AJVR

AVMA

Radiographic analysis of the dorsal hoof wall thickness in clinically normal draft horses

Casey D. Larsen, DVM*; Thomas E. Wilkinson Jr., DVM, DACVR; Gregory D. Roberts, DVM, DACVR; Sarah C. Guess, DVM, DACVIM; John S. Mattoon, DVM, DACVR; Macarena G. Sanz, PhD, DACVIM

Veterinary Teaching Hospital, Washington State University, Pullman, WA

*Corresponding author: Dr. Larsen (caseydlarsen@gmail.com)

Received July 1, 2023
Accepted October 17, 2023

doi.org/10.2460/ajvr.23.06.0145

OBJECTIVE
To evaluate the radiographic thickness of the dorsal hoof wall in normal draft horse feet.

ANIMALS
33 adult draft horses with no history of laminitis, no clinically obvious lameness, and visibly unremarkable front feet were included.

METHODS
This was a prospective, descriptive study of clinically normal draft horses' front feet. Lateromedial radiographs were acquired of the front feet. A ratio of the dorsal hoof wall thickness to the length of the distal phalanx (DHWP3 ratio) was calculated.

RESULTS
The dorsal hoof wall thickness to length of the distal phalanx was calculated as 0.33 ± 0.03 (range of 0.28 to 0.39) in this population of draft horses.

CLINICAL RELEVANCE
With very few exceptions, the heterogeneous population of draft horses evaluated in this study had a DHWP3 ratio greater than previously published values in lighter breeds (< 0.30).

Keywords: horse, hoof wall, laminitis, draft horse, sinking laminitis

Laminitis is a debilitating and often fatal condition in horses, in which separation of the laminar junction between the hoof wall and dermis occurs.[1] Early detection of laminitis is crucial to initiate appropriate therapy before the occurrence of irreversible damage, as horses are more likely to be euthanized if distal displacement of the distal phalanx occurs.[2]

There are several patterns of displacement of the distal phalanx. These include (1) rotational displacement (palmar rotation of the distal phalanx), (2) asymmetrical displacement (medial or lateral sinking), and (3) symmetrical displacement ("sinking").[3] The soft tissues of the dorsal hoof wall thicken symmetrically in cases of distal displacement of the distal phalanx without rotation, also referred to as laminar swelling.[4]

Linford[5] found that early diagnosis of laminitis can be supported radiographically by detecting subtle thickening of the dorsal hoof wall. Previous studies[5–7] have established normal values of the dorsal hoof wall in a variety of lighter breeds, with proportional measurements being more accurate than absolute measurements as they take into account the size of the horse and correct for any magnification variance.[8] These published ranges are relied on to detect deviation from normal in cases of laminitis.

Normal reference measurements have not been established for draft horses. Anecdotally, the ratios of the dorsal hoof wall thickness to the length of the distal phalanx (DHWP3 ratios) in draft horses result in values greater than those previously reported, even in patients that are not suspected to be suffering from laminitis.

This study aims to determine if a group of clinically normal draft horses will have DHWP3 ratios similar to previously reported normal values in

lighter breeds. We hypothesize that normal draft horses will have larger DHWP3 ratios relative to previous reports in lighter breeds.

Methods

Patient selection

This prospective, descriptive study was approved by the Institutional Animal Care and Use Committee. Owners and trainers of draft horses were prospectively recruited for participation. Adult draft horses of various breeds (Belgians, Clydesdales, mixed breeds), with no history of laminitis, and visibly unremarkable feet were recruited for the study. Enrolled horses had no obvious signs of lameness at the walk at the time of radiographic acquisition. Similarly qualified in-hospital patients between January 2022 and April 2023 who were being treated for non–foot-related conditions (eg, laryngeal paralysis, sinonasal disease) were also enrolled.

Radiographic protocol

Nonsedated, standing lateromedial radiographs of the front feet were acquired at a predetermined focal film distance of 40 inches.[5,9] Enrolled horses were positioned to stand squarely with both front feet placed on wooden blocks. Digital radiography equipment was used for image acquisition (MinXray, Inc, Canon Medical Systems, and DRTECH), and exposure parameters (mAs and kVp) were optimized for each patient. An external marker of the dorsal hoof wall was not utilized as the external aspect of the hoof wall is easily identifiable using digital radiography and postprocessing image manipulation (window/level).[10]

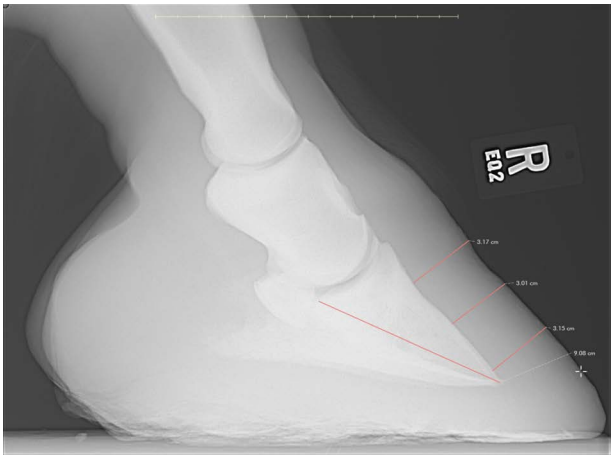

Figure 1—Lateromedial right front foot radiograph with measurements of the dorsal hoof wall and length of the distal phalanx.

Radiographic analysis

The dorsal hoof wall was measured in 3 locations on uncorrected lateromedial radiographs: (1) 6 mm proximal from the distal aspect of the distal phalanx, (2) immediately distal to the base of the extensor process, and (3) midway between measurements 1 and 2. The length of the distal phalanx was measured from the tip to the palmar cortex, at the mid aspect of the articulation with the navicular bone.[5]

To calculate the proportion corrected DHWP3 ratio (proximal, mid, and distal), each measurement of the dorsal hoof wall was divided by the length of the distal phalanx **(Figure 1)**. An average of the 3 dorsal hoof wall measurements was also calculated and compared to the length of the distal phalanx for an averaged DHWP3 ratio.

These measurements were obtained using lateromedial radiographs on DICOM viewing software (Ambra Health, Intelerad Medical Systems Incorporated). Measurements were acquired by a third-year diagnostic imaging resident (CDL).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistical Software, version 28.0.0.0 (IBM Corp). Descriptive statistics were performed using standard methods and are reported as median (IQR) when nonnormally distributed and as mean (SD) when normally distributed. The Shapiro-Wilk test was cross-checked with the Kolmogorov-Smirnov test due to the sample size to assess normality with examination of frequency histograms where needed to assess distributions. The *P* values listed for normal distributions are based on the Shapiro-Wilk test. Two-sided *t* test was used to compare means between left and right with Leven's test for equality of variances. ANOVA was used to assess differences

Table 1—Summary of statistical analysis from the measurements of the right and left front feet.

Variable	Mean	Median	SD	IQR	Minimum	Maximum
Proximal DHW (mm)	34.37		3.99		25.4	44.3
Mid DHW (mm)	31.14		3.50		24.4	39.8
Distal DHW (mm)	30.85		3.20		22.7	38.0
Average DHW (mm)	32.12		3.30		25.1	40.3
Length of P3 (mm)		98.65		7.8	77.1	113.6
Proximal DHWP3 ratio	0.350		0.029		0.292	0.426
Mid DHWP3 ratio	0.318		0.028		0.258	0.384
Distal DHWP3 ratio		0.319		0.034	0.244	0.367
Average DHWP3 ratio	0.328		0.025		0.276	0.389

Average DHWP3 ratio = Average of the 3 dorsal hoof wall measurements (proximal, mid, and distal) to length of the distal phalanx. DHW = Measured thickness of the dorsal hoof wall. [c]DHWP3 ratio = Proportion corrected ratio of the dorsal hoof wall to length of the distal phalanx. P3 = Distal phalanx.

between left and right, breed (Belgian, Clydesdale, and mixed breeds), and location of dorsal hoof wall measurement (proximal, mid, and distal aspects of the distal phalanx).

Results

A total of 64 front feet from 33 horses were enrolled for participation in the study. There were 24 geldings and 9 mares included with an age range from 5 to 19 years. White line disease was discovered in 1 foot of 2 patients within our study population. These feet were excluded from the study.

The mean DHWP3 ratio was 0.33 with an SD ± 0.03 **(Table 1)**. Averaged DHWP3 ratios (average of all 3 measurements divided by length of P3) ranged from 0.28 to 0.39. Without proportionally corrected values (ie, with magnification), the mean radiographic thickness of the dorsal hoof wall ranged from 25.1 mm to 40.3 mm. All variables were normally distributed except the length of the distal phalanx (P = .008) and the distal DHWP3 ratio (P = .044). There was no significant difference between breeds for any of the measurements.

Discussion

Assessment of the position of the distal phalanx within the hoof capsule is imperative in the clinical evaluation of laminitis.[11] This is most readily accomplished via radiography. The primary form of radiographic displacement described in the literature has historically been limited to palmar rotation of the distal phalanx. However, in 1986, Baxter[12] described symmetrical displacement or "sinking," which is more difficult to identify. Distal displacement of the distal phalanx was identified in its latest stages in 12 horses where the most reliable clinical indicator was limited to dorsal cavitation or depression of the coronary band.[12] Radiographic thickening of the dorsal hoof wall was seldom appreciated in this study (only in 25% of horses). The difficulty in identifying distal, symmetrical displacement of the distal phalanx has contributed to several publications[5,6,11] on the normal radiographic anatomy of the equine foot.

Magnification must be addressed in radiography since structures are magnified as the distance between the structure and the imaging detector increases.[13] This is particularly relevant in draft horses, more so than lighter breeds, who may have large flaring hoof walls that further displace the imaging detector from the axial aspect of the limb.

One of the first publications[5]that quantified the thickness of the dorsal hoof wall evaluated a population of racing Thoroughbreds. This study described 2 methods to correct for magnification when evaluating the dorsal hoof wall in horses: (1) a proportion corrected ratio of the dorsal hoof wall thickness to the length of the palmar cortex of the distal phalanx and (2) an external marker of known diameter, placed on the midline at the level of the coronary band. Magnification-corrected and proportion-corrected ratios were shown to not have significant differences.[5] This study uses the first method as it is easily performed with most viewing software and is available to most practitioners, without the need to have an external marker of known diameter in the field.

Several additional publications including ponies,[14] various light breeds,[6,11] warmbloods,[15] and donkeys[16] have utilized proportion corrected ratios to evaluate the dorsal hoof wall in equids. To date, there are no published values for draft horses. To this end, this study evaluated the radiographic thickness of the dorsal hoof wall in a population of normal draft horses.

Our findings support our hypothesis, DHWP3 ratios are larger in this population of normal draft horses with no history of laminitis. The average DHWP3 ratio was 0.33 ± 0.03 with a range of 0.28 to 0.39. Previous values published for lighter breeds report the normal proportion corrected DHWP3 ratios of < 0.30 to be normal.[3,5,8,15] In this population of draft horses, 95% are grouped within 2 SD (0.28 to 0.39).

This study has several limitations. The height and weight of the subjects were not recorded in any form. This precluded any attempted correlation between hoof wall thickness and patient size, as has been attempted in previous publications.[15] The time of radiographic acquisition was not controlled relative to hoof trimming cycles. Hoof trimming has been found to cause several statistically significant effects on the radiographic measurement of horses' feet.[17] The thickness of the dorsal hoof wall may be reduced distally by rasping the hoof wall at the time of trimming; however, the proximal aspect of the dorsal hoof wall was not affected.[17] The size of the imaging plate (26 X 20 cm) was unfortunately too small to completely include the entire foot of some of the largest horses' feet. Care was taken to include the areas of interest and, when needed, preferentially exclude the tip of the hoof capsule and palmar aspect of the heels.

In conclusion, the dorsal hoof wall compared to the length of the distal phalanx is thicker in this population of normal draft horses (proportion-corrected ratio of 0.33 ± 0.03, range of 0.28 to 0.39). This is a relevant difference compared to published values in lighter breeds and should be considered when evaluating draft horses for symmetrical distal displacement of P3.

Acknowledgments

None reported.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.

Funding

Funding for this project was provided by Washington State University's Veterinary Teaching Hospital.

References

1. Merritt J, Davies H, Parks AC. Digital biomechanics relevant to laminitis. In: Belknap JK, Geor RJ, eds. *Equine Laminitis.* John Wiley & Sons, Inc, Wiley-Blackwell; 2017:39–46. doi:10.1002/9781119169239.ch5
2. Hunt RJ. A retrospective evaluation of laminitis in horses. *Equine Vet J.* 1993;25(1):61–64. doi:10.1111/j.2042-3306.1993.tb02903.x
3. Belknap JK, Parks AC, Dern K. Laminitis. In Stashak TS, Baxter GM, eds. *Adams and Stashak's Lameness in Horses.* Wiley Blackwell; 2020:490.
4. Hood DM. The mechanisms and consequences of structural failure of the foot. *Vet Clin North Am Equine Pract.* 1999;15(2):437–461. doi:10.1016/s0749-0739(17)30154-2
5. Linford R. Qualitative and morphometric radiographic findings in the distal phalanx and digital soft tissues of sound thoroughbred racehorses. *Am J Vet Res.* 1993;54(1):38–51.
6. Cripps PJ, Eustace RA. Radiological measurements from the feet of normal horses with relevance to laminitis. *Equine Vet J.* 1999;31(5):427–432. doi:10.1111/j.2042-3306.1999.tb03844.x
7. Peloso J. Case-control study of risk factors for the development of laminitis in the contralateral limb in Equidae with unilateral lameness. *J Am Vet Med Assoc.* 1996;209(10):1746–1749.
8. Parks AC, Belknap JK. Diagnostic imaging. Belknap JK, Geor RJ. *Equine Laminitis.* John Wiley & Sons, Inc, Wiley-Blackwell; 2017:226–238. doi:10.1002/9781119169239.ch27
9. Koblik P, O'Brien T. Effect of dorsopalmar projection obliquity on radiographic measurement of distal phalangeal rotation angle in horses with laminitis. *J Am Vet Med Assoc.* 1988;192(3):349–349.
10. Rowan C, Puggioni A, Kearney C, Skelly C. The effect of radioopaque markers to delineate the dorsal hoof wall on image quality in digital equine radiography. Abstracts from the 2016 European Veterinary Diagnostic Imaging Annual Conference, Wroclaw, Poland, August 31 to September 3, 2016. *Vet Radiol Ultrasound.* 2016;57(6):646–669. doi:10.1111/vru.12426
11. Grundmann INM, Drost WT, Zekas LJ, et al. Quantitative assessment of the equine hoof using digital radiography and magnetic resonance imaging. *Equine Vet J.* 2014;47(5):542–547. doi:10.1111/evj.12340
12. Baxter GM. Equine laminitis caused by distal displacement of the distal phalanx: 12 cases (1976–1985). *J Am Vet Med Assoc.* 1986;189(3):326–329.
13. Thrall DE. Introduction to radiographic interpretation. In: Thrall DE, ed. *Textbook of Veterinary Diagnostic Radiology.* 7th ed. W. B. Saunders Company; 2018:113.
14. Thieme K, Ehrle A, Lischer C. Radiographic measurements of the hooves of normal ponies. *Vet J.* 2015;206(3):332–337. doi:10.1016/j.tvjl.2015.10.005
15. Mullard J, Ireland J, Dyson S. Radiographic assessment of the ratio of the hoof wall distal phalanx distance to palmar length of the distal phalanx in 415 front feet of 279 horses. *Equine Vet Educ.* 2018;32(S10):2–10. doi:10.1111/eve.13004
16. Collins SN, Dyson SJ, Murray RC, Burden F, Trawford A. Radiological anatomy of the donkey's foot: objective characterisation of the normal and laminitic donkey foot. *Equine Vet J.* 2011;43(4):478–486. doi:10.1111/j.2042-3306.2010.00312.x
17. Kummer M, Geyer H, Imboden I, Auer J, Lischer C. The effect of hoof trimming on radiographic measurements of the front feet of normal Warmblood horses. *Vet J.* 2006;172(1):58–66. doi:10.1016/j.tvjl.2005.03.008