Predictive modeling of the equine heel

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Abstract

Recently it has been proposed that healthy soft tissue structures of the equine heel play a primary role in equine soundness. Historically, little attention has been given to the significance of the health of the equine soft tissue structures, which are uniquely positioned so as to provide support and protection to the navicular apparatus. Namely these tissues are the digital cushion and collateral cartilages. We believe that volume characteristics of these structures can be accurately predicted through physical examination and routine diagnostic imaging. The goal of this study is to determine whether the volume of the soft tissue structures of the equine heel can be predicted by the insensitive and non-invasive methods of physical, radiographic, and ultrasonographic examination. Thirteen left hind feet were collected from adult Thoroughbred horse cadavers (4-20 years of age). Physical, radiographic, and ultrasonographic examinations were performed on the hooves and multiple parameters were recorded. The hooves were then scanned using computed tomography (CT) and magnetic resonance imaging (MRI). Data from the CT and MRI scans were processed through Mimics® medical imaging software, to create 3D images of the middle phalanx, collateral cartilages, and digital cushion. The volumes of the 3D reconstructed tissues were recorded for comparison with ultrasonographic, radiographic, and physical exam parameters. It was found that the feet were able to be categorized into high, medium, and low total heel volume (THV) and navicular volume (NV), and coronary band circumference was the only parameter evaluated that predicted DCV and THV with accuracy (p < 0.0004, r² = 0.693). The clinical parameters evaluated here were only sensitive enough to detect approximately 60% difference between feet in this study thus, it is doubtful that common clinical diagnostic techniques (physical, radiographic and ultrasonography) will be sufficient for evaluation of heel development in future research endeavors on mature horses.

Introduction

Traditionally, equine foot lameness has been attributed to pathology of the bones, synovial structures, tendons and ligaments, and the lamina of the foot. Historically, little attention has been given to the significance of the health of the equine soft tissue structures, which are uniquely positioned so as to provide support and protection to the navicular apparatus. Namely, these tissues are the digital cushion and collateral cartilages. We believe that volume characteristics of the soft tissue structures of the equine heel can be accurately predicted through physical, radiographic, and ultrasonographic examination. The goal of this study was to determine whether the volume of the soft tissue structures of the equine heel could be predicted by the insensitive and non-invasive methods of physical, radiographic, and ultrasonographic examination.

Materials & Methods

Thirteen left hind feet were collected from adult Thoroughbred horse cadavers aged 4 – 20 years. The feet were imaged using computed tomography (CT) and magnetic resonance imaging (MRI). CT images were obtained on the frozen feet in a transverse plane, perpendicular to the palmar angle of the distal phalanx, at 1.0 mm intervals and then filtered with a “kernel” for bone edge and soft tissue enhancement to create 0.6 mm images. The feet were thawed prior to MRI scanning. MRI images were obtained in the same plane using 1.5 mm intervals, a human knee coil, and either a 3 Tesla magnet (n=10) or a 1.5 Tesla magnet (n=3). Data from the CT and MRI scans were processed using Mimics® medical image processing software. Three-dimensional images were constructed of the digital cushion, collateral cartilages, and the middle phalanx. The volumes of these anatomical structures were determined. Physical, radiographic, and ultrasonographic examinations were performed on the same feet. A physical examination scoring system for the equine heel was established in a previous study and used to examine all feet (Table 1, Figure 2). Each foot was imaged through the frog using ultrasonography to determine the thickness of the digital cushion (Figure 1). Calculated heel volume was determined by the multiplication of the parameters of digital cushion volume between collateral cartilages (Figure 2a) and heel depth measured using Metron® (Figure 3) and the average thickness of the digital cushion (Avg. Thickness of DC = CSD x [DC+FD]). Coronary band circumference was also measured (Figure 2b). The relationships between clinical exam measurements (independent variables) and Mimics® values (dependent variables) were explored using repeated measures analysis. P values ≤ 0.05 were considered significant.

Results

Using the parameters designed for this study (Table 1), each foot was ranked based on predicted volume (Table 3). Data from the physical examinations is shown in Table 2. The volumes of the digital cushion (DCV), total heel soft tissue (THV), and middle phalanx (P2 Volume) were determined by three-dimensional reconstruction (Figures 4 and 5). The feet were then ranked based on the following: PE Vol. with frog, PE Vol. without frog, DCV, THV, Calc. Vol., DC thickness, and coronary band circumference. These rankings are displayed in Table 3 to allow direct comparison. Through statistical evaluation it was found that coronary band circumference was predictive of THV (p = 0.0004, r² = 0.693). No other direct correlations existed between clinical examination findings and volumes from three-dimensional reconstructions; however, there was a trend towards being able to categorize feet into high, medium, and low THV and DCV.

Discussion

Coronary band circumference (Table 3, highlighted) was the only parameter evaluated that predicted DCV and THV with accuracy (p < 0.0004, r² = 0.693). However a trend was noted whereby several other parameters accurately categorized the hooves into low, medium, and high THV and DCV (Table 3). Data from this study serves as a very preliminary screening for clinical examination measures that may serve as predictor variables for anatomical characteristics of the equine heel. Physical and clinical examination parameters may be useful to later categorize hooves into low, medium and high volume for clinical purposes. This could be used clinically to determine “hoof readiness” for athletic use of the horse. Previous studies indicate that a 5-10% change in volume of the equine heel can be expected over a 6-month period of hoof stimulation. The clinical parameters evaluated here will not be sufficient to detect the percent change as they were only sensitive enough to detect approximately 60% difference between feet in this study. It is also valuable to note that this study focused on the variation of THV and DCV within mature horses of a single breed (TB), therefore subtle differences between the feet were difficult to appreciate.

Based on the results of this study it is doubtful that common clinical diagnostic techniques (physical, radiographic and ultrasound examination) will be sufficient for evaluation of heel development in future research endeavors on mature horses. Therefore, soft tissue evaluation in future studies will require costly diagnostic imaging (MRI and CT scan) for Mimics 3D reconstruction in order to accurately evaluate small changes in soft tissue volumes.

References


Footnotes

1. CT was performed using a Siemens SOMATOM Definition CT Scanner
2. MRI was performed using a Siemens Vario Open-Bore 3T Scanner
3. MRI was performed using a Philips Infinion 1.5T Scanner
4. Mimics® medical imaging processing software by Materialise
5. Metron® by EponaTech LLC
6. SASK PROG GLIMMIX, Cary, NC

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