TO EVALUATE HOW CORE PHYSIOLOGICAL (CARDIOVASCULAR) PARAMETERS RESPOND TO A PROGRAMME OF INTERVAL TRAINING USING GLOBAL POSITIONING SYSTEM (GPS) HEART RATE MONITORS IN NATIONAL HUNT (NH) RACEHORSES.

RESEARCH ARTICLE

KIERAN SCOTT KENWORTHY

STUDENT NUMBER: 13027279

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DECLARATION

This dissertation is a product of my own work and is not the work of any collaboration.

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Name: Kieran Scott Kenworthy
Signed:
Date: 29/11/16
E-mail address: Kieran.Kenworthy@Hartpury.ac.uk

Faculty/ School: UWE Hartpury

Student name: Kieran Scott Kenworthy

Award: BSc (Hons) Equine Science

Module: Undergraduate Dissertation

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ABSTRACT

Rationale: The rationale behind this study was to find out the training and exercise progress using the Fine Equinity heart rate monitors and to see if any difference in cardiovascular fitness in national hunt racehorses were achieved over a period of time utilising four training sessions

Methods: Overall, group and independent measures was used due to testing several variable heart rates using the Fine Equinity heart rate monitors attached to the girth for each horse within the study. There was also a correlation test to find out if official ratings corresponded to percentage of heart rate max each horse achieved.

Results: A series of tests were run to find out any significance in percentage of heart rate max across four training sessions, percentage of heart rate max, percentage of heart rate max at the end of exercise, heart rate max recovery after 60 seconds, and correlation of official ratings and heart rate max across all horses. Individual tests were then run consisting of the same tests used across all horses for the sample population (n=10). All tests run was non-significant (P>0.05)

Conclusions: Cardiovascular fitness did not improve over the period of the study. The study has suggested that trainers may not apply the principle of individualisation to training. Furthermore, the study has shown that racehorse trainers do not take a scientific approach to training and exercise and traditional perception methods are used to gauge if a racehorse is improving their cardiovascular fitness.

CHAPTER 1
1.0 INTRODUCTION

1.1 Heart rate monitoring systems and horseracing

Heart rate monitoring (HRM) systems are used with a separate unit that measures electrical activity across the heart via electrodes placed on the skin, that transmit the electrical activity through a wire which calculates the number of pulses and converts it to a rate per minute (Bitschnau et al., 2010). There has been recent interest in HRM within the horse racing industry to assist in training and exercise for thoroughbred racehorses (Kingston et al., 2006) Their use of new technologically advanced HRM systems which involve Global Positioning System (GPS) and heart rate (HR) monitoring for racehorses. The majority of research into HR analysis occurred before 2007 (Kingston et al., 2006; Vermulen and Evans, 2006) and there is a lack of research into the use of HRM in national hunt (NH) racehorses and how effectively these new technological advances can improve training methods and competition performance. HRM is often used to scientifically assess the health and wellbeing of humans and many animals to either diagnose heart disease or confirm an irregular heartbeat that may cause significant complications therefore, it has the potential to be applied in these contexts to racing (Allen, van Erck-Westergren and Franklin, 2015; Allen, Young and Franklin, 2015).

Eventing have recently used HR monitoring during training in the form of a HR Velcro strip that straps onto the girth and a watch to receive the data (Serrano, Evans and Hodgson, 2010). There has been speculation that some HR devices are not accurate or consistent and do not give a continuous amount of data to improve cardiovascular performance in equine athletes (Vermulen and Evans, 2006) Commercial HRM systems mostly display HR every 5, 15 or 60 seconds which causes uncertainty of how accurate HRM systems are due to the expense of high quality electrodes (Fonseca et al., 2010). Although new advances in HRM technology for horses such as Fine Equinity has shown higher accuracy and a receiving rate at low as two seconds to receive a more accurate reading and therefore HRM is being used more frequently in sports to assess fitness (Larsson, 2003; Mukai et al., 2003a).

Technology including HR analysis is becoming more mainstream but there is limited baseline data to enable users to understand how technology should be applied in training. HR data has been shown to be a reliable indicator of workload in racehorses (Kingston et al., 2006). Quantitative assessment of fitness levels (HR analysis) can formulate evidence based training regimens which can monitor progress within training regimens to aid race selection and facilitate adaptation of training regimens to optimise individual horse's performance (Ohmura et al., 2010; Tan, Wilson and Lowe, 2008; Kingston et al., 2006; Vermulen and Evans, 2006). HR and GPS technology is available to facilitate integration of physiological monitoring into NH racehorse training regimens by creating individual horse profiles. Therefore, research is required to show the performance benefits of integrating technology into training. By clarifying racehorse fitness scientifically within the racing community, racehorse trainers would have a better indication of a racehorse being fit enough to race and potentially increase their chances of winning, and reduce the risk of injuries and respiratory complications which would benefit public perception and animal welfare concerns within the industry.

1.2 HR monitoring in human athletes

Elite human athletes use HR monitoring to improve training and performance during exercise and is a vital part of improving cardiovascular and endurance fitness (Larsson, 2003). By using high technologically advanced HR equipment such as Polar HR devices, it enables athletes and coaches to assess fitness for a specific purpose to gain in depth knowledge of an athletes' cardiovascular potential during training. Standard Exercise Testing (SET) is used frequently within human studies due to their response of accepting and understanding a standard exercise test, therefore research will be more accurate and persistent (de Bruijin et al., 2016; Halson, 2014; Gür and Matur, 2013; Fonseca et al., 2010). Due to the use of human athletes using HR monitoring devices, racehorse trainers within the UK, Dubai, America and Australia are attempting to replicate the use of HR monitoring during training to improve race results (Gramkow and Evans, 2006, Leisson, Jaakma and Seene, 2008; Mukai et al., 2003b). Current research has shown that there is no relevant base-line data during competition due to ethical reasons and governing body restrictions (Fonseca et al., 2010; Kingston et al., 2006; Vermulen and Evans, 2006). By equine and human sports governing bodies allowing HR systems to be used within competition but under the radar to the public, health and welfare concerns can be addressed by monitoring heart rate and has the potential to reduce injury, fatality and to create baseline data for researchers (Plews et al., 2013). Overall, this shows a large gap within athletic and equine research with regards to HR device accuracy and functionality during training and competition. HRM systems by Fine Equinity consist of the electrodes sending data to the receiver on the opposite side of the girth sleeve to ensure of the highest signal output, whilst receiving stride length, stride frequency with the use of a gyroscope and accelerometer to accurately judge speed as well as altitude and can in real time be live streamed to your smart phone or other device anywhere in the world with the use of GPS technology. Therefore, Fine Equinity is a better approach to assisting in exercise and training and could also be beneficial for human athleticism.

1.3 Muscle adaptation to exercise

Thoroughbreds have been regarded as the primary breed in racing for hundreds of years (Harrison and Turrion-Gomez, 2006). Research indicates due to their quick but efficient muscular adaptations the thoroughbred has shown that their maximal oxygen uptake (VO2max) is higher than most other breeds, therefore the breed can cope with more strenuous exercise (Yamano et al., 2006). The thoroughbred has adapted physiologically such as its anaerobic capacity of 60%, which is higher than other breeds (Evans, 2007). The ability to increase red blood cells that are dispersed into the blood stream from the spleen through splenic contraction which acts as a natural doping method, which therefore increases glycogen stores within muscle fibre, particularly type IIX muscle fibres. Type IIX fibres are primarally for very short-duration, high intensity bursts of power such as near maximal exercise that are needed for instance; jumping out of starting stalls (Cywinska et al., 2013). Research by Hyytiäinen et al., (2014); Leisson, Jaakma and Seene, (2000); Rivero et al., (2006) and Essén-Gustavasson et al., (1989) suggests that muscle biopsies from the middle gluteus are favoured due to its excessive role in locomotion to indicate whether a thoroughbreds' muscle is adapting through training and exercise by analysing the percentage of different muscle fibre types.

A study by Essén-Gustavasson et al., (1989) extracted muscle biopsies from the left and right middle gluteus and the sternophalicus to compare locomotory and non-locomotory muscles and found that glycogen levels within the muscle decreased by 10-15% during two weeks of training indicating that training regimens play a role in muscle adaptation. Within the middle gluteus it was shown that capillary density and oxidisation increased over the time but was maintained during de-training. The average number of type IIA fibres found within the study showed that these type IIA fibres decreased after 5 weeks of training due to exercise and adaptation of muscle. Essén-Gustavasson, (1989) noted that muscle bulk in horses used in the study became large and more defined, therefore visual perception of muscle cannot actively give an indicator of musculoskeletal adaptation and fitness. The sample population was uneven (4 mares, 1 gelding) which may indicate inaccuracy in data collection, as there may have been correlation between sexes. By looking at muscle on a microscopic level, biopsy samples can show a variation of different muscle types due to their colour through a staining process (Eivers et al., 2009). Blood lactate levels can also assist on an indication that a thoroughbred is adapting physiologically and how well a thoroughbred can efficiently decrease their lactate levels within the blood; a study seen by Cywinska et al., (2013). By measuring lactate in the blood before and after exercise can be beneficial to create baseline data to see whether a horse is becoming fitter and adapting to training which can be a less invasive procedure.

1.3.1 <u>Short Term Exercise Responses</u>

There are short term effects to skeletal muscular adaptation such as a rise in temperature of muscle, a lower pH will occur due to lactic acid build up and changes in Kpa (Partial pressure of oxygen) which is called the Bohr Effect or the Haemoglobin Disassociation curve (Mukai et al., 2010). Fig. 1 shows the disassociation between haemoglobin and oxygen. The curve can shift to the right, which means that the haemoglobin-binding curve is less affinitive to oxygen (Crocker and Jones, 2013). The curve will shift to the left due to the respiratory system; therefore, pH acidity will decrease due to exhaling carbon dioxide (Crocker and Jones 2016). Inhalation of air will be cooler than body temperature, which will indicate body temperature will decrease therefore the horse, will have a low Kpa. Any type of aerobic or anaerobic exercise will adapt musculature due to the principles of the Bohr effect (Stickland and Lovering, 2006).

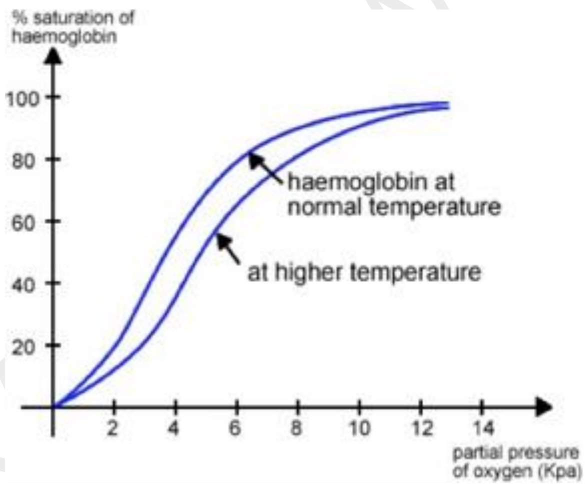

Figure 1: The disassociation curve (Bohr Effect) (Oxford Journals, 2016)

1.3.2 *Metabolic Pathways*

The horse requires a large amount of energy for strenuous exercise. Energy is transformed through metabolic pathways from chemical to kinetic energy; which is needed for muscle contraction. Kinetic energy is the form of ATP (Adenosine Triphosphate) (Derave et al., 2010). Muscles have a limited capacity for storing ATP. Muscle utilises fuel stores using aerobic and anaerobic metabolism. Anaerobic metabolism does not need oxygen to break down fuel stores, therefore provides a rapid means of producing a limited supply of energy (Votion et al., 2007). In the absense of oxygen, only carbohydrates are metabolised for ATP production. The end products of anaerobic metabolism are lactate and heat which are produced within the muscles of the horse (Kitaoka et al., 2009). Aerobic metabolism is needed to metabolise the pyruvate to regenerate ATP in the presence of oxygen due to aerobic exercise. Mitochondria play an important role as mitochondria can generate ATP more efficiently than glycolysis (Derave et al., 2010). The end products of aerobic metabolism are water and carbon dioxide, therefore does not contribute to fatigue within the muscles. Aerobic exercise can be sustained for much longer than anaerobic exercise due to these end products (Votion et al., 2007).

1.4 Training workload and cardiovascular responses

It is known that gradually increasing workload decreases HR max and therefore increases fitness levels (Gabbett et al., 2016). Research has shown in many human sports that a gradual increase in workload improves cardiovascular fitness (Carey et al., 2016; Clarke et al., 2013; Lovell et al., 2013; Parshuram, 2004). Whilst exercise is taking place the heart pumps blood through the body to deliver the right amount of blood to working muscles and the lungs must be able to fill blood with enough oxygenated blood to assist in muscle contraction. The muscles must extract fuels such as fatty acids, oxygen and glucose from the blood and transfer them for metabolic by-products (carbon dioxide, lactic acid and heat) that may cause the body to fatigue if it is not exchanged efficiently enough (Bassett, 2000). VO2 max measures the efficiency of the cardiovascular, muscular and respiratory systems and therefore a higher VO2 max in a horse indicated they are more able to cope with demands of a given exercise (Evans and Rose, 1988).

VO2 max the most important adaptations and indicators that occur within training. Studies by Betros et al., (2002) has shown that VO2 max improvement has appeared within the first 2-3 weeks of training. It was founded that racehorses had a 9% increase in VO2 max after 10 days of moderate intensity training. Although when training for a longer period it was shown that VO2 max increase was only seen within the first 6-8 weeks. Consequently, increases in VO2 max will confer a higher marked increase in overall work capacity therefore, a longer period before the horse begins to fatigue (Borresen and Ian Lambert, 2009; Blomqvist and Saltin, 1983).

Intensity of exercise during the first few weeks of training is shown to be an inaccurate determinant of change in VO2 max as a study by van Erck et al., (2007) has shown that there was no significant difference in VO2 max during training using two groups of horses that trained at either 40% VO2max which would indicate trotting or 80% VO2 max cantering (Devienne and Guezennec, 2000). Furthermore, workload may not be an important indicator for increasing VO2 max as workload is more important for adaptation of skeletal muscle (Younges et al., 2016.

1.5 Variations in current literature

Several studies agree that SET is difficult to undertake when attempting to assess training and exercise with the use of HRM systems due to the horses' inconsistent speed with variables including different tack, saddle, riding style, surface, terrain and weight during field testing (Fonseca, 2010; Vincent et al., 2006, Vermulen and Evans, 2006). Vermeulen and Evans (2006) states that no SET protocol was used for their research which suggests that there is minimal scientific evaluation of racehorse training programmes being carried out; such a statement can also be supported by Kingston et al., (2006). Kingston et al., (2006) found that only 88% of overall HR data was obtained in the study, the limitations of the device have shown that the antenna was poorly placed onto the riders' skull cap, which meant the receiver had to reach from the device in a pocket just below the saddle to the riders' head whilst in the jockey position which would be as far as the horse's neck. This reinforces the lack in functionality of the device and the reliability of its technology and design. No research to date has evaluated optimal recovery times with the use of HRM systems or have identified similarity to a professional racehorse trainers' perception of fitness that have been compared to HR data. Current research has shown that different HRM systems are being used to gain results because improper signal from an antenna to device is restricting sufficient data results during testing, variables such as environment, terrain, weather and altitude can affect the way a HR monitor responds to the receiving device and cannot always show consistent data (Kingston et al., 2006, Vermulen and Evans, 2006, Vincent et al., 2006).

1.6 *Rationale, aims and objectives*

This study was to assess how efficient a racehorse responds to training and exercise using heart rate monitoring equipment within national hunt racing and to evaluate cardiovascular responses within frequent interval training.

Hypothesis: 'when a national hunt racehorse taking part of a training program of interval training, cardiovascular fitness will increase'.

Null hypothesis: 'when a national hunt racehorse taking part of a training program of interval training, cardiovascular fitness will stay the same'.

This will enhance the racehorse trainers' perception of fitness and give a broader in-depth knowledge of how well a horse responds to their training methods. The overall aim of this study was to apply high tech Fine Equinity HRM systems to aid in scientific evaluation of NH racehorse fitness and to inform and assist the trainer. The objectives were to find out how NH racehorses adapted to interval training, and to distinguish optimal recovery times and peak HR for individual NH racehorses and as a group.

CHAPTER 2
2.0 METHODOLOGY

2.1 Data Collection

Data collection was established at a National Hunt racing yard between January to March 2016 with on-site permission being utilised using Fine Equinity HR monitors to collect relevant data (Appendix D). Thoroughbreds (n=10) were involved in the study and were assessed every Monday for 12 weeks during their normal training programmes. Two three furlong gallops were utilised at a mean speed of 20mph (9m/s) using an all-weather gallop which contained a mix of sand, rubber and wax with a depth of eight inches.

2.2 Sample Population

The study was approved by The Hartpury College Research Ethics Committee in 2015. A total of 10 thoroughbreds utilised from one National Hunt racing yard in Naunton, Cheltenham, UK trained by the same trainer with 25 years' experience were assessed during the British National Hunt Season between January to March 2016. Horses that participated within the study were physically fit and healthy and was excluded If the horse was injured, became lame, or was a host of any disease or disorder. The normal training regime for the horses remained throughout data collection

2.3 Training Protocol

All horses (n=10) were trained every Monday for 12 weeks' dependent on the condition and health of the horses within the study. Fine Equinity supplied technologically advanced heart rate monitoring equipment capable to collect speed, stride length, stride frequency and altitude with live streaming and GPS tracking from their website or smartphone (Appendix D). The HR monitoring girth sleeves were placed on the horses during tacking up with half tree racing saddles, bridle, saddle pad and felt pad within their own stable and regular work rider and were withdrawn when distressed with the presence of fresh water, straw bedding and morning, lunch and evening food intervals. The electrodes and receiver pocket were placed on the left portion of the barrel behind the left elbow. The horses warmed up by walking to the gallop (1000m) and cooled down by walking back to their stables (1000m). Each horse had their own specific training programme and completed between gallops (n= 3) of three furlongs and repetitions (n=3).

2.4 Experimental Protocol

Live streaming using the Fine Equinity app found on the Apple App Store was used to assess accuracy and know real-time data wherever their location.

1. Horses were tacked up in the stable, the HR girth sleeve was placed over the girth that secures the saddle.

Plate 1: Girth sleeve 1

2. The electrode side was sponged with water and was placed onto the left side of the horse behind the elbow for a better connection.

Plate 2: Girth sleeve 2

3. The receiver was switched on and secured into the pouch on the girth sleeve.

Plate 3: HR receiver and girth sleeve

4. After data was collected the horses walked back to the yard to cool down (1000m). The rider dismounted the horse and un-tacked and placed their equipment in the stable and then proceeded to wash the horses down, rugged them and made sure the horses had plenty of water. Once the electrodes were released from the barrel of the horse the system automatically stopped data and recorded the data for the horse taking part.

5. The girth was then placed on the next horse within the study using the same work rider and tack.

6. The devices were then uploaded onto a secured windows computer using Fine Equinity software and allocated each data piece to the horses being used on that day.

2.5 Data Processing and Analysis

2.5.1 Racing history profiles

Racing history was taken for each horse and created a basic profile of: age, official ratings from the British Horseracing Authority (BHA), races undertaken under rules and winnings achieved in GBP (see table 1). Racing history was used to build up profiles for each individual horse to show their experience within British NH horseracing to date.

2.5.2 Group horse analysis

Data were assumed non-parametric due to small sample size (Field, 2014). Kruskal Wallis was used to assess the difference between meanHR expressed as %HRmax and 4 training sessions, end%HRmax as %HRmaxend and %HRmax, %HRmax and %HRend 60 seconds. Post hoc independent samples t-test was then used to assess significance for all horses training sessions. Bonferroni correction was used $P<0.02= P<0.05/5$).

2.5.3 Individual horse analysis

All data was analysed using IBM (Statistical Package for The Social Sciences) SPSS (Version 24). Assumptions of normality were not violated. A series of Friedman's non-parametric ANOVA analyses were used on an individual basis to define within subjects' differences across training progress for three gallop runs and average work done for meanHR expressed as %HRmax to facilitate comparison across horses and end HR% as %HRmax and HRR-60s as %HRmax in HR max mean, Significance was set at $P<0.05$. where sig diffs were found, subsequent post hoc, Wilcoxon matched pairs analyses established where between runs differences existed. A Bonferroni correction to control for type 1 errors was applied to post hoc and significance was adjusted from $P<0.05$ to $P<0.02$ (= $P<0.05/3$) (Field, 2014).

2.5.4 Correlations of official ratings vs Percentage HR max mean

Spearman's was run to test for correlation between official ratings and %HR max to see if there was any significance between the two variables for all horses (n=10) (Field, 2014).

CHAPTER 3

3.0 RESULTS

3.1 NH racing profiles

Age, racing experience and performance rating of the horses was variable (Appendix L) (Table 1).

Table 1: Racing history of sample population

Horses	Age (Years)	Official Rating (BHA)	Races Undertaken (Under rules)	Winnings (GBP)
H1	11	126	50	72,103
H2	9	134	14	18,947
H3	11	131	30	43,439
H4	8	122	10	11,338
H5	5	131	12	25,795
H6	9	116	24	16,895
H7	8	132	21	18,781
H8	11	115	35	23,560
H9	9	125	26	56,386
H10	10	140	31	60,502
Minimum	**5**	**115**	**10**	**11338**
Maximum	**11**	**140**	**50**	**72103**
Mean	**9.1**	**127.2**	**25.3**	**34774.6**
Standard Dev	**1.85**	**7.95**	**12.10**	**21548.64**

3.2 Descriptive group statistics

3.2.1 HR max percentage across training

No significant differences in %HR max was found for individual horses across the training period evaluated. However, these differences were found to be non-significant (P>0.05 Appendix E) (Figure 2,3).

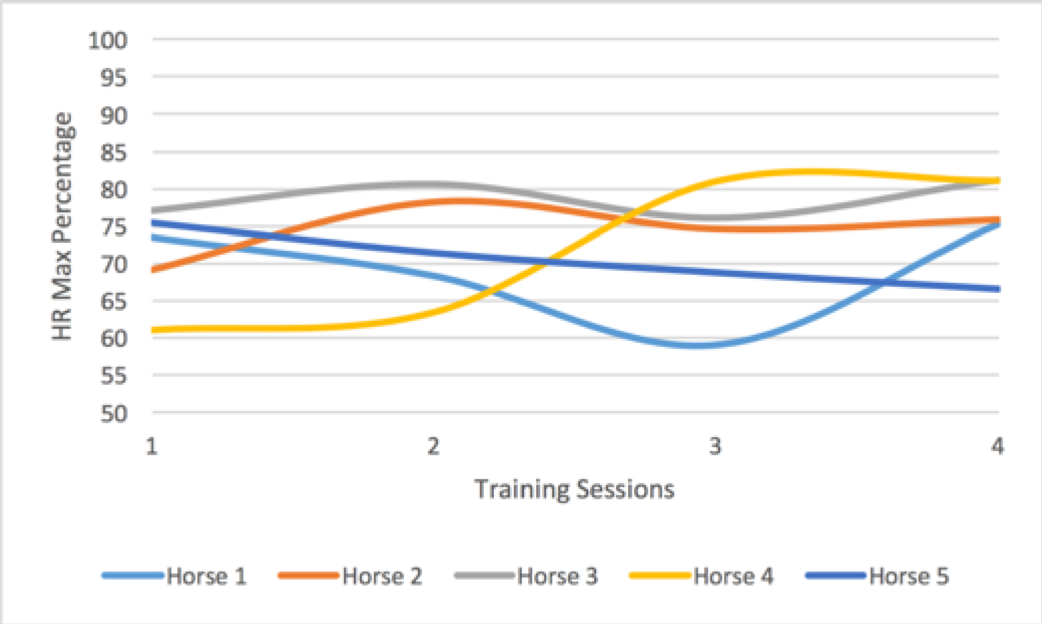

Figure 2: HR max percentage during 4 training sessions horses 1-5

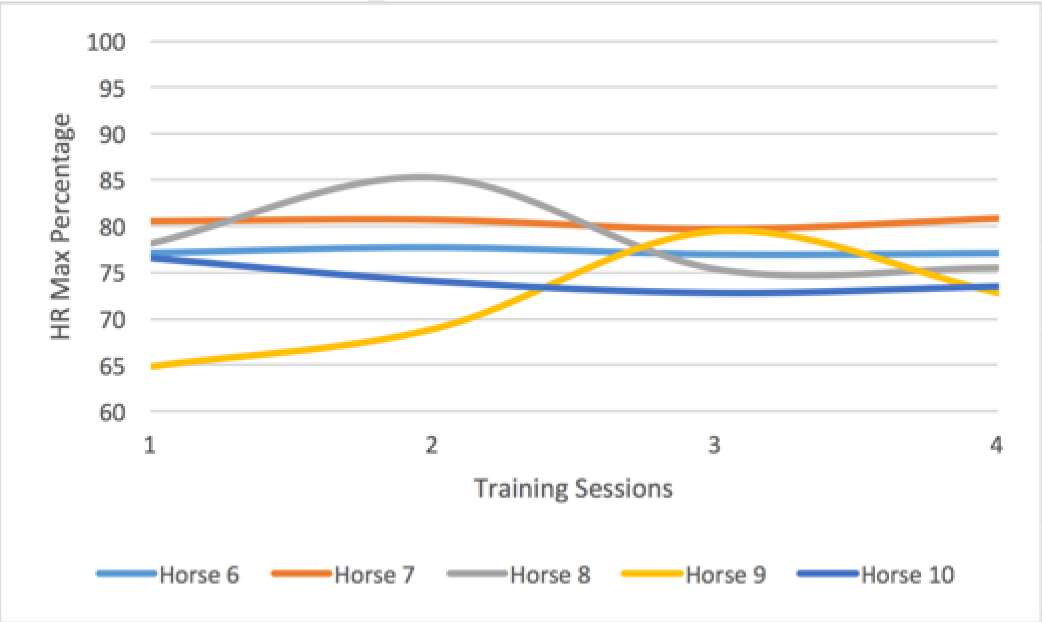

Figure 3: HR max percentage during 4 training sessions horses 6-10

3.2.2 Percentage HR Max vs End Percentage HR Max

HR max percentage and HR max percentage at the end of exercise across training was observed in all horses. However again the variability was non-significant (P<0.05; Appendix F).

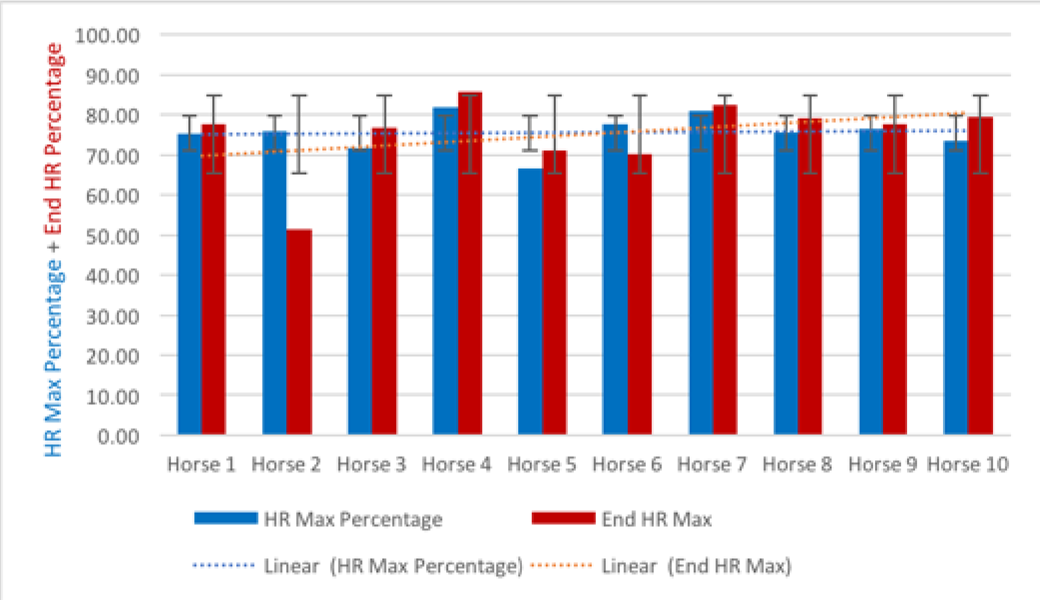

Figure 4: HR max percentage vs End %HR Max

3.2.3 Percentage HR Max vs End Percentage HR Max recovery

Mean %HR max and end %HR max recovery (-60 seconds) was tested across training sessions. Findings were non-significant (P>0.05; Appendix G).

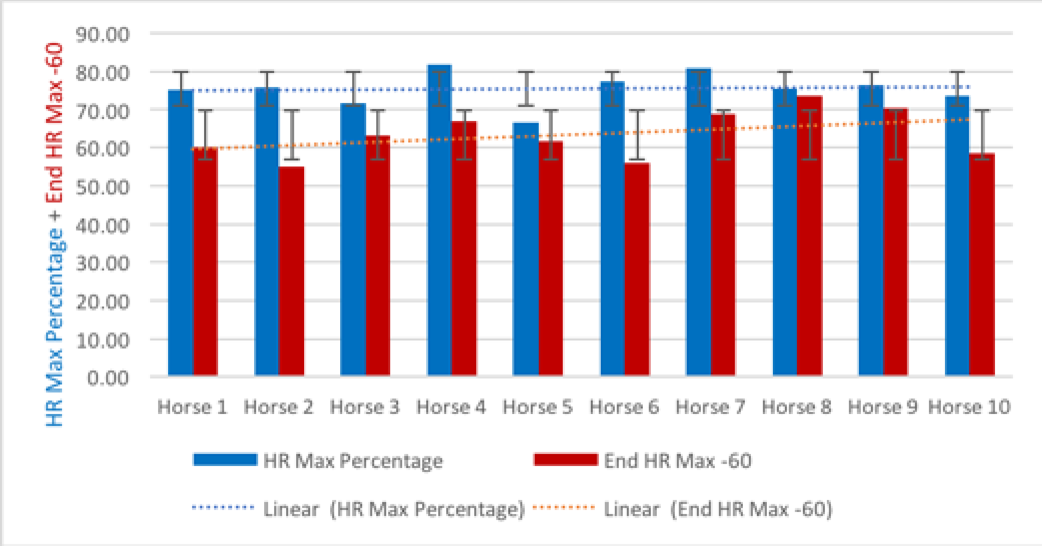

Figure 5: Mean %HR max vs End %HR Max –

3.2.4 Official Ratings and percentage HR Mean

The correlation between official ratings and HR max percentage Across the period was investigated, no relationship was observed between horses' OR and the mean HR max percentage they were working at (P>0.05 Appendix H)

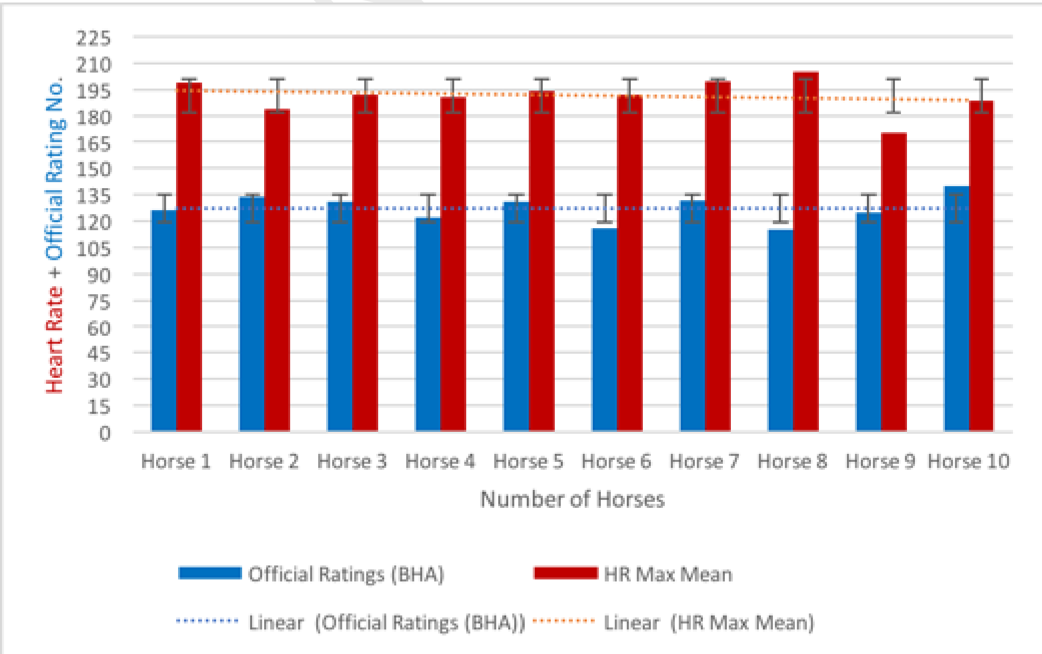

Figure 6: HR and OR training session 1

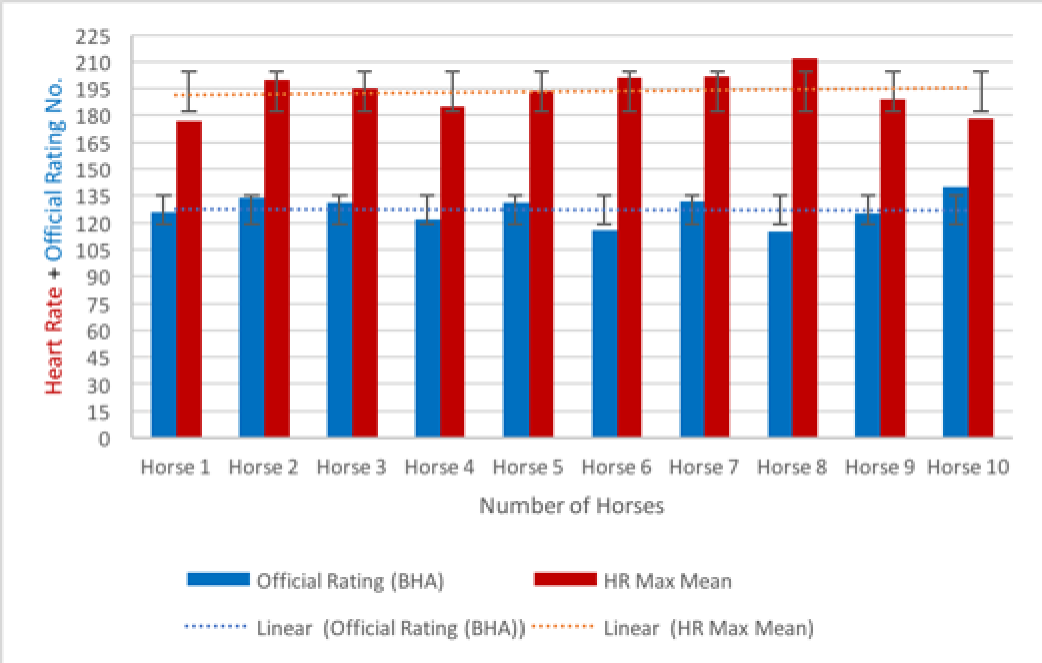

Figure 7: HR and OR training session

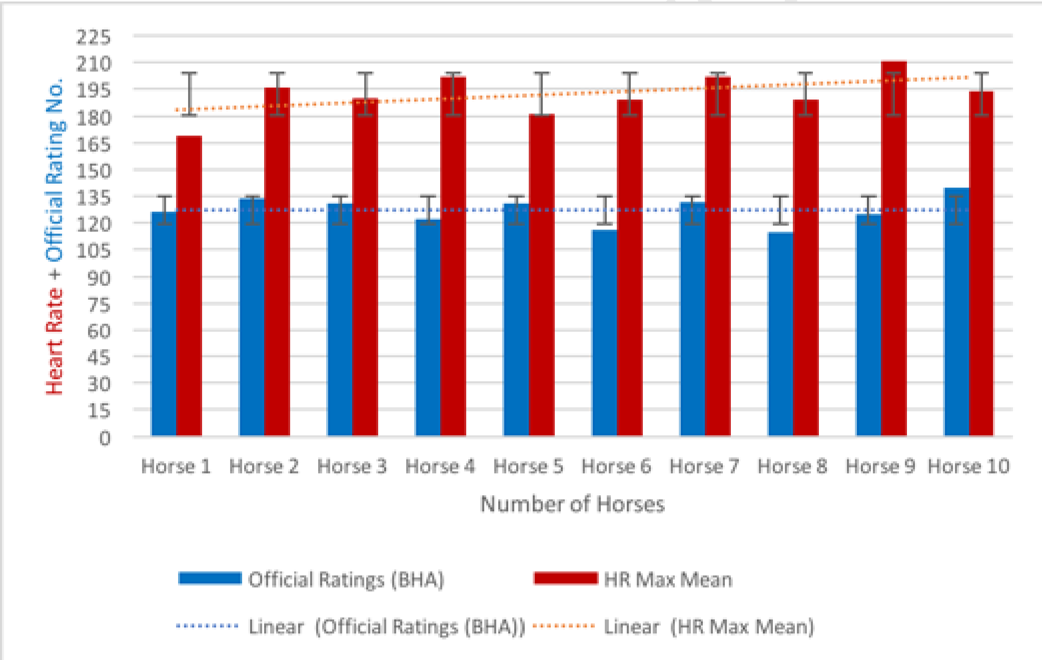

Figure 8: HR and OR training session 3

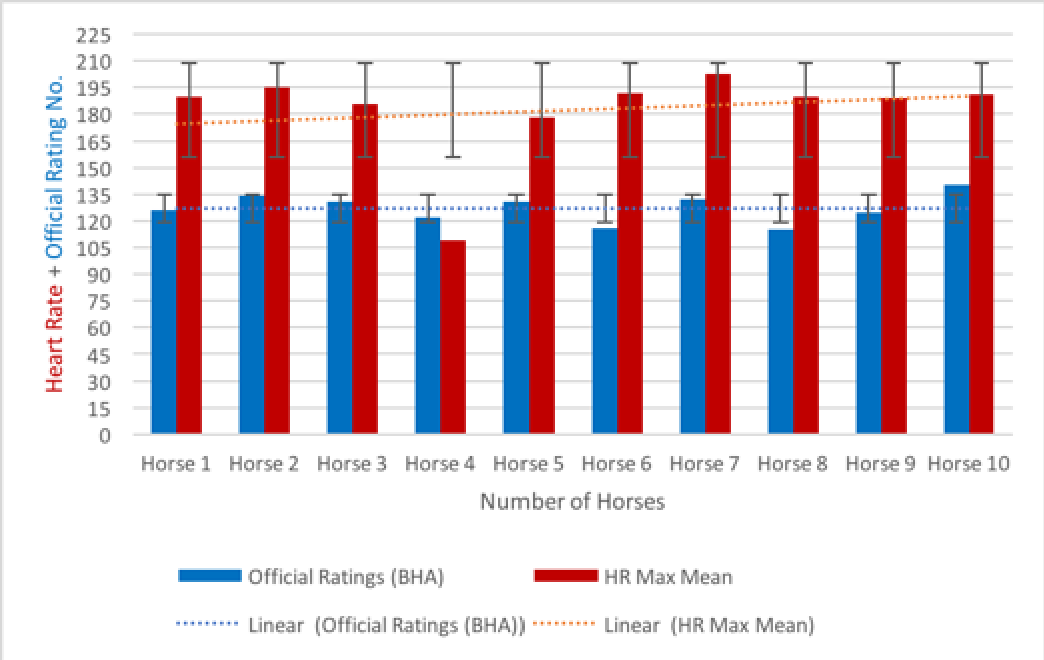

Figure 9: HR and OR training session 4

3.2.5 Percentage HR Max across training

Kruskal Wallis was run to define the difference between the ten horses and four training sessions. Findings were non-significant (P>0.05).

3.2.6 Percentage HR max vs End Percentage HR max

Kruskal Wallis was run to define the difference between HR max and end %HR max. Due to result being (P>0.05) a Mann Whitney U and Bonferroni Correction was not needed as the data was not applicable for pairwise comparison analysis (Field, 2014).

3.2.7 Percentage HR Max vs End percentage HR Max recovery

Kruskal Wallis was again applied to define differences between %HR max and end %HR max post 60 seconds of exercise. Findings were non-significant (P>0.05).

3.2.8 Official ratings and HR max mean

Spearman's was run to test for correlation between official ratings and %HR max Official ratings (see table 1) was compared with HR max mean for across horses to assess significance between the 2 variables. This was to show if there was similarity between the official rating (OR) that the horses earned and the HR max mean the horses achieved during the study (see figures 4-7). Findings were non-significant (P> 0.05).

3.3 Descriptive individual statistics

3.3.1 Individual analysis

The Friedmans two-way ANOVA was used in all individual tests between variables to quantify any significance (Appendix I, J, K).

3.3.2 Percentage HR Max Mean

Individual HR max percentage was analysed (see figure 2,3). Findings for all 10 were non-significant (P>0.05) (table 2).

Table 2: P values for %HR max mean across training sessions

Horses	P values
Horse 1	P> 0.272
Horse 2	P>0.209
Horse 3	P>0.165
Horse 4	P>0.17
Horse 5	P>0.392
Horse 6	P>0.960
Horse 7	P>0.308
Horse 8	P>0.051
Horse 9	P>0.17
Horse 10	P>0.444

3.3.3 Percentage HR Max End

Individual HR max percentage at the end of exercise was analysed (figure 4). Findings for all 10 horses were non-significant (P>0.05) (table 3).

Table 3: P values for %HR end across training sessions

Horses	P values
Horse 1	P>0.019
Horse 2	P>0.145
Horse 3	P>0.217
Horse 4	P>0.008
Horse 5	P>0.50
Horse 6	P>0.19
Horse 7	P>0.58
Horse 8	P>0.187
Horse 9	P>0.39
Horse 10	P>0.555

3.3.4 Percentage HR Max Recovery

Individual HR max percentage 60 seconds' post exercise was analysed (figure 5). Findings for all 10 horses were non-significant (P>0.05) (table 4).

Table 4: P values for %HR max end -60 across training sessions

Horses	P values
Horse 1	P>0.212
Horse 2	P>0.13
Horse 3	P>0.112
Horse 4	P>0.022
Horse 5	P>0.306
Horse 6	P>0.101
Horse 7	P>0.026
Horse 8	P>0.077
Horse 9	P>0.013
Horse 10	P>0.212

CHAPTER 4
4.0 DISCUSSION

4.1 Percentage HR max mean and training sessions

The main findings of the present study suggested that HR was consistent across the training sessions, although there was a persistent increase and decrease of HR over time (P>0.724) (figure 2,3). When exercising a racehorse or any athlete, an individual's HR Max should decrease over time when subjected to a regular, progressive training programme (Gür and Matur, 2013; Gramkow and Evans, 2006; Howley, 2001). HR across training sessions from the sample population (n=10) suggests that consistency shows that the racehorse trainer was not applying training programmes individually for each horse and therefore indicates that there was a wide range of fitness levels between the ten horses (Bitschnau et al., 2010). Although only horse five and horse ten during the four training sessions consisting of 12 gallops in total showed a gradual decrease in %HR Max which suggests that over time, these horses were becoming gradually fitter (Borresen and Ian Lambert, 2009) (figure 2,3). It could also indicate that the horses had become more adapted to the training sessions due to repetitive bouts of exercise. The non-significant changes in HR across training sessions from the sample population (n=10) suggests that the racehorse trainer was not applying the principle of individualisation to training. It was likely that there was a wide range of fitness levels between the ten horses although due to data collection taking place on a Monday after a day of rest, the horses had an average speed of 20 mph (9m/s) which could explain why the results did not change as the horses were averaging the same speed (Bitschnau et al., 2010) (Appendix L).

Due to the nature and traditional methods of training racehorses, a racehorse trainer can only perceive a horses' fitness through breeding, gender, age, medical history, previous injury, official rating, respiration rate, visual fatigue and perspiration (Kingston et al., 2006). Due to several variables, it is difficult to scientifically evaluate a horses' fitness accurately without the use of HRM equipment (de Bruijin et al., 2016). By combining a professional racehorse trainer’s experience with the use of HRM equipment in training programmes it allows a better in depth knowledge of how fit an individual horse is. Using HRM equipment allows the trainer to take a scientific approach to training and exercise and keep accurate track of his or her horses’ fitness and any changes that are needed to be added to their training programmes to improve their fitness levels (Vermulen and Evans, 2006). Furthermore, time can also be a significant factor; therefore, racehorse trainers set training sessions which can contain a large amount of horses exercising up a track at the same time in concession and could suggest that the trainer cannot always gauge how fit an individual horse is. Consequently, HRM is quick and sufficient making fitness monitoring more accurate.

4.2 Percentage HR max and percentage HR end of exercise

It was founded that all horses had shown either the same %HR max during and at the end of exercise or it had slightly decreased. No significant differences were observed between %HR max and %HR at the end of exercise (Appendix F). This may have been due to the nature of the training session layout; horses were trotted down the gallop to proceed their exercise up the gallop. As three gallops were completed per training session, the horses did not have sufficient time to recover between gallops due to trotting back down the same distance that the horses galloped up (n=3). This could suggest that the horses are not being progressively overloaded enough to elicit a change in fitness, although it has been suggested that active rests such as trotting after galloping have been shown to be beneficial for improving fitness (Fonseca et al., 2010)

4.3 Percentage HR max and percentage HR max recovery

Percentage HR max was compared to %HR max recovery after 60 seconds’ post end of exercise to see how quickly the horses returned to resting HR. No significant differences were found (P>0.517 Appendix G). When the horses had finished each training session, the riders would walk them back (1000m) to the yard to untack and move onto the next horse. The result has shown that the time of recovery the horses were subjected to suggests it was not enough and indicates that the horse's anaerobic fitness needs to improve (de Bruijin et al., 2016).

4.4 Official ratings and percentage HR max

Official ratings and %HR max was tested to see if there was any correlation between the variables, the findings were non-significant (p>0.804) (r=-.845). Official ratings are used to judge how well a horse is doing within the racing calendar and can be an indication of fitness to racegoers.

4.5 Individual tests

Individual tests were run for all 10 horses to see if there was any improvement on an individual scale across the training sessions, the findings were non-significant due to time being a factor, if more data from training sessions were collected, results would have been significantly different (table 2,3,4). Only horse five and horse ten showed a gradual decrease in %HR Max during the 4 training sessions (consisting of 12 gallops in total) which suggests that over time, these horses were becoming gradually fitter (Appendix I, L).

4.6 Recommendations for HR analysis in NH training

Recent upcoming companies such as Fine Equinity does not only provide a means for a trainer to solely use HRM equipment but also their online website can be used to allocate and create training programmes and to depict speed, stride length and stride frequency profiles to compare with the same horse across the NH season. Therefore, it would provide more detailed feedback to trainers.

4.7 Limitations

Potential limitations within the current study are mainly the duration and the low sample population in comparison to similar studies (Kingston et al., 2006).

Due to this limitation, the results were effected as every test that was carried out was non-significant although visually the results suggested a difference had occurred due to the peaks and troughs of %HR max over the period of four training sessions (Figure 2,3). Data was collected on a non-work day which meant the horses galloped at an average of 20mph (9m/s) due to having a day off every Sunday and therefore several horses within the study were mainly working in an aerobic state (Appendix L). Due to this factor, high intensity training (HIT) needed to be more intense and therefore needs longer time to recover during low intensity training (LIT) (Gibala et al., 2012).

Only three sets of HRM systems were loaned to collect the data, therefore only three horses for each training session could be collected which caused some horses not to be collected due to the horses being in the same training session. Also, only four training sessions were used as the batteries within the HR monitor in the girth sleeve became dead, therefore the system only measured speed, stride length, stride frequency and altitude. Data was collected mid-season near the Cheltenham Festival and therefore it was not an accurate indicator of fitness progression because fitness would already be peaking for competition, therefore the trainers goal may have been to maintain fitness levels and not fatigue the horses before competition. Consequently, future studies should look at training sessions at the start of the season in late August.

It was attempted in the current study to apply HRM equipment on horses to jump over hurdles and fences to evaluate the stride length between jumps and over hurdles and fences. This would have been an interesting result to find out as no research to date has observed the effectiveness for HRM systems when jumping. Mapping of the gallops by the company was laid out before data collection started; to assess how long the gallop was through GPS. Due to this; data could not be collected as there was a separate field laid out with hurdles and fences and were not positioned on the track so mapping of the field could not be applied at the time.

4.8 Further research

Further research is needed to evaluate new HRM systems and how trainers can use them to their full potential. By using HRM within a major under rules race it will allow researchers to set baseline data and evaluate training sessions vs competition. To date no research has evaluated HR, speed, stride length or stride frequency within a race with the use of HRM systems due to confidential issues by the BHA and how such study may damage the racing industry's reputation.

HRM also has not yet been used to detect talent and ability over hurdles and fences, research in this area would not only benefit accuracy of measuring fitness parameters in horses, but could potentially detect horses that may not benefit within NH due to small stride lengths and could reduce risk of injury due to this factor.

Due to advances in new HRM equipment, it would be beneficial to the industry if a large amount of sample population was used over the course of the NH racing season to properly observe the horses throughout a whole season. This would also be a good indicator for racehorse trainers if a horse is progressing through the season.

CHAPTER 5
5.0 CONCLUSION

The results of the current study adds value to research regarding the use of new HRM systems being used in everyday training and exercise within the horseracing industry. Due to the sample size and duration of the study findings were non-significant. Although due to new HRM systems being introduced into regular training in horseracing it allows a more scientific approach to training and gives a racehorse trainer the ability to learn more about an individual horse within their yard.

The use of HRM systems and equipment has shown that a trainer can easily implicate such equipment within their training programmes which would also be beneficial for veterinary surgeons to assess cardiovascular health, jockeys to identify fitness ability, stable staff that regularly exercise the horses and racehorse owners to check up on their horses' fitness.

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APPENDICES

APPENDIX A – Signed proposal and ethics form

DISSERTATION PROJECT PROPOSAL AND ETHICS FORM 2015-16

Personal and project information:

Name: Kieran Scott Kenworthy

Programme of study: BSc (Hons) Equine Science

Potential Supervisor: Dr. Jane Williams

Project title:	To evaluate how core physiological (cardiovascular) parameters respond to a programme of interval training in National Hunt (NH) racehorses.

Which type of Project are you proposing (please tick)

Research Article	X
Vocationally Relevant Inquiry	
Critical Review of Literature	

Background and rationale: Give a brief background and rationale for the project. This should include a review of previous research on the topic and a justification of why this project is unique and of scientific importance. This must be supported by appropriate references.

Aims and objectives: List the overall aim of your project and provide several achievable objectives that you hope to complete through your study.
Objectives To establish if relationships exist between core cardiovascular parameters and BHA official ratings (OR) in NH racehorses To determine if training regimens used in NH racehorses support the physiological demands of racing (fitness: time spent in aerobic vs. anaerobic performance / would need BHA permission to obtain race data) To explore the potential of standard exercise testing (SET) to measure progress in NH training regimens To discover if a relationship exists between heart rate (HR), stride length (SL) and speed (with aim to extrapolate useful HR / fitness data from allowed race day data collection)

Experimental design and methods: Summarise the methods you will use to achieve the aims and objectives of the project. Depending on the nature of your project, this might include information such as study site, study species, sample size, equipment and resources needed, sampling and recording methods and media and statistical analysis. The methods must be supported by appropriate references.

Methodology

To undertake HR analysis of NH racehorses (n=20) during their normal training regimen for 6 months within a single NH yard, using the Fine Equinity HR monitoring system utilising the following protocol:

- Initial physiological assessment: SET
- Trainer to use HR monitor within training for selected horses (ideally continually but if not targeted sessions, gallop and jump schooling, agreed with trainer) -> Monitor training progress via selected exercise variable (outlined below)
- 3 or 4 week assessment of fitness via SET
- Ideally to complement with race day data

Data Collection:

Record horse demographic / performance variables:

- Age
- Height
- Weight: horse and work rider
- Previous history: health, injury, performance
- Previous flat career
- Sales price
- Time in training
- Time in training with current trainer
- Days since last race
- Incidents (training) which could impact performance: scopes, bloods, virus, lameness etc.
- OR: Start, end, SET weeks, record any changes (after races), mean±SD
- Trainer rating of horse's fitness level: start, end, SET, prior to races (0 not fit -> 10% race fit)
- Trainer rating of horse's performance level: start, end, SET prior to races (1->10, very poor to excellent
- Training data: gallop times / speeds, furlong splits
- Race performance and travel time
- Horse bodyweight: start, end, pre-race, prior to SET

Record Management Data:

- Diet
- Exercise bouts: type, distance, gallop used (if more than one), surface, duration, gait, jump schooling, treadmill etc
- Stable management: stabled vs turnout

Record physiological variables (adapted from Williams and Flander 2014; Lamperd and Williams, 2013; Pollock et al., 2009; Kingston et al., 2006; Vincent et al., 2009:

- HR: Baseline (prior to exercise), minimum, maximum, mean duration of exercise, at standardised intervals within exercise (furlong splits)
- HR variability:
- Percentage time spent in HR zones: duration / furlongs within exercise
- Percentage time spent in anaerobic vs. aerobic HR: duration / furlongs
- Speed: entire distance, furlongs
- Stride length: entire distance, furlongs
- Stride frequency: entire distance, furlongs
- HR recovery: Monitor 10 min intervals for an hour post training
- Percentage of HR maximum: mean for entire distance, furlongs
- V150 / V200: Calculate velocity at which HRs of 150 and 200bpm (formula: Pollock et al., 2009)
- Distance and speed travelled to attain defined HR (e.g. to 150bpm

Standard exercise test (SET)

Set vary between previous studies (average 800m / 4 furlong gallop, speeds between 8- 17m/s to: actual test to be agreed with trainer to ensure participation (length of 'normal' gallop and sub maximal gallop speed ~13m/s). Two approaches can be used:

1. SET = Set distance at a defined speed-> assess HR, expect reduction in HR as fitness increases (use for SET training sessions)
2. $Velocity_{HR}$ = measure distance travelled / time taken to achieve a defined HR value e.g. 100bpm and 150bpm (use to assess progress during normal training)

Data Analysis

A combination of descriptive statistical analysis will be undertaken for individual horses and comparing performance across the cohort (all, split by OR categories, experience, age):

- Descriptive mean±SD; plot descriptive 'journey': variables progress over time
- Statistical:
    - o Tests of difference in key physiological variables between SET sessions
    - o Correlation between HR and trainer assigned fitness level, HR and performance measures (OR, trainer performance level), HR and fitness defined by HRmax% horse is working at for defined time periods

oUnivariable logistic regression between physiological variables performance measures to identify if causal relationships exist oMultivariable logistic regression model: all variables to OR rating to explore inter-relationships

Please note that whilst Hartpury equipment and existing resources are available for utilisation by students, funds are not available to cover project costs (e.g. equipment purchase, travel, accommodation).

Ethical considerations: Please list the ethical concerns that you believe are inherent in this project and explain how you plan to address them. This may not be relevant for a literature review or handling secondary data but is likely to be important for most projects.This could be through such methods as storing data appropriately and adhering to the data protection act, considering the 3Rs and limiting suffering.This must be supported by appropriate references. **Please note that whilst if ethical concerns are fully addressed the supervisor is able to sign off paperwork, where ethical concerns remain the paperwork will need to be submitted for ethical review. This may take up to 3 weeks.**

Equine welfare is paramount for this research article. Possible ethical considerations when collecting data from (NH) national hunt racehorses will be first; making sure the horse's taking part are in a secure, safe environment and is comfortable mentally and physically. It is important that any serious strenuous exercise will not be tolerated in order to receive data collection. Any horse that participates will be healthy and will not be accepted for data collection if injured, lame, a host of any disease or disorder. The normal training regime for racehorse thoroughbreds will remain throughout data collection. The data protection act 1998 will be upheld to the upmost security with laptop passwords. Riders must be insured under the yard in order to participate riding horse's that are involved in data collection.

Documents enclosed with this proposal and ethics form (put a X in the appropriate boxes). These documents MUST be completed before you can be signed off by your supervisor to begin data collection.	
Completed questionnaire (if you are completing a questionnaire based project this MUST be enclosed)	
Risk assessment (this MUST be enclosed for all experimental research)	
Site permission form (this MUST be enclosed where the research is conducted off-site)	
Placement approval certificate (if applicable)	

Participant permission form (this MUST be enclosed unless your project does not have any human / animal participants)	
Other (please specify)	

Signature of student		**Date**	

Signature of supervisor		**Date**	

APPENDIX B – Site permission form

HARTPURY
UNIVERSITY CENTRE

Name
Number
Email (use Hartpury/UWE email address)

Site permission form:

Note: this MUST be completed where the research is conducted off-site.

This must be completed by the student and then read and signed off by the manager/owner of the facility/location where the off-site research is being conducted.

Please note that completion of this Site Permission form ONLY grants permission to conduct research at the site. In order to gain permission to utilise animals located/housed at the site, a separate participant permission form MUST be completed by the animal(s)' owner/trainer.

To whom it may concern,

I [**insert name of manager/owner**] in my capacity as manager/owner [**delete as appropriate**] of [**insert facility/location**] grant permission for [**insert student name**] to conduct research looking at [**insert title of dissertation project**] at my establishment from [**insert date**] to [**insert date**].

I understand that the project involves [**briefly outline method**] and will facilitate work which will be presented as a dissertation, with aims to publish in an appropriate journal. I also understand that a paper and electronic copy will be kept at Hartpury College.

Yours sincerely,

Signature of manager/owner_______________________________________

Location/facility____

Please print name/s: ____

Date: ____

APPENDIX C – Participant form

HARTPURY
UNIVERSITY CENTRE

Participant Consent Form

Study Title:

Participant Name/s:
Address:
Contact number/s:
Email address:

I / We in the capacity as the individual(s) listed/Owner/representatives of the Owners [**insert name**]/Trainer [**delete as appropriate**], hereby give my / our permission for [**student**] and associates to undertake [**brief outline method**] for the subjects detailed below in respect of the above study.

In addition to granting consent for participation in this research, I/ We also grant consent for the data obtained from this to be used and analysed over the course of the research study.

Subjects to be included in the research: please identify

I / We understand that data collected will be coded to ensure anonymity and that examinations will be performed accompanied by a member of allocated staff to enable any individuals to be removed from the study at my / our request. I / We are aged over 18 years and are the official keeper/s of the animals identified [**include if relevant**].

Signature: ____

Please print name/s: ____________________________________

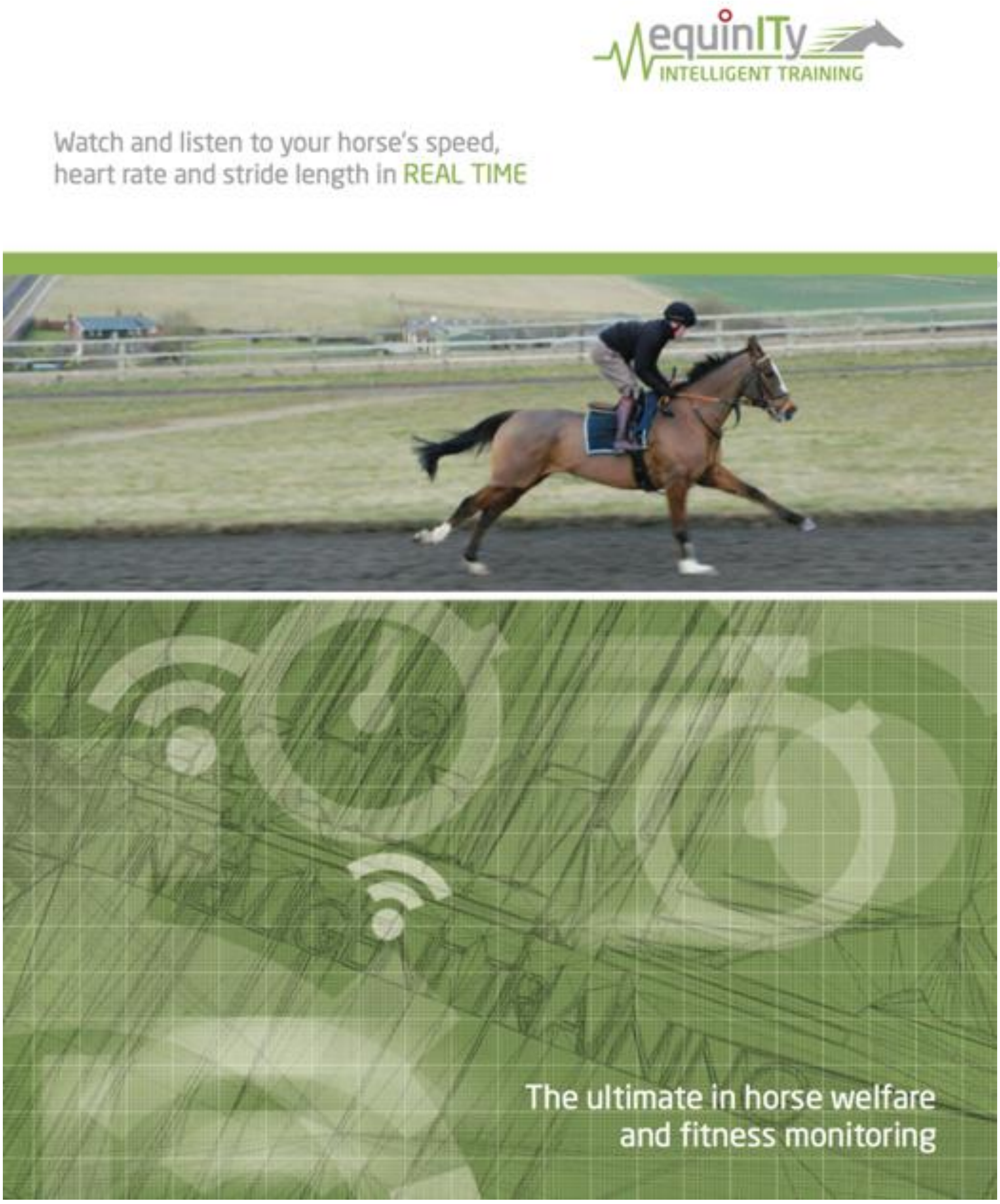
Date: ____

Please tick the box below identifying if you wish your participation to be publicly acknowledged.

YES, acknowledge me ☐ NO, please do not acknowledge me ☐

4

APPENDIX D – Copy of the Fine Equinity Brochure



What is equinITy?

equinITy is a leading-edge, web-based horse welfare, training and yard management tool. It was developed "in the yard" in response to racehorse trainers' desire to assess and monitor their horses' welfare and fitness using an intuitive, non-invasive and cost-effective system.

Winning features

- **Key measures** such as distance, split times, strides per furlong, stride length, speed, location and altitude give trainers more information to optimise the training schedule for their horses
- **GPS and Stride Monitoring** technologies, expertly integrated to provide scientific information and reports to complement the trainer's expert horsemanship
- **Continuous Heart Rate Monitoring** gives an early indication of improving fitness or potential health deterioration, and also determines the heart rate recovery time
- **Real-time Streaming** allows gallop-side monitoring for trainers and owners from a smart phone or tablet

A professional perspective…

"I'm a trainer who strives to constantly innovate and introduce new ideas into the yard to provide a competitive edge and increase the wellbeing of our horses. Having been involved from the outset in the development of **equinITy**, it has become an invaluable tool in helping us to achieve our best results in recent seasons both by numbers and quality of winners. **equinITy's** evolution to provide stride data in addition to heart rates and GPS information gives us an insight into the horses welfare which would otherwise be impossible to achieve."

Brian Ellison, Malton, UK

"I was thrilled with Mubtaahij's win in the UAE Derby on Dubai World Cup night. We used the new equinITy device on him in the build up to the Derby, which was a great help. Not only did he look amazing physically, but his data backed up exactly what I was seeing in front of me. His work showed that he could cruise at a high speed with a long stride length allowing him to conserve energy and thus quicken off a strong pace, which is exactly what he did on the big night."

Mike de Kock, Gauteng, South Africa

"equinITy is an extra pair of eyes and ears on my horses. By collecting data each day I can build up a profile for my horses based on scientific fact as well as my own assessment. This acts as a 'tip off' if a horse has worked poorly, or to confirm a horse is ready to race.

My filly Egyptian Symbol had a slight temperature after chalking up her second win in a row. After an easy week she had a good gallop on the Tuesday and was not only visually impressive but the data indicated she was back to her old self. The horse is now 3 from 3 and right on track for the $10m Jeep Magic Millions Raceday in January."

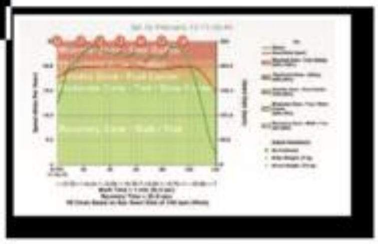
Bjorn Baker, New South Wales, Australia

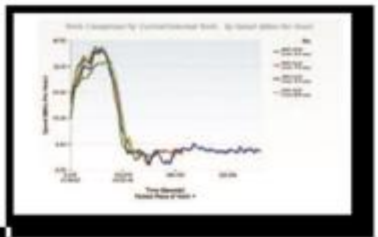
"Heart rate monitors and GPS devices are now commonly used in all branches of professional and amateur sport to individualise and optimise athletes' training resulting in improvements in performance at every level. Easy availability of reliable heart rate and speed data over time for an individual horse provides the best method of monitoring its overall health. This information is always the starting point for the investigation of any subsequent poor performance and from the perspective of a specialist equine cardiologist who is regularly tasked with evaluating these cases, I really look forward to a time when this kind of data is available routinely and not rarely."

Dr Lesley E Young BVSc DVA DVC DipECEIM PhD MRCVS
RCVS Recognised Specialist in Veterinary Cardiology

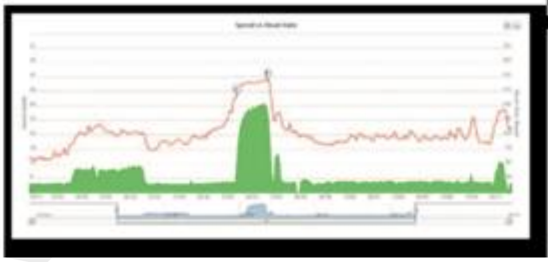
- **Secure and confidential website** is used to store the downloaded data
- **Easy access** to reports and training data from anywhere in the world via the internet
- **Intelligent analysis** of the data produces highly informative, user-friendly, graphical performance reports
- **No additional equipment** is introduced into the yard

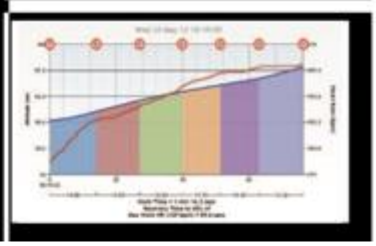
Rich in content

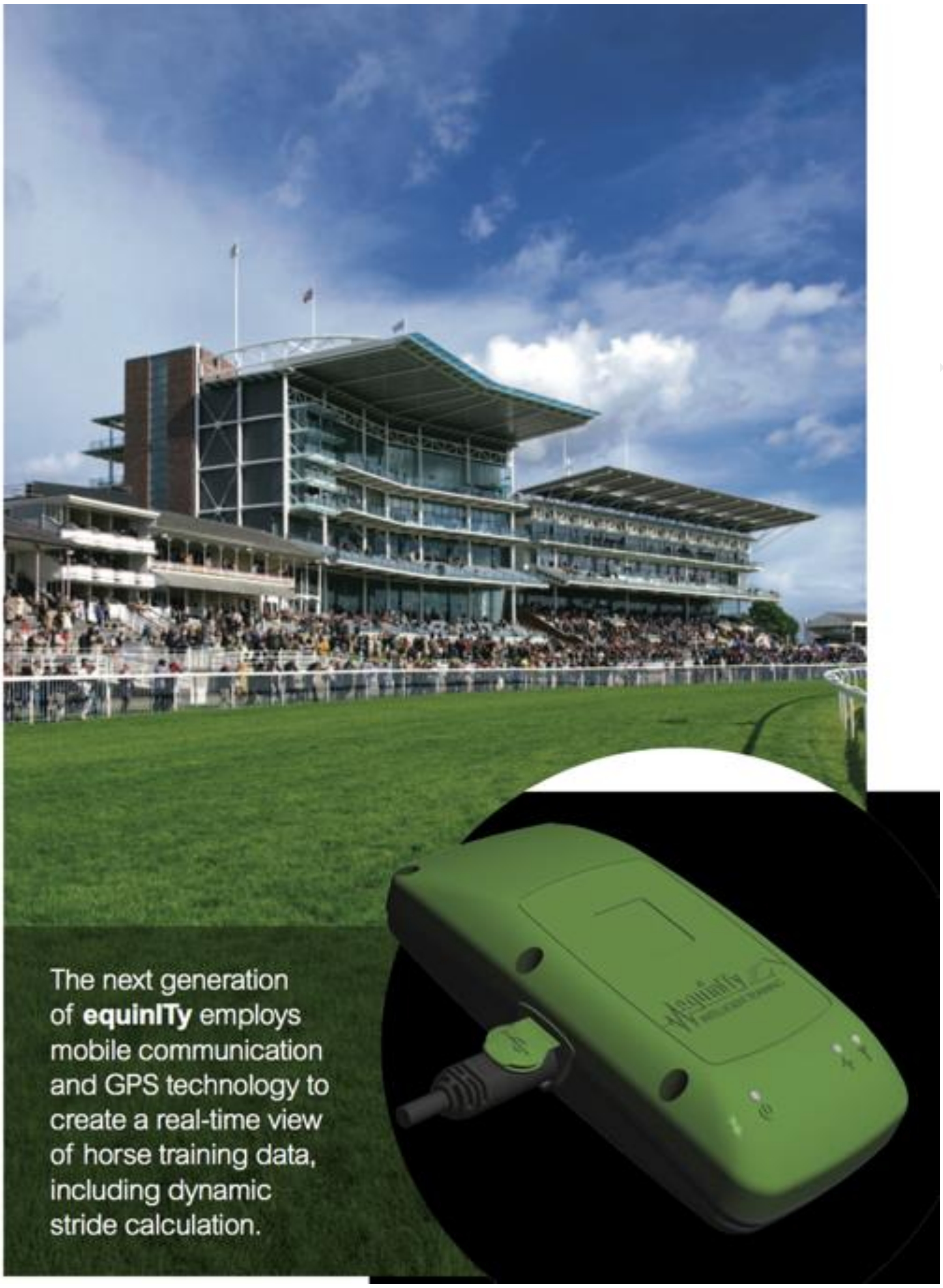




- **Visualise** horse tracking information in a graphical map view, allowing drill-down to specific data points and animation - bringing each of piece of work "to life!"
- **Heart Rate vs Speed** is displayed in a variety of different ways, including the ability to view performance within predefined "training zones"
- **Split Times** and recovery times are automatically calculated and can be displayed in a range of different formats
- **Compare Multiple Pieces of Work** from the same or different horses, allowing you to review performance over a period of time and trend a variety of different factors
- **Heart Rate vs Altitude** provides analysis of the relationship between different gallops and horse performance
- **Powerful Charting Capability** allows the ability to zoom in, focus on and explore specific data
- **Work Summary** generates a single screen overview of a work item, allowing notes to be added by the trainer and also automatically displays the respective weather conditions at the time and location of the work
- **RaceFinder,** using Weatherbys' real-time database, makes it very easy to find races for all horses in your yard, automatically using ratings, best trips and other attributes to optimise the searching process
- **Yard Management** features providing work scheduling and high quality reporting to save time and effort






The next generation
of **equinITy** employs
mobile communication
and GPS technology to
create a real-time view
of horse training data,
including dynamic
stride calculation.

APPENDIX E – %HR max and training sessions across all horses

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRMAX is the same across categories of TrainingSessions.	Independent-Samples Kruskal-Wallis Test	.724	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX F - %HR max and end %HR max across all horses

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of ENDHRMAX is the same across categories of TRAININGSESSION.	Independent-Samples Kruskal-Wallis Test	.975	Retain the null hypothesis.
2	The distribution of PERCENTAGEHRMAX is the same across categories of TRAININGSESSION.	Independent-Samples Kruskal-Wallis Test	.972	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX G - %HR max and end %HR recovery (-60)

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PERCENTAGEHRMAX is the same across categories of TRAININGSESSIONS.	Independent-Samples Kruskal-Wallis Test	.975	Retain the null hypothesis.
2	The distribution of HREND60 is the same across categories of TRAININGSESSIONS.	Independent-Samples Kruskal-Wallis Test	.517	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX H – Official ratings and %HR max correlations

Correlations

			HorseMeasure	Groups
Spearman's rho	HorseMeasure	Correlation Coefficient	1.000	.032
		Sig. (2-tailed)	.	.845
		N	40	40
	Groups	Correlation Coefficient	.032	1.000
		Sig. (2-tailed)	.845	.
		N	40	40

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HorseMeasure is the same across categories of Groups.	Independent-Samples Kruskal-Wallis Test	.804	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX I – Individual tests %HR mean

Horse 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.272	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.209	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.165	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Gallop4 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.017	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.392	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.960	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 7

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.308	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 8

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.051	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.017	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 10

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.444	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX J – Individual tests end %HR

Horse 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.019	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.145	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.217	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.050	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.019	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 7

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.026	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 8

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.187	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of gallop1, gallop2, gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.039	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 10

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.555	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX K – Individual tests %HR Recovery (-60)

Horse 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.212	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.013	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.112	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.022	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.306	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.101	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 7

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.026	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 8

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.077	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.013	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Horse 10

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Gallop1, Gallop2, Gallop3 and Mean are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.112	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX L – Raw data profiles for each horse

Horse 1

HORSE NAME: Horse 1	Training session 1				Training session 2				Training session 3				Training session 4				Training session 5			
	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
HEART RATE (HR)																				
HR start	116	134	146	132	163	166	87	139	96	143	149	129	160	157	107	141	181	169	143	164.3
HR minimum	116	134	146	132	163	166	87	139	96	143	149	129	160	157	107	141	181	169	143	164.3
HR maximum	197	211	189	199	193	194	145	177	145	175	186	169	189	194	188	190	247	204	206	219
HR mean	159	200	172	177	184	188	120	164	114	137	174	142	183	184	175	181	236	197	196	209.7
HR end	197	203	184	194.7	189	191	144	175	141	173	180	165	184	193	181	186	235	197	204	212
HR end -60	128	164	144	145.3	138	122	114	125	115	130	158	134	142	135	155	144	180	152	164	165.3
Percentage of HR max (HRmean)	66.3	83.3	71.7	73.75	76.7	78.3	50	68.3	47.5	57.08	72.5	59	76.25	76.67	72.92	75.3	98.33	82.083	81.67	87.36
Percentage of HR max (HRend)	82.1	84.6	76.7	81.11	78.8	79.6	60	72.8	58.8	72.08	75	68.6	76.67	80.42	75.42	77.5	97.92	82.083	85	88.33
Percentage of HR max (HR end-60s)	53.3	68.3	60	60.56	57.5	50.8	47.5	51.9	47.9	54.17	65.83	56	59.17	56.25	64.58	60	75	63.333	68.33	68.89
Percentage of time: anaerobic	16.5	86.2	0	34.23	34.6	39.8	0	24.8	0	0	3	1	2.3	29.4	14	15.2	95.5	86.6	18	66.7
Percentage of time: aerobic	83.6	13.7	100	65.77	65.4	60.2	100	75.2	100	100	97	99	97.7	70.6	86	84.8	3.6	13.4	83	33.33
SPEED (m/s)																				
Speed HR max	9.2	9	9.5	9.233	9.8	9.9	9	9.57	6.3	9.4	10.1	8.6	9.7	10.2	9.2	9.7	9.6	10.4	10.2	10.07
Speed mean	8.2	8.3	8.2	8.233	8.6	8.7	5.8	7.7	8.6	8.2	9	8.6	9	9.3	9.2	9.17	8.6	8.8	8.9	8.767
STRIDE DATA																				
Mean stride frequency (strides/min)	47.7	46.6	42	45.45	41.5	41.4	51.4	44.8	49.8	51.59	47.84	49.8	48.48	47.51	49	48.3	48.82	47.4	46.99	47.74
Mean stride length (m)	4.22	4.32	4.9	4.48	4.19	5.2	3.91	4.43	4.04	3.69	4.65	4.13	4.15	4.23	4.11	4.16	4.13	4.24	4.28	4.217

Horse 2

HORSE NAME: Horse 2	Training session 1				Training session 2				Training session 3				Training session 4				Training session 5			
	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2		Session	Gallop 1	Gallop 2		Session	Gallop 1	Gallop 2	Gallop 3	Session
HEART RATE (HR)																				
HR start	142	154	148	148	174	148	156	159	109	135		122	150	147		149	157	170	163	163.3
HR minimum	121	122	148	130.3	128	123	122	124	109	138		124	150	147		149	126	136	110	124
HR maximum	192	199	161	184	219	185	195	200	193	198		196	193	196		195	187	180	185	184
HR mean	159	190	149	166	201	178	184	188	182	176		179	184	180		182	186	189	165	180
HR end	121	122	148	130.3	128	123	122	124	122	122		122	124	122		123	110	112	115	112.3
HR end -60	190	196	185	190.3	202	182	193	192	111	133		122	119	145		132	152	164	186	167.3
Percentage of HR max (HRmean)	66.3	79.2	62.1	69.17	83.8	74.2	76.67	78.2	75.8	73.33		74.6	76.67	75		75.8	77.5	78.75	68.75	75
Percentage of HR max (HRend)	50.4	50.8	61.7	54.31	53.3	51.3	50.83	51.8	50.8	50.83		50.8	51.67	50.83		51.3	45.83	46.667	47.92	46.81
Percentage of HR max (HR end-60s)	79.2	81.7	77.1	79.31	84.2	75.8	80.42	80.1	46.3	55.42		50.8	49.58	60.42		55	63.33	68.333	77.5	69.72
Percentage of time: anaerobic	15.5	66.7	57	46.4	64	0	28	30.7	26.5	67.7		47.1	13.3	24.4		18.9	75	45.5	30	50.17
Percentage of time: aerobic	84.5	33.3	43	53.6	36.1	100	70	68.7	73.5	32.2		52.9	86.7	74.6		80.7	25	55.5	70	50.17
SPEED (m/s)																				
Speed HR max	6.6	6.9	8	7.167	9.2	9.3	4.6	7.7	9.2	9.6		9.4	10	4.3		7.15	9.1	9.5	8.7	9.1
Speed mean	9	10	10.1	9.7	7.9	8.4	6.2	7.5	8.2	8.6		8.4	8.7	8.5		8.6	8.2	8.5	8.3	8.333
STRIDE DATA																				
Mean stride frequency (strides/min)	37.8	35.5	34.6	35.97	47.3	46.5	45.9	46.6	46.9	44.8		45.9	50.3	50.5		50.4	48.3	46.7	45.5	46.83
Mean stride length (m)	5.5	6.2	6.3	6	4.2	4.3	4.6	4.37	4.2	4.8		4.5	4.3	3.9		4.1	4.5	4.3	4.2	4.333

Horse 3

HORSE NAME: Horse 3	Training session 1				Training session 2				Training session 3				Training session 4			
	Gallop 1	Gallop 2		Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
HEART RATE (HR)																
HR start	161	167		164	179	175	179	178	157	161	168	162	141	138	147	142
HR minimum	161	167		164	179	175	179	178	157	161	168	162	141	138	147	142
HR maximum	190	194		192	188	195	202	195	186	193	192	190	225	151	182	186
HR mean	183	190		186.5	186	192	202	193	179	188	186	184	215	141	161	172
HR end	176	190		183	186	192	198	192	183	190	188	187	224	148	180	184
HR end -60	179	183		181	146	139	132	139	184	165	155	168	173	138	144	152
Percentage of HR max (HRmean)	76.3	79.2		77.71	77.5	80	84.17	80.6	74.6	78.33	77.5	76.8	89.58	58.75	67.08	71.8
Percentage of HR max (HRend)	73.3	79.2		76.25	77.5	80	82.5	80	76.3	79.17	78.333	77.9	93.33	61.67	75	76.7
Percentage of HR max (HR end-60s)	74.6	76.3		75.42	60.8	57.9	55	57.9	76.7	68.75	64.583	70	72.08	57.5	60	63.2
Percentage of time: anaerobic	1.2	48.1		24.65	98	80.3	69	82.4	8.2	30.7	9	16	95.6	0	0	31.9
Percentage of time: aerobic	98.8	51.9		75.35	2	19.7	31	17.6	91.8	69.3	91	84	4.4	100	100	68.1
SPEED (m/s)																
Speed HR max	8.3	8.5		8.4	9.3	10.9	10.9	10.4	8.1	6.8	9.3	8.07	8.5	8.9	10.1	9.17
Speed mean	8	8.5		8.25	9.2	9.4	10	9.53	8.4	8.7	8.5	8.53	9	9.1	8.8	8.97
STRIDE DATA																
Mean stride frequency (strides/min)	49.6	48.4		49.01	38.9	38.1	34.3	37.1	48.3	47.4	48	47.9	47.8	47.43	48.42	47.9
Mean stride length (m)	4	4.1		4.05	5.6	5.7	6.4	5.9	4.1	4.2	4.1	4.13	4.21	4.24	4.16	4.2

Horse 4

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 4**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	103	107	146	118.7	132	143	142	139	154	171	155	160	183	141	179	168
5	HR minimum	103	107	146	118.7	132	143	142	139	154	171	155	160	183	141	179	168
6	HR maximum	188	193	193	191.3	183	192	180	185	201	207	197	202	201	223	203	209
7	HR mean	140	152	153	148.3	135	162	160	152	192	200	191	194	199	191	199	196
8	HR end	188	192	192	190.7	170	191	170	177	199	204	194	199	199	217	202	206
9	HR end -60	168	146	137	150.3	129	149	139	139	173	152	163	163	185	156	142	161
10	Percentage of HR max (HRmean)	58.3	63.3	63.8	61.81	56.3	67.5	66.67	63.5	80	83.33	79.583	81	82.92	79.58	82.92	81.8
11	Percentage of HR max (HRend)	78.3	80	80	79.44	70.8	79.6	70.83	73.8	82.9	85	80.833	82.9	82.92	90.42	84.17	85.8
12	Percentage of HR max (HR end-60s)	70	60.8	57.1	62.64	53.8	62.1	57.92	57.9	72.1	63.33	67.917	67.8	77.08	65	59.17	67.1
13	Percentage of time: anaerobic	11.5	7.2	7	8.567	11.5	8.2	7	8.9	74.3	85.3	65	74.9	87.6	52.1	93	77.6
14	Percentage of time: aerobic	88.5	92.7	93	91.4	88.5	91.7	93	91.1	25.7	14.7	35	25.1	12.4	47.8	7	22.4
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.7	10.1	10.3	10.03	10.5	9.4	9.8	9.9	11.1	12	8.5	10.5	9.7	10.4	10	10
19	Speed mean	8.4	8.8	9.1	8.767	9	8.6	8.7	8.77	9.2	9.7	9.2	9.37	8.6	8.9	9.2	8.9
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	47.8	45.7	44.8	46.09	46.7	45.2	43.27	45.1	38.9	35.78	45.66	40.1	48.18	45.83	44.55	46.2
23	Mean stride length (m)	4.21	4.21	4.5	4.307	4.41	4.53	4.5	4.48	4.52	5.12	4.41	4.68	4.18	4.4	4.52	4.37

Horse 5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 5**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	103	160	155	139.3	109	148	149	135	175	92	132	133	110	143	167	140
5	HR minimum	103	160	155	139.3	109	148	109	122	175	92	132	133	110	143	167	140
6	HR maximum	200	191	191	194	184	210	187	194	194	160	188	181	191	164	179	178
7	HR mean	171	187	185	181	131	203	180	171	188	128	179	165	174	145	160	160
8	HR end	200	187	188	191.7	170	207	185	187	192	158	177	176	190	153	168	170
9	HR end -60	155	176	174	168.3	109	176	155	147	178	119	173	157	156	143	145	148
10	Percentage of HR max (HRmean)	71.3	77.9	77.1	75.42	54.6	84.6	75	71.4	78.3	53.33	74.583	68.8	72.5	60.42	66.67	66.5
11	Percentage of HR max (HRend)	83.3	77.9	78.3	79.86	70.8	86.3	77.08	78.1	80	65.83	73.75	73.2	79.17	63.75	70	71
12	Percentage of HR max (HR end-60s)	64.6	73.3	72.5	70.14	45.4	73.3	64.58	61.1	74.2	49.58	72.083	65.3	65	59.58	60.42	61.7
13	Percentage of time: anaerobic	51	1	4	18.67	0	9.6	0	3.2	44.3	0	0	14.8	10	0	0	3.33
14	Percentage of time: aerobic	49	99	96	81.33	100	89.3	100	96.4	55.7	100	100	85.2	90	100	100	96.7
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.6	8.2	9.7	9.167	8.8	9.6	9.9	9.43	9.7	8.6	8.9	9.07	9.6	9	7.5	8.7
19	Speed mean	8.2	8.7	8.7	8.533	8.2	8.9	8.8	8.63	8.8	7.6	7.7	8.03	7.9	8.1	8.1	8.03
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	48.9	45.4	45.5	46.62	47	46.1	45.74	46.3	46.5	54.76	53.94	51.7	53.8	53.23	54.23	53.8
23	Mean stride length (m)	4.12	4.13	4.43	4.227	4.28	4.03	4.41	4.24	4.33	3.68	3.73	3.91	3.74	3.64	3.78	3.72

Horse 6

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 6**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	150	157	168	158.3	162	175	96	144	145	153	162	153	152	167	166	162
5	HR minimum	150	157	168	158.3	162	175	96	144	145	153	162	153	152	167	166	162
6	HR maximum	186	210	180	192	206	209	187	201	182	205	179	189	186	209	180	192
7	HR mean	179	200	176	185	199	198	162	186	173	203	178	185	182	201	175	186
8	HR end	179	204	150	177.7	200	202	186	196	182	201	145	176	172	191	143	169
9	HR end -60	159	154	135	149.3	163	154	110	142	150	159	138	149	144	136	122	134
10	Percentage of HR max (HRmean)	74.6	83.3	73.3	77.08	82.9	82.5	67.5	77.6	72.1	84.58	74.167	76.9	75.83	83.75	72.92	77.5
11	Percentage of HR max (HRend)	74.6	85	62.5	74.03	83.3	84.2	77.5	81.7	75.8	83.75	60.417	73.3	71.67	79.58	59.58	70.3
12	Percentage of HR max (HR end-60s)	66.3	64.2	56.3	62.22	67.9	64.2	45.83	59.3	62.5	66.25	57.5	62.1	60	56.67	50.83	55.8
13	Percentage of time: anaerobic	0	87.3	0	29.1	90.5	75.3	50	71.9	0	84.3	0	28.1	8.8	85.3	1	31.7
14	Percentage of time: aerobic	100	13.7	100	71.23	9.4	24.7	51	28.4	100	10.7	100	70.2	92.2	11.7	99	67.6
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.03	10.6	8.9	9.507	9.2	7.5	9.6	8.77	8.9	10	9.4	9.43	8.5	9.4	8.9	8.93
19	Speed mean	7.9	9.2	8.4	8.5	7.5	7.5	8.7	7.9	8	8.5	8.8	8.43	8.4	8.9	9	8.77
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	51.2	46.8	51.2	49.76	54	52.1	48.29	51.4	52.2	50.23	53	51.8	53.21	49.23	54	52.1
23	Mean stride length (m)	3.93	4.3	3.98	4.07	3.73	3.87	4.17	3.92	4	4.53	4.32	4.28	4.3	4.56	4.6	4.49
24																	

Horse 7

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 7**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	156	172	170	166	176	137	168	160	147	148	133	143	170	158	147	158
5	HR minimum	156	172	170	166	176	137	168	160	147	148	133	143	170	158	147	158
6	HR maximum	200	203	198	200.3	207	197	203	202	206	202	197	202	205	204	199	203
7	HR mean	190	198	192	193.3	201	184	196	194	196	192	186	191	197	195	190	194
8	HR end	194	189	192	191.7	203	191	202	199	204	193	195	197	202	199	193	198
9	HR end -60	159	150	165	158	153	146	155	151	156	162	175	164	168	155	172	165
10	Percentage of HR max (HRmean)	79.2	82.5	80	80.56	83.8	76.7	81.67	80.7	81.7	80	77.5	79.7	82.08	81.25	79.17	80.8
11	Percentage of HR max (HRend)	80.8	78.8	80	79.86	84.6	79.6	84.17	82.8	85	80.42	81.25	82.2	84.17	82.92	80.42	82.5
12	Percentage of HR max (HR end-60s)	66.3	62.5	68.8	65.83	63.8	60.8	64.58	63.1	65	67.5	72.917	68.5	70	64.58	71.67	68.8
13	Percentage of time: anaerobic	41.8	87.6	82	70.47	85.8	37.1	79	67.3	80.7	74.4	53	69.4	85	79.2	72	78.7
14	Percentage of time: aerobic	44.3	12.4	18	24.9	14.2	63	21	32.7	19.3	25.6	47	30.6	15	21	28	21.3
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.9	9.2	9.7	9.6	10	9.6	8.9	9.5	10	10.2	8.6	9.6	9.7	10.8	10.5	10.3
19	Speed mean	7.9	7.9	8.3	8.033	8.8	8.4	8.9	8.7	9	8.3	8.6	8.63	8.6	8.5	9	8.7
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	51.4	51.5	44	48.99	40.9	49.7	47.77	46.1	47.6	49.72	47.82	48.4	47.99	48.09	47.07	47.7
23	Mean stride length (m)	3.91	3.91	4.9	4.24	5.36	5.05	4.02	4.81	4.23	4.16	4.21	4.2	4.19	4.19	4.28	4.22

Horse 8

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 8**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	107	138	182	142.3	171	193	170	178	139	151	142	144	140	152	140	144
5	HR minimum	107	138	182	142.3	171	193	170	178	139	151	142	144	140	152	140	144
6	HR maximum	180	202	233	205	197	201	239	212	200	188	180	189	201	189	181	190
7	HR mean	146	195	222	187.7	194	198	222	205	186	177	180	181	188	178	178	181
8	HR end	179	197	219	198.3	192	198	223	204	197	187	180	188	198	190	181	190
9	HR end -60	116	196	220	177.3	194	199	199	197	192	162	173	176	192	167	172	177
10	Percentage of HR max (HRmean)	60.8	81.3	92.5	78.19	80.8	82.5	92.5	85.3	77.5	73.75	75	75.4	78.33	74.17	74.17	75.6
11	Percentage of HR max (HRend)	74.6	82.1	91.3	82.64	80	82.5	92.92	85.1	82.1	77.92	75	78.3	82.5	79.17	75.42	79
12	Percentage of HR max (HR end-60s)	48.3	81.7	91.7	73.89	80.8	82.9	82.92	82.2	80	67.5	72.083	73.2	80	69.58	71.67	73.8
13	Percentage of time: anaerobic	0	83.3	96	59.77	90.7	100	92	94.2	68.9	0	0	23	78.9	9	2	30
14	Percentage of time: aerobic	100	16.7	4	40.23	9.3	0	8	5.77	31.1	100	100	77	21.1	91	98	70
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.2	10.2	9.3	9.567	10.5	10.7	9.7	10.3	10.3	10.3	9.9	10.2	10.7	10.7	9.3	10.2
19	Speed mean	8.2	8.9	8.1	8.4	8.5	10.7	8.7	9.3	8.8	9.1	11.6	9.83	8.9	9.6	8.7	9.07
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	46.1	42.6	45.9	44.86	44.7	51.8	43.59	46.7	43.6	36.72	38.16	39.5	44.45	36.82	41.83	41
23	Mean stride length (m)	4.37	4.74	4.38	4.497	4.51	4.85	4.62	4.66	4.62	6.37	5.29	5.43	4.63	6.37	4.23	5.08
24																	

Horse 9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 9**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session
3	*HEART RATE (HR)*																
4	HR start	125	169	148	147.3	117	140	147	135	147	127	156	143	141	160	155	152
5	HR minimum	125	169	145	146.3	117	140	147	135	139	130	156	142	141	160	155	152
6	HR maximum	181	169	161	170.3	192	191	185	189	239	197	198	211	184	191	191	189
7	HR mean	147	171	149	155.7	177	156	163	165	194	186	192	191	178	187	185	183
8	HR end	181	157	148	162	183	189	185	186	209	184	189	194	183	187	188	186
9	HR end -60	121	123	149	131	117	140	147	135	143	156	168	156	157	176	174	169
10	Percentage of HR max (HRmean)	61.3	71.3	62	64.83	73.8	65	67.91	68.9	80.8	77.5	80	79.4	74.17	77.92	77.08	76.4
11	Percentage of HR max (HRend)	75.4	65.4	61.7	67.5	76.3	78.8	77.08	77.4	87.1	76.67	78.75	80.8	76.25	77.92	78.33	77.5
12	Percentage of HR max (HR end-60s)	50.4	51.3	62.1	54.58	48.8	58.3	61.25	56.1	59.6	65	70	64.9	65.42	73.33	72.5	70.4
13	Percentage of time: anaerobic	75.5	19.9	100	65.13	30.8	0	0	10.3	55.6	60.9	81	65.8	0	0	4	1.33
14	Percentage of time: aerobic	24.5	80.1	0	34.87	69.2	100	100	89.7	55.6	39.2	19	37.9	100	100	96	98.7
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	7.1	7.8	8	7.633	8.8	5.5	9.1	7.8	9.2	9.5	10	9.57	9	8.2	9	8.73
19	Speed mean	9.8	9.1	10	9.633	8.8	8.8	8.4	8.67	8.5	8.7	9.1	8.77	7.7	8.7	8.7	8.37
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	31.9	42.8	36.6	37.1	44.6	44.1	45.4	44.7	47.4	46.5	45.4	46.4	44.7	45.4	45.5	45.2
23	Mean stride length (m)	6.9	4.7	6.3	5.967	4.5	4.5	4.4	4.47	4.2	4.4	4.4	4.33	4.6	4.4	4.4	4.47
24																	

Horse 10

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**HORSE NAME: Horse 10**	Training session 1				Training session 2				Training session 3				Training session 4			
2		Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2	Gallop 3	Session	Gallop 1	Gallop 2		Session	Gallop 1	Gallop 2		Session
3	*HEART RATE (HR)*																
4	HR start	136	156	163	151.7	141	156	128	142	149	150	93	131	133	149	92	125
5	HR minimum	136	156	163	151.7	141	156	128	142	149	150	93	131	133	149	92	125
6	HR maximum	189	193	187	189.7	186	156	192	178	199	188	194	194	202	186	184	191
7	HR mean	179	188	184	183.7	179	188	168	178	180	172	172	175	184	172	173	176
8	HR end	184	191	180	185	183	191	180	185	183	187	193	188	202	176	193	190
9	HR end -60	156	143	140	146.3	125	130	152	136	142	138	154	145	140	142	138	140
10	Percentage of HR max (HRmean)	74.6	78.3	76.7	76.53	74.6	78.3	70	74.3	75	71.67	71.667	72.8	76.67	71.67	72.08	73.5
11	Percentage of HR max (HRend)	76.7	79.6	75	77.08	76.3	79.6	75	76.9	76.3	77.92	80.417	78.2	84.17	73.33	80.42	79.3
12	Percentage of HR max (HR end-60s)	65	59.6	58.3	60.97	52.1	54.2	63.33	56.5	59.2	57.5	64.167	60.3	58.33	59.17	57.5	58.3
13	Percentage of time: anaerobic	0	48.5	0	16.17	0	2.5	12	4.83	49.9	5	36	30.3	55.7	4.6	46	35.4
14	Percentage of time: aerobic	100	51.6	100	83.87	100	95.5	88	94.5	51.1	95	65	70.4	44.3	96.4	55	65.2
15																	
16																	
17	*SPEED (m/s)*																
18	Speed HR max	9.9	10.2	8.5	9.533	9.9	10.2	9.8	9.97	8.8	9.7	12.2	10.2	13.6	9.5	12.5	11.9
19	Speed mean	8.6	9	8.5	8.7	8.9	9	9.8	9.23	8.8	8.6	10.8	9.4	11.7	8.9	10.3	10.3
20																	
21	*STRIDE DATA*																
22	Mean stride frequency (strides/min)	46.4	43.8	46.8	45.65	45.9	43.6	45.51	45	45	45.97	30.84	40.6	29.9	44.98	30.44	35.1
23	Mean stride length (m)	4.35	4.63	4.31	4.43	4.38	4.63	4.44	4.48	4.44	4.38	6.17	5	7.47	4.52	7.13	6.37
24																	