A COMPARATIVE STUDY OF THE LOAD DISTRIBUTION OF THE BEARING SURFACE OF THE EQUINE FRONT FOOT BETWEEN AN OPEN HEELED SHOE WITH CAUDAL SOLE PACK AND A HEART BAR SHOE ALONE

Paul Young Dip HE

A dissertation submitted to the

University of Central Lancashire Faculty of Nursing

Bachelor of Science with Honours

In

Farriery Science

April 2018

University of Central Lancashire

Acknowledgements.

My grateful thanks to all the tutors and fellow students who taught me how to think!

Jon Mather whose enthusiasm and commitment to the advancement of education amongst the farriery community is inspiring.

Dr Lorraine Allan, who guided me through all the processes of academia.

My longsuffering children who constantly fought to keep my computer alive through my clumsiness.

Abstract.

Introduction.

This study is primarily concerned with the progression and enhancement of techniques that have been used for many years in farriery. The advent of glues and pour in hoof packing has opened the possibility of new ways of addressing pathologies that exceed the expectations of the treatments that have for many years been the mainstay of the working farrier and veterinary surgeon. It is the palmer half of the foot this study is concerned with, a pour in hoof pack mimics the properties of the frog and digital cushion. It can potentially enhance functionality and therefore the healing process with increased surface area and with a firm but pliable support the horses can feel comfortable on. The heart bar shoe is entrenched in the armoury of the farriery community and for many years done sterling work. It is site specific and is an immovable metal plate with the potential to produce pain and infection if incorrectly applied.

Aims and Objectives.

The aim is to take forward traditional protocols using scientific research to produce convincing results that new materials and techniques can supersede traditional ways. The objective of this study was to investigate whether a caudal sole pack could be more beneficial to functionality and recovery than a heart bar shoe.

Hypothesis.

The hypothesis of this study was that a caudal hoof pack in an open heeled shoe is more beneficial than the use of a heart bar shoe alone.

Method and Materials.

One horse was used and on one foot as a control was put on a standard horse shoe, on the other foot were put the various interventions incorporated into the same type of standard horse shoe. Readings from the pressure mat the horse stood on were taken and analysed on a laptop computer.

Conclusion.

The set of data produced from the pressure mat in this study provided sufficient evidence to indicate that the use of a heart bar shoe was questionable. Data suggested the horse was more comfortable with the insertion of a caudal hoof pack. It also showed a reluctance to weight bear on the heart bar shoe, this could possibly lead to it being less ambulatory and therefore have less functionality of the hoof. The use of a caudal hoof pack is also a quick and easy way to provide emergency first aid with the added benefit of increased comfort and support.

Significance.

With all the benefits mentioned above it is also a speedy procedure that can be administered at a moment's notice without the inconvenience of having to go and make or order in the heart bar shoes thus delaying vital help to an animal. It is going back to enhancing and mimicking the natural substances of the hoof and working with its form and function.

Contents.

Chapter 1: Introduction

1.1: Rationale

Horses have been shod with various materials since early times, one of the oldest being in Asia 430 BC (Hickman 1988). This was to prevent excessive wear of the hoof as domestication had overtaken the feral equidae, as a result, non sympathetic hoof trimming due to lack of knowledge proliferated. The horse can absorb and tolerate a certain amount of influential imbalance (van Heel et al 2005) but too much can lead to sometimes catastrophic collapse of the equine distal limb in various forms. As a result of pathologies incurred from the activities of work or even war, on behalf of their human masters' various shoes have been applied to keep horses sound and in work. Richardson (1890) and Lungwitz (1891) in their books advocated bar shoes to help alleviate these problems.

Fig 1.1 Image of old bar shoes. (www.johnwinter.net)

These shoes have done sterling work for a considerable time, but as a result of the advent of deformable hoof packing a new dimension presented itself. This firm but deformable urethane substance can have the ability to support, as well as bar shoes have, but has the ability to provide added functionality which can greatly assist in the healing process (Vettec hoof care 2012). O'Grady (2008) advocated the employment of as much of the solar surface of the foot as possible which utilised as many internal structures as possible when it comes to its use in laminitis. To this end the researcher has been using sole packing in place of bar shoes with success and concluded that this needed to be researched within scientific protocols. The nature of the hoof packing mimics the consistency of the frog, therefore by its very nature has the

potential to enhance the action of the frog. This, when applied to a hoof that has an atrophied frog or one that by the conformation of the hoof has little or no contact with the ground has distinct advantages. One advantage hoof packing has when applied to an atrophied frog is that there is no one pressure area as in a metal heart bar which lies directly upon the frog. The hoof packing lies in the complete caudal half of the foot and is in contact with the sole, bars and frog It is pliable and provides a greater surface area thus reducing pressure placed upon structures and brings into biomechanical function structures previously non active in this area. Support is supplied over a greater area with a substance similar to naturally occurring ones. With this rationale in mind this study endeavoured to provide some much needed data with which an answer could be extrapolated.

1.2: Introduction

The horse's hoof is the horny insensitive structure at the distal end of each limb. The visible structures are the horny wall and on the solar surface the sole, bars and frog. Within lay various soft tissues around the third phalanx (P3) and palmer proximal, above the horny frog, lays the fibro cartilaginous digital cushion (Fig 1.2). The frog is 50% water and a soft flexible structure whist the digital cushion is fibro elastic (Sellnow 2001).

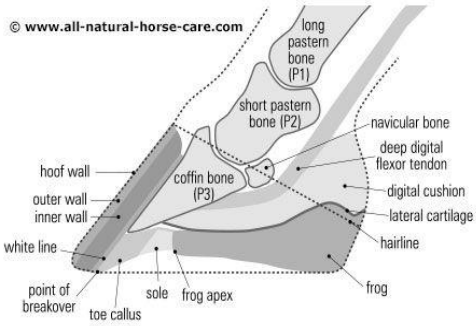

Fig 1.2. Sagittal Section of Hoof (www.equipodiatry.com)

It is the palmer half of the hoof that this study is primarily concerned with, Johnson and Back (2006) stated that hoof balance and conformation is directly related to distal limb loading and is essential to maintaining good health of the limb. Williams and Deacon (1999) defined good

balance as when both heels strike the ground together and thus disperse and attenuate the forces generated by the foot striking the ground. This system relies heavily on the frog and the digital cushion to absorb and dissipate the forces generated by the ground reaction force (GRF) and the reciprocal descent of the horse's body mass (Colles 1989). One of the main function of the hoof capsule is to absorb shock and assist in the transfer of weight from the bony column (Butler 2005). When all the structures are working together in harmony the anatomy of the horse is working at its optimum state, this is called the 'mechanism' with external shock dissipated by 90% before it reaches the first phalanx (P1) (Douglas et al 1998). The sole and frog have a high degree of elasticity due to their high sulfhydryl content which allows them to have a high degree of elasticity (Pollitt 1988). The digital cushion and the lateral cartilages that lay alongside the palmer part of P3 play an important role in the circulation of blood, this is crucial to maintaining healthy structures through osmosis of the nutrients that the blood carries to the various structures. The digital cushion and lateral cartilages compress the venous plexus that lay alongside these structures during the stance phase and release pressure and allow blood flow during the swing phase. The absorption and dissipation of shock on impact is synchronous with the action of the structures involved in blood flow (Bowker 2001).

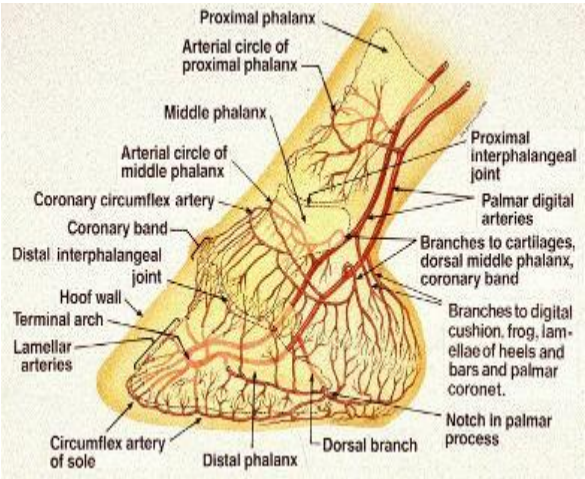

Fig 1.3 Image of blood flow in the hoof. (www.balancedhoofservices.com)

The researcher for many years has used a pour in sole pack to assist in full solar support and shock absorption. The use of a caudal sole pack for support instead of a bar shoe seemed a logical progression. A pour in hoof pack mimics the elastic properties of the frog and digital cushion and potentially enhances function. In a compromised foot, the increase in natural

function and therefore increased blood flow potentially facilitate the depositions of nutrients to the tissue (Colles and Ware 2010) and enhances a speedier recovery which can only be a good result. It also increases the surface area, which reduces kg/cm² (www.plymouth.ac.uk 2005) pressure on the solar surface of the foot, facilitating the comfort of the horse and reducing the potential of further damage to a compromised structure. With the packing flooding all the caudal cavities it increases the volume of the solar surface of the foot with the ability to enhance functionality a distinct possibility. The use of the heart bar shoe is entrenched in the shoeing fraternity. Although it works well a caudal sole pack has the potential to do a better job through comfort, increased support and surface area with enhanced healing capabilities.

The heart bar shoe is site specific. It is a fixed metal plate that lays on the frog with either positive pressure, where it lays gently on the frog for constant support in cases of extensive disengagement of the laminae to P3, or negative pressure where there is a small gap between it and the frog and it only acts in the stance phase when the descending bodyweight comes into contact and is used to primarily support the descending bony column in the case of laminitis or collapsed heels (Stashak 2011). It has not the capability to enhance any type of function as it is only an immoveable metal plate. (Fig 1.4.)

Fig 1.4. Traditional heart bar shoe in place (www.fullerequinevet.com)

Chapter 2: Literature Review

2.1. Introduction

The literature review was conducted through an extensive search through Wiley Open Access and Science Direct sourcing journals such as the Equine Veterinary Journal, American Association of Equine Practitioners, The Veterinary Journal, American Farriers Journal and the college library. Key words included, pour in hoof packing, solar support, laminitis treatment, bar shoe applications. Once all the relevant papers have been sourced and read, common themes between them were noted and discrepancies highlighted. This gave an insight into designing this study's own research methods and protocols that could, or even should not be followed when doing further studies into the related subject. As a farrier of some years standing the researcher gained a deeper insight into the type of product and application techniques used which was of great benefit producing and understanding the results.

2.2. Literature Review.

van Heel (2004) stated farriery has mainly progressed by observation not scientific evidence. Apprentices' recommended text books, advocate bar shoes for pathologies such as, laminitis, sheared heels and quarter cracks. (Milner and Hughes 2011, Ryan 2015). This intervention works well, but beyond being told it stabilises the hoof and increases surface area by the addition of a bar which increases the amount of steel in contact with the ground area no explanation or research data is forthcoming (Hickman 1988, Curtis 1999, Williams and Deacon 2002, Colles and Ware 2010.) Pressures generated by the GRF and the descending body weight with the distribution of forces occurring on various structures of the foot are not explained. Therefore, an understanding of unloading or overloading of the various structures that are affected cannot be fully comprehended, resulting in interventions that could be disadvantageous. Huppler et al (2016) stated that research on the effects of forces affecting the hoof capsule after application of orthopaedic shoes are in short supply, which supports the need

for this pilot study. The researcher in compiling the literature review became aware of the shortage of material that was available in this area of pour in hoof packing.

Huppler et al (2016) further commented that on deformable surfaces bar shoes produced a more positive palmer angle of P3 with pressure peaks observable at the heels. An explanation of why this occurs would have given a valuable insight into the physics of force and motion and enable the formulation of a more well informed plan of action. If more research had been done to ascertain why, then information such as this would allow the farrier or veterinary surgeon to formulate a more suitable shoeing plan. The choice of a suitable shoe type or application of hoof packing would have a much more specific and valid rationale. In their study title are the words 'effects of Eggbar, Heartbar'. This indicates that the research should have gone further and studied the effects of higher forces found on the structures within the hoof. Previously any data such as this was not available, and information is still sparse. Hagen et al (2016) observed on a firm surface a unilateral wide branch shoe produced distinct pressure peaks but were reduced on deformable surfaces. The data and research protocol were good but why deformable surfaces produced even loading and reduced pressure peaks was not explained, this is an important element. Deformable surfaces support the solar surface when shod, aiding the pressure distribution, which is an important factor that could influence farriers' decisions. Although they were not researching bar shoes the principle is similar. Huppler et al (2016) tested a barefoot horse and when shod with standard horseshoes on deformable surfaces, distribution of pressure proved to be distributed evenly with the support of the compacted surface material on the solar surface of the hoof. To the researcher's knowledge nothing has been investigated regarding the effect of mud and dirt that accumulates in the sole of the horse's foot. This is a naturally occurring phenomenon that seems to lend support and functionality and is an inextricable process in the natural function of the hoof. This could and indeed should have at least been mentioned and compared to a pour in hoof pack. Colles (1989) suggested frog pressure was the primary force that expanded the heels but Dyhre-Poulson et al (1994) suggested that the caudal and distal movement of P1 and P2 principally expanded the heels. In their investigations Roepstorff et al. (2001) found both these theories were valid and inseparable. The researcher feels in several cases caudal sole packing could be the treatment of choice as it fulfils the criteria of frog support due to contact with the ground through the medium of the pour in sole packing and the depression theories, by the descent of the phalanges

with the reciprocal resistant force again being provided through the caudal sole pack and is the nearest one could get to barefoot function whilst shod.

Johnston and Back (2006) stated steel shoes increase the magnitude of impact but the use of compliant materials diminishes that force. In a study by Hood et al (2001) a cohort of unshod horses showed loading was principally on the solar aspect of the foot. Thus, a shod foot with a sole pack could potentially restore lost function. The study of the effects of foam sole supports in Schleining et al's (2011) study showed pressure peaks reduced when the sole packing was introduced to the area of the solar surface of the hoof. It was suggested it could be an effective treatment for laminitis, but more could have been said about the use with or without bar shoes. van Heel and Back (2006) in their study of poly-urethane filled hooves, filled the hoof to within 2-3 millimetres of the ground surface. A pressure plate showed no difference between that and a non filled shod hoof. Tested again over the same pressure plate covered in 2.5 to 3 cm of sand a marked difference was noted. Their hypothesis that the use of hoof packing increased the surface area is lacking in certain areas as their packing was 2-3 millimetres off the solid floor, therefore ground reaction force on the solar surface would not be initiated therefore casting doubt upon the accuracy of the findings of the study. Hood et al (2001) observed that on deformable surfaces a normally shod foot with no packing had a similar reaction to barefoot, where the sole and frog had loaded and assumed a substantial amount of pressure. Their use of Vettec, Equibuild ® is questionable, this product sets to a very hard finish, a medium or soft packing is more likely to mimic the natural functions of the frog. This hardness is the choice of most hoof care practitioners, this discrepancy could lead to inconsistent findings.

Chapter 3: Methodology

3.1 Introduction

Methodology is a systematic and standardised regime that investigates problems or conditions that require an answer. Research breaks down into two paradigms, qualitive and quantitive. Qualative data is not in the form of numbers rather results from a questionnaire for example where participants opinions are recorded. Quantitive data is based on numbers and testing theories (Thomas 2009). Data from this research was collated from pressure mat readings and was translated by the computer into numbers, thus quantative research was chosen for the study as statistical analysis of data was required to extrapolate the findings. This method validates large numerical data sets by accurately collecting data from the pressure mat and displaying the results. There was not a control group and only one horse was used as the data was measuring an intervention to uphold or refute a hypothesis

3.2 Aims and Objectives

The researcher's aim was to take forward traditional protocols by producing data gathered by scientific methods. This method would not just be empirical opinion, but a scientific proven method substantiated by hard data. Proof that other methods have the capability to give better results would be taken seriously by farriers and veterinary surgeons. This aid to the recovery of the horse is a quick and easy protocol to apply. Its ease of application would bring it within the remit of the veterinary surgeon on a routine visit as a first aid application. The benefits to the horse would primarily be comfort through cushioning and support with increased area of ground to solar surface contact and interaction. The owner could visibly see a soft packing supporting the foot which hopefully would give greater peace of mind. The speed and ease of application would favour not only the horse but the practitioner.

3.3 Hypothesis/Research Questions

Hypothesis

A hypothesis is an idea the researcher has which requires scientific validation (Bell 2010). It is generated by using available knowledge and asks a question or questions using a research study that can be repeated and tested by others (Gray 2010).

The hypothesis for this research study was that a caudal hoof pack in an open heeled shoe is more beneficial than the use of a heart bar shoe alone.

3.4 Materials and Methods

The horse which was used was provided by the stables of a college in the North West of England that they considered representative of their population of horses. It was a 15hh 21 year old ex Argentinean polo pony weighing 447 kilograms. It was being used for various activities such as, equitation lessons for students, some hacking out and low grade jumping. By using a single animal, it was its own control, it reduced chances of accidents and ethically minimised the use of animals. An assessment of the horse was done by both the researcher and the operator of the pressure plate, both being experienced farriers, to confirm soundness using the lameness grading advocated by cal.vet.uedu.edu/lamenessgrading (Appendix 1), thereby ensuring even loading on the pressure plate. The horse would have been excluded from the study and replaced if any pathologies were evident, such as gross lesions or limb deformities. One foot was used throughout the study to minimise interventions and shorten the procedure.

After being walked for a few minutes, to eliminate any residual stiffness from being stabled overnight, the trim protocol based on the foot mapping protocol as described by Caldwell et al (2010) was used.

Fig. 3.1. Example of the foot mapping protocol on the hoof used in the study

This involved exfoliation on the sole being removed and the white line exposed, the junction of the sole and the horny wall were also cleaned down to live healthy tissue. The bars and frog were trimmed of loose, damaged tissue, with the true point of the frog determined by exposing where the sole ran into the frog. The medial and lateral seat of corn was cleaned down to live sole, determined by its waxy appearance. The excess hoof wall was cut down to the level of the sole at the toe and continued back, level to the widest part of the frog. The bearing border was maintained level with the medio/lateral plane of the sole. The hoof wall was shaped to correspond to the flow of the white line on the sole's peripheral edge, with a constant and relative thickness and any flares removed. After the trim, the horse was stood on the pressure mat by an experienced handler who was wearing appropriate PPE, to allow data to be collected to give a barefoot baseline reading. Then a Werkman Warrior special side clipped open heeled shoe was nailed onto both front feet using four nails by the researcher, an experienced qualified farrier.

Fig.3.2 An example of the Werkman Warrior special shoe used with Play-Doh and caudal packing in situ. www.theshoeinglab.com

Two nails were used in each side of the toe and one in each quarter, the same shoe on the right foot was modified into a heart bar shoe by the researcher and the same nail holes were used. This protocol allowed for standardisation and consistency. The horse was again stood on the pressure plate to allow readings to be taken. The pressure mat used in this study was a Tekscan pressure mat running research foot 6.33 software. The mat has 2000 sensels arranged in rows and columns. The output of each sensel is divided into 256 increments and displayed as a value, raw sum, in the range of 0-255 by the software. The mat can be calibrated so the raw digital output of the sensel can be converted into actual units of pressure i.e. kg/cm². Data from the readings were collected and entered on Minitab®. The same procedure was followed using a heart bar shoe (Fig 1.3), this shoe was the same open heeled shoe with a heart bar welded in, Jon Atkinson heart bar inserts were used (Fig.3.3)

Fig 3.3 Example of a Jon Atkinson heart bar welded in. www.handmadeshoesltd.co.uk.

The frog plate acts as a support for tissues and bony structures within the hoof capsule by supporting the descending frog (Colles 2010). The exact same procedure was followed again with both the open heeled shoe and heart bar shoe but this time with pour in caudal hoof packing and data collected in the same manner as before. Hoof packing was applied in the caudal part of the foot, the cranial portion blocked out by the application of Play-Doh which filled the void and removed after the pack had set. The surface was covered by a foam board to ensure a smooth finish with no spillage (Fig.3.4).

Fig.3.4 Foam board used in study in situ

The hoof packing used was BONDtech Equine Hoof Pad Medium (www.bondtech.uk.com). This product was inserted up to the widest point of the foot, determined by a permanent marker drawn across the sole and the web of the shoe, so consistency was achieved by allowing the Play-Doh to be applied to the same place each time. Packing was applied to the level of the ground surface then loaded by the horse's body weight to ensure no excess pressure was permanently applied to the foot. One data set of 30 second duration from each variation was considered enough. The horse was standing still each time which lead to less discrepancies and variations compared to achieving a foot strike from a trotting horse. The data collected was imputed into Minitab® (www.minitb.com) which is a statistical programme designed for statistical analysis. A mean was obtained from all the sets of data relating to each shoe variation. This gave an average data figure from which observations were extrapolated. Data was

considered valid when the horse stood squarely on the pressure plate and looked quietly ahead, any data sets that showed the horse had been moving or swaying were discarded.

3.5 Reliability and Validity

Research must be able to be reproduced by others to gain credibility and reliability using the same methods, this will produce consistency and validity (Cohen et al 2000). In this study only, a small amount of materials was used. One pair of shoes and the same nail holes were used throughout, with the researcher being familiar with the process from years of application at work. The use of a single horse and consistency of commercial products used also contributed to the reduction of variables. Validity was also upheld by using electronic equipment, pressure mat and laptop computer, these reduced human errors and only collect data and showed what the subject horse was producing. The same experienced operator was involved in the collection of data.

Standardisation not only reduced variables but also allowed future researchers to easily repeat the procedures. The use of widely available commercial products standardised all materials in this study and future research. The foot trim was standardised to a published foot mapping protocol (Caldwell et al 2010). Human error was an issue that was minimised by another experienced farrier checking and rechecking all farriery procedures to ensure consistency was adhered to. A horse handler, wearing PPE, who was familiar and comfortable with the horse, was used. The horse standing still, relaxed and looking straight ahead helped consistency. Mat readings were taken at each intervention with an average taken, this again reduced variables.

3.6 Data collection and analysis

Pressure mat readings were collected onto a laptop computer and stored for later analysis and tabulated in Excel. Data was put through Minitab® data analysis software and descriptive

statistics produced. An ANOVA and a paired t-test were test was performed to see if the sets of data were significantly different to each other and histograms, graphs and tables produced.

3.7 Ethical considerations

The research was approved by the Myerscough College Ethics Committee with the welfare of the horse paramount. All data was stored on a password locked computer with anonymity and confidentiality as standard. A letter of consent was obtained from Myerscough Equine department with their full knowledge of all procedures that were involved (Appendix 2). Withdrawal of the horse could be instigated at any time by the designated carer of the horse and authorised by the college to do so. Data held on the laptop was deleted after the study to protect all participants. The researcher/farrier was bound and followed the code of practice laid down by the Worshipful Company of Farriers. (WWW.farrier-reg.gov). All participants were briefed on safety procedures and PPE were worn. A clean safe environment was established for horse and humans where all hazardous equipment was removed or made safe. A trained handler that the horse knew and trusted was used. Thus, the handler could report that in their opinion the horse was getting fractious and was also able to keep him happy and calm during all procedures. The procedures only consisted of standing on a rubber mat several times and was not in any way traumatic or strenuous.

Chapter 4: Results.

ANOVA

Table 4.1 Peak Force Total

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	21956.258	5	4391.252	1408.387	0.001
Within Groups	16818.108	5394	3.118		
Total	38774.366	5399			

There was a significant difference in total peak force between groups across both forelimbs combined (f=1408, df=5, P<0.001)

ANOVA

Table 4.2

	Sum of Squares	df	Mean Squares	F	Sig
Peak Force. Left Foot					
Between Groups.	19200.520	5	3840.104	2865.041	0.001
Within Groups.	7229.746	5394	1.340		
Total.	26430.265	5399			

Peak Force. Right Foot					
Between Groups.	2429.536	5	485.907	255.916	0.001
Within Groups.	10241.584	5394	1.899		
Total	12671.120	5399			

There was a significant difference in Total Peak Force between groups of Left and Right Foot

Between Groups Left Foot (f=2865.041, df=5, p<0.001)

Between Groups Right Foot (f=255.916, df=5, p<0.001)

ANOVA

Table 4.3 **Contact** Pressure

	Sum of Squares	df	Mean Square	F	Sig
Left Foot					
Between Groups	77.239	5	15.448	7202.896	0.001
Within Groups	11.568	5394	0.002		
Total	88.807	5399			

Right Foot					
Between Groups	50.840	5	10.168	3236.734	0.001
Within Groups	16.945	5394	.003		
Total	67.786	5399			

There was a significant difference in Contact Pressure across both forelimbs

Between Groups Left Foot (f=7202.896, df=5, p<0.001)

Between Groups Right Foot (f=3236.734, df=5, p<0.001)

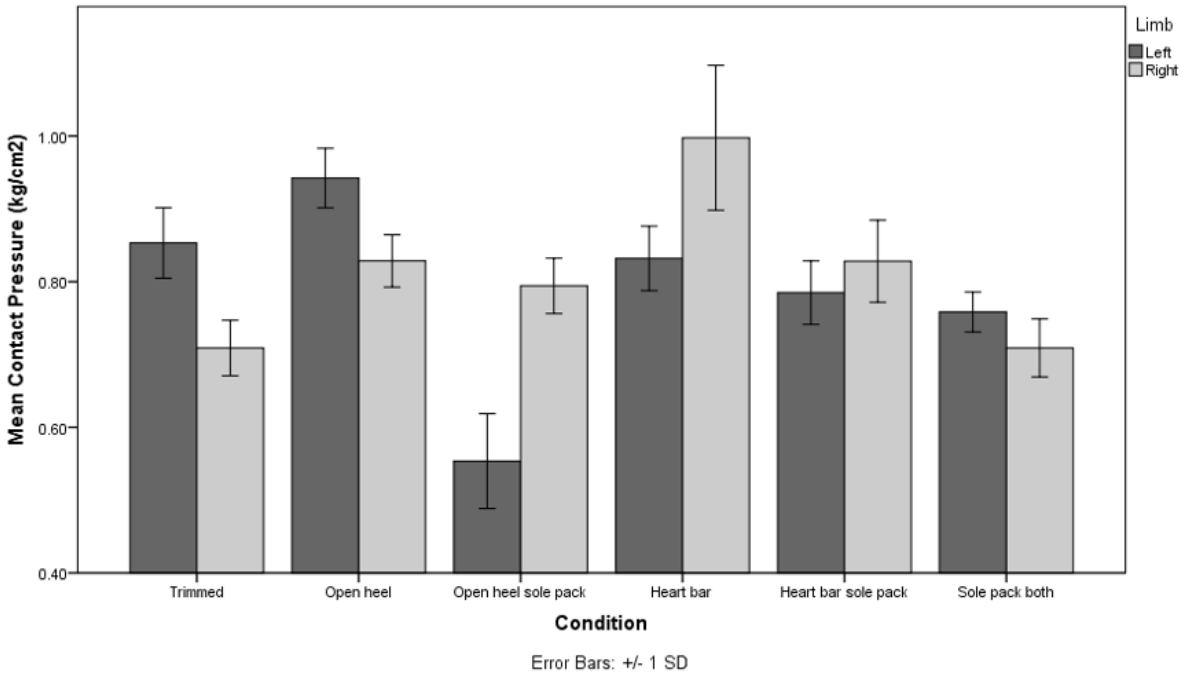

Fig 4.4. Heart bar condition shows maximum contact pressure despite increase in peak force in left foot

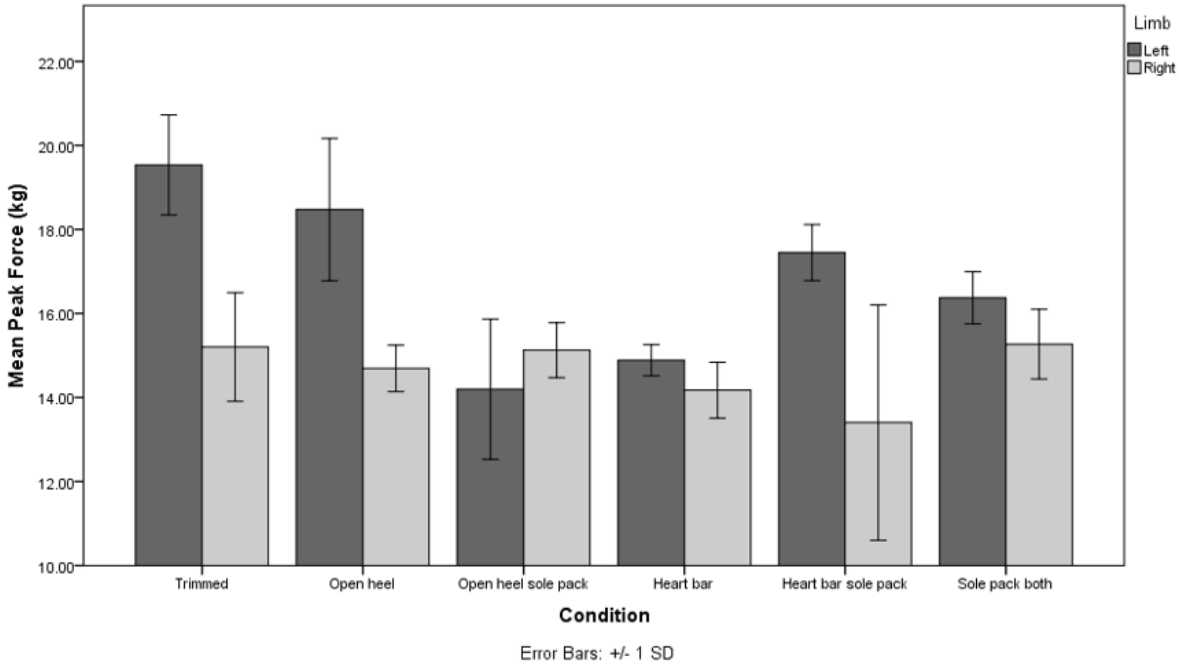

Fig 4.5 Note the fluctuations in the error bar data in right foot Heart bar with sole pack

Table 4.6 **PAIRED T-TEST**

Trimmed

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	19.5347	900	1.19093	.03970
	Peak_Force_R	15.2051	900	1.29305	.04310
Pair 2	Contact_Pressure_L	.8532	900	.04847	.00162
	Contact_Pressure_R	.7088	900	.03799	.00127

Table 4.7

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	-.400	.000
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	.343	.000

Table 4.8

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	4.32967	2.07885	.06930	4.19367	4.46567	62.482	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	.14436	.05028	.00168	.14107	.14765	86.133	899	.000

This shows a significantly higher peak force through the left fore (19.53 kg/cm²) than through the right (15.21kg/cm²) (t=62.48, df=899, P<0.001). Along with a significantly higher contact pressure of 0.8532 kg on the left compared to 0.7088 kg (t=86.133, df=899, P<0.001)

Table 4.9

Open heel

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	18.4737	900	1.69511	.05650
	Peak_Force_R	14.6919	900	.55100	.01837
Pair 2	Contact_Pressure_L	.9422	900	.04077	.00136
	Contact_Pressure_R	.8285	900	.03593	.00120

Table 4.10

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	.208	.000
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	.123	.000

Table 4.11

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	3.78177	1.66967	.05566	3.67254	3.89100	67.949	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	.11366	.05091	.00170	.11033	.11699	66.985	899	.000

When both front feet were shod with open heeled shoes the preference for weight bearing on the left fore persisted with a significantly higher Peak Force t=67.949, df=899, P<0.001) and a significantly higher Contact Pressure (t=66.985, df=899, P<0.001 seen on the left forelimb

Table 4.12

Open heel with sole pack

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	14.1942	900	1.66844	.05561
	Peak_Force_R	15.1275	900	.65406	.02180
Pair 2	Contact_Pressure_L	.5535	900	.06512	.00217
	Contact_Pressure_R	.7943	900	.03809	.00127

Table 4.13

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	.621	.000
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	.240	.000

Table 4.14

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	-.93333	1.36223	.04541	-1.02245	-.84422	-20.555	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	-.24075	.06708	.00224	-.24514	-.23636	-107.669	899	.000

When the sole pack was applied to the right fore the horse's limb preference reversed with a significantly higher Peak Force now being seen on the right limb (t=-20.56, df=899, P<0.001) coupled with a significantly higher Contact Pressure (t=-107.699, df=899, P<0.001)

Table 4.15

Heart bar

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	14.8864	900	.37141	.01238
	Peak_Force_R	14.1744	900	.66601	.02220
Pair 2	Contact_Pressure_L	.8319	900	.04426	.00148
	Contact_Pressure_R	.9975	900	.09951	.00332

Table 4.16

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	.113	.001
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	-.121	.000

Table 4.17

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	.71198	.72514	.02417	.66454	.75942	29.455	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	-.16557	.11369	.00379	-.17301	-.15813	-43.691	899	.000

A significantly greater Peak Force can be seen in the left fore than the right (t=29.46, df=899, P<0.001). The Contact Pressure is greater in the right fore (t=43.69, df=899, P<0.001)

Table 4.18

Heart bar with sole pack

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	17.4500	900	.66594	.02220
	Peak_Force_R	13.4036	900	2.80302	.09343
Pair 2	Contact_Pressure_L	.7849	900	.04362	.00145
	Contact_Pressure_R	.8280	900	.05636	.00188

Table 4.19

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	-.337	.000
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	-.012	.710

Table 4.20

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	4.04634	3.09176	.10306	3.84408	4.24861	39.263	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	-.04308	.07170	.00239	-.04777	-.03838	-18.023	899	.000

This condition shows a significant swing back to the left limb weight bearing preference. Peak Force on the left fore recorded at 17.45 kg/cm² and right fore at 13.40 kg/cm² (t=39.26, df=899, P<0.001)

Contact Pressure was still significantly higher on the right fore (t=-18.023, df=899, P<0.001)

Table 4.21

Open heel with sole pack on both

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Peak_Force_L	16.3743	900	.62062	.02069
	Peak_Force_R	15.2682	900	.82964	.02765
Pair 2	Contact_Pressure_L	.7583	900	.02745	.00091
	Contact_Pressure_R	.7090	900	.03980	.00133

Table 4.2

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Peak_Force_L & Peak_Force_R	900	-.036	.276
Pair 2	Contact_Pressure_L & Contact_Pressure_R	900	.477	.000

Table 4.3

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Peak_Force_L - Peak_Force_R	1.10609	1.05400	.03513	1.03714	1.17504	31.482	899	.000
Pair 2	Contact_Pressure_L - Contact_Pressure_R	.04931	.03600	.00120	.04695	.05166	41.088	899	.000

This condition shows a return to the original weight bearing preference seen in the Trimmed condition, with an increase of Peak Force in the left limb (t=31.48, df=899, P<0.001) Contact Pressure also shows an increase (t=41.09, df=899, P<0.001) in the left limb

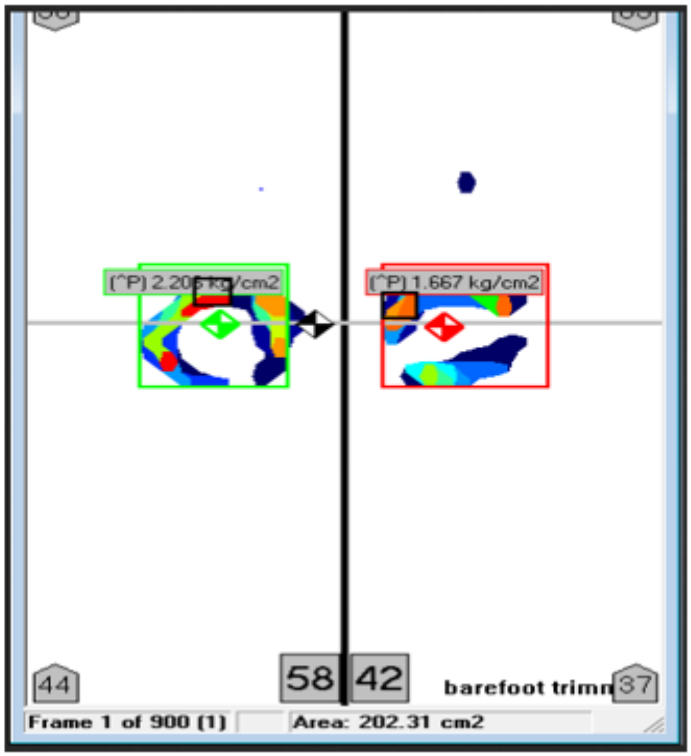

Fig 4.1. Image of Frame 1 of the pressure mat video. 900 frames over 30 second period.

Table 4.4

Table of mean data produced from pressure mat video

					Averaged Contact Frame 1-900							
Condition	Force (Kg)		Contact Area (Cm²)		Contact Pressure (kg		Peak Force (Kg)		Peak Con Press (Kg c		% force	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
As Presen	81	88	75.14	72.25	1.08	1.219	23	19	1.972	2.145	48%	52%
Untrimme	64.4	115.36	95.37	106.93	0.703	1.086	16.23	24.4	1.9	2.11	36%	64%
Trimmed	119	96	124.27	118.49	0.954	0.813	25	20	2.98	1.743	55	45
Shod	71.99	81.5	72.25	92.48	1.014	0.907	24.59	19.52	2.13	1.69	46	54
R sole pck	49	105	74.14	112.71	0.653	0.93	18	20	1.55	1.747	31	69
Hrt bar	72	65	75.14	60.69	0.959	1.075	20	19	1.722	2.162	52	48
H/Br+Sl pk	67	76	66.47	78.03	1.004	0.977	23	15	2.014	1.333	46	54
Sol pckx2	68	64	69.36	75.14	0.976	0.857	22	20	1.893	1.747	50	50
					Movie Averaged Frames 1-900							
Condition	Force (KG)		Contact Area (CM²)		Contact Pressure (KC		Peak Force (KG)		Peak Con Press (KG c		% Force	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
AS Pres	81	83	66.47	54.91	1.214	1.519	23	19	1.972	2.145	48	52
Untrimme	1.9	2.11	83.81	98.26	0.781	1.175	16	24	1.9	2.11	36	64
Trimmed	117	90	109.82	104.04	1.069	0.868	25	20	2.198	1.743	56	44
Shod	72	81	57.8	75.14	1.247	1.078	25	20	2.127	1.688	46	54
Hrt Bar	69	64	66.47	49.13	1.038	1.311	20	19	1.722	2.162	51	49
H/BR+Slpk	66	74	63.58	72.25	1.045	1.021	23	15	2.014	1.333	47	53
Sol Pk x2	67	64	66.47	69.36	1.015	0.919	22	20	1.893	1.747	51	49

Chapter 5: Discussion and Recommendations

5.1 Discussion

This study set out to determine the efficacy of a caudal sole pack against the use of a heart bar shoe. The use of a caudal sole pack was hypothesised to be more beneficial to the horse than the use of a heart bar shoe alone. A heart bar shoe (Fig 1.4) as defined in Hickman's Farriery (1988) transfers some weight from the hoof wall to the frog. He also stated as does O'Grady (2008) that excessive pressure of the bar upon the sensitive structures beneath can lead to damage, possible pain and infection. This statement underpins the whole philosophy of the researcher's choice of research. A pour in sole pack mimics the consistency of the frog and digital cushion and has no specific pressure points as does the heart bar as it lays solely on the frog. It has the effect of potentially increasing the mass and therefore the biomechanics and functionality of the digital cushion and frog by its position and consistency.

The horse that was used was particularly suitable as the right fore had low weak heels with the toe running forward and had a flat sole. The left fore was a more normal conformation with a stronger heel and a more upright structure. Unfortunately, the photographs that were taken did not show adequately the differences so have not been included. Only one foot was used for the different interventions, the right fore, to see if hoof packing or the heart bar shoe were preferable to the horse than the open heeled concave shoes that it presented with. The left fore was shod with the same type of shoe as the right fore upon which the interventions were applied and left on as a control. The pressure mat showed the pressure distribution and peak force with each intervention transferring the data to the laptop. The researcher was looking for increases in loading or unloading, displayed by the pressure readings within the data sets. The right fore displaying a higher pressure reading would indicate more comfortable format for the horse to utilise. This would indicate that the intervention applied was comfortable for the horse to load more weight upon thus potentially creating a more even distribution pattern between the right fore and the left fore. This in itself could avert a potential supporting limb lameness in certain situations.

With the first pressure mat reading the horse was stood on the mat with nothing done to her in the ‘As presented’ mode. The horse had had no intervention and the loading was shown to be more on the right fore. This could be because of the conformation of the foot with its long toe and low weak heels. The difference in pressure was 0.281 Kg/cm² between left and right. The peak force in this intervention was, along with ‘Heart Bar with Sole Pack’ intervention, the only intervention to show a contra-lateral variance with contact pressure. This variance could be explained by the left fore periodically unloading the compromised right fore to give it some relief and possibly help with perfusion. The shoes were removed and this the ‘Barefoot Untrimmed’ procedure produced similar results, but less pressure applied to both feet. This would suggest the horse was uncomfortable loading onto bare feet for two reasons. One it was not used to it and secondly and more importantly the structure of the feet made it uncomfortable to bear weight with the thin flat soles resting on the floor. The difference in pressure left and right, being 0.241 Kg/cm². Although there was little foot growth on the feet to trim off the researcher lowered the heels of the hoof in the ‘Barefoot Trimmed’ intervention of the left fore to increase the surface area therefore reducing Kg/cm² pressure. This also had the effect of bringing the limb forward to some extent matching the right fore’s configuration. This change in stance attitude would load the caudal half of the foot thereby reducing pressure on the dorsal sole. With the two front feet in similar positions whilst standing it was much easier for the horse to load both limbs more evenly. The effect of this was to switch the higher pressure over to the left fore and gave a much lower difference in pressure readings, 0.145 Kg/cm² and a general increase in loading the front feet. This suggests that in the uncomfortable ‘Barefoot Untrimmed’ scenario it loaded its hind feet to unload the front end whereas with the trimmed feet it transferred some load back to the front limbs as it was more comfortable to do so. $P<0.001$ in both contact pressure and peak force. Peak force values left fore 19.53, right fore 15.20.

The feet were then shod with Werkman Warrior Special horse shoes, a wide web shoe, (Fig 3.2) as is the standard practice of the researcher in his farriery business onto a foot mapped hoof (Fig 3.1). The pressure figures were higher suggesting the comfort of shoes with the wide web gave a greater surface area thus reducing Kg/cm². The pressure was markedly more even between the two front feet compared to the small much narrower concave shoes in the ‘As presented’ scenario. This alone is a very significant change as combined with the foot trim the comfort level and even loading of the two front feet is impressive. Pressure differences

left/right of 0.114 Kg/cm² was significantly lower than any previously observed. There still persisted a preference to weight bear on the left with a significantly higher peak force value of left fore 18.47, right fore 14.69 with the P values remaining at P<0.001. The open heel shoes remained on the feet and to the right fore was applied the caudal hoof pack (Fig 3.2). The result of this intervention was that the pressure on the right fore increased significantly, indicating that the hoof pack made it more comfortable to bear weight on this compromised structure. The left fore pressure dropped down to 0.553 Kg/cm² with only the 'Barefoot Untrimmed 'scenario approaching this level. The fact that the horse was more comfortable with the pack was very encouraging. Pressure difference left/right 0.241 Kg/cm² was the same as in the 'Barefoot Untrimmed' scenario. Peak force values of 14.19 and 15.13 were reported for left and right limbs respectively, these values are much closer than reported for the previous conditions and would support the idea that a more symmetrical weight bearing had been achieved.

With the shoe and hoof pack removed a heart bar (Fig 3.3) was welded in, the shoe was replaced in the same place using the same nail holes. When the heart bar shoe was fitted to the right hoof the horse appeared to once again switch its weight preference with a significantly greater Peak Force seen in the left fore than the right. However, contact pressure was found to be greater in the right fore, the left and right values were closer for this condition than any of the others showing the most even weight bearing across the forelimbs. The peak force values indicating some discomfort with the heart bar in place which is at variance with the caudal hoof pack data. Pressure difference left/right 0.66 Kg/cm². Although the difference in loading of the front feet was not as marked compared to the hoof pack it strongly suggested a preference, P values remaining at P<0.001. The left and right values were found to be closer for this condition than any of the others, showing the most even weight bearing across the forelimbs.

The heart bar was left in situ and the caudal hoof pack applied again to the foot which completely encapsulated the heart bar. This combination saw a significant swing back to a left limb weight bearing preference with a peak force of 17.45 left fore recorded compared to 13.40 for the right limb. The right fore limb peak force was the lowest seen in any condition this was coupled with the highest Standard Deviation seen at 2.80. This reduced force and increased fluctuation could potentially indicate the case study horse was very unsure about weight bearing on the heart bar/sole pack combination. The peak force was at variance with contact

pressure in this intervention which was still significantly higher on the right hand side despite increased peak force on the left foot in both the heartbar conditions. On investigation the data figures revealed that within the first quarter of the 900 frames the highest figures occurred with the figures settling down to a constant 17.00 Kg/cm² average. After the application of the heart bar it would have taken some time and experiment on the part of the horse to find out the comfort levels of the new intervention.

The right fore shoe was then removed, and the heart bar and hoof pack taken out with the shoe replaced as before. With both front feet filled with a caudal hoof pack the horse returned to the original weight bearing preference seen when trimmed with an increase in both peak force and contact pressure. However, these differences were much smaller than seen in either the trimmed or open heeled conditions potentially indicating an increased comfort which resulted in more even weight bearing, P values remaining at $P<0.001$. The data for this intervention showed the most even loading patterns yet. The system of applying a hoof packing also has the added benefit of eliminating the possibility of incorrect fitting of the heart bar thus causing pain through excessive pressure and abscess.

4.2 Recommendations:

This small pilot study showed enough encouraging data to expand further studies into the efficacy of caudal hoof packing against the use of a heart bar shoe alone. A greater population and variety of types of feet with horses of different weights and conformation should be used to give a broader spectrum of data with which to draw conclusions conclusively. The almost universal use of a deformable surface with such a vast variety of types of surfaces has a profound influence upon the performance and moreover the increased propensity to incur an injury. These surfaces range from Olympic standard to soft sand and shredded carpet and could potentially influence the performance of the various interventions applied due to pathologies incurred by the horse. Different hardness's of pack are available in soft, medium and hard with medium used in this study. The investigation into the differences the various hardness's of the hoof packing had on the reaction of the feet and the horse would further the knowledge of what type of packing to use to gain the utmost efficiency in different types of feet and weight of

horse with their work on the surface they most used. The depth of packing applied to the solar surface of the hoof should be evaluated. The researcher allowed for the descent of the sole whilst in the stance phase when pouring in the packing by filling the foot and then putting it on the floor just before it hardened to weight bear with excess packing expelled through the heels. This allowed the packing to descend with the sole whilst weight bearing in the temporal stride pattern to a level that had contact with the ground surface. The hoof packing filled level with the bearing surface of the horse shoe with the foot non weight bearing and then stood on the pressure mat would provide important data to ascertain the amount of pressure the solar surface of the foot is comfortable with and be fully effective. This data set provides enough evidence to question the efficacy of using heart bar shoes alone and indeed in many cases if at all. The application of a caudal hoof pack is a quick and easy way to provide therapeutic aid to a compromised structure or pathologies within the hoof. With the working farrier and the veterinary surgeon in mind on his daily round the time saved is a valuable asset with the time the farrier had to go and make the shoes or order some in negated and with the cost to the owner potentially lower. This study worked on a static horse with no exercise or adjustment period allowed between each intervention due to time constraints and the availability of the horse, this should be addressed in any future studies. Future research should investigate whether the supportive value of the hoof packing, or the increased solar depth of the hoof provided by the packing is the primary causal effect for the improvements

Conclusion.

The hypothesis for this study asked the question, is the application of a caudal hoof pack more beneficial than the use of a heart bar shoe alone. The data gathered from all the interventions applied strongly suggests that the horse was more comfortable and as a result is happier to bear weight on the foot. As with any pathology the relief of pain is of paramount importance and this indicates that packing has the ability to assist in this. The pressure mat images gave a visual indication of the pressures incurred through the various interventions through the colours, blue being the least and red the highest (Appendix 3). It is a simple way to provide immediate relief from both farrier and veterinary surgeon on their daily routine visits. It also eliminates the possibility of an incorrectly fitted heart bar that can cause extreme pain and abscess formation. The researcher has for some time being using this protocol and the empirical evidence gathered

over the years has been very satisfactory. The limitations at the moment are that not enough research has been done to ascertain the optimum hardness.

Scott Moores (2018) in a personal communication, stated that in his research, into the capsular hoof morphology, a medium Cottams hoof pack (Arthur Cottams. Horseshoes. 2018) was used. This was applied to a foot with a riding style concave horse shoe attached that had the clips removed. The hoof capsule mimicked the hoof capsule movement of an unshod barefooted horse with a full sole hoof pack in place. The weight of the horse and the structure of the foot, be it a strong thick wall and thick sole on a cob or a weak walled and thin soled foot on a light Thoroughbred horse must be taken into consideration. The density and hardness of the hoof packing would have to be increased in a tough strong foot. This data supplied from a different research study upholds the hypothesis of this study and adds further validation to the benefits that a caudal sole pack would not only be supportive and more comfortable but greatly assist in the resumption of a normal foot function which can only be of benefit to the horse and assist in the healing process

Although Scott Moores currant research indicates a medium pack consistency is best. Could the packing volume and coverage be improved, these are the limitations at the moment. The clinical relevance of this study could have far reaching effects. Clearly more research into this subject is much needed as it is relevant to everyday practice to countless horses, farriers and veterinary surgeons, not only locally but worldwide.

Word Count 6766

Reference List:

Arthur Cottam (Horseshoes) Ltd. Carrwood Road. Chesterfield Trading Estate. Chesterfield. Derbyshire.S41 9QB

www.atlantic-equine.co.uk/web-page-2. (Accessed on:20/03/17)

Baxter, G.M. (Ed.) (2011) *Adams and Stashak's lameness in horses*. 6th edition. Ames, IA: Iowa State University Press.

Bell, J. (2010) *Doing your research Project: A guide for first time researchers in education, health and social science 5th Edition.* Maidenhead: Open University Press

Butler, D. & Butler, J. (2004) *Principles of horseshoeing (P3): The Ultimate Textbook of Farrier Science and Craftsmanship for the 21. Century*. Maryville: Doug Butler Enterprises.

Butler, K.D. (1985) *The Principles of Horseshoeing 2.* Laporte, Colorado, USA: Butler Publishing

www.bondtech.uk.com (Accessed on 7/10/17)

Bowker, R.M. (2001) 'Hemodynamic Flow Hypothesis for Energy Dissipation in the Equine Foot' *Hoofcare & Lameness*, Issue No 70

www.cal.vet.upenn.edu/projects/lameness/newlameness/ gradinglameness.htm (accessed on 21/03/17)

Caldwell, M.N. & Duckett, D. (2010) 'The Equine foot. Biomechanical and Anatomical form, Function. Hoof Balance and symmetry, a review of current theory' Myerscough College, Preston, Lancashire.

Caldwell, M.N. Reilly, J. D. & Savoldi, M (2010). 'Quantative hoof trimming protocol for research purposes' *Forge Magazine,* April 2010

Colles, C.M. (1989) 'The relationship of frog pressure to heel expansion', *Equine Veterinary Journal*, Vol. 21, No 1, pp. 13–16.

Colles, C. & Ware, R. (2010) *The Principles of Farriery.* London: J. A. Allen & Co.

Curtis, S. (1999) *Farriery- Foal to Racehorse*. Newmarket: R & W Publications.

Douglas, J.E., Biddick, T.L. Thomasson, J.J. and Jofriet, J.C. (1998) *Stress/Strain Behaviour of the Equine Laminar Junction.* Journal of Experimental Biology. 201: 2287-2297

Dyhre-Poulsen, P., Smedegaard, H.H. Roed, J. & Korsgaard, E. (1994) 'Equine hoof function investigated by pressure transducers inside the hoof and accelerometers mounted on the first phalanx', *Equine Veterinary Journal*, Vol 26, No. 5, pp. 362–366

.

Eustace, R.A. (1996) *Explaining Laminitis and its Prevention.* Bristol: J.W. Arrowsmith ltd.

http://WWW.farrier-reg.gov.uk/registered-farriers/guide-to-professional-conduct/farriers-responsibilites-to-horses/ (Accessed on:03/10/17) Glue-u adhesives BV. Ringbaan- Oost 4. 5013 CA Tilbury, The Netherlands.

O'Grady, S., & Parks, A. 'Farriery Options for Acute and Chronic Laminitis', AAEP Convention proceedings (2008)

O'Grady, S. 'Farriery for the Young Horse', AAEP Convention proceedings (2008)

O'Grady, S. (2009) 'The Practical Application of Bar Shoes' *The Natural Angle'* Vol. 12, No.2.

Gray, D.E. (2009) *Doing Research in the Real World 2nd Edition.* London: Sage Publications

Hagen, J., Hüppler, M. Häfner, F. Geiger, S. & Mäder, D. (2016) 'Modifying Horseshoes in the Mediolateral plane: Effects of side wedge, wide branch, and unilateral roller shoes on the Phalangeal alignment, pressure forces, and the footing pattern', *Journal of Equine Veterinary Science*, Vol. 37, pp. 77–85.

Handmade Shoes (UK) Ltd. Units 3-4, Williams Court, Pitstone Green Business Centre. Pitstone. Leighton Buzzard/ LU 79 GJ.

Hastie, P.S. (2001) *The BHS Veterinary Manual (British Horse Society).* Addington: Kenilworth Press.

van Heel, M.C.V., Barneveld, A. Weeren, P.R. & Back, W. (2004) 'Dynamic pressure measurements for the detailed study of hoof balance: The effect of trimming', *Equine Veterinary Journal,* Vol 36 No 8. pp. 778–782.

van Heel, M.C.V., Moleman, M. Barnveld, A. van Weeren, P.R. & Back, W. (2005) 'Changes in Location of Centre of Pressure and Hoof Unrollment Pattern in relation to an 8 Week Shoeing Interval in the Horse' *Equine Veterinary Journal,* Vol.37, No 6, pp.536-540

Hickman, J. & Humphrey, M. (1998) *Hickman's Farriery: A complete illustrated guide*. 2nd Edition. London: J.A. Allen & Co.

Hood, D.M., Taylor, D. & Wagner, I.P. (2001) 'Effects of ground surface deformability, trimming, and shoeing on quasistatic hoof loading patterns in horses', *American Journal of Veterinary Research,* Vol 62 No 6, pp. 895–900.

Hüppler, M., Häfner, F. Geiger, S. Mäder, D. & Hagen, J. (2016) 'Modifying the surface of Horseshoes: Effects of Eggbar, Heartbar, open toe, and wide toe shoes on the Phalangeal alignment, pressure distribution, and the footing pattern', *Journal of Equine Veterinary Science,* Vol 37, pp. 86–97.

https//imprintshoes.co.uk (Accessed 0n: 2/1/17)

Johnston, C. & Back, W. (2006) 'Hoof ground interaction: When biomechanical stimuli challenge the tissues of the distal limb', *Equine Veterinary Journal,* Vol 38 No 7, pp. 634–641.

Lueher, K. Okanagan School of Natural Hoof Care. Available at: http://www.oksnhe.com/articles (Accessed: 17/2/16).

Lungwitz, A. (1891) 'The changes in the form of the horse's hoof under action of the body weight'. *Journal of Comparative Pathology and Therapy,* Vol. 4, pp 191-211

Millman, J. (2015) 'Bar shoes their use, function and construction, (online), Available from: www.jackmillmanfarrierservices.com (Accessed on 26/2/17)

Milner, P., & Hughes, I. (2011) 'Remedial farriery part 1: Foot balance', *Companion Animal,* Vol 16 No 6, pp. 8–11.

www.minitab.com (Accessed on 7/10/17)

Ovnicek, G.D., Page, B.T. & Trotter, G.W. (2003) 'Natural balance trimming and shoeing: Its theory and application', *Veterinary Clinics of North America: Equine Practice,* Vol 19 No 2, pp. 353–377.

Parks, A. (2006) 'Structure and function of the equine digit in relation to palmer foot pain', *Veterinary Clinics of North America Equine Practice,* pp. 285–307.

Pollitt, C.C. & Daradka, M. (1988) 'Equine Laminitis Basement Membrane Pathology', *Equine Veterinary Journal Supplement,* Vol. 26, pp. 139-144

Ramsey, G.D., Hunter, P.J. and Nash, M.P. (2011) 'The effect of hoof angle variations on dorsal lamellar load in the equine hoof', *Equine Veterinary Journal,* 43 No 5, pp. 536-542

Richardson, M.T. (1890) *The practical horseshoer.* Boulder: Johnson Books.

Rossdale, P. (1984) *The horse*. London: J.A. Allen.

Ryan, T.P. (2015) 'Quarter crack, a case history' *Forge Magazine'* December. pp. 4-6.

Schleining, J.A., McClure, S.R. Derrick, T.R. & Wang, C. (2011) 'Effects of industrial polystyrene foam insulation pads on the centre of pressure and load distribution in the forefeet of clinically normal horses', *American Journal of Veterinary Research*, Vol 72(5), pp. 628–633.

Sellnow, L. (2001) 'The Equine Foot-Form and Function' *thehorse.com*

Smythe, R. H. & Gray, P.W. (1998) *Horse structure and movement*. 3rd Edition. London: J. A. Allen & Co.

www.soundhorse,com/technical articles/hoof packing/ (Accessed on: 20/11/16.)

Strasser, H. (2006). 'The Harmful Effects of Shoeing' (Abridged), Available from: http//www.the horseshoof.com/shoeing.html (Accessed on: 2/1/17)

Stashak, T.S. & Adams, R. (2002) *Adams' lameness in horses*. 5th edition. Philadelphia: Lippincott Williams & Wilkins.

Stromsholm ltd. Wood Court, Chesney Wold, Bleak Hall, Milton Keynes, MK61NE

Texscan, Inc. 307 West First Street. South Boston, MA. 02127-1309, USA

Thomas, G. (2009) *How to do your Research Project.* London: Sage Publishing

.www.vettec.com/faqs-sole-guard (Accessed on: 21/11/16.

https://www.plymouth.ac.uk/uploads/production/document/path/3/3755/PlymouthUniversity-MathsandStats-pressure.pdf accessed 3/12/17

Williams, G. & Deacon, M. (1999) *No foot, no horse: Foot balance - the key to soundness and performance*. London: Kenilworth Press.

Appendix 1: cal.vet.uedu.edu/lameness grading

Grading the Lameness

Grade 1.

The lameness is not recognizable at the walk but is evident at the trot. Usually, with a forelimb lameness, the horse's head drops down when the sound foot lands and raises up to its regular height when the affected side lands. There may be an asymmetry in the gluteal rise with hind limb lameness. There also may be an audible difference between the landing of the sound foot versus the lame foot (i.e. the horse lands with less weight on the lame foot). Grade 1 lameness' are most typical in chronic, non progressive diseases.

Grade 2.

The lameness is barely perceptible in the walk, and very apparent at the trot. Head movements, although not often visible at the walk, become obvious at the trot, with some head and neck lifting as the lame foot hits the ground. This is an attempt to reduce the weight bearing on the affected limb.

Grade 3.

The lameness is apparent at both the walk and trot. Head and neck lifting are obvious with the forelimb lameness and with a hind limb lameness, head nodding is apparent when the opposite forelimb hits the ground.

Grade 4.

With this degree of lameness, the horse will not place the foot completely flat during weight bearing. They will be reluctant to jog.

Grade 5.

This is a non-weight bearing lameness. This is often associated with fractures, subsolar abscesses, severe tendonitis, and septic arthritis.