs of 24 horses were included in this study. The mean body weight and age were 307.25 ± 16.48 kg and 4.80 years, respectively. There were 15 (62.50%) mares and nine (37.50%) stallions. No significant differences were found between left and right forelimbs radiographs in all measured distances and angles.

Table 1 includes all the descriptive statistics of all variables related to the front feet. Furthermore, the mean and standard deviation of measurements in males and females and different age groups were studied in this study. The relationship between age, sex and weight with radiographic indices was evaluated using linear regression. The FD positively correlated with weight ($p < 0.05$). The horses under 3 years of age had a significantly greater U angle than the horses over the age of three ($p < 0.05$; Table 2). Also, PCL in the Turkmen stallions was significantly higher than the mares ($p < 0.05$; Table 2). In this investigation, PCL in horses under the age of three was significantly lower than horses over 3 years of age ($p < 0.05$; Table 2).

Discussion

Assessment of the hoof parameters related to distal phalanx position with radiography is critical in examining laminitis. Lateromedial radiographs represent valuable

data for the evaluation of the anatomical alignment of the 3rd phalanx.¹³ The current study documented the normal radiographic measurements of the distal phalanx in the hoof capsule of the Turkmen horse breed.

Anatomical dislocation of the distal phalanx is evaluated as FD.¹⁴ These measurements were based on the lateromedial radiographs obtained from 48 forelimbs of sound Turkmen horses. Eustace and Caldwell have remarked that the most useful prognostic criterion is the measurement of the vertical distal displacement of the distal phalanx.¹⁵ Indeed, knowing the normal FD is essential. The present study measured the normal FD in Turkmen breed and reported it as 5.85 ± 3.42 mm. In a previous study conducted by Cripps and Eustace,⁴ this parameter was reported to be 4.14 ± 2.17 mm in different breeds of horses, including the Thoroughbred, Hanoverian or Hanoverian cross. The normal FD of forelimbs achieved for the Thoroughbred breed was 5.20 ± 1.97 mm⁴.

Table 1. Mean, standard deviation and 95.00% reference interval of each radiographic measurement recorded in 48 front feet of normal Turkmen horses.

Parameters	No.	Mean \pm SD	Lower (95.00% CI)	Upper (95.00% CI)
FD (mm)	48	5.85 \pm 3.42	-0.90 (-2.30 - 0.55)	12.60 (11.15 - 14.00)
SD (mm)	48	10.40 \pm 3.34	3.85 (2.46 - 5.23)	17.00 (16.00 - 18.34)
CFF (mm)	48	45.70 \pm 2.90	40.83 (39.75 - 42.00)	51.00 (49.88 - 52.04)
PCL (mm)	48	55.30 \pm 2.80	49.77 (48.61 - 51.00)	60.77 (59.61 - 61.93)
P (mm)	48	18.70 \pm 2.04	14.69 (13.84 - 15.53)	22.72 (21.87 - 23.56)
D (mm)	47	18.14 \pm 2.23	13.76 (12.83 - 14.70)	22.52 (21.60 - 23.45)
MP (mm)	48	38.17 \pm 1.84	34.56 (33.80 - 35.33)	41.78 (41.02 - 42.55)
Angle S ($^{\circ}$)	47	52.91 \pm 3.75	45.55 (44.00 - 47.12)	60.26 (58.69 - 61.84)
Angle T ($^{\circ}$)	46	51.37 \pm 3.28	44.94 (43.55 - 46.30)	57.81 (56.42 - 59.20)
Angle U ($^{\circ}$)	47	45.13 \pm 5.11	35.11 (33.00 - 37.25)	55.16 (53.02 - 57.30)

FD: Founder distance; SD: Sole depth; CFF: Corium of frog-founder; PCL: Palmarocortical length; P: Thickness of the dorsal soft tissues measured 5.00 mm distal to the junction of the extensor process to the dorsal cortex; D: Thickness of the dorsal soft tissues measured 6.00 mm proximal to the most distal point of the dorsal cortex; MP: Middle phalanx length; Angle S: Angle between the dorsal hoof wall and the ground; Angle T: Angle between the dorsal cortex of the distal phalanx and the ground; Angle U: Angle between a line connecting the centers of curvature of the proximal and distal inter-phalangeal joints and the ground; SD: Standard deviation; CI: Confidence interval; No.: Number of feet.

Table 2. Mean and standard deviation of the distances and angles of the third phalanx and hoof in different age groups for left and right forelimbs and male and female horses in lateral radiographs.

Parameters	Less than 3 years		More than 3 years		Male		Female	
	No.	Mean \pm SD	No.	Mean \pm SD	No.	Mean \pm SD	No.	Mean \pm SD
FD (mm)	24	4.81 \pm 3.70	24	6.89 \pm 2.84	18	5.60 \pm 3.18	30	6.02 \pm 3.60
SD (mm)	24	9.81 \pm 2.35	24	10.99 \pm 4.07	18	9.46 \pm 3.60	30	10.97 \pm 3.11
CFF (mm)	24	45.93 \pm 2.28	24	45.46 \pm 3.45	18	45.06 \pm 3.31	30	46.08 \pm 2.61
PCL (mm)	24	53.78 \pm 2.76	24	56.76 \pm 1.94	18	55.96 \pm 1.75	30	54.86 \pm 3.23
P (mm)	24	18.60 \pm 1.94	24	18.80 \pm 2.18	18	18.51 \pm 2.90	30	18.82 \pm 1.34
D (mm)	24	18.02 \pm 2.26	23	18.27 \pm 2.24	18	17.68 \pm 3.04	29	18.42 \pm 1.53
MP (mm)	24	38.33 \pm 1.70	24	38.02 \pm 1.99	18	38.19 \pm 1.97	30	38.17 \pm 1.79
Angle S ($^{\circ}$)	24	53.23 \pm 4.51	23	52.57 \pm 2.82	18	53.92 \pm 3.46	29	52.28 \pm 3.84
Angle T ($^{\circ}$)	24	51.59 \pm 3.74	22	51.14 \pm 2.76	17	51.57 \pm 3.05	29	51.26 \pm 3.45
Angle U ($^{\circ}$)	24	47.71 \pm 4.79	23	42.45 \pm 3.98	18	46.27 \pm 4.07	29	44.43 \pm 5.61

FD: Founder distance; SD: Sole depth; CFF: Corium of frog-founder; PCL: Palmarocortical length; P: Thickness of the dorsal soft tissues measured 5.00 mm distal to the junction of the extensor process to the dorsal cortex; D: Thickness of the dorsal soft tissues measured 6.00 mm proximal to the most distal point of the dorsal cortex; MP: Middle phalanx length; Angle S: Angle between the dorsal hoof wall and the ground; Angle T: Angle between the dorsal cortex of the distal phalanx and the ground; Angle U: Angle between a line connecting the centers of curvature of the proximal and distal inter-phalangeal joints and the ground; SD: Standard deviation; No.: Number of feet.

The FD values reported here for the Turkmen breed are comparable to those reported for other horse breeds. The existence of differences in the reported values might be due to the differences in breed, phenotype, type of activity, body weight and size of the hoof box. A significant positive correlation was demonstrated between body weight and FD in the Turkmen breed in males and females. This could indicate that overweight horses may be at a higher risk of laminitis.

The measurement of the dorsal hoof wall and the soft tissue that belongs to it is an important part of a diagnostic radiography of feet. The normal average of the dorsal hoof wall and the soft tissue that belongs to it was reported to be 15.00 - 18.00 mm for most healthy horses of the most breeds.¹⁶ The average in the Cripps and Eustace report for the front feet of various breeds was 16.30 ± 2.40 mm.⁴ In the current study, the normal average of this parameter being assessed by Thrall method was 18.70 ± 2.04 mm and 18.14 ± 2.23 mm at two points of P and D, respectively.⁹ Additionally, the average of this parameter in the study of Linford *et al.*, was reported to be 14.60 ± 1.00 mm.¹⁷ The difference in value may indicate the important breed differences regarding this parameter, similar to the study of Cripps and Eustace.⁴

In the current study, different angles of the 3rd phalanx and foot were recorded in front feet as follows: S angle: $52.91 \pm 3.75^\circ$; T angle: $51.37 \pm 3.28^\circ$; U angle: $45.13 \pm 5.11^\circ$; SD: 10.40 ± 3.34 mm; CFF: 45.70 ± 2.90 mm; PCL: 55.30 ± 2.80 mm; MP: 38.17 ± 1.84 mm. Measurements such as angles and distances are needed to determine the position of the 3rd phalanx in the hoof capsule.

The relationship between the independent variables, including age, weight and sex and the dependent radiographic variables was also assessed.

Among measured dependent variables, FD, PCL and U angle had a significant statistical correlation with the independent variable. Different studies have suggested that hoof parameters can be affected by age, weight, gender and activity.^{18,19}

The amount of PCL had a significant correlation with sex and age. The PCL in the Turkmen stallions was significantly higher than mares. Also, it was significantly lower in horses under the age of three than horses over the 3 years of age. In this regard, the average amount of 1.85 mm among females was lower than that among males. The normal average of PCL among the older than 3 years of age category was 3.02 mm more than that of the younger than 3 years of age category. Consequently, the data suggest that for achieving a normal PCL average among the Turkmen breed horses, the independent variables of sex and age should be considered.

The measure of U angle and age had a significant correlation. The horses under three years of age had a significantly greater U angle than the horses over the age of three. In a way, the average amount of U angle among

over the age of three category was 5.04 degrees lower than the under 3 years of age category. This difference may be associated with the animals sexual maturity process.

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Conflict of interest

The authors declare that they have no conflict of interest.

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