A Comparison of Two Different Dorsal Hoof Wall Trimming Techniques.

Steven Beane A.W.C.F.

Manor Cottage Farm, Trenholme Bar, Northallerton, North Yorkshire, DL6 3JZ.
E-mail: stevenbeane@hotmail.co.uk

Dissertation

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Abstract:

Introduction:

There is considerable anecdotal evidence amongst hoof care professionals to suggest that trimming the dorsal wall flat in line with the phalangeal axis may contribute to degradation of horn quality and loss of mass and integral strength in the toe region.

Aims:

This study aims to compare external morphological measurements between two different dorsal hoof wall (DHW) trimming protocols and investigate the effects of DHW trimming on solar arch morphology in a group of riding school horses trimmed and shod to the national standards of competence for farriery.

Materials and methods:

This study used a random double cross over trial to investigate the effects of two different DHW trimming methods. Six riding school horses from a mixed population were selected with each horse acting as its own control. All horses were shod over 9 shoeing cycles at intervals of 35 days with handmade fullered concave shoes to the national standards of competence for leisure horse fit (Lantra 2011).

Results:

Results from this study found no evidence in the sample (n=6) to support the hypothesis that there would be a difference in linear hoof measurements between feet trimmed with two different methods of DHW dressing, the traditional flat line method or the so called dorsal rounding technique. Results show statistically significant differences in solar arch morphology between feet initially trimmed with the dorsal rounding technique and those trimmed in the more traditional manner.

Conclusion:

These results suggest that different trimming techniques can affect the mechanical behaviour of the hoof wall under certain conditions. The results suggest that the so called dorsal rounding technique may prove to be of benefit to the overall health of the hoof by inhibiting excess DHW and solar arch deformation. Clearly further research is warranted.

Word count: 4979 excluding figures and references.

Key words: hoof balance, hoof trimming, dorsal wall rounding, solar arch

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. The content of my thesis is the result of work I have carried out since the commencement of my research for the Worshipful Company of Farriers fellowship award and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma.

Signed………………………………………

Steven P Beane AWCF.

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1. Introduction

Equine hoof conformation is considered an important factor affecting performance (Linford 1993). Poor hoof conformation has been shown to increase the risk of injury in horses and is a consequence of the anatomy of the horse and biomechanical function in high-performance activities (Kane et al 1998). The equine hoof serves as the interface between the ground and the skeleton of the equine limb, its structure is capable of dissipating forces associated with impact shock and loading. In addition, the shape and balance of the horse's hoof is a significant factor contributing to catastrophic injury in the horse (Kane et al 1998). Hoof care professionals insist that the correct foot balance is critical in maintaining health and biomechanical efficiency (Johnston and Back, 2006). During the last century various models of hoof trimming and correct hoof balance, largely based on the historical works of Russell (1897) and others (Dollar & Wheatley 1898, Magner 1899), have been debated, yet to date there is little in the way of scientific data and agreement on the optimal model of hoof conformation. Hoof conformation can be altered by human intervention, such as by hoof trimming and the application of horseshoes (Kummer et al. 2006; van Heel et al. 2005). Historical observation, the personal experiences of individual farriers and beliefs and successes of their practical application have sustained the activities of trimming and shoeing for thousands of years.

Existing studies that have evaluated the effects of poor foot balance do not make reference to any specific dorsal wall trimming protocol, which could be replicated in subsequent research. The body of work presented in this thesis will investigate the relationship between hoof morphology of the foot by comparison of a standardised and repeatable hoof trimming protocol commonly termed dorsal wall rounding with the trimming protocol described within the National Standards of Competence for Farriery (Lantra 2011) **(ANNEX F).** Furthermore, it is the intent that this standardised trimming protocol known as dorsal wall rounding could be readily applied to routine hoof care.

The Worshipful Company of Farriers (WCF) produces detailed guidelines for the standards of trimming and shoeing of horses in the UK. These guidelines outline foot balance and shoe fitting criteria for different styles of work and type of horse within critically acceptable tolerances of craftsmanship. These guidelines are based on the historical texts from a range of authors (Lungwitz 1891; Russell 1897 and Dollar & Wheatley 1898) dating from 1890.

Conventional farriery teaching is based on the principal that the bearing border of the foot (BB) should be trimmed perpendicular to the longitudinal axis and this is reiterated in current texts (Williams & Deacon

1999 Curtis 2002, 2006, & Stashak 2002). These authors acknowledge the importance of achieving correct hoof pastern axis (HPA) and assume that trimming will centralise the point of force (POF) within the hoof capsule. The maintenance of normal HPA can be achieved by aligning the dorsal hoof wall angle (DHWA) with the angle of the central axis of the phalanges. In practice HPA is generally easily manipulated by excess trimming of the dorsal hoof wall (DHW) in the toe region and reduced trimming of the heels.

In the resting horse, relationships between limb conformation and static foot balance are examined by viewing the foot from the lateral, dorsal and solar aspects. From the lateral aspect, the foot pastern axis should be straight and in the forelimb is said to be about 50-52° to the ground with the toe and heel angles presenting parallel (Stashak 2002). Ideally the vertical height of the heel is said to be one third that of the toe (Stashak 2002) and a vertical line from the centre of rotation of the distal interphalangeal joint is said to bisect the ground surface of the foot **(Figure 1)**. In addition, a vertical line that bisects the third metacarpal should intersect with the ground at the most palmar aspect of the weight-bearing surface. This relationship defines static dorsopalmar balance and conformation (Parks 2003).

Anecdotal evidence amongst farriers suggests a link between excessive thinning of the DHW, and the subsequent loss of integral strength, and a loss of solar arch depth. A standardised trimming methodology for retaining DHW strength has been the subject of much debate between farriers for a number of years. Historical texts (Hickman & Humphrey 1988) have categorically stated that rounding of the DHW (dumping) is classed as bad farriery practice and is potentially detrimental to hoof health. However in recent years dorsal wall rounding has been advocated as a method of retaining DHW integrity in those feet considered to be weak and subject to excessive distortion (Allison personal communication). To date no peer-reviewed evidence exists to support or refuse to accept either parallel hoof wall alignment or dorsal wall rounding as a methodology for maintain or improving hoof conformation in shod horses. The current study will examine the effects of both trimming methods on a range of hoof measurements over an extended period.

In recent years a bare foot model based on the observations of the North American feral horse has been proposed as the ideal foot balance form (Jackson 1992; Ovnicek 2003). Clayton et al (2011) studied bare foot warm blood dressage horses trimmed on a six weekly cycle using a natural balance trimming protocol. This method incorporates bevelling of the dorsodistal bearing border perpendicular to the angle of the DHW (Ovnicek 2003), who also noted consistent changes to the length of the DHW and an increase in DHWA. Continued maintenance of the trim resulted in beneficial increases in the solar angle of P3. Clayton et al (2011) concluded that significant morphological changes can take place in the hoof in response to the trim. Significantly the authors concluded an increase in solar angulations of P3 might well be of potentially beneficial to the health of the foot.

Anatomy and Physiology of the Equine Hoof – The hoof is a complex modification of the integument surrounding, supporting and protecting structures within the distal limb of the horse (Dyson 2011). The bulk of the hoof wall consists of the stratum medium, which is the main load bearing part of the hoof wall and extends from the coronary band (CB) to the bearing border (BB). Balchin (2009) in a study of the sagittal section of 200 cadaver front feet using Fanabacci's golden ratio (3: 4: 5) demonstrated that the coronary band and DHW were at right angles and formed a right-angled triangle with the DHW and bearing border. The DHW is said to be of uniform thickness when viewed in a transverse section from its origin at the coronary border to the ground bearing border and parallel to the dorsal surface of P3. However the BB of the DHW presents perpendicular to the axial skeleton and oblique to the coronary border and is therefore increased in width at the perpendicular ground-bearing surface (**Figure 2).**

DHW generation is from the epidermal basal cells of the coronary corium (Stump 1967, Pollitt 2001). A large number of hair like papilla also described as nipple like projections fit into one of the holes on the surface of the epidermal coronary groove and in life, are responsible for nurturing an individual hoof wall tubule which run diagonally from the CB to the BB. The horn tubules are arranged into four zones of density (Reilly et al 1996), the strongest and most densely populated zone being the outer layer **(Figure 3)**. Intertubular horn is formed at right angles to the tubular horn, filling the void between the horn tubules (Bertram and Gosline 1987) **(Figure 4)**. This construction achieves mechanical stability within the horn with the mechanical properties of the horn tubules being best suited to compressive force whilst the Intertubular horn provides stability through tension (Bertram and Gosline 1987). The equalisation of both compressive and tensile forces allows ground reaction forces to be dispersed within the structure without regional overload (Thomason 2007).

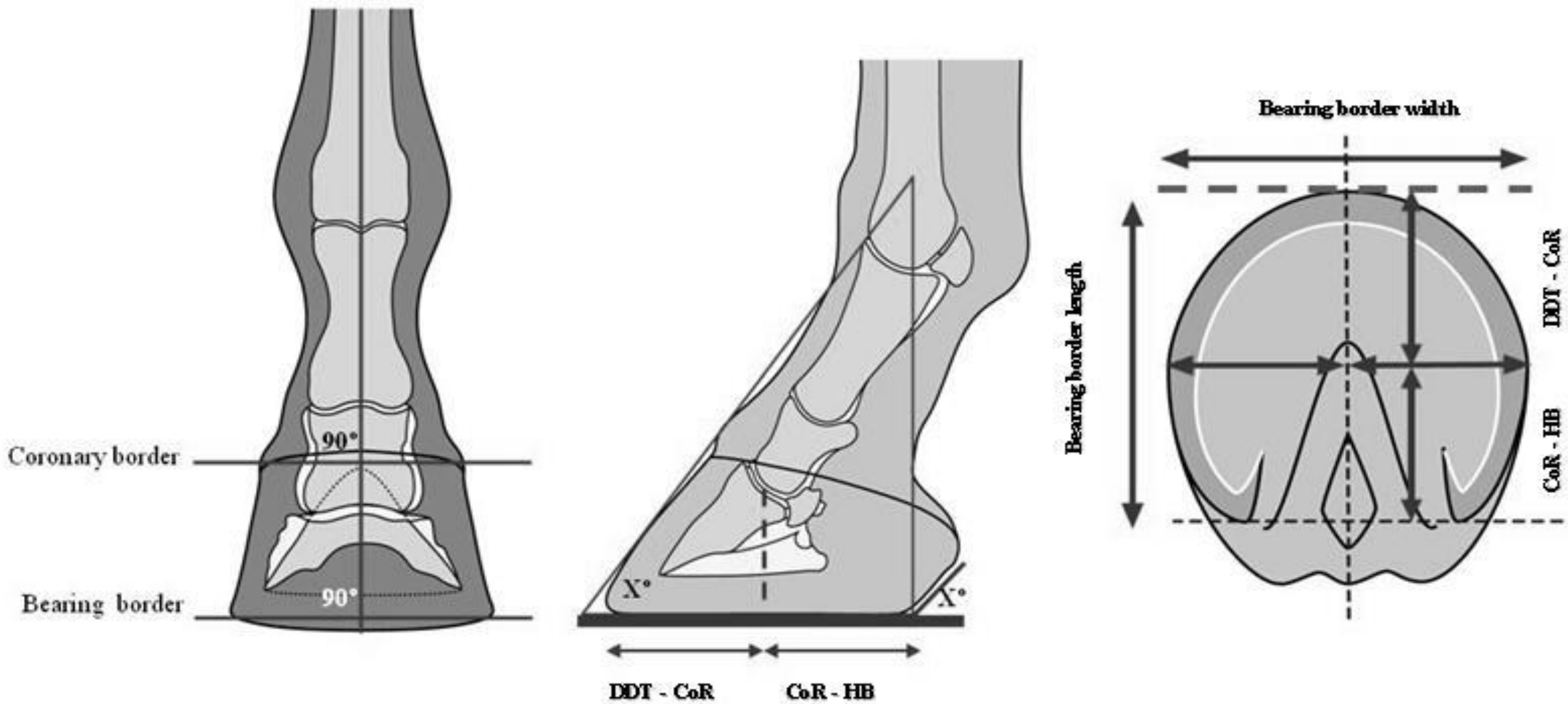

Figure 1 A Schematic illustration of Professor William Russell's 1897 interpretation of ideal foot balance model. Russell suggested that coronary circumference was of equal height at any two opposing medial or lateral points and perpendicular to the sagittal axis of the limb (left) and that the ideal foot should exhibit heel / toe angle parallelism with the phalangeal axis. Russell further argued that the bearing border was symmetrical about its centre which he placed palmar of the frog apex. To this day Russell's (1897) model of symmetry within the equine foot remains the basis for current farriery teaching. Dorsal distal tip (DDT) ; Centre of rotation (COR) ; Heel bearing (HB) *Modified after Parks*

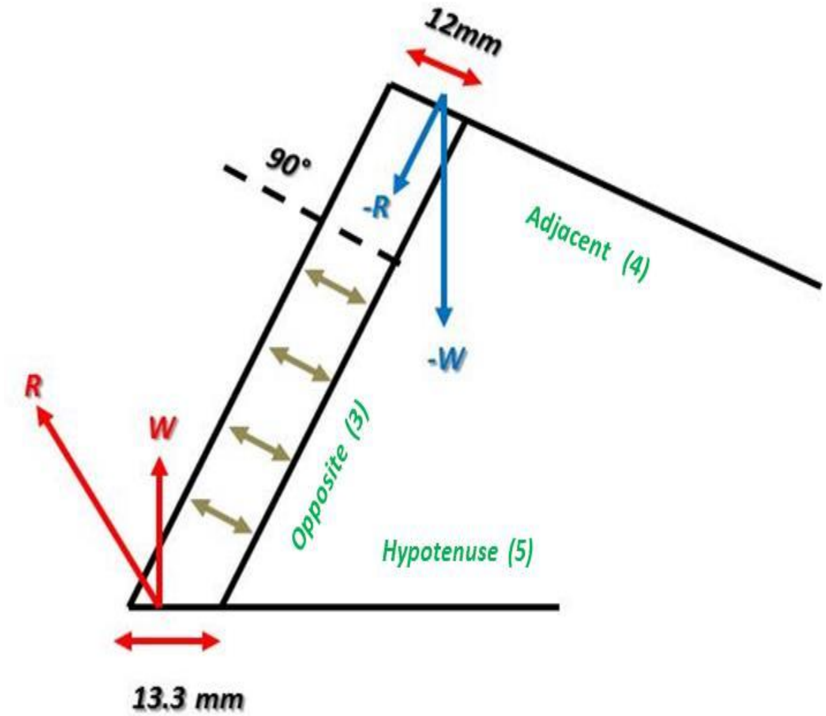

Figure 2 A schematic illustration of the DHW perpendicular relationship to the coronary border. The ground bearing border presented perpendicular to the force (-W) is increased by 10.83% increasing the moment. The resultant (R) GRFv induces a shear force which contributes to the dorsal migration of the dorsodistal hoof wall (flare).

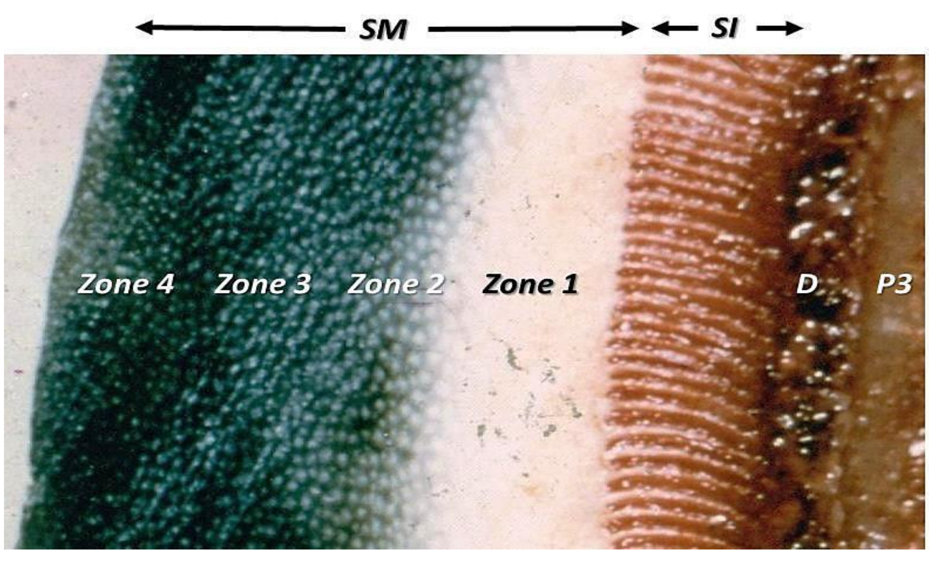

Figure 3 The inner layers of the hoof wall, including the stratum medium (SM), illustrating the differing layers of tubular density. The stratum internum (SI) consists of around 600 non-pigmented keratinised, primary epidermal laminae, each of which bears 100-150 non-keratinised, secondary epidermal laminae which dovetail with their adjacent counterparts of the secondary dermal laminae originating from the dermis (D). *Modified after Rooney (1969)*

The effect of force on the hoof – The hoof capsule is said to be viscoelastic that has the ability to deform under load and then return to its original shape once the weight is removed. It is accepted that abnormal weight distribution on the foot or disproportionate forces placed on a section of the hoof wall, over time, cause it to assume an abnormal shape (O'Grady 2013). The mechanical behaviour of the hoof structures reflects a relationship between applied forces or a stress, and the hoof structures response to that stress is deformation or strain (Douglas et al 1998). The initial deformation curve reveals a linear relationship in which strain is directly proportional to the applied stress. However, a point is reached, known as the proportional limit or elastic limit, at which a departure from stress-strain linearity and permanent plastic deformation occurs **(Figure 5)**. The increase in strain leads to plastic deformation of the horn and structural failure of the hoof such as low weak heels, which has been associated with pathology (Kane et al 1998).

The sole is arched in formation. In engineering terms mechanically the arch resolves loading forces into compressive stresses and, in turn eliminates tensile stress and is referred to as arch action. As the forces in the arch are carried to the ground, the arch will push outward at the base, called thrust. As the rise, or height of the arch decreases, the outward thrust increases. In order to maintain arch action and prevent the arch from collapsing, the thrust needs to be restrained, either with internal ties or external bracing (Ambrose 2012). This appears to be much the same way that laminal interdigitation and the frog stay and bars accommodate compressive and tensile force within the foot (Thomason 2008).

During normal weight bearing and locomotion, the middle phalanx rotates initially backward onto the palmar/plantar hoof pushing the palmar/plantar hoof into the ground causing the hoof wall to deform in a consistent pattern **(Figure 6)**. The proximal dorsal wall rotates caudoventrally (Lungwitz 1891; Thomason 1992) about the distal dorsal border and whilst there is lateromedial flaring caudally (Lungwitz, 1891; Colles, 1983; Thomason et al. 1992). Both Thomason et al (1992) and Douglas et al (1998) concluded that the principle forms of deformation experienced by the hoof capsule are bending and compression. Hood et al (1992), used transducers capable of discriminating between bending and compressive deformation, and observed that the DHW was subject to either pure bending, or compression and bending, during static weight-bearing. It is this compressive force that leads to dorsal migration of the DHW (Caldwell et al 2015) (**Figure 6)**.

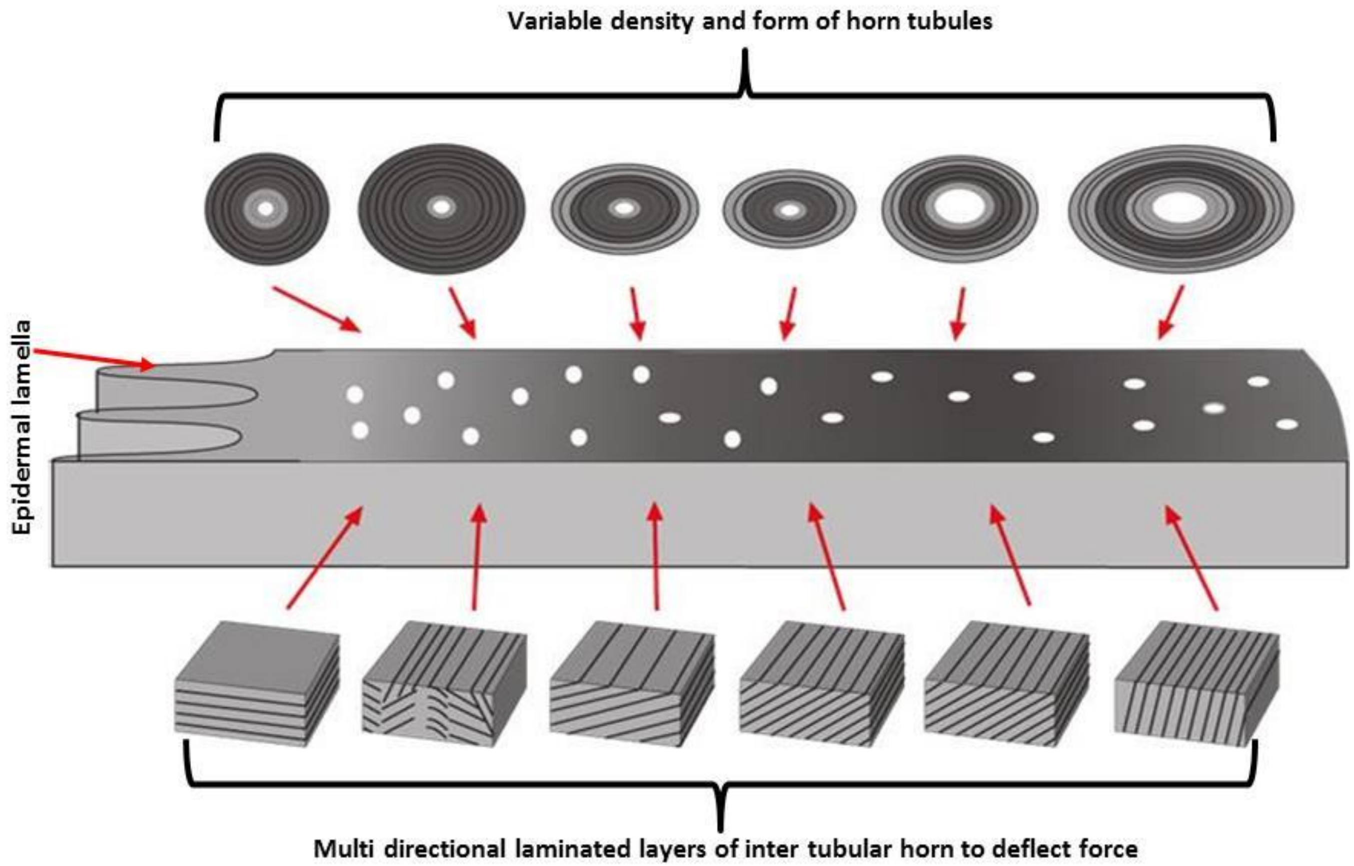

Figure 4 Hoof wall Intertubular material composite diagram illustrates a three-dimensional representation of the Intertubular material organization from each representative region. The plane of Intertubular material varies depending on its position through the thickness of the hoof wall. (*Illustration reproduced from Kasapi and Gasoline 1988*).

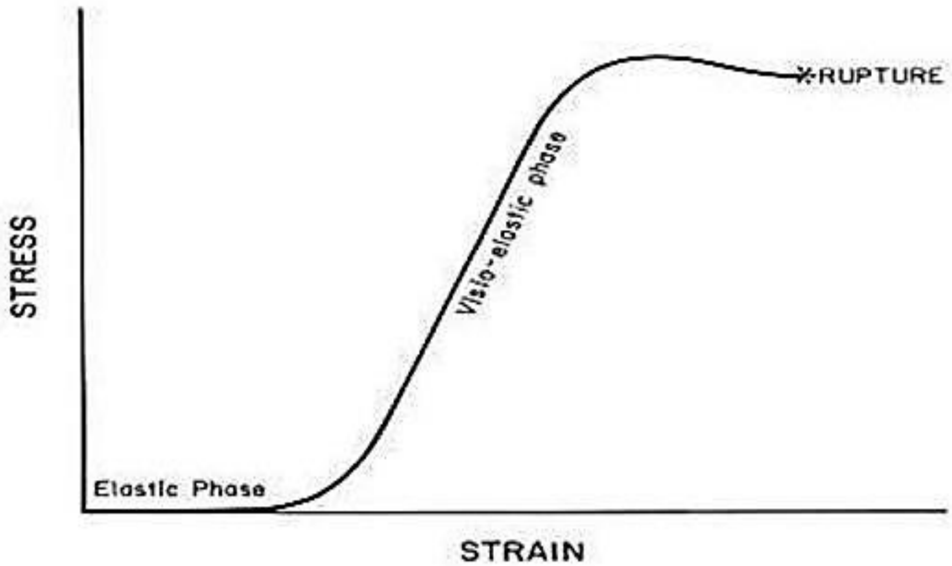

Figure 5 Representative of tensile stress–strain curves for the equine hoof wall. The initial stiffness increases progressing from the inner to the outer region of the wall (*Kasapi and Gasoline 1997*).

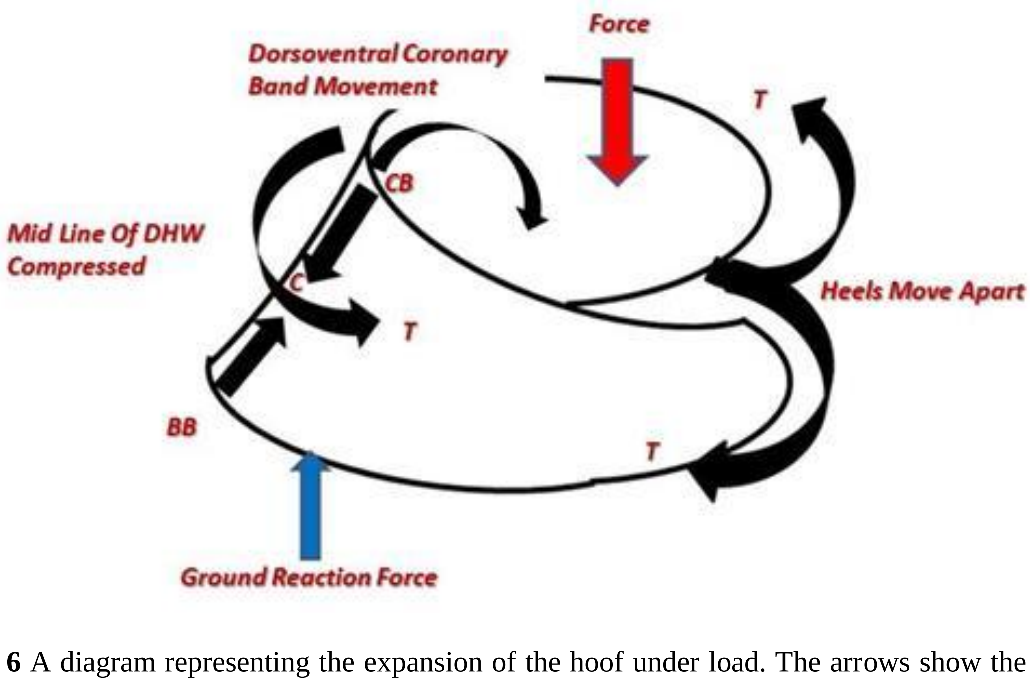

Figure 6 A diagram representing the expansion of the hoof under load. The arrows show the change in shape, which occurs during weight bearing. The dorsal wall flattens and moves palmarly, particularly proximally, accompanied by abaxial movement of the quarters and heels. *Modified after Lungwitz (1897)*

Hoof balance and the relationship to pathologies – There is a considerable weight of anecdotal evidence within the literature supporting the contention that poor foot conformation predisposes to foot pain, lameness or lower limb pathology (Kane et al. 1998; Eliashar et al 2004) and therefore maintaining hoof balance to a desirable shape is important in maintaining correct form and function of the foot. Dyson et al (2011) noted that it was clear that the causes of foot pain are multifactorial.

Farriery techniques have been shown to influence skeletal alignment within the foot (Kummer et al 2006; 2009), and the biomechanical hoof mechanism involved in shock absorption (Roepstorrf et al 2001) and as such presumably is of consequence to the orthopedic health of the horse. Several farriery texts (Emery. et al; 1977; Hickman & Humphrey. 1988; Stashak. 1990; 2002; and Butler 2005) focus on specific aspects of the current foot balance model whilst offering contradictory advice on trimming methodology, most notably with regards to trimming of the DHW and sole. This advice, based on individual interpretation and practice, is presumably formulated on local environmental considerations. None however, make reference to evidence-based trimming protocols.

Corrective farriery including the use of the dorsal wall rounding technique aims to restore foot balance. It is directed at relieving force concentrations in specific areas and distributing the forces associated with weight bearing throughout the foot.

2. Aims

Based on the lack of evidence-based studies, there is a necessity to investigate the hoof's morphological characteristics in order to gain a greater understanding of the effect of trimming the DHW. It would be advantageous to hoof care professionals if one common universally accepted method of restoring hoof proportions whilst maintaining the mechanical properties of horn could be accurately established. Such a study could also form the basis for establishing a quantifiable and prescriptive model for gross foot morphological distortions.

The aims of this study are:

1 Comparison of external morphological measurements between two different DHW trimming protocols

2 Investigate the effects of DHW trimming on solar arch morphology

3. Hypotheses

Ho1. There is a significant difference in DHW orientation and measurements over the trial period between feet trimmed to the national standard of competence for farriery (Lantra 2011) and those trimmed using the dorsal wall rounding technique.

Ho2. Flare dressing the DHW parallel to the HPA (flat lining) results in a reduction of the solar arch depth.

4. Materials and Methods

Study design - a blind double cross over study.

Sample collection - Six horses from a mixed population of riding horses weighing between 427 kg and 607 kg and ranging from 1.57 meters to 1.7 meters with each horse acting as its own control. All ideally would have been chosen on breed, type and weight. However major factors in the selection were similar good foot and limb conformation, the environment and similar foot size. The sample were managed in the same environment and weekly work regime, stabled on straw bedding along with 3 hours daily turn out in the same pasture and 8 to 10 hours weekly school work, for the duration of the study. All horses were assessed from a dorsal and lateral aspect for conformation using a standardised scoring system, (Mawdsley et al 1996) **(Annex E).** Horses with conformation scores outside the range of 3-5 in any single criteria were excluded. Horses with previous history of fore limb lameness were excluded. The detailed statistical data for the sample population are displayed in **Annex A.** Owner consent was obtained for horse usage **(Annex B).**

All horses were shod over 9 shoeing cycles at intervals of 35 days with new handmade fullered concave shoes to the national standards of competence for leisure horse fit (Lantra 2011) **(Annex F)**. Throughout the current research measurement data was collected every 35 days for nine repetitions from all the samples.

Four external hoof measurements were chosen, two linear hoof measurements and two solar depth measurements from the solar impressions. The first linear measurement, commonly referred to as Duckett's Dot (DD) is taken on the ground surface of the hoof, from a point 9.5mm (3/8") palmar to the apex of the frog to the centre of the dorsodistal toe (Duckett 1990). This is an important external reference point and is thought to relate to a line running vertically from the extensor process of the distal phalanx, through the centre of the semilunar line and therefore considered to represent the centre of pressure (COP). The second linear measurement DHWL is taken from the true hairline junction at the proximal aspect of the DHW to the dorsal distal bearing border. **Figure 7** illustrates the external reference points measured from the dorsopalmar plain and those along the BB. Pre-trim data was collected from the external reference points and were taken by hand, using standard engineer's Digital calipers. Two solar impression measurements were taken: MFP at the highest point of the medial aspect of the solar impression at its widest point; DBB was taken at the highest point of the solar impression along the sagittal axis dorsal of the true point of frog **(Figure 11)**.

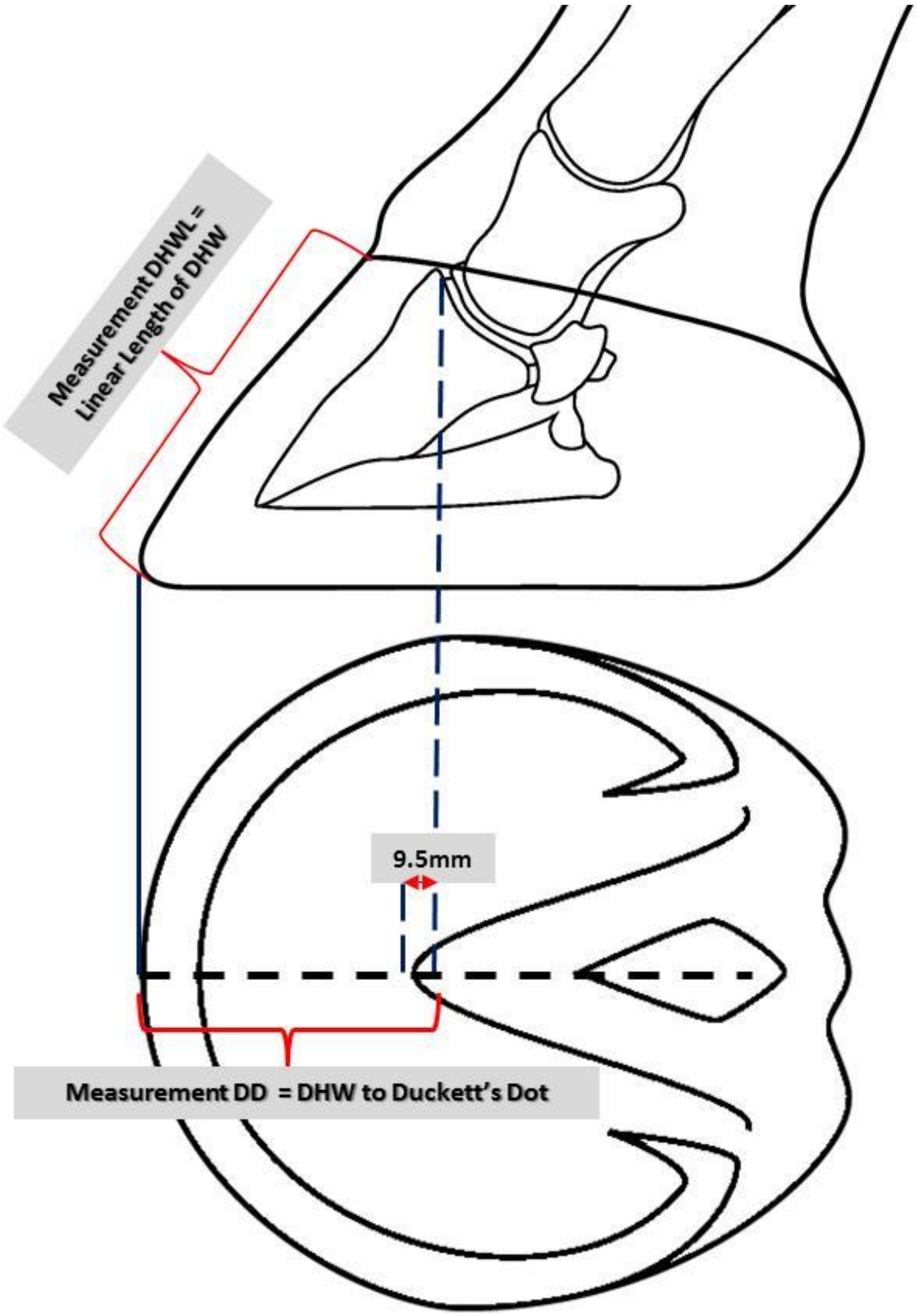

Figure 7 Illustrates the external measurements taken from the hoof pre-trim at day 1 and subsequently at the end of each 3rd shoeing cycle (105 days)

Trimming protocol –

To ensure consistency all horses were trimmed and shod by the author.

The basic trimming protocol used in this study was based on the national standards. The trim is undertaken to address the frog, sole and white line first, followed by the bearing border and DHW. Briefly, the collateral margins of the frog were trimmed along its length to form an angle approximately 55°- 60° to the bars. The ground-bearing surface of the frog was then trimmed with the caudal aspect of the bearing border of the frog becoming level with the horizontal plane of the bars to be able to allow ground contact during loading periods of the stance phase prior to reducing the wall. The white line was then trimmed to the level of the true interface of the solar horn, identified by the waxy horn at the sole-white line interface. After this, excess wall was trimmed at the bearing border from toe to heel to produce a horizontal plane with the sole and the heels reduced in height to extend the bearing border approximately to the widest or highest aspect of the trimmed frog. Following rasping the hoof flat, any flaring of the DHW was reduced from quarter to quarter, leading to a consistent hoof wall bearing border taking care not to lower the bearing border below the sole. Slight beveling of approximately ten percent of the dorsal hoof wall width external to the white line (**Figure 8**), was initially performed on the left fore (dorsal wall rounding) and alternated at the end of each third shoeing cycle (105 days) **(Figure 9)**.

The dorsal rounding technique is achieved by creating a convex proximodistal curvature of the distal third of the DHW. This achieved by rolling the rasp from approximately1/3rd of the height of the DHW towards the ground-bearing border to achieve a radius on the DHW. The dorsal rounding technique gives the DHW the appearance of variable dorsal hoof wall angles along its proximodistal length.

The flat lined national standard wall dressing was initially performed on the right fore. The flat line trim aims to achieve a uniform plane and angle proximodistal along the entire length of the DHW. The DHW wall was flare dressed 2/3rds of the height of the DHW from the distal bearing border to achieve the appearance of a uniform DWA.

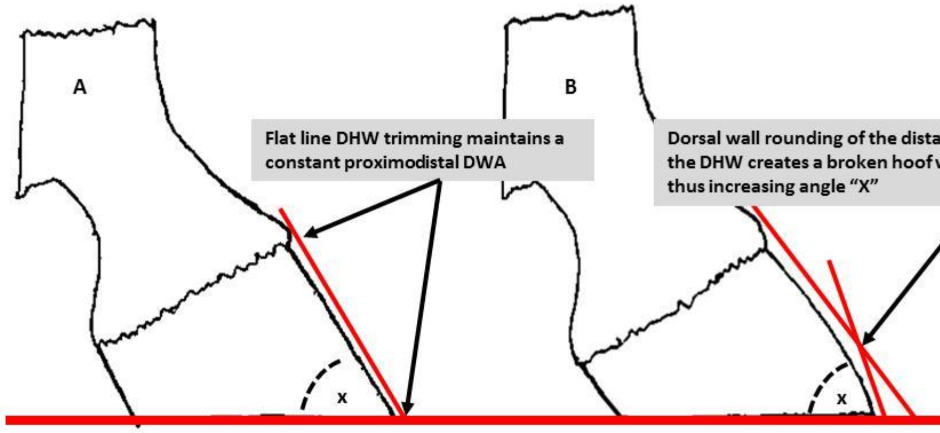

Figure 8 Illustrates the difference in standardised dorsal hoof wall trimming protocols. The dorsal rounding technique (B) is achieved by creating a broken hoof wall axis by rasping a convex proximodistal curvature of the distal third of the DHW. The right fore feet of the horses in the study group were initially trimmed with the traditional flat line method (A) which maintains a constant proximodistal DWA.

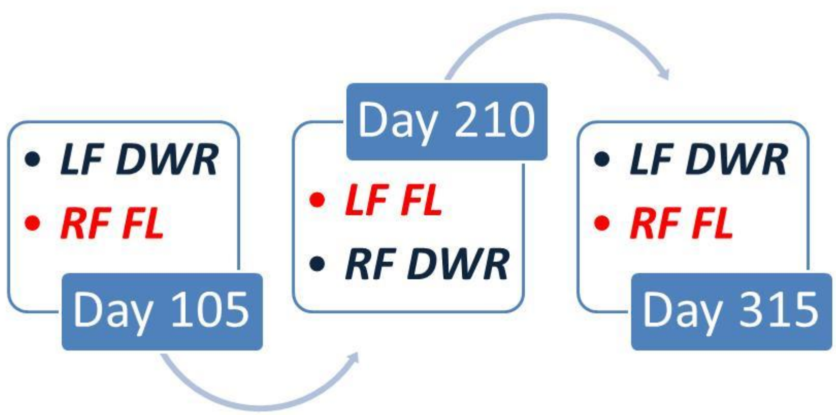

Figure 9 Illustrates the data collection cycle. Data was originally collected at day one pre-trim and subsequently every 105 days at the end of each third shoeing cycle. The dorsal hoof wall trimming protocol was alternated every 105 days

Shoeing protocol –

For consistency and validity of the results a new handmade steel fullered concave shoe fitted to the national standard for leisure horse style was applied on each occasion. Nail placement was restricted to the dorsal half of the shoe. For constancy no clips or toe variations were incorporated (**Figure 10**). No additional traction devices were added. The entire sample was shod in 10mm (3/8th) height section of fullered concave throughout the whole study period. The sample was shod cold on every occasion; this prevented any possible alteration to the foot dressing during the application of a hot horseshoe.

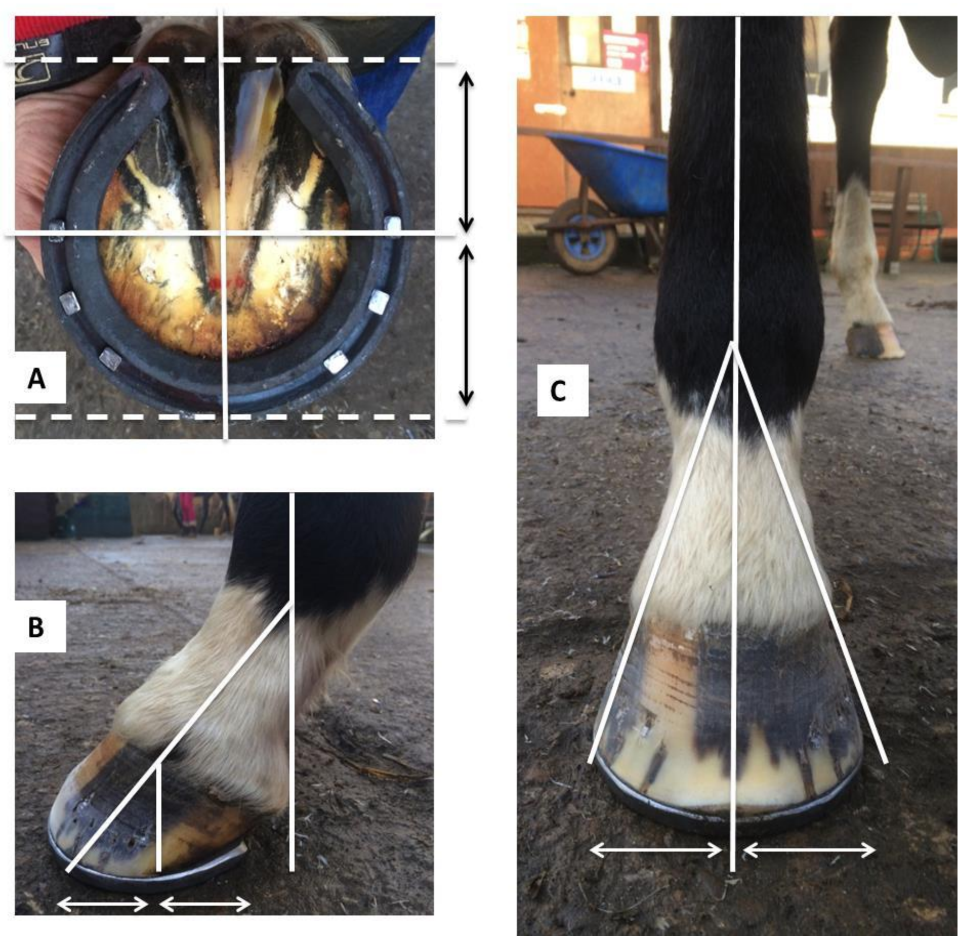

Figure 10 Illustrates the shoeing protocol used for all horses. The illustration highlights the nail hole position, symmetrical branches and is fitted to the heel buttress +5mm (A) and the fitting with length of the shoe (B) and width (C) in the palmar half of the foot. This fitting style is said to minimize the effects of any restrictions in normal physiological function of the foot caused by the attachment of a steel horseshoe. (Butler 2005). Also illustrated is the dorsal wall rounding technique (B).

To assess the affect of the two standardized trimming protocols on the solar arch morphology two vertical sole depth measurements were taken from solar impressions. The solar impressions were generated using proprietary liquid urethane pour in pad material (Medium Pad® (Cottam.[1])) **(Annex C).** Impressions were taken pre-trim, prior to shoe removal from each foot at each subsequent third shoeing cycle (105 days) before alternating the trimming technique **(Figure 9)**.

To ensure consistency and ease of removal of the solar impressions, Vaseline was applied to the solar margin prior to the liquid urethane pour in pad material being applied, with the limb non-weight bearing. Proprietary 5mm foam boards were applied to the bearing border of the shoe to ensure a uniform fill parallel with the ground surface of the shoe (**Figure 11**).

Data collection and analysis –

Pre-trim linear measurement data for the DHWL and the distance between the dorsodistal bearing border and Duckett's dot was collected every thirty-five days **(Figure 7)**. Two vertical height measurements were taken from the solar impressions. Measurement DBB was taken at the highest point of the solar impression along the sagittal axis dorsal of the true point of frog. Measurement MFP was taken at the highest point of the medial aspect of the solar impression at its widest point (**Figure 11**).

General - Descriptive statistics were generated in Microsoft Excel®[2] data analysis software. Individual data samples were transferred to Minitab 17®[3] for detailed statistical analysis. Graphical illustrations for pre trim variation of foot balance indicators and trim validation variables were generated in Microsoft excel®. Data were tested for normality using Anderson-Darling test. Significant differences were determined by Students *t*-test and one-way analysis of variance (ANOVA) with Tukey post hoc corrections.

Statistical significance for all data was analysed at $P<0.05$

P = calculated probability, the probability of getting the same results by chance. For statistics to be statistically significant the P value must be less than 0.05, therefore below 0.05 means statistically significant. Above 0.05 means not statistically significant.

[1] Arthur Cottam and Co (Horseshoe) Ltd. Carrwood Road, Chesterfield Trading Estate, Chesterfield. S41 9QB
[2] Microsoft Excel: Microsoft UK PLC; Microsoft Campus, Reading Thames Valley Park Reading RG6 1WG
[3] Minitab 17: Minitab Ltd: Brandon Court, Unit E1-E2, Progress Way, Coventry CV3 2TE. United Kingdom

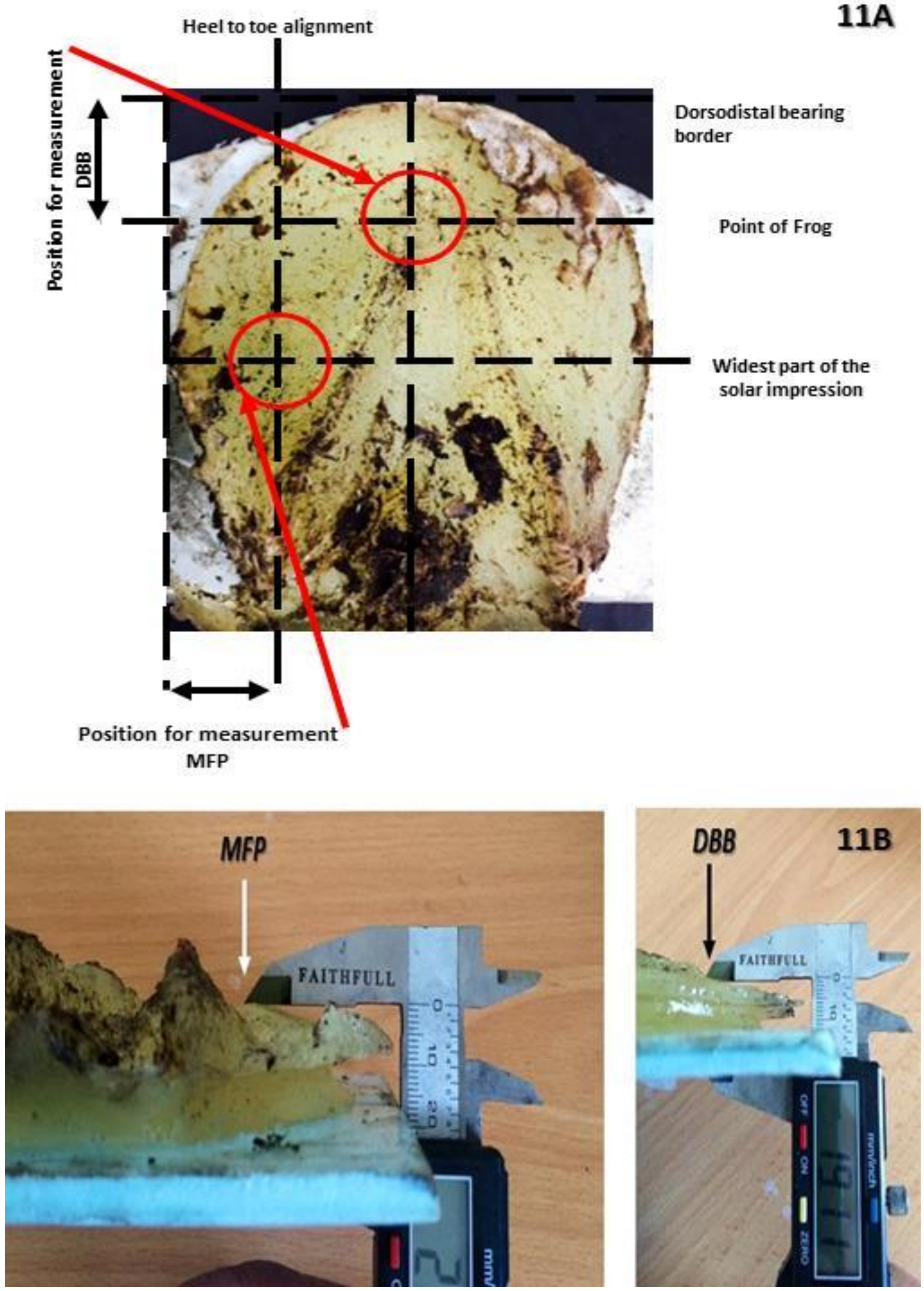

Figure 11 The solar impression measurements of **MFP** were taken at the highest point of the medial aspect of the solar impression at its widest point and measurement **DBB** was taken at the highest point of the solar impression along the sagittal axis dorsal of the true point of frog (11A). The solar depth measurements (11B) included the 5mm depth of the proprietary foam board and the shoe thickness.

5. Results

It was hypothesised that there would be a significant difference in both linear DHWL and solar measurements between feet trimmed with the dorsal rounding technique and those trimmed with a commonly used flat line technique. These hypotheses were tested, using the methodology previously described. The descriptive statistics and results for the overall trial period are displayed in **Table 1.**

Table 1 Displays the details of the pre-trim mean ± SD linear and solar measurements at day 1 and subsequently over three 105 data collection cycles prior to alternating trimming method. Statistical results are displayed within **Table 2** highlight significant differences in all measurements between individual horses $p<0.05$ for all measurements. The results illustrate the individual variability within the sample whilst demonstrating that hoof balance may be influenced by factors outside the scope of this study.

All data was distributed normally $P>0.05$.

The results displayed in **Table 2** and **Figure 13** indicate there were significant differences between trimming type on solar depth morphology, $p<0.05$. **Table 2** Highlights there were significant differences in both linear and solar measurements for individual horses ($p<0.05$ all) between trimming methods. However the results also demonstrate there were no interactions between individual horses and trimming periods or type for any of the measurements, $p<0.05$. This is supported by the interaction plots from multi factorial ANOVA's **(Annex D D2).** These results suggest that the application of different trimming methods can influence hoof conformation of the type often witnessed in practice. However post hoc analysis shows variations in results between individual horses **(Annex D D2).**

Variable	DAY	TRIM	N	Mean (MM)	St Dev
LF DHWL	1		6	89.8	6.6
	105	Round	6	83.5	8.3
	210	Flat	6	83.0	8.4
	315	Round	6	87.0	7.7
LF DD	1		6	59.5	5.3
	105	Round	6	54.7	2.4
	210	Flat	6	53.3	3.4
	315	Round	6	54.3	4.1
RF DHWL	1		6	90.0	6.9
	105	Flat	6	80.7	9.6
	210	Round	6	85.5	7.7
	315	Flat	6	83.7	8.2
RF DD	1		6	60.8	5.3
	105	Flat	6	54.5	3.9
	210	Round	6	55.0	3.6
	315	Flat	6	55.5	4.5
LF DBB	1		6	18.57	1.76
	105	Round	6	19.13	1.81
	210	Flat	6	16.22	1.67
	315	Round	6	18.45	1.78
LF MFP	1		6	21.63	2.34
	105	Round	6	22.32	2.41
	210	Flat	6	18.73	2.47

	315	Round	6	22.47	1.74
RF DBB	1		6	17.65	1.74
	105	Flat	6	17.92	1.78
	210	Round	6	17.42	1.25
	315	Flat	6	17.40	1.32
RF MFP	1		6	21.20	2.84
	105	Flat	6	21.53	2.88
	210	Round	6	20.45	2.06
	315	Flat	6	21.27	1.97

Table 1 Descriptive statistics from linear and solar impression measurements throughout the trial period. Trim = Trimming protocol, N = Sample number, Mean = Measurement mean average, St Dev = Standard deviation.

Measurement	**Variable**	**Significance P-Value**
Left DHWL	Horse	P<0.00
Left DHWL	Trim Method	P<0.15
Right DHWL	Horse	P<0.001
Right DHWL	Trim Method	P<0.05
Left DD	Horse	P<0.001
Left DD	Trim Method	P<0.39
Right DD	Horse	P<0.04
Right DD	Trim Method	P<0.84
Left MFP	Horse	P<0.01
Left MFP	Trim Method	P<0.001
Right MFP	Horse	P<0.04
Right MFP	Trim Method	P<0.54
Left DBB	Horse	P<0.05
Left DBB	Trim Method	P<0.001
Right DBB	Horse	P<0.07
Right DBB	Trim Method	P<0.68

Table 2 Statistical results of one way ANOVA for linear and solar measurements between trimming period and method between each data collection period. A significant P value of less than 0.05 ($p<0.05$) demonstrates the likelihood of there being a significant difference within the data between the groups.

There were statistically highly significant differences in the LF solar measurements (highlighted in red) related to the trimming method. There were no interactions between horses and trimming method for the left fore MFP and DBB measurements **(annex D, D2).**

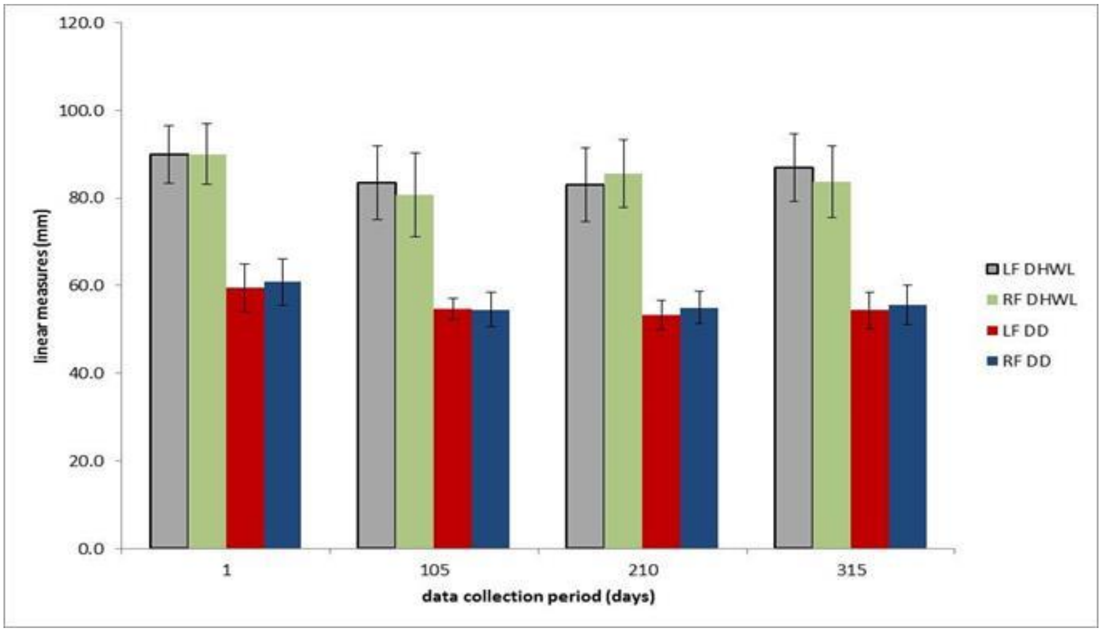

Figure 12 The mean linear DHW measurements. Data is quoted as mean at each data collection point in millimeters (mm). Error bars denote standard deviation.

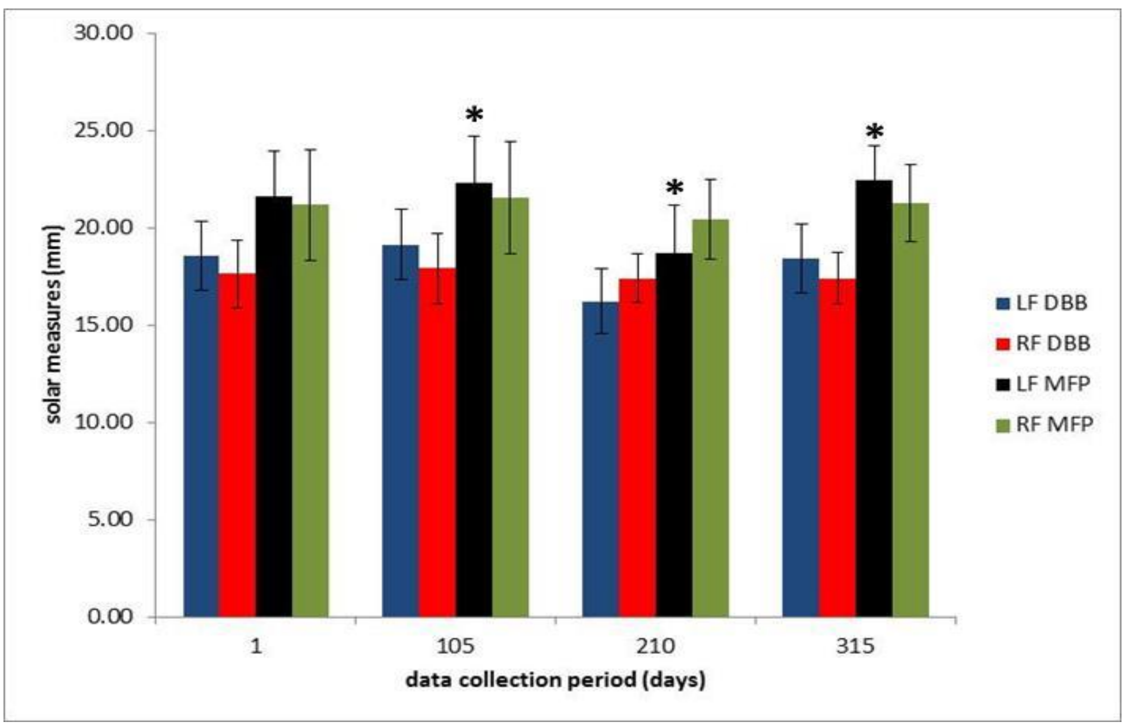

Figure 13 The mean solar measurements. Data is quoted as mean at each data collection point in millimeters (mm). Error bars denote standard deviation. There was a significant difference (*) $p<0.05$ in the left fore at each data collection point. *Significance was tested at $p<0.05$.*

Results indicate there were no significant differences in mean pre-trim linear measurements between alternative trimming measurements, $p>0.05$, prior to alternating trimming methods **(Table 2)**. However there were significant differences in solar measurements at the medial frog point and the dorsodistal bearing border in the left front between data collection points $p<0.05$ both.

Figure 13 also highlights the main effects on the variation of solar measurements at DBB between feet initially trimmed using dorsal wall rounding and those trimmed with a flat DHW. The RF feet were initially trimmed with the flat line DHW technique and exhibit no difference in DBB solar measurements. Significantly the LF exhibits a similar trend in difference of the DBB solar measurement to the differences in LF MFP.

The visual effects of the different trimming methods on a representative sample (horse A) throughout the data collection period are illustrated on **(Figure 14).**

It is noteworthy however that when the trimming methodologies were alternated at day 105 four of the six right fore feet (75%) initially trimmed with the flat line hoof method exhibited clinical signs of sub solar hematoma at a point slightly dorsal to the true point of frog **(Figure 15)**.

Summary of Results

1. There were no significant statistical differences between trimming methods in all pre-trim linear measurements over the duration of the study.
2. There were significant statistical differences in solar depth measurements between left and right front feet that related to the trimming method used on day 1 $p<0.05$.
3. There were no interactions between the periods between alternating trimming type for any of the data measurements.

This investigation found evidence to support the hypothesis that there is a significant difference in solar arch morphology between trimming methods. Accordingly, this limited study indicates that Ho2 should be accepted.

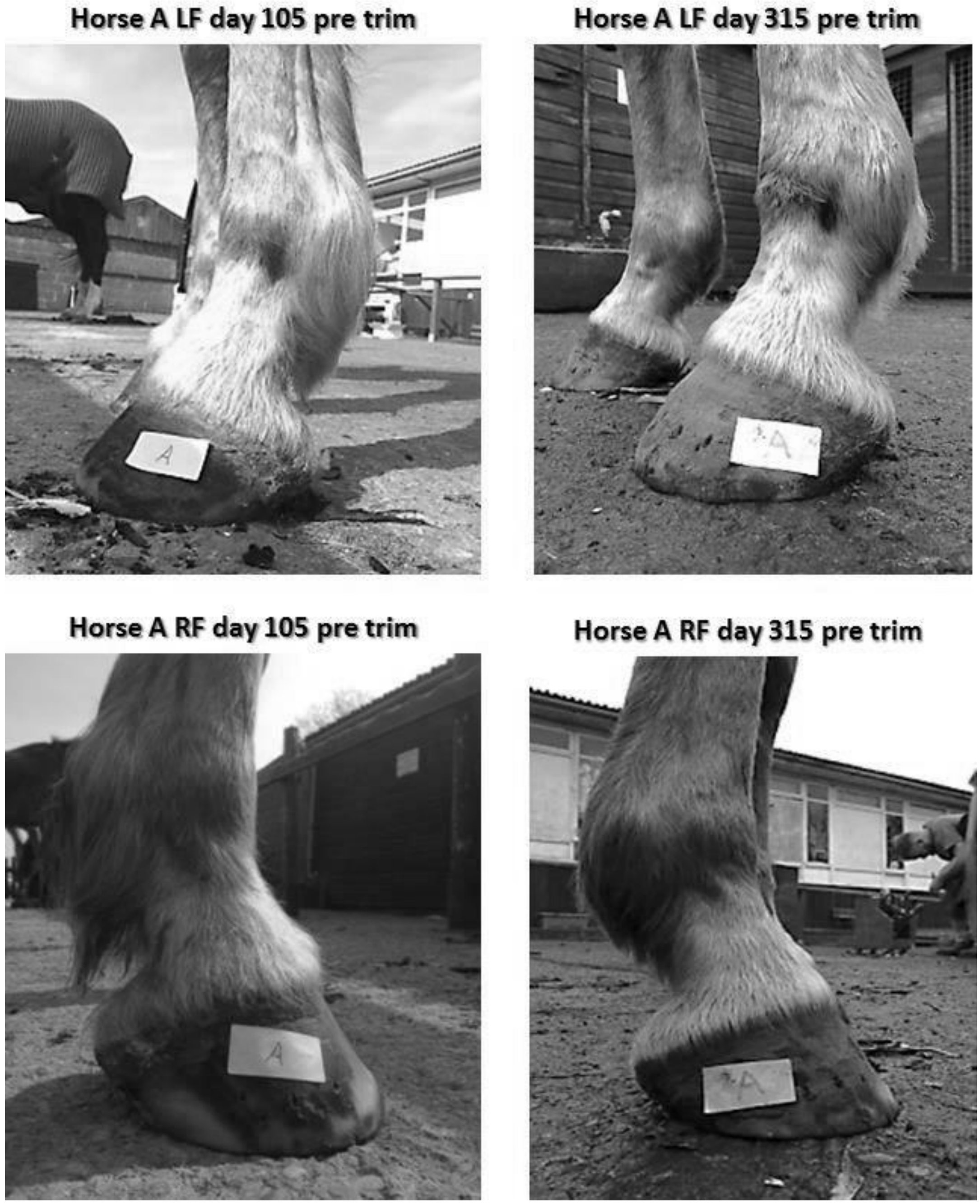

Figure 14 The lateral view of the typical main effects between two different trimming methods on the left and right front feet (horse A) at data collection period's day 105 prior to the changes in trimming methods and day 315 at the end of the trial. The trimming methods are displayed in figure 8.

Severe solar bruising evident in horse C day 105

Typical solar bruising evident in horses D, E & F at day 105

Figure 15 The loss of solar arch depth was further evident by clinical appearance of bruising at a point slightly dorsal to the true point of frog in four of the six horse in the sample in the right fore feet (75%).

6. Discussion

It was hypothesized that there would be significant differences in linear DHWL between feet trimmed with the dorsal rounding method and those trimmed with a commonly used flat line method. It was further hypothesized there would be a significant difference in solar arch measurements between the two trimming methods. Both hypotheses were tested, using the methodology previously described, in the current study incorporating a double cross over study of six similar riding school horses.

Current theories

Current farriery best practice is based on the principal that the bearing border of the foot should be trimmed perpendicular to the longitudinal axis of the lower limb; this is reiterated in current texts (Williams & Deacon 1999 Curtis 2002, 2006, & Stashak 2002). This researcher acknowledges the importance of achieving a normal hoof pastern axis, however in practice HPA is generally easily manipulated by excess trimming of the DHW in the toe region and reduced trimming of the heels.

Main findings

This investigation found no evidence in the study sample (n=6) to support the hypothesis that there would be a difference in linear hoof measurements between feet trimmed with two different methods of DHW dressing, the traditional flat line or the dorsal rounding methods; accordingly hypothesis Ho1 was rejected. There were, however, significant statistical differences in solar arch morphology between feet initially trimmed with the dorsal rounding method and those trimmed in the more traditional flat line method (**Figure 13, Table 2**), Accordingly, this limited study indicates that Ho2 should be accepted.

Study design

The study utilised a double cross over design with each horse as its own control. This type of study is an acceptable methodology in clinical studies where large sample sizes are difficult to find. The design allows a direct comparison of the effects different treatments have against the originally applied trimming protocol. The results showed the double cross over design for data collection to be an effective methodology for farriery-based research. This can be clearly seen on the interaction plot for the left fore (LF) in **Annex D D2**.

Limitations of the study

A larger sample size would provide more comprehensive results. However it proved difficult to secure a larger group of horses that were all kept in the same environment, with similar foot and limb conformation and foot size. The cross over pilot study methodology was chosen to demonstrate the effects of the small sample size. Statistical power analysis suggests a sample size of 20 for any subsequent longitudinal study.

The results indicate that additional morphological measurements such as the vertical height of the DHW, DHWA, heel angle (HA), heel height and additional solar arch measurements may have produced a more complete data set from which to compare overall morphological changes to the hoof. A more detailed analysis of digit conformation using radiology may have influenced the final analysis of the results and allowed for direct comparison of treatment type to individual conformation. This may have proved to be of greater clinical significance. An increased number of shoeing cycles between change in trimming methodology may produce a more thorough evaluation of the effects of the trim, therefore allowing the flat lined dressed foot more time to recover, during the change of trimming protocol from flat lined to dorsal rounded.

Post trim measurements may have demonstrated consistency of trimming methodology; however the trimming protocol used has been shown to produce consistent measurements **(Annex D D1).** Additionally all trimming was performed by the author to the standardised trimming methods previously described.

All the above would suggest that further research is required to measure the effects the different trimming techniques have on a variety of conformation types.

Importance/relevance of main findings

The results show statistically significant differences in solar arch measurements between trimming methods ($p<0.05$) and suggest that flare dressing the DHW flat and parallel to an ideal phalangeal axis may increase the likelihood of solar arch deformation and collapse. The results from the current study contradict the weight of anecdotal evidence in support of DHW flare dressing as defined within numerous farriery texts (Hickman & Humphrey 1988; Williams & Deacon 1999; Stashak 2002; Curtis 2002, 2006).

Results also demonstrate a strong trend in the differences in dorsal wall migration for individual horses **(Table 2)** over the duration of the trial period $p<0.05$. The variation in results between individual horses **(Annex D D2)** suggests that considerations outside the scope of the current study influence the mechanical behaviour of the hoof under load particularly when the strength of the DHW is compromised. Initially the right fore was trimmed using the standard flat line technique. The main effects on solar arch deformation **(Figure 13**) suggest that following the initial trimming of the right fore using the flat line method the DHW integral strength may have been compromised. This appears to suggest that the flat line trimming method inhibited the hoofs ability to effectively manage peripheral weight bearing. The results clearly show a loss of solar arch depth at MFP, which remained unchanged in the right fore following the initial data collection. The loss of solar arch depth was further evidenced by clinical appearance of bruising at a point slightly dorsal to the true point of frog in in four of the six right fore feet in the sample (75%) **(Figure15).**

Previous studies support the hypotheses that solar arch angulation is potentially beneficial to the health of the foot (Hood et al 2001; Clayton 2011). It is well documented in current farriery literature that the ideal solar arch is domed in appearance and that the solar arch flattens under load. Other studies have also demonstrated that under normal conditions the maximum load at mid stance and during the acceleration stage of the stance phase causes the dorsodistal hoof wall to migrate dorsally (Douglas et al 1998). This is believed to be part of the hoofs normal physiological ability to lessen the effects of load. The results from the current study suggest that manipulation of the DHW affects the range of this deformation. Dorsal wall rounding may maintain or increase the hoofs ability to manage peripheral loading of the hoof wall by maintaining both strength and durability. This is partly supported by Hircock et al (2014) who, using rosette triaxle strain gauges, demonstrated an increase in principle strain at the dorsodistal hoof wall following compressive wall deformation associated with Laminitic episodes.

The implications of the results are that trimming and shoeing protocols should be tailored to the individual needs in order to best manage the biomechanical forces that influence hoof health. In particular the trim should not only maintain correct geometric proportions but should retain DHW strength. Where this is not possible as a result of anatomical variation or distortion, shoe placement and modification of the shoe to reduce leverage at unrollement might be more beneficial than flat lining the DHW to match the phalangeal axis. In the authors opinion the DHW requires pressure during unrollement to allow for a smooth energy transfer. So therefore DHW shoe contact is paramount to hoof health. These results demonstrate dorsal wall rounding has a positive influence in the reduction of compressive forces associated with hoof capsule distortion.

7. Conclusion and clinical relevance

In conclusion, these results suggest that different trimming techniques can affect the mechanical behaviour of the hoof wall and that under certain conditions the loss of integral strength of the DHW. Combined with sheer force created by extended extensor moments on the hoof this may well affect the solar arch morphology. It would appear that dorsal rounding might deflect force vectors associated with the elastic deformation characteristics of horn and this might suggest that the dorsal rounding method might prove to be of benefit to the overall health of the hoof by inhibiting excess DHW and solar arch deformation. Further more extensive research as described is warranted in the future.

Manufacturers Addresses:

Arthur Cottam and Co (Horseshoe) Ltd. Carrwood Road, Chesterfield Trading Estate, Chesterfield. S41 9QB

Microsoft Excel: Microsoft UK PLC; Microsoft Campus, Reading Thames Valley Park Reading RG6 1WG

Minitab 17: Minitab Ltd: Brandon Court, Unit E1-E2, Progress Way, Coventry CV3 2TE. United Kingdom

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Annex **A.** Descriptive Horse Data

Name	Breed	Sex	Age	Height	Weight Kg.	Steel section & length
A	T/B	Mare	13	17.0hh	607	7/8x3/8 x 13”
B	T/B	Gelding	18	15.2hh	474	3/4 x3/8 x 12”
C	T/B x Welsh	Mare	18	14.0hh	427	3/4 x3/8 x 12”
D	Welsh	Gelding	20	14.1hh	482	3/4 x3/8 x 12¼”
E	T/B	Mare	15	16.2hh	584	7/8x3/8 x 13”
F	Welsh	Gelding	16	14.2hh	461	3/4 x3/8 x 12¼”

Descriptive data of the sample used in the current study.

Annex **B.** Owner consent

Robinsons Equiteach
Tunstall Lane
Stokesly
Cleveland
North Yorkshire

To Whom it May Concern:

This is to confirm that I have been advised, and consented to, the nature of the research to be carried out on my horse's feet by Steven Beane AWCF.

I understand that should I so wish I can withdraw all of my animals from this trial at any time without notice.

I have been advised that all descriptive data relating to myself or any of my animals included in this trial will be deleted on its successful completion.

Yours Sincerly

Annex **C.** Safety Data Sheet

Material Safety Data Sheet
PAD MEDIUM A
Rev. 01/2006

Cottam veterinary solutions

ARTHUR COTTAM HORSESHOES LTD

COTTAM HOOF PAD MEDIUM

TWO COMPONENTS PU ELASTOMER

1. IDENTIFICATION:
   - **Name of Substance or Preparation:** PAD MEDIUM Part A
   - **Unique Reference Number:** PAD MEDIUM A
   - **Supplier:**

     Arthur Cottam & Co Horseshoes Ltd, Carrwood Road, Chesterfield Trading Estate, Chesterfied, England S41 9QB

     Telephone: +44 (0) 1246 454249 Fax: +44 (0) 1246 260274

2. COMPOSITION AND INGREDIENTS:

Components Contributing to Hazard Classification	% by Wt.	CAS No.	Hazard	Risk phrases
Polyether Polyol	100	9082-00-2	N/A	N/A

3. HAZARDS IDENTIFICATION:
   - **CHIP Classification:** -
   - **Risk Phrases:** -
   - **Other Information:** -

4. FIRST AID MEASURES
   - **Immediate medical attention required?** No.
   - **Professional assistance from physician required?** No.
   - **Inhalation:** Remove to fresh air and allow to rest.
   - **Skin Contact:** Wash contaminated area with soap and water. Use skin cream to prevent dryness. Launder contaminated clothing.
   - **Eye Contact:** Flush immediately with water for 10-15 minutes prising eyelids open with fingers. If irritation persists seek medical attention.
   - **Ingestion:** Give plenty of water to drink and seek medical attention.

5. FIRE FIGHTING MEASURES:
   - **Extinguishing Media:**
     - **Suitable:** Foam, dry chemical, CO_2, water mist.
     - **Not to be used:** Water as jet.
     - **Other Comments:** Where large quantities are involved breathing apparatus should be used.
   - **Special Exposure Hazards:** None.
   - **Special Fire Fighting Procedures:** None.
   - **Protective Equipment Required:** Where large quantities are involved breathing apparatus should be used.

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6. **Accidental Release Measures:**
   - **Personal Precautions:** Wear suitable protective clothing.
   - **Environmental Precautions:** Do not allow to enter drains or watercourses.
   - **Clean-Up Procedures:** Use absorbent (eg. sawdust, earth or sand) and sweep up into suitable disposal container.

7. **Handling and Storage**
   - **Handling:** Observe standard industrial hygiene practices.
   - **Storage:** Store in a dry place at 5-25°C in tightly sealed original containers.

8. **Exposure Controls**
   - **Take Measures to Prevent:** Contact with eyes.
   - **Exposure Control Limits:** -
   - **Respiratory Protection:** Normal ventilation should be adequate for this product. However this is used in conjunction with an isocyanate, refer to that Safety Data Sheet for further details.
   - **Hand Protection:** Wear suitable gloves.
   - **Skin Protection:** Wear suitable protective clothing.
   - **Eye Protection:** Wear goggles or safety glasses. Locate eyewash bottle in immediate area of work.

9. **Physical and Chemical Properties:**
   - **Appearance:** Liquid
   - **Colour:** Transparent
   - **pH:** N/A
   - **Boiling Point:** N/M
   - **Melting Point:** N/M
   - **Flashpoint:** >200°C
   - **Autoflammability:** N/M
   - **Flammability:** Not flammable
   - **Explosive Properties:** N/A
   - **Oxidising Properties:** N/A
   - **Vapour Pressure:** Very Low
   - **Relative Density:** 1.04
   - **Solubility in Water:** Insoluble
   - **Other:** -

10. **Stability and Reactivity:**
    - **Conditions to Avoid:** Naked flame, extremes of temperature.
    - **Materials to Avoid:** Isocyanates, strong acids and oxidising agents.
    - **Hazardous Decomposition Products:** Above 200°C and on combustion - oxides of carbon.

11. **Toxicological Information:**
    - No information available.

12. **Ecological Information:**
    - This product is, in part, biodegradable. However it does contain small quantities of materials wish may be harmful to aquatic life.

13. **Disposal Considerations:**
    - **Likely residues and waste products:** None.
    - **Safe handling of residues and waste product:** Dispose of by controlled incineration or authorised landfill in accordance with local authority regulations.

Cottam veterinary solutions

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Cottam veterinary solutions

14. Transport Information:

- **UN No.: -**
- **ADR/VLG: -**
- **ADNR/VBG: -**
- **RID/VSG: -**
- **IMO/IMDG: -**
- **ICAO/IATA: -**

This product is not classified as hazardous for transport.

15. Regulatory Information:

- **Supply Label Information: -**
- **Risk Phrases: -**
- **Safety Phrases:**
  - S36 Wear suitable protective clothing
- **Other: -**

16. Other Information

- **Training advice:** Please read all datasheets carefully. If any point remains unclear or if further training is required please contact Inchimica division of Intermedia s.a.s.
- **Recommended uses and restrictions:** Polyol component for two-part polyurethane in conjunction with an isocyanate. No other use recommended.
- **Further information sources:** Please refer to the Safety Data Sheet for the accompanying isocyanate for further information.
- **Sources of key data used to compile this SDS:** Raw material data. Occupational Exposure Limits 1997. Guidance Note EH40/98. Approved Supply List (CHIP Regulations 1996).

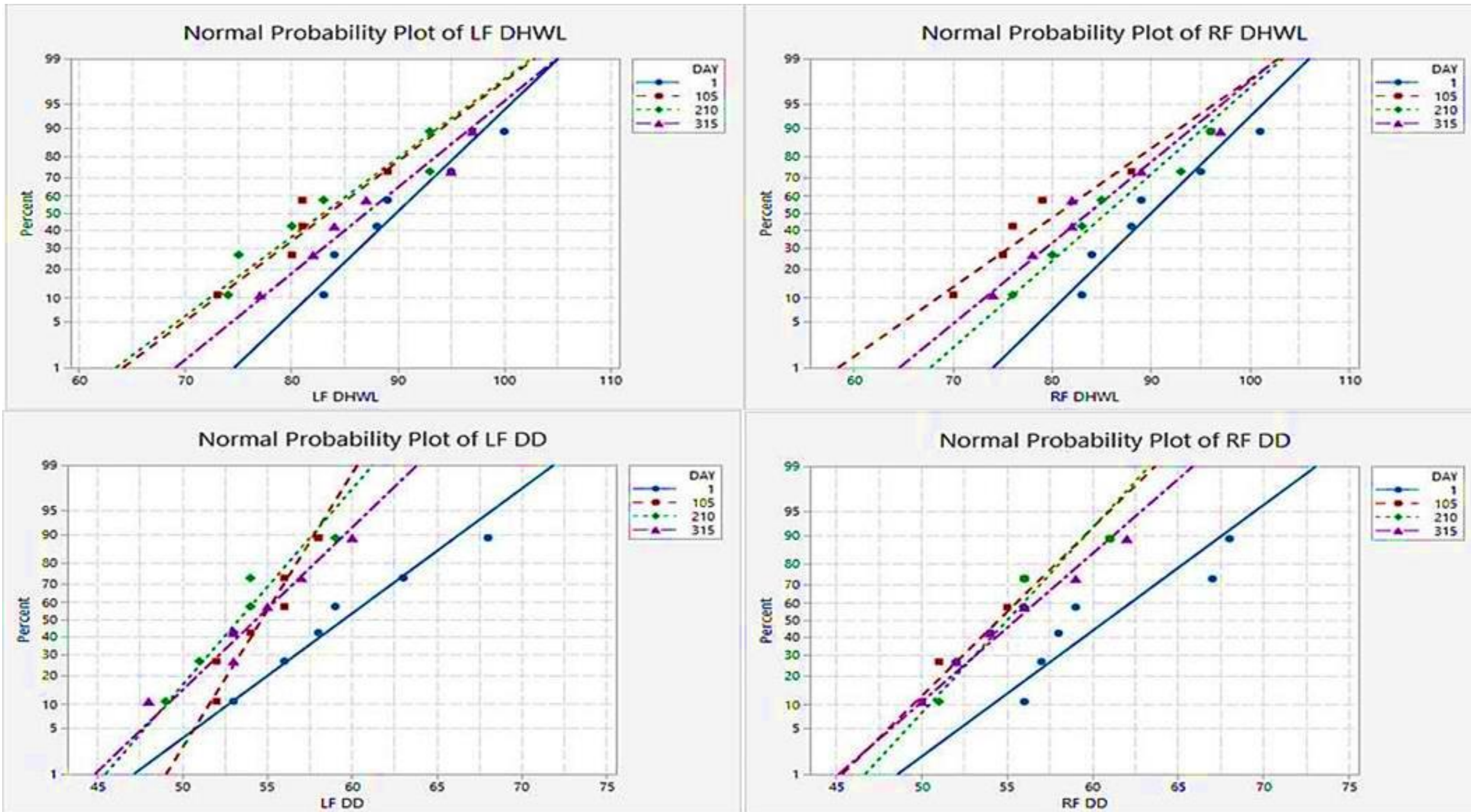
This Safety Data Sheet has been prepared and supplied in accordance with the **Chemicals (Hazard Identification and Packaging) Regulations 1994** as amended for use by persons capable of understanding the information contained herein for the protection of the health and safety of users.

It is therefore important that this data sheet is passed to the appropriate person so that the information may be acted upon if necessary.

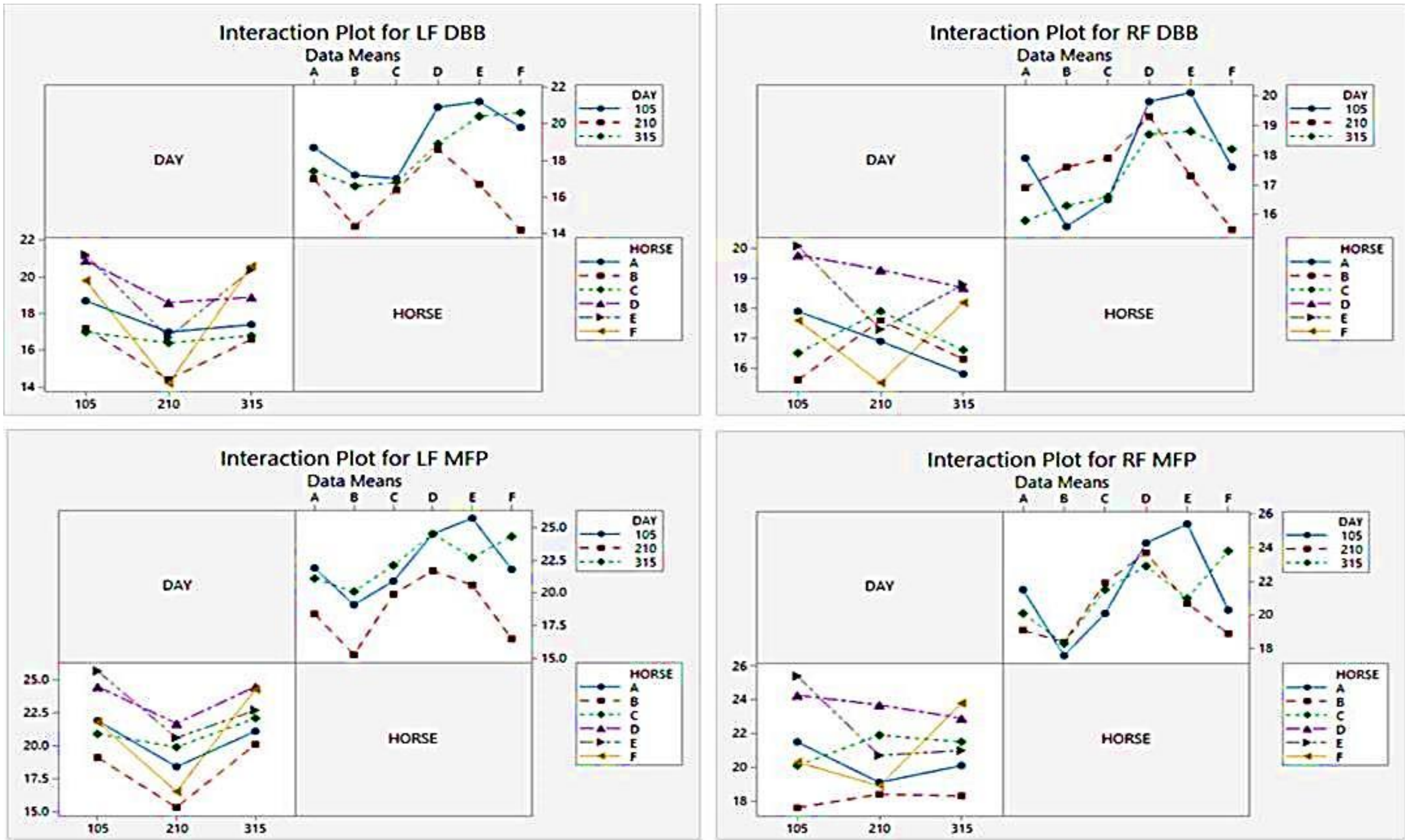
NOTE: This SDS has been prepared from information we believe to be reliable, however it is provided without warranty, expressed or implied, as to its correctness. Since the conditions of handling, storage, use and disposal of this material are beyond our control we accept no responsibility whatsoever for any loss, damage or expense which results from the handling, storage, use or disposal of this material.

Arthur Cottam & Co Horseshoes Ltd, Carrwood Road, Chesterfield Trading Estate, Chesterfield, England S41 9QB Telephone: +44 (0) 1246 454249 Fax: +44 (0) 1246 260274
Web www.cottamhorseshoes.com Email sales@cottamhorseshoes.com

Annex **D.** Additional statistical data.

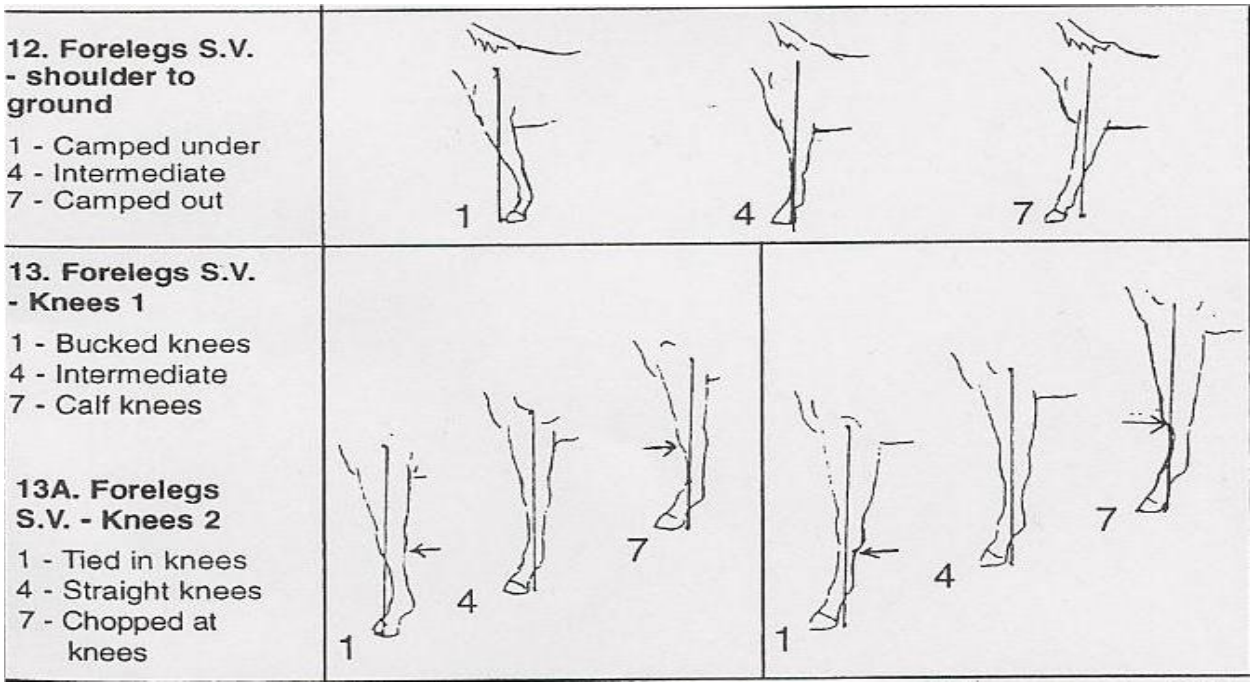


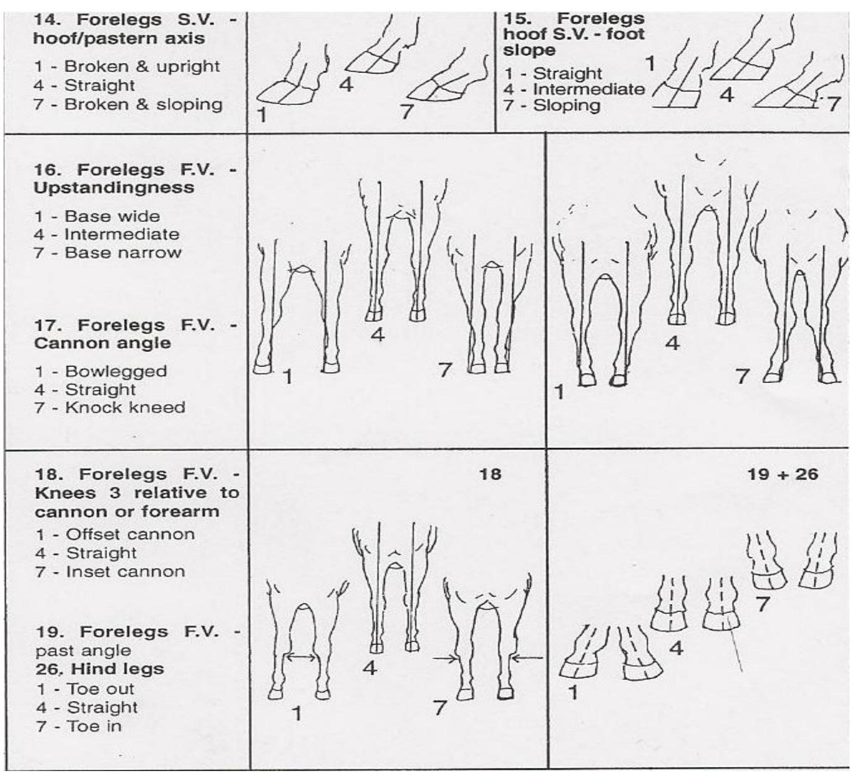
D1 The distribution probability for linear measurements of dorsal hoof wall length (DHWL) and solar length from the point of frog to dorsodistal border of the hoof wall (DD) at days 1, 105, 210 & 315. With the exception of DD at day1 distribution was normal p>0.05. Significance was tested at 95%



D2 The results of multi factorial ANOVA between solar measurement variables and the treatment type and individual horses shows no interactions between horse and treatment type for all measurements. Significance is calculated at p<0.05 and is adjusted using Tukeys post-hoc analysis.

Annex **E.** Mawdsley et al conformation scoring.





Annex **F.** National Standards in Farriery.

The following is extracted from the Lantra 2011 (updated by 1st 4 Sport 2014) assessment guide for the national standards in farriery for apprentices & approved training farriers of the advanced apprenticeship in farriery page 36 and 37.

Unit 8 Trim and dress hooves

Recommended Types of Evidence	Recommended Assessment Block	Notes
1. Observation of practical performance 2. Q & A 3. Witness testimony	End of Block 7	• A minimum of 4 feet to be assessed to prove consistency & competency during formal college assessment • Assessment to be linked to other Units, ie units 4 through to and including 11 - amending foot care plan after fitting

Assessment Guidance	
Factors • Age (Young, Mature & Old) • Equine temperament • Condition of hooves • Welfare • Environment • Use of equine	Factors • Fore & Hind feet • A shod equine • An equine to be left unshod

The subject of farriery theory covers several different aspects of the knowledge and understanding required, which includes but is not limited to the following:

- The candidate should be able to demonstrate a working knowledge of common conformation defects in adult equines, in addition to being able to demonstrate background knowledge of normal conformation and movement

- The candidate should be able to demonstrate background knowledge as to the likely contribution to the effect of pathology, diseases and interference injuries to the equine

Assessment questioning as outlined above, i.e. written, oral etc, should test the candidate's knowledge and understanding on gait, flight pattern, deviation of flight pattern in relation to conformation, and must include in depth questioning on.

- The practice and principles of foot balance, this should include
  - Medial lateral, dorsal palmar and solar view aspects in relation to both the hoof pastern axis and general limb conformation
  - Geometric proportions of the hoof
  - Physiology of the hoof's structures as they relate to foot balance
  - Categories and types of feet and how they might relate to the physiology and function of the balanced or imbalanced foot

- Shoe selection and application in relation to breed and type of work and should include a working knowledge of
  - Environmental considerations
  - Gait considerations
  - Temperament characteristics of differing types of equine
  - Preventative and remedial measures which might be taken with equine feet
  - Shoeing cycle times

It is clear that within this unit the art of **achieving and maintaining correct foot balance** is a **core skill**. Written and oral questioning **specific to foot balance** should be of sufficient quantity, and robust enough, to satisfy this **core** requirement of the underpinning knowledge. Similarly assessment **of practical application of foot balance theory should be robust enough to ensure the ongoing welfare of the equine** and for the successful completion of the Diploma in Farriery - Work-Based.

Note:
Foot trimming and preparation are one of the most subjective areas of practical farriery. **For the avoidance of doubt, The Worshipful Company of Farriers Examinations Board** has stated that medial lateral hoof balance shall be assessed by means of the bearing solar border, presenting perpendicular to the longitudinal axis of Metacarpal / tarsal bone, and has determined this as the basis of its assessments for the **Diploma Examination** standards, (practical element).

Except where conformation dictates and the health and welfare of the equine might be at risk (and this should be agreed with the candidate prior to the commencement of assessment) the **WCF** method should be used at all times during formal assessment / sampling opportunities.

The following is extracted from the Lantra 2011 (updated by 1st 4 Sport 2014) assessment guide for the national standards in farriery for apprentices & approved training farriers of the advanced apprenticeship in farriery page 121.

For the purpose of this Reference Guide, the following fit definitions will apply to the associated equine types, as listed overleaf.

Riding Horse Style Fit – riding pony, leisure, pleasure and roadster styles

- Which by definition may generally be slower working, should have shoes fitted with
  - **Upright heels with length as minimum to widest point of frog ± 1/8" or in any event the heels must cover the full buttress heel**

Fit definition – a riding horse style fit is defined, for this purpose, as a symmetrical balanced shoe as defined in 1.3 of the Reference Guide (Assessment Guidance), fitted to the widest point of the frog ± 1/4" or 6mm, and of sufficient width from the quarters as to accommodate all aspects of natural physiology of the foot. The fit should accommodate conformation defects and abnormalities, as agreed and discussed between the candidate and the witness/assessor. Equines with a shoe fitted to this style would be expected to have a shoeing cycle of no less than 5 weeks.