5-8-2015

The Effects of Three Shoeing Methods on Hoof Growth and Health in Horses

Amanda Morris
amandalusianfarm@gmail.com

The Effects of Three Shoeing Methods on Hoof Growth and Health in Horses

Amanda Leigh Morris

B.S., University of Connecticut, 2008

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

at the

University of Connecticut

2015

APPROVAL PAGE

Master of Science Thesis

The Effects of Three Shoeing Methods on Hoof Growth and Health in Horses

Presented by

Amanda Leigh Morris, B.S.

Major Advisor ____
Dr. Jenifer Nadeau

Associate Advisor ____
Dr. Sandra Bushmich

Associate Advisor ____
Dr. Thomas Hoagland

University of Connecticut

2015

Acknowledgements

I am very grateful for the support I have received from so many people that has helped me complete my degree and thesis:

My major advisor, Dr. Jenifer Nadeau, for her support and guidance through the project design and thesis writing process;

Dr. Daniel Fletcher for giving me the opportunity to be a part of the graduate program and for the many hours of listening and advice he gave me;

All of the staff at Horse Unit 1, especially John Bennet, Kathy Pelleter, Billy, and Andrea;

My advisory committee, Dr. Sandra Bushmich and Dr. Thomas Hoagland, for their patience and continued support;

Dr. Richard Mancini and Ranjeeth for their help with statistical analysis;

Caitlin Lewis for her friendship and help in GPS retrieval;

My family for their unwavering support and encouragement;

Dr. Alexis Soutter for her help from Easyboot Care Inc.;

Jessica Chickering for helping to teach me about the barefoot process;

My horses, for giving me the inspiration to complete my degree.

Table of Contents

List of Figures and Tables

Nomenclature

GFR- ground reactive forces

P 3- third phalanx

DDFT- deep digital flexor tendon

PEL-primary epidermal laminae

SEL- secondary epidermal laminae

TEL- tertiary epidermal laminae

P 1- pastern bone

P2- distal phalanx

BLM- Bureau of Land Management

GPS- Global Positioning System

km- kilometers

cm- centimeter

KPH- kilometers per hour

RH- right hind

LH- left hind

RF- right front

LF- left front

Abstract

Fourteen mixed breed mares and geldings ranging in age from 4 to 20 years were selected to participate in this study to determine the effects on hoof growth and health with three shoing method. Each horse was randomly assigned a treatment: shod, barefoot, or Easyboots. Measurements were taken on the body and on the hoof at the beginning and conclusion of each shoeing method. Global Positioning Systems (GPS) were attached to each horse using a surcingle during turnout at the beginning and conclusion of each shoeing method.

There were minimal changes in morphometric measurements between the barefoot, Easyboot and shod treatments over the course of the study. Hoof measurements showed a trend for significant differences to be observed between barefoot and shod treatments. Significant change was observed on the left front hoof between all three treatments, indicating the response in this hoof could be due to greater weight bearing capacity and therefore a trend for left sidedness. Toe length was shortest in the left front hooves when horses were barefoot and longest when horses were shod ($p<0.01$). The left front hoof showed the outside heel height was highest for the barefoot treatment and lowest for the Easyboot treatment ($p<0.05$). Lowest inside heel height was measured on the right and left front hooves during the Easyboot treatment and was highest during the shod treatment ($p<0.05$). A significant difference was observed between barefoot and shod treatments with $p<0.01$). The greatest length measurement was for the shod treatment and lowest for the barefoot treatment of the left front hoof ($p<0.05$). Data obtained from the four GPS units shows no significance in total distance traveled or average speed regardless of shoeing method. The results of this study indicate that each hoof responds to environmental factors independently. This study should be repeated to determine if the results stay the same. These results should aid in hoof trimming and treatment decisions to provide optimal health for the horse.

Literature Reviewed

Proper health of the hoof is necessary for correct movement of the horse. Each horse has its own ideal hoof shape and size, and for each horse this varies from fore to hind limbs to meet the ideal weight bearing capacity and flight patterns. In a study by Schamhardt, et al entitled "Kinematic differences in the distal portions of the forelimbs and hind limbs of horses at the trot" researchers showed that the forelimbs move with greater velocity and acceleration than hind limbs (2003). The entire lower limb completes a repetitive sequence in order for the horse to move forward in locomotion. In this series the hoof absorbs the ground reactive forces (GRF) throughout each stride. One stride consists of five phases: initial contact, impact, stance, breakover, and flight. Measurements from each phase show that there is a significant reduction in energy from initial contact of the heel and the ground to the first phalanx. This indicates that the structures of the hoof must be absorbing and dissipating energy.

Humans expose the domestic horse to environmental stressors that influence the structures of the hoof both in appearance and integrity. These stressors combined with genetic factors may be a reason that today's domestic horse population suffers from a broad range of hoof ailments. Understanding the form and function of the hoof can allow veterinarians, farriers, and horse owners to make informed decisions about the methods of hoof care and treatment they should use.

Mechanisms of Hoof Growth:

There are many factors that impact hoof growth, including age, season, nutrition, and structure sensitivity. On average the hoof grows ¼ to 3/8 inch per month (Wood 2009). The hoof is a highly adaptive structure. The composition of the hoof of a neonate differs from that of a mature adult, as seen a study by Bowker in 2007. As soon as a foal is born the hoof is exposed to a different environment and begins to change to meet the demands of surviving in that environment. A similar situation takes place as the horse matures; a change in environment results in a change in the hoof, either positive or negative. This change can range from the style of trimming to the moisture content of the ground, to the diet (Bowker 2007).

The exact mechanism of hoof growth is unknown. It is known that growth is inversely related to pressure on the coronary band. This could be a result of vascular changes occurring at the digital cushion and impacting the coronary band. Ideally hoof loss and growth are in balance with each other to produce equal bands of growth for the entire circumference of the hoof. Hoof loss occurs at the ground surface interface as the hoof is worn, beginning at the coronary band and growing downward towards the toe. The coronary band produces germinal epithelium cells that migrate distally towards the toe. Separation and reformation of desmosomes between the primary and secondary laminae layers allows for this movement to occur (Parks 2003).

Keratin is the main protein found in the hoof wall. Its unique properties offer stability, strength, and protection for the hoof. The disulfide bonds found in keratin provide strong structural integrity and the amino acids of the bond (methionine and cysteine) provide the necessary components that make the wall insoluble to potential permeating forces. Keratinocytes are found in the tubules of the hoof wall. Each tubule is continuous, meaning it extends from its origin at the coronary band all the way down to where the wall makes ground contact. Here, between the papillae of the tubule, keratinocytes mature and become intertubule hoof. Microscopic cross examination of the hoof wall tubule shows keratinocyte maturation occurring at a right angle to the hoof wall. This anatomical feature forms a keratin matrix that adds to the mechanical stability of the hoof allowing it to have a multidirectional property. Mature keratin cells are cemented together to form the horny layer of the hoof (Kaneps and Turner 2004). Figure 1 shows the lamellae tubules.

The tubules of the hoof wall are arranged by density. This allows for optimum energy dissipation as ground reactive forces act on the hoof. The outermost layer of the hoof has the greatest density, and density decreases inwards towards the laminar layer creating a total of four density zones. This arrangement allows the hoof to be durable. One example can be seen in the process of cracks forming in the hoof wall. The properties of the interface between density layers prevent the crack from migrating inward towards sensitive interior structures. In studying vibrations associated with contact to ground reactive forces, the layers of the hoof wall are able to absorb 90% of the energy before it reaches the coffin bone (Kaneps and Turner 2004).

The corium supplies the nutrients for hoof wall formation as well as supplies microcapillaries to the inner laminar structures. It encircles the circumference of the hoof at the hairline.

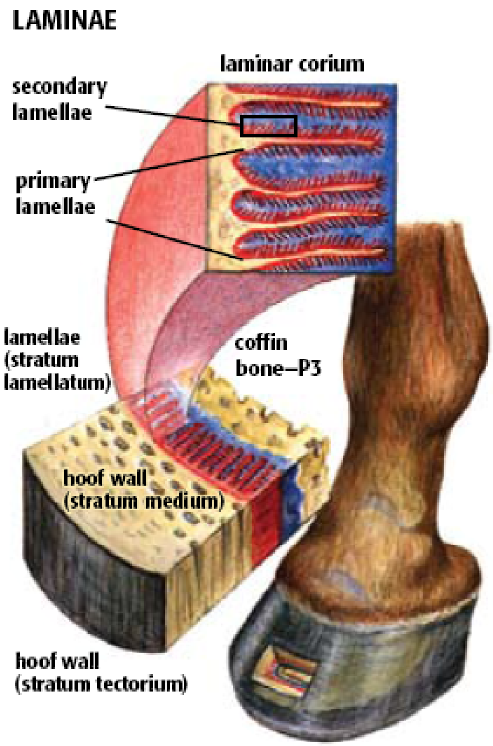


Figure 1.Illustration of the internal lamellae layers. Taken from "The Equine Foot" (Sellnow 2006).

Structural Components and Their Functions:

The hoof is comprised of outer protective structures and sensitive inner structures that can be affected by the alignment of the bones through the lower limb.

Exterior Structures

The outer structures of the hoof include the wall, sole, and frog. The wall is observed when the horse is standing with the hoof on the ground. It is a continuously growing structure made of horny material that begins at the coronary band and encapsulates the coffin bone. It is observed at the toe, quarters and heel of the hoof. When the hoof is viewed from the solar surface the wall is also observed at these points as well as at the bars of the hoof. In addition to protection it is thought that the bars offer traction for the hoof. The wall and the frog come in contact with the

ground, the sole does not (McClure 1999). Figure 2 shows the location of the toe, quarter, heel and coronet from the lateral aspect of the hoof.

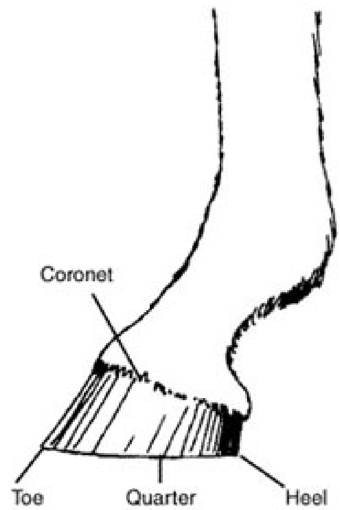


Figure 2.Location of the toe, quarter, heel and coronet, lateral view.From McClure 1999.

The wall is comprised of three layers. The outermost layer is the periople. The periople extends from the coronary band down the hoof approximately one inch and functions much like a human cuticle. The remaining outer portion of the wall is the stratum tectorium. This acts like a human finger nail. It is composed of keratinized epithelial cells which function to maintain the water content of the hoof wall. The middle layer of the hoof wall is the densest portion and is referred to as the stratum medium. The innermost layer is the most sensitive and contains the laminae. Laminae are leaf like projections that act to connect the hoof wall to the coffin bone. The point where the laminae connect to the sole of the foot is called the white line (Sellnow 2006). Figure 3 shows the location of these structures from the solar aspect of the hoof.

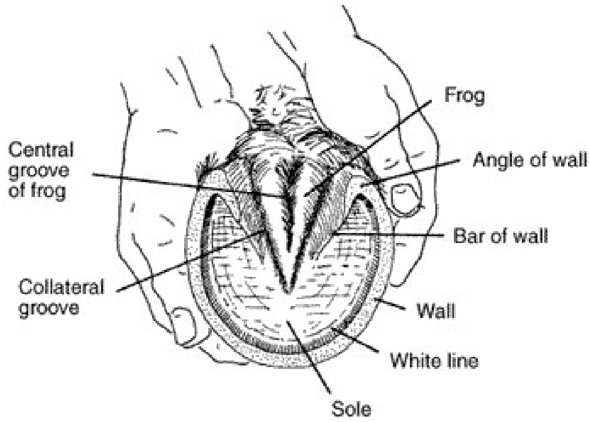


Figure 3.Location of structures from the solar aspect of the hoof.From McClure 1999.

The sole is the interface between the ground and the palmer surface of the internal hoof structures. The sole should have a concave shape, which indicates correct position of the coffin bone in the hoof capsule. The sole is a weight bearing surface to the internal structures of the foot, but not to the ground (Sellnow 2006). The depth of the sole should be sufficient to protect the internal structures from puncture or injury. When the sole is thin it compromises the integrity of internal structures. The sole is comprised of germinal epithelial cells that are constantly replaced as dead cells are exfoliated. This occurs naturally in wild horses. In domestic horses the trimmer needs to remove the dead sole, especially when the horse is in an environment that is not conducive to self wear. Dead sole is characterized by its chalky appearance and ease of removal.

Due to the concave shape of the sole the only contact it makes with the ground is where it meets the white line. The white line is the point where the stratum interium layer of the hoof wall meets the sole. This demarcation follows similar laws of the hoof wall; becoming thicker at the toe and thinner at the heel. The white line is observed only at the solar surface of the hoof and can give an indication of hoof health (Kainer 1989). For example, blood in the white line indicates hemorrhaging and therefore separation of the laminae.

When the horse is moving correctly, the frog comes in contact with the ground first. The frog has high elasticity, and when compressed places pressure on an internal hoof structure called the digital cushion. These two features act as a pump allowing blood to flow in and out of the hoof. This is the concept behind Dr. Robert Bowker's hemodynamic flow hypothesis of energy

dissipation (Bowker 1998). Figure 4 demonstrates this concept. Blood flow allows for the exchange of nutrients and therefore affects hoof growth.

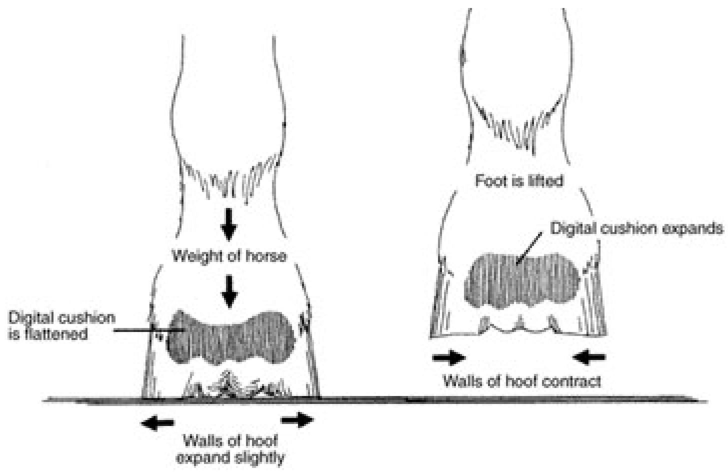


Figure 4. Effects of weight bearing and non weight bearing phases on the digital cushion
Taken from “Functional Anatomy of the Horse Foot” (McClure 1999)

Dr. Bowker has made great strides in unveiling foot physiology in the horse. Dr. Bowker has focused on understanding how the energy of the impact of a hoof on the ground is dissipated following the well known theory “for every action there is a reaction of equal force.” He theorized that blood flow to the hoof and throughout the hoof structures is responsible for dissipating the energy caused by the impact of the hoof to the ground. However, when measuring energy flow through the digital cushion he found that “when the hoof is in the air, it registers at zero pressure….but when it hits the ground, instead of registering positive pressure, it is actually negative.” This indicated that negative pressure could be created by the outward movement of hoof cartilage. Dr. Bowker observed “horses with good feet have more blood vessels in the lateral cartilage of their hooves ….located inside the lateral cartilage of the digital cushion…tended to be made of more cartilaginous material instead of elastic tissue [than those that had histories of foot problems].” (Bowker 1998). This indicates that hemodynamic flow plays a crucial role in providing the hoof with the nutrients needed to maintain correct structure as well as providing the fluid necessary for hoof movement during impact.

The theory of hemodynamic flow has been tested by several farriers and veterinarians through trimming practices that are believed to promote hoof growth. The principles include trimming with a short breakover and having the frog rest on the ground. This encourages the frog and back portion of the hoof to carry the weight of the horse which promotes the growth of fibrous and cartilaginous tissues.

Heel

The heel is the most caudal portion of the hoof wall (Sellnow 2006). In correct movement the heel is the first weight bearing structure to come in contact with the ground. The angle of the heel should be parallel to the dorsal hoof wall (Parks 2003). Excessive heel height has been shown to strain tendons and ligaments in the lower distal limb, especially the deep digital flexor tendon (DDFT) (Lawson et al 2007).

Bars

Bars are an extension of the hoof wall that turn inward from the heel towards the apex of the frog (Bowker 2003). The bars play a role in weight bearing and providing traction, as well as contributing to the hoof wall and sole. The orientation of the bars suggests that they support the hoof both distally and proximally. On histology the bars of the hoof differ in composition compared to the hoof wall. The bars are more keratinized compared to the hoof wall. These cells are different than the primary epidermal laminae (PEL) and secondary epidermal laminae (SEL), and are therefore called tertiary epidermal laminae (TEL) (Burg et al 2007).

Interior Structures

Proper alignment of the bones, tendons, and ligaments of the lower distal limb is imperative for correct locomotion. Any variation can impose significant negative effects on movement. Changes to the bones, tendons, and ligaments of the lower distal limb can affect the hoof capsule as can changes to the hoof capsule on the alignment of these critical structures.

Bones

The digit of the hoof has three phalanxes: the pastern bone (P1), the middle phalanx (P 2), and coffin bone (P 3) (Burg et al 2007). The navicular bone is located distal to P 3 and the short

pastern bone. Figure 5 shows the location of these bones and their associated joints and tendons. P 3 articulates only at one end. It differs from other bones in several ways: it is surrounded by soft tissues, it does not have a cortex or medullary cavity, and it has three surfaces: articular, parietal, and solar. The articular surface is flat with a space for the navicular bone to fit. The parietal surface is porous which allows for the attachment of blood vessels. The solar surface does not have the same porous characteristic as the parietal surface. It is demarcated by the semilunar line which divides the flexor surface and the planumcutaneum. At the flexor surface the extensor process, solar grooves, and solar foramina are present (Parks, 2003).

The cannon bone is the only true metacarpal left from the evolution of the horse. Between the digit and the cannon bone is the fetlock joint. Between P1 and P2 is the pastern joint. Between P2 and P3 is the distal interphalangeal (DIP) joint (Burg et al 2007).

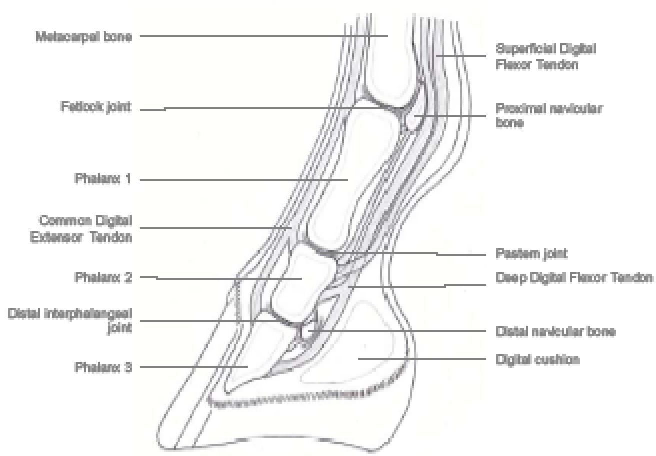


Figure 5.Location of bones, joints and tendons of the lower distal limb. From Burg et al 2007.

Tendons

Tendons and ligaments help provide support and fluid motion. Both play a critical role in stabilizing the leg because there is not a large amount of muscle in the lower leg and no muscle in the digit. There are many ligaments and accessory ligaments, which can be divided into five groups.

There are two major tendon groups in the foot: extensor and flexor tendons, and of these there are two main tendons, the extensor tendon and the DDFT.

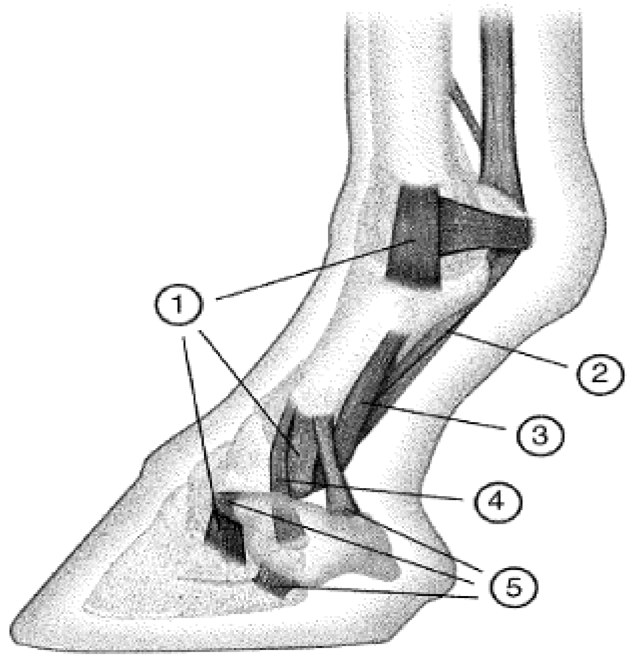


Figure 6.Location of ligaments of the lower distal limb. 1. Collateral ligament; 2. distalsesamoidean ligaments; 3. palmar ligament; 4. collateralsesamoidean ligament; 5. ligaments to the ungula cartilage. From Parks 2003.

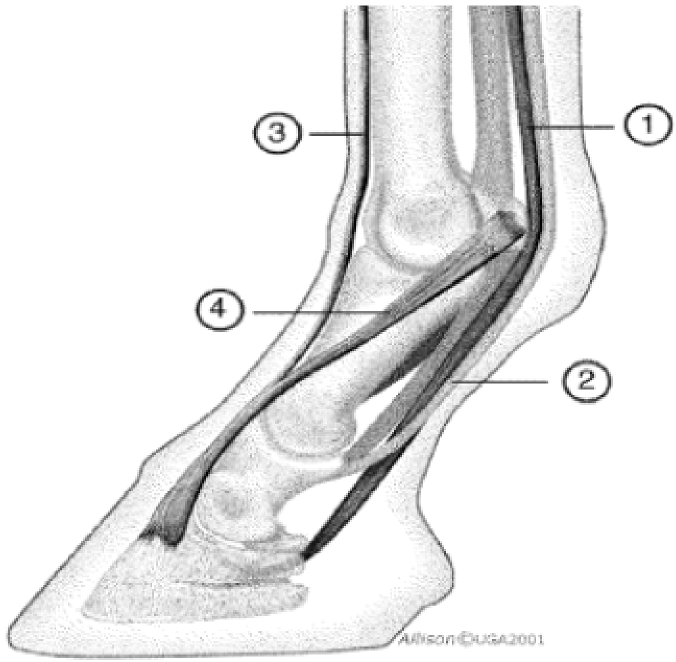


Figure 7.Location of tendons of the lower distal limb. 1. Deep digital flexor tendon; 2 superifical digital flexor tendon; 3. common digital extensor tendon; 4. extensor branch to suspensory ligament. From Parks 2003

Soft Tissues

The digital cushion is located at the base of the distal phalanx joint. It is comprised of fibroelastic tissue with adipose deposits with a small amount of fibrocartilage, vasculature, and nerves. Each region of the digital cushion serves a purpose. The digital cushion becomes dense collagenous connective tissue as it merges with the DDFT. The digital cushion becomes looser, consisting of more adipose tissue and subcutaneous nature as it forms the base of the bulbs of the heels. The digital cushion also forms the deep layer of the frog. (Kainer 1989). The function of the digital cushion is to absorb shock and cushion the bones of the lower distal phalanx during times of compression (weight bearing phase of locomotion). (Sellnow, 2006)

Diseases of the hoof

Thrush

Thrush is a bacterial infection that affects the frog and sulci. It is caused by moisture trapped in these areas from a combination of soiled bedding and improper trimming of the frog. Thrush is not uncommon in horses in any environment (Parks 2003). Even a small opening in the frog or on occasion, hoof wall, can create a setting for the keratolytic organisms that cause thrush. *Fusobacteriumnecrophorum* is the most common bacterium isolated in cases of thrush. In chronic cases this bacterium can spread to the sensitive internal structures of the hoof, causing swelling and lameness (Reeves 1989). Treatment of thrush includes proper trimming and cleaning of the frog, application of an astringent agent, and consistent removal of soiled bedding from the environment (Parks 2003).

White Line Disease

White line disease is a condition characterized by separation of the hoof wall. It generally occurs at the toe and quarters, between the stratum medium and laminar horn layers. Clinical presentation may or may not be associated with lameness. Often the condition is reported at the time of hoof trimming. Causes for white line disease have been suggested but not verified. They include environmental, nutritional, and mechanical factors as well as infectious organisms (O'Grady 1997, Turner 1998). White line disease is progressive. As the sole begins to separate from the hoof wall pathogens gain access to the sensitive interior structures of the hoof. This can be compounded by cracks or nail holes in the hoof that also compromise the integrity of the hooves protective properties (O'Grady 1997). As the hoof wall becomes more damaged rotation of the coffin bone can occur and the condition can become painful for the horse. In severe situations treatment of white line disease requires resection and debridement of the diseased portion of the hoof (O'Grady 1997). White line disease is a fairly recent condition, first noted in veterinary literature by Redden in 1990. It falls under several different sub names including dew poisoning, yeast infection, Candida, hoof rot, onychomycosis (Turner 1998) and seedy toe (O'Grady 1997).

Lameness

Foot balance and conformation can be a cause of lameness. Andy Parks, MRCVS, evaluated the terms balance and conformation in the parameters of lameness. Foot balance can affect the way the rest of the distal limb reacts to the force of the hoof to the ground. Changes can occur to the bone structures of the hoof, leading to changes in the shape of the hoof capsule and ultimately the pattern of hoof growth. Lameness can occur with an injury as well as with repetitive stresses on the structures of the hoof due to imbalance and poor conformation. Visual examination and radiographs are the most common evaluation of balance and conformation of the hoof. A visual examination includes examination of the hoof between the limb and the ground, hoof morphology, and observation at the walk and trot to make a determination on limb landing, weight bearing, and break over. Treatment for an imbalanced hoof is proper trimming and/or the application of a therapeutic shoe. In severe cases this need to be performed in stages as the hoof capsule is being forced to distort. Conformation cannot be fixed by trimming or shoeing, but can alleviate stresses through compensation.

Laminitis

Laminitis is defined as inflammation of the laminae leading to degeneration of the union horny and sensitive laminae (Merck Veterinary Manual 2011). The most common cause of laminitis is increased carbohydrate in take, such as grain overload. Other triggers include over grazing on lush grass, over exercise of an unfit horse, colic, and endotoxemia. These ailments cause a cascade of events to occur resulting in blood supply to and from the hoof to be shunted (Merck Veterinary Manual 2011).

Laminitis can affect one hoof or all four hooves. Commonly signs of laminitis are observed in the fore hooves. Depending on the severity of the case, laminitis can be classified as acute, sub acute or chronic. “Laminitic rings” are observed in mild cases and in severe cases founder can occur. In cases of chronic laminitis rotation of the coffin can be observed in outward changes of the hoof capsule and confirmed through radiographs. Another sign of laminitis is heat in the hoof, especially near the coronary band. A strong digital pulse can be noted as well (Merck Veterinary Manual 2011). Laminitis is always accompanied by the clinical presentation of

lameness; however lameness does not necessarily indicate laminitis. Laminitis can be present in varying degrees and can be excruciatingly painful for the horse.

Founder

Founder is the separation of the distal phalanx and the inner hoof wall (Merck Veterinary Manual 2011). The lack of attachment forces P3 to rotate forward and down into the hoof capsule. Figure 8 shows the rotation of P3 and separation from the distal hoof wall (DHW). Hemorrhaging indicate areas of extreme pressure (Pollit 2004).

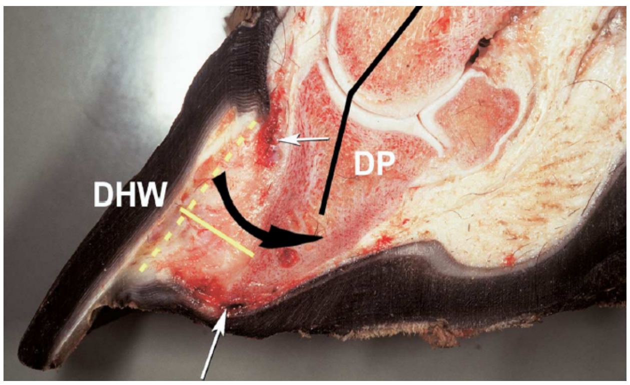


Figure 8.Rotation of the coffin bone leading to separation of the hoof wall from the coffin bone (Pollit 2004).

Founder can be irreversible and can result in euthanasia. Chronic laminitis has a classic stance in an effort to distribute the weight of the animal off the forelimbs: the horse stands with the hind legs tucked underneath the body, and the weight of the forelimbs on the caudal portion of the hoof (Pollit 2004), often called a “sawhorse stance”.

Figure 9.A horse in the classic laminitic stance (Pollit 2004).

Shoe Evaluation

Shoeing is truly an art that has been supplemented in recent years by scientific methods. As Parks points out in his 2003 article, it is important to understand the conformation of the hoof and how a shoe can affect movement of the distal limbs. Horse shoes can be used as basic protection to the hoof from wear and trauma or modified to enhance the performance of an animal or aid in treatment of certain hoof ailments. Shoeing can improve balance, traction, and breakover (Parks 2003). Proper care must be taken in the application of a horse shoe to the horse's hoof as well as maintaining the hooves for optimal use. The average horse is shod every six to eight weeks.

Before a shoe can be applied to a hoof the hoof must be prepared. If the horse is wearing shoes the old shoes must first be removed. The hoof capsule is trimmed to obtain optimal balance for the horse. A hoof knife is used to remove excess sole, bars, and frog. The nippers and the rasp are used to trim the hoof wall to the desired length. In some cases portions of the hoof wall may be trimmed to allow a space between the hoof wall and the shoe. This is referred to as floating the hoof wall. The benefit of floating the hoof wall is to allow pressure from bearing the weight of the horse to be relieved from one area of the hoof and compensated for by the surrounding

areas and the presence of the shoe. This can promote a greater rate of hoof growth at the coronary band which may aid in healing a portion of the hoof that needs treatment (Parks 2003).

The shoe is attached to the hoof using horse shoe nails. Nails come in different shapes and sizes appropriate for the shoe and hoof they are to be used in conjunction with. Nails are driven from the ground surface through the nail holes punched in the shoe and then through the hoof wall. The nail bevel is positioned toward the sole of the hoof, outside the white line, to avoid damage to internal hoof structures. The nail should exit the hoof wall approximately 1.9cm from the ground surface (Parks 2003). In the hands of an experienced farrier there should be minimal damage to the hoof wall. A less traditional method of shoe attachment is the use of adhesives. According to Parks adhesives offer advantages for certain situations including "1. when nailing is too painful; 2. when there is insufficient wall for nailing the shoe; and 3. depending on the application, it permits greater expansion of the foot" (Parks 2003). Disadantages of adhesives include the cost, durability, and potential damage to the underlying hoof wall (Parks 2003).

A horse shoe can be made out of metal or polymer materials. Different materials give varying weight to the shoe. Weight influences the biomechanics of movement. Therefore a heavy shoe will cause require more energy to be expended for acceleration and deceleration at the beginning and end of each limb cycle compared to a light shoe. Although not yet scientifically proven, it is believed that weighting a shoe at specific points can change the presentation of specific gaits. For example toe weights may increase flexion of the limb for a horse with poor flexion. Different materials also offer varying degrees of durability, shock absorption, as well as cost effectiveness. These factors give the farrier, veterinarian, or owner options for determining the best shoe for the desired purpose (Parks 2003).

The basic horse shoe is made out of metal and shaped to represent the shape of the hoof wall in relation to the ground. Therefore the shoe must be wide enough to cover the hoof wall and immediate adjoining sole. Since the shoe mimics the hoof wall it has the same reference points: toe quarters and heel. It should also be flat in relation to the ground. The shoe can be described in terms of four surfaces: the hoof surface, the ground surface, and the inner and outer edges or rims of the shoe. The shoe can be divided into two branches extending from the toe to the heels:

the medial branch and the lateral branch. The width and thickness of the branches is referred to as the web. The shoe is referred to as stamped or punched when there are nail holes present. Generally there are three to four nail holes stamped in each branch. At the heel the basic shoe is open because it does not form a continuous loop across the heel bulbs (Parks 2003).

The plastic shoe was evaluated in a study by Perino et al 2007 on the use of pressure point evaluation in horses. The study aimed to evaluate the ability of different shoes to reduce lameness. The treatments included unshod, shod with steel shoes, and shod with plastic shoes. Hooves were first trimmed for a state of normal balances, and after an 18 week period just the left front hoof was trimmed in an unbalanced manner. Data was collected using a Tekscan sensor mat and Rosette strain gauges. These tools show force, pressure, and contact area of the hoof with the ground. The study concluded that the plastic shoe appears to reduce lameness in the balanced and unbalanced state.

Evaluation of the Wild Horse Hoof

Shoeing for natural balance is a controversial topic, but is amalgamated by the concept of the wild horse model. The wild horse has the same hoof and structures as the domestic horse, and is able to maintain their hooves without the interference of humans to meet their functional needs, as has been the case for thousands of years. Therefore, the wild horse provides a model for what a hoof should look like for optimal health and function.

The way in which the wild horses hoof is worn reflects the environment that the horse lives in. The wild horse has a hoof wall that is worn down to the level of the sole, creating a callus referred to as sole callus. Sole callus is live functional epidermal tissue that has extended beyond its boarder and is observed as a raised area just inside the hoof wall. The hoof wall chips away as it is worn and often appears broken at the quarters which are also the widest part of the hoof. This is often observed in horses that live in soft sandy areas. In areas with harder terrain the heels are often worn down shorter than the frog. The apex of the frog is in contact with the ground and a callus is often seen here as well. Radiographs show that as this point is the center of the distal

phalanx. The sole callus and the callus at the frog become weight bearing surfaces as are the bars. (Ovnicek 2003).

It has been suggested that dirt packed into the hoof plays a role in hoof maintenance. In 2003 Eugene D. Ovnicek, a Registered Journeyman Farrier, said that dirt compaction is partially responsible for pastern alignment with the distal phalanx. Dirt compaction supports structures of the hoof at the frog, bars, and buttress of the heels (Ovnicek 2003).

A study in wild horses further solidified these findings. Ovnicek stated that "The purpose of the wild horse study was to see if there were hoof wear patterns that were consistent, unlike many domestic horses that have a wide range of hoof shapes and wear patterns." The Bureau of Land Management (BLM) assisted in the study. Each horse was placed in lateral recumbency for the hooves to be examined. Information gathered was compared between the wild horses and domestic horses. This included the amount of dirt packed into the foot around the frog and bars. A notable difference was observed between wild and domestic horse hooves. The distance from the frog apex to the wall at the toes was shorter than domestic hooves that are shod. The bars of the wild horse all terminated about ¾" from the frog apex. The heels varied based on terrain. In abrasive terrain the heels were worn back to the frog buttress. In softer terrain the heels were not worn. This is seen in domestic horses that live in sandy areas. All the horses had an enlargement of the frog that was callused, showing signs of weight bearing, also seen in domestic horses (Ovnicek 2003).

Hoof Balance and Force

To evaluate contact points with the ground dirt was removed from the foot, the bottom of the foot was painted and pressed against cardboard. The contact points were found to be at the medial/lateral toe, quarters and the heels. Lines were drawn across the foot from the cranial edge of the toe quarter to the heel mark to determine the point of breakover.

The researchers stated that the information gathered made it more easy recognize hoof deformity in domestic horses just by evaluating the hoof from the bottom. Looking at the ground surface

mass in this manner directly correlated to horses that stumble or land toe first having more ground surface mass ahead of the centerline, or widest part of the hoof.

A new concept developed by the researchers is that the callus plays an important part in supporting P 3. Often in the domestic horse this is over trimmed and the laminae attachment to P 3 may then be compromised as seen when horses are “off” for a few days after being trimmed.

Another observation is the heel first landing consistently observed in the wild horse. In the domestic horse when the hoof is trimmed to place the breakover ¼” ahead of P 3 and the heel is trimmed to place the frog buttresss in contact with the ground, the pastern alignment improved and the navicular bone became more vertical. This also leads to a consistent heel first landing. The researchers propose that this will “avoid stumbling, forging, interfering, improve hoof deformities that lead to heel soreness, contracted heels, and navicular diseases…”

Barefoot trimming

Barefoot trimming is used for horses which do not wear shoes and live in an environment where that does not allow for self maintenance of the hoof. A barefoot trim is not the same as preparing a hoof for a shoe but leaving the shoe off. A barefoot trim follows the ideas of natural balance as seen in the wild horse model. The average barefoot horse in a domestic environment needs to be trimmed every four to six weeks.

First the hoof knife is used to remove excess sole, bar, and frog. Excess sole is identified as any chalky substance that is easily removed. Next the hoof wall it trimmed using nippers and a rasp so that excess hoof wall is removed and the remaining wall is at the same level as the sole. The sole callus is used as a reference point, as seen in figure 10. The back edge of callus at the toe is the natural break over point. At the toe the wall is rasped 10 to 15 degrees relative to the plane of the sole. The quarters and heels are rasped to achieve medial lateral balance. In some cases the quarters may be floated, as they are with shod horses, if there is excessive growth. Finally the rim of the hoof is rounded (Ovnicek 2003).

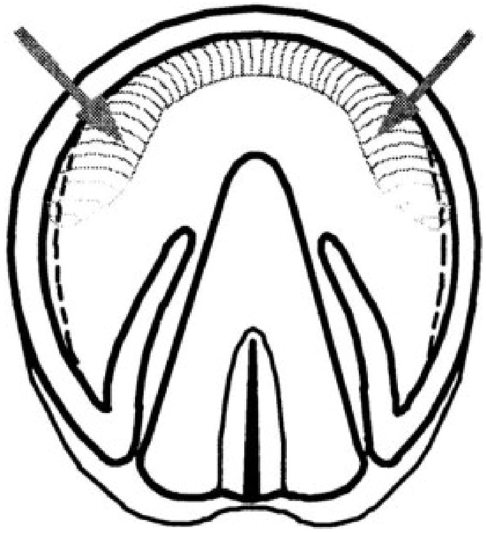


Figure 10.Sole Callus. (Jones 2002)

Easyboots

Easy Care Hoof Boots is one of many brands of horse boots that slip over the hoof capsule used to provide protection, traction, correction and comfort for the horse. The Easyboot was first introduced in 1972 by Dr. Neel Glass, a nuclear physicist at the National laboratory in Los Alamos, NM. The idea behind the Easyboot stemmed from the need to provide protection and support for the domestic horse without the invasive side effects of using a traditional nailed on shoe.

Easyboots can be used as a pair just on the fore limbs or a set of four. Easyboots come in a variety of styles to meet the needs of different disciplines, various hoof shapes, and to meet different needs (i.e. a therapy boot versus a trail boot). Easyboots are made from polyurethane, a tough yet elastic material. This allows the boots to stretch when needed to slip onto the hoof and conform to the hoof, like a second skin. For this reason is it is important that the boot is properly fitted to the horse. An ill fitted boot can result in rubbing, moisture build up, and the boot spontaneously detaching from the hoof. It is also important that the horse maintains a regular trimming schedule because the hoof is not being worn naturally which will help uphold proper fit.

Figure 11 shows the method used to measure a horse hoof to determine proper fit. The barefoot hoof is measured at the widest point, called the fulcrum, as observed from the solar surface. The length of the hoof is measured from the buttress line of the heel to the toe. The proper boot size is determined by comparing these two measurements to the Easycare boot chart.

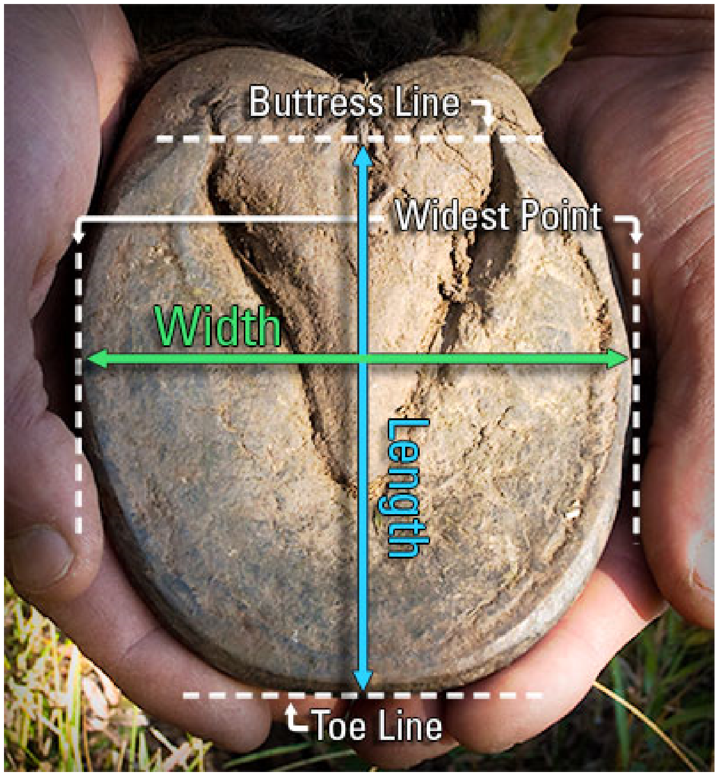


Figure 11.Location of measurements to fit Easyboots. (http://www.easycareinc.com/education/measure.aspx)

Global positioning system and horses

Global positioning systems (GPS) were first used as a way to mark a position anywhere on Earth. Further advances in GPS use have led to their applications in vehicles, airplanes, animal tracking. The most recent advances in GPS tracking include the ability to track the user's vital signs. Hebenbrock et al saw the advantage of this in a 2005 study investigating the use of GPS in sport horse training. The goal of this study was to investigate the accuracy of using GPS to monitor the position and velocity of horses as well as vital signs during exercise. Although GPS

tracking devices have been used on a variety of animals, horses have not been a species that GPS use has been well documented with (Hebenbrock 2005).

The study investigated the use of a commercially available GPS unit for reliability of pulse, distance, velocity, and heart rate recording. A standard 1000m track was used to evaluate the horses with five repetitions. After calculating agreement and variability the researchers concluded that the commercial GPS system had a high degree of accuracy for measuring horse heart rates, distance, and velocity individually and simultaneously (Hebenbrock 2005).

In 2010 Hampson et al investigated the use of GPS with three objectives: 1. as a monitoring system for horses 2. To evaluate paddock design and 3.To track movement of mares with foals. The data gathered was used to evaluate general health and hoof quality as it correlated to movement. A vehicle tracking GPS was attached to collars and placed on the horses for 6.5 days. The results showed an increase in paddock size correlated to an increase in total distance traveled. The domestic horse averaged 7.5km/day. Foals traveled similar distances compared to their dams. Feral horses traveled an average of 17.9km/day, a significant increase compared to domestic horses. The study concluded that horses kept in stalls and small paddocks are more sedentary compared to feral horses and changing the configuration of a paddock while keeping the exterior perimeter the same did not have an effect on distance traveled.

Further suggested uses of GPS for horses include the ability to quantify an objective assessment and surveillance of an animal during competition or objective information at a vet check point. GPS has the potential to provide a new perspective regarding critical biomedical information in behavioral studies. Its general use allows for supervision of an animal in training or performance over long distances. The only foreseen limitation is the battery life of the GPS unit (Hebenbrock 2005).

References

Bowker R.M., Linker K., Van Wulfen Kimberly K., Sonea I.M. Anatomy of the distal interphalangeal joint of the mature horse: relationships with navicular suspensory ligaments, sensory nerves and neurovascular bundle. *Equine Vet J.* 29 (1997), pp.126-35

Bowker R.M., Linker K., Van Wulfen Kimberly K., Springer S.E. Functional anatomy of the cartilage of the distal phalanx and digital cushion in the equine foot and hemodynamic flow hypothesis of energy dissipation.*Am J Vet Res. 59 (1998),* pp. 961-968

EASYCARE, Inc. http://www.easycareinc.com/education/about_easycare.aspx 2006 Easycare, Inc.

EASYCARE, Inc. http://www.easycareinc.com/education/new_to_boots.aspx 2006 Easycare, Inc.

Hampson, BA, JM Morton, PC Mills, MG Trotter, DW Lamb, CC Pollit. Monitoring distances travelled by horses using GPS tracking collars. *Aust Vet J*. 5 (2010), pp 176-181

Hebenbrock, M. A new tool to monitor training and performance of sport horses using Global Positioning System (GPS) with integrated GSM capabilities.*Deutsche tierarztlicheWochenschrift.*112 (2005), pp. 262-265Jones, William E. Shoeing for natural balance.*J Equine Vet Science* 22 (2002), pp. 468

Jones, William E. Bowker's foot physiology.*J Equine Vet Science* 22 (2002), pp. 553

Kainer, Robert. Clinical anatomy of the equine foot.*Vet Clin North Am Equine Pract 5 (1989), pp. 1-27*

Kaneps, Andris J. Turner, Tracy A. Diseases of the foot. *Equine Sports Medicine and Surgery; Basic and Clinical Sciences of the Equine Athlete* 2004; 260-88

O'Grady, S.E. White line disease.*J Equine Vet Science, 17 (1997), pp.236-237*

O'Grady, S.E. Trimming and shoeing the horse's foot.*J Equine Vet Science*. 23 (2003), pp.169-170

Ovnicek G. Natural balance trimming and shoeing. In: *RossMW*, *DysonSJ*, editors. **Diagnosis and management of lameness in the horse**. Saunders, Philadelphia, *2003*:*271–273.*

Page, Barbara. Function of the foot support mass. *J Equine Vet Science*. 21 (2001), pp. 143

Parks, Andrew. The foot and shoeing. In: ROSS, M.W.; DYSON, S.J. **Diagnosis and management of lameness in the horse**. Missouri: Saunders, 2003. pp. 250-71

Parks, Andrew. Form and function of the equine digit.*Vet Clin North Am. EqPract*19 (2003), pp. 285-307

Parks, Andrew. Foot balance and conformation: clinical perspectives. *J Equine Vet Science* 4 (2005), pp. 230

Perino**, V.**, Kawcak C.E., Frisbie D.D., Reiser R.F., McIlwraith C.W. The accuracy and precision of an equine in-**s**hoe pressure measurement **s**ystem as a tool for gait analysis.*J Equine Vet Science* 27 (2007), pp. 161-166

Pollit, Christopher C. Equine laminitis *Clinical Techniques in EqPract* 7 (2004), pp. 34-44

Schamhardt, HC. Kinematic differences between the distal portions of the forelimbs and hind limbs of horses at the trot. Am J Vet Res. 56 (1995), pp.1522-8

Sellnow, Les. The equine foot.*The Horse* 2006

Strasser, Hiltrud, Sabine Kells.*A Lifetime of Soundness: The Keys to Optimal Horse Health Lameness Rehabilitation and the High-performance Barefoot Horse*. Qualicum Beach, BC: S. Kells, 2000. Print.

Turner, Tracy A. Examination of the equine foot. *Vet Clin North Am EqPract 19* (2003), pp. 309-332

Materials and Methods

Animals and Treatment: Fourteen mixed breed mares and geldings ranging in age from 4 to 20 years were selected to participate in this study. The horses were selected by the researcher, barn manager, and two farriers based on their individual use in the University Practicum lesson program, current hoof health, and history of hoof ailments. History taken into consideration included accounts of lameness and abscesses. Each horse was randomly assigned a treatment: shod, barefoot, or Easyboots. Each horse acted as its own control and received each treatment once for a period of two trimming cycles except Easyboots which lasted for a period of 1 trimming cycle. Easyboots received a treatment period of 1 trimming cycle to minimize the disturbance of horse use in the Practicum Program. Each trimming cycle lasted four weeks. All shoeing and trimming was performed by the two University farriers. All procedures and treatments were approved by the University of Connecticut Animal Care and Use Committee.

Each horse undergoing the shod treatment received the same shoe they would wear normally. Special shoeing or shoeing methods were not required. The shoes used were plain metal horse shoes appropriate to the size of the horse's hoof or a metal horse shoe with silicon filled pads. Each horse was shod to its specific needs: either two forelimbs or all four limbs.

Barefoot trims followed the methods of the farriers to prepare the hoof for a shoe, but not apply the shoe.

The Easyboot Glove[1] was selected as the specific boot to use for this study because of its ease of use and versatility to fit the range of horses used. Each horse was professionally fitted with two boots, one for each forelimb, by a representative Easyboot dealer. Each horse undergoing the Easyboot treatment was trimmed to be barefoot. The boots were applied only when the horse was being used in lessons or turnout to minimize rubbing on the heels or development of fungal or bacterial infections. The puts were applied following the instructions provided by Easycare, Inc.

---

[1]Easycare, Inc. 2300 E. Vistoso Commerce Loop Rd.Tucson, AZ85755 Tel 800-447-8836

Global Positioning Systems (GPS) were attached to each horse using a surcingle during turnout at the beginning and conclusion of each trimming cycle. The Garmin Edge 305[2] was selected for this study because of its capabilities to measure speed and distance traveled. The measurements taken by the GPS were limited by the device's battery life. The company reports that a full battery life spans 12 hours. During this study the battery life lasted 8-10 hours.

Each GPS unit was powered on and timer started outside the barn because the unit did not receive a signal inside the barn. The unit was placed in a Pelican Box[3], closed tightly, and attached to an elastic surcingle using two zip ties around the circumference of the Pelican box and two zip ties at either end of the box. Excess zip tie length was cut with a pair of scissors. The Pelican Box was chosen because of its lifetime guarantee to be waterproof, crush proof, and dust proof. The Pelican Box is made out of a polypropylene copolymer material that is light weight, durable and highly chemical resistant. The interior and exterior dimensions of the Pelcian Box, (L x W x D) 4.37" x 2.87" x 1.68" and 5.88" x 4.06" x 2.12" respectively were an ideal size to hold and protect the GPS units. The box was then wrapped in brightly colored vet wrap to ensure its security to the surcingle, minimize any rubbing on the horse from the zip ties, and to add in locating the unit if it were to become detached from the animal during turn out. The surcingle was attached to the horse at the girth line with the Pelican box positioned at the sternum. The clip to the surcingle was further secured using a zip tie and vet wrap. Finally, vet wrap was used to create a breast plate for the surcingle to keep it from slipping back to the horse's waist during turnout. This was achieved by wrapping a portion of the vet wrap several times around the surcingle at the point of the horses shoulder, bringing the vet wrap tightly across the horses chest, and repeating the wrapping on the opposite side of the surcingle at the shoulder.

Horses were turned out in their respective pastures overnight wearing the GPS device as described. Surcingles were removed the following morning by cutting the vet wrap and zip ties with scissors. The GPS was then plugged into a computer using a USB cord to download the information and recharge the device.

---

[2] Garmin International, Inc. 1200 East 151st Street. Olathe, Kansas66062, USA. Tel. 913/397.8200

[3] Pelican Micro Case #1010 Pelican Products, Inc. 23215 Early Avenue Torrance, CA 90505 Tel: (310) 326-4700

Throughout the duration of the study each horse was evaluated to determine their efficacy to maintain their respective treatment. If a horse showed significant signs of a negative impact of the hoof treatment received as determined by the barn manager, farriers, and veterinarian then the horse did not continue with the study. By the final Easyboot treatment 7 horses remained active in the study.

Sample Collection and Analysis: Measurements were taken on the body and on the hoof at the beginning and conclusion of each trimming cycle. Body measurements included: girth circumference, waist circumference, body length, neck length, neck height, height, weight, and cresty neck score (CNS) following methods described by R.A. Carter (2009) and body condition score (BCS) was determined following the Henneke scoring system (1983). Body measurements were taken using a measuring tape.

Hoof measurements included: toe length taken from the coronary band at the hair line to the edge of the hoof wall at the ground interface, heel height from the medial and lateral aspects taken from the highest point of the heel at the hairline to the ground interface, width of the hoof at the quarters from the plantar surface, length of the hoof from the hoof wall at the toe to the buttress of the heels from the plantar surface, and new growth taken from the coronary band at the hairline to a notch made with a rasp in the hoof wall at the time of the last trim by the farrier.

After the GPS unit was removed from each horse it was plugged into a computer using a USB cord to download the information and recharge the device. Information retrieved included the minimum, average, and maximum speeds traveled and distance traveled during the recording period of turn out. A map produced using Google Earth shows the path traveled during turnout.

Data was analyzed using SAS 9.3[4]. Least square means and standard errors were calculated. $P<0.05$ was considered significant.

---

[4]SAS Institute Inc. 100 SAS Campus Drive Cary, NC 27513-2414 USA Phone: (919) 677-8000 U.S. or Canada: 1-800-727-0025 Fax: (919) 677-4444

References

Carter RA, Geor RJ, Burton Staniar W, Cubitt TA, Harris PA. Apparent adiposity assessed by standardized scoring systems and morphometric measurements in horses and ponies. *Vet J.* 179 (2009), pp. 204-210

Henneke D. R., Potter G.D., Kreider J. L. and Yeates B. F. Relationship between condition score, physical measurements and body fat percentage in mares. *Eq Vet J* 15 (1983) pp.371 - 372

Results

Morphometric Measurements

Table 1 shows the mean morphometric measurements in centimeters for barefoot, Easyboot, and shod treatments. Girth circumference decreased with the shod treatment. Waist circumference decreased with the Easyboot treatment. Body length decreased with the barefoot treatment. A significant difference was observed for body length between barefoot and Easyboot treatments or shod treatments. Neck length increased with the Easyboot treatment while neck height increased with the shod treatment. Cresty neck score (CNS) was increased during the barefoot treatment.. Body condition score (BCS) decreased during the Easyboot treatment. Height decreased during the shod treatment.

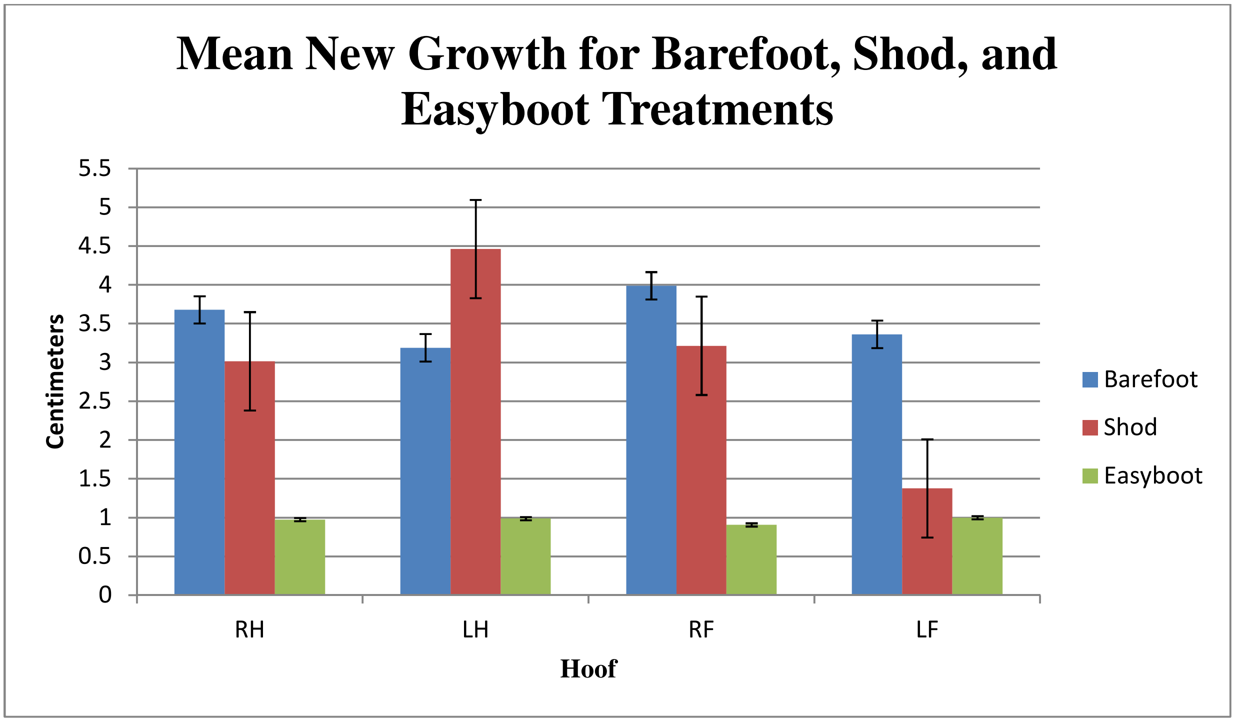
	Girth Circumference	Waist Circumference	Body Length	Neck Length	Neck Height	Cresty Neck Score (CNS)	Body Condition Score (BCS)	Height
Barefoot	186.4	198.4	114.3[a]	95.5	10.7[a]	3.4[a]	5.9	151.9
Easyboot	186.9	197.1	117.3[b]	99.3	9.4[a]	2.9[b]	5.3	151.6
Shod	183.1	198.6	117.3[b]	94.5	13.2[b]	2.7[b]	5.7	150.9

means not sharing like letters differ $P \leq 0.05$

Table 1. Mean morphometric measurements in centimeters for barefoot, Easyboot, and shod treatments.

New Growth

There were no significant differences for new growth in the hind or fore hooves. Barefoot treatment tended to have increased new growth compared to the shod and Easyboot treatments on the right hind, right front, and left front hooves. The Easyboot treatment tended to have decreased new growth for all four hooves. (Figure 12.)

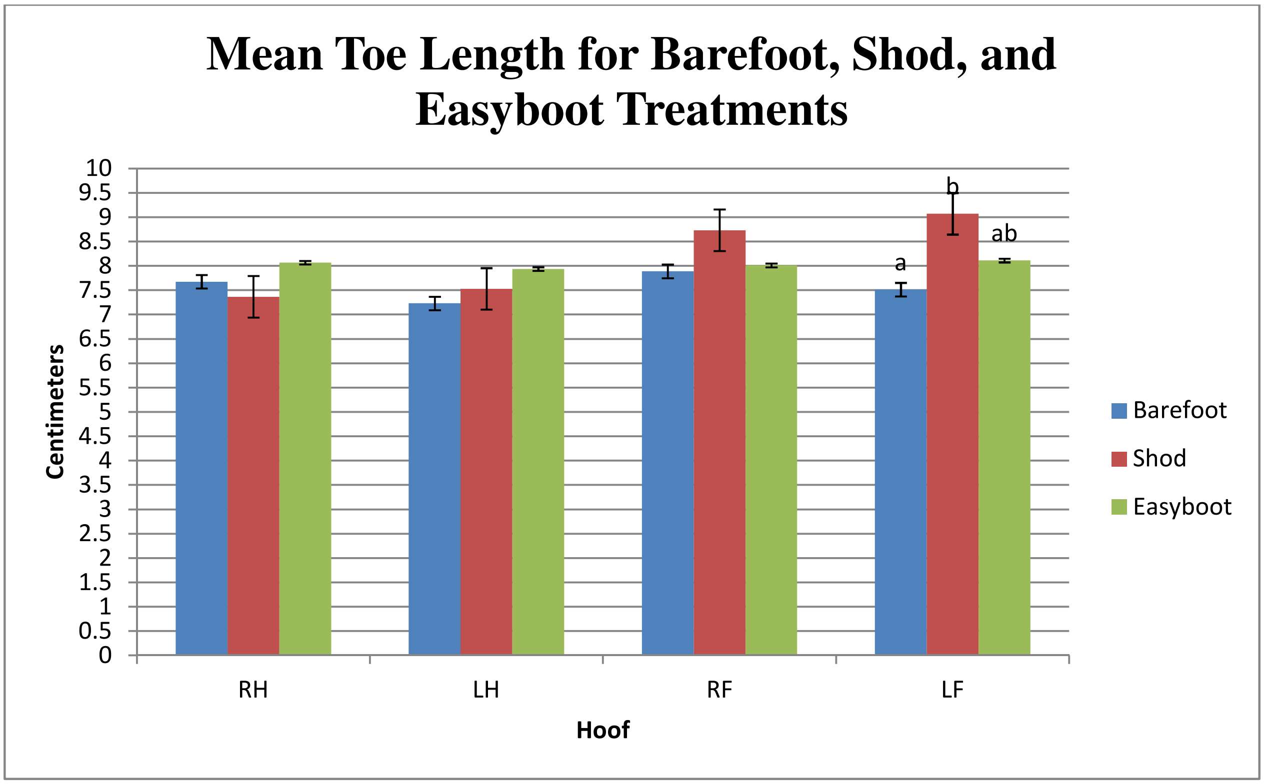


means not sharing like letters differ P≤ 0.05

Figure 12. Mean new growth for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Toe Length

There were no significant differences for toe length measurements of the right hind , left hind, or right front hooves. There was a trend for increased toe length on the right and left hind hooves with Easyboot treatment and a trend for increased toe length on the right and left front hooves with shod treatment. Differences were observed in the left front hoof between the barefoot and shod treatments ($p<0.01$) and shod and Easyboot treatments ($p<0.05$) (Figure 13.).

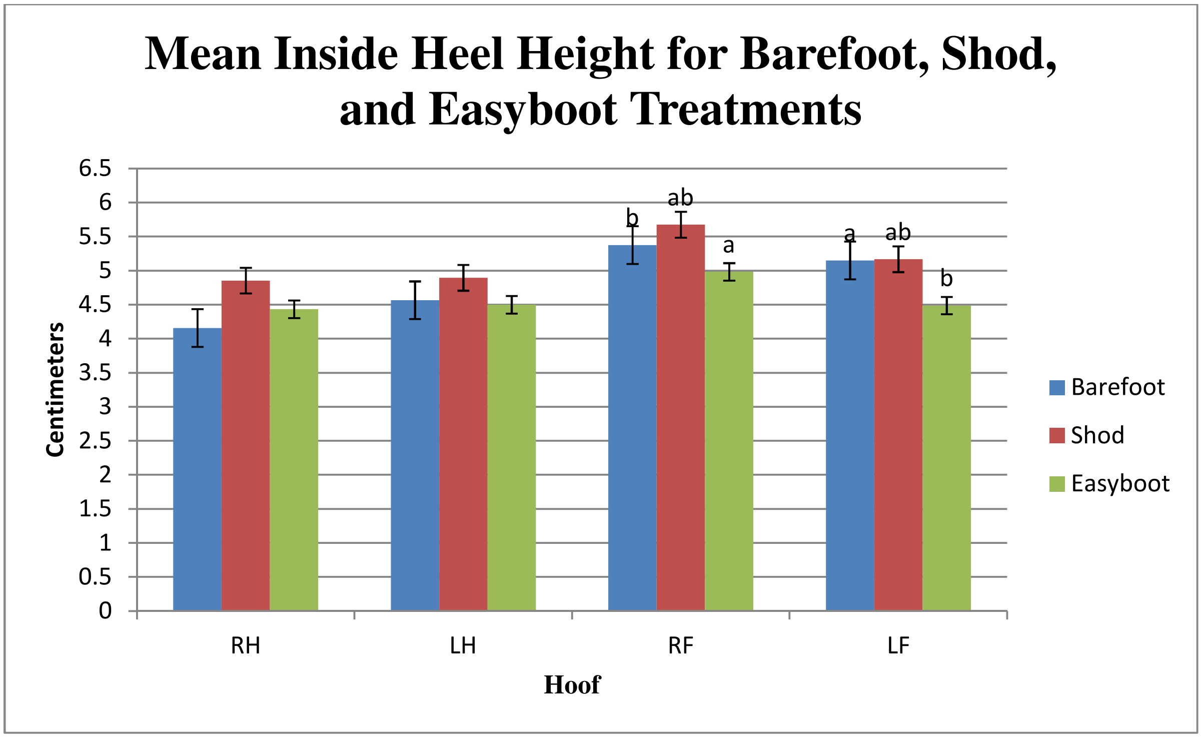


means not sharing like letters differ P≤ 0.05

Figure 13. Mean toe length for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Inside Heel Height

Inside heel height measurements for the right hind were higher compared to outside heel height. There were no significant differences for inside heel height measurements of the left hind hoof. Inside front hooves had the lowest heel height during the Easyboot treatment and the greatest heel height during the shod treatment ($p<0.05$) (Figure 14).

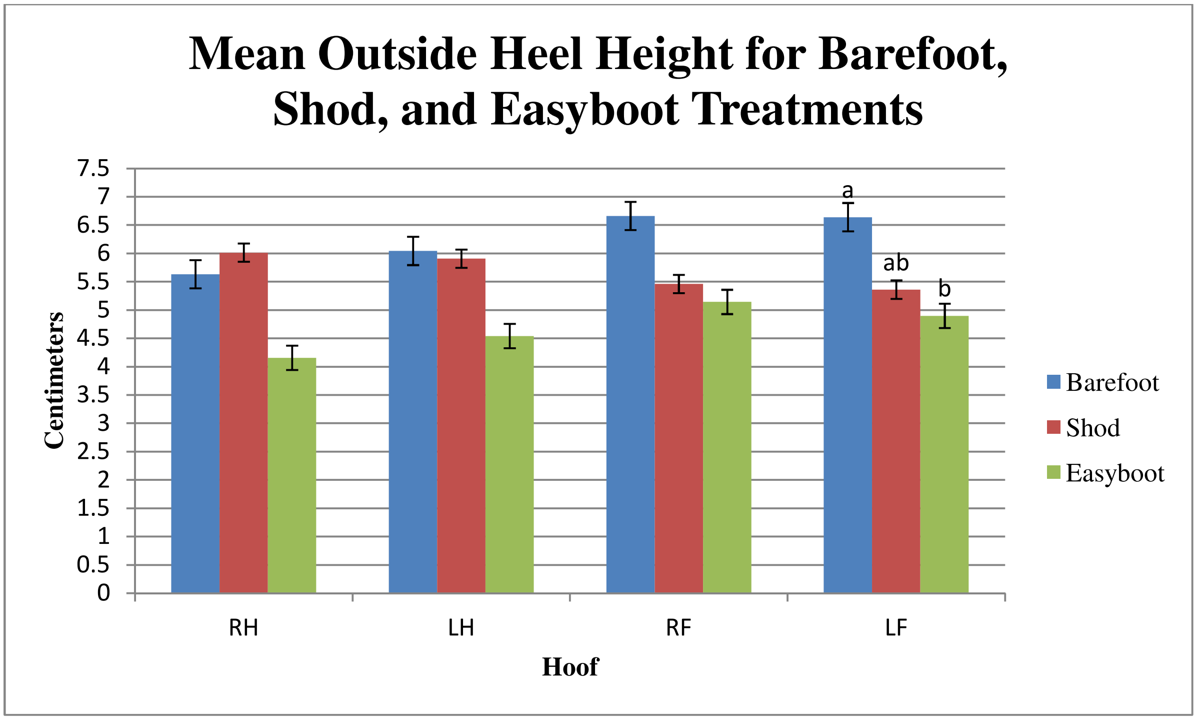


means not sharing like letters differ $P \leq 0.05$

Figure 14. Mean inside heel height for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Outside Heel Height

Outside heel height was lowest on the right hind during the barefoot treatment and uring the shod treatment. No significant differences for outside heel height were observed for the left hind hoof or right front hoof. Easyboot treatment resulted in a decrease in outside heel height on all four hooves. Differences were observed between barefoot and shod treatments and Easyboot and shod treatment on the left front hoof ($p<0.05$). (Figure 15).

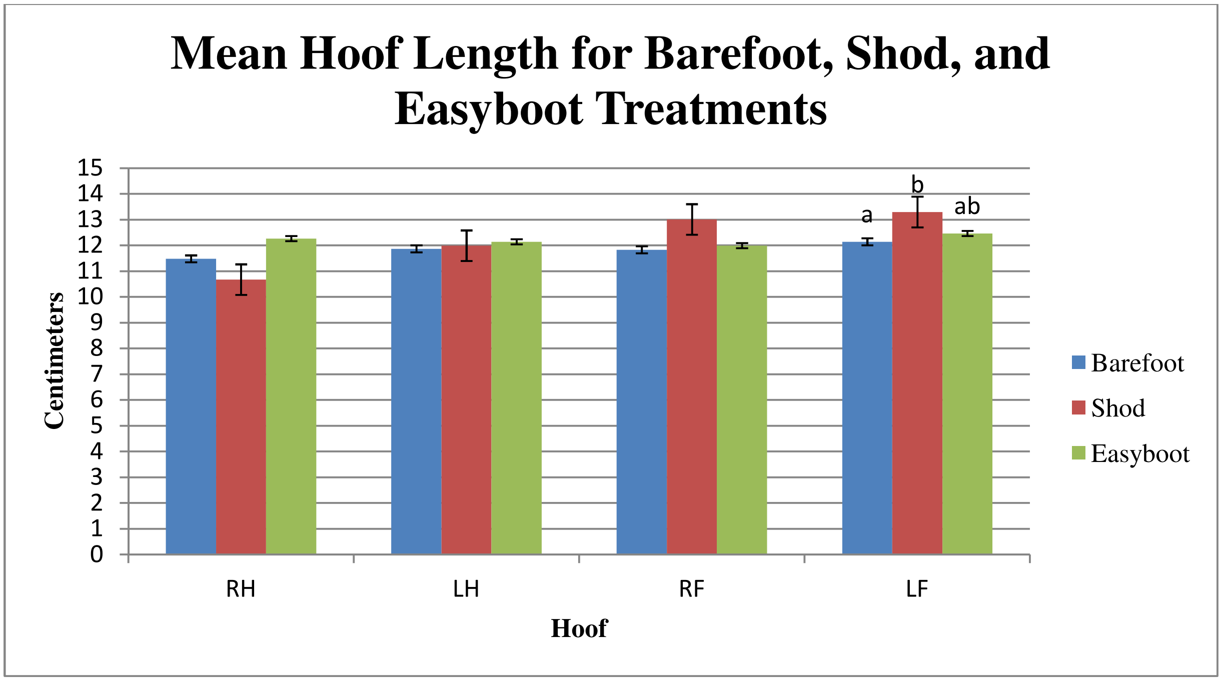


means not sharing like letters differ P≤ 0.05

Figure 15. Mean outside heel height for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Length

The hind hooves showed no significant differences for length measurements. Length measurements were similar for barefoot and Easyboot treatments on the right front hoof. In the left front hoof, shod hooves were longer ($p<0.05$) than barefoot hooves (Figure 16).

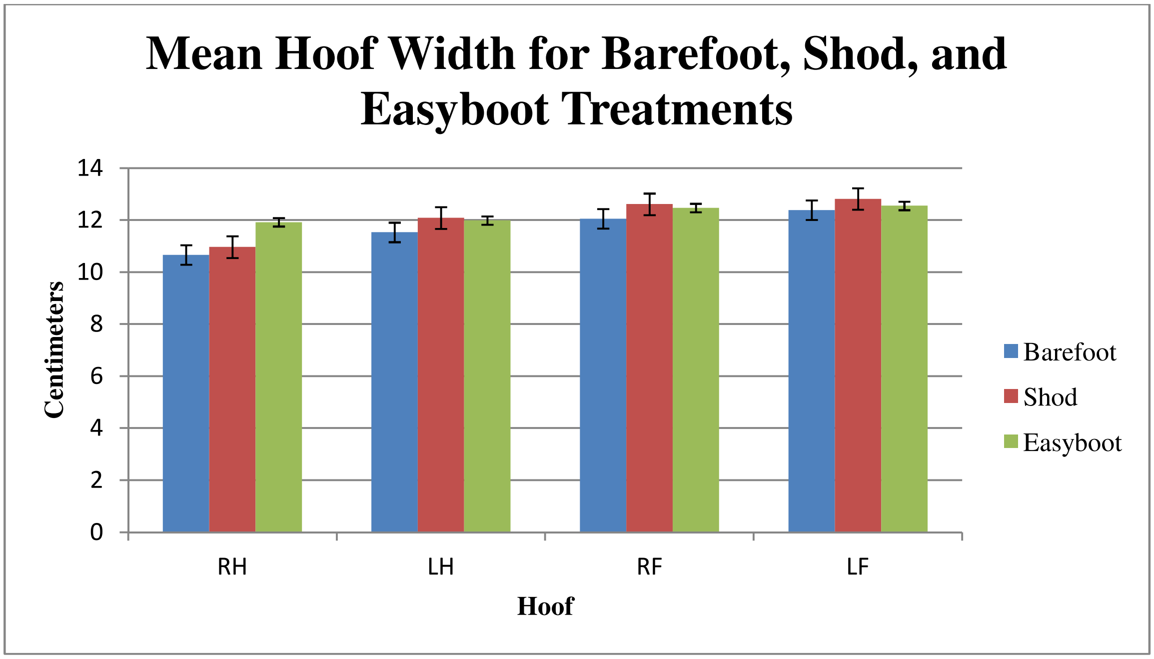


means not sharing like letters differ P≤ 0.05

Figure 16. Mean hoof length for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Width

No significant difference were observed for width measurements for the right hind, left hind, right front, or left front hooves (Figure 17).



means not sharing like letters differ P≤ 0.05

Figure 17. Mean hoof width for barefoot, shod, and Easyboot treatments for right hind, left hind, right front, and left front hooves.

Discussion

Interpretation of these results is difficult because there was a time difference between the randomization of the barefoot and shod treatments and the application of the Easyboot treatment of approximately four weeks. In this time frame horses which were randomly assigned to switch from the barefoot to the Easyboot treatment were shod for use in the Practicum riding program and therefore essentially taken out of the study. We were unable to allow for additional time for a horse to transition between any of the shoeing treatments due to their demands in the Practicum program. The most common reason for a horse to be pulled from the study was lameness following the transition from shod to barefoot; followed by rubbing caused by Easyboots. According to barefoot practitioners it can take 2-3 weeks for a horse to adjust from being shod to barefoot, and a full year or more for a horse to completely rehabilitate to a barefoot hoof.

The method of GPS use and attachment was a trial and error process resulting in the loss of two initial GPS units. A previous study attached GPS units to the halters of the horse during turn out. We felt that under our pasture circumstances a halter would be a danger to the horse to wear during turn out and that the unit would be more likely to become detached if attached in a location that the horse could easily rub. Our concept of an elastic surcingle attachment seemed a logical option. Difficulties arose when we found the Pelican box open, or the entire surcingle unit detached from the horse after the turn out period. We chose to remedy these problems by using vet wrap and zip ties to ensure proper closer of the Pelican box, and to safely create a breast collar for each surcingle. The vet wrap breast collar helped secure the surcingle in its proper place but if the horse was caught on something, could also break easily. The vet wrap also prevented any rubbing or discomfort the horse may have from the surcingle shifting positions.

The Garmin Edge 305 GPS units did not receive a signal in or close to our main barn, and therefore we removed 2 horses who did not receive turnout in the same pastures as the other horses from the study.

It was difficult to maintain the initial number of horses for the duration of the study. The horses used were active in the university's practicum riding program and were chosen with collaboration from the barn management and farriers. General soreness, common after a horse's feet are trimmed or a shoe is removed, made it difficult for these animals to continue performing in the practicum program and resulted in 7 of the initial 14 horses being removed from the study.

Likewise, using animals from the practicum program made the application of the Easyboots difficult. There is an acclimation period for the boots, and even through the boots were professionally fitted to each horse, rubbing on the heels was noticed. One horse was removed from the Easyboot treatment because of a large amount of rubbing of the boot on her heel as well as rubbing at the site of the Velcro® gator attachment. The horses only wore boots during turnout and riding to allow for the hooves and boots to breathe. There was difficulty with the boot application during riding because the student who was riding the horse applied the boots. In

some cases the boots were not used, and in others the boots were applied incorrectly despite available instructions. In cases of incorrect application the boots were always too loose and in some instances resulted in the boots coming off during riding. During turn out there was only one case of a boot detaching from the horse in which the Velcro® gator broke.

The Easyboot treatment for all four hooves resulted in the least new growth. Barefoot treatment showed the greatest amount of new growth. The trend for the barefoot treatment to show the greatest new growth occurred with what was hypothesized to be the least inhibiting treatment. This supports the theory that a less invasive shoeing method allows for more hoof growth per month. Perhaps the greater growth rate in shod and Easyboot treatments is to replace the structures that are dead or dying due to the influence of the shoe or Easyboot.

Differences in toe length were observed with each treatment. There was a trend for the front hooves resulting in shod hooves having the longest toe length measurements and barefoot hooves having the shortest toe length. The greatest variation between treatments is observed on the left front hoof with significance measured between barefoot to shod and Easyboot to shod. The left front hoof had the most amount of new growth. This could indicate that the left front hoof has greater weight bearing capability compared to the right front and hind hooves.

Inside heel height measurements for all four hooves showed a similar trend with shod measurements being the highest. On the front hooves Easyboot use resulted in higher inside heel height than shoeing. For the hind hooves the trend is for barefoot to be higher than shod. These results could indicate that inside heel height needs to be greater in order to support the use of the shoe. Position of the hoof capsule influences the position of the internal structures of the hoof which contributes to the progression of hoof inflammation and disease (Bowker 2003).

Outside heel height measurements tended to be higher than inside heel height measurements. Easyboot measurements had the shortest heel height for all four hooves. For the left hind, right front, and left front hooves, barefoot measurements were the highest. For the right front measurements, the shod treatment was the highest. It would have been beneficial to have measured heel bulb length to observe a change in heel width to compare to heel height.

Measurements taken on the inside and outside heels of the right hind hoof indicate that the hoof is not meeting the ground at a level interface. Using a force plate would have been helpful for this portion of the study to measure pressure exerted on each hoof component. Differences in the pressure exerted could also be attributed to each horse's differences in conformation and locomotion. Uneven wearing of the hoof or pressure exerted by a shoeing method could impact hoof structure and compromise hoof health.

It was hypothesized that with minimal interference the hoof would expand to a measureable difference. However, there was a greater trend towards significance observed for Easyboot versus shod measurements than barefoot versus shod. Perhaps the Easyboot may influence the hoof to take on the shape of the boot. These findings also indicate that the hoof can maintain the

shape of the shoe with or without the shoe on. Barefoot practitioners claim that the hoof will expand within a certain time frame of the shoe being removed, so a greater difference in barefoot versus shod measurements were expected. Further studies to investigate these finding include the evaluation of differences in horses who are barefoot versus shod over longer periods of time, investigating memory cell capacity in the hoof, and evaluation of the influences on hoof shape.

GPS data showed no significant trend for mean total distance traveled and for average speed for any treatment. Weather conditions could have also influenced mean distance traveled and average speed. Weather conditions can be referenced in appendix.

In this study shoeing method was the focus of measurement but rate of wear and seasonal changes are inevitable. Measurements were taken to the $1/16^{th}$ of an inch (1.59 mm). This could be the difference in one stroke of the farrier's rasp between one hoof and another. The farriers were instructed to perform the shoeing methods as they normally would. Considerations for specific trimming methods, such as hoof mapping, were not used. Further studies could identify such specific methods to help decrease the effect due to variation in farrier technique, although the same farrier shod or trimmed each horse in the study.

For future studies it would be advantageous to create a specific protocol to assess lameness or soreness for each hoof treatment. This protocol should include the number of days between initiating a treatment and removing a horse from a study and allow for adjustment to a new trimming method. It would also be beneficial to utilize a GPS unit specifically designed for use on equines. Use of a force plate would be valuable to show areas of pressure with different shoeing methods. Another option would be to paint the bottom of the horses hoof and make an impression on a piece of paper. This would show the points of contact with the ground which would also indicate pressure points.

Data collected throughout this study indicates that each hoof responds to environmental factors independently. (Equine owners and professionals need to be aware that shoeing methods do directly affect hoof growth and health and this can have a direct effect on the rest of the body. The hoof is responsible for supporting the weight of the horse, and the internal structures play a role in proper circulation through the lower limbs. It has been cited that horses with respiratory or digestive disorders may also suffer from poor hoof health (Strasser 2000). Data collected from this study may aid in hoof trimming and treatment decisions to provide optimal health for the horse.

Each shoeing method resulted in significant changes in different areas of the hoof. One method did not prove to have a greater advantage over the others in this particular study. More data is needed to conclude if there is a standard hoof treatment that would be the most beneficial for horses. With so many different methods of shoeing and trimming hooves, and so many horses responding differently to these methods, no one shoeing method may be found to excel over the others.

Appendix

Weather Report

Table 2 shows the temperature, dew point, humidity, precipitation, and wind speeds during data collection.

	Mean Temp	high (F)	low (F)	dew pnt F	humidity	precip (in)	wind mph
28-Jun	82	91	73	72	79	0.02	5
29-Jun	77	88	68	64	64	0	5
23-Jul	68	73	62	67	93	0.7	2
26-Jul	78	86	73	72	88	0.18	4
20-Aug	72	84	57	56	65	0.01	3
23-Aug	64	68	60	62	94	0.09	12
13-Sep	60	64	55	57	88	0.03	3
14-Sep	64	77	51	53	81	0	1
15-Sep	54	69	43	41	63	0	4
28-Sep	70	73	66	70	96	0.77	8
7-Oct	57	66	48	48	82	0.02	4
2-Dec	36	42	30	24	62	0	6
31-Dec	34	50	18	24	79	0	1

Table 2. Weather report