The effect of trimming on movement symmetry over time in domestic horses measured with an inertial sensor system

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A thesis submitted in partial fulfilment of the Fellowship of the Worshipful Company of Farriers Examination.

Acknowledgements

I would like to give my sincerest thanks to World Horse Welfare for allowing us to carry out the study at their premises and also use their horses and expert staff. Thank you to the University of Bristol for their support and allowing us to use their Equinosis equipment and to Margalida Mas DVM MRCVS PGDip for her help, expertise and knowledge in this area and using the Equinosis system and finally to Kate Allen BVSc (Liv.), CertEM(IntMed) (RVCS), PhD, Dip ACVSMR for her continued support.

I would also like to thank Jason Somerville AWCF BSc (Hons) for all his help and support during my time spent in higher education.

It is important to acknowledge that without the support and reassurance of my wife Sadie, my children Freddie and Emmie, I would not have kept going when all seemed lost and insignificant during some tough times during this study. Thank you so very much.

Last and by no means least, I would like to thank all my peers who have been on this journey with me for their support and help.

Abstract

The study is based on previous work which used 23 horses and showed that only the trimming of feet improved the horse's symmetry during movement. Historically it has been advised that horses need regular trimming, no longer than every 6 weeks and it is common practice for farriers to advise their clients that this is the recommended treatment. This study was undertaken to establish the optimum time between trims by observing and measuring the following: Does the horse move with greater symmetry following the trim? How long does this benefit last? What is the optimum time between trims to benefit the locomotion of the horse?

The hypothesis and approach for this study was that a standardised trimming protocol will improve the movement symmetry of the horse during locomotion and that the results gained will give the optimum trimming cycle for the horse over time to gain maximum movement symmetry from the trim. The study research approach was undertaken using both quantitative and experiential research methods.

The study consisted of 26 horses, 17 mares and 9 geldings, aged 1.5 to 18 years. The horses had an inertial sensor system (ISS) fitted which recorded movement symmetry data pre-trim, post trim and after 2, 4 and 6 weeks.

The results showed there was a statistically significant difference in forelimb asymmetry between pre-trim and week 4 and 6 with an increase in asymmetry. No significance was seen in movement symmetry in the hindlimbs.

In conclusion, a standardised trimming protocol was associated with a significant increase in forelimb asymmetry and no significant change in hindlimb asymmetry. These results were unexpected and further research is warranted to understand these. It is possible that application of a standardised trimming protocol to this population of horses is not appropriate.

Declaration

I hereby declare that the work within this Fellowship dissertation is my own. Any sources have been duly referenced and any illustrations or diagrams that are not mine are used with the permission of the owner

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Chapter 1-Methodology

1.1 Introduction

Historically it has been advised that horses need regular trimming, no longer than every 6 weeks (Williams & Deacon 2010) and is common practice for farriers to advise their customers that this is the recommended treatment. Trimming and shoeing techniques aim to protect the equine hoof against excessive wear, assist in the treatment of lameness by unloading a specific site and maintain or enhance function (Eliashar, 2012). The equine foot is considered balanced when its conformation maximises its mechanical efficiency and corrective trimming and/ or shoeing may ensure the foot achieves optimum function regardless of the workload and surface to which it is exposed and may contribute to reduce the incidence of injury (Eliashar, 2012).

Previous studies have found that trimming does not change the landing of a foot but significantly shortened the landing duration suggesting faster complete support of all structures within the foot, This would allow the centre of pressure (CoP) to move faster towards the centre of the foot allowing all load bearing structures to give full support (Van Heel et al 2004). The CoP is the point at which the highest ground reaction force (GRF) is generated within the hoof capsule during the stance phase. The GRF is the external impact acting on the limb during the stance phase of the stride when the foot contacts the ground, its magnitude depends on the horse's weight and speed and on the surface characteristics (Eliashar, 2012). The CoP varies in location cyclically throughout the phases of the stride, creating a lever arm for the Distal Inter Phalangeal (DIP) joint. Trimming and/or shoeing a balanced foot does not change the CoP location during stance but it may increase contact surface area and promote an even load distribution, and it may help dissipate GRF by altering landing duration (Van Heel et al 2004). During the landing phase of the stride, dissipation of forces occurs throughout the hoof and structures within it, including bones and soft tissues with 90% of the shock being dissipated before it reaches the proximal phalanx (Pollit, 2007). Trimming has been linked to a more equal load distribution which is beneficial to the internal structures of the foot and loading (Van Heel et al 2004). It is clear that external hoof structures play a crucial role in the biomechanics of the equine digit

A recent study of the effects of a 6-weekly trimming cycle found that it increased the frog area at expense of the total solar area, causing palmar/plantar migration of the heels and an increase in support length. When applied to domestic animals, trimming might optimise biomechanics by decreasing the solar angle of the pedal bone (Clayton et al 2011). The CoP has been used as a magnitude to measure the loading on the distal limb (Eliashar, 2012), and it tends to shift in a palmar/plantar direction from the toe as part of changes in hoof conformation during a trimming interval. This causes variations in the flexing moment of the DIP joint, and the horse might compensate for these changes with a gradual change in hoof shape and landing phase to facilitate the break-over (Van Heel et al. 2005). This response process may translate to changes in movement symmetry over a trimming interval, and one study showed that a shorter trimming cycle might reduce the effect of an increased DIPJ and give optimum performance by reducing the duration of the landing phase and achieving a more symmetrical landing pattern (Moleman et al 2006). However, certain factors from these results might not be applicable to all types of horses due to the intrinsic nature of the environmental challenges; such as workload, ground surface characteristics, individual biomechanics, concurrent musculoskeletal conditions, previous history of trimming, etc. For this reason, some horses might adapt to or benefit from a longer trimming interval, and this study aims to provide evidence that an extended trimming cycle might remain of benefit to the foot biomechanics and translate into an improvement in movement symmetry.

Recent research has focused on the influence of trimming and shoeing on gait symmetry as an indirect indicator of mechanical difference affecting force production between contralateral limbs. A study carried out on military working horses subjected to a short shoeing cycle of 2-3 weeks involved evaluation by means of an Inertial Sensor System (ISS) pre-trimming, before and after shoe removal, immediately post-trimming and after shoe fitting.

All significant differences were relative to the trimming and balancing evaluation, as it affects distal limb inertia, resulting in a more symmetrical foot placement between contralateral limbs. The study found a relatively minor change in movement symmetry after shoe fitting - the major effect of trimming can be explained as it affects both the stance and the swing phase of the stride and may increase the symmetry on the landing phase (Pfau et al. 2016).

It has been reported that the technique and experience of the farrier has a remarkable effect on the outcome of the application of the same trimming protocol (Kummer et al. 2009), and even the fact that the farrier is left or right handed might have a profound impact on the final result (Ronchetti et al. 2011).

1.2 Aims

The present study aims to further investigate the effect of hoof trimming on movement symmetry, and to establish the optimum timespan of the changes produced by this intervention on the biomechanics of the equine digit.

1.3 Study population

From a total of forty ponies located at the Glenda Spooner Farm (World Horse Welfare) in Shepton Mallet (Somerset, UK), twenty-six were selected as potential candidates to this study population (Table 1.1). Age range was 1.5-18 years old. Horses included 9 geldings and 17 mares. All horses were crossbred and included Cob and Cob Cross (13), Native Pony (10) and Arab Cross (3). Permission was given for the study by the director of WHW (Appendix I).

The horses were selected according to the following study inclusion criteria:

1) Minimum height of 11.0 hands.
2) No known previous history of lameness and/or no recent history of lameness.
3) Adequate training and handling to allow trot up on a lead rope.
4) Successful lameness evaluation by a qualified veterinary surgeon, including static examination and trot up in a straight line on concrete. (Evaluation during lunged exercise was not possible due to age and handling ability of the horses).
5) All horses received a score on a static conformation evaluation described by Mawdsley et al. (1996) which was performed by a single observer (not the author) (Appendix II).

Table 1.1: *Details of horses pre-selected to this study population. M: male. F: female.*

Horse	Age (years)	Height (hands)	Breed	Gender	Time since last trim (weeks)
1	9	15.1	Cob Cross	M	9
2	2	12.2	Arab Cross	F	6
3	17	13.0	Welsh x Cob	M	7
4	6	13.1	Welsh x Cob	F	9
5	3	12.1	Native Pony	F	8
6	3	11.2	Native Pony	F	9
7	16	13.3	Cob	F	6
8	6	13.2	Cob Cross	F	3
9	6	14.0	Arab Cross	M	6
10	9	13.1	Cob	M	7
11	8	14.3	Cob	M	10
12	6	14.0	Cob Cross	F	6
13	3	13.0	Native Pony	F	7
14	6	12.1	Native Pony	M	9
15	3	13.0	Cob	F	10
16	8	12.3	Cob	F	5
17	1.5	12.3	Arab Cross	M	1
18	8	13.1	Native Pony	F	5
19	4	13.2	Native Pony	F	9
20	5	13.2	Welsh x Cob	F	12
21	18	14.2	Cob	F	7
22	3	13.2	Native Pony	F	5
23	14	14.0	Cob	F	8
24	12	11.3	Native Pony	F	7
25	16	11.2	Native Pony	M	5
26	3	11.0	Native Pony	M	5

1.4 Research method

As part of the preliminary phase of this research project, a pilot study using 2 horses was undertaken (Appendix III). Each horse had a different trimming protocol applied to it with the following goal:

- To determine the suitability and repeatability of the trimming protocol for this study (Appendix III).

This is a quantitative experimental study gathering data on the movement symmetry of the horse using an inertial sensor system (ISS), Equinosis® Q[1] and lameness locator software.

The Equinosis® Q with Lameness Locator is a veterinary diagnostic system which analyses the degree of asymmetry during each phase of the motion cycle of the horse's limbs. It comprises of three wireless microelectronic sensors that measure movement of the head (poll) and pelvis (tuber sacrali) associated with the forelimb and hindlimb locomotion respectively. These measurements are computed to the overall gait and speed of the horse, registered by a sensor placed on the right fore pastern. The measurement of the maximum and minimum difference in head and pelvis height for every forelimb and hindlimb stride allows for measurement of movement symmetry during the cranial and caudal aspects of the swing phase of the stride. Equinosis uses cut off metrics for the head and pelvis movement to determine the degree of asymmetry (Table 1.2). It is an indirect measure of the degree of asymmetry associated to the landing and push-off phases, hence allowing characterisation of the type of lameness where it is present. This data is then shown visually by the use of the lameness locator software (Appendix IV). Similar equipment has been used in previously published research within the scope of the present study (Pfau et al. 2016).

The process is completely non-invasive, the microelectronic sensors measure precisely how the horses move and the sensors compute precise measurements, tracking head and torso movement accurately to less than one millimeter at 100 meters.

Parameter	Definition	Cut-off recommended by Equinosis
Pelvis Diff Max	Difference between the maximum height reached by the pelvis during the landing phase of the stride of the right hindlimb and the maximum height of the pelvis during the landing phase of the stride of the left hindlimb	+/- 3 mm
Pelvis Diff Min	Difference between the lowest height of the pelvis during the landing phase of the stride of the right hindlimb and the lowest height of the pelvis during the landing phase of the stride of the left hindlimb	+/- 3 mm
Vector Sum (Total Diff Head)	Overall amplitude of head movement asymmetry for forelimb	8.5 mm

Table 1.2: *Metrics used for exclusion criteria.*

Equinosis® Q with Lameness Locator provides a mean value of the measurement obtained from each stride. The Vector Sum (VS) is used to measure the amplitude of fore limb asymmetry, whereas Pelvis Diff Max and Pelvis Diff Min measure the amplitude of hind limb asymmetry. All three metrics can have either positive or negative values which are defined by the predominant side of asymmetry, for that greater amplitude of movement asymmetry associated with the right fore or right hindlimb will be defined with positive values and left-sided movement asymmetry will be associated with negative values. In the present study, the right or left asymmetry component was not taken into consideration given that the aim of the study was to quantify the effect of a trimming intervention in the overall degree of asymmetry, regardless of its predominant side. For this reason, in common with previous studies (Maliye 2015), all values for asymmetry metrics were multiplied by a factor of -1 in order to work only with positive value.

The system uses 3 inertial sensors which are fitted to the horse (Figure 1.1).

Figure 1.1: *Gait anaylsis inertial sensors.*

The feet were picked out and wire brushed clean prior to the application of the gait analysis sensors being applied to the horse (Figure 1.2).

Figure 1.2: *A clean foot ready for the gait analysis to begin.*

The sensor application process was then undertaken as follows: One sensor was placed on the poll, a second sensor on the pastern of the right fore limb and a third sensor on the pelvis.

The Equinosis sensors were applied using their neoprene straps (Figure 1.3).

Figure 1.3: *Application of the gait analysis sensors on the poll, pastern and pelvis.*

After the horses had had their hooves brushed out and had been fitted with the ISS they were trotted up once over a 50 metre hard surface in a straight line, so that they became familiar with the environment and activity. The horses were then trotted up and back twice (up to approximately 200 metres) while recording movement data from the ISS. This ensured that objective, complete data was obtained for a minimum of twenty-five strides for every examination. After the initial assessment on trot-up and the first data recording to obtain pre-trim results all the horses were trimmed by the same AWCF qualified farrier (The author), according to the trimming protocol described by Duckett (1990).

All the horses were then trotted up again to gain post trim data. The horses were evaluated using ISS at 2, 4 and 6 weeks from the day of trimming. At each visit the feet were cleaned out and the Equinosis inertial sensors applied, and the trot up repeated to gain a further 25 strides for each horse on each visit.

The data collected gave us pre-trim and post trim results, after 2 weeks, 4 weeks and 6 weeks. All the data collected was stored on a pass code locked computer which was installed with the Equinosis software. In the case of poor data recording or the horse misbehaving, which could lead to inaccurate measurements, the examination would be re-started. All horses were kept on identical management, daily routine and work level.

1.5 Trimming protocol

Following a literature review on equine biomechanics and application of remedial farriery to address foot balance problems through trimming and shoeing, 2 trimming protocols were identified and evaluated further for suitability (Appendix lll). The trimming protocol described by Duckett (1990) was ultimately selected for this study, as this method relies on external reference points on the hoof capsule as landmarks to create a map of internal points of the foot to which the trimming can be tailored. (Figure 1.4).

Figure 1.4: *External reference points on the solar surface and dorsal hoof wall measured using engineers' calipers.*

The hypothesis of this method is that the Centre of Pressure (CoP) of the weight-bearing limb corresponds to an external reference point (referred to as Ducket's dot) located 9.5mm caudal to the frog apex. This method relies on a second reference point (otherwise known as Duckett's bridge) at the widest part of the foot, which correlates with the Centre of Rotation (CoR) of the distal interphalangeal joint as its external projection. Three essential distances were measured by means of engineers' calipers:

1. The distance between the CoP and the caudal-most weight bearing point of the heels.

2. The distance between the dorsal-most edge of the dorsal hoof wall (toe) and the CoR.

3. The total dorsal hoof wall length (figure 1.4).

All three measurements were the same.

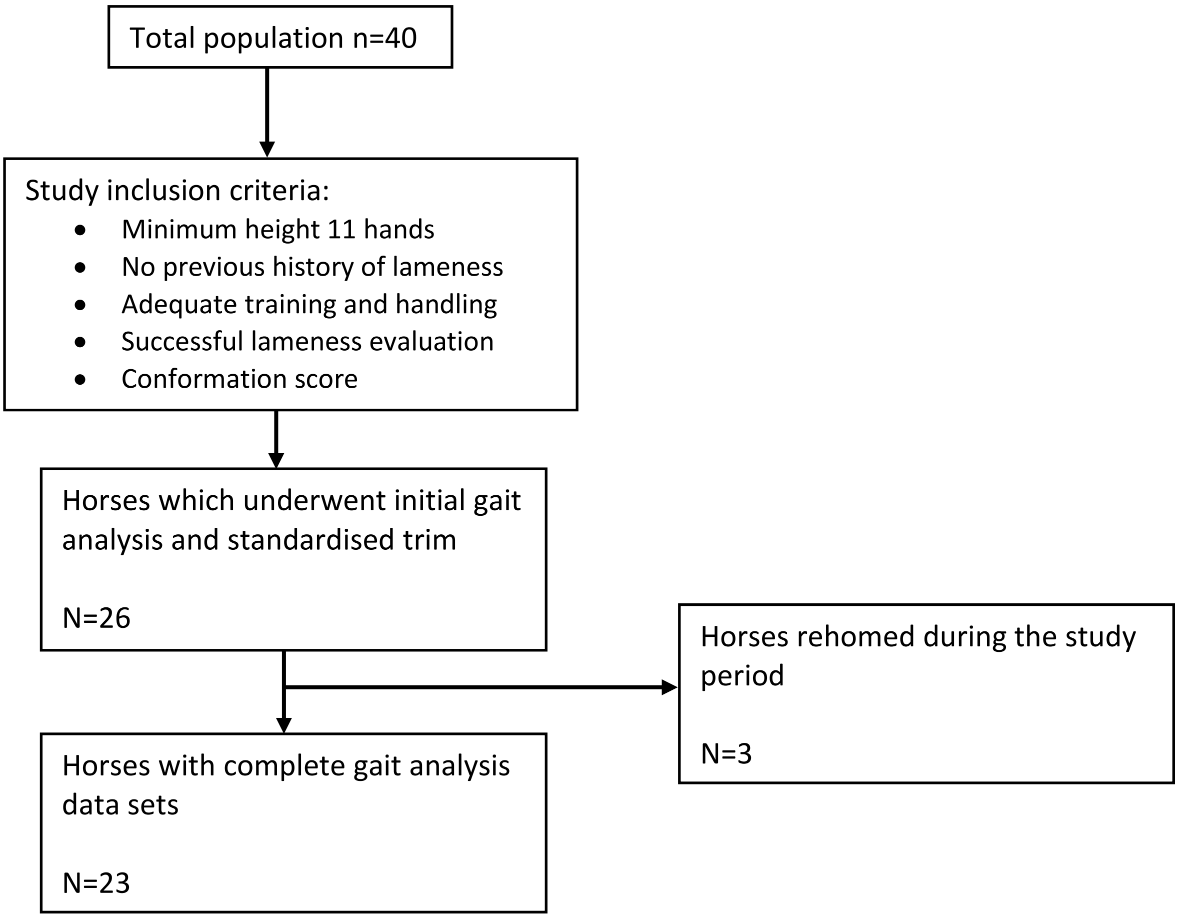
Ducket's trimming protocol was performed on all horses from the study population by an experienced farrier (The author).

1.6 Data collection

Inclusion / exclusion criteria

From the selected group, three horses were rehomed during the study period (horses 21, 24, 25); the data collected from these horses was not included in the final analysis as it was incomplete.

Table 1.3: *Flow diagram of study population showing the application of inclusion and exclusion criteria to the study population.*



The above flow chart (Table 1.3) shows the size of the original population at the start of the study and how the strict inclusion/exclusion criteria left the final 26 for the study, 3 of which were rehomed leaving 23 with full data sets.

1.7 Statistical analysis

Statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS 24) software. Variables were assessed for normality both graphically and by means of the Shaphiro-Wilk test, which corroborated that data was not normal distribution. For this reason, median values were reported for all three variables: (i) Pelvis Difference Minima, (ii) Pelvis Difference Maxima, and (iii) Vector Sum for forelimbs. A related samples Friedmans test was used to analyse differences in movement symmetry between the five time points or data collection times: time 1, (pre-trimming), time 2 (post-trimming), time 3 (2 weeks post-trimming), time 4 (4 weeks post-trimming) and time 5 (6 weeks post-trimming). Related samples Wilcoxon signed rank tests were applied for pairwise comparisons of Vector Sum values. Statistical significance was set at $p < 0.05$.

1.8 Ethical considerations

The study was carried out with the permission of WHW. It was clearly explained what the study would involve, that the horses' welfare would be paramount, and all the data would be kept confidentially on a password protected computer and that WHW could withdraw from the study at any time (Appendix I). Only sound fit horses were used and if any became lame during the study they would be removed, and veterinary attention would be sought.

The equipment was transported to the site so as not to distress the horses. All horse handlers were competent staff of WHW who dealt with the handling of the horses during the study and the appropriate protective equipment was worn at all times. The horses were fitted with the Equinosis equipment and trotted up before the data was recorded to settle the horses and obtain good data.

All data retrieved was stored on a key locked lap-top for security reasons. When the data was finished with it was deleted and any hard copy data was shredded and burned to comply with data protection.

Chapter 2-Results

2.1 Data tables

All the horses selected by the inclusion criteria had their data recorded and saved on an Excel[2] spread sheet for analysis, leaving 23 full data sets which is recorded on (table 2.1).

Table 2.1: Horse data for Diff max median, Diff max SD, Diff min Median, Diff min SD and Vector sum for pre-trim, post trim, week 2, week 4 and week 6.

	PELVIS		PELVIS			PELVIS		PELVIS		
	Diff Max	Diff Max	Diff Min	Diff Min		Diff Max	Diff Max	Diff Min	Diff Min	
HORSE	Mean	SD	Mean	SD	Vector sum	Mean	SD	Mean	SD	Vector sum
1	-5.3	4.3	7.9	3.8	1.8	-3.2	4.7	5.3	4.0	10.4
2	-6.9	4.8	2.8	3.5	10.5	-5.8	3.0	5.6	4.1	3.2
3	-4.8	4.4	-3.8	6.3	13	-3.0	3.8	-3.7	3.5	25.1
4	4.4	6.5	7.6	6.1	10.3	5.3	4.1	3.8	5.3	16.6
5	5.2	6.3	3.1	7.6	3.9	-0.2	3.9	4.3	6.6	7
6	-0.1	2.3	0.1	2.9	5.7	0.5	3.2	0.2	3.2	15.1
7	-1.5	3.3	-10.6	3.4	27	0.0	3.8	-6.9	3.7	22.1
8	-0.6	2.4	-0.6	2.7	2.9	-0.5	3.9	-1.3	2.5	2
9	7.6	5.7	8.8	4.2	5.9	3.0	4.8	4.0	4.6	4.4
10	-1.3	2.2	-2.2	2.4	14.6	-0.8	2.2	-2.0	2.0	10.7
11	3.7	3.2	2.1	3.0	5.5	3.7	3.3	0.5	3.2	3.1
12	-1.0	4.2	1.5	4.3	1.1	-1.1	4.4	1.3	3.4	5.7
13	-1.0	3.3	4.5	3.7	5.1	-2.3	4.3	3.8	3.8	4.6
14	4.6	2.8	-2.0	4.9	4.6	4.1	2.7	-3.1	4.3	3.5
15	0.7	2.2	-1.5	2.5	12	-0.6	3.3	-2.0	3.5	20.6
16	6.1	4.1	5.0	3.8	11.3	4.6	3.7	2.4	3.2	8.5
17	-1.1	3.6	1.4	3.8	4.4	-2.0	2.6	2.1	2.9	1.6
18	-4.9	3.8	4.0	4.0	20.8	-2.0	3.4	4.0	6.0	21.1
19	0.8	4.8	3.2	3.5	11.6	-0.9	3.1	1.9	3.5	13.1
20	-1.5	2.8	5.4	2.9	4.2	-0.1	1.8	5.8	2.7	2.9
21	left study									
22	2.1	3.0	2.3	3.5	2.5	1.7	3.0	2.2	3.9	3.1
23	-0.8	4.3	-0.2	3.9	7.6	0.4	4.2	0.5	3.9	6.6
24	left study									
25	left study									
26	0.2	3.0	3.8	4.4	14.2	0.0	2.6	1.5	2.9	20.9

	WEEK 2					WEEK 4					WEEK 6				
	PELVIS		PELVIS			PELVIS		PELVIS			PELVIS		PELVIS		
	Diff Max	Diff Max	Diff Min	Diff Min		Diff Max	Diff Max	Diff Min	Diff Min		Diff Max	Diff Max	Diff Min	Diff Min	
HORSE	Mean	SD	Mean	SD	Vector sum	Mean	SD	Mean	SD	Vector sum	Mean	SD	Mean	SD	Vector sum
1	-4	5.3	5.9	6.3	19.5	-2.1	10.2	2.4	6.8	13.6	-0.6	3.2	5.6	3.9	2
2	-5.2	3.3	10.8	4.4	4.8	-3.6	3.1	5.3	3.4	7.6	-1.2	4.9	10	3.6	4.2
3	-2.7	4.9	-12.2	6.5	22	0.6	4.3	-10.6	4	32.7	-5.4	5.2	-5.1	7.2	13.6
4	1.8	5.2	6.6	5.1	28.6	0.5	3.9	8.7	4.7	22.7	0.1	3.8	4.9	2.8	17.8
5	-0.3	5.1	2.4	5.9	26.1	-0.5	3.9	2.3	4.1	38.8	-0.3	5.5	-0.5	5.8	16.4
6	1.7	4.4	1.4	6.5	9.1	0.9	3.5	2.5	6.1	21.9	0	5.8	-1.4	5.1	17
7	-0.1	4.6	0	4.8	25.3	-2.1	3.7	-3.1	3.6	22.2	-1.7	2.9	-6.4	4.3	19.5
8	0.5	5.5	0.6	3	12.8	-1	3.1	-2.4	2.8	6	2	2.8	1.7	2	9.4
9	7.4	3.5	11.1	3.6	4.5	6.9	5	9.7	4.8	6.4	6.7	3.7	5.3	3.6	16.3
10	-0.2	1.9	-1.1	2.9	14	-0.8	2.4	0.6	2.7	11.1	-4.7	2.3	0.3	2.6	9
11	-1.2	4	-4.1	3	0.4	0.4	3.2	0	2.5	5.4	2	3.1	-2.2	2.1	2.9
12	1.6	5.2	-4.7	3.4	7.6	4.9	7	2.9	3.9	7.4	0.9	3.7	2.7	4.7	22.4
13	-1.2	4.8	5.3	5.8	11.9	1.5	4.9	5	4.9	21.2	-2.6	3.9	4.9	3.8	4.2
14	0.8	3.6	-4.4	4.4	6.9	3.6	3.6	-2.2	4.5	9	0	3.7	-2.3	3.7	15.2
15	2.4	3.3	-0.9	4.8	2.7	4.5	3.3	-1.4	3.9	13.6	-1	3.7	-1.7	3	8
16	3.5	3.5	4.6	3.3	6.6	0	3.1	-0.5	3.5	14.1	2.4	2.7	1.4	3	1.5
17	-0.5	3	0.2	3.1	13.8	-0.9	3.1	-1.8	2.6	11	-2.7	4.9	2.7	3.9	11.1
18	0.2	3.9	0.5	3.7	15.9	-1.9	2.9	-0.1	3.4	17.3	-3.5	3.1	-2.9	5.2	25.8
19	3.2	3.7	1.2	3.6	12.3	1.6	4.9	2.8	4.2	12.7	-0.9	4.2	4.4	2.9	27.9
20	-3.3	2.8	3.9	2.9	4.8	-0.8	3	3.3	2.9	1.2	-2	3.5	4.1	4	9.7
21															
22	-2.4	3.2	-2.1	3.9	10.1	0.5	3.6	4.4	2.9	12.2	2.2	4.6	7.2	4.6	3.6
23	0	3.8	-1.8	3.9	4.7	3.5	5.1	1.1	3.8	21.2	6.5	4	3.9	4.8	10.2
24															
25															
26	0.8	3.9	-2	4.2	33.8	0.7	2.2	1.5	2.7	17.2	0	3	3	4.3	20.7

2.2 Conformation score results

The conformation score used a number system to grade conformation from 1-7 with 4 being the optimal score. This showed that the forelimb hoof pastern axis (HPA) scores ranged from 3-5 with 13 horses having the optimal score of 4 and the Foot slope ranged from 3-6 with 13 horses having the optimal score of 4. Hindlimb HPA showed the scores ranged from 2-5 with 14 horses having the optimal score of 4 and Foot slope ranged from 2-5 with 11 horses having the optimal score of 4 (Appendix II).

2.3 Variation in the median value for each symmetry metrics.

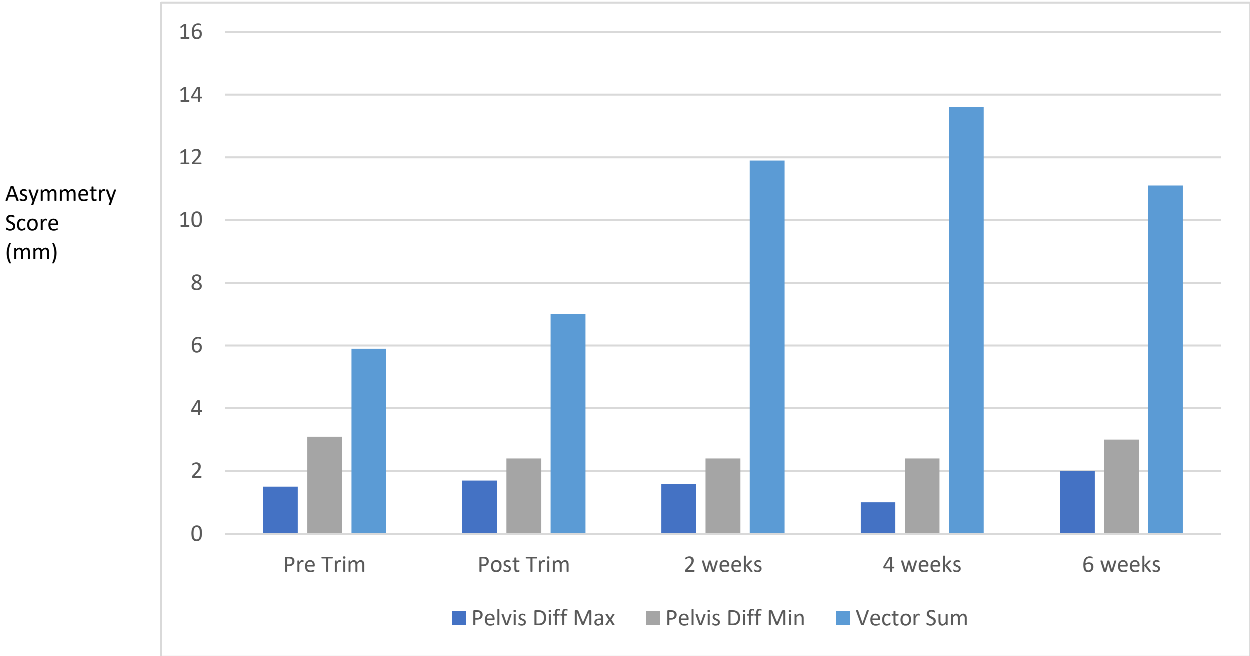


Figure 2.1: *Variation in the median value for each symmetry metrics (Pelvis Diff Max, Pelvis Diff Min, VS) at each time point throughout the study period measured in millimeters (MM).*

The results of the Friedman test indicated that there were no statistically significant differences in Pelvis Diff Max (p = 0.485) or Pelvis Diff Min (p = 0.651) distributions along the study. However, the difference in distribution of Vector Sum was statistically significant (p = 0.026). The results of the related samples Wilcoxon signed rank test showed statistically significant increases in Vector Sum when pre trim (time 1) was compared to (time 4) week 4 (p = 0.006) and to (time 5) week 6 (p = 0.036). No significant difference was observed when comparing Vector Sum pre and post trimming intervention (p = 0.475) and pre and (time 3) 2 weeks (p=0.061).

2.4 Variation in forelimb asymmetry (Vector sum)

Median Vector Sum scores increased after trimming reaching a maximum at week 4, before starting to decline slightly at week 6. The asymmetry scores at week 4 (p=0.006) and week 6 (p=0.036) were statistically significant. (Figure 2.2).

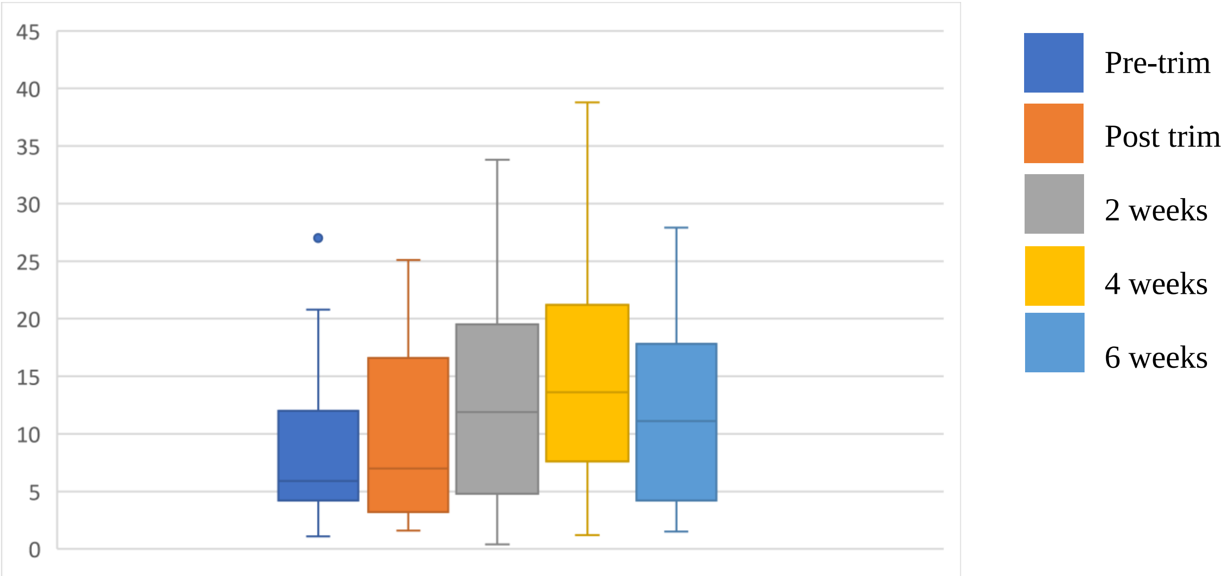


Figure 2.2: B*ox and whisker plot showing variation in Vector Sum (VS) as a measure of amplitude of forelimb asymmetry measured in millimeters (MM). The median value for that particular data set is represented with a line (-) in the quartile.*

2.5 Variation in hind limb asymmetry results (Diff min)

Over the course of the 6-week shoeing cycle there was no significant difference in Pelvis Diff Min (p=0.651). There was a slight decrease in the median value after trimming which was maintained at week 2 and week 4. There was a slight increase by week 6.

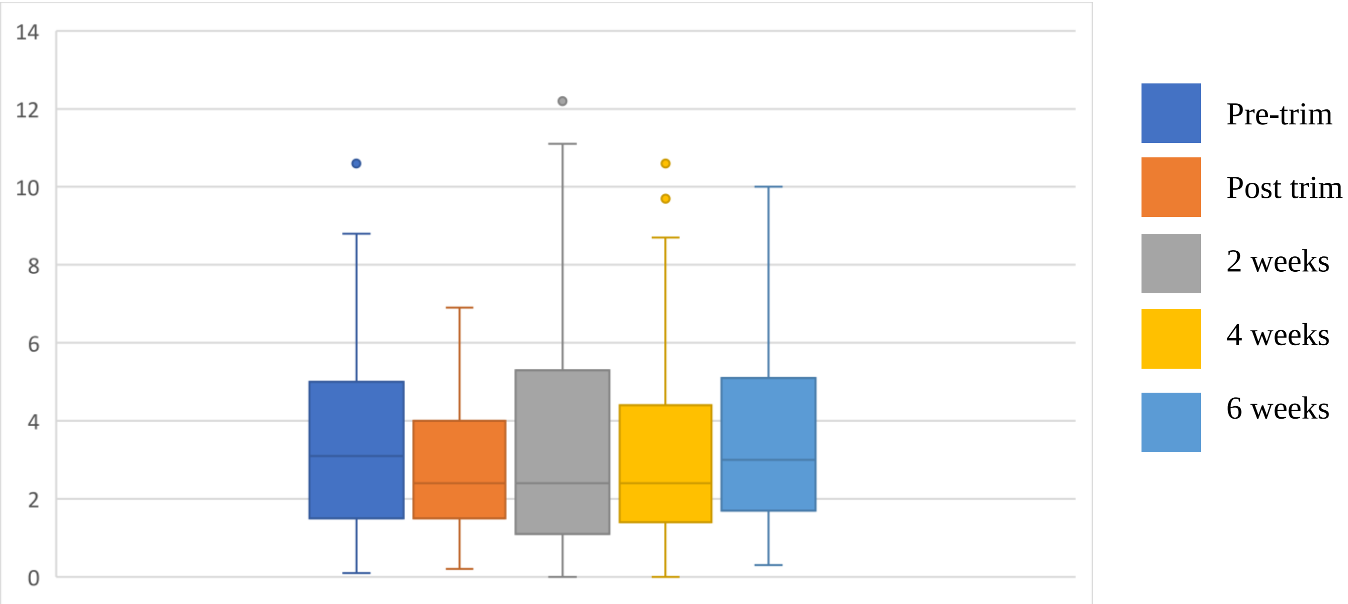


Figure 2.3: *Box and whisker plot showing variation in Pelvis Difference Minima (Pelvis Diff Min) as part of the measurement of hindlimb asymmetry measured in millimeters (MM). The median value for that particular data set is represented with a line (-) in the quartile.*

2.6 Variation in hind limb asymmetry results (Diff max)

Pelvis Difference Maxima (Pelvis Diff Max) showed variation in the median values and interquartile ranges over the 6-week period. However, overall there were no significant differences in Pelvis Diff Max ($p=0.485$).

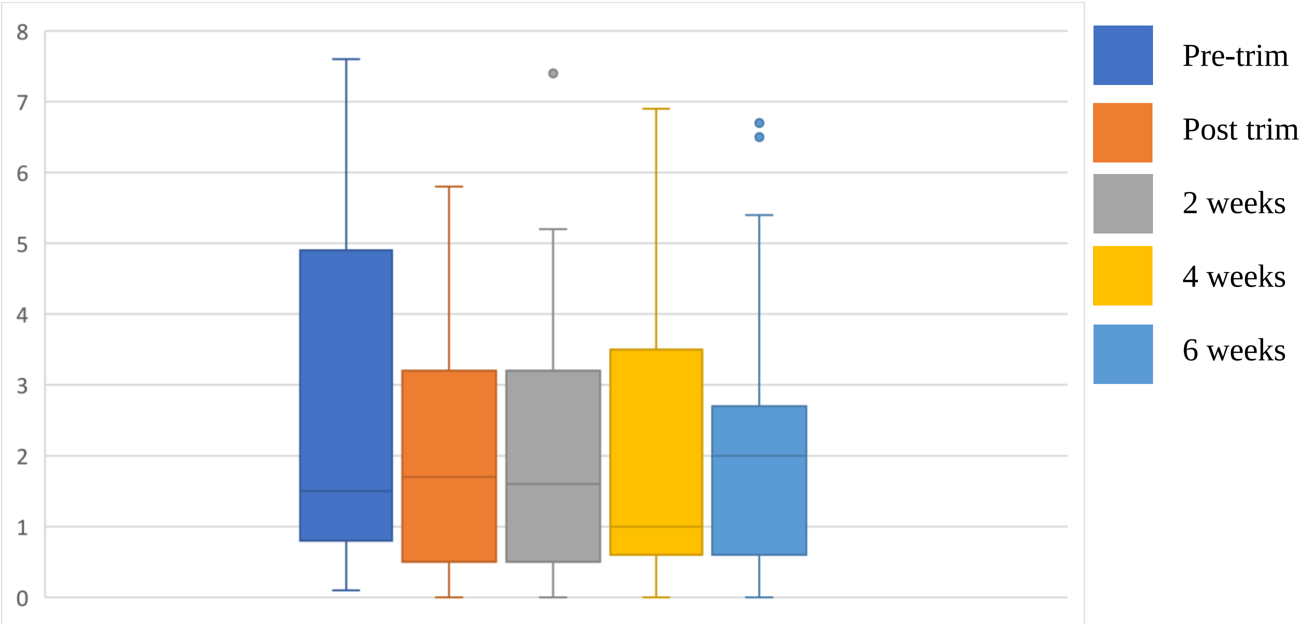


Figure 2.4: *Box and whisker plot showing variation in Pelvis Difference Maxima (Pelvis Diff Max) as part of the measurement of hindlimb asymmetry measured in millimeters (MM). The median value for that particular data set is represented with a line (-) in the quartile.*

Chapter 3-Discussion

3.1 Discussion

The aim of this study was to assess the effect of a standardised trimming protocol on movement symmetry, and the magnitude of this effect across a six-week trimming cycle. The hypothesis was that the trimming intervention would improve the overall symmetry of the horse's movement, and that changes in the degree of asymmetry might be used to extrapolate the optimum length of the trimming cycle in order to maximise locomotion.

The results of this study did not support this hypothesis. Over the 6-week shoeing cycle the forelimb asymmetry significantly worsened, which was an unexpected result. It is possible that the trimming resulted in biomechanical changes in hoof loading which result in pain. Others have shown that a trimming protocol may need several more cycles to allow the horses to go through a response process (Clayton et al 2011) and to gain the benefits of the trim in terms of improvement in movement symmetry. Over the 6-week shoeing cycle there were slight changes in hindlimb asymmetry, but overall these were not statistically significant.

Interestingly, there was an increase in forelimb asymmetry immediately after trimming, which became statistically significant at week 4 and 6. It is not uncommon that horses show changes in gait due to the effect of trimming on the biomechanics of the equine digit which eventually leads to changes in the CoP and a change in the breakover duration which might occasionally cause a degree of pain that manifests in movement asymmetry. The overall forelimb asymmetry increased post trim and at 2 and 4 weeks after trimming, 4 weeks was the peak of the increase in asymmetry decreasing slightly by week 6, there was a greater inter-individual variability between horses than at the beginning of the study.

The effect of the trimming intervention on hindlimb movement asymmetry differed from that of the forelimbs in Pelvis Difference Minima (Pelvis Diff Min) even though it was not statistically significant. Immediately after trimming there was a decrease in hindlimb asymmetry during the landing phase of the stride at which the median value stayed the same throughout the study until week 6 which had a slight increase, this suggests that the trimming improved the movement symmetry. The inter quartile range increased at week 2 then decreased week 4 possibly suggesting that the horses responded well to the trim initially with a slight inter-individual variability at week 2 which settled to give the optimum week of week

4. When considering the landing phase of the stride, dissipation of forces occurs throughout the hoof and structures within it and this could potentially be the most important part of the hind limb action for continued performance.

When considering Pelvis Difference Maxima (Pelvis Diff Max) the flight phase of the stride, there was an improvement in inter quartile range but the median value for hindlimb gait symmetry increased even though it was not statistically significant. This may suggest that horses went through an adaption process post trim with a slight decrease in asymmetry at week 2 which again could be the response period as at week 4 there was a larger improvement suggesting the trimming improved the movement symmetry and again with Diff min the optimum week being week 4, This finding is consistent with previous literature (Pfau *et al.* 2016) reporting improvements in specific parts of the stride cycle.

There are several limitations to the study which may impact on the results. The study population all had welfare issues and had been subject to poor diet leading to poor horn quality and also a poor trimming cycle. The time period between the last trim and the start of the study varied widely, up to 12 weeks with 15 of the 23 horses having a trimming interval greater than 6 weeks. In future studies, regular trimming could be undertaken prior to the study to allow horses to go through a response process (Clayton et al 2011). It is possible that application of a standardised trimming protocol to this population of welfare horses is not appropriate and that individual trimming protocols to account for differences in conformation, hoof shape, hoof quality and environment may be more appropriate.

Although the included horses were not considered lame when assessed by a veterinary surgeon, analysis of the objective data showed that every horse had greater asymmetry than the accepted normal values for this equipment at one or more points during the study (8.5mm for forelimb and 3mm for hindlimb). Previous studies have shown that objective gait evaluation is considered more sensitive than subjective evaluation (McCracken et al 2012). It is possible that the horses considered lame by the objective analysis have underlying mild orthopaedic disorders, and this may be contributory to the lack of improvement in symmetry following trimming.

Ground conditions were not measured or controlled for during the study. The study was started in March when the ground was wet and continued through to May when the weather had become hot and the ground baked which has the potential to have affected movement symmetry due to solar bruising. The horses in this study were kept out and hence likely to be affected by changes in weather and ground conditions. However, objective measures of ground hardness were not made at each evaluation point. Although the hypothesis relating to ground conditions cannot be evaluated retrospectively, the records from WHW show that the author was presented with more foot sore horses in April than in the previous months which corresponds to week 4 (Appendix V). Although the included horses were not considered lame when assessed by a veterinary surgeon, it has been shown that ISS is more sensitive at a lower level of sole pressure than subjective evaluation (McCracken et al. 2012). In future studies, it would be better to conduct the study during a time when ground conditions are less likely to change or to use a population of horses that are predominately stabled and hence less likely to be affected by hard ground.

Equinosis advise a cut off to determine the difference between a sound or symmetrical horse and a lame or asymmetric horse. The cut off values recommended are 8.5mm for fore limb and 3mm for hind limb metrics. Over the study period there was a slight increase in the number of horses exceeding 8.5mm for forelimb metrics and a slight decrease in the number of horses exceeding 3mm for hindlimb metrics.

Chapter 4-Conclusion

4.1 Conclusion

A standardised trimming protocol was associated with a significant increase in forelimb asymmetry and no significant change in hindlimb asymmetry. These results were unexpected and further research is warranted to understand these. It is possible that application of a standardised trimming protocol to this population of horses is not appropriate and that individual trimming protocols to account for differences in conformation, hoof shape, hoof quality and environment may be more appropriate. Alternatively, uncontrolled confounding factors, for example ground hardness, may have been associated with the increase in forelimb asymmetry. These factors may have a greater role in asymmetry than any potential beneficial effect of trimming. Therefore, future studies should account for a greater number of confounding variables to further elucidate the relationship between trimming protocols and asymmetry.

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Manufacturers
[1]Equinosis® Q, 104 E Broadway, Columbia, MO 65203, USA.
[2]Microsoft Excel office 365, Redmond, Washington, United states.

Appendix I: Correspondence with World Horse Welfare

Margalida Mas Fiol DVM MRCVS
Equine Centre at Langford Vets
Stock Lane, Langford
BS40 5DU, United Kingdom

Deputy Chief Executive Mr. Tony Tyler
World Horse Welfare
Glenda Spooner Farm
Brincil Hill, Kingsdon, Somerton
TA11 7LA, United Kingdom

Thursday 1st February 2018

Dear Mr. Tyler,

I am writing to you to provide an accurate outline of a potential study that we would like to have the opportunity to carry on with the horses kept at WHW Glenda Spooner Farm. The study consists of evaluation of the effect of a certain protocol of trimming in movement symmetry in horses by using an inertional sensor system of gait analysis. Anna Hammond develops a large part of the routinary work at GSF and therefore she has a privilegiate knowledge about all the horses and which of them would meet the inclusion criteria for our study. She has been in contact with your centre manager Claire Dickie who kindly provided a draft list of ponies that would be suitable to be selected. Paul Horner is a well-known accredited farrier and he would provide a specific trimming protocol which will then be evaluated as of how it affects horse's gait symmetry over time. I am a qualified veterinarian and post-graduate student at the University of Bristol and I have been given the opportunity to develop this project by both Anna Hammond and Yvonne Elce, equine surgeon and leading clinician at the Equine Centre which owns the inertional sensor system used in this project.

PROJECT BACKGROUND

Structure and function of the hoof are affected by multiple factors and respond to mechanical challenges by adaptation of growth rate and shape. Shoeing aims: 1) Protect against excessive wear. 2) Aid to treat lameness. 3) Maintain or enhance function. Trimming is a key point to build and maintain a healthy hoof as it affects and determines its conformation (shape, size) and balance (interaction between the foot shape and function in relation to the distal limb and to the ground which the horse works on). Basic measurements to achieve the best fitting trim include ground reaction force (GRF) and point of zero moment (PZM) which determine the extending and flexing moments of the distal interphalangeal joint, and therefore they affect the horse's gait symmetry and stance. (Eliashar *et al*. 2012).

A foot is balanced when its conformation maximizes its mechanical efficiency through adequate trimming, and/or shoeing, and it maintains shape and size in spite of the influence of workload and surface. Trimming and shoeing aim to unload a specific site, induce changes in toe length, position or shape, heel length or height and ground contact area. Several studies have investigated the effects of different trimming protocols on hoof morphology (Clayton *et al*. 2011), interaction with the ground and loading of the distal limb (Wilson *et al*. 1998) and movement symmetry (Pfau *et al.* 2016).

AUTHORS INVOLVED IN THE PROJECT

Paul Horner (BSc Hons AWCF Master Farrier), Margalida Mas Fiol (DVM, MRCVS), Anna Hammond (BVM&S Cert EM (Int. Med.) MRCVS RCVS Advanced Practitioner), Yvonne A. Elce (DVM DipACVS MRCVS).

PURPOSE OF THE STUDY AND HYPOTHESIS

Following on previous investigations of the effect of trimming and shoeing on gait symmetry (Pfau *et al*. 2016), the aim of this study is to **further investigate changes on movement symmetry before and after hoof trimming and the effect of time and trimming intervals on hoof growth and gait symmetry**. This will be based on objective gait analysis by means of an inertional sensor system (Equinosis® Q Lameness Locator).

Hi Claire
¬†
Sorry for some reason your first email did not come up as unread so I missed it but this one was timed well as Roly is in today.
¬†
We are both very happy that they go ahead with the study.
¬†
Many thanks
¬†
Tony
¬†
¬†
¬†
From: Claire Dickie
Sent: 15 February 2018 10:09
To: Tony Tyler
Subject: FW: gait assessment and trimming study at gsf
¬†
Hello,
Hope all is well with you? Marga has asked me to check with you that we are ok to go ahead? Do you have any concerns or are you happy to consent to this? If you could let me know so I can pass a message on we would be very grateful as they are hoping to get started in the next couple of weeks.
Catch up soon,
C x
¬†
From: Claire Dickie
Sent: 02 February 2018 10:47
To: Tony Tyler
Subject: gait assessment and trimming study at gsf
¬†
Hi Tony,
Please see attached letter from Marga re gait assessment project. They are keen to start on 9th Feb if you give consent.
Can
Hello,
Hope all is well with you? Marga has asked me to check with you that we are ok to go ahead? Do you have any concerns or are you happy to consent to this? If you could let me know so I can pass a message on we would be very grateful as they are hoping to get started in the next couple of weeks.
Catch up soon,
C x
¬†
From: Claire Dickie
Sent: 02 February 2018 10:47
To: Tony Tyler
Subject: gait assessment and trimming study at gsf
¬†
Hi Tony,
Please see attached letter from Marga re gait assessment project. They are keen to start on 9th Feb if you give consent.

Can you please let me know your thoughts?
C x

Appendix II: Mawdsley conformation score information sheet

A. Mawdsley *et al.* 463

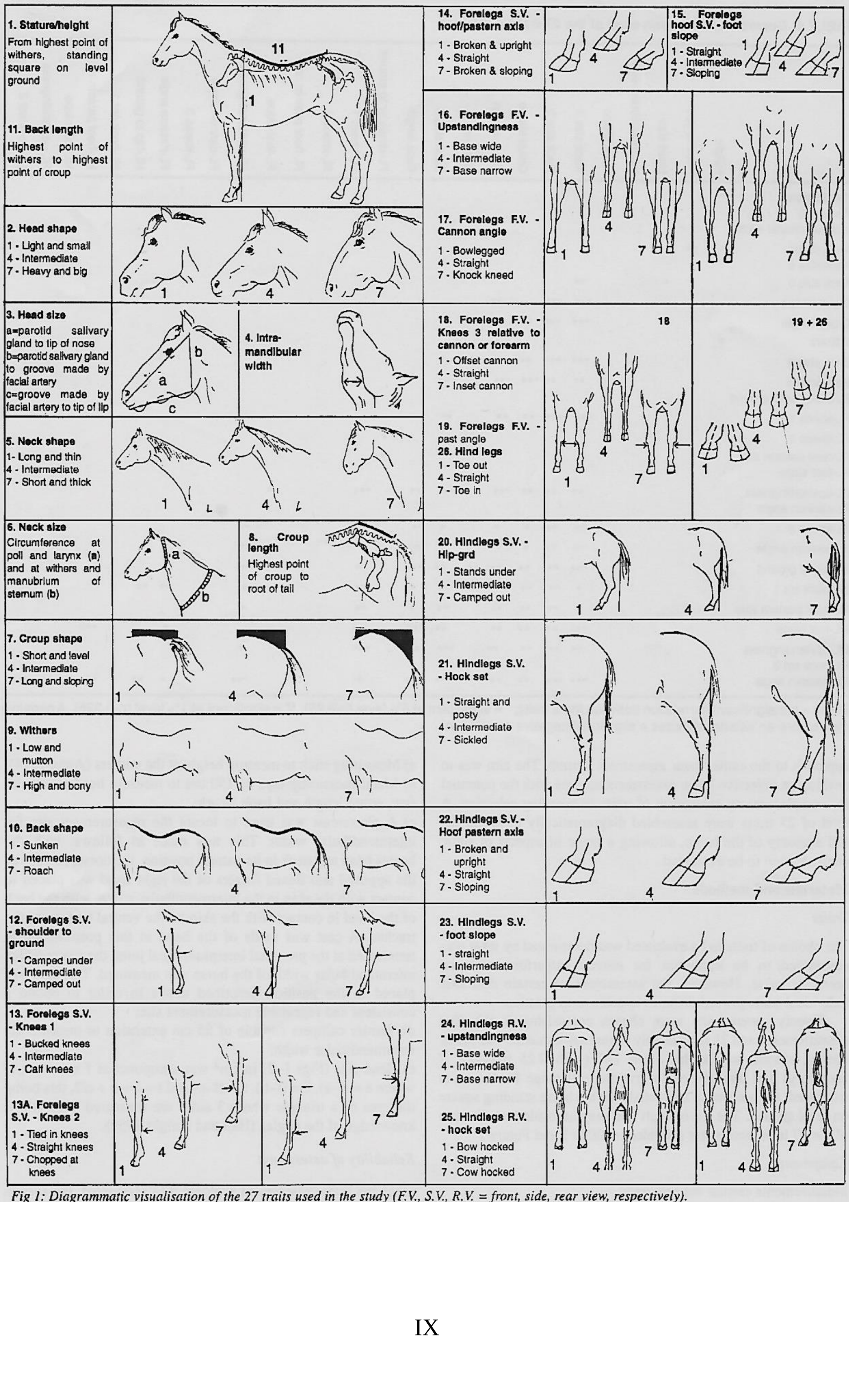


Fig 1: Diagrammatic visualisation of the 27 traits used in the study (F.V., S.V., R.V. = front, side, rear view, respectively).

Appendix II: Conformation score horse information table.

HORSE		FORE	LIMB	SIDE	VIEW	FORELIMB	FRONT	VIEW	HIND	LIMB	HINDLIMB	SIDE	VIEW	REAR VIEW	Pastern
NAME	Shoulder	Carpi 1	Carpi 2	HPA	Foot Slope	Upstanding	Cannon angle	Carpi 3	Hip	Hock set	Upstanding	HPA	Foot Slope	Hock set	Angles
Ang	4	5	5	5	4	5	4	4	5	5	4	4	3	5	4
Belinda	4	5	4	4	4	4	4	4	4	5	5	4	5	5	3
Belle	4	4	4	3	4	3	6	3	5	5	5	3	4	5	4
Clippy	3	3	4	4	4	4	5	4	3	3	3	3	3	4	3
Chester	3	4	5	5	5	5	5	3	4	5	4	4	4	5	3
Cocoa	3	4	4	5	3	3	5	4	4	4	5	4	3	5	3
Declan	4	4	4	4	5	5	5	4	3	5	3	4	5	4	3
Dolly	4	5	5	4	5	3	5	3	4	5	3	4	5	4	5
Dolly R.	4	4	5	4	4	4	5	4	4	5	4	4	5	5	5
Dotty	4	4	5	4	4	4	5	3	4	5	4	4	4	5	3
Duke	3	4	4	4	5	5	3	3	4	5	5	5	5	5	5
Elsa	4	5	4	5	3	4	5	4	3	4	3	4	4	4	4
Fairy	4	5	5	5	4	5	4	4	4	5	4	4	3	5	4
Flo	4	4	4	5	3	4	5	3	4	4	3	3	2	5	4
Freddie	4	4	5	5	6	5	5	3	5	4	4	5	4	4	3
Jess	3	5	4	5	5	4	3	4	3	5	5	5	4	5	5
Mango	3	4	4	4	5	3	4	3	4	5	5	5	5	5	3
Millie	4	4	4	4	4	5	4	2	4	5	4	4	4	4	4
Mulan	4	5	4	5	5	5	4	3	3	4	4	4	4	5	4
Ned	4	4	4	5	5	5	3	3	4	4	4	3	3	5	5
Pepsi	4	4	4	5	5	5	4	4	5	4	4	2	2	4	4
Pudding	3	4	4	4	4	2	3	3	3	5	4	3	2	5	3
Poet	4	5	5	5	4	5	5	3	4	4	4	4	4	6	3
Spirit	4	4	5	4	4	3	5	4	5	4	4	4	4	4	4
Turtle	3	4	5	4	4	5	5	4	4	4	5	5	4	4	3
Violet	3	4	4	4	4	4	4	3	5	4	4	3	3	5	4

Appendix III

Pilot study

As part of the preliminary phase of this research project, a pilot study was outlined with the following goals: 1) To determine the suitability and repeatability of the trimming protocol for this study, and 2) To assess the consistency and reliability of the changes in foot balance associated with said trimming protocol.

Trimming protocol

As a result of the literature review on equine biomechanics and application of remedial farriery to address foot balance problems through trimming and shoeing, 2 trimming protocols where chosen for the pilot study Duckett (1990) and Ferrie (2007).

Duckett (1990): The hypothesis of this method is that the centre of pressure (CoP) of the weight-bearing limb corresponds to an external reference point (referred to as Duckett's dot) located 9.5 mm caudal to the frog apex. This method relies on a second reference point (otherwise known as Duckett's bridge) at the widest part of the foot, which correlates with the centre of rotation (CoR) of the distal interphalangeal joint as its external projection.

Duckett's trimming method was performed on a horse by an experienced farrier. The sole surface was cleaned and the reference landmarks for the CoP and the CoR were outlined with indelible marker. Two essential distances were measured by means of engineer calipers:

1. The distance between the distal most edge of the dorsal hoof wall (toe) and the CoR.
2. The distance between the CoP and the caudal most weight bearing point of the heels (Figure 1).

Figure 1: *Example of foot mapping prior to performing a trim to a standard farriery protocol.*

The total toe length was also measured with engineer calipers which should be the same distance as the previous 2 measurements when the trimming is performed correctly. An external radiopaque marker was placed on the reference point after trimming the hoof according to Duckett's protocol (Figure 2) and prior to taking lateromedial radiographic views of the trimmed feet.

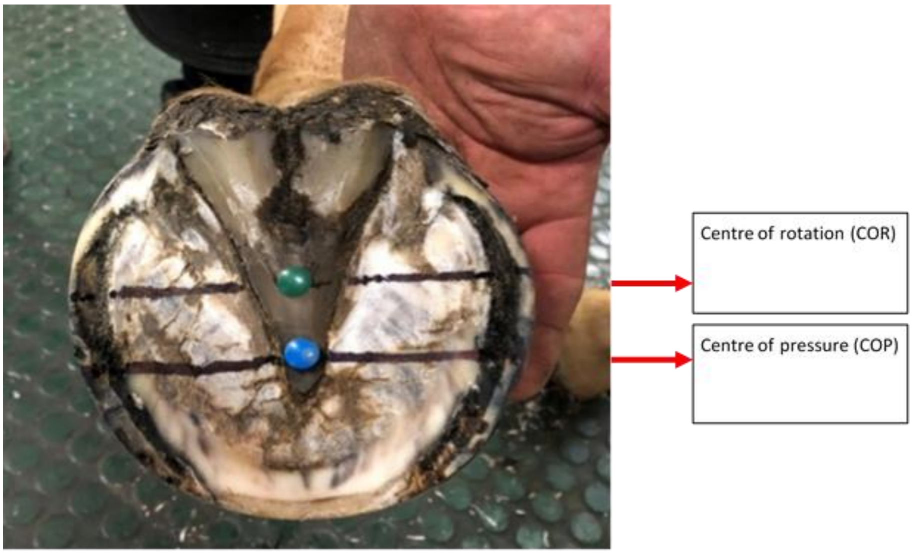


Figure 2: *External reference points located on the sole surface using marker pen and drawing pins.*

Lateromedial and 45-degree dorso-palmar radiographic views were obtained post trimming, to assess the correspondence between the external reference points described on Duckett's trimming method and the internal set points of the centre of pressure and the centre of rotation of the distal interphalangeal joint (Figure 3).

The red line represents the CoP and the yellow line the CoR.

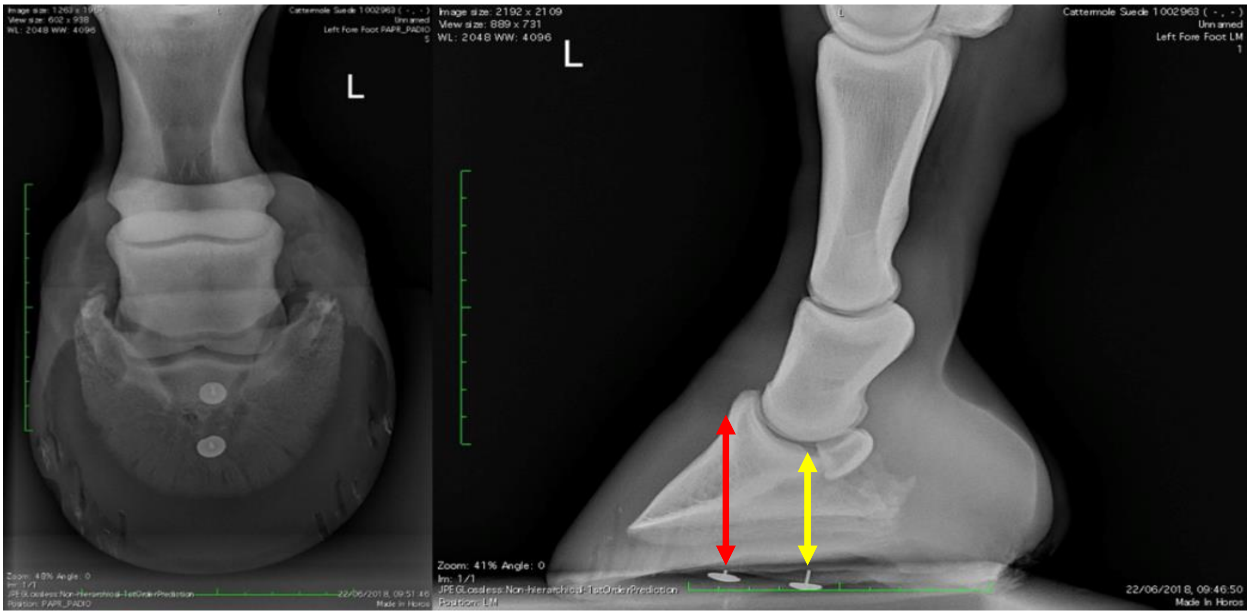


Figure 3: *Radiographic views after application of the trimming method described by Duckett, with radiopaque markers placed on the external reference points.*

Ferrie (2007): The hypothesis of this method is that the centre of the coronary band if measured in a linear method should correspond with the centre of the navicular bone when a vertical line is dropped down, this is also the midline of the coronary band. The forward portion of coronary band from the midline should then divided into thirds, dropping another vertical line at the divide of the first third will give an external reference point of the centre of the coffin joint (figure 4). The hoof should then be divided 50/50 by this line across the solar plane.

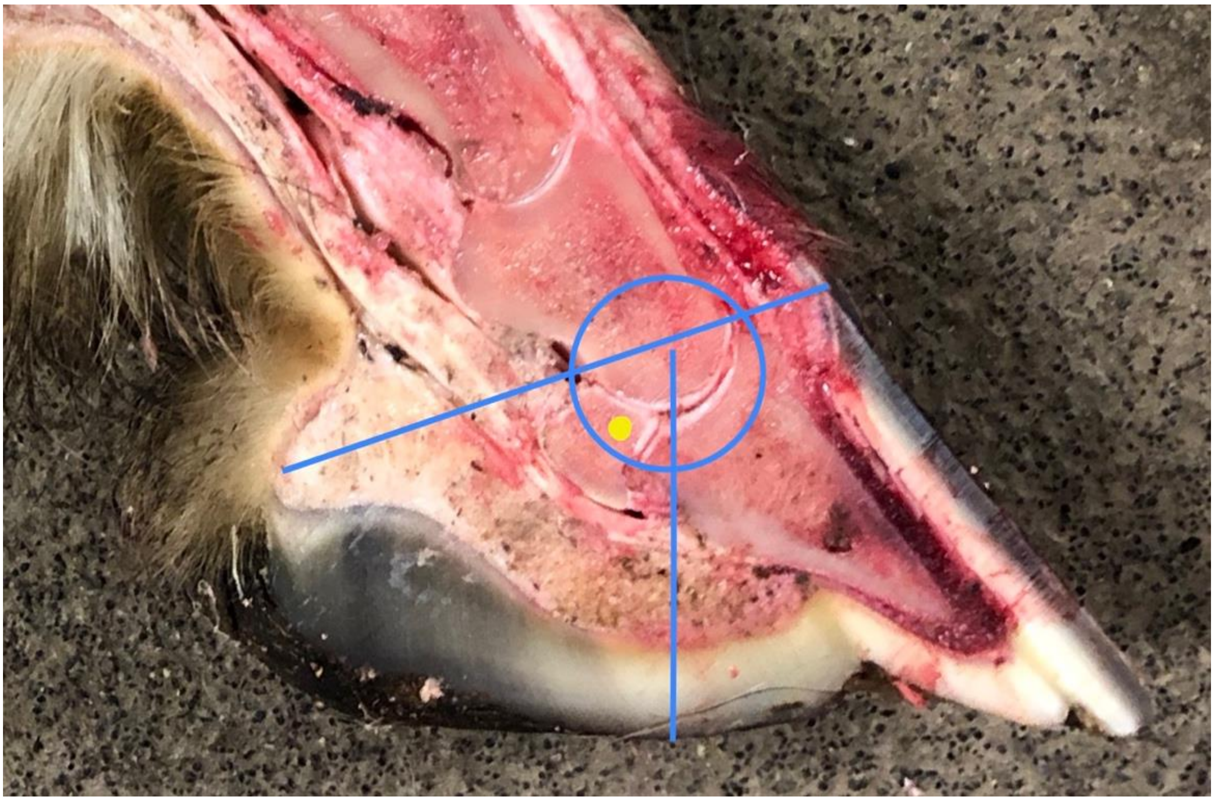


Figure 4: *lateral image of sagittal hoof section showing internal data points.*

Digital calipers were used to measure the linear length of the coronary band in order to find the vertical external reference point which represents the centre of the coffin joint (figure 5).

Figure 5: *The use of digital calipers to establish the external reference points.*

Once the reference point was marked on the bottom of the hoof the proportions of foot were checked for 50/50 divide by using engineers' calipers (figure 6).

Figure 6: *The use of engineer's calipers to check the 50/50 divide after trimming.*

The toe is rasped off at 45° to achieve the 50/50 divide. When the feet were not as perceived to be normal a shoe with the break over reduced can be used to achieve this.

Duckett (1990) was selected due to its applicability, as this method relies on external reference points on the hoof capsule as landmarks to create a map of internal points of the foot to which the trimming can be tailored.

Appendix IV: Data sheets pre-trim

THE EQUINOSIS with LAMENESS LOCATOR®

Trial Report

Case #:
Owner: WHW, GSF
Horse: ANG

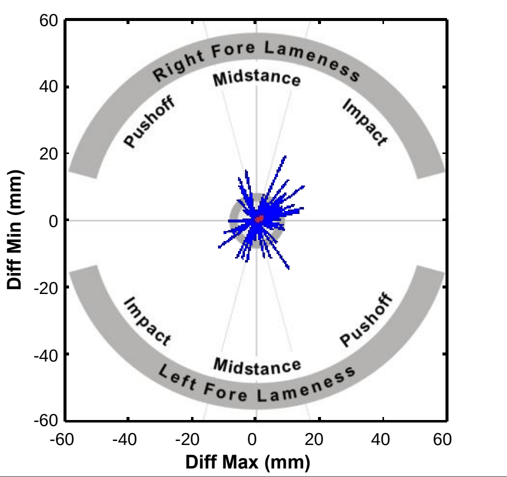
Trial:	Straight Line
Date:	Friday, March 9, 2018 at 5:55 AM
Surface:	Concrete
Blocks:	
Attending:	

Analysis Settings: Default - Delta = 0.1

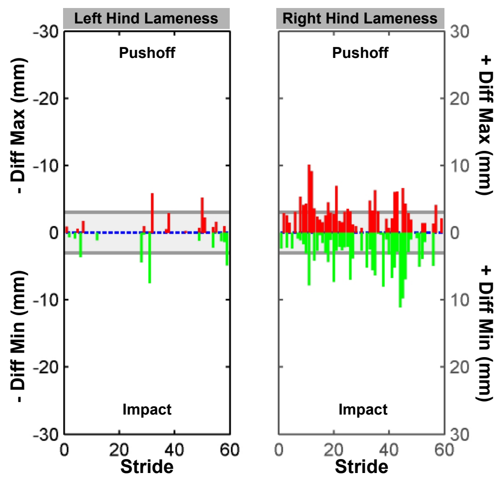
Quantification of Asymmetry

Stride Rate: 1.6 Strides Assessed (fore/hind): 60/59

Forelimb Strides



Hindlimb Strides



Lameness Metrics

Thresholds for Max/Min Head: +/-6 mm

Diff Max Head:	Mean:	2.3 mm	SD:	6.8 mm
Diff Min Head:	Mean:	1.0 mm	SD:	7.0 mm

Threshold for Total Diff Head: 8.5 mm

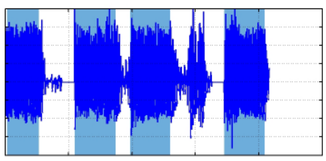
Total Diff Head (Vector Sum): 2.5 mm

Thresholds for Max/Min Pelvis: +/-3 mm

Diff Max Pelvis:	Mean:	2.1 mm	SD:	3.0 mm
Diff Min Pelvis:	Mean:	2.3 mm	SD:	3.5 mm

Q Score (fore): R 2.5 Imp **Q Score (hind): R 2.1 Push / R 2.3 Imp**

Stride Selection



Trial AIDE

There is "no" evidence of LF lameness.
There is "no" evidence of RF lameness.
There is "no" evidence of LH lameness.
There is "no" evidence of RH lameness.

Evaluator Notes

D1 Pre Trim

Generated with Lameness Locator® 2017 by Equinosis® (1.70.1.35) Friday, March 9, 2018 at 6:01 AM

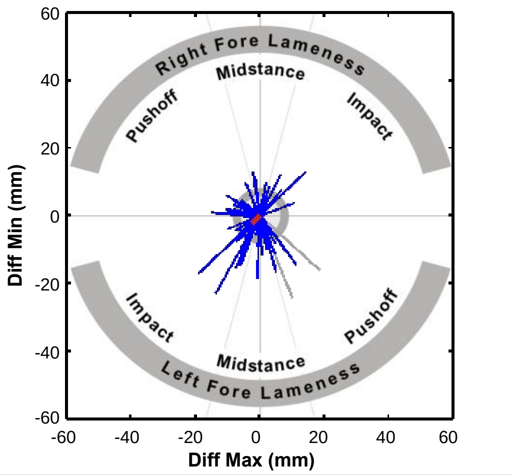
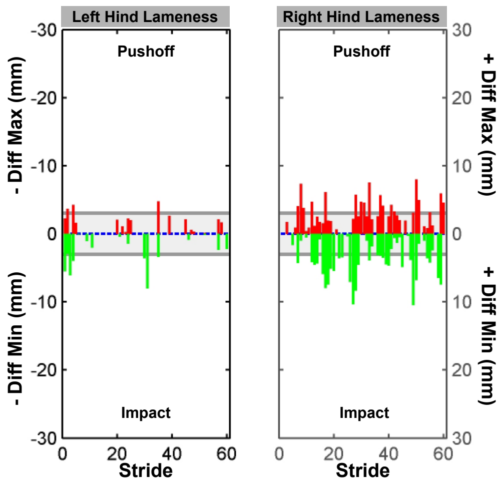
Data sheets post trim

THE EQUINOSIS with LAMENESS LOCATOR®	**Trial Report**
	Case #:
	Owner: WHW, GSF
	Horse: ANG

Trial:	Straight Line
Date:	Friday, March 9, 2018 at 6:24 AM
Surface:	Concrete
Blocks:	
Attending:	**Analysis Settings:** Default - Delta = 0.1

Quantification of Asymmetry

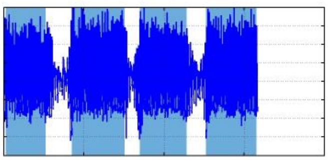
Stride Rate: 1.6 Strides Assessed (fore/hind): 58/60

Forelimb Strides	**Hindlimb Strides**
	

Lameness Metrics

Thresholds for Max/Min Head: +/-6 mm				
Diff Max Head:	Mean:	-2.3 mm	SD:	6.6 mm
Diff Min Head:	Mean:	-2.1 mm	SD:	8.6 mm
Threshold for Total Diff Head: 8.5 mm				
Total Diff Head (Vector Sum):		3.1 mm		
Q Score (fore):	**L 3.1 Imp**			

Thresholds for Max/Min Pelvis: +/-3 mm				
Diff Max Pelvis:	Mean:	1.7 mm	SD:	3.0 mm
Diff Min Pelvis:	Mean:	2.2 mm	SD:	3.9 mm
Q Score (hind):	**R 1.7 Push / R 2.2 Imp**			

Stride Selection	**Trial AIDE**
	There is "no" evidence of LF lameness. There is "no" evidence of RF lameness. There is "no" evidence of LH lameness. There is "no" evidence of RH lameness.

Evaluator Notes

D1 Post Trim

Generated with Lameness Locator® 2017 by Equinosis® (1.70.1.35) Friday, March 9, 2018 at 6:28 AM

Appendix V: Vet notes

Date 3/4/18

Horse:	**Examination & Vet notes**
Name: **Bluey** DOB: Reason for exam: trot up Microchip: Weight:	3/10 RF lame, warm foot and pastern. HT -ve and soles hard now but frogs still soft. Change from sand to straw yard and keep painting frogs iodine. Complete rest and re-ex 2 weeks. Discuss full lameness exam but WHW decided not for now as treatment unlikely to be anything other than rest.
Name: **Melvyn** DOB: Reason for exam: rex (1w) Microchip: Weight:	Walking better, still very weak. Increase turnout and introduce sure-grow. Sedate with 1 ½ ml sedivet (WHW own so don't charge). Trim hind feet scared of farrier.
Name: **Ruby (shet)** DOB: Reason for exam: rex eye (1w) Microchip: Weight:	Sill menace reflex present in centre portion. Pupil now same aperture as other right eye. Some enophthalmus advised could be progressive but no blepharospasm. Cataract posterior lens capsule and posterior synechiae not distorting iris margin. Can go out but poor sight so not in big group.
Name: **Doodle** DOB: Reason for exam: rex (1w) Microchip: Weight:	Sedate 1 ½ ml sedivet (WHW own) remove packing and sockets granulated in well.

Date 3/4/18

Horse:	**Examination & Vet notes**
Name: **Clippy** DOB: Reason for exam: trot up (1w) – off bute. Microchip: Weight:	Fine in straight line, still mildly lame on tight turn. RF HT -ve but LF still some sensitivity in heels. Keep in yard for another week, no exercise.
Name: **Goody** DOB: Reason for exam: x ray feet??? Microchip: Weight:	Much better front feet, dig pulse normal. Still waiting on ACTH result.