Horse Hoof Usability Study: Patrick Finnegan Equine

Movement Innovation Lab, Queen's University Belfast

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Research Project

The equine population in the United Kingdom (UK) is approximately one million, kept by over 550,000 owners, with horse riding remaining a top sport and recreational pastime (British Horse Industry Confederation, 2009; British Horse Society, 2013). The industry provides a livelihood for an estimated 220–270,000 people in the UK (British Horse Industry Confederation, 2009), of which approximately 2,800 are registered farriers providing vital hoof care (The Farriers Registration Council; British Horse Society, 2013). The RSPCA advocates the daily inspection of horse hooves by all owners, including the underside to prevent injury and/or lameness (RSPCA). Additionally, the RSPCA recommends owners should have their horse(s) seen by a registered farrier 'every four to six weeks, even if they are unshod' (RSPCA). It is estimated that each farrier visit costs 'around £25 for trimming and £50-£55 for shoeing per visit' (Equine World).

Patrick Finnegan, a professional farrier and engineer, of Patrick Finnegan Equine has designed and developed a 'Hoof Stand' aimed at reducing the physical strain and danger involved in regular hoof care for owners, farriers and grooms. This report presents the findings of a usability study examining the difference in ergonomics when fitting show jumping studs on a simulated horse hoof with, and without, this newly designed hoof stand.

Research Design

An expert farrier and ten novice participants were asked to fit two showing jumping studs in the following sequence:

I. Pick up and secure the horse's hoof (either in the stand or between the legs).
II. Clean out and remove threaded plugs from two stud holes.
III. Fit show jumping studs into the holes, which were previously cleaned out.
IV. Set the horse's hoof back safely on the ground (either from the hoof stand or between the legs).

All participants completed two sets of five repetitions of the above sequence under loaded conditions simulating those normally experienced by farriers, handlers and grooms. Participants were randomly assigned to an experimental group:

*Group 1: Performed 5 repetitions of the actions described above **without the aid** of the Patrick Finnegan Hoof Stand, followed by 5 repetitions **with the aid** of the stand.*

*Group 2: Performed 5 repetitions of the actions described above **with the aid** of the Patrick Finnegan Hoof Stand, followed by 5 repetitions **without the aid** of the stand.*

All participants were initially given a full demonstration by an expert farrier, giving them the opportunity to familiarise themselves with the procedure, but also become accustomed to the weight of the simulated horse leg. Performance was recorded using two AMTI force plates, allowing Ground Reaction Forces (GRF) to be precisely tracked and measured. The participant movement was captured using the Qualisys Motion Capture system. The data from this system was used for visualisation purposes and time analysis. Heart rate data was collected during each repetition.

Apparatus

The following apparatus were used during laboratory testing:

Patrick Finnegan Hoof Stand (See Figure 1).

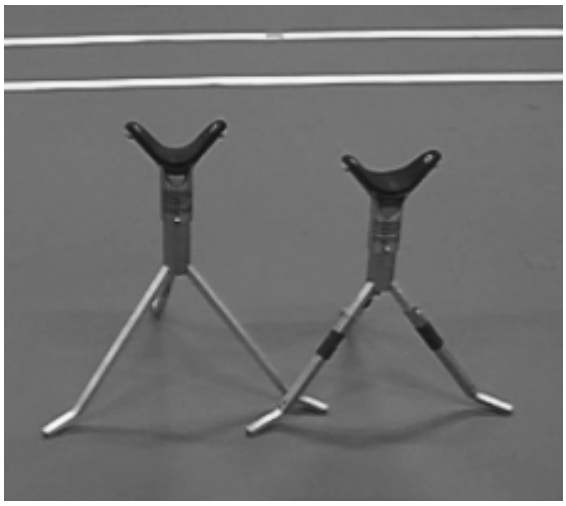

Figure 1 - Two of the Patrick Finnegan Equine Hoof stands in situ. Through the use of adjustable legs, the hoof stand was set to the correct height for each participant.

Simulated horse leg

Designed and built by Patrick Finnegan Equine to mimic the weight and loading experienced when performing hoof care type actions (See Figure 2). A 25.4kg weight was suspended at two different points on a wooden beam to mimic the weight of a horse leg. To accommodate for levels of fitness and physical strength between the male and female participants, the weight of the simulated horse leg had to be altered. The weight was placed closer to the male participants to simulate a heavier weight (12.7kgs) and suspended further from female participants to reduce the weight (8.5kgs).

Figure 2 - The simulated horse leg in situ, with a 25.4 kg weight clearly suspended from the wooden beam to approximate the weight of a horse's leg that a farrier, handler or groom would normally support.

Qualisys Motion Capture System

Records 6D positional information from infra-red reflective markers. A total of 39 markers were placed at key anatomical positions to provide visualisation of movement during task performance. Data was captured at 100Hz.

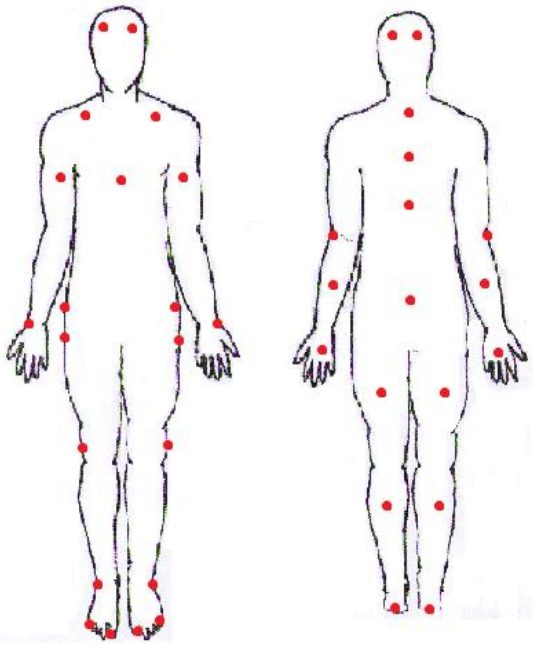

Figure 3 – Placement of Qualisys motion capture markers

AMTI force-plates

Used to capture pressure sensor data in the form of force and moment. The data was captured at 100Hz and fully synchronised with the Qualisys motion-capture system.

Heart-rate

Measured using a Garmin Forerunner 310xt with heart-rate strap sampling at 60Hz.

Participants

Ten novice participants were recruited; five male and five female. The male participants had an average weight of 94.4kgs, and an average height of 178.6cm. The female participants had an average weight of 65.4kgs, and an average height of 166.1cm. Vital statistics for each participant are displayed in Table 1.

Participant Number	Experimental Group	Gender	Age	Height (cm)	Weight (kg)	Handedness
1	1	M	35	169	90	R
2	1	M	37	186	115	L
3	2	M	27	178	80	R
4	1	M	33	173	82	R
5	2	M	29	187	105	R
6	1	F	27	160.5	69	R
7	2	F	29	171.74	63	R
8	1	F	27	165.25	66	R
9	2	F	43	168	70	R
10	2	F	34	165	59	R

Expert Farrier	Gender	Age	Height (cm)	Weight (kg)	Handedness
	M	59	186	109	R

Table 1 – Summary personal characteristics of novice participants and our expert farrier.

Results

The results have been broken down into several categories: average time to complete task, average time supporting weight of horse hoof, heart rate data and ground reaction force data.

Average Time to Complete Task

The average time to complete the task (See page 3) was defined as the following:

> *The time recorded between the first frames of motion-capture data as the participant picks up the simulated horse hoof, and the last frames when the participant safely returns the horse hoof onto the ground.*

The motion-capture data for each trial was recorded in milliseconds, trimmed using the definition above, and converted into seconds to capture the average time to complete the task. Results were averaged across trials for each participant.

Statistical analysis revealed there is a significant difference in the average time taken to complete the task when using and not using the hoof stand (p=.005; See Table 2 and Figure 3). This is due to participants taking significantly longer in conditions with the hoof stand. This significant increase in the overall time taken when using the hoof stand is seen for both male and female participants (p=.224). Female participants display an average increase in time to perform the task of 11.51 seconds, or 27 %. Male participants display an average increase of 6.98 seconds, or 18 %.

Condition	Average time to perform task (s)		Average time supporting full Load (s)		% Difference in time supporting full load	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
With Stand	53.05	45.27	16.12	6.28	57.24%	82.82 %
Without Stand	41.54	38.29	37.73	35.93	-	-

Table 2 - A) Novice participants average time taken to perform overall task (seconds) B) Average time supporting the load (seconds).

The expert farrier mirrored the general trend for increased time taken to complete the task using the hoof stand, with an overall increase of 4 seconds, or 11% (See Table 3).

Condition	Average time to perform task (s)	Average time supporting full Load (s)	% Difference in time supporting full load
With Stand	40	11.76	69.13%
Without Stand	36	38	-

Table 3 - A) Expert farrier's average time taken to perform the overall task (seconds) B) Average time supporting the load (seconds).

Average Time Supporting Weight of Horse Hoof

Average time supporting the weight of the horse hoof was defined as the following:

> **With stand:** *The time recorded between the first frames of AMTI force and moment data as the participant picks up the simulated horse hoof, and the last fames when the participant safely places the horse hoof onto the stand IN ADDITION TO the time recorded between the first frames when the participant picks up horse hoof from the stand, and the last frames when they safely return the hoof onto the ground.*
>
> **Without stand:** *The time recorded between the first frames of AMTI force and moment data as the participant picks up the simulated horse hoof, and the last frames when the participant safely returns the hoof onto the ground.*

The AMTI force and moment data was precisely synchronised with the Qualisys motion-capture data, sampling at 100Hz. The force data from both force plates was summed, and frames in which the participant exerted equal to or greater than 80% of their maximum force was extracted. The time between the first frame of 80% maximum force and the last frame of 80% maximum force was used to calculate the average time supporting the weight of the horse hoof.

Results indicate that all participants show a statistically significant decrease in the time required to support the full load when using the hoof stand (p<.001). This was demonstrated by all participants, with no significant difference between gender (p=.092; See Table 2 and Figure 3), with an average reduction of 26 seconds or 70%. Combining this with the average time to carry out the task, it can be noted while using the hoof stand takes longer; it does so at significantly reduced loads.

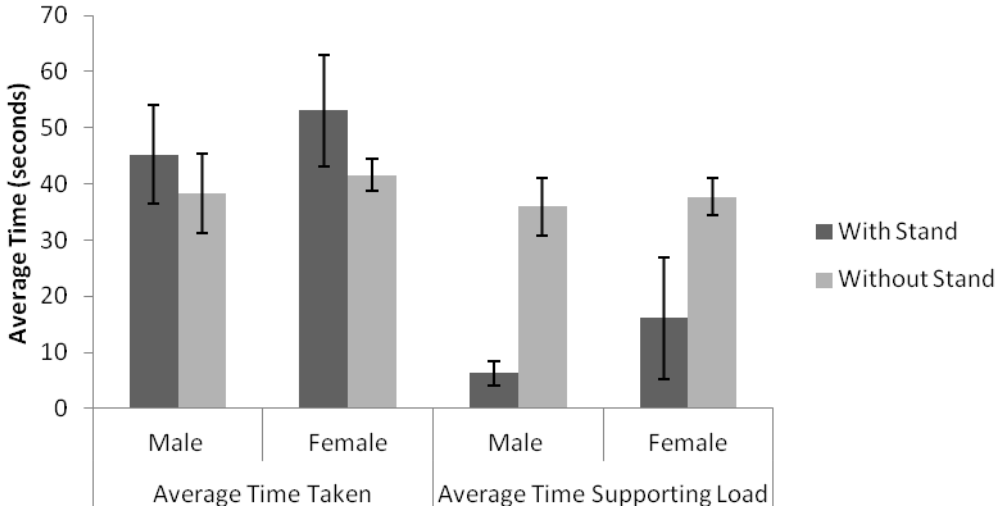

Figure 3 - Average time to carry out the task and associated time supporting the full load (seconds).

Heart Rate Data

Real time heart rate data was captured at 60 Hz. Data was subsequently analysed offline. Heart rate data for all participants is shown in Table 4, with summary data supplied in Table 5. As can be seen in Table 4, all participants demonstrate a decrease in average heart rate during trials using the hoof stand. This reduction in heart rate is significant (p=.004), demonstrating that the hoof stand provides assistance to participants whilst performing the task.

Participant Number	Gender	Heart Rate (bpm)		% Difference in average heart rate (without stand – with stand)
		Without Stand	***With Stand***	
1	M	98	93	-5.10 %
2	M	105	104	-0.95 %
3	M	105	102	-2.86 %
4	M	88	85	-3.41 %
5	M	108	101	-6.48 %
6	F	143	136	-4.90 %
7	F	104	103	-0.96 %
8	F	105	88	-16.19 %
9	F	83	78	-6.02 %
10	F	108	101	-6.48 %
Expert Farrier		90	82	-8.89 %

Table 4 - Summary heart rate data for all participants.

Condition	Heart Rate (bpm)		% Difference in Average Heart Rate (Without stand – With stand)
	Without Stand	***With Stand***	
Overall Group Average (inc. expert)	103	97	-5.93 %
Overall Group Average (exc. expert)	105	99	-5.62 %
Overall Female Average	108	101	-7.3 %
Overall Male Average	101	97	-3.83 %

Table 5 - Overall group summary of heart rate data.

Summary descriptive data confirms that all participants, male and female, display a decrease in average heart rate when using the hoof stand. Despite initial indications that a larger reduction in heart rate was observed in the female group (See Table 5), this failed to reach significance (p=.576). These results indicate that regardless of gender, and/or experience, all participants demonstrate a decrease in average heart rate when using the hoof stand (See Figure 4).

N.B. It should be noted that female participants were provided with a lighter weight than male participants. This was to accommodate for levels of fitness and physical strength within the female cohort.

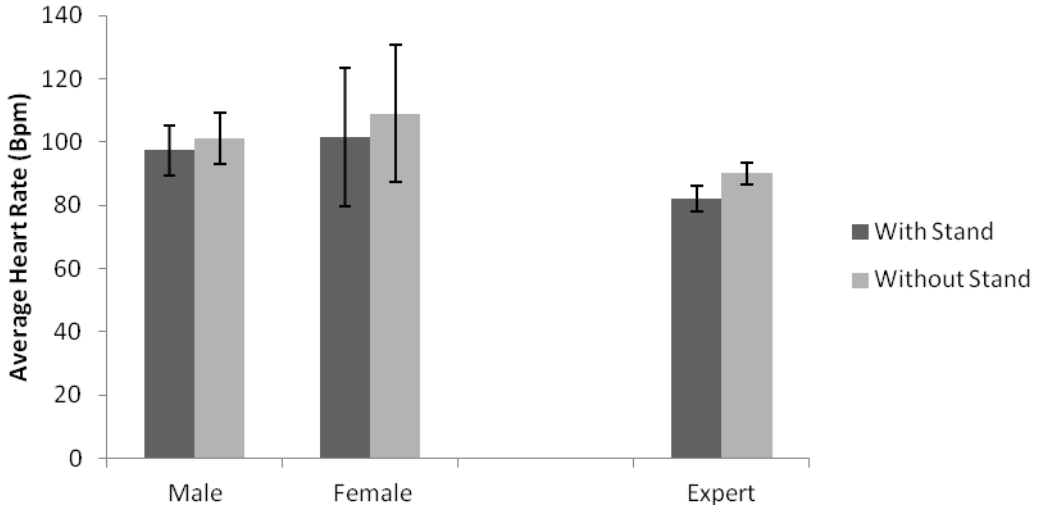

Figure 4 - Average Heart Rate (bpm) for novice Participants and expert farrier.

Ground Reaction Force (GRF) Data

Ground reaction force data was sampled at 100 Hz throughout each trial using two AMTI force plates (one located under each foot, with foot position carefully controlled). A sample trace from both force plates can be seen in Figure 5.

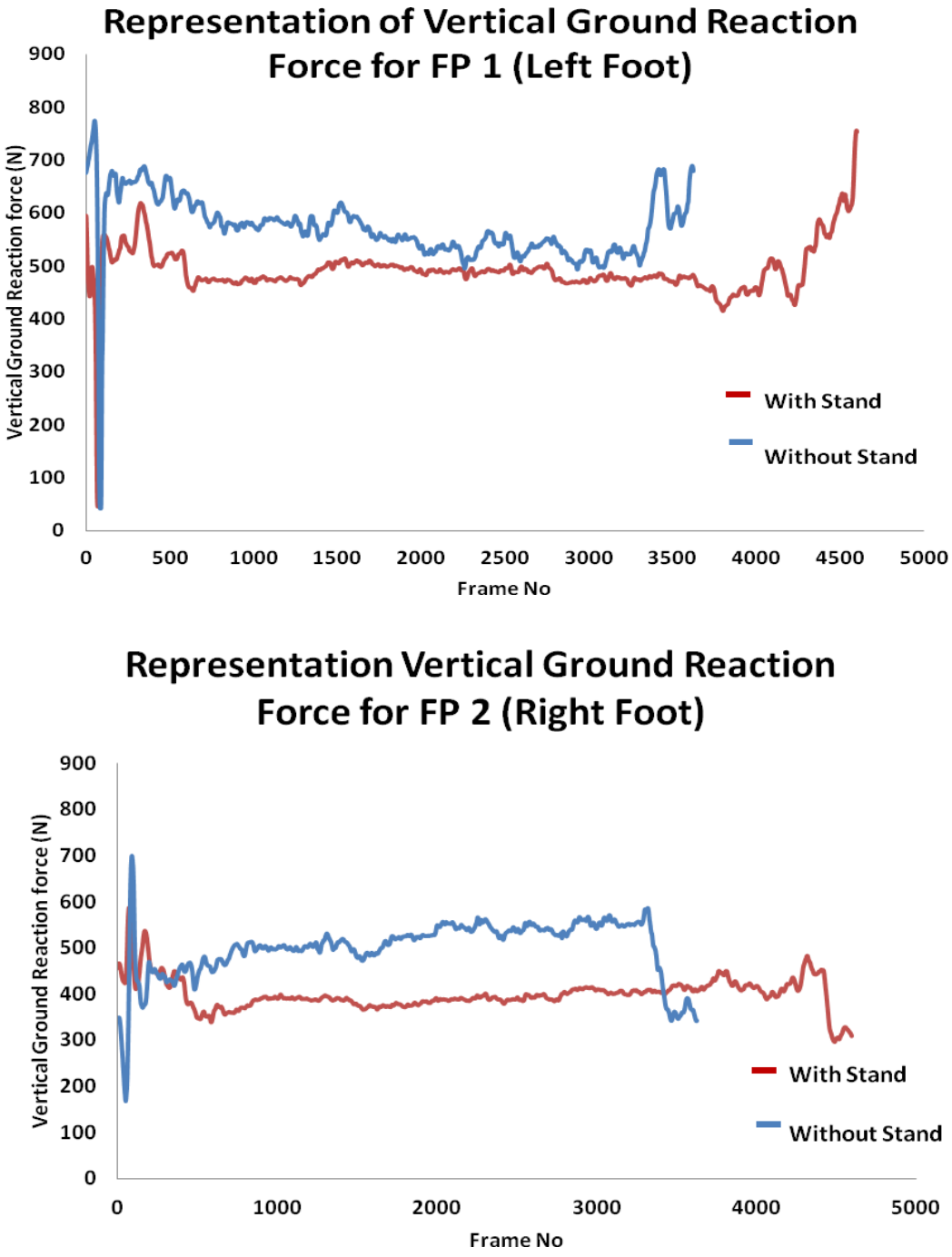

Figure 5 - Time Series data of GRF exerted by the expert farrier when performing the task with and without stand.

The difference between the participants undertaking the task with and without the hoof stand can be demonstrated by visualising the ground reaction forces exerted by the expert farrier (See Table 6). Higher levels of force are exerted by both the right and left leg when performing the action without the stand, while using the hoof stand leads to a sustained reduction in the GRF throughout the trial (See Figure 5).

Expert	Average Ground Reaction Force (N)		Average Time to Perform task (s)
	FP1	**FP2**	
With Stand	538.14	386.62	40.37
Without Stand	594.19	486.68	36.12

***FP1 refers to force plate number 1, recording GRF data for the left foot. FP2 refers to force plate number 2, recording GRF data for the right foot.**

Table 6 - Summary GRF for an expert farrier.

This reduction in GRF whilst using the hoof stand is mirrored in the results of both male and female novice participants (see Table 7 and Figure 6).

	Average Ground Reaction Force (N)				**Average Time to Perform task (s)**	
	Female Average		***Male Average***		***Female***	***Male***
	FP1	**FP2**	**FP1**	**FP2**		
With Stand	363.82	270.55	486.85	317.87	53.05	45.27
Without Stand	387.49	328.38	525.93	370.26	41.54	38.29

***FP1 refers to force plate number 1, recording GRF data for the left foot. FP2 refers to force plate number 2, recording GRF data for the right foot.**

Table 7 - Summary GRF data for all novice participants.

N.B. It is important to reiterate that female participants were provided with a lower weight to accommodate levels of physical fitness and strength. This led to variation in the levels of GRF measured between genders.

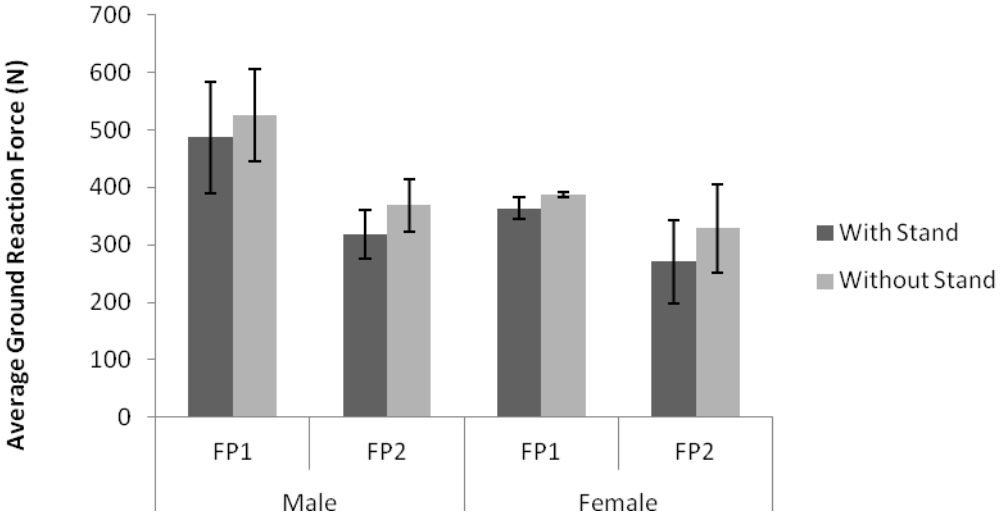

Figure 6 - Summary descriptive data for Average GRF (Newton) exerted through both force plates by male and female participants with and without use of the hoof stand.

Multivariate analysis indicates this reduction in GRF when using the hoof stand is statistically significant (p<.001). Moreover, there is a significant effect of foot dominance (p<.001), resulting in participants exerting significantly higher levels of force through the left force plate.

Overall, this study indicates that the use of the Patrick Finnegan 'hoof stand' results in a significant reduction in heart rate (p=.004) and ground reaction forces (p<.001) exerted by participants when fitting show jumping studs. The addition of extra apparatus (hoof stand) does lead to a significant increase in the time taken to perform the overall task (p=.005), however the time required to sustain or carry the full load is significantly reduced by using the hoof stand (p<.001).

Summary and Conclusions

Overall the results of this study demonstrate the following:

- The addition of the hoof stand leads to a significant increase in overall time taken to perform the task.
- Despite an overall increase in time, results indicate a significant reduction in the time the participant must carry or 'support' the full load (weight). (An average reduction of approximately 26 seconds or 70% for novice participants).
- This significant reduction in the length of time supporting the full load or 'horse's leg' when using the hoof stand is coupled with a significant reduction in average heart rate. This benefit was seen in both novice, and expert participants, with an average reduction of 6%.
- Finally, results indicate a significant reduction in the Ground Reaction Forces exerted by all participants when using the hoof stand.

Appendix A – Video File Resources

The following is a list of visual resources generated and provided for use by the client.

- Expert farirer video files showing task with, and without, the hoof stand.
- Expert farrier video files showing the task performed in a longer session. The expert farrier carried out task non-stop for five shoes to simulate a typical full-length session.
- Video file of the expert farrier markered and simulated bones in the Qualisys motion capture software. Two views are captured. Side on and front-facing with, and without the hoof stand.
- Video file of a novice participant markered and simulated bones in the Qualisys motion capture software. Two views are captured. Side on and front-facing with, and without the hoof stand.
- Several short promotional videos were created for general use by the client. These are:
    - Constructing the hoof stand.
    - Extending the hoof stand.
    - Displaying the hoof stand.
    - Showing the multifunction use of the hoof stand.

Note: The videos are provided in AVI format making use of the Xvid Codec for compression. All sound has been removed from the videos.

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