Abstract

Introduction. A commonly encountered anomaly when the front feet of the horse are compared is the occurrence of two differently shaped and sized front feet which can be defined as so-called “uneven” feet. Asymmetry of the forelimbs of the horse is acknowledged as a common condition, which can result in asymmetric movement, abnormities of gait and even lameness. Any possible link between asymmetrical front feet and their corresponding stride parameters to the researcher’s knowledge has yet to be discovered.

Study design. A pilot quantitative and experimental study of ten horses.

Aims. To investigate if a selection of unbroken horses exhibited asymmetrical front feet and if there was an association with asymmetrical stride characteristics.

Materials and methods. Ten unbroken horses were selected with the owner’s consent and the hoof surface area of both front hooves were calculated (Parés 2011). The horses then had 25mm markers attached to the centre of the lateral and medial aspect of the front feet and were assessed for stance duration, stride duration, stride length and stride velocity by making 6 passes, with a handler, across a camera positioned at 90° to the horse. The measurements were calculated at walk and trot by Kinovea® software. The horses were then all trimmed to a protocol described by Caldwell et al (2010) and the measurements of both hoof surface area and stride characteristics repeated to address any hoof balance variability.

Results. The results were analysed using a paired t test and a general linear model ANOVA. There was no significant difference in left and right front hoof surface area at pre and post trim. There were significant differences in stride characteristics in trot but not at walk. The kinematic symmetry indices (KSI) increased post trim with the exception of stance and stride duration at walk.

Conclusion. The causes and effects of static and dynamic asymmetry are multi-factorial, the results of this pilot study did not show a link between uneven feet and dynamic asymmetry.

Significance. Correct and careful farriery can help influence static and dynamic symmetry, provide a shorter stride length and breakover whilst increasing the velocity of movement.

Chapter 1 – Rationale and Introduction

1.1 Rationale

Asymmetry of the forelimbs of the horse is acknowledged as a common condition (Wilson et al 2009) which can result in asymmetric movement, abnormities of gait and even lameness (Roepstorff et al 2009). The researcher has a particular interest in this area and how farriery intervention might possibly rectify the problem with particular regard to facilitating sound gait and optimal performance in a variety of equine disciplines. To date, most of the literature regarding asymmetry in the horse has been anecdotal with little evidence of if it exists and the affect it might have on gait.

1.2 The hoof

The hoof is the insensitive and non-vascular covering of the end of the limb and can be divided into the wall, sole and frog (Colles and Ware 2010). A hoof that is proportional to body size allows an ideal distribution of body weight over the laminar surface area, prevents the over compression of the sensitive and bony structures and allows for normal expansion of the hoof during movement (Butler and Butler 2005). The hoof serves the normal functions of the epidermis by protecting the underlying sensitive structures from friction, extreme hot and cold temperatures, dehydration and infection (Hickman and Humphrey 1988). The hoof capsule is said to consist of 50% carbon, oxygen, nitrogen, hydrogen and sulphur. The hoof wall contains 10% moisture, the solar surface 30 % moisture and the frog 42% moisture. The average percentage of fat in the hoof wall is 0.75%, the solar surface contains 0.25% fat and the frog 0.50% fat (Van Nassau 2007). According to Curtis (2006), the dorsal wall, side wall and quarters has a growth rate of 7mm per month, taking 9-12 months to completely grow out. Curtis (2006) further suggested that the growth rate can be affected by factors such as genetics, age, seasonal differences, illness and the area of the hoof. The hoof wall is the part of the hoof that can be seen when the foot is placed on the ground. The horn in this area is a modification of the epidermis, skin, and is produced by the coronary corium (Hickman and Humphrey 1988). The lower surface of the coronary corium contain hundreds of microscopic conical structures known as papillae, which produces keratinized intra tubular horn cells. The wall does not form a complete circle but is reflected inwards and forwards at an acute angle at the heels to form the bars. The bars appear on the ground surface of the foot as ridges between the sole and frog (Butler and Butler 2005). The hoof wall bears most of the horse’s weight, resists wear and trauma and cuts into the ground to provide traction. The stratum externum of the dorsal hoof wall commonly called the periople, which is found adjacent to the coronary corium, is a soft layer of horn whose primary function is to regulate moisture levels within the hoof wall (Reilly et al 1998). It is thickest proximally and gradually disintegrates distally (Fig. 1.1).

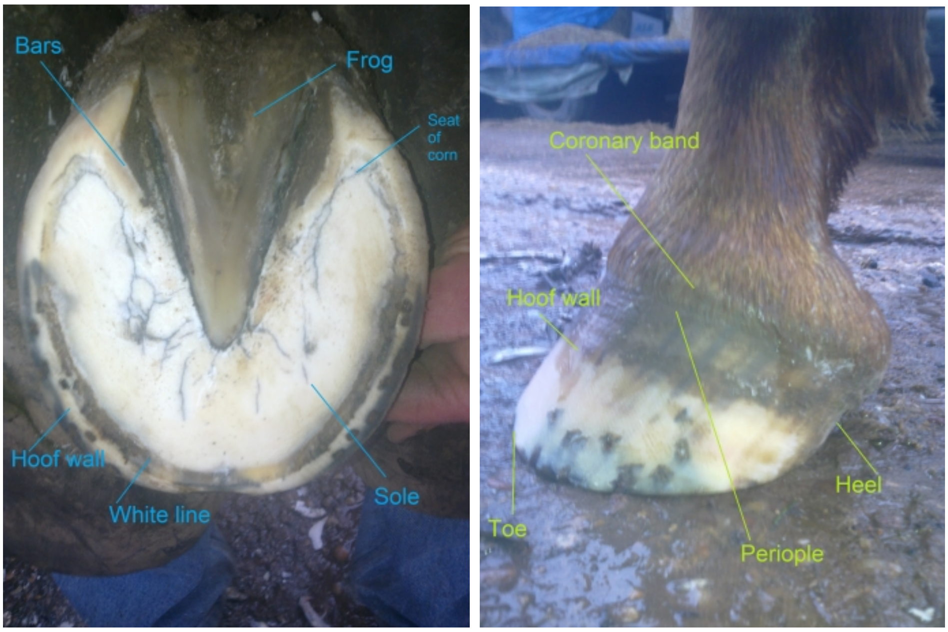

Fig. 1.1 Visible external anatomy of the hoof. Left - basel surface, right - lateral view.

The stratum medium or middle layer of horn, forms the main bulk of the wall and is made up of four layers of varying density, spring like horn tubules orientated parallel to each other. These horn tubules are cemented together by keratinized fibrils known as inter tubular horn (Pollitt 1998). The inner layer, stratum internum, consists of the epidermal lamellar which interdigitate with the dermal lamellar forming a strong bond that attaches the hoof wall to the distal phalanx (Pollitt 1998). The other epidermal structures of the hoof include the sole and frog which are constructed in the same manner as the hoof wall but differ in orientation, density and moisture content according to their primary function. Approximately 6-9mm of horny sole covers the sole corium in the average sized horse although the sole can be thinner in thoroughbreds and warmbloods (Balch et al 1997). The horny frog is produced from the frog corium and is positioned between the bars of the hoof to aid in traction and shock absorption (Reilly et al 1998).

1.3 The stride

A stride is the action of the leg between successive footprints made by the same foot. The stride may be divided into a swing and a stance phase (Clayton and Back 2001). The swing phase is when the foot is off the ground and moving. The stance phase is from initial ground contact through to unrollment and is best categorised into four stages; the first being impact, initial contact and primary shock absorption, the second impact deceleration, the third is the support stage and stabilisation and finally unrollment and propulsion (Thomason et al 2009). Horses change speed by altering the spatial and temporal relationships between their limbs to produce different gaits and to vary the extension within a gait (Back and Clayton 2001). Within any gait, the stride velocity is the product of stride length and stride duration. The walk gait is a four beat gait, averaging at four miles per hour. Back and Clayton (2001) stated that a good walk should display even, active, rhythmical steps with impulsion. The trot gait is a symmetrical, diagonal two beat gait in which the limbs form diagonal pairs (Fig. 1.2).

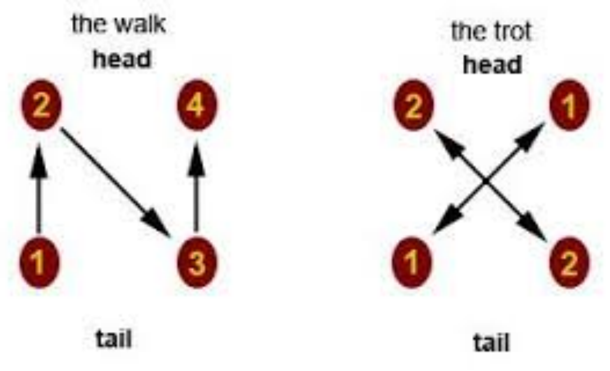

Fig 1.2 This image illustrates the footfalls of the walk and trot gait.

The sequence of footfalls at the trot is right hind + left front then left hind + right front. At trot each pair of limbs strike the ground at a rate of 70-80 beats per minute.

(McGreevy and McLean 2010). A recent study by Wood (2013) investigated the effects of steel and aluminum shoes on stride length at trot and found a significant difference of stride length between steel and aluminum shoes.

1.4 Static asymmetry

A commonly encountered anomaly when the front feet of the horse are compared is the occurrence of two differently shaped and sized front feet which can be defined as so-called “uneven” feet (Ducro et al 2009). Frequently the smaller hoof will be quite differently shaped from its partner, with more growth height occurring at the heels and converging compression marks occurring midway on the anterior hoof wall (Fig. 1.3).

Fig. 1.3 Differing heel heights and angles are common with mismatched feet. The hoof that is closest has a lower heel and more acute heel angle compared to the hoof in the background.

The appearance of this type of hoof has led to the belief that the hoof is contracted, whilst the larger hoof is thought to have gained its size due to bearing more weight (Weller et al 2006). The causes of this condition are considered to include flexural limb deformity, limb length disparity, uneven bone growth due to injury, pectoral paralysis (Butler and Butler 2005), grazing stance (Van Heel et al 2006) and lameness (Colles and Ware 2010).

Arabian et al (2001) using free body calculations suggested a formula for calculating hoof mass using stepwise linear regression analysis. Parés (2011) developed a non linear model for estimating hoof surface area in unshod Cavall Pirinec Catalá horses. Parés and Oosterlinck (2012) then used the developed hoof surface area equation to investigate hoof size and symmetry in young Catalan Pyrenean horses reared under semi-intensive conditions, the study found a very high left-right symmetry, 98%, for hoof surface area. In a recent unpublished study using volume displacement by Caldwell et al (2012) they suggested a formula based on specific external hoof measures, for calculating hoof volume as a means of identifying asymmetrical feet from cadaver specimens. The study however, stated that asymmetry in linear measurements do not necessarily equate to asymmetry of volume which may cause limitations when comparing the hoof data to limb length data.

1.4 Dynamic asymmetry

The survival of horses is dependent on their ability to successfully evade all predators and cover short distances rapidly; this has resulted in horses evolving as well balanced sprinting animals with long limbs (Clayton 2004). Perfect balance in the equine is currently defined as symmetry in both appearance and movement thus maintaining symmetrical stride lengths and smooth and equal lead leg changes

(Buchner 2001). Typically the closer a horse comes to displaying symmetrical movement, the more it is considered to be a “natural mover” (Gray 1989) which is desirable in performance horses (Fig 1.4).

Fig. 1.4 This image illustrates the trot gait which is asymmetrical, diagonal two beat in which the limbs form diagonal pairs.

Little research has been performed into why asymmetry exists in the horse although it has been suggested, in a study on grazing stance of juveniles by Van Heel et al (2006). There have been numerous publications of the effects of straightness training for the horse (Klimke 1985, Bell 2005, Higgins 2009, McGreevy and McLean 2010) which suggest that the rider can have an influence on the degree of asymmetry in the horse. The central tenet of the diagnosis of equine lameness is the evaluation of locomotion symmetry, however to the researcher’s knowledge; no systematic study of the locomotion symmetry of sound horses trotting in standard conditions has been reported. This link between asymmetrical front feet and their corresponding stride parameters to the researcher’s knowledge has yet to be discovered.

Chapter 2 - Literature Review

2.1 Introduction

The amount of available research in farriery has until recently been limited. The research methods used for this study included, sourcing veterinary publications such as the Equine Veterinary Journal and university libraries. The internet research utilised scientific paper specific search engines; Science Direct, Wiley on-line and Google Scholar. Keywords searched included equine hoof, equine asymmetry, stride length, hoof measurements and gait analysis.

2.2 The existence of static asymmetry and laterality

Van Heel et al (2006) hypothesised that the occurrence of uneven feet was related to the development of lateralised grazing behaviour in foals. 24 warm blood foals were selected, however, there was no mention of any exclusion criteria or if ethical approval had been acquired. Two people were assigned twelve foals each and made observations every ten minutes for one eight hour day per week. A preference test was developed that encouraged the foals to reach a test area and eat food from the ground fifteen times, from varying distances. The difference between the front feet was measured using video recording with a known measurement placed in view of the camera for calibration. The foals were then placed into two groups; preference or non-preference. Unevenness was defined by the relative intra-individual difference in hoof angle. The foals with a value above the mean were considered uneven. There is no mention however, of how any measurements, such as the position of the hoof in relation to the camera or whether the foal was stood weight bearing on all four feet were made, which throws doubt on the validity and reliability of the study.

The differences were tested with a one-tailed *t* test and linearity tests performed with a linear regression analysis. Both of these statistical analysis are not considered suitable for the data obtained. Petrie and Watson (2006) stated that when comparing two data sets a two tailed significance test is required to provide reliable statistical data. Petrie and Watson (2006) also stated that linearity cannot be tested by linear regression as it is performed assuming linearity to be the case, which again questions the validity and reliability of the study. The results showed that 46% of the foals at 27 weeks had developed a significant preference and as a consequence a mean difference of 5.2 degrees was seen in hoof wall angle.

17 of the foals used in the study were then used again at 3 years of age for another study by Van Heel et al (2010). The study suggested that as a consequence of grazing, the foot of the protracted limb developed a more acute hoof angle and the retracted limb developed a more upright hoof. The horses were trimmed by one farrier at 2-3 month intervals, there is no mention of a trimming protocol or standard. As the horses were on such a long trimming cycle with no data collected regarding hoof measurements and parameters, the results obtained would contain many variables. A preference test was developed where the horse had to walk in 15 repetitions, from varying distances, to a food reward on a marked spot on the ground. There measurements were calibrated and each horse was filmed using digital video. For each trial the distance between the front feet had to exceed the (mean + 2 x s.d.) of all 5 control measurements between the front feet were scored as left or right preference. The front feet were assessed for dorsal hoof wall angle and analysed using a *t* test and linearity was tested by regression analysis, this is inappropriate as regression analysis is performed assuming there is already linearity in the data (Petrie and Watson 2006). The small sample size also questions the

validity of the study. The data was collected by a single analyst with no mention of the repeatability of data collection which would leave the results open to individual bias. The discussion stated that there was a strong likelihood that uneven dorsal hoof wall angles between front feet was linked to preference stance when foraging, although this is questionable with only 4 out of the 17 horses studied displaying the characteristics. The discussion also reflected upon the fact that the data would have been influenced by the young horses' isolation from the herd when foraging for food. The findings of the dorsal wall angle difference between front feet were similar to previous findings of Moleman (2005) and Van Heel et al (2006).

Ducro et al (2009) investigated the heritability of foot conformation and the relationship to sports performance in a Dutch warm blood population. The study acknowledged the findings of Van Heel et al (2006) and aimed to quantify if certain sires produced foals with uneven sized feet. The study investigated 44,480 horses bred by 630 sires which were assessed for conformation in order to be registered in a studbook. The measurements and assessments were made by many different assessors whose qualifications and experience were not stated which questions the reliability and validity of the study. The results stated that 250 sires had a 5% chance of producing an offspring with uneven feet and ten sires had a 20% chance of producing an offspring with uneven feet. The studbook entry recorded an average of 5% of horses as having uneven feet which is in disagreement with Van Heel et al's (2006) and (2010) findings.

Warren-Smith and McGreevy (2010) investigated the use of pedometers to estimate motor laterality in grazing horses. 6 horses of varying age, breed and sex were kept in paddocks of approximately 5 hectares and fitted with proprietary exercise boots with an accelerator pedometer placed in each boot by an attachment strap. The horses were left for 8 hours a day for 5 days with the boots attached, after which the boots were removed and readings recorded. The methodology in this study appears to be more reliable and repeatable than the data collected in a similar study by Van Heel et al (2006) as they did not have any human interaction or observation which might have influenced the findings. The results were analysed using a paired t test which is an appropriate statistical study for evaluating two data sets. Over a 5 day period the mean scores for leg movements indicated a left bias in all horses. Although the methodology is significantly different, the findings are in agreement with Van Heel et al (2006) and (2010) that preferences can develop within the horse.

2.3 Measurement of hoof size and asymmetry

A recent study by Parés (2011) suggested a non linear model for estimating hoof surface area in unshod Cavall Pirinenc Catala horses. 228 hooves from 57 horses were obtained from an abattoir after euthanasia. The horses were all around twelve months of age and any hooves with gross lesions such as hoof wall avulsions were excluded from the study. The hooves were drawn around on paper and processed through software, partially developed for the purpose of assessing hoof surface area. A Pearson's correlation was used to investigate relationships between the various hoof measurements. The study indicated that it was possible to estimate hoof surface area from linear measurements and that they were repeatable, non intrusive and easily performed. The implications of this study are that any practitioner can take two measurements of hoof width and hoof length on the solar hoof surface, enter them into the pre-determined formula and have an instant calculation of hoof surface area. Acting upon this evidence, this method was adapted in this study to determine hoof surface area and whether there was any left-right hoof asymmetry.

Parés and Oosterlinck (2012) then developed the hoof surface area model to investigate hoof size and symmetry in young Catalan Pyrenean horses reared under semi intensive conditions. The aim of the study was to investigate the solar length, width, area and symmetry of fore and hind hooves of Catalan Pyrenean horses. The study obtained 128 distal limbs from an abattoir immediately after normal slaughter. None of the hooves had been trimmed or had any other interventions and were considered naturally shaped. Hooves with gross lesions like hoof wall avulsions were excluded from the study. Solar measurements were taken by outlining the perimeter of the distal hoof wall with pen on paper. The measurements and analysis were performed by one operator which leaves the results open to individual bias. The results stated that a high degree of left and right symmetry in the front feet of the Catalan Pyrenean horses existed and that despite a lack of hoof care, no obvious limb dominance, laterality, could be demonstrated using directional symmetry indices. This is in contrast with other studies on laterality (Gray 1989, Van Heel et al 2006, Ducro et al 2009, Warren-Smith and McGreevy 2010) which noted significant laterality. In earlier studies (Kane et al 1998, Arabian et al 2001, Roland et al 2003) the values used for calculation of hoof surface area were smaller than those of Parés and Oosterlinck (2012) which can be explained by the fact that the horses used in that study were of a different breed or age which would have a direct effect on the data obtained.

2.4 The existence of dynamic asymmetry

Pourcelot et al (1997) investigated the locomotion symmetry of sound horses at trot. The aim was defined as being to evaluate locomotion symmetry of sound horses trotting on a track. 13 French warm blood horses of a similar age and height were used in the study. There was no mention of any exclusion criteria or if the sample size was justified for this type of study. The horses were filmed on a rubber examination track which was 20 metres long and 2 metres wide. They were first accustomed to the track then led at a slow trot, 3.15 ± 0.15 m/s. At the end of the trot up, a calibration structure was placed in the view and filmed by 4 high speed cameras. The vertical displacement time and joint angle time were calculated for each joint and converted into a 3D file of actual co-ordinates. The variables were controlled and included ensuring the horses were all trotted up by the same handler and repeating the processes until 5 consistent trot ups of a similar speed were performed and any inconsistent footage was deleted. The results described the coronet, shoulder and elbow as having significant statistical asymmetry in vertical displacement time. The researchers concluded that due to the high values of intra-individual variability in the findings that several trials would be necessary to quantify the locomotion symmetry of the horse. The vertical displacement time diagrams of the coronary bands of the hooves indicated that the asymmetry occurred mainly at the end of the swing phase of the stride. The study indicated that the findings provided standard symmetry indices of sound horses at a slow trot. However, due to the small sample size it can only be a reflection of the 13 horses selected rather than a general assumption of the wider population.

Audgie et al (2001) investigated the kinematic analysis of limb movements in lame trotting horses. The aim was described as using kinematic data to describe the symmetry of fore and hind limbs although it is not clearly stated what they hoped to achieve with this or indeed if they had a hypothesis. A total of 37 horses were used with 24 of those being diagnosed as clinically lame by the Veterinary School of Alfort. 12 were diagnosed with unilateral forelimb lameness and 12 were diagnosed with unilateral hindlimb lameness which allowed for 3 groups of data. 26 reflective markers were applied to the skin of each horse to precise anatomical landmarks. Recordings and 3D movements of the markers were obtained as previously described (Pourcelot et al 1997) using four high speed cameras. A computer programme was used to calculate the kinematic symmetry indices (KSI) with a value of 1.0 being perfect symmetry and 0.0 being completely different. As described by Pourcelot et al (1997), the term 'indice' refers to the symmetry of a pair of markers, whereas the term 'index' refers to the symmetry of the forelimb. There was no mention of the reliability and repeatability of the data obtained. For example, there is no mention of whether the same handler was used, the type of surface the horse was trotted on or if there were any tests for normality with the data acquired. The discussion did indicate that the results could have been affected by inconsistent marker placement on the horses and that asymmetric marker placement could be as high as ± 13°, which gives cause for concern. The findings were similar to those of Pourcelot et al (1997), as the experimental design was very similar this could have been expected. The findings were in disagreement with the findings of Back et al (1993) and Buchner et al (1996). The discussion suggested that the compensation patterns of the head and neck may have influenced the displacement of some of the markers and that hindlimb lameness may have affected the symmetry of the forelimbs. They concluded that the findings indicated that the symmetry of limb movements present different patterns of alteration in lame horses compared to sound horses. As the study used lame horses to obtain kinematic data, the ethical rigour of the study is questionable.

The method of using reference markers adhered to anatomical landmarks was also used by Peham et al (2001). This study focused on the influence of lameness on stride length consistency. 21 horses were selected with mild to moderate lameness and were assessed at trot on a treadmill for a minimum of 12 motion cycles. The horses were assessed whilst lame and following a nerve block. 19 of the 21 horses showed an increase of stride length when nerve blocked sound. However it is not known how long the horses had been accustomed to the treadmill and if this may have influenced the findings. As the horses were suffering from various pathologies and were of various ages, the stride characteristics could have varied significantly both at pre and post analgesia, which casts doubt on the validity and reliability of the study. The asymmetry values were in disagreement with the study by Audgie et al (2001) although this might be explained by the fact the data in this study was obtained from a treadmill and not an examination track.

Roepstorff et al (2009) performed a study investigating the kinetics and kinematics of the left and right rising trot in the horse. The hypothesis of the study was that rising trot would cause one forelimb or hindlimb to move and be loaded differently and this would vary according to the sitting and rising side. There were 7 horses used for the study which were ridden by their expert rider. This sample size is justified later in the discussion as the horses were performing at elite dressage level and therefore less likely to be affected by laterality as they would have been trained to correct any intra-stride asymmetry. The horses then had reflective 19mm diameter markers applied to both wings of the atlas, the spinous processes of T6, L5 and S3, both coxal tuberosities and the lateral sides of the hooves. The horses were then asked to perform rising trot for fifteen strides on both reins and the parameters were compared between left and right rising trot using Qualisys Track Manager Software. The parameters measured included stance duration, peak force, impulse and step length. The results stated that the left fore limb was significantly more loaded in terms of peak forces and impulses when used as the sitting limb in rising trot. The findings of forelimb retraction were similar to that of De Coq et al (2004), this study also found that the addition of a saddle and rider weight increased forelimb retraction.

2.5 Measurement of stride characteristics

The measurement of the stride has been mostly performed attaching reflective markers to the lateral coronary band of the hoof (Pourcelot et al 1997, Audgie et al 2001, Peham et al 2001, Clayton 2004, Roepstorff et al 2009, Wood 2013). The horses in these studies were filmed at 90 degrees to the line of travel and the distance travelled by the marker was assessed using gait analysis software. Most gait analysis software has the ability to measure the time of the footage, so the stride velocity, stance duration and stride duration can also be calculated. During the more recent studies, it was possible to use a higher resolution and increased frame rate with the cameras which allowed for clearer and more accurate results. It is the researcher's opinion that the biggest variable that occurred in all of the previous studies was the differences of age, breed, sex and work regime of the sample size which may have had a significant effect on the findings. This study aimed to provide useful data of asymmetry in adult horses of the same breed and sex that have not been influenced by schooling.

Chapter 3 - Methodology

3.1 Introduction to methodology

Research methodology is a way of thinking; examining critically the various aspects of daily professional work; understanding and formulating guiding principles that govern a particular procedure and developing new theories that contribute to the advancement of a practice. It is a habit of questioning what you do, and a systematic examination of clinical observations to explain and find answers for what you perceive, with a view to instituting appropriate changes for a more effective professional service (Kumar 2011).

A system of models, procedures and techniques used to find the results of a research problem is called the research methodology (Panneerselvam 2004). The purpose of research is to discover answers through the application of scientific protocols. The main aim of research is to discover the truth which is hidden (Kothari 2006). This study focuses on the relationship between variables which is known as a hypothesis testing research study (Kothari 2006). The objectives of research may be classified into quantitative and qualitative. This study used a quantitative design which optimised certain measures of performance of the system of study (Panneerselvam 2004) as opposed to a qualitative design which aims to investigate perceptions.

3.2 Objectives and Aims

This study aimed to investigate the incidence of both static front foot asymmetry and asymmetry of stride length in a cohort of unbroken horses of a similar breed and size. This study also explored if correlations existed between asymmetrical feet and stride parameters. This study could therefore be described as one involving pure research and quantitative evidence.

A research problem must be identified or defined without any ambiguity. Unless it is clearly defined, it will not be possible to proceed and carry out the project, if a researcher proceeds with ill-defined problems, the data gathered may end up with misleading conclusions (Panneerselvam 2004). The problem identified within this study is that most information regarding equine asymmetry is anecdotal without any numerical or statistical data to back up the claims made at conferences or in textbooks. The objective of this study was to develop a method of accurately assessing the symmetry of horses' front feet and locomotion at both walk and trot.

3.3 Hypothesis

A hypothesis is a supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation (Kothari 2006). As stated by Gray (2009), research questions and hypotheses are merely the configuration of issues into a transparent and measurable formulation. The hypothesis for this study is that horses of a similar type, height and weight do not exhibit asymmetrical front feet in terms of hoof size and do not exhibit asymmetrical stride characteristics at walk and trot.

3.4 Research design

Research design provides a complete guideline for data collection and the modelling research should be used to find the best result through a model which consists of an objective function and a set of constraints (Panneerselvam 2004).

3.5 Materials and methods

10 unbroken Cob mares which had previously been used for breeding foals and were kept barren ready for sale, of a similar height, weight and diet were selected. They were then assessed for their left and right hoof parameters which were measured and entered into a pre-prescribed equation by Parés (2011) to create hoof surface area (HSA) data. The horses were then filmed and the stride parameters of the left and right forelimbs assessed by Kinovea® gait analysis software.

3.6 Sample size

The basic objective of any sampling design is to minimise, within the limitation of cost, the gap between the values obtained from the sample (Kumar 2011) and those prevalent in the study population. Due to time and financial constraints of this study along with selecting horses with minimal inter variability, the sample size was set as 10 horses.

Inclusion Criteria

In an attempt to reduce the number of variables in the study, an inclusion criteria was used where 10 unbroken Cob mares of a similar height, ±8 cm from 148 cm and aged between 5 and 8 years, were randomly selected from a population of 25 that were kept barefoot and on the same diet, ad lib haylage and grass, exercise regime, and out at grass. Their feet had not been kept on a regular trimming cycle. Descriptive data of the sample size can be found in Appendix 1. Any horse that fell out of the height tolerance of ±8 cm from 148 cm or was deemed to be lame or unruly were excluded from the study (Baban et al 2009). Similarly any horses with hooves that had gross lesions such as, hoof wall avulsions, were excluded from the study due to the possibility of inconsistent hoof measurements that may affect whole group comparison (Parés 2011).

3.7 Comparison Group

The use of a comparison group may have given the researcher more confidence when inferring that the independent variable, the trim, was responsible for changes in the dependant variable. This would have allowed the researcher to measure between group differences, before exposure to the intervention, which could have substantially reduced the threat of selection bias by revealing whether the groups differed on the dependant variable prior to intervention (Marczyk et al 2005). For this study, the 10 selected horses were assessed and measured for hoof surface area along with stride characteristics pre and post trim protocol, which helped to remove any hoof balanced related variable.

3.8 Data collection

Whilst deciding about the method of data collection to be used, the researcher should keep in mind two types of data, primary and secondary. Kothari (2006) described primary data as data that is collected for the first time, and is original in character, whereas secondary data has already been collected by someone else, and has already been passed through a statistical process. Primary data is collected either through experiments or through survey (Panneerselvam 2004). A researcher conducting an experiment gathers quantitative measurements with the help of which they examine the truth of the hypothesis. In the case of a survey, the data can be collected in a number of ways including, observation, personal interviews, telephonic interviews or mailed questionnaires (Kumar 2011).

The primary data collected in this study comprised of the hoof measurements that were calculated as a result of the examination of each individual calibrated photograph. Primary data was also collected from the digitally calibrated videos for the stride characteristics. This was then entered onto a spreadsheet using Microsoft Excel 2013®. All the data collected was primary data.

3.9 Measuring Protocol

Hooves

The hooves were measured pre and post trim for hoof width (HW) and hoof length (HL) by photographing the feet with a circular, stick on label which measured 1.9 cm, as advocated by Roepstorff et al (2009) attached to the sole of the hoof to provide a means of calibration. A Nikon 1 J1 camera was used for high definition images. White et al (2008) investigated the accuracy of digital photographs for analysis of foot conformation and found a high agreement index between radiographs and photographs with the advantage of no radiation hazard. There was also high levels of intra and inter operator agreement in the study which justified the protocols applied. Using Kinovea® measurement software, the HW and HL were analysed. Hoof width was defined as being the widest part of the hoof between the quarters and hoof length being the point from the centre of the toe to the most palmar aspect of the central sulci of the frog (Fig. 3.1).

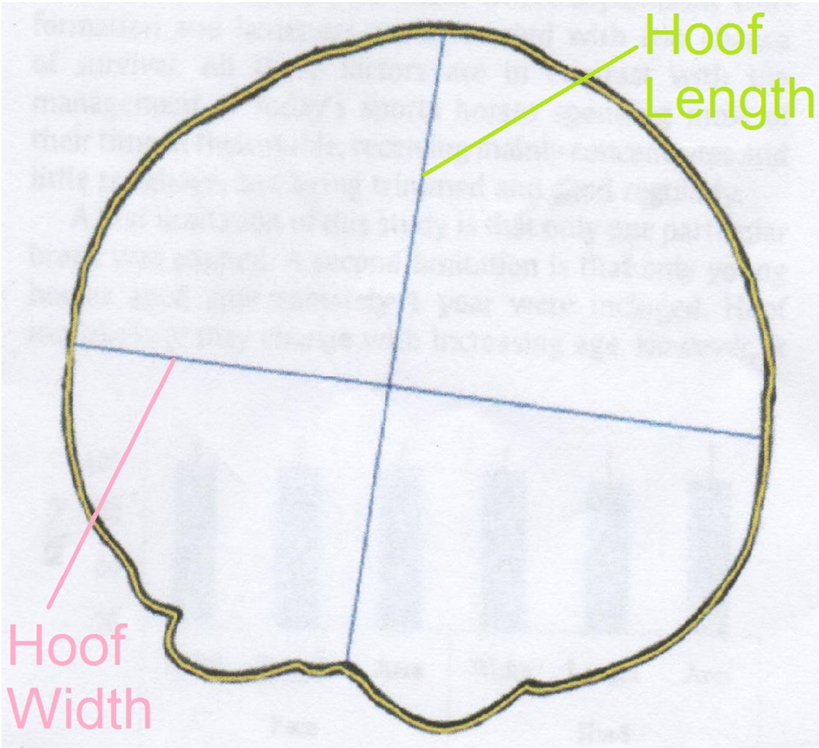

Fig. 3.1 The measurement technique for hoof width and hoof length – adapted from Parés and Oosterlinck (2012).

All of these measurements were taken in centimetres (cm) and entered into the Parés (2011) pre prescribed area calculation below:

$$(1.2295 \text{ x HW})^{1.0710} \text{ x } (\text{HL})^{0.7723} = \text{HSA cm}^2$$

The HSA of the left and right hooves was then calculated. The horses were trimmed on the front feet by the researcher using a standardised trimming protocol (Caldwell et al 2010) and assessed by an experienced farrier for accuracy and competency (Fig. 3.2).

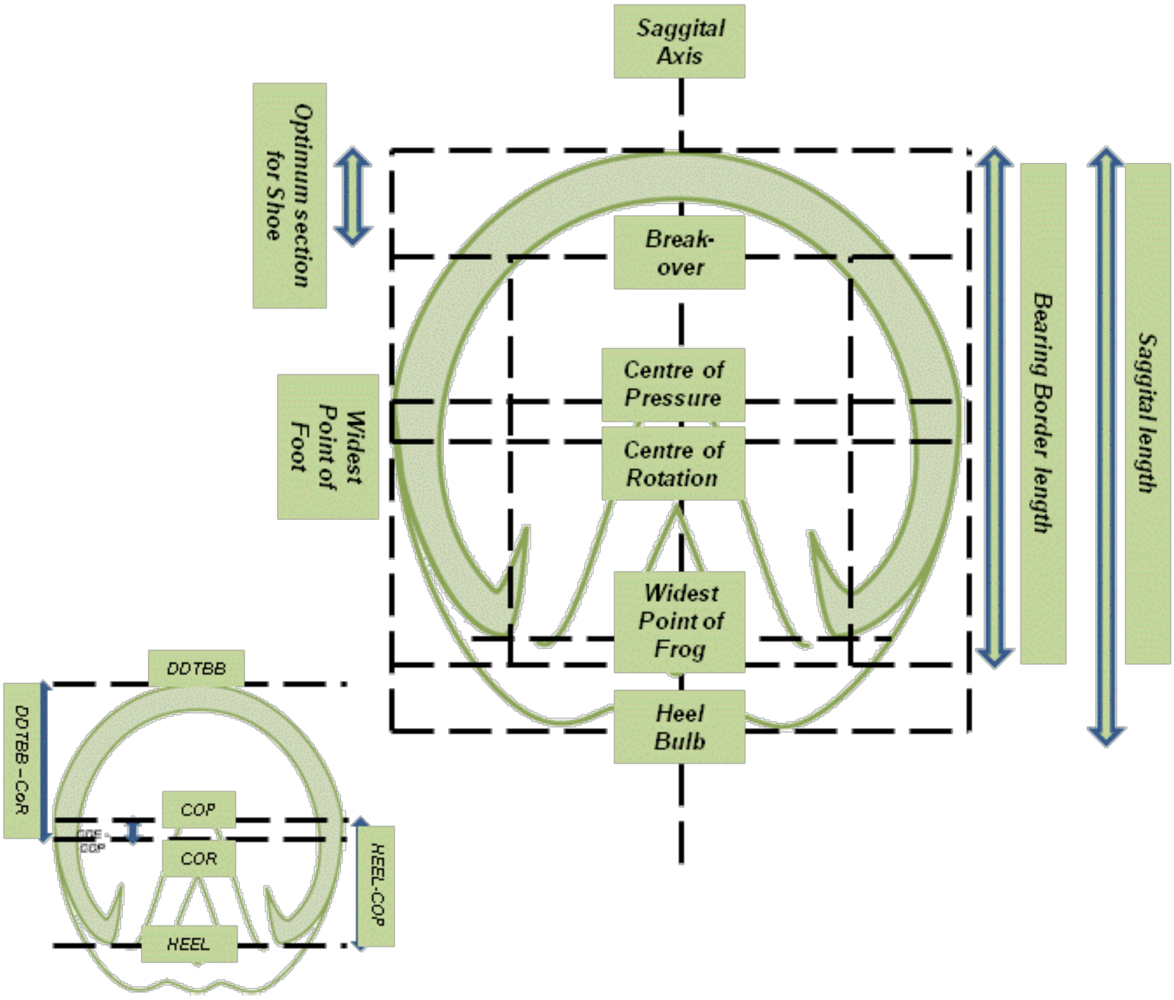

Fig. 3.2 A schematic illustration of the foot mapping protocol used to identify the position of key external reference points for both hoof balance and trim validation measures. Adapted from Caldwell (2013).

Trimming protocol

The horses were assessed and measured pre trim (Fig. 3.3) and a general assessment of mediolateral and dorsopalmar balance was performed.

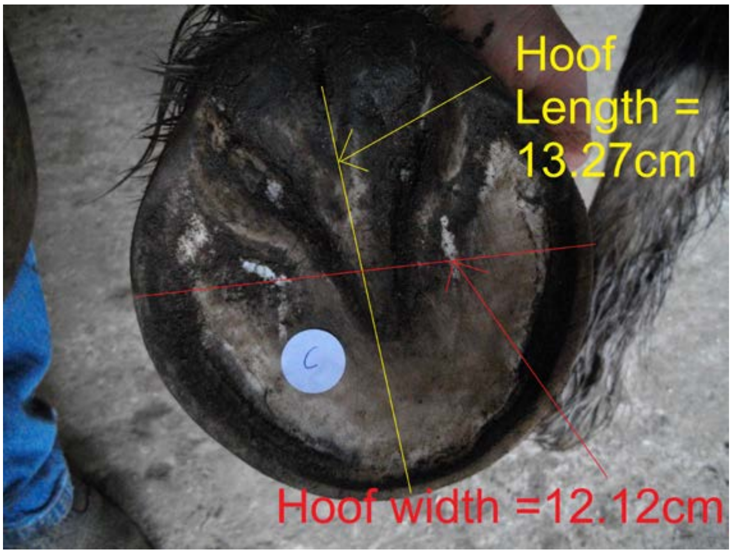

Fig. 3.3 An example of the measurements at pre trim of hoof width and hoof length which are used to help calculate hoof surface area.

The colateral sulci were then trimmed so that they were fully visible along with the true apex of the frog. The area from the seat of corn to the true point of frog was then exfoliated. Then carefully removing the rest of the exfoliating horn the true solar plane was revealed. The excess wall at the bearing border was removed to a horizontal plane with the live sole which determined the vertical height of the dorsal wall. The dorsal wall was only flair dressed, when there were deviations in symmetry to correspond to the phalangeal axis. The linear length of the toe was corresponded to the distance from the dorsodistal border of the toe to the widest part of the foot which represents the centre of rotation (Duckett 1990). The heels were trimmed, approximately to the widest part of the palmar aspect of the exfoliated central sulci. The measurements were then repeated for the trimmed hooves. The static symmetry indices (SSI) were compared between the left and right feet. As described by

Pourcelot et al (1997), the term ‘indice’ refers to the symmetry of a pair of markers. This allowed for an assessment of the intra asymmetry of each horse and inter asymmetry between the sample population.

Stride

The day before the study the horses were walked and trotted in a straight line with a handler alternatively on both sides, a minimum of 5 times (Peham et al 2001). This ensured the horses were sound and also familiarised the horse with being lead on the right hand side, as most horses are used to being lead on the left side. On the day of the study, the 10 selected horses were filmed pre trim. For this process, an indoor barn was used with a concrete surface that was level and dry (Audgie et al 2001), which allowed for freedom of locomotion. The lighting was controlled to provide sufficient contrast between the limbs and the surroundings. A pair of white markers were placed one metre apart, before and after the range of camera view to guide and encourage the horse and handler to move in a straight line. A video camera was placed in front of this line of travel to ensure straightness was maintained (Fig. 3.4).

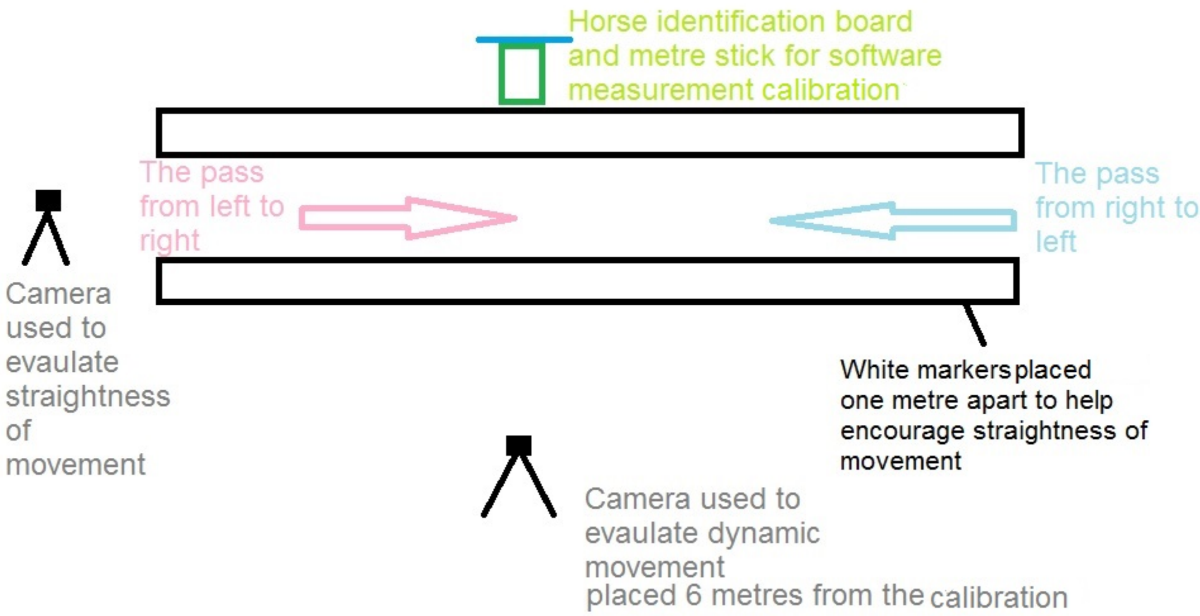

Fig. 3.4 An illustration by the researcher of the dynamic experimental set up for video capture of walk and trot.

A high speed video camera, Nikon 1 J1 (400 fps), on a tripod was placed six metres away at 90 degrees from the white markers. This was 60cm high and had a dressage marker and metre stick placed in view of the camera to allow for horse identification and measurement calibration of the video footage, using the measurement of the metre stick. The horses had 25mm circular self-adhesive markers attached to the centre of the lateral and medial aspect of the coronary hairline in alignment with the widest part of the hoof (Roepstorff et al 2009), as a reference point. The markers were coloured white or black to increase the visibility against the horse’s markings. If the horse had excessive feather, the obscuring hair was trimmed so that a clear definition of the hoof and coronary band could be seen from the video footage.

The horses were then lead from left to right in walk with the handler on the left side of the horse. They were then lead from right to left with the handler on the right side of the horse. This process was repeated three times to ensure the horses travelled at a constant pace with the handler. The same process was then repeated in trot. The reason for this procedure was to remove any bias from the handler during locomotion and to prevent the handler obscuring any video footage of the stride which increased the validity and reliability of the study (Fig. 3.4).

The horses were assessed at both the walk and trot gaits because the canter and gallop gaits are considered to be asymmetrical gaits (Clayton 2004). The same process was then repeated post trim. Once video footage had been collected, Kinovea® analysis software measured the stride length (SL) and stride velocity (SV) of the forelimbs by using distance and time measurement. Stride duration (STRD) and stance duration (SD) of the left and right forelimbs were calculated using a stopwatch featured in the software.

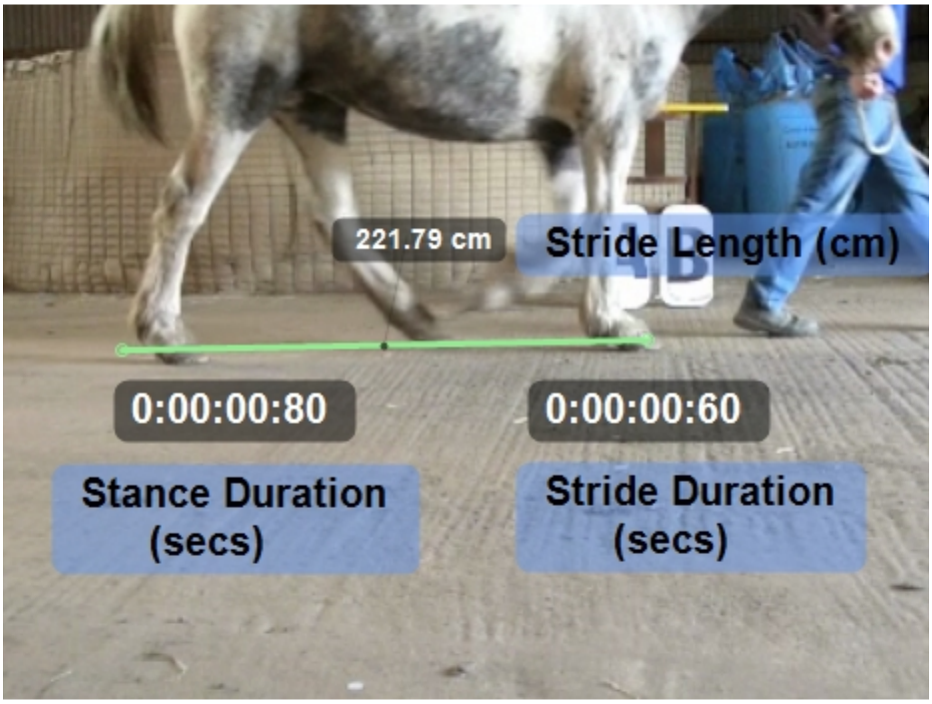

Fig 3.5 An example of how Kinovea® software measures the stride parameters. The stance phase is calculated when the stopwatch is started upon impact and stopped during unrollment. The stride duration is calculated when the stopwatch starts as the hoof leaves the ground and stopped as the hoof impacts the ground. Stride length assessment is assessed as the distance between the lateral marker at the coronary band between full weight bearing on one full stride.

All results were recorded in Microsoft Excel 2013® where the results of the stride characteristics were compared against the results of hoof surface area to establish left and right forelimb asymmetry. As described by Pourcelot et al (1997), the KSI were compared between left and right feet.

3.10 Standardisation

Bell (2010) suggested that a study needs to be repeatable by different researchers so the methodology has to be consistent and reliable, which is increased by the standardisation of all possible variables in the study. In addition to the sample size and specific selection for this study, various exogenic factors were controlled in the research design to assist in the standardisation process. The horses had a minimum of three passes of the camera for each fore limb which allowed the horses to travel at a constant pace with the handler and reduced the effects of handler bias. The results of the stride characteristics were averaged and considered to be representative for that limb (Clayton 1994). Drevemo et al (1980) stated that most of the stride variables show good repeatability over the short and long term. The data obtained in the form of digital photographs and video analysis was selected at random by an experienced farrier and checked for accuracy against the researcher's findings.

3.11 Data analysis

Once data has been collected it has to be analysed. Categories then have to be established and applied to the raw data that it can be coded and tabulated so that statistical inferences can be drawn (Kumar 2011). The results were recorded in Microsoft Excel 2013® and entered into Minitab 16® statistical software for statistical analysis. A *t* test: paired sample for means was used to compare the values of the left and right mean symmetry indices along with the effects of the trim on the data recorded. The paired *t* test was used as it is assumed that the mean of the difference between the paired, left and right, observations in the population is zero (Petrie and Watson 2006). A P value <0.05 was considered to be significant (Pourcelot et al

1997). The results were then assessed with a general linear model ANOVA to evaluate the effects of the variables. Probability plots were generated to explore distribution trends and main effects plots to explore the effects of inter and intra asymmetry of the sample size.

3.12 Interpretation of results

Interpretation means the transformation of a statistical result (Kahn 2008) into a logical and coherent explanation. The analysis of data after data collection yields a set of results either in the form of statistics, regression equations, identification of significant factors or in the form of acceptance of rejection of the hypothesis (Panneerselvam 2004).

3.13 Reliability, Repeatability and Validity

The reliability of the data is considered in this study from the perspective of removing as many variables as possible. The horses used were all of the same breed, gender, had the same diet and work regime with minimal variations in height and weight. This allowed for a representation of this breed to be assessed and successful completion of the study allows for the same experimental design to be repeatable in other breeds, differing heights and weights or schooled horses. This will provide comparable data and monitor the effects of the variables upon the outcome. The data collection was performed solely by the researcher with assistants monitoring the process to ensure accuracy along with additional cameras to ensure straightness and freedom of movement in dynamic assessment.

In a research study through modelling/algorithm, the results after interpretation must be validated by using past data (Leach and Drevemo 1991, Back et al 1996, Elishar et al 2002, Roepstorff et al 2009, Parés 2011, Parés and Oosterlinck 2012). Comparing previous results is important as confidence in the reliability of the study can be questioned if other research groups have difficulty confirming results or take a completely different approach (Crombie 1996). This process of validation ensures the credibility of the results. If there are any major differences between the results of the model and that of the real world problem in the past, then the assumptions and modelling exercise should be revisited (Panneerselvam 2004) until the results are validated.

The static images of the feet pre and post trim are available online at http://s1277.photobucket.com/user/bscfarrier/profile/. The images have a known calibration of 1.9 cm in the form of a circular sticker placed on the sole of the hoof and providing the same software is used, can be measured for accuracy. This allows for transparency of the results. The hooves trimmed were assessed by an experienced farrier (Fig. 3.4) for competency and accuracy. The video footage of the horses were measured three times by the researcher for each pass and the results mean averaged to ensure accuracy.

In the case of testing the hypothesis, the concept of validation has a different meaning. The credibility of the inferences of hypothesis testing is already built in through a significance level ($p < 0.05$). Inferences from the research can act as guidelines for framing policies or some correction in the system for further betterment (Panneerselvam 2004).

3.14 Ethical Considerations of the study

The 10 horses used for this study had full written consent from the owner along with a signed letter from the horses' veterinary surgeon confirming the horses were fit for purpose in the study (Appendices 2 & 3). If at any time the horses' wellbeing was in question the study would have been stopped until veterinary intervention was sought. The results of this study were kept confidential with the subjects not identified in the results. The researcher adhered to the Farriers Registration Council's document, "Farrier's Guide to Professional Conduct 2011" (Farriers Registration Council 2011) throughout the study and followed data protection guidelines (Data Protection Act 1998), to ensure no horses could be identified from the study. The owner of the horses was informed they had the right to withdraw from the study at any time. No identifying information has been shown in the study and all data has been treated with confidentiality and stored in a password protected computer. Any identifiable information held by the researcher for the purpose of the study was deleted from the computer hardware or destroyed by shredding of paper copies at the end of the study. In order for this study to be undertaken an ethical proposal form was presented to and approved by Myerscough College's Ethics Committee.

Chapter 4 – Results

The hypothesis for this study was that horses of a similar type, height and weight do not exhibit asymmetrical front feet in terms of hoof size and do not exhibit asymmetrical stride characteristics at walk and trot. The descriptive data and significance tests are laid out in tables 4.1 - 4.7 below.

Table 4.1 Whole group (n = 10) for hoof surface area measurements and the statistical significance of left-right symmetry and pre-post trim. Data are reported as ± 1 standard deviation.

Measurement	Left Foot Mean (SD)	Right Foot Mean (SD)	LRD P-Value
Pre Trim HSA (cm^2)	189.74 (33.72)	194.87 (47.32)	0.20
Post Trim HSA (cm^2)	162.80 (30.9)	166.44 (23.34)	0.20
PPTD P - Value	<0.01	<0.01	

Key:

HSA – Hoof surface area PP – Pre and post LRD – Left-right difference

PPTD – Pre-post trim difference

Pre Trim

Table 4.2: Whole group (n = 10) results for pre trim hoof surface area measurements. Data are reported as ± 1 standard deviation.

Measurement	Left Foot Mean (SD)	Right Foot Mean (SD)	Mean SSI (%)	LRD P-value	LRD r
HSA (cm^2)	189.74 (33.72)	194.87 (47.32)	97.37	0.20	0.93

Key:

HSA – Hoof surface area SSI – Static symmetry indices r – Pearson's Correlation value

LRD – Left-Right

The horses used in this study showed static symmetry indices of the HSA which ranged between 83.99% and 99.93% with a mean of 97.37%. 7 of the 10 horses had a larger right hoof surface area although over the whole group there was found to be no significant difference in hoof surface area using a t test: paired sample for means (P = 0.20). A Pearson's correlation of r 0.93 between the left-right data indicates a strong trend towards symmetry of HSA.

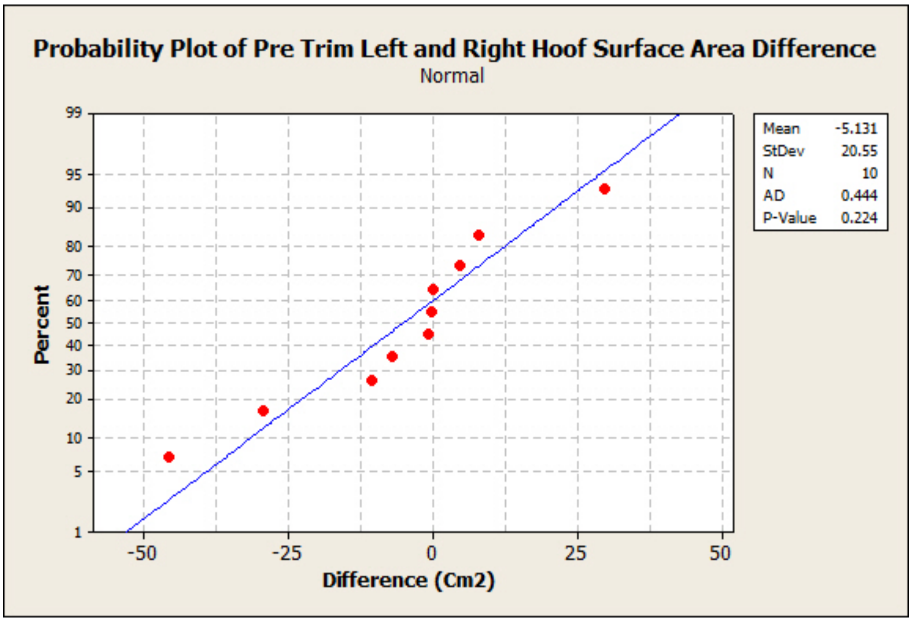

Fig. 4.1 Probability plot of pre trim hoof surface area difference. The data was normally distributed using a probability plot ensuring a paired t test was appropriate for the data.

Post Trim

Table 4.3: Whole group (n = 10) results for post trim linear and hoof surface area measurements. Data are reported as ± 1 standard deviation.

Measurement	Left Foot Mean (SD)	Right Foot Mean (SD)	Mean SSI (%)	LRD P-value	LRD r
HSA (cm^2)	162.80 (30.9)	166.44 (23.34)	97.81	0.20	0.82

Key:

HSA – Hoof surface area SSI – Static symmetry indices r – Pearson's Correlation Value

LRD – Left-right difference

Following farriery intervention, the horses displayed a range of 81.19% to 97.64% for static symmetry indices of HSA with a mean of 97.81%. 7 of the 10 horses again showed a larger right HSA. The whole group had no significant difference in foot size (P = 0.20) with a Pearson's correlation of r 0.83 between left-right data indicated a strong trend toward symmetry of HSA. Using a general linear model ANOVA, there were significant differences of hoof surface area for each horse pre and post trim (P< 0.01) as each hoof reduced in size. The inter asymmetry of the whole group (P< 0.01) was significant as the horses had different sized hooves. There was no significant difference between left and right HSA (P= 0.29).

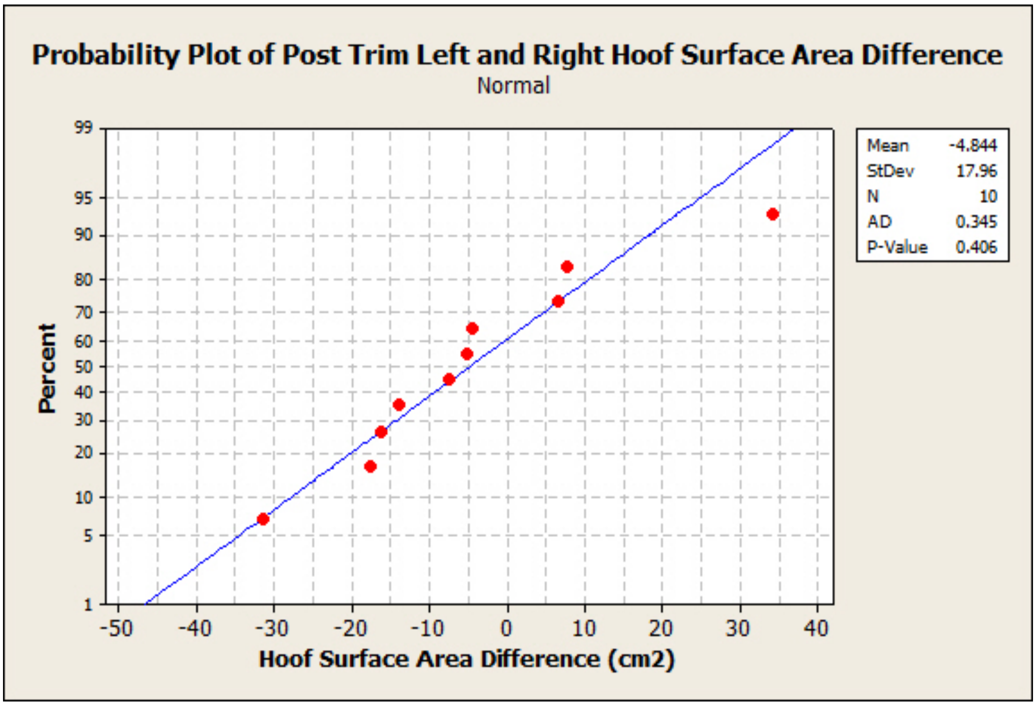

Fig. 4.2 Probability plot of post trim hoof surface area difference. The data was normally distributed using a probability plot ensuring a paired t test was appropriate for the data.

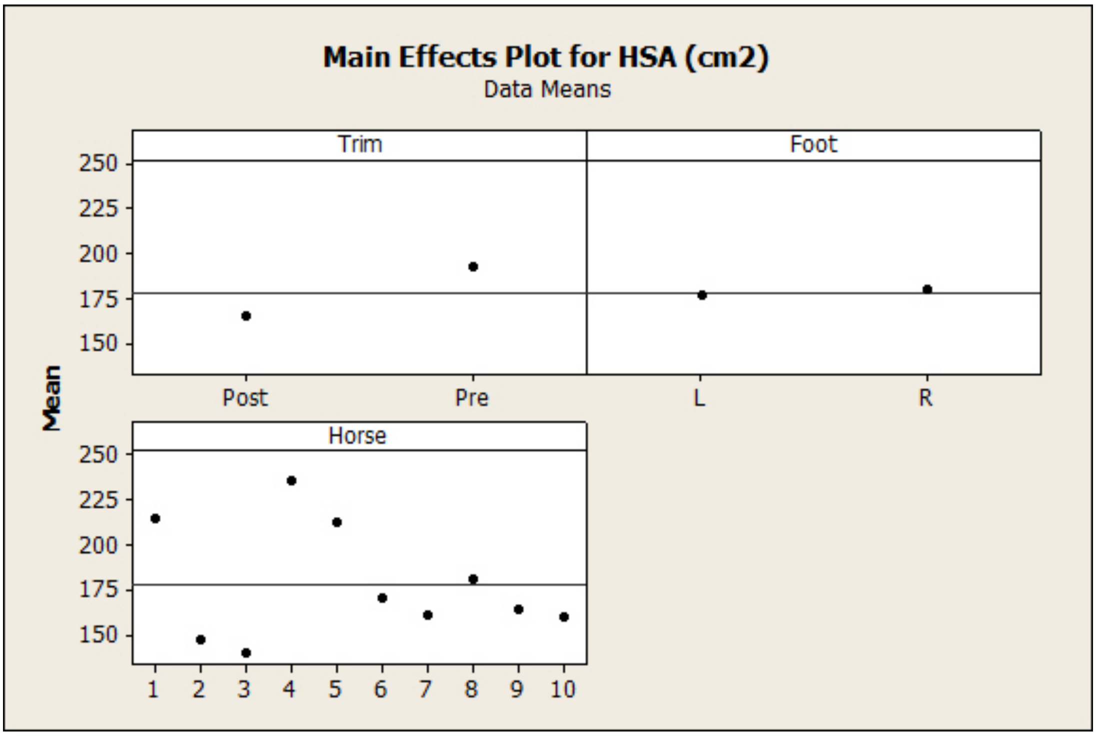

Fig. 4.3 Main effects plot for whole group hoof surface area data. This describes the HSA as being smaller post trim (P <0.01) along with a slightly larger HSA (P= 0.2) for the right foot. There is also a range of different HSA between each horse (P <0.01).

4.2 Dynamic Asymmetry

Stance Duration

Table 4.4: Mean average and statistical differences of the sample size (n = 10) stance duration. Data are reported as ± 1 standard deviation.

Gait	Trim	Left foot (secs) Mean (SD)	Right Foot (secs) Mean (SD)	KSI (%)	LRD P-value	LRD r	PPTD P-Value
Walk	Pre	0.67 (0.10)	0.67 (0.09)	100.00	0.47	0.59	
Walk	Post	0.72 (0.06)	0.68 (0.05)	94.40	0.01	0.82	0.04
Trot	Pre	0.31 (0.11)	0.29 (0.10)	93.50	0.10	0.95	
Trot	Post	0.26 (0.04)	0.25 (0.05)	96.20	0.08	0.75	0.01

Key: KSI – Kinematic Symmetry Indices **r – Pearson's correlation value**

LRD – Left-right difference **PPTD – Pre-post trim difference**

The difference in left and right stance duration was not significant (P >0.05) with the exception of post walk stance duration (P <0.05). The KSI decreased following farriery intervention at walk whilst increased at trot. Using a general linear model ANOVA, there were no significant differences for walk and trot between pre and post trim (P = 0.48) and left and right intra asymmetry (P = 0.11). However, there were significant differences between the stance duration between gaits and the inter asymmetry of the group (P <0.01) for both.

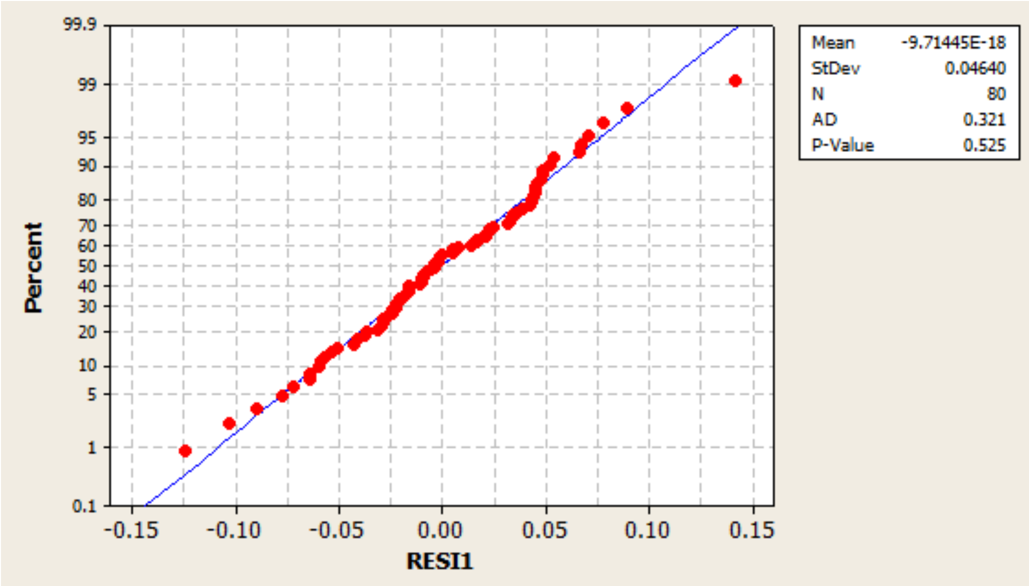

Fig. 4.4 Probability plot of stance duration data. The data was normally distributed using a probability plot ensuring a paired t test was appropriate for the data.

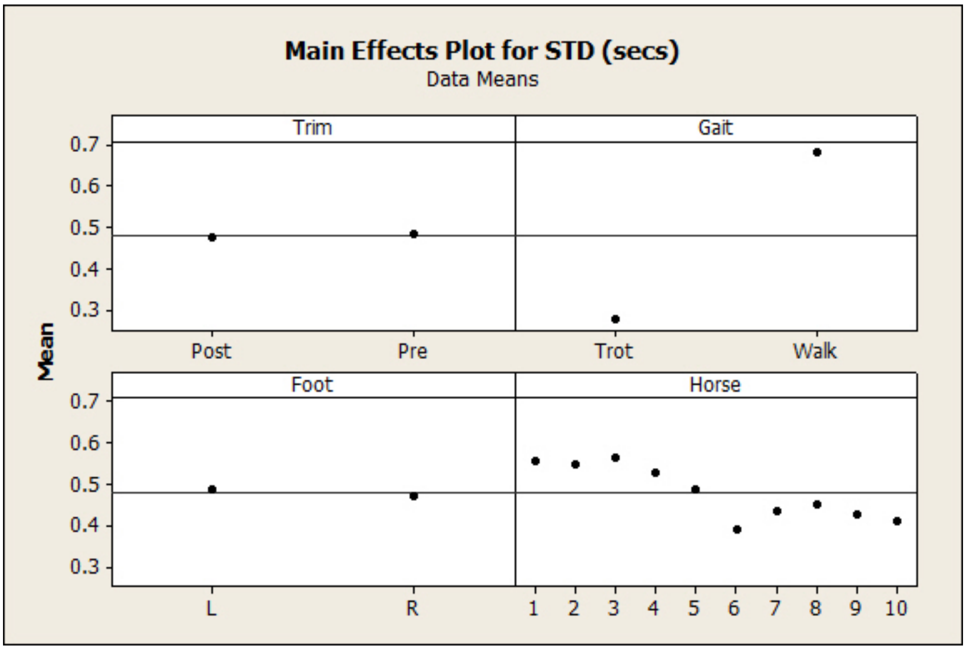

Fig. 4.5 Main effects plot for stance duration data. This describes the non-significant difference between left and right feet (P =0.11) and trim difference (P=0.48). The significant differences were the stance duration between each horse (P < 0.01) and walk and trot difference (P < 0.01).

Stride duration

Table 4.5: Mean average and statistical differences of the sample size (n = 10) stride duration.

Gait	Trim	Left foot (secs) Mean (SD)	Right foot (secs) Mean (SD)	KSI (%)	LRD P-value	LRD r	PPTD P-Value
Walk	Pre	0.55 (0.08)	0.54 (0.07)	98.18	0.20	0.79	
Walk	Post	0.48 (0.03)	0.49 (0.03)	97.96	0.40	0.12	< 0.01
Trot	Pre	0.43 (0.03)	0.41 (0.02)	95.35	0.01	0.65	
Trot	Post	0.40 (0.02)	0.39 (0.03)	97.50	0.08	0.54	<0.01

Key: **KSI – Kinematic Symmetry Indices** **r – Pearson's correlation value**
LRD – Left-right difference **PPTD – Pre-post trim difference**

The difference in left and right stride duration was not significant (P >0.05) with the exception of pre trot stride duration (P <0.05). The KSI decreased following farriery intervention at walk whilst increased at trot. Using a general linear model ANOVA, there was no significant differences between inter asymmetry of the group (P = 0.53) and left and right intra asymmetry (P = 0.23). However, there were significant differences of the stride duration between gaits and pre and post trim (P <0.01).

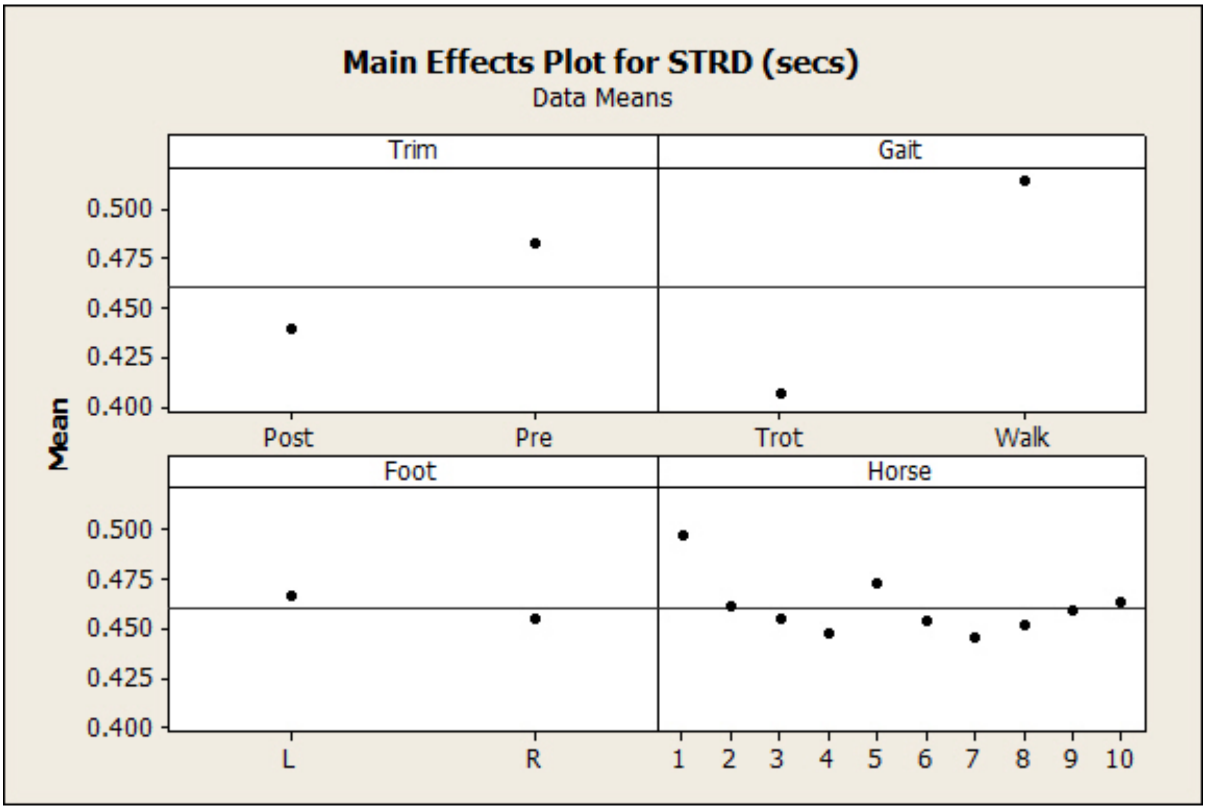

Fig. 4.6 Main effects plot for stride duration data of the sample size. This explains the significant difference in stride duration post trim (P <0.01) and walk and trot (P <0.01). There are no significant differences between the left and right feet (P = 0.23) and between each horse (P = 0.53).

Stride Length

Table 4.6: Mean average and statistical differences of the sample size (n = 10) stride length. Data are reported as ± 1 standard deviation.

Gait	Trim	Mean Left (cm)	Mean Right (cm)	KSI (%)	LRD P-value	LRD r	PPTD P-Value
Walk	Pre	196.85 (20.06)	203.49 (19.22)	96.74	0.10	0.68	
Walk	Post	190.27 (14.68)	195.86 (16.70)	97.15	0.10	0.67	0.04
Trot	Pre	236.32 (23.90)	269.59 (24.99)	87.66	0.01	0.04	
Trot	Post	234.66 (23.30)	257.46 (30.73)	91.14	0.02	0.35	0.13

Key: KSI – Kinematic Symmetry Indices **r – Pearson's correlation value**

LRD – Left-right difference **PPTD – Pre-post trim difference**

The difference in left and right stride length was not significant in walk (P >0.05) but was significant at trot (P <0.05). The KSI increased following farriery intervention at both walk and trot. Using a general linear model ANOVA, there was no significant difference between pre and post trim (P = 0.48). There were significant differences of the stride length between gaits and left-right intra asymmetry in addition to the inter asymmetry of the group (P <0.01).

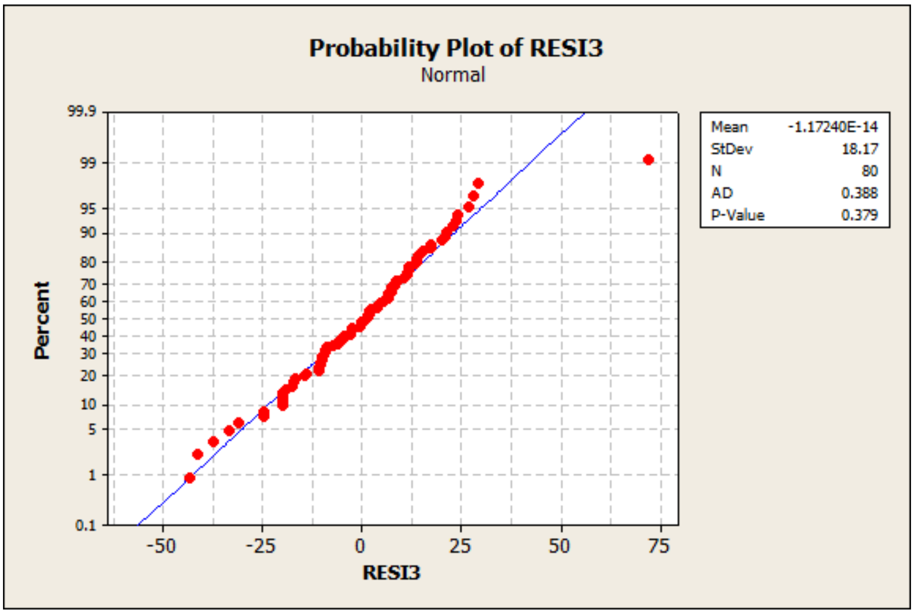

Fig 4.7 Probability plot of stride length data. The data was normally distributed using a probability plot ensuring a paired t test was appropriate for the data.

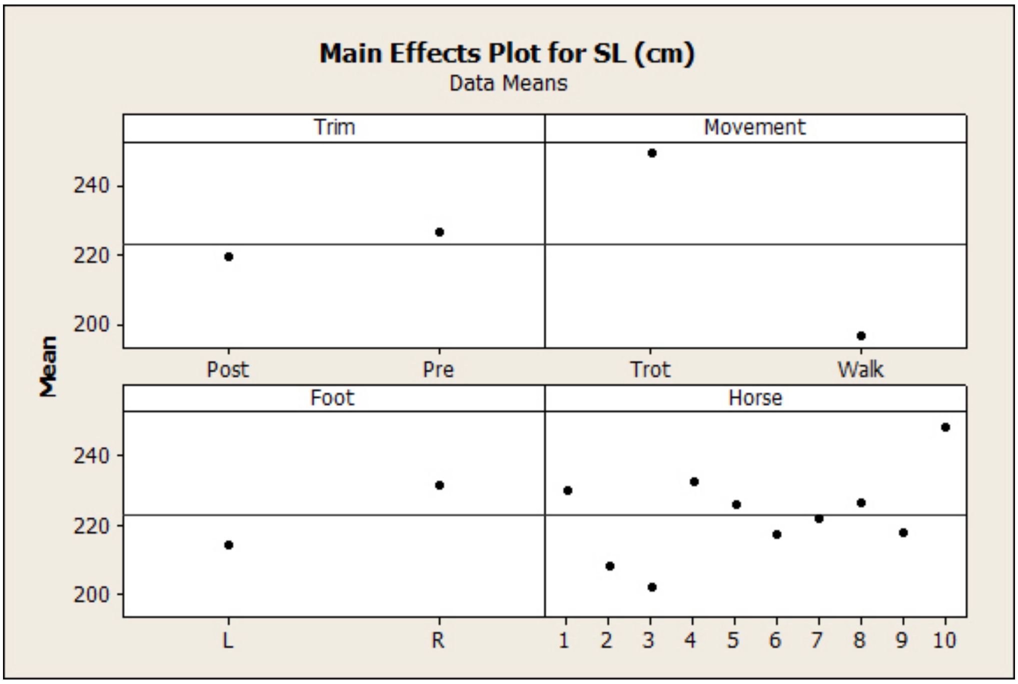

Fig. 4.8 Main effects plot for stride length data of the sample size. This shows the significant differences between left and right feet (P <0.01), the walk and trot gait (P <0.01) and between each horse (P <0.01). There was not a significant difference following the trim (P = 0.48).

Stride Velocity

Table 4.7: Mean average and statistical differences of the sample size (n = 10) stride velocity. Data are reported as ± 1 standard deviation.

Gait	Trim	Left foot (m/s) Mean (SD)	Right foot (m/s) Mean (SD)	KSI (%)	LRD P-value	LRD r	PPTD P-Value
Walk	Pre	3.62 (0.50)	3.84 (0.59)	94.27	0.08	0.65	
Walk	Post	3.94 (0.22)	4.03 (0.4)	97.77	0.20	0.30	0.03
Trot	Pre	5.48 (0.69)	6.54 (0.54)	83.79	<0.01	0.11	
Trot	Post	5.88 (0.44)	6.73 (1.13)	87.37	0.01	0.57	0.17

Key: **KSI – Kinematic Symmetry Indices** **r – Pearson's correlation value**
LRD – Left-right difference **PPTD – Pre-post trim difference**

The difference in left-right stride velocity was not significant at walk (P >0.05) but was significant at trot (P <0.05). The KSI increased following farriery intervention at walk and trot. Using a general linear model ANOVA, there were significant differences between pre and post trim in addition to and the inter asymmetry of the group (P = 0.04) for both. There was also a significant difference between the gaits and left-right intra asymmetry (P <0.01).

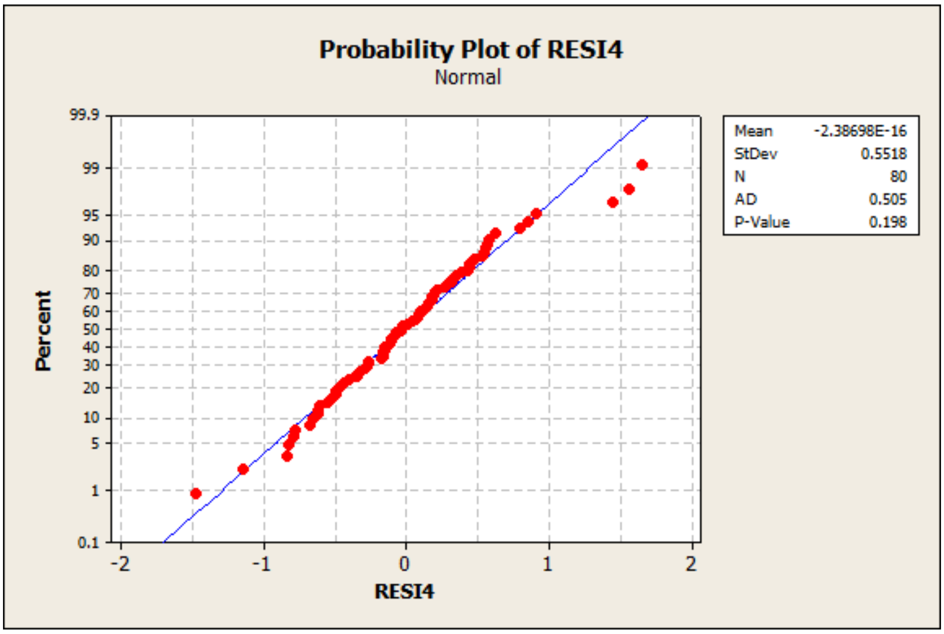

Fig 4.8 Probability plot of stride velocity data. The data was normally distributed using a probability plot ensuring a paired t test was appropriate for the data.

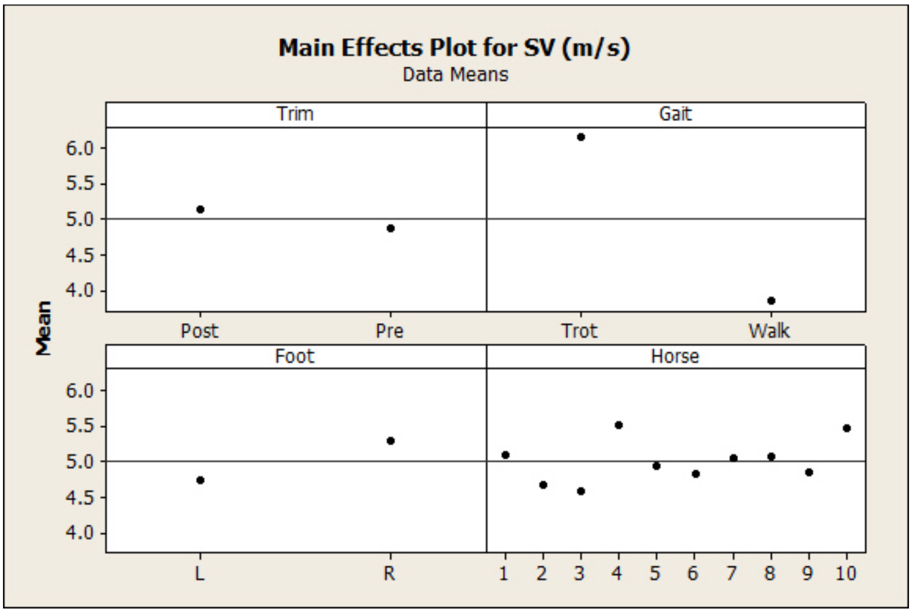

Fig. 4.9 Main effects plot of stride velocity in the sample size. This explains how the velocity of the horse increased post trim (P= 0.04), the trot had a higher velocity than walk (P <0.01). The significant difference in velocity between each horse (P= 0.04) and the intra asymmetry (P <0.01).

Chapter 5 - Discussion

5.1 Static asymmetry

The right foot hoof surface area was larger pre and post trim although the difference was not statistically significant ($P > 0.05$), this corresponds with the hoof symmetry findings of Parés and Oosterlinck (2012) that despite not having regular hoof care, the left and right symmetry was high. Following the trim, the hooves represented a closer static symmetry index in terms of linear measurements and hoof surface area. The general linear model ANOVA found the trim had a significant effect on the linear measurements and hoof surface area ($P < 0.01$) which could be the effect of removing excess horn. The data recorded between each horse varied significantly ($P < 0.01$) this could be explained by the fact that the horses had differing amounts of hoof growth, hoof shape and size along with differing conformation. The findings of the pre trim measurements differ from those by Parés (2011) and Parés and Oosterlinck (2012) although this can be explained by the fact that both these studies were performed on yearlings with smaller feet whilst this study focused on mature horses with larger feet. Individual findings of the sample size are found in Appendix 4.

5.2 Dynamic asymmetry

<u>Stance Duration</u>

The horses had a longer stance duration on the left limb compared to the right limb in both gaits at pre and post trim with the exception of the walk at pre trim which had no difference and produced a KSI of 100%. The paired t test found the asymmetry was only considered statistically significant for walk at post trim ($P = 0.01$), the KSI decreased at walk post trim to 94.4% which the researcher considers to be a surprising finding, particularly as the KSI for trot increased following farriery intervention. The findings of the left and right fore limb would help explain that the stride length and velocity was increased on the right limb as it spent less time on weight bearing. The results of this study differ slightly to the findings of Roepstorff et al (2009) with the stance duration being longer in that study although as the measurements were taken with the horse worked in a circle with a rider performing sitting trot, this may explain the difference in stance time. The stance duration was faster than the findings of Elishar et al (2002) although the horses in that study were shod which may explain the difference. However, the findings are broadly similar to those of Back et al (1996) with the kinematics of walk showing a good correlation with those of trot when the effect of a higher speed on intra-limb coordination is taken into consideration.

Stride Duration

The horses had a longer stride duration on the left limb compared with the right limb although this was only considered statistically significant using a paired t test for trot at pre trim ($P = 0.01$). Following the pattern from the stance duration, the KSI decreased at walk following farriery intervention whilst increasing at trot. The general linear model ANOVA found the trim provided a reduction in stride duration ($P < 0.01$) whilst the inter asymmetry of the whole group was not considered significant ($P = 0.53$), this suggested the whole group moved at a similar time frame. The findings of this study for stride duration are similar to those of Elishar et al (2002).

Stride Length

The horses in this study showed intra asymmetry at walk, this was not statistically significant at walk pre and post trim ($P = 0.10$). However, there was a significant difference, at the trot pre and post trim (P= 0.01 and P= 0.02 respectively). The KSI increased following farriery intervention although it was still considered low at post trim trot (91.14%). There were significant differences in the inter asymmetry of the group (P <0.01) which would suggest that although the horses were moving asymmetrically in trot, they moved in differing distances to the other horses in this group. The findings of this study vary significantly to those of Roepstorff et al (2009), this can be explained by the fact the horses in this study stride was measured in a straight line whereas Roepstorff et al (2009) performed their measurements with horses moving in a circle in sitting trot. The findings of this study show a post trim shorter stride length distance compared to those of Wood (2013), which can be explained by the fact the horses were of a smaller height for this study.

Stride Velocity

The difference in left-right stride velocity at walk was not statistically significant at pre trim (P = 0.08) or post trim (P = 0.20). The difference in left-right trot velocity was considered statistically significant at pre trim and post trim (P <0.01 for both variables). There was an increase of KSI for both gaits following farriery intervention. The variability of each horse for inter asymmetry (P <0.01) again suggests that the horses were moving at different speeds to each other. The results of this study are comparable with the findings of Leach and Drevemo (1991). Individual findings of pre and post trim stride characteristics are found in Appendices 5 and 6.

5.3 Comparison of static and dynamic asymmetry

Although the difference in left and right feet were not considered significant at pre and post trim, farriery intervention provided a trend towards symmetry for every factor measured in trot. However, only half these factors measured in walk demonstrated more uniform symmetry with both stance and stride duration reduced following the trim. The researcher considers that, given the pre-post trim differences, that the standardised protocol had a positive effect on locomotion. The trim resulted in a larger stride length and increased velocity whilst having a shorter stance duration and stride duration at both walk and trot. The most asymmetric gait was trot, particularly in terms of stride length and velocity, these contrast with the findings of Pourcelot et al (1997) which recorded standard symmetry indices at slow trot. As these horses were unbroken, the effects of schooling and straightness training could not have an effect on the results. The horses used were all mares of the same breed, Cob, and around the same age so it can be considered the findings are representative for that breed and type. As a consequence of the results, the hypothesis that there is no difference between left and right feet hoof size is accepted whereas it is rejected for the dynamic assessment due to the degree of asymmetry in trot.

5.4 Limitations of the study

The horses used were unbroken and therefore would not perform dynamic assessment as competently as broken horses that are used to being lead or ridden, repeating this study every month over a twelve month period would help reduce this variable as also the consistency of the speed of the camera passes would also be affected by this. The hooves measured were not on a regular trimming cycle, whilst this would represent the horses in what would be their natural state, some distortions would not have been able to have been accounted for in the trim. This could be overcome by repeating the same study procedure over a 12 month period to obtain data relative to the domestic horse model. Although these are important factors it must be appreciated that having a group of mature unbroken horses of similar diet, exercise regime, breed, sex and height for a study is very rare and this study provides some useful information.

Chapter 6 – Conclusion and recommendations

6.1 Conclusion

The causes and effects of static and dynamic asymmetry are multi-factorial and further work is required to explore positive and negative effects upon locomotion and performance. The findings of the static assessment show that trimming to a strict farriery protocol could improve the symmetry indices of hoof width, hoof length and hoof surface area. The effects of farriery intervention were measured at pre and post trim with the trot gait benefiting from the trim by an increased KSI. The stance and stride duration of the walk gait had a reduced symmetry indices following farriery intervention which the researcher found to be a surprising result although this could be explained by the horses becoming accustomed to the trim applied. The stride length and velocity of walk did show closer symmetry following the trim which justified the positive effects of farriery intervention.

Equine gait analysis provides a simple and objective method of standardising the locomotion of the horse at any age or stage of training (Back and Clayton 2001). It could be a repeatable and quantifiable method of assessment for kinematic and kinetic data. Gait analysis could also be used to predict the potential of young horses or if any asymmetrical movement was to develop whilst training for competitions.

One of the major advantages with this experimental design is that it is very cost effective and easily reproduced in the everyday farriery environment. As time progresses, the equipment and software may become more financial viable enabling many other studies investigating equine locomotion to be produced.

6.2 Recommendations for future study

The study could be repeated on the same horses in the same environment over a further twelve month period, although this would have little effect upon the handling issues, the feet will have had regular farriery care and the true effects of farriery and symmetry of the feet could be measured. As the hoof surface area difference was not statistically significant, it could be interpreted that the asymmetrical movement is caused as a developmental factor. Further studies investigating grazing stance, preferred lead limb and conformation similar to those of Van Heel et al (2006) and Weller et al (2006) could be performed on the same horses. A study comparing the findings of the horses at pre and post breaking/schooling using the same experimental protocol would help investigate the effect of the rider upon symmetry.

6.3 Clinical Relevance

Correct and careful farriery can help influence static and dynamic symmetry, provide a shorter stride length and breakover whilst increasing the velocity of movement. This study helps to clarify the importance of routine and regular foot trimming.

Manufacturer's addresses

Kinovea:

Kinovea Inc.,
P.O Box 1133,
Monroe, GA 30655,
USA

Microsoft Excel 2013:

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

Minitab 16:

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

Nikon:

Nikon House,

380 Richmond Rd,

Kingston upon Thames,

KT2 5PR

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APPENDIX 1

Descriptive Data of the Horses			
Horse	Age	Height (cm)	Weight (Kgs)
1	5	150	570
2	6	149	429
3	7	150	456
4	6	148	555
5	8	148	532
6	7	151	434
7	6	148	460
8	7	151	462
9	6	148	477
10	6	147	423
Mean	6.4	149	479.8
s.d	0.84	1.41	53.44
s.e	0.27	0.45	16.9
Min	5	147	423
Max	8	151	570

APPENDIX 2

Lynsey Aldridge,
114 Hill Street,
Hednesford,
Cannock,
Staffordshire,
WS12 2DR

Dear Mr Jerram,

I give full permission for the use of 10 of my horses for the farriery dissertation "An assessment of static and dynamic asymmetry". I can confirm they are all well behaved and of good health with up to date vaccination and worming records.

Yours sincerely

Lynsey Aldridge

APPENDIX 3

Warren House Veterinary Centre Ltd,
Lichfield Road,
Brownhills,
West Midlands,
WS8 6LS

To whom it may concern,

I can confirm as the veterinary surgeon of the ten horses selected by Marc Jerram FdSc AWCF for the farriery dissertation of assessing static and dynamic asymmetry are fit for purpose and in good health. I will be available should any veterinary assistance be required at any time during data collection.

Yours Sincerely

GARY KELLY B.V.M & S,MRCVS
Warren House Veterinary Centre Ltd
Lichfield Road, Brownhills
West Mids WS8 6LS

APPENDIX 4

Trim	Horse	HW (cm) (L)	HW (cm) (R)	HL (cm) (L)	HL (cm) (R)	H.S.A (cm) (L)	H.S.A (cm) (R)	SSI (%)	Key	
Pre	1	17.6	18.4	15.2	16.8	220.18	249.47	88.26	HW	Hoof width
Pre	2	12.9	13.3	14	13.5	148.15	148.83	99.54	HL	Hoof Length
Pre	3	13.3	13.4	12.4	12.3	139.38	139.62	99.82	H.S.A	Hoof Surface Area
Pre	4	16.4	20	18.7	17.8	239.57	285.23	83.99	L	Left
Pre	5	17.6	17.5	16.2	15.9	231.29	226.59	97.97	R	Right
Pre	6	15.2	16.1	14.6	14.5	182.42	192.99	94.53	SSI	Static Symmetry Indices
Pre	7	15	13.9	15.4	13.7	187.42	157.82	84.21		
Pre	8	16.5	17.2	14.8	14.6	201.29	208.25	96.66		
Pre	9	14.1	13.9	14.3	14.6	165.65	165.77	99.93		
Pre	10	15.4	15.4	14.3	13.5	182.05	174.14	95.65		
Trim	Horse	HW (cm) (L)	HW (cm) (R)	HL (cm) (L)	HL (cm) (R)	H.S.A (cm) (L)	H.S.A (cm) (R)	SSI (%)		
Post	1	15.7	15.6	14.8	15.4	190.85	195.46	97.64		
Post	2	12.7	13.3	12.4	13.5	132.65	148.83	89.13		
Post	3	13	12.7	13.2	12.7	142.74	135.13	94.66		
Post	4	16.9	15.6	16.7	15.1	226.71	192.51	84.92		
Post	5	15.4	15.7	14.7	16.1	185.97	203.68	91.31		
Post	6	12.5	14.4	13.1	14.1	136.07	167.59	81.19		
Post	7	12.9	13.5	13.2	14	141.57	155.54	91.02		
Post	8	13.5	13.9	14.5	13.2	159.81	153.35	95.96		
Post	9	14	13.3	14.8	13.9	144.76	152.23	95.10		
Post	10	12.7	12.8	13.1	13.6	138.40	143.67	96.34		

APPENDIX 5

			Stride measurements pre trim						
Walk	Horse No.	STD (secs) (L)	STD (secs) (R)	STRD (secs) (L)	STRD (secs) (R)	SL (cm) (L)	SL (cm) (R)	SV (m/s) (L)	SV (m/s) (R)
	1	0.76	0.71	0.75	0.73	206.1	215.43	2.75	2.95
	2	0.66	0.79	0.51	0.55	160	174.63	3.14	3.18
	3	0.76	0.83	0.52	0.52	161.33	177.27	3.1	3.41
	4	0.82	0.66	0.52	0.58	196.77	215.27	3.78	3.71
	5	0.68	0.62	0.48	0.5	200.13	191.87	4.17	3.84
	6	0.48	0.57	0.61	0.5	207.23	210.47	3.4	4.21
	7	0.65	0.63	0.53	0.52	202.1	215.8	3.81	4.15
	8	0.69	0.67	0.53	0.47	216.2	220.7	4.08	4.7
	9	0.59	0.62	0.52	0.52	215.8	185.87	4.15	3.57
	10	0.6	0.57	0.53	0.49	202.8	227.57	3.83	4.64
Trot	Horse	STD (secs) (L)	STD (secs) (R)	STRD (secs) (L)	STRD (secs) (R)	SL (cm) (L)	SL (cm) (R)	SV (m/s) (L)	SV (m/s) (R)
	1	0.41	0.4	0.41	0.4	214.1	279.23	5.22	6.98
	2	0.5	0.43	0.5	0.43	196.13	270.33	3.92	6.29
	3	0.4	0.39	0.44	0.39	218.5	264.6	4.97	6.78
	4	0.38	0.39	0.38	0.39	244.07	282.87	6.42	7.25
	5	0.27	0.25	0.44	0.44	227.67	281.93	5.42	6.71
	6	0.17	0.23	0.42	0.4	254.27	267.5	5.78	6.22
	7	0.24	0.2	0.41	0.39	223.4	253.27	5.45	6.03
	8	0.26	0.22	0.44	0.43	254.47	267.5	5.78	6.22
	9	0.22	0.22	0.43	0.38	259.6	215.1	6.04	5.66
	10	0.21	0.18	0.47	0.43	270.97	313.53	5.77	7.29

Key	
STD	Stance Duration (seconds)
STRD	Stride Duration (seconds)
SL	Stride Length (centimetres)
SV	Stide Velocity (metres per second)
(L)	Left front limb
(R)	Right front limb

APPENDIX 6

		Post trim stride measurements							
Walk	Horse	STD (secs) (L)	STD (secs) (R)	STRD (secs) (L)	STRD (secs) (R)	SL (cm) (L)	SL (cm) (R)	SV (m/s) (L)	SV (m/s) (R)
	1	0.81	0.75	0.47	0.5	205.37	210.07	4.37	4.2
	2	0.8	0.68	0.41	0.49	160.6	162.23	3.92	3.31
	3	0.75	0.76	0.49	0.48	171.03	178.2	3.49	3.71
	4	0.73	0.7	0.51	0.5	191.7	211.27	3.76	4.23
	5	0.76	0.69	0.51	0.55	201.63	194.2	3.95	3.53
	6	0.63	0.6	0.48	0.47	190.33	195.47	3.97	4.07
	7	0.69	0.68	0.48	0.45	190.1	202.63	3.96	4.5
	8	0.65	0.61	0.48	0.45	188.9	202.23	3.94	4.49
	9	0.67	0.66	0.53	0.47	207.63	185.6	3.92	3.95
	10	0.66	0.63	0.48	0.5	195.37	216.7	4.07	4.33
Trot	Horse	STD (secs) (L)	STD (secs) (R)	STRD (secs) (L)	STRD (secs) (R)	SL (cm) (L)	SL (cm) (R)	SV (m/s) (L)	SV (m/s) (R)
	1	0.32	0.28	0.39	0.33	234.17	275	6	8.33
	2	0.26	0.26	0.4	0.4	229.4	311.6	5.74	7.79
	3	0.29	0.34	0.4	0.4	220.77	224.7	5.52	5.62
	4	0.27	0.26	0.37	0.33	237.6	281.37	6.42	8.53
	5	0.31	0.31	0.44	0.42	249.5	262.57	5.67	6.25
	6	0.24	0.19	0.36	0.39	188.63	224.1	5.24	5.75
	7	0.22	0.18	0.39	0.39	230.83	257.37	5.92	6.6
	8	0.29	0.22	0.4	0.41	223.87	238.17	5.6	5.81
	9	0.22	0.22	0.43	0.39	255.17	218.3	5.95	5.6
	10	0.21	0.21	0.41	0.4	276.7	281.4	6.75	7.04

Key	
STD	Stance Duration (seconds)
STRD	Stride Duration (seconds)
SL	Stride Length (centimetres)
SV	Stide Velocity (metres per second)
(L)	Left front limb
(R)	Right front limb