The morphological changes in Thoroughbred racehorse feet following a period of barefoot rehabilitation.

By

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Abstract

Introduction

It is commonly believed that the Thoroughbred racehorse's feet are often of lesser quality and strength and as a result more complex and difficult to manage than a lot of other equine breeds. With horses bred for speed, conformation and desirable bloodlines, the quality and condition of the feet is often left unconsidered. Barefoot ideology and the scientific research into the benefits of barefoot versus shod continues to prove the positive impact of removing shoes. This study investigated the benefits of barefoot management and rehabilitation of feet over a period of time for the Thoroughbred racehorse in training.

Study design

A quantitative study capturing morphological hoof capsule measurements on a cohort of 14 Thoroughbred racehorses in light training over a 3-month period.

Aims/Objectives

The aims of this study were to provide both the farriery and equine owning and training communities with a better understanding of the impact of barefoot rehabilitation of Thoroughbred foot that could potentially lead to a reduction in common hoof related lameness or poor performance.

The objective was to investigate the natural changes of the hoof over a period of 3 months across horses both shod and unshod (barefoot) and determine whether a period of barefoot rehabilitation was beneficial to restoring the health and condition of the hoof capsule.

Hypothesis

It was hypothesised that a barefoot rehabilitation programme for horses during a period of light work would have a positive effect on improving the health and function of the hoof capsule by significantly improving the balance and geometric orientation of the hoof closer to that of ideal.

Materials/Methods

14 horses had their shoes removed at the end of the flat racing season and all 28 feet were systemically photographed using a calibrated image capturing system known as Metron hoof. Nine horses were trimmed to remain without shoes whilst the remaining five horses had shoes reapplied. This process was repeated a further two times around 45-day intervals giving three different time points of data. Each photograph provided the measurements of each hoof in the lateral, dorsal and solar plane. Morphological changes of the feet were then measured across the three time points.

Results

The study showed that horses that went without shoes on average showed a significant improvement in heel morphology as opposed to those that remained in shoes. Heel angle (HeA) increased significantly in those horses without shoes compared to those with shoes as too did heel height and separation. Hoof angle (HA) did increase in those horses that went barefoot but did not differ significantly to those that remained shod. The relationship to hoof angle and heel angle differed between the two groups with the barefoot horses showing a significant reduction in the overall hoof and heel angle difference whilst those shod did not show a significant difference although an increase in the hoof and heel angle was witnessed.

Conclusion

Thoroughbred racehorse feet responded positively to a period of barefoot rehabilitation. Barefoot management of Thoroughbred feet improved the morphology of the palmar hoof significantly within a short (3 month) period. This significant improvement in the balance and orientation of the hoof, could positively contribute to the reduction in lameness as a result of improved hoof conformation.

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Chapter 1. Introduction

1.1: Rationale

It is widely believed across various equine stakeholders, veterinarians to farriers, from horse trainers to owners, that by removing the shoes of most horses can have a beneficial impact on the overall hoof health and function (De Klerk (2021), O'Grady (2016), Malone and Davies (2019) & Clayton et al. (2011)). Anecdotal evidence of this adoption within the Thoroughbred racing/training industry has proven this to have some value in especially in the 'down' season and as a rehabilitation of those feet following a busy and intense season. Barefoot rehabilitation has again anecdotally been shown to go a long way in the prevention of the typically seen conformation of Thoroughbred horses known as 'long toe low heel' (LTLH) syndrome or conformation. It is believed that this prevention of LTLH is achieved by allowing the foot its own natural ability to regulate balance and proportional orientation through its ability to wear and for the foot to function within its normal, biomechanical parameters (Kane et al. (1998)). It is believed that the removal of shoes will help to stimulate palmar function through improved engagement of the frog, sole and bars with the ground (Strasser 2004). The engagement of this external architecture contributes to the hoof haemodynamic mechanism and with stimulation of the digital cushion and lateral cartilages, the hydraulic mechanism of pressurisation of blood flow within the hoof capsule helping to dissipate high impact shock energies (Bowker 1997). Not only will stimulated blood flow contribute to the healthy hoof mechanism, it will also help to stimulate horn growth both of the sole, wall and heels, reversing the negative effects of the application of a shoe on the overall hoof balance particularly in the dorso-palmar orientation (Johnston and Back (2006).

Although the expected improvements of hoof orientation through the removal of shoes have been well documented and proven (Malone and Davies (2019) & Clayton et al. (2011)). The rehabilitation of Thoroughbred racehorses' feet whilst in light training regimes within the UK has very little scientific evidence, as too is there little evidence justifying the significance of a relatively short window of time.

This study will look to document the morphological changes of the Thoroughbred hoof, within a time frame that could be commercially achievable in the career of a Thoroughbred racehorse.

1.2: Introduction:

The unintended consequence of shoeing horses, particular Thoroughbred racehorses in the UK is the continuous struggle to maintain soundness and overall hoof health (Morrison 2013). These two aspects link strongly to that of the horse's hoof angles and geometric proportions. With a magnitude of factors to consider it is commonly understood that towards the end of the racing season, feet of a large majority of Thoroughbred racehorses appear to have a much lower hoof angle, reduced heel height and greater discrepancy between toe and heel angle thus promoting the syndrome of long toe low heel (Peel et al. 2006).

It is believed that this type of commonly seen hoof conformation predisposes horses to soft tissue injuries including that of tendon and suspensory injuries (Kane et al. 1998). Research has proven that prolonged predisposition to this conformational abnormality also predisposes horses to pathology of the palmar/plantar region, particularly that of low or underrun heel angles (Balch et al. 2001).

It is in the author's experience that when those equines have their shoes removed, hoof morphology and the ability to rehabilitate into a much healthier, functional and balanced structure is highly achievable with minimal intervention.

1.2.1: Anatomical Considerations

Anatomy of the hoof both internally and externally is well documented (Roland et al., 2003; Bowker et al., 1997). However key elements relative to this study are the relationship between insensitive and sensitive palmar/plantar structures and influences of the external hoof capsules on the form and function on those internal structures. Overall haemodynamic function should be considered along with its relation to the management and dissipate of the high impact shock forces with the hoof, especially for those horses in gallop training (Peel et al. 2006). Often the structure of a healthy functioning foot, will minimize the stresses of weight bearing reaching the bony column, connective tissue and epidermal laminae.

Transferring impact energy into movement of both the heels through displacement of the digital cushion and consequently the lateral cartilages are considered part of the hydraulic mechanism. This mechanism involves the venous vasculature that on those 'good' footed horses is embedded within the lateral cartilages. Those considered 'bad' footed horses often display venous vasculature axial to the lateral cartilages and therefore less effective in in the hydraulic function (Bowker 2003).

Long toe low heel feet for example often receive ground contact further forward than the ideal or in region of the softer tissue structures of the digital cushion and lateral cartilages. Instead, they are weight bearing around the palmar processes of the distal phalanx (Coffin Bone) resulting in less energy absorbed by the hydraulic mechanism and greater amount of high impact forces transferring to the bone structures. This will often lead to bone pain, bruising, fractures or chronic arthritis. Morrison (2013) claimed that due to the thin wall and sole of Thoroughbred feet, these horses would be highly susceptible to hoof capsule distortion. The article later stated that the ideal Thoroughbred hoof would possess a heel angle within 5 degrees of that of the toe angle (hoof angle) and the centre of the distal interphalangeal joint DIPJ or widest part of the foot should be located in the centre of the weight bearing surface of the shoe.

Figure 1.2.1: Image above shows the morphological change that occurs predominately in the palmar region of the hoof. Failure to address this morphological change through routine farriery or barefoot Authors own images.

rehabilitation predisposes horses to underrun heels and increases the risk of associated problems. The hoof de-rotates over throughout the period of the shoeing cycle (Moleman et al. 2006).

1.2.2: Biomechanical Considerations

The biomechanical function of the hoof is linked to its overall conformation. Changes made to the bottom of the foot effect the overall angulation of the hoof, the hoof pastern axis and the moments of force about the distal interphalangeal articulation (O'Grady 2018). Break over, and the relationship to the forces experienced upon the deep flexor unit and navicular apparatus are crucial for achieving biomechanical efficiency and reducing pain and pathology to the palmar/plantar region. Increased toe length and acute hoof angles will lead to increases in lever moments about the distal interphalangeal articulation requiring greater force and time to rotate the heels around the toe (van Heel et al. 2006). It is this increase in the magnitude of force and the time that force is applied, that internal anatomical structures become exposed to potential injuries and damage.

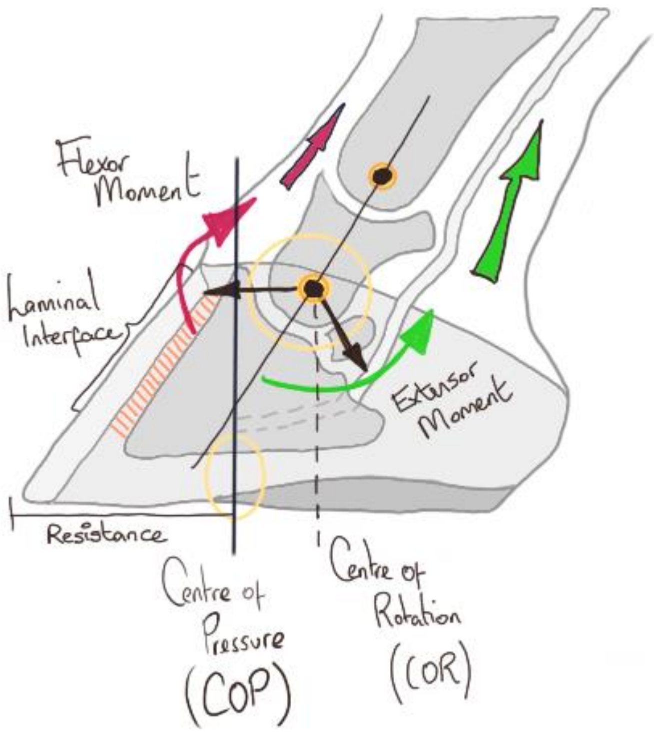


Figure 1.2.2: Illustration showing the biomechanics of the equine digit, that of the moments around the distal interphalangeal articulation. The location of the centre of pressure to the centre of rotation and the direct impact of the toe length and lever arm. *Authors own images.*

Van Heel et al. (2005) found that the change in hoof angle in 18 Warmbloods during a standard shoeing cycle was approximately 3.3 degrees over an 8-week shoeing cycle, thus inducing a change in the dorso-palmar balance about the distal interphalangeal articulation. This suggested that the hoof migrated distally but disproportionally between the toe and the heels. Previously Wilson et al. (1998) discussed the point of force within the hoof both in the medio-lateral and dorso-palmar planes and stated that changes in the DP orientation changed not the position of that force, but the time that force is applied for. This suggested that the greatest effect upon morphological change in the hoof is not directly the total force applied, but the length of time in which that forces is applied. It is apparent that the hoof ground interaction may engender physiological or pathological tissue adaptations (Johnston and Back, 2006) and the form of the external hoof is indirectly related to the form and function of the internal structures (Thomason and Peterson (2008)).

1.3: Conception of the study

It is the purpose of this study to look at the external morphological changes of the Thoroughbred hoof from the approximate end of the flat racing season and during a period of reduced work and slight rehabilitation. Very rarely do Thoroughbred horses in training have the opportunity for their feet to experience a period of no shoes.

This is a morphometric study documenting, with the use of calibrated imagery, the morphological changes of a sample of Thoroughbred racehorse's feet. The study was performed over a period of approximately 3 months with farrier intervention on a regular three-week (21 day) interval with a standardised trimming and shoeing protocol (see Appendix 1&2).

Morphological changes in hoof conformation and balance from two groups of horses, 1 shod and 1 barefoot after having shoes removed.

The significance of hoof conformation to the physical performance of the Thoroughbred racehorse requires further investigation, however hoof conformation and the predisposition to common hoof related injuries has been well documented. Johnston and Back, (2006) stated that hoof conformation is directly related to distal limb loading and that maintaining optimal balance therefore plays an essential role in preventing tissue injuries in the distal limb.

As this study is the first scientific study to examine the effects of barefoot rehabilitation in flat racing Thoroughbred horses within Newmarket, and by documenting the morphological changes to the hoof during this period, should help to support anecdotal evidence and provide a scientific basis for a shift in the attitude and tradition in the management of Thoroughbred racehorse feet.

1.3.1: Barefoot Ideology

Discussion around the benefits of barefoot management and the diametric consequence of shoeing has become a strongly debated discussion amongst equine professionals and owners alike. The debate strongly orientates around the form and function of the hoof and its internal anatomical structures, and how those anatomical structures become compromised with the addition of a shoe (Strasser 2004). Healthy functioning digital cushions, composed of fibrous and cartilaginous elastic tissue, along with thick cartilages coursed with a unique vasculature network represent a hoof capsule with a healthy hoof mechanism (Bowker 1997). It is believed that the application of a shoe, especially those adopting a rim style fit, disrupt the natural physiological function of the hoof leading to a reduction in the natural haemodynamic flow and therefore, high impact energy dissipation. Although there is scientific research to strongly support the theory that 'barefoot is best', from an anatomy and physiology standpoint, little research has yet to of been carried out on the pros vs cons of shoes when it comes to the management of high performing equine athletes. Regulations across disciplines varies extensively as to does the environment and surfaces in which the horses are trained and competed upon. This study does not look to fuel the endless debate upon right or wrong, it does however look to extract the proven science and apply that to the management of Thoroughbred feet with the intention of improving performance and soundness.

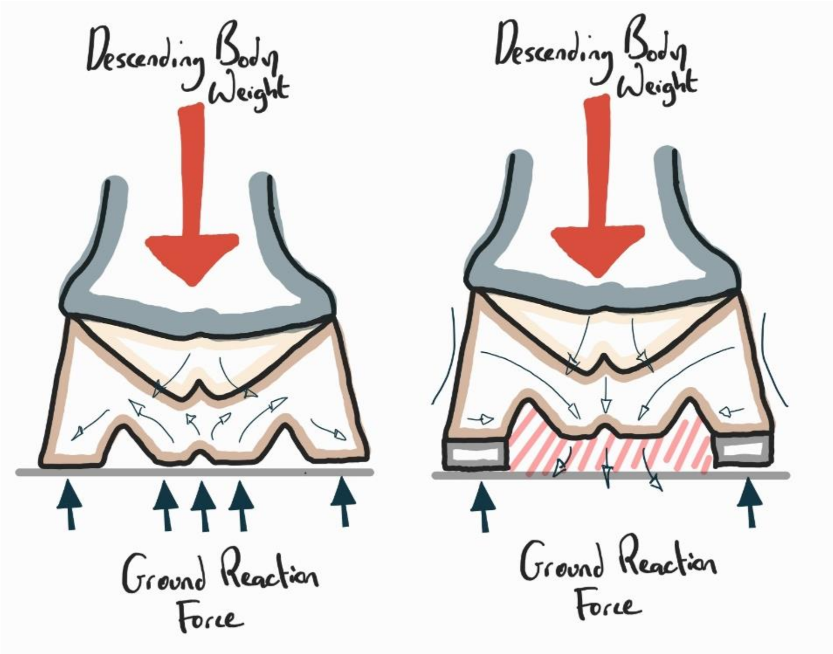


Figure 1.3.1: Difference between the shod and unshod hoof as it reacts with the ground bearing surface under load. Notice the greater surface area of the unshod hoof in contact with the ground in comparison with that of the shod hoof. The peripheral rim fit shoe raises the hoof from the ground creating a void directly below the distal phalanx. The frog and soft tissue structures have less stimuli from the ground reaction force often leading to caudal hoof failure. Authors own images.

Chapter 2: Literature Review

2.1: Introduction

The information obtained for this literature review was found in the Equine Veterinary Journal, Equine Veterinary Education, onlinelibrary.wiley.com, and a range of veterinary and farriery related textbooks.

Barefoot rehabilitation of Thoroughbred feet whilst in training is a relatively new concept to what is a very routine and traditional industry. Progression in farriery and veterinary research into the understanding of the biomechanics of the hoof and kinematics of high-speed training has fuelled the quest to better understand the impact upon feet and the links to potential injury or poor performance. With further research from Kane et al (1998) linking poor hoof morphology to musculoskeletal injuries, Moleman et al. (2006) discussing the effects on hoof biomechanics as a result of poor hoof conformation and the links between hoof orientation and the increase in peak force upon soft tissue structures (Eliashar et al. 2004), there seems to be a mind-set shift towards ways of managing or improving equine hoof conformation to not only maximise potential but to greatly reduce risk of injury.

2.2: Existing research on this topic

2.2.1: Studies relating Hoof angles to training regime.

Often poor performance or injury is a consequence of equine hoof conformation and that of poor hoof and heel angles and overall, the palmar angle of the distal phalanx. Peel et al. (2006) set out to investigate the links between gallop training of Thoroughbred racehorses and the flattening of feet. Stating that low hoof angles at the toe often were associated with lack of soundness and that only anecdotal evidence existed that suggested hoof angles reduce through training preparation. Peel et al. (2006) went on to state that it is not clear what factors caused those low hoof angles but alluded to the fact that high speed training may significantly reduce those overall hoof angles. Peel et al (2006) concluded that an adaptation to training regimes could be made for horses with abnormally low hoof angles, which begs the questions that if training regimes are to remain routine and traditional in its approach, should more conscious efforts not then be made to help rehabilitate those horses highlighted as abnormally low hoof angled horses? The sample horses used within the study did however have intervention by several different farriers throughout and claimed that racehorses showed an increase in hoof angle post farriery intervention but failed to capture the extent of this hoof angle increase. They failed to set out a detailed trimming protocol and so reliability on any standardisation of trimming methods or the effects upon hoof angle and overall hoof form would be questionable. A standardised trimming protocol similar to that set out by Caldwell (2016) was used in this study and all trimming and/or shoeing was performed by just one farrier, the author.

2.2.2: Morphological changes when going barefoot

Taylor et al. (2020) tested 15 elite Thoroughbred racehorses and showed a statistically significant difference in a positive change not only in hoof angle but also heel angle, frog width and solar concavity during a barefoot training program. This supports the overall hypothesis of this study and the effects of barefoot management of Thoroughbred feet in relation to improvements in hoof orientation to a pre-determined ideal. This study failed to examine a control group of horses with shoes applied in order to differentiate between the two, nor was the study able to quantify the significance of changes resulting from the training of horses in South Africa, UK and UAE during the study.

Clayton et al (2011) looked at 7 Arabian horses and the management of those feet barefoot. Concluding that bevelling the toe and engaging the frog and bars during weight bearing resulted in elevation of the heel angle and ultimately the solar angle of the distal phalanx, later stating that this resulting morphological change may be beneficial in treating underrun heels. Although further research would be required, this correlation between change in hoof angle and the treatment of underrun heel could be significant in the management of Thoroughbred racehorses considering the significant cause of fore limb lameness in Thoroughbred racehorses is often related to weak or collapsed heels.

Morrison (2013) stated that it is generally accepted that balanced Thoroughbred feet are usually characterised as having not only a palmar pedal bone angle of between 2 and 5 degrees but also a heel angle within 5 degrees of the toe angle. This theory was too echoed by Curtis (1999). It is of the author's opinion that with continuous shoeing of Thoroughbred feet, this figure is very uncommon but with barefoot rehabilitation, a closer correlation can be achieved over time.

2.2.3: Studies on the relationship between toe and heel angle

Little research has been done on the relationship to toe and heel angle when compared to barefoot and shod Thoroughbred racehorses. Malone and Davies (2019) investigated the changes in hoof shape of a cohort of 11 Quarter horse mares with an age range from 6 – 22 years of age. This study stated that there was only a slight increase in hoof angle of those barefoot horses as opposed to shod horses whilst also stating a significantly larger decrease in proximal hoof circumference of those in shoes. They failure to measure and compare the difference or changes in that of the heel angle. The study also found no significant differences in heel width or heel height. This is contrary to the findings of De Klerk (2021) who investigated a cohort of 46 leisure horses, 25 shod horses and 21 barefoot. The finding were that heel angle and width differed significantly between the two groups and stated that the toe to heel angle relationship of the shod population was greater than the barefoot population. The study would also determine a high prevalence of underrun heels when toe and heel relationship would be greater than 5 degrees with 75.5 % of shod horses and 40.5% of barefoot horses found to be within this range.

2.2.4 Studies on barefoot methodology and the effects upon hoof morphology

Multiple studies highlight the positive effects of barefoot methodology regarding improving hoof morphology over time (Bowker (1997), Clayton (2011) & O'Grady (2016)). Benoit et al. (1993) claimed that adding a shoe to the equine foot with different properties to that of the hoof would create multiple interfaces. The idea led to the discussion around the concussive dampening effect of the lower limb and ultimately the impact intensity increases upon the hoof wall.

Throughout history scientific publications have captured the unintended consequence of horse shoeing on hoof morphology and function. Lungwitz (1910) provided evidence on the difference in corium structures of both the shod and unshod hoof. Bein (1983) studied the shock absorption mechanism and compared that of both the shod and unshod hoof. The study concluded stating that 60-80% of the hoofs natural shock absorption mechanism is absent in shod hooves and those that walked on hard surfaces (asphalt) received 3 times the impact force of that of an unshod hoof.

Clayton et al (2011) looked at the effects of barefoot trimming on morphology and concluded that engaging the frog and bars in weight-bearing, resulted in elevation of the heel angle and solar angle of P3. This study used a small pool of 7 horses that had previously been barefoot for 3-4 year prior but with only minimal farriery intervention. Data collection occurred after the determined barefoot trimming process which trimmed the hoof to a predetermined ideology. None of these studies capture data of the natural hoof state and all data collected was post farriery intervention.

Chapter 3: Methodology

3.1: Introduction

A methodology is a systematic approach to the gathering of data for intended purpose of research. Two main research paradigms; qualitative and quantitative can be applied. Qualitative methodology is based upon the opinion or social attitude towards a topic often recorded in words (Creswell 2001). Quantitative methodology is based upon numerical data with different variables including that of time. Two methodology paradigms can be used in collaboration with one another however it is commonly seen that any form of research is either one or the other. Both methods, however, are extremely effective at collecting data to explore the reasoning behind researched problems or for predicting possible solutions.

For this study, a quantitative methodology was chosen as the research undertaken in this study aimed to collect numerical data from a series of calibrated hoof photographs tracking the morphological changes in shape over a 3-month period. A cohort of individual horses was chosen as part of an experimental methodology with random assignment into two individual group: experimental group and control group. The experimental group contained 9 horses while the control group contained 5. This number was decided upon as a result of available horses with a particular yard. Each horse would require repeat farrier intervention on a regular cycle and therefore time was a limiting factor along with feasibility and logistics of arranging additional help such as holders.

All horses completed a minimum of 3 months full training exercise prior to being selected for this study.

Horse selection process:

Horses selected for this study had to satisfy the following parameters:

- Undergone full training for min. 3 months prior to selection.
- Sound without any known hoof abnormalities effecting soundness.
- Between the ages of 2 and 6

- Shod for a minimum of 12 weeks prior to being selected for the study.

All horses had images and measurements taken pre farriery intervention. The digital imagery was captured only once shoes where removed. Photographs were taken of both left fore and right fore hooves. The control group had shoes reapplied and remained shod throughout the study. The shoeing was performed by the same farrier throughout following a standardised shoeing protocol (See appendix 2).

In order to monitor the morphological changes of the hoof a 'Datum line' was needed in order to establish a known reference point for consistent measurements. The last most palmar aspect of the coronary hairline was used.

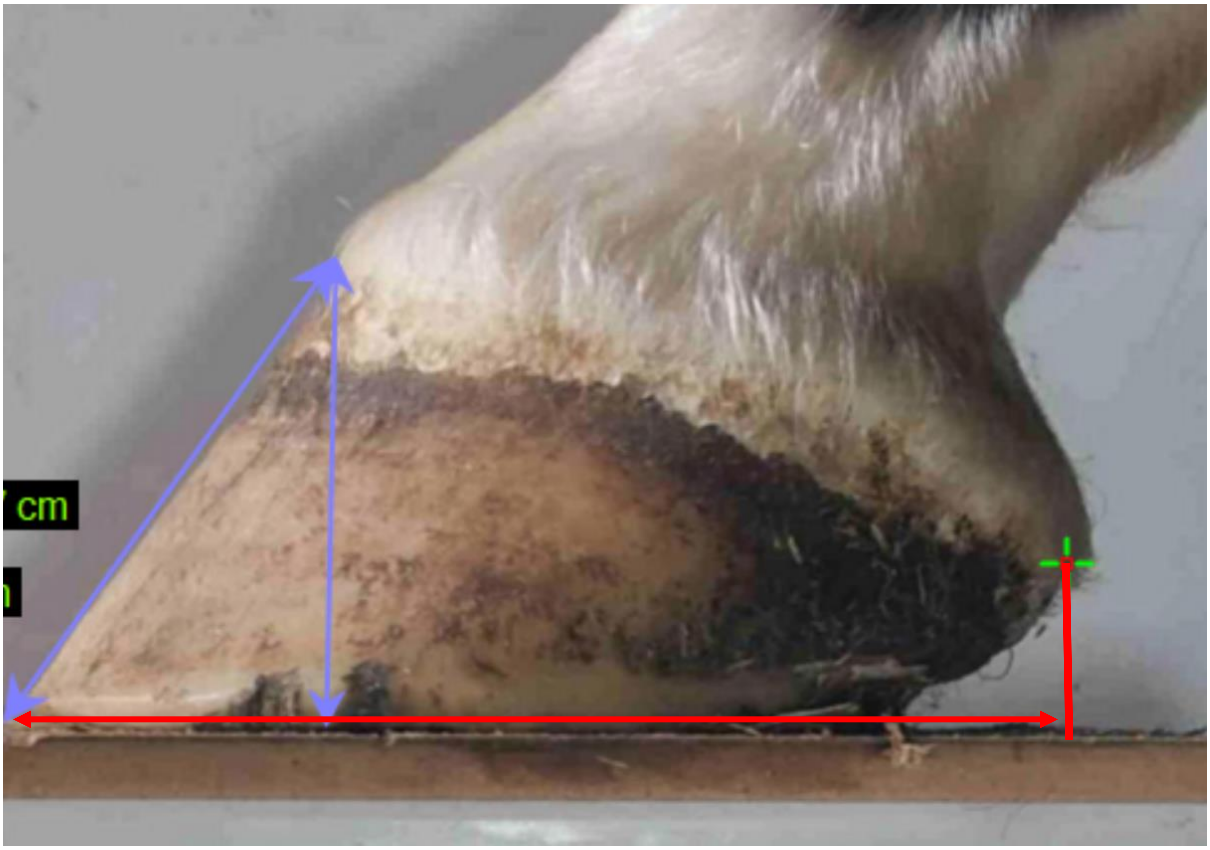


Figure 3.1: Image of a hoof in the metron system viewed from the lateral aspect. The datum point is highlighted with a green and red crosshair at the most palmar aspect of the coronary hairline. A plumbline is used to create a known reference point which will be used to measure the sagittal length, centre of rotation and frog apex distances. Authors own images.

3.2: Aims and Objectives:

The aims of this study are to provide both the farriery and equine owning communities with a detailed and clear understanding of the advantages of short periods of barefoot rehabilitation on overall hoof health, form and function. The aim is to scientifically record the changes in form of the hoof capsule and document the effects on hoof balance and geometrical proportions. The outcome would be used to quantify the effects of barefoot rehabilitation of Thoroughbred racehorses in training. The study will also help towards improving the welfare of those Thoroughbred racehorses in training by educating those responsible for their care on the benefits of barefoot rehabilitation and the consequences of poor hoof morphology.

The objective of this paper is to investigate the physical changes in Thoroughbred racehorse feet during a period 90 days without shoes whilst maintaining a regular but light training program consistent for that period of the racehorse training period.

3.3: Hypothesis

The Cambridge academic content dictionary defines a hypothesis as "an idea or explanation for something that is based on known facts but has not yet been proven". A hypothesis is often the idea behind the scientific research and through the experimental research, data collection and statistical review process, the hypothesis can be proven or disproven depending upon the outcome.

The hypothesis for this study is that hoof balance will significantly improve when shoes are removed for a period of time. The removal of shoes will have a significant effect on the morphology of the palmar region of the hoof. The disparity between toe angle and heel angle will decrease with an increase in both the length and angle of the heels. The overall length of the hoof will decrease with a shortening of the heel to bulb distance, along with an increase in the heel separation distance for those horses that go without shoes.

3.4: Materials and Methods

Data was collected every 18-21 days and done so pre farriery intervention. The method of collection was systematic and the protocol for collection was followed strictly. That protocol is listed below:

1. The shoes of the fore feet where removed, the feet were cleaned out with a hoof pick and wire brush to remove lose or exfoliating horn and any debris.
2. Both fore feet were placed upon the Metron block for images to be taken. Both feet were placed upon the blocks in order to achieve symmetry and follow recommended protocol like that when performing radiographs.
3. The camera was located within the Metron hardware camera cradle and positioned in accordance with the Metron guidelines (Craig 2018).
4. The camera was set to x2 magnification and positioned at 1 meter from the block.
5. A lateral-medial image was taken followed by a dorso-palmar image.
6. The process was repeated for both Left and Right forelimbs.
7. The horse was removed from the blocks.
8. Each limb was lifted and using the finger calibration marker, solar images where taken.
9. The camera was again set at x2 magnification and positioned 21 inches from the solar plane of the hoof.
10. Images where then imported into the Metron Mind system for calibration and marking.
11. Measurements where then obtained using the Metron system artificial intelligence software and any errors were amended using the guided markup protocol.

Following the capture of digital imagery all feet were then trimmed to the determined guidelines detailed within the appendix (see appendix 1).

The trimming and shoeing protocol for those feet remaining in shoes followed the guidelines laid out in appendix 1 & 2. The population remaining without shoes followed the guidelines laid out in appendix 1. A consideration for depth of wall was made for when trimming those horses that remained without shoes. Those being trimmed for shoeing would be trimmed to the solar plane as to where those going without would be trimmed leaving slight depth of wall.

Horses selected for this study were inspected by various equine practitioners for any signs of lameness. None were found to be lame, and all were deemed fit for participation within the study.

Horse behaviour was considered for health and safety of those persons involved in the study but also as a commercial risk to those involved. Horses needed to be handled appropriately whilst out of their box and behavioural information was collected to ensure all horses would stand on the metron hoof blocks without issues.

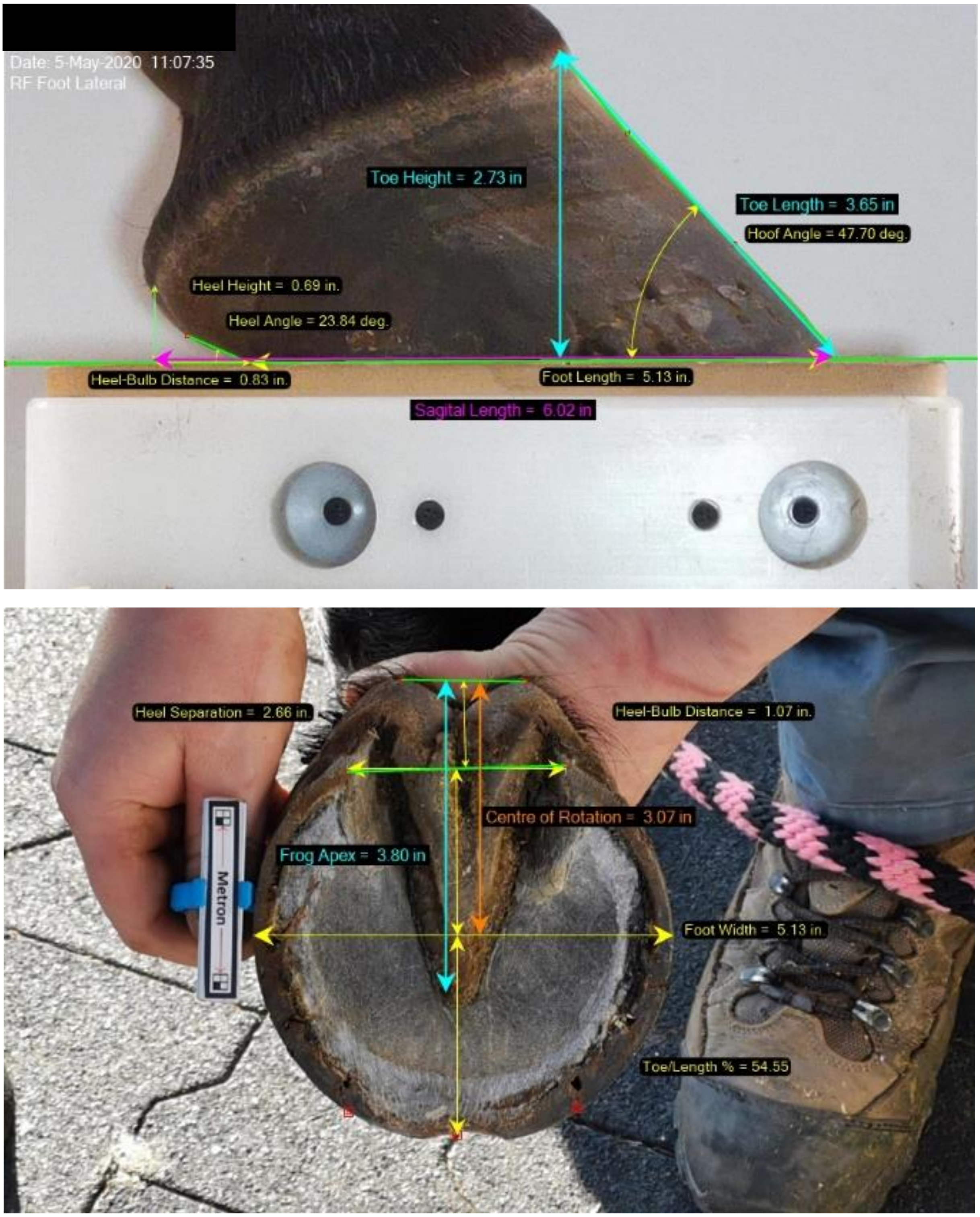
The average age of all horses was (mean 3.7 years) with a range from 2 -6 years of age. The sex of horses varied between filly, colt and gelding (2 fillies, 9 geldings and 3 colts).

3.4.1 What measurements are going to be taken?

Each case was measured pre farriery intervention on a standard 3-week cycle. The Metron hardware equipment was used to collect photographs of the lateral, dorsal and solar aspect. Calibration and image markup was automatically carried out by the artificial intelligence software, MetronHoof.

DTP	Datum Point – Most palmar point of coronary band between hair and hoof.
TH	Toe Height
TL	Toe Length (Linear)
FL	Foot Length
HA	Hoof Angle
SL	Sagittal Length
HH	Heel Height

HeA	Heel Angle
HBD	Heel Bulb Distance
HS	Heel Separation
THL%	Toe to Heel Length percentage
FA	Frog Apex
FW	Foot Width
COR	Centre of Rotation



Figures 3.4: The images show the MetronHoof hardware and software being used to correctly calculate the desired hoof measurements. The image on the top is a lateral image of the hoof placed upon the 4-point calibration metron block. The image on the bottom is a solar view image using the 5.08cm hoof marker placed flat in line with the solar plane of the hoof. Authors own images.

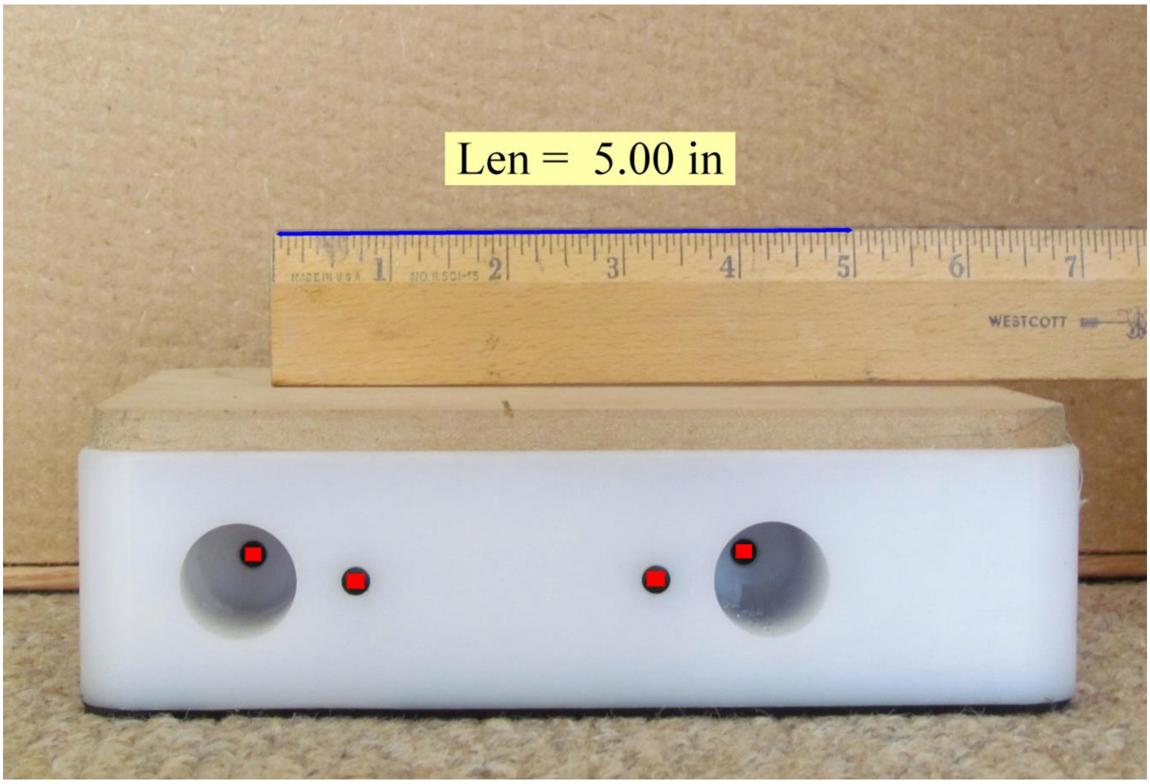


Figure 3.5: Four-point scaling used by the metron block assures accurate measurements along the centreline of the block. The metron hoof artificial intelligence software automatically detects the marker within the block. Upon the occasion error in determining the marker location, a correction would be made manually. Image courtesy of Epona online guidance & support - https://www.eponamind.com/metronhoof/

3.5: Reliability, Validity and Standardisation:

Reliability

Reliability of a study is defined by the studies repeatability thus reducing it participant or researcher bias or error. The design of this study was done to maximise on population numbers and therefore overall statistical significance. Data collection occurred on all horses pre farriery intervention to minimise the participant (farrier) bias. Farriery intervention was carried out by the same person throughout the study to standardise procedure and reduce variance in the work. Both the trimming and shoeing protocol were determined based upon the protocol detailed within Caldwell et al. (2016) study. The processing of imagery was performed using the Metron Mind artificial intelligence software and the images were collected using the Epona Hoof guidelines detailed in appendix 3. The study occurred within a commercially working environment which did result in various uncontrollable factors, predominately that of exercise regime.

Validity

Validity is defined as the extent to which a concept is accurately measured in a quantitative study (Heale and Twycross, 2015). This study used horses within a typical age range that would represent the average population of Thoroughbred flat racing horses in training in the Newmarket area. The study did however use a population of horses from within the same yard. This would limit the validity of the study to a very specific population of horses controlled by the same parameters.

Standardisation

Standardisation is the process taken to ensure that key and essential elements towards the reliability and validity of the research are identical throughout (Epstein and Timmermans, 2018). In order to ensure the standardisation of this study all farriery interventions were carried out by one farrier throughout. This would limit the variance within shoeing style and ability. Those population of horses remaining in shoes would be shod using the same style and brand of horseshoe and horseshoe nail through the time period.

Data collected from all horses was done so within the shortest period of time before the first and last horse within the restrictions of a commercially working environment. This would limit the effects of a variety of uncontrollable factors such as weather.

Data was collected using the Metron hoof hardware which was consistent throughout. The camera was the same camera used to capture all images within the study.

3.6 Data Collection and Analysis

Data was collected from processing the photographs with the MetronHoof software. The artificial intelligence software would automatically calibrate the images based upon the position of the known markers within the blocks. Once the AI software was calibrated, angular and linear measurements were placed upon each image. Each image was manually inspected for potential errors. Any errors found were manually corrected and verified.

All data was exported as a csv file and transferred to a Microsoft excel spreadsheets for sorting and presenting.

Data was then entered into Minitab 20, a statistical analysis software programme. The data was initially tested for normality using an Anderson Darling normality test. All data was determined as parametric data and tested using one way analysis of variance test (ANOVA) using Tukey comparison testing.

Significance was set at $p<0.05$.

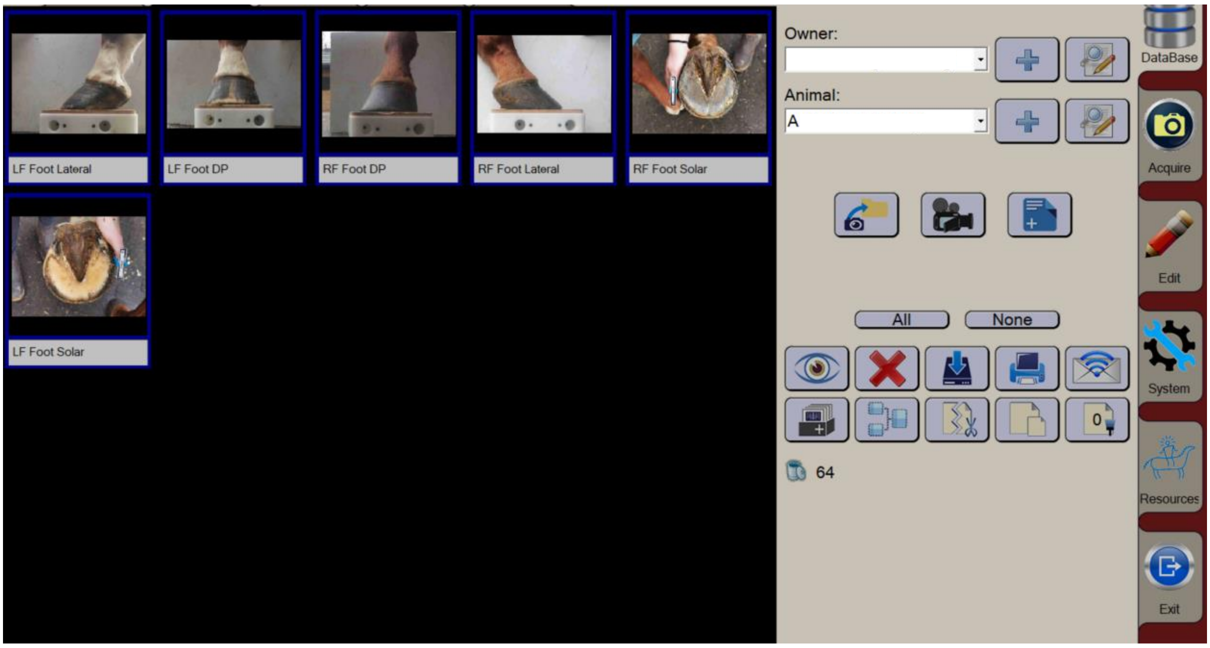


Figure 3.6.1: The image above shows the user interface of the Metron Hoof software. The software captures and stores the images for each horse within the individual horse's profile. Each set of images are stored based on date of capture. Authors own images.

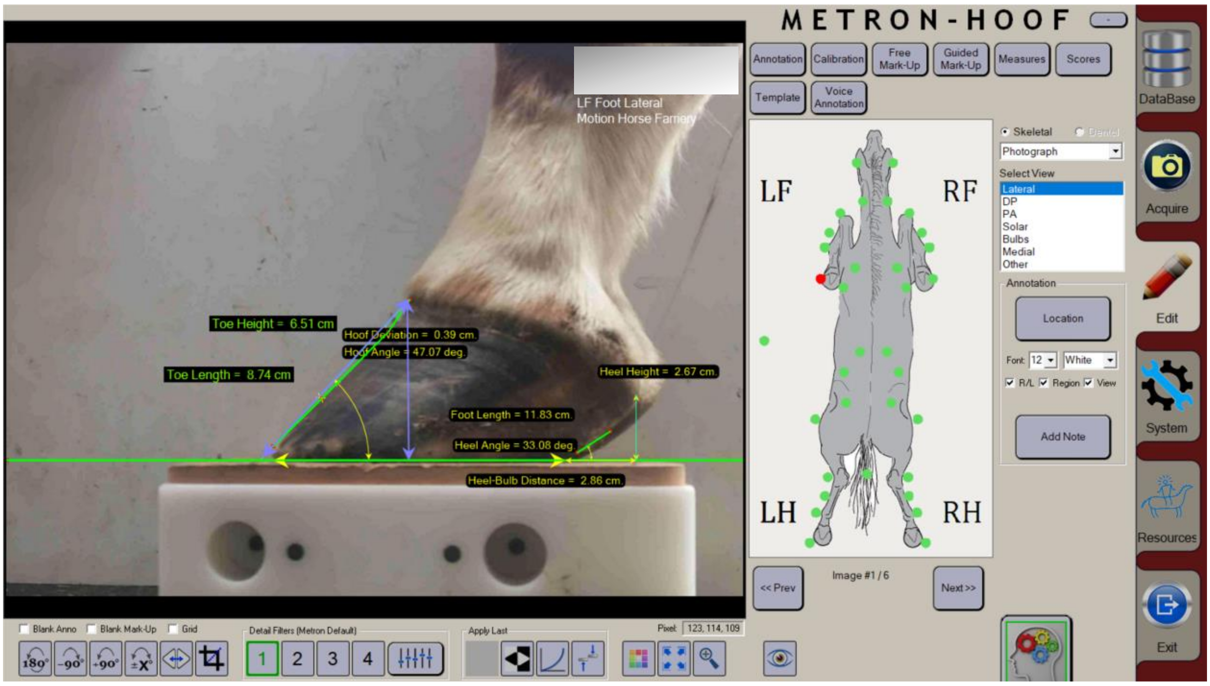


Figure 3.6.2: The image above shows the user interface of the measurement and calibration process within MetronHoof software. Each image is manually verified for correct calibration and measurements. Authors own images.

3.7: Ethical Considerations

All horses used within this study were cared for and under the responsibility of one person. Permission to use the population of horses was requested and approved before commencing the study. It was discussed that confidentially and anonymity of horses was paramount throughout. All names were removed for the purpose of the study and each horse was assigned a alphabetical letter for identification.

All horses were cared for and handled by a competent, familiar and experience handler throughout. Handlers and participants involved wore the appropriate PPE throughout. No horse was to be handled and out of their box for more than 15 minutes. This would reduce the possibility of horses becoming agitated or impatient during the measuring procedure.

The trainer had the right to withdraw any horse prior to or during the study, however this did not occur.

Prior to commencing this study approval was obtained from the Myerscough College Ethics Committee (see appendix 4).

Chapter 4: Results

4.1 Summary data

The results collected from all 14 horses was collected and exported through MetronHoof system to form a spreadsheet table summarised in Table 4.1 (see appendix 5).

Hoof Angle	Hoof Devi	Heel Angle	Heel Heigh	Outer Wal	Outer Wal	Outer Wal	Inner Wall	Inner Wall	Heel Separ
50.186	0.804	33.024	2.608	111.999	0.462	5.971	106.828	0.687	6.065
52.22	0.444	31.646	2.516	110.734	0.352	5.793	108.227	0.642	5.768
53.848	0.476	32.398	2.715	115.693	0.631	6.755	99.329	0.519	5.693
47.749	0.359	30.887	1.812	113.973	0.165	6.263	112.561	0.786	6.302
48.704	0.186	34.958	1.6	112.896	0.299	5.737	113.246	0.976	5.943
50.5	0.423	34.554	2.043	112.885	0.331	6.261	109.54	0.72	6.078

Heel-Bulb	Foot Lengt	Foot Widtl	Toe Height	Toe Length	Centre of I	Frog Apex	Sagital Ler	Time Point	Limb
3.411	12.097	13.485	7.782	10.003	9.14	9.961	15.443	1	LF
2.48	12.445	13.92	7.724	9.803	8.148	9.61	14.863	2	LF
2.86	12.271	13.465	7.496	9.211	8.244	10.204	15.081	3	LF
2.782	11.919	13.814	7.092	9.564	8.029	10.017	14.63	1	RF
2.58	12.66	14.02	7.073	9.355	8.129	10.126	15.099	2	RF
2.962	12.302	13.739	7.462	9.51	8.477	10.564	15.226	3	RF

Figure 4.1.1: Above table shows the data collected for each horse using the Eponamind system. The data was then exported to Microsoft excel spreadsheet. The data set from each horse was combined and transferred to a Minitab data set to assess the statistical significance. See appendix for full table.

The mean results for each horse that went barefoot throughout this study is summarised below.

Variable	**Time Point 1**	**Time Point 2**	**Time Point 3**
Hoof Angle (degrees)	**50.19**	**51.42**	**52.65**
Heel Angle (degrees)	**34.08**	**39.93**	**42.01**
Heel Height (cm)	**2.13**	**2.56**	**2.66**
Heel Separation (cm)	**6.31**	**7.04**	**7.27**
Toe Height (cm)	**6.82**	**6.76**	**6.84**
COR (cm)	**7.511**	**7.73**	**7.59**
Heel to Bulb distance (cm)	**2.52**	**2.92**	**2.96**
Toe length (cm)	**8.77**	**8.56**	**8.53**
Sagittal Length (cm)	**14.16**	**14.76**	**14.23**

Figure 4.1.2: Mean of variables summarising the morphological changes in all barefoot hooves from the start of the study, at the midpoint of the study and at the end. Significant differences over time were detected using repeated measures ANOVA and Tukey testing.

The mean results for each horse that was shod throughout this study is summarised below.

Variable	**Time Point 1**	**Time Point 2**	**Time Point 3**
Hoof Angle (degrees)	**50.92**	**50.98**	**51.24**
Heel Angle (degrees)	**33.96**	**32.45**	**33.94**
Heel Height (cm)	**2.14**	**2.29**	**2.22**
Heel Separation (cm)	**6.02**	**5.93**	**5.96**

Toe Height (cm)	**6.88**	**7.16**	**6.86**
COR (cm)	**7.71**	**8.52**	**8.16**
Heel to Bulb distance (cm)	**2.67**	**2.96**	**3.02**
Toe length (cm)	**8.84**	**9.23**	**8.72**
Sagittal Length (cm)	**14.23**	**15.42**	**14.78**

Figure 4.1.3: Mean of variables summarising the morphological changes in all shod hooves from the start of the study, at the midpoint of the study and at the end. Any significant differences over time were detected using repeated measures ANOVA and Tukey testing.

The values for each corresponding variable were tested for normality using the Anderson Darling normality test. This test looks at the distribution of data within the data set and determines if it fits either a normal distribution or not. For this study both the shod and barefoot data set were tested using the AD normality test. Both proved to be parametric with p values greater than 0.05.

Figure 4.1.4: The above images show the morphological change in the orientation of the hoof from a horse who had its shoes removed. Authors own images.

4.2: Heel Angle

Anderson Darlington normality testing was used to test the data for heel angle of both the shod and barefoot population of horses. The testing showed p-value for Shod 0.488 and Barefoot p-value of 0.18. This normal distribution confirmed that the data was parametric and that the following tests would determine the significance.

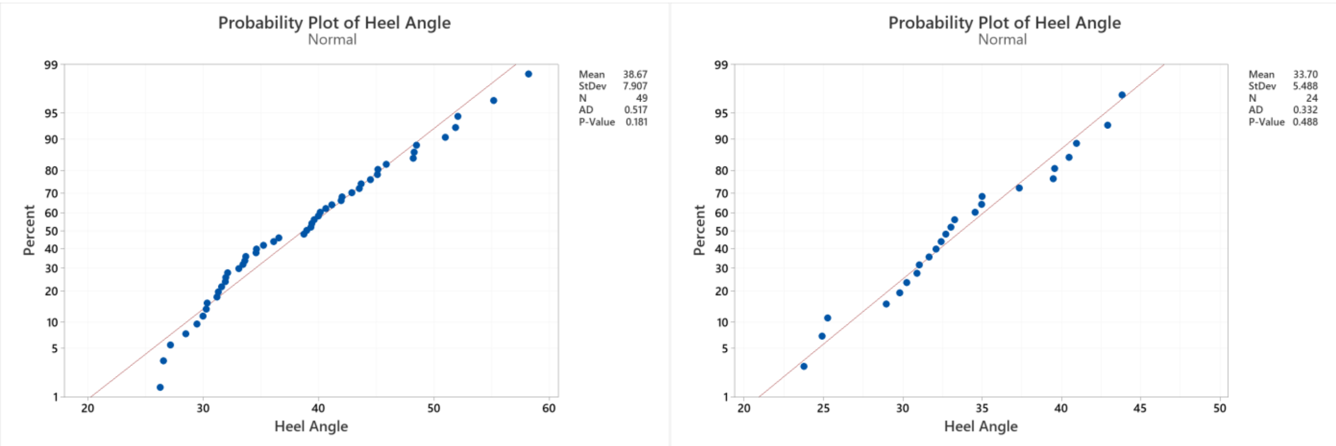


Figure 4.2.1: Above charts show the Anderson Darlington normality tests of both the heel angle of the shod and barefoot population of horses within this study.

A Tukey ANOVA test was done to determine the significance of the difference between the mean values between 3 different time points (see tables 4.2.2 & 4.2.3).

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping
1	10	33.97	A
3	10	33.94	A
2	4	32.45	A

Means that do not share a letter are significantly different.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Time Point	2	7.490	3.745	0.11	0.892
Error	21	685.156	32.626		
Total	23	692.646			

Figure 4.2.2: Above table show the one-way ANOVA comparison of heel angle over time of all shod horses.

Grouping Information Using the Tukey Method and 95% Confidence				
Time Point	**N**	**Mean**	**Grouping**	
3	18	42.01	A	
2	14	39.93	A	B
1	17	34.083		B

Means that do not share a letter are significantly different.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Time Point	2	580.9	290.44	5.52	0.007
Error	46	2419.8	52.60		
Total	48	3000.7			

Figure 4.2.3: Above table show the one-way ANOVA comparison of heel angle over time of all barefoot horses.

This found that grouping information for shod horses across all 3 time points remained in group 'A'. This would suggest there is no significant difference in the heel angle value for shod horses across the time period with a p value of 0.892. Barefoot heel value testing would however show an 'A & B' grouping at time point 2, a 'B' grouping at time point 1 and 'A' grouping at time point 3. This would suggest a significant difference with a p-value 0.007.

4.3: Heel Height

Heel height appears to increase in those horses that went barefoot as opposed to those who remained shod. The interval plot (see figures 4.3.1 & 4.3.2) would show the range of the heel height data for both populations with a steady increase in the interval plot for those that went barefoot. The range in the barefoot population data remained relatively constant however the range increased during time point 2 for those shod population. This may relate to the reduction in exercise intensity seen between time point 1 & 2.

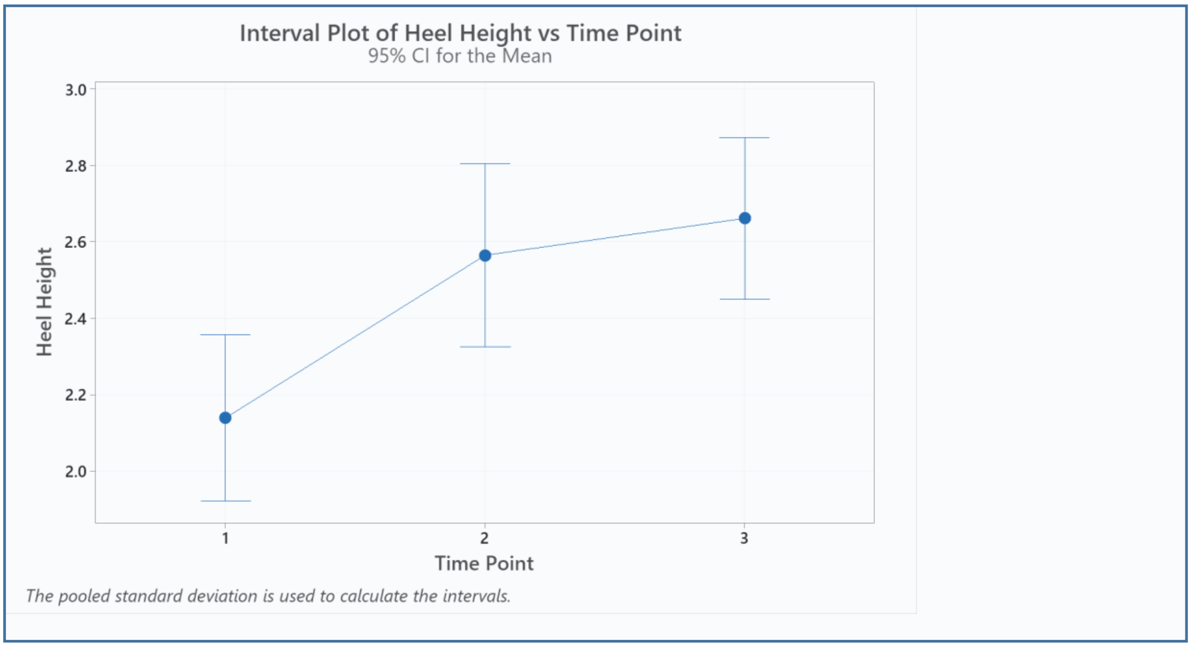


Figure 4.3.1: Mean values of 'heel height vs time' for barefoot population when tested using Tukey ANOVA test with 95% confidence.

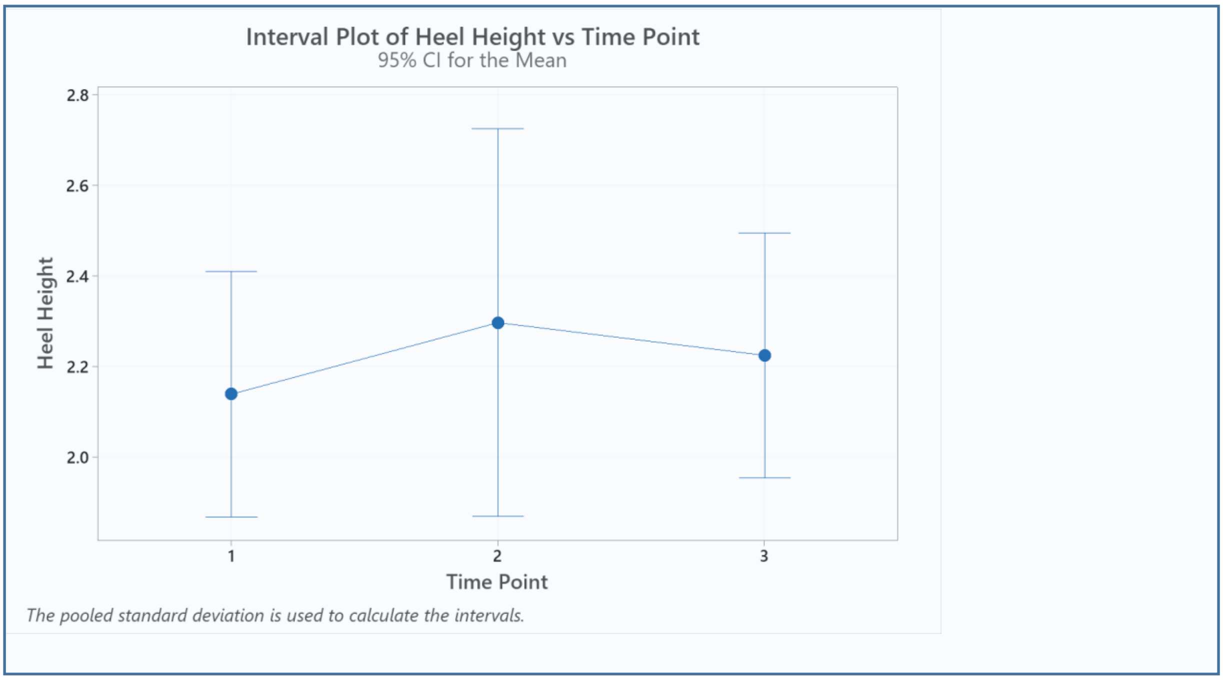


Figure 4.3.2: Mean values of 'heel height vs time' for shod population when tested using Tukey ANOVA test with 95% confidence.

The results showed no significant difference in the morphology in the heel region of those horses who remained shod in heel height, heel separation and heel angle.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping
2	4	2.296	A
3	10	2.224	A
1	10	2.138	A

Means that do not share a letter are significantly different.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Time Point	2	0.08084	0.04042	0.24	0.790
Error	21	3.56259	0.16965		
Total	23	3.64343			

Figure 4.3.3: Above table show the one-way ANOVA comparison of heel height over time of all shod horses.

The results collected showed a significant difference in the morphology in the heel region of those horses who went barefoot in heel height, heel separation and heel angle.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping	
3	18	2.6608	A	
2	14	2.564	A	
1	17	2.139		B

Means that do not share a letter are significantly different.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Time Point	2	2.631	1.3154	6.64	0.003
Error	46	9.116	0.1982		
Total	48	11.746			

Figure 4.3.4: Above table show the one-way ANOVA comparison of heel height over time of all barefoot horses.

4.4: Heel Separation

The mean difference in heel separation for the barefoot population across the 3 time points was 9.6 (mm) as opposed to -0.6 (mm) for the shod population. This would indicate a widening of the heels of those barefoot horses, and a slight contraction of the heels for the shod population. Tukey ANOVA test would however prove a non-significant difference in heel separation for the shod population with p-value 0.948 (see figure 4.3.3) whilst the same test on the barefoot population would show a significant difference and p-value 0.001 (see figure 4.3.4).

Means

Time Point	N	Mean	StDev	95% CI
1	17	6.319	0.478	(6.010, 6.627)
2	14	7.048	0.859	(6.708, 7.388)
3	18	7.275	0.550	(6.975, 7.575)

Pooled StDev = 0.632217

Figure 4.4.1: mean value and standard deviation for heel separation for shod population across the 3 time points.

Means

Time Point	N	Mean	StDev	95% CI
1	10	6.020	0.403	(5.703, 6.338)
2	4	5.937	0.633	(5.435, 6.439)
3	10	5.966	0.498	(5.649, 6.284)

Pooled StDev = 0.482781

Figure 4.4.2: mean value and standard deviation for heel separation for shod population across the 3 time points.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping
1	10	6.020	A
3	10	5.966	A
2	4	5.937	A

Means that do not share a letter are significantly different.

Figure 4.4.3: Grouping information using Tukey method and 95% confidence to compare the heel separation for shod population over the 3 time points.

Time Point	N	Mean	Grouping	
3	18	7.275	A	
2	14	7.048	A	
1	17	6.319		B

Grouping Information Using the Tukey Method and 95% Confidence

Means that do not share a letter are significantly different.

Figure 4.4.4: Grouping information using Tukey method and 95% confidence to compare the heel separation for barefoot population over the 3 time points.

4.5: Hoof Angle

Hoof angle is the angle of the hoof created between the toe and he ground bearing surface. The average hoof angle for barefoot horses increased by a mean of 2.46 degree between TP1 and TP3. The shod population increased by a mean of 0.32 degree between TP1 and TP3.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping
3	10	51.247	A
2	4	50.98	A
1	10	50.923	A

Means that do not share a letter are significantly different.

Figure 4.5.1: Grouping information using Tukey method and 95% confidence to compare the hoof angle for shod population over the 3 time points.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping
3	18	52.647	A
2	14	51.422	A
1	17	50.195	A

Means that do not share a letter are significantly different.

Figure 4.5.2: Grouping information using Tukey method and 95% confidence to compare the hoof angle for barefoot population over the 3 time points.

No significant changes were found in the hoof angle of both the shod and barefoot population of horses although the hoof angle did slightly increase for both population of horses on average.

4.6: Hoof Angle to Heel Angle

Hoof angle to heel angle is the sum of the difference between the hoof angle and heel angle. When comparing the shod population there is non-significant data to prove a difference in the change in relationship between hoof angle and heel angle. In the barefoot population however Tukey ANOVA test would show a significant change in the relationship between hoof angle and heel angle with p-value 0.022.

	TP1	TP2	TP3		
Hoof/Heel Angle shod (degrees)	16.96	18.53	17.3	**Sum of TP3-TP1**	0.34
Hoof/Heel Angle Barefoot (degrees)	16.11	11.49	10.64	**Sum of TP3-TP1**	-5.47

Figure 4.6.1: Comparison of the relationship between Hoof angle and Heel angle across the 3 time points with the overall difference from start to finish.

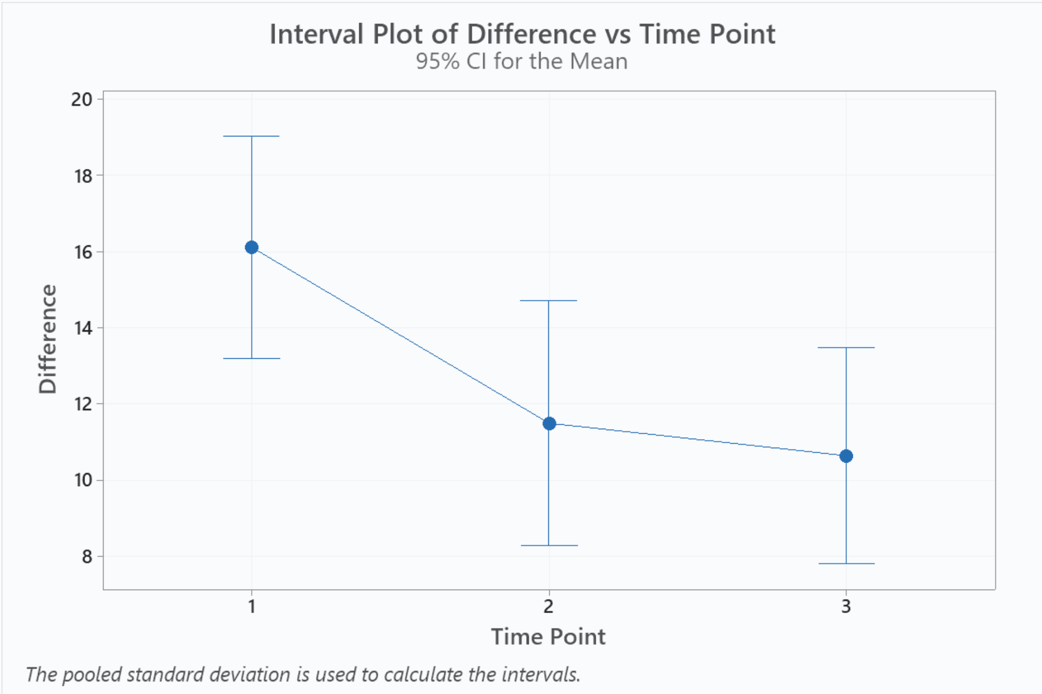


Figure 4.6.2: Interval plot showing the range in data of the difference in hoof angle to heel angle over the 3 time point period. Note the range at each time point is relatively consistent but with an overall decrease in the difference over time.

Grouping Information Using the Tukey Method and 95% Confidence

Time Point	N	Mean	Grouping	
1	17	16.112	A	
2	14	11.49	A	B
3	18	10.64		B

Means that do not share a letter are significantly different.

Figure 4.6.3: Tukey ANOVA grouping information of the hoof and heel angle difference over time point. The grouping between time points 1 and time point 3 do not share the same letter and are therefore significantly different.

Chapter 5: Discussion and Recommendations

5.1 Discussion

This study has shown that for a period without shoes the Thoroughbred racehorse hoof can make significant morphological improvements to the overall hoof capsule. Those morphological changes in hoof orientation would lead to the greatest improvement in the palmar region of the hoof. This would be displayed by a steeper heel angle, slightly increase heel height and also increased heel separation. The hoof morphology of all horses within the study at the beginning displayed a morphological state as a result of a minimum of 1 season in training whilst wearing horseshoes. Those horses that remained in shoes however showed no significant morphological changes. Within the hypothesis, it was predicted that continuous use of shoes would have a negative impact on hoof morphology. The study has found no significant changes in hoof orientation or morphology that would support this theory.

5.1.1: Changes between time points (1-2 & 2-3)

During the period between point 1 and 2 the morphological change in those horses that went without shoes showed a rapid change in shape and orientation. This was a period of approximately 45 days. Heel separation increased approx. 30% more so in the first 45 days than that of the later 45 days. This would also be true for the the significant improvement in heel height and heel angle during the same period.

The time of the year in which the first 45 days occurred however was around December and the later 45 days being throughout January and early February. As this was a commercial working study the rapid changes in hoof orientation and overall shape and form may be a result of a lower intense workload with the run up to a festive holiday and a wind down for the year. This reduced exercise and intensity may be a contributing factor as contrary to the first 45 days the following 45 days would be in the new year where exercise intensity would steadily begin to increase in preparation for the season ahead. Although no changes were found in the shod group over the time period clearly a negative impact/restriction of developments had already occurred highlighted by the significant and rapid improvement in the barefoot group once shoes were removed. This could indicate that the negative effect of shoeing is limited in some degree to horses of this age, possibly due to higher levels of growth rate (Curtis 1999). There is a possibility that findings may be different in a population of older horses.

It is also worth considering that given the speed and magnitude of the most significant changes being between TP1 & TP2, that the impact of this new management regime even with a short period of no shoes, would have a significantly positive effect on hoof morphology.

Figure 5.1.1: Series of images from Metron software demonstrating the change in hoof morphology over across the 3 different time points. The immediate changes in hoof morphology can be clearly witnessed

in those hooves that went without shoes. Little change in hoof shape and orientation is evident in the shod horse. Authors own images.

5.1.2: Change in Hoof Angle

It was found that no significant changes were witness in the hoof angle of both the shod and barefoot population. However, there was a mean increase in hoof angle of 2.46 degrees in the barefoot population as opposed to 0.32 degree in the shod population. This would suggest that hoof angle does have a greater increase when horses go barefoot than that of when shod however considering the population size, this change was not found to be significant. It is important to note however that the angle of the hoof wall is calculated from the tip of the toe to the coronary hairline. Changes in hoof angle was visibly evident just below the coronary region. Due to the growth rate of hoof and the time period of this study, the increase in the angle of new horn growth was not significant to affect the overall angle of the hoof. The deviation point created in the hoof wall as a result of this angle changed was measured and showed to increase throughout the study. This would warrant further investigation and an increase in the period in which the study was carried out in order to conclude on the significance of hoof angle between shod and barefoot.

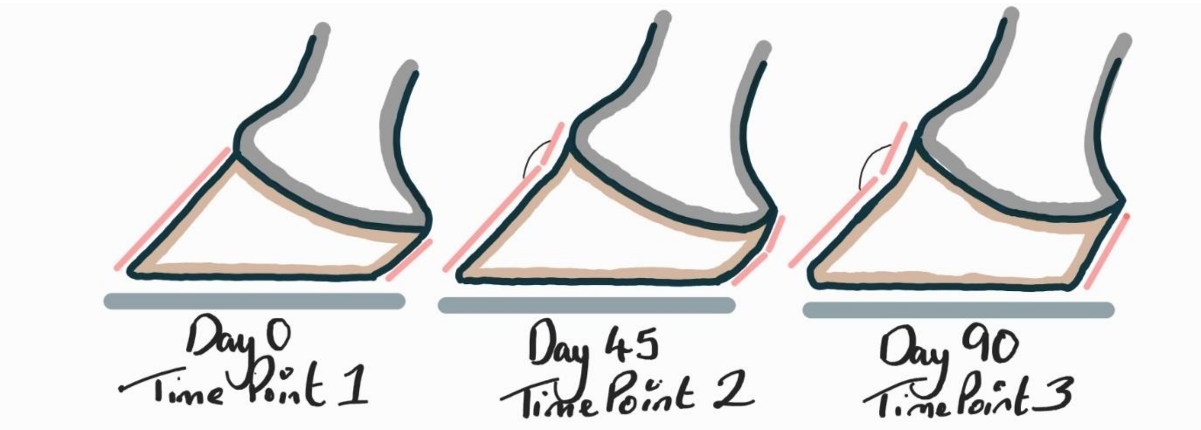


Figure 5.1.2: The above illustration demonstrates the change in hoof wall angle below the coronary hairline. The overall hoof angle measurement calculated showed no significant change across both populations. Authors own images.

5.1.3: Changes in Heel Angle

Heel angle changed significantly for those horses who went barefoot with a mean average increase in heel angle of 7.93 degrees as opposed to -0.02 degree for shod horses. Although the analysis of data would show a non-significant change in the heel angle of the shod population, it could be extrapolated that with the comparison to those barefoot horses that did show significant increase heel angle, that the application of a shoe has a compromising effect on the overall health and form of the heels.

No significant changes were found in the toe length of both population of horses. However, those horses that remained in shoes had an average hoof angle to heel angle difference of 17.3 degrees at TP3 as opposed to 16.96 at TP1 showing a increase in this difference of 0.34 degrees. The barefoot horses had a similar TP1 value of 16.11 degrees which decreased by 5.47 degrees throughout the study to 10.64 degrees at TP3. Although this far from the recommend 5-degree difference between hoof angle and heel angle as stated by Curtis (1999) & Morrison (2013), it demonstrates the need for barefoot rehabilitation in order to prevent or minimise the commonly seen low toe low heel conformation.

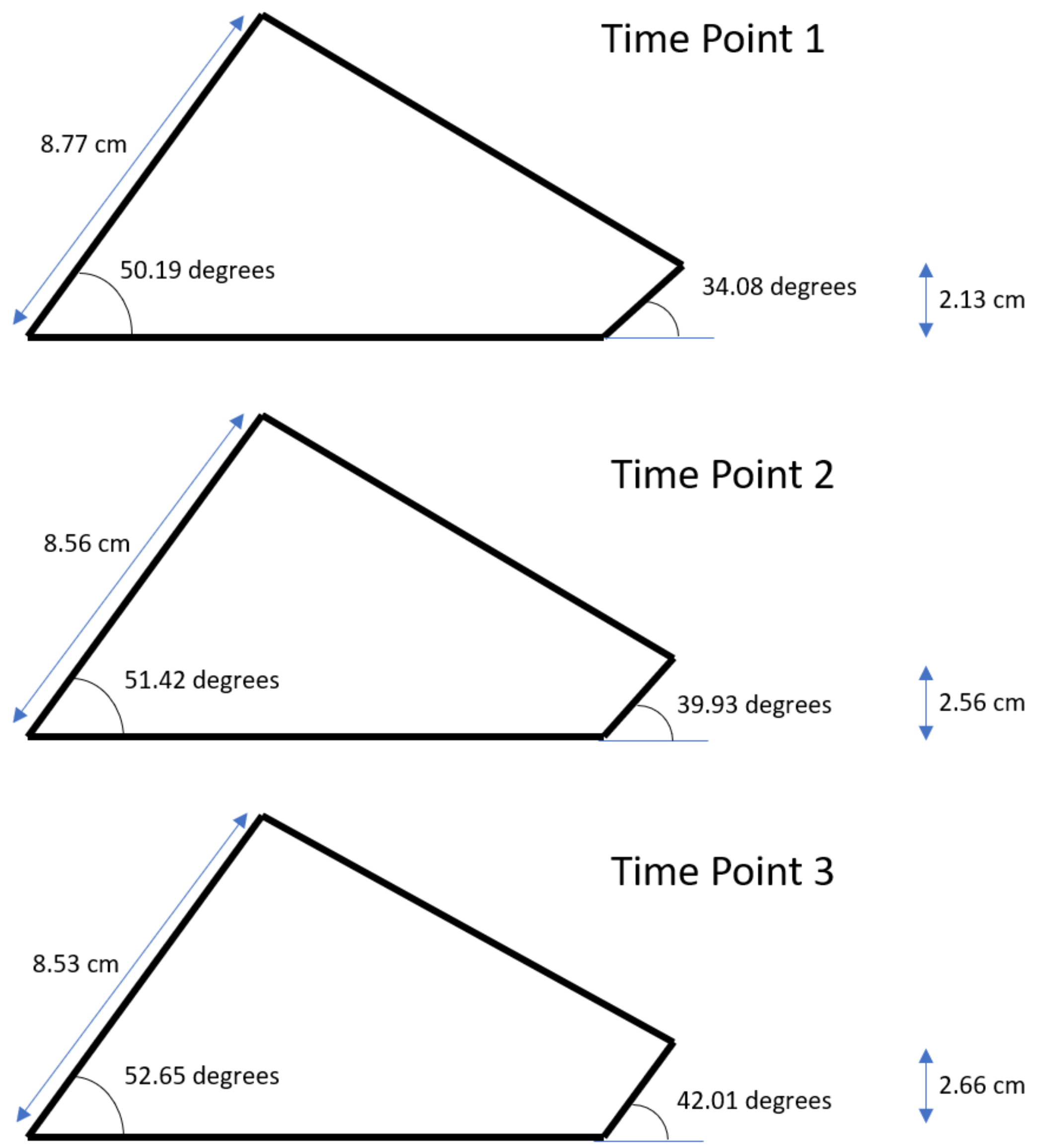
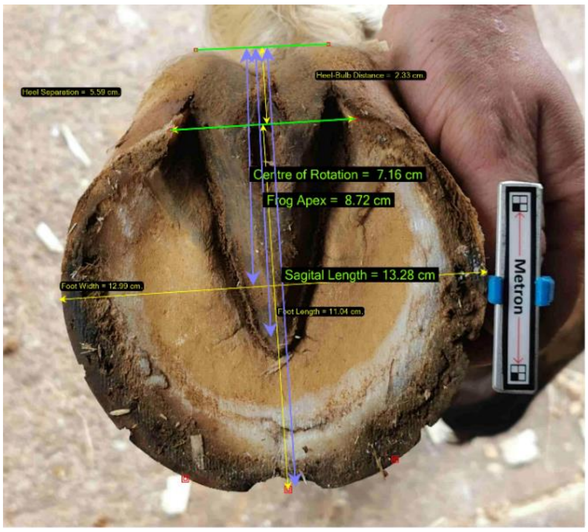


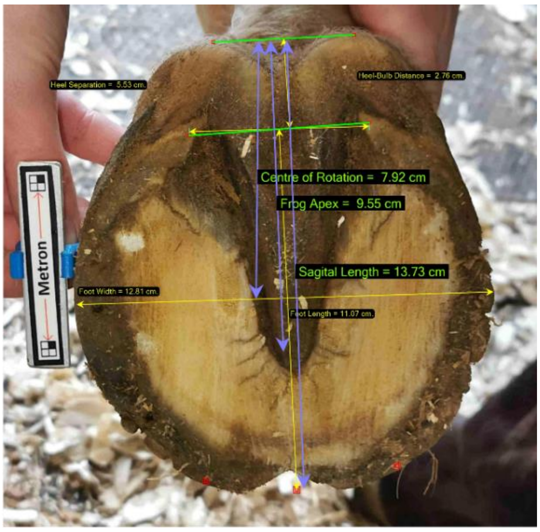
Figure 5.1.3: Mean hoof dimensions from a lateral aspect showing the changes from Time Point 1 (top) to time point 2 (middle) and time point 3 (bottom). Authors own images.

5.1.4: Morphological changes to the solar aspect

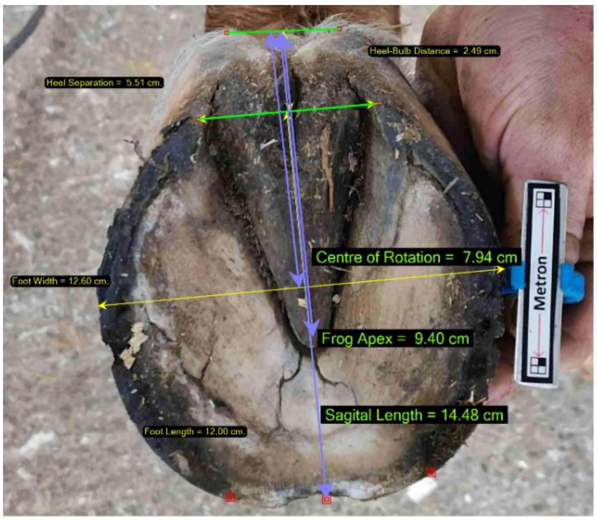
Heel separation significantly increased in those horses that went barefoot as opposed to those that remained in shoes. This would coincide with the observations made by De Klerk (2021) and Malone and Davies (2019). It is believed that wider heels and subsequently wider frogs are advantageous to the function of the hoof mechanism. Increased frog mass creates a larger surface area for weight distribution along with increased hemodynamic function aiding blood flow, stimulating growth and energy dissipation. Widening of the heels and increases in frog mass would contribute to significant improvements seen in the heel angle and heel height also. As significant changes where witness in both the heel height, heel angle and heel separation, it can be believed that barefoot rehabilitation of feet has an immediate and significant impact predominantly in the palmar region.



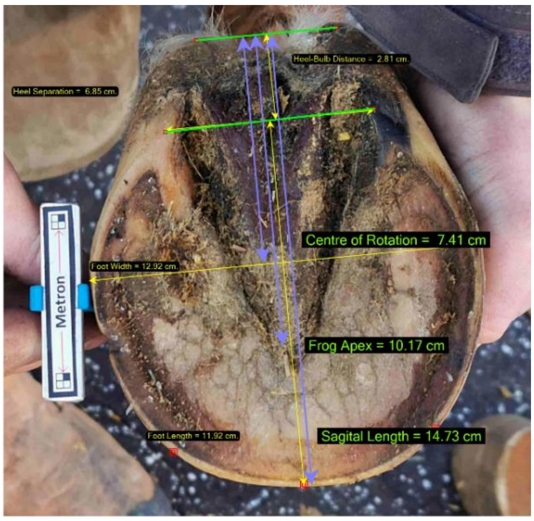
Horse I – Shod TP1



Horse I – Shod TP3



Horse G – Barefoot TP1



Horse G – Barefoot TP3

Figure 5.1.4: Images above show a comparison of two horses within the study. Horse I was shod throughout whilst Horse G went barefoot. Each image contains the metron mark up and upon visual inspection it can been that the heel width and overall frog size and shape increased in Horse G whilst decreasing for Horse I. It is also interesting to note the condition and form of the bars. Authors own images.

5.2: Results Limitations

As the study population size was of relatively small numbers this limited the number of values collected for both shod and barefoot populations. Having a small population of horses shod (5) may have affected the normality of the data collected to some degree. An increase or even equal population of shod horses to barefoot horses would have meant a greater number of values for the tested variables and this may have changed the significance of some of the testing. This would be especially true when considering the negative effect of shoeing and having statistically significant data to prove the difference between shod and barefoot. The negative effect of shoeing may be better understood if the time period of the study would have been extended and data from those barefoot horses that then went back into shoes was collected.

Controlling the exercise regime of individual horses was beyond the capabilities of this study as it was performed in a working commercial yard. This does however reflect the working conditions and real-life expectations that the aims of the study were hoping to determine. It should be noted however that exercise, training and the intensity of training has been proven to effect hoof morphology.

5.3: Recommendations

The findings of this study would suggest that barefoot rehabilitation of Thoroughbred feet during a period of reduced exercise intensity would have a positive impact on the morphology of the hoof, the palmar (heel) region.

This has potential benefits to the management of Thoroughbred racehorses who are commonly seen to have long toe low heel syndrome. This type of hoof conformation would lead to an increased risk of heel pain and bruising with some scientific studies going as far as possible links to catastrophic soft tissue injuries. Anecdotal evidence would suggest heel pain and bruising as one of the leading cause of periods of lameness in Thoroughbred racehorses within Newmarket racing yards, as this study has proven, with the removal of shoes the hooves have a opportunity to restore to, or improve towards, what would be regarded as a much healthier, functional, shape and form.

5.4: Further Research

The necessity to apply shoes is not questioned by the author within this study. Rules and regulations within the racing industry both in the UK and overseas would result in the need to apply shoes to horses' feet. The study is strongly suggesting that when a period of time is available within the training calendar, barefoot rehabilitation of feet would have a strong and positive impact on improving the overall health and function of the hoof. This could potentially reduce the risk or chance of lameness as a result of poor hoof conformation during the racing season. Further research would be needed to associate the risk of lameness and the morphology of Thoroughbred feet. Studying the morphological changes to feet following a period without shoes who are then shod, would potentially support the aims of this study further.

Further investigation with increased population size especially for those who remain shod could lead to data set of significant outcomes. This significant outcome could prove the anecdotally witnessed deterioration of shod feet throughout the racing season. This could therefore lead to significant mindset change within the industry on the management and maintenance of Thoroughbred feet out of season.

Word Count: 7414

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Appendices

Appendix 1

Trimming Protocol:

1. Foot is cleaned removing any debris using a wire brush and hoof pick.
2. Collateral margins of the frog lightly trimmed along their entire length at an angle of approx. 55-60 degree to the bars. Central sulci trimmed lightly to restore the shallow central sulci groove along with the top of the frog trimmed flat with the removal of any lose or necrotic horn. The true apex of the frog determined (the junction between the horny frog and sole).
3. Periople or extending frog around the heel buttresses carefully trimmed away to expose the true heel origin.
4. White line is carefully exfoliated to expose healthy yellow horn at the true solar border.
5. Sole is very lightly exfoliated removing only large areas of horn build up. Sole callus around the toe margin is not trimmed.
6. Bars are straightened with the removal of bent or folded horn.
7. Seat of corn is lightly eased out to remove loose exfoliating horn to below the level of the bearing border of the hoof wall.
8. Toe is backed up using a rasp perpendicular to the solar plane to reduce stretching forward of the dorsal toe region and to create even white line and wall thickness around the foot from quarter to quarter.
9. Excess wall at the bearing border is used to bevel the outer edge with its overall height being horizontal to the plane of that of the trimmed sole. The bevelling of the hoof wall aims to achieve an angle of approx. 45 degrees to the solar plane. (Avoid trimming the bearing border any lower than the sole in any one area).

10. Heels are trimmed down, extending the bearing border to the approx. location of the widest or highest part of the trimmed frog.

11. Hoof is then rasped from heel to heel using even and equal pressure around the entire bearing border. Create a flat and level surface whilst maintaining the bevel around the hoof walls leading edge.

Appendix 2

Shoeing Protocol:

1. Steel shoes specifically for Thoroughbred racehorse training will be applied.
2. Shoes will be fitted competition style designed to suit a shoeing cycle of 3 weeks.
3. Shoes will be fitted symmetrically providing approx. 2-3mm of length and width to the heel buttress.
4. Nails used for application will be Mustad hammer head nails size 0-2 depending upon foot size and wall thickness.
5. All shoes fitted will be toe clipped shoes with no other shoe modification or traction device.

Appendix 3

Ethics Form

Appendix 4

Full data set for both shod and barefoot population of horses.

Horse	Hoof Angle	Hoof Deviation	Heel Angle	Heel Height	Outer Wall Angle	Outer Wall Deviation	Outer Wall Length	Inner Wall Angle	Inner Wall Deviation
A	45.056	0.188	32.093	2.374	115.086	0.277	5.85	108.203	0.287
A	47.07	0.394	33.085	2.672	105.376	0.304	5.133	110.225	0.421
A	50.858	0.511	43.491	2.971	122.487	0.453	6.224	100.401	0.32
A	46.934	0.35	31.933	2.317	107.254	0.279	5.501	113.199	0.537
A	46.984	0.662	51.856	3.613	117.019	0.402	6.391	96.466	0.134
A	50.177	0.993	48.272	3.134	111.465	0.438	6.08	106.716	0.401
B	48.98	0.119	29.458	1.44	112.393	0.191	4.983	111.616	0.534
B	49.364	0.571	33.663	2.275	114.706	0.32	5.587	103.832	0.46
B	53.413	0.568	52.028	2.153	113.749	0.274	5.035	109.575	0.641
B	52.358	0.05	34.607	2.06	101.532	0.124	4.619	111.836	0.747
B	52.486	0.462	48.161	2.674	111.695	0.463	5.719	95.605	0.379
B	53.71	0.422	55.125	2.719	110.546	0.376	5.255	102.953	0.866
C	54.09	0.299	38.953	2.382	114.864	0.179	6.208	90.829	0.284
C	58.767	0.281	58.158	3.048	113.997	0.2	5.85	89.357	0.256
C	58.244	0.341	50.966	2.935	113.791	0.457	5.865	91.318	0.176
C	51.701	0.358	39.336	1.983	110.678	0.089	5.21	102.937	0.31
C	53.129	0.375	48.456	2.405	110.409	0.437	5.476	98.963	0.43
C	55.385	0.254	45.057	2.836	103.557	0.466	4.937	105.489	0.714
D	46.775	0.227	30.343	1.702	116.308	0.349	5.351	105.687	0.218
D	46.323	0.52	26.275	1.891	114.384	0.297	5.391	105.113	0.385
D	46.704	0.199	31.891	1.643	117.732	0.055	5.52	108.388	0.382
D	47.149	0.616	28.474	2.272	113.239	0.244	5.709	104.438	0.28
E	47.697	0.217	33.589	1.937	112.641	0.402	5.459	102.347	0.436
E	50.475	0.414	26.565	2.295	104.77	0.298	5.148	102.01	0.626
E	49.98	0.301	33.444	2.447	109.635	0.422	5.885	99.819	0.589
E	48.754	0.244	36.098	2.12	113.636	0.499	5.66	99.773	0.368
E	50.679	0.471	30.253	2.046	113.034	0.578	5.431	86.874	0.123
E	52.255	0.244	40.12	2.627	97.701	0.43	4.768	107.717	0.613
F	47.833	0.644	27.175	1.593	118.907	0.425	5.54	100.704	0.354
F	49.913	0.191	31.59	1.555	119.234	0.14	4.993	101.353	0.396
F	54.819	0.345	45.101	2.328	117.365	0.362	5.338	106.558	0.315
F	50.738	0.36	42.016	2.268	112.868	0.318	4.592	108.581	0.593
F	54.738	0.504	41.148	2.476	112.352	0.402	4.597	105.685	0.453
G	51.919	0.441	38.721	2.869	115.34	0.714	6.438	94.793	0.118
G	52.4	0.512	42.859	3.23	108.343	0.354	5.425	95.922	0.402
G	52.501	0.363	41.945	2.95	112.088	0.519	6.2	94.236	0.317
G	49.752	0.382	31.307	2.241	106.749	0.225	4.785	113.005	0.472
G	52.603	0.636	40.626	2.426	96.907	0.25	4.896	106.217	0.393
G	50.394	0.418	31.176	2.279	106.77	0.345	5.121	102.8	0.475
H	52.519	0.318	34.572	2.651	107.266	0.254	5.388	102.689	0.383

H	51.551	0.313	35.216	2.485	102.176	0.09	4.855	104.347	0.361
H	52.352	0.362	39.588	2.622	106.348	0.296	5.356	103.313	0.366
H	52.683	0.33	39.967	2.376	101.326	0.251	4.82	104.425	0.286
H	53.743	0.415	36.528	2.908	99.919	0.332	5.246	100.875	0.418
H	53.271	0.224	44.491	3.235	108.674	0.285	6.386	96.286	0.236
P	53.885	0.339	29.972	1.704	111.814	0.565	6.359	95.581	0.524
P	55.424	0.15	45.833	2.929	106.085	0.598	5.776	91.532	0.549
P	55.682	0.283	39.397	2.965	100.065	0.308	5.823	103.89	0.792
P	56.657	0.326	43.668	3.091	103.771	0.411	5.77	90.5	0.501

Horse	Hoof Angle	Hoof Deviation	Heel Angle	Heel Height	Outer Wall Angle	Outer Wall Deviation	Outer Wall Length	Inner Wall Angle	Inner Wall Deviation
I (Shod)	53.85	0.08	42.901	2.255	118.462	0.438	6.662	95.834	0.349
I (Shod)	52.531	0.344	32.714	2.085	114.577	0.206	5.486	102.833	0.229
I (Shod)	51.087	0.571	29.785	1.492	108.486	0.286	4.516	113.012	0.488
I (Shod)	49.417	0.357	30.239	1.794	113.962	0.233	5.444	109.855	0.423
K (Shod)	56.125	0.555	40.941	2.759	107.557	0.395	6.818	101.162	0.447
K (Shod)	54.407	0.568	32.078	2.216	100.293	0.192	6.145	105.963	0.662
K (Shod)	48.684	0.413	25.266	1.665	111.3	0.721	5.063	114.243	0.629
K (Shod)	49.108	0.281	24.894	1.929	113.946	0.457	5.821	110.366	0.245
L (Shod)	50.28	0.23	28.944	2.28	116.85	0.545	6.673	94.829	0.033
L (Shod)	50.456	0.261	33.244	2.395	115.472	0.162	6.18	95.874	0.37
L (Shod)	50.387	0.147	31.035	1.928	118.06	0.394	5.921	94.789	0.149
L (Shod)	49.744	0.228	34.98	2.035	113.104	0.178	5.894	102.313	0.051
M (Shod)	50.186	0.804	33.024	2.608	111.999	0.462	5.971	106.828	0.687
M (Shod)	52.22	0.444	31.646	2.516	110.734	0.352	5.793	108.227	0.642
M (Shod)	53.848	0.476	32.398	2.715	115.693	0.631	6.755	99.329	0.519
M (Shod)	47.749	0.359	30.887	1.812	113.973	0.165	6.263	112.561	0.786
M (Shod)	48.704	0.186	34.958	1.6	112.896	0.299	5.737	113.246	0.976
M (Shod)	50.5	0.423	34.554	2.043	112.885	0.331	6.261	109.54	0.72
O (Shod)	51.929	0.236	39.575	2.522	105.573	0.334	5.396	112.08	0.73
O (Shod)	54.68	0.591	39.459	2.965	102.001	0.354	6.259	106.576	0.613
O (Shod)	52.999	0.331	43.816	2.798	109.44	0.222	5.707	100.115	0.411
O (Shod)	48.95	0.104	37.327	2.06	114.29	0.636	6.532	105.316	0.34
O (Shod)	48.321	0.41	23.756	2.103	115.287	0.677	6.049	108.064	0.246
O (Shod)	49.461	0.245	40.464	2.228	116.281	0.496	5.893	100.552	0.238

Progress Diary:

Date	Time	Comments
Sep-20	1 hour	Discussed MIP & Research Proposal
	1 hour	Order and received Metron Hoof measuring hardware.
	2 hours	Determined the trimming and shoeing protocols to be used throughout this study. Written them up and will be placed within the appendix.
	2 hours	2-hour laptop session with Metron to install Metron software and demonstrate usage.
Oct-20	3 hours	Discussed possibility of study within Newmarket environment
	1.5 hours	Watched a webinar by Metron Hoof on standardised measuring with radiographs and photographs. Very helpful when it comes to methodology.
		A new three-tier system of Covid-19 restrictions starts in England
	0.5 hours	Permission from Horse owners/trainer granted
	3 hours	Began to write up the methodology
		PM announces a second lockdown in England to prevent a "medical and moral disaster" for the NHS - Brilliant, this is a concern for business.
Nov-20	2 hours	Discussion around Ethical considerations with work colleagues
	4 hours	Data collections begin
	4 hours	Data collection is slow and time consuming. Weather is a challenge with working outdoors. Picture quality is poor if images are taken with stable. Horses must be outside for better image quality. Weather is a pain.
		Second national lockdown comes into force in England - This is now a real issue for collecting data. Farriers can continue to work however unnecessary travel should be stopped.
		Corona Virus lockdown is becoming a challenge with moving between yards. Must use horses in one yard. This will massively impact overall population size.
Dec-20	1 hour	Completed ethical consideration from and submitted to cat
		Second lockdown ends after four weeks and England returns to a stricter three-tier system of restrictions
	4 hours	More Data collection - this is never ending.
Jan-21		Tough weather conditions, it's snowing! Horses to remain in stables and not leave. No data collection.
	4 hours	Timepoint 3 data collection begins.
		England enters third national lockdown
Feb-21	3 hours	All data is now collected.
	4 hours	Begin to compare images of feet both shod and barefoot. The changes in overall hoof shape, size and orientation is clearly visible, this is very assuring.
	2 hours	Morph video technology within Metron software used to compare samples and shows the predicted results wonderfully.
Mar-21	9 hours	Begin to calibrate and mark up all images in Metron - Very time-consuming process (will take me weeks!!!)
		PM expected to publish roadmap for lifting the lockdown
		Planned return to school for primary and secondary school students in England

	3 hours	Finally, Myerscough reopens and we can return. - Discussion with Cat & Jon around statistics and analysing the data. Good feedback from Jon and Cat so hopefully study is on track.
	5 hours	Export data as CSV file to Microsoft excel and organise the appropriate data needed for study. Metron records a lot more parameters than needed.
Apr-21	3 hours	Discover Minitab after technical issues at Myerscough College.
	2 hours	Transfer database from excel to Minitab for statistical analysis. Very good p values for the data shown.
	5 hours	Data is parametric. Testing shows significant results for barefoot horses. Needed more horses shod though.
	5 hours	Write up of results into study. Had to remember to not discuss the results save it for the discussion.
	4 hours	Begin to create visual illustrations to help capture the results. Simple drawings help to illustrate what happens to both heel and hoof angle, also can be used in Poster.
May-21	10 Hours	Continue to write up dissertation. There is plenty of discussion topics as there is considerable number of things changes in the hoof. I must discuss each topic and avoid weighting the discussion on just obvious parameters.
	1 hour	Submit draft dissertation to Cat, Jon and Steve for feedback
	3 hours	Received feedback from cat and jon. Everything looks ok, mainly grammar, referencing and layout changes.
	5 hours	Final amendments to dissertation before final hand in
	2 hours	Poster creation
	1 hour	Submit everything! DONE