INFLUENCE OF AMBIENT TEMPERATURE AND RELATIVE HUMIDITY ON YOUNG PERFORMANCE HORSES

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by

Kelly S. Carlson

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APPROVED:

Kyle Stutts, PhD
Thesis Director

Jessica Leatherwood, PhD
Committee Member

Mark Anderson, PhD
Committee Member

John Pascarella, PhD
Dean, College of Science and Engineering Technology

DEDICATION

I would like to dedicate this to my mother and father, for all their time, money, and energy spent on me. They taught me to never give up, even when times get rough, and to chase my dreams no matter what. I am forever grateful for their encouragement and guidance throughout everything I endure in life.

ABSTRACT

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Heat stress is a concern in performance horses due to the daily exercise they receive. To determine the influence of ambient temperature and relative humidity on young performance horses, twelve Quarter Horses (2-3 yr, 444 kg) were utilized in a randomized complete block design for a 5-wk study. Horses were stratified by age, sex, and weight between exercise treatments. Exercise treatments consisted of a morning (AM; n = 6) and an afternoon (PM; n = 6) exercise bout to evaluate the effects of differing temperatures and humidity on physiological characteristics of horses. The mean ambient temperature for the AM exercise bout was 16˚C with a mean relative humidity of 81%, while the mean ambient temperature for the PM exercise bout was 29˚C with a mean relative humidity of 38%. Whole blood lactate (LAC), heart rate (HR), respiration rate (RR), rectal temperature (RT), and circumferences and temperatures of the carpal and metacarpal joints, were measured immediately prior and immediately following the standardized exercise bout on d 14, 21, 28, and 35. HR, RR, and RT were measured 30 min into the recovery period and LAC was measured 2 and 24 h into the recovery period. Circumferences and temperatures of the joints were also measured 24 h into the recovery period. Differences in parameters measured were determined using the GLM procedure of SAS and the 0 min data was used as a covariate to account for differences among horses that existed prior to exercise. RR, RT, and HR were greater ($P < 0.01$) in the PM group after exercise and in the recovery period compared to the AM group. Two hours into the recovery period, the PM group had a greater LAC ($P < 0.05$). This indicates that

the horses may have had an impaired ability to dissipate heat during the recovery period due to the higher ambient temperatures. Understanding the physiological responses of horses during recovery at different ambient temperatures, may enable industry professionals to modify daily exercise regimens to allow the equine athlete to perform at their full potential and prevent injury or harm to the animal.

KEY WORDS: Equine, Exercise, Heat stress, Lactate, Inflammation

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

In recent years, equine futurities have awarded over $10 million each year to young performance horses, predominately in Texas. Texas is home to more than 1 million horses, with the total impact of the horse industry exceeding $11 billion annually. The pressure placed on the young equine athlete has resulted in problems related to fatigue. Problems such as heat stress, loss of stamina, and injury have become a serious concern among trainers. Insufficient attention has been given to the young performance horse's training programs without the use of a treadmill in a controlled environment. In recent studies, controlled environments have been used to determine proper training programs to simulate the exercise protocol (Linder et al., 2010; Rammerstorfer et al., 1997).

Training of the young performance horse does not usually occur in a controlled environment. The development of daily training strategies under low temperatures and high humidity may prevent or delay the career ending injuries in the young equine. Heat production associated with strenuous exercise must be matched by adequate heat dissipation or it can result in life-threating hyperthermia. This balance is accomplished by different mechanisms depending on species. A particular problem for horses when compared to humans is that horses are capable of prolonged exercise at higher metabolic rates, but have a lower surface area to mass ratio (Hodgson et al., 1993). Characterizing physiological responses of horses to exercise regimens can help the trainer prepare the equine athlete to perform at their full potential. Physiological responses to training are

not well understood by trainers, veterinarians, or horse owners (Rammerstorfer et al., 1997). Therefore, investigation of physiological responses will benefit the equine industry at both the basic scientific and applied levels.

This research has significant relevance to the health and well-being of all horses entering performance training. Previous literature has focused on mature exercising horses in controlled environmental conditions. However, demonstrating the effects of ambient temperature and relative humidity within a common training environment can provide valuable recommendations to industry professionals and veterinarians. Being able to assist in preparing the equine athlete to perform to their potential in competitive events can give them an edge in competition. This study provides the initial data to establish an exercise model to alter physiological responses and has the potential to be the standard method to exercise horses in the future.

Literature Review

Previous studies have demonstrated the effects of ambient temperature and humidity on thermoregulatory responses in a laboratory setting, with exercise tests conducted utilizing a temperature-controlled environment and a high speed treadmill (Williams et al., 2002). Exercise conducted on an indoor treadmill may not always reflect the outdoor environment, where horses train daily and compete (Hargreaves et al., 1999). Indoor studies have not evaluated the effect of radiant heat load during exercise or the loss of the cooling surface area due to the saddle and saddle pads which may adversely affect thermoregulation (Foreman et al., 1995). In addition, the cooling effect of the horse moving through the air in contrast to fans in front of the treadmill, as well as the effects of the terrain, can influence the physiological response (Geor et al., 1996).

Athletic performance testing in horses is usually based upon testing in human athletic performance. Human athletes perform a series of monitored tests to best find an exercise protocol to fit that individual. This is now mimicked in the equine industry to find an exercise approach to each workout (Allen et al, 2016). However, no testing has focused significantly on how temperature and humidity play a role in the exercise bout. It is important that horses be evaluated in a training setting taking into account some or all of these factors in order to complement laboratory experiments.

Thermoregulation may limit exercise performance under hot and humid conditions. Hargreaves at al. (1999) reported increased packed cell volume, heart rate, respiratory rate, and total protein in mature horses in hot (31.3 ± 0.9°C), humid (67 ± 3%) conditions when compared to cool (17.6 ± 0.4°C), dry (47 ± 3%) conditions. Research conducted in humans concerning the response of exercising in hot, humid conditions has indicated increases in plasma packed cell volume, increased body temperature at rest and during exercise, increased exercising heart rate, improved skin blood flow, an increased stroke volume, lowered distribution of cardiac output between skin and muscle capillary beds, and lowered threshold for onset of sweating (Art and Lekeux, 1995; Marlin et al., 1999). The effects of exercise and heat stress together place the cardiovascular and thermoregulatory systems under severe pressure (Williams et al., 2002). This causes the thermoregulatory systems of the body to adapt to surrounding environmental conditions. However, rapid transition in extreme environments must result in an acclimation response which would allow the horse to cope with the changing conditions (Marlin et al., 1999). In contrast, data is limited concerning the acclimation effects of young horses to high ambient temperatures and humidity. Human acclimation involves physiological and

biochemical adaptations, while acclimation of horses appears to result in a progressive reduction in thermal and cardiovascular demands (Geor et al., 1996; Marlin et al., 1999).

Exercise can be associated with an increase in blood lactate concentrations in horses, as it is used regularly to assess the level of fitness in the sport horse (Harris and Snow, 1992). The anaerobic threshold is supposed to identify the maximal intensity of exercise and the intensity to achieve maximum lactate is believed to be optimal to improve endurance in horses (Linder, 2010). It is well documented that blood lactate is dependent on factors such as intensity, duration, and frequency of exercise (Lindner et al., 2009). According to Harris and Snow (1992) blood lactate concentration will peak at the end of exercise. Lactate concentrations range from 0.5-1 mMol/L at rest and, depending on the exercise, can reach 2-4 mMol/L. The anaerobic threshold of blood lactate frequently used is 4 mMol/L. Some racehorses have been noted to reach up to 10 mMol/L. After the anaerobic threshold is reached, lactate production increases and is harder to remove (Allen et al, 2016). However, studies comparing blood lactate concentrations to environmental conditions relating to thermoregulatory responses are scarce.

Heart rate, respiration rate, and rectal temperature are key indicators of the impact of exercise performance. Vitals in equines increase due to heat load and cardiorespiratory demands on the animal. Heart rate and respiration rate indicate the fitness of the animal as well as the intensity of the exercise they are performing. Repeated measurements of these vitals can determine an increase in fitness during a training program (Allen et al, 2016). Rectal temperature at rest or before exercise should be 37.5˚C to 38.6˚C. When temperatures are significantly greater than that after exercise

there is an indicator of heat stress on the horse. This may also be a sign of a longer and more intense recovery period.

Inflammation in equine can be an indication of the recovery status from exercise. This inflammation could be due to the intensity of the exercise or soft tissue damage from the training program. Inflammation can appear in as little as minutes after exercise, but could take up to 24h to be evident. An injured joint can be protected by inflammation to start the healing process. Taking circumference measurements of the joints in all four limbs is an easy and noninvasive indicator of inflammation. A better understanding of why there is inflammation after exercise or in recovery can help us make better training programs to fit each individual horse.

Previous work has demonstrated ambient temperature and relative humidity influence common physiological parameters associated with exercise (Lindinger et al.,1995). However, studies are limited in evaluating young horses in actual training conditions rather than in a laboratory setting. In addition, mean ambient temperatures in prior studies have ranged from 31.3-33 °C with a mean relative humidity of 46%. Local ambient temperatures (Huntsville, TX) range from 19 °C with a mean relative humidity of 90% during the morning to a temperature of 35 °C with a mean relative humidity of 30% in the afternoon during the spring and summer months. Therefore, not only will this study provide information relating to an exercising protocol for different combinations of temperature and humidity, but it will also provide information relating to heat stress in the equine athlete. This study will also provide enough information to provide equine athlete trainers proper knowledge of when to exercise their horses to minimize the effects of heat stress.

Objectives

The *long term* goal of our work is to elucidate potential dietary strategies that can be utilized to improve energetic efficiency in young horses in training. The *immediate goals* of this research were to characterize thermal and cardiorespiratory responses of young horses to submaximal exercise under different combinations of temperature and humidity, and to investigate the physiological response to exercise and recovery following an exercise protocol by quantification of plasma lactate. Lastly, we will examine heat related stress during exercise by utilizing blood lactate concentration as an indicator.

CHAPTER II

MATERIALS AND METHODS

All care, handling, and sampling of horses was approved by the Sam Houston State University Institutional Animal Care and Use Committee (Protocol Number: 16-04-06-1027-3-01).

Twelve clinically healthy 2- and 3-year-old Quarter Horses were utilized in a randomized complete block design for a 5-wk study. Horses were stratified by age, sex, and BW between exercise treatments. Exercise treatments consisted of a morning (AM; n = 6) and an afternoon (PM; n = 6) exercise bout in order to evaluate the effects of differing temperatures and relative humidity. This study was conducted in conjunction with the Equine Behavior and Training Course (EQSC 4391). Horses were housed in individual 3 x 3 m stalls with *ad libitum* access to water and fed a diet consisting of a commercial pelleted concentrate (Cargill Inc., Minneapolis, MN) and coastal Bermudagrass hay formulated to meet nutritional requirements for young horses in training.

Horses were subjected to a pretrial exercise regimen (d 0-13) to establish a baseline physiological response as well as to standardize the level of fitness across experimental units. The pretrial regimen consisted of a thirty-minute aerobic (heart rate below 150 bpm) workout during the EQSC 4391 class time (1300 h) in the Priefert 6 Horse Free Walker (Priefert, Mount Pleasant, TX). On d 14, 21, 28, and 35 the exercise protocol consisted of an anaerobic (heart rate above 150 bpm) AM and PM workout. On all other days of the study the horses were exercised at an aerobic pace for 1 h during the Equine Behavior and Training Course (EQSC 4391). The horses were subjected to this

exercise bout once per week for 4 consecutive wk after the adaptation period, and each wk, horses were rotated from the AM to PM exercise bout and from the PM to AM exercise bout. This schedule allowed the horses to experience the AM workout twice and the PM workout twice during the 4-wk period to account for differences in the ambient temperature and relative humidity. During the exercise bouts, horses were equipped with on-board heart rate monitors (Polar USA, Lake Success, NY) to evaluate intensity of exercise, speed, and distance traveled. All exercise was conducted at the SHSU Indoor Riding Facility (Huntsville, TX) in a Priefert 6 Horse Free Walker with a diameter of 22.05 m.

On d 14, 21, 28, and 35, horses in both the AM and PM groups were subjected to a standardized exercise test (SET) to put the horses in an anaerobic physiological state. The SET began with a 2 min walk at 5.6 km/h, traveling to the left and then right for 1 min each. Then, the horses completed a 3 min trot at 11.3 km/h, traveling to the left and then right for 1.5 min each. Next, the horses began a 5 min extended trot at 16.9 km/h, traveling to the left and then right for 2.5 min each. The horses then sped up to a 10 min lope at 20.9 km/h, traveling to the left and then right for 5 min each. Lastly, the horses ended with a 10 min extended lope at 24.1 km/h, traveling to the left and then right for 5 min each. Every week the SET increased by 1 min per gait, for a total of 5 additional min, to account for any increase in fitness level in the horses.

Respiration rate and rectal temperature were collected prior to and immediately following the SET, as well as 30 min after the SET in the recovery period. Heart rate was collected prior to and following the SET, as well as during the SET at 2 min, 4 min, 6 min, 12 min, 18 min, and 24 min. Heart rate was also collected at 30 min after the SET

in the recovery period. Heart rate and respiration rate were taken by the same technician each week during the study. Lastly, blood samples were obtained via jugular venipuncture immediately before and after the SET, as well as at 2 and 24 h into the recovery period. Plasma lactate was determined at baseline and during exercise utilizing a portable lactate analyzer (Lactate Plus, Sport Resource Group Inc, Minneapolis MN) and samples were also stored at -20 °C for later lactate dehydrogenase analysis by a certified laboratory (Texas Veterinary Medical Diagnostic Laboratory, College Station, TX).

To evaluate inflammation in the joints due to exercise, circumference and temperature of the carpal and metacarpal joints were measured prior to and immediately following the SET. Circumference was measured with a soft tape measure and temperature was measured using a FLIR thermal imaging camera on all four limbs. Immediately following the measurements taken after the SET, TuffRock Poultice (TuffRock Pty Limited, Weston NSW, Australia) was applied to left limbs of all horses completely covering the carpal and metacarpal joints. The poultice was applied by the same person each week of the study to be sure the application was consistent. The TuffRock Poultice remained on the horses' limbs for 24h after application. The poultice was then brushed off the limbs and measurements of the carpal and metacarpal joints were obtained with a soft tape measure and the FLIR thermal imaging camera on all four limbs.

Statistical Analysis

The GLM procedure of SAS was used to determine differences in the onset values (before exercise) between the AM and PM groups. For measurements obtained after the

standardized exercise test, the GLM procedure in SAS was used with the corresponding onset value (before exercise) as a covariate to account for differences in initial heat load prior to exercise. For the measurements comparing the inflammation in limbs, the GLM procedure in SAS was used to determine differences in the limb over time.

CHAPTER III

RESULTS

Mean heart rate (HR) of horses prior to the exercise test, immediately following, and in the recovery period are shown in Table 1. There were no differences ($P = 0.46$) detected between the AM and PM groups before exercise or immediately following exercise ($P = 0.14$). However, during recovery there was a difference in HR ($P < 0.01$) between the AM and PM groups. During the recovery period, the PM group had a mean heart rate of 53.7 bpm compared to 44.5 bpm for the AM group. This suggests the horses in the PM group had a more difficult time recovering from the SET.

Table 1

Mean heart rate (bpm) of horses obtained using a heart rate monitor (Polar USA) before and after completing a standardized exercise test (SET) and in the recovery period following the SET.

	AM	PM	P - Value
Pre SET	38.4 ± 1.2	39.7 ± 1.2	P = 0.46
Post SET	112.6 ± 11.1	136.7 ± 11.1	P = 0.14
Recovery Period	44.5 ± 2.0	53.7 ± 2.0	P < 0.01

Mean respiration rate (RR) before exercise, immediately following exercise and in the recovery period are displayed in Table 2. There was a difference ($P < 0.05$) between the AM and PM groups prior to undergoing the standardized exercise test (SET). The AM group had a mean respiration rate of 14.1 bpm compared to 19.0 bpm for the PM group. Likewise, there was also a significant difference ($P < 0.01$) between the two groups immediately following exercise and in the recovery period. This indicates that the horses in the PM group had a much higher respiration rate before and after exercise, as

well as in the recovery period, and could not recover from the SET as quickly as the AM group due to the elevated temperature in the afternoon. This also shows that the PM exercise group's respiratory system had to work harder in order to complete the test.

Table 2

Mean respiration rate (bpm) of horses before and after completing a standardized exercise test (SET) and in the recovery period following the SET.

	AM	PM	P - Value
Pre SET	14.1 ± 1.7	19.0 ± 1.7	$P < 0.05$
Post SET	70.6 ± 5.0	97.8 ± 5.0	$P < 0.01$
Recovery Period	23.2 ± 3.1	41.4 ± 3.1	$P < 0.01$

Mean rectal temperature (RT) before and after the SET, as well as in the recovery period are displayed in Table 3. There were no differences ($P = 0.96$) detected between the AM and PM groups before exercise. However, there was a difference ($P < 0.01$) between the AM and PM groups immediately following exercise and in the recovery period. The PM group had a mean rectal temperature of 39.7 ˚C compared to 39.2 ˚C for the AM group after the standardized exercise test (SET), and the PM group had a mean rectal temperature of 38.6 ˚C compared to 38.3 ˚C for the AM group in the recovery period. This indicates that the horses in the PM group had a greater body temperature and it took them significantly longer to recover from the exercise.

Table 3

Mean rectal temperature (˚C) of horses before and after completing a standardized exercise test (SET) and in the recovery period following the SET.

	AM	PM	P - Value
Pre SET	37.4 ± 0.1	37.4 ± 0.1	P = 0.96
Post SET	39.2 ± 0.1	39.7 ± 0.1	P < 0.01
Recovery Period	38.3 ± 0.1	38.6 ± 0.1	P < 0.01

Mean serum lactate concentration was obtained before and after exercise, as well as in the recovery period at 2 h and 24 h and are shown in Table 4. There were no differences detected between the AM and PM groups prior to exercise (P = 0.61) or following exercise (P = 0.19). However, there was a difference (P < 0.05) between the two groups at 2 h of recovery. The AM group had almost returned to normal 2 h after exercise, and the PM group had elevated concentrations of lactate during the recovery period. This suggests that the horses in the PM group had a more difficult time exercising and performing as well as recovering from the SET.

Table 4

Mean whole blood lactate (mMol/L) of horses measured using a portable lactate analyzer prior to the standardized exercise test (SET), immediately following the SET, 2 h into the recovery period, and 24 h into the recovery period by exercise group.

	AM	PM	P – Value
Pre SET	0.5 ± 0.5	0.6 ± 0.5	P = 0.61
Post SET	3.3 ± 0.4	4.1 ± 0.4	P = 0.19
2 h Recovery	0.7 ± 0.1	1.2 ± 0.1	P < 0.05
24 h Recovery	0.6 ± 0.1	0.6 ± 0.1	P = 0.82

Lactate dehydrogenase was measured in blood samples collected immediately before and after exercise, after exercise, 2 h after exercise, and 24 h after exercise. Samples were analyzed by the Texas Veterinary Medical Diagnostic Lab (College Station, TX) and results are shown in Table 5. There were no differences between the AM and PM group after exercise, 2 h in the recovery period, or 24 h into the recovery period. However, there was a difference ($P < 0.01$) between the AM and PM groups before the SET. The AM exercise group had a greater lactate dehydrogenase concentration (251.0 U/L ± 10.8) compared to the PM group (200.3 U/L ± 10.8). This suggests that the horses in the AM group started with a higher lactate dehydrogenase concentration; however, it increased immediately after exercise and was still increased 2 h into the recovery period. The lactate dehydrogenase concentration for the PM group was lower prior to the SET compared to the AM group but increased to a similar concentration after exercise and remained at a similar concentration 24 h into the recovery period.

Table 5

Mean lactate dehydrogenase concentration (U/L) of horses prior to the standardized exercise test (SET), immediately following the SET, 2 h into the recovery period, and 24 h into the recovery period by exercise group.

	AM	PM	P - Value
Pre SET	251.0 ± 10.8	200.3 ± 10.8	P < 0.01
Post SET	264.4 ± 9.4	281.0 ± 9.4	P = 0.25
2 h Recovery	262.4 ± 20.6	274.6 ± 20.6	P = 0.69
24 h Recovery	217.0 ± 12.5	218.1 ± 11.3	P = 0.95

The mean circumferences of the carpal and metacarpal joints before and after exercise are shown in Table 6. There were no differences detected on the front carpal joints prior to ($P = 0.17$) or after exercise ($P = 0.15$). There were also no differences detected on the front metacarpal joints ($P = 0.31$) before exercise. However, there was a difference in the circumference of the front metacarpal joints ($P < 0.05$) immediately after exercise. There was a difference in the circumference of the rear carpal joints before exercise, even though there were no differences ($P = 0.34$) after exercise. Alternatively, there were no differences in circumference of the rear metacarpal joints ($P = 0.82$) prior to exercise; however, there was a difference ($P < 0.05$) in the circumference of the rear metacarpal joints after exercise was completed.

Table 6

Mean joint circumferences of the front and rear carpal and metacarpal joints in horses prior to the standardized exercise test (SET) and immediately following the SET by exercise group.

	AM	PM	P – Value
Front Carpal			
Pre SET	30.9 ± 0.1	30.6 ± 0.1	P = 0.17
Post SET	30.8 ± 0.1	30.5 ± 0.1	P = 0.15
Front Metacarpal			
Pre SET	26.6 ± 0.1	26.7 ±0.1	P = 0.31
Post SET	26.4 ± 0.1	26.0 ± 0.1	P < 0.05
Rear Carpal			
Pre SET	38.1 ± 0.3	37.2 ± 0.3	P < 0.05
Post SET	38.0 ± 0.2	37.7 ± 0.2	P = 0.34
Rear Metacarpal			
Pre SET	28.5 ± 0.1	28.5 ± 0.1	P = 0.82
Post SET	28.4 ± 0.1	28.0 ± 0.1	P < 0.05

The mean joint circumferences of the carpal and metacarpal joints associated with the application of the Tuff Rock Poultice (treatment) are shown in Table 7. There were no differences between treated and control joints during the 24-h period on the front and rear carpal and front metacarpal joints. However, there was a difference ($P < 0.01$) between the treatment and control on the rear metacarpal joints. Prior to the standardized exercise test (SET), the treated rear metacarpal joint was 28.8 cm compared to 28.3 cm of the control. After the SET the treated rear metacarpal joint was greater in circumference (28.4 cm) compared to the control (27.9 cm). After the application of the TuffRock Poultice in the 24 h recovery period the circumference was still greater (28.9 cm) compared to the control (28.4 cm). This indicates that the TuffRock Poultice did not have any effects on reducing inflammation.

Table 7

Mean joint circumferences of the front and rear carpal and metacarpal joints in horses prior to the standardized exercise test (SET), immediately following the SET, and after application of TuffRock Poultice (treatment) to the joints of the left limbs for 24 h.

	Treatment	Control	P – Value
Front Carpal			
Pre SET	30.9 ± 0.2	30.7 ± 0.2	P = 0.53
Post SET	30.7 ± 0.2	30.7 ± 0.2	P = 0.53
24 h	30.7 ± 0.2	30.4 ± 0.2	P = 0.53
Front Metacarpal			
Pre SET	26.7 ± 0.1	26.7 ± 0.1	P = 0.43
Post SET	26.1 ± 0.1	26.3 ± 0.1	P = 0.43
24 h	26.6 ± 0.1	26.7 ± 0.1	P = 0.43
Rear Carpal			
Pre SET	38.0 ± 0.3	37.5 ± 0.3	P = 0.18

(continued)

	Treatment	Control	P – Value
Post SET	38.1 ± 0.3	37.7 ± 0.3	P = 0.18
24 h	37.7 ± 0.3	37.6 ± 0.3	P = 0.18
Rear Metacarpal			
Pre SET	28.8 ± 0.2	28.3 ± 0.2	P < 0.01
Post SET	28.4 ± 0.2	27.9 ± 0.2	P < 0.01
24 h	28.9 ± 0.2	28.4 ± 0.2	P < 0.01

The mean temperatures of the carpal and metacarpal joints measured with the FLIR thermal imaging camera before exercise, after exercise, and 24 h following exercise are displayed in Table 8. There were no differences detected between joints of the treatment and control legs. However, there were differences (P < 0.01) in joint temperatures between the treatment and control legs over the three different time periods.

Table 8

Mean temperature as determined by a thermal imaging camera (FLIR Systems; Wilsonville, OR) of the front and rear carpal and metacarpal joints in horses prior to the standardized exercise test (SET), immediately following the SET, and after application of TuffRock Poulice (treatment) onto the joints of the left limbs for 24 h.

	Treatment	Control	P – Value
Front Carpal			
Pre SET	28.3 ± 1.0	28.2 ± 1.0	P = 0.89
Post SET	30.2 ± 1.0	30.5 ± 1.0	P = 0.89
24 h	28.3 ± 1.0	28.2 ± 1.0	P = 0.89
Front Metacarpal			
Pre SET	27.2 ± 1.2	27.3 ± 1.2	P = 0.93
Post SET	29.3 ± 1.2	29.5 ± 1.2	P = 0.93
24 h	27.2 ± 1.2	27.0 ± 1.2	P = 0.93

(continued)

	Treatment	Control	P – Value
Rear Carpal			
Pre SET	31.3 ± 0.9	31.0 ± 0.9	P = 0.51
Post SET	32.9 ± 0.9	32.9 ± 0.9	P = 0.51
24 h	31.1 ± 0.9	30.6 ± 0.9	P = 0.51
Rear Metacarpal			
Pre SET	28.6 ± 1.1	28.4 ± 1.1	P = 0.75
Post SET	30.3 ± 1.1	30.5 ± 1.1	P = 0.75
24 h	28.6 ± 1.1	28.1 ± 1.1	P = 0.75

CHAPTER IV

DISCUSSION

Previous studies have focused on the mature Quarter Horse and training methods for older horses in competitions. However, minimal studies have focused on the training and exercising aspects of the younger Quarter Horse, especially in differing combinations of ambient temperature and humidity. Heart rate (HR), respiration rate (RR), rectal temperature (RT), lactate concentration (LAC), and inflammation are all key factors in determining the fitness levels of horses. Hargreaves et al. (1999) also found that thermoregulation limits exercise performance in horses and reported that heart rate, respiratory rate, and rectal temperature increase during hot and humid conditions compared to cool and dry conditions in mature Quarter Horses. After exercise during the hot and humid conditions, HR, RR, and RT were all above normal parameters, which is similar to the results of the PM exercise group in the current study. In the study by Hargreaves et al. (1999) the vitals after exercise during the cool and dry conditions are again similar to the vitals of the AM exercise group in the current study. The vitals HR, RR, and RT were all greater in the PM group after exercise and into the recovery period compared to the AM group. Therefore, our study determined that it was more difficult for the horses to complete and recover from the PM exercise bout due to the elevated ambient temperature.

The PM exercise group had a significantly greater RT compared to the AM group after exercise. This was also observed in the recovery period where the PM exercise group had a greater RT than the AM group. According to Kahn et al (2005), rectal temperatures from both groups after exercise, as well as in the recovery period are above

normal range for horses (37.7 ± 0.5 ˚C). To help prevent greater body temperature, horses will dissipate heat via evaporative cooling by increasing their respiration rate and sweating (Holcomb et al, 2013). Therefore, it was more difficult for the afternoon group to dissipate heat and it took longer for them to recover from the exercise, due to the elevated ambient temperature and the associated relative humidity. As a result of exercise, respiration rate increased after exercise and in the recovery period for both the AM and PM groups. The PM group had a significantly greater RR compared to the AM group immediately after exercise and into the recovery period. The normal range reported for horses at rest under thermoneutral conditions is between 10 and 14 bpm (Kahn et al., 2005). In extreme conditions a horse's RR can reach 180 bpm when undergoing strenuous exercise on a treadmill in a climate controlled room at 30˚C and 80% relative humidity (Marlin et al., 1999). This indicates that the horses in the PM group had a greater RR compared to the AM group due to decreased heat dissipation as a result of the temperature and humidity combination experienced during the PM exercise bout.

Lactate concentrations can determine the aerobic-anaerobic threshold to identify the maximum intensity of exercise (Linder, 2010). The PM group had a numerically greater lactate concentration that exceeded the anaerobic threshold of 4.0 mMol/L compared to the AM group after exercise. Similar results were observed 2 h into the recovery period, with the PM group having a greater lactate concentration compared to the AM group. In other studies (Linder, 2010) the anaerobic threshold as indicated by the lactate concentration of 4.0 mMol/L, was reached after exercising for 26 min. In the current study the PM group reached the anaerobic threshold when measured immediately

after exercise and the AM group did not. This suggests that once horses have reached the anaerobic threshold of 4.0 mMol/L, the recovery time increases for the horses to return to baseline values.

Lastly, inflammation in the limbs is a good indicator of soft tissue injury and an extended recovery time. According to Pascoe (2016), inflammation will occur when a ligament or tendon fails from repetitive stress. In the current study, there was no inflammation present after exercise, which is an indication that the horses were in the proper condition to be undergoing strenuous exercise. Application of the TuffRock Poultice appeared to have no beneficial effects in terms of reducing swelling in joints. Joint circumferences were not different between joints treated with the poultice and those that were not. When the temperatures of the joints were measured using a thermal imaging camera, there was an increase in temperature after exercise and then a decrease in temperature 24 h into the recovery period following exercise. This occurred in both the treated and control joints, indicating that the horses' joints had increased blood flow from the exercise bout resulting in an elevated temperature. There were no differences in circumference of joints treated with poultice and those that were not at 24 h into the recovery period, indicating the poultice did not have an effect on reducing inflammation at 24 h into the recovery period. It is possible that there may have been differences in joint circumference due to inflammation at 12 h into the recovery period; however joint circumference was not measured at that time. Therefore, more research is needed to determine if the poultice is effective in reducing inflammation and the length of time required for the poultice to be effective.

Implications

Vitals, inflammation and whole blood lactate are good indicators of the horse's physiological response to exercise and heat stress. In the current study, elevated ambient temperatures, even with lower humidity were more challenging for young horses to tolerate during exercise. This was caused by the impaired ability to dissipate heat from the submaximal exercise due to the elevated temperature. The prolonged increased heart rate and respiration rate in the PM group also indicates that the horses had a more difficult time recovering from the exercise due to the higher temperatures.

Better understanding the roles of temperature and humidity on the physiological response in young performance horses during exercise can help develop better training programs to fit the needs of these equine. Based on the results of this study, young, performance horses should undergo training during the portion of the day when ambient temperatures are lowest, or training can occur during greater ambient temperatures if the length and rigor of the training session is decreased to compensate for the elevated temperature.

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VITA

Kelly S. Carlson

Education

Sam Houston State University, *Huntsville, TX*

Master of Science in Agriculture **May 2017**

- Advisor: Kyle J. Stutts, Ph.D.

Sam Houston State University, *Huntsville, TX*

Bachelors of Science in Agricultural Business **May 2015**

Teaching Experience

Graduate Teaching Assistant

Department of Agricultural Sciences and Engineering Technology, *Sam Houston State University*

Equine Behavior and Training **Fall 2015-Fall 2016**

- Assisted in coordination of laboratory training and curriculum for students.
- Application of initial handling, halter breaking, leading, and lunging.
- Instructed on topics such as the steps of desensitizing and riding.
- Further developed horsemanship skills and effective communication between the horse and rider.

Equine Reproduction and Foaling **Fall 2015-Fall 2016**

- Assisted students with data collection for foaling project.
- Educated students on the signs of foaling and stages of parturition.
- Cared for mare and foal immediately following birth.
- Instructed on foal handling and assisted students with obtaining foal growth measurements.

Equine Science **Fall 2015-Fall 2016**

- Responsible for instructing, monitoring, and grading students based on the curriculum presented for each class.

- Topics included: history, breeds, identification, selection, behavior, nutrition, reproduction, health, facilities, activities, and equine business.
- Provided students with basic information required for successful selection, ownership, care, and enjoyment of horses.

Equine Selection and Evaluation **Fall 2015-Fall 2016**

- Responsible for monitoring and grading students based on the curriculum presented for each class.
- Instructed basic selection of demonstration horses required for successful note taking and evaluation for placing a class
- Prepared horse judging classes for students to test their knowledge

Whitetail Deer and Fawn Research **Summer 2016-Present**

- Responsible for the care and maintenance of white-tailed does and their fawns
- Responsible for the initial fawn care after birth
- Cared for bottle-fed fawns including: collecting, tagging, preparing bottles and feeding, cleaning pens, and assisting in the measuring of fawns

Related Experience

Chinese Horsemanship Program **Summer 2016**

- Instructor for the American Quarter Horse Association in China at three farms (Unbridled China, Inner Mongolia at Brother Fortune, and YeHe Farm) to approximately 10-40 participants per clinic.
- Topics included both foundation and advanced horsemanship skills.

Undergraduate Research Program **Spring 2013**

- Conducted research on horses related to exercise protocols
- Presented research at the Southern Section meeting of the American Society of Animal Science in San Antonio, Texas as well as at the Undergraduate Research Symposium at Sam Houston State University

Skills

Equine

- Student instruction and horsemanship

Cervids

- Care and maintenance of white-tailed deer

Microsoft Office Applications

- Word, Excel, PowerPoint