Comparison of Conditioned and Non-conditioned University Horses After Semester Break

By

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To my mom, Mary Klingaman, my dad, Russell Klingaman, and Nick Stellmack for supporting me in all my endeavors.

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ABSTRACT

During periods of disuse, horses often receive pasture turn-out without exercise. This study evaluated fitness of conditioned and non-conditioned horses after a semester break. Twelve mature horses were assigned to a conditioned group that maintained light-to-moderate riding or non-conditioned group receiving no ridden exercise during summer break. Research began at the beginning of Fall semester. On d 0, 14, and 28 heart rate and physical measurements were recorded. Peak heart rate was not different between treatments ($P=0.17$) but increased for both treatments throughout the study ($P=0.04$). Resting heart rate of conditioned horses tended to be lower ($P=0.08$). Gaskin circumference of non-conditioned horses was larger ($P=0.04$), although non-conditioned horses tended to have larger average body weight ($P=0.07$). Conditioned horses had higher topline muscling scores ($P=0.02$). Horses that were conditioned over a semester break had mixed improvement in fitness suggesting that horses retain a degree of fitness during rest with pasture turn-out.

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CHAPTER 1: LITERATURE REVIEW

Introduction

It is not uncommon for horses used for recreational riding, lessons, or sport to receive time off from exercise due to climate, owner/trainer availability, injury, off-season for competition horses, or cessation of coursework and riding lessons during university summer breaks. When returning horses back to fitness, questions related to the physiology of exercise versus rest must be considered, including the following: How quickly do horses lose fitness during rest or disuse? Compared to stalled horses, does pasture turnout contribute to maintenance of horse fitness? How quickly do horses regain fitness after returning to exercise? To address these questions, understanding the physiological mechanisms that allow for an increase in fitness and performance is vital to understand.

This review will consider measurements of fitness and available technology used in fitness assessment, some of fitness-related physiological mechanisms in horses applicable to this research, and finally, a review of limited available literature on loss of fitness during time off and return to fitness.

Measurements of Fitness

Physical fitness of horses can be measured in many ways including heart rate, muscling, Body Condition Score (BCS), body fat composition, body weight, or biological markers such as plasma lactate, bone mineral content, and oxygen uptake (Evans, 2008).

Using these measures to calculate fitness and response to exercise can allow for horses to perform to the best of their ability.

The type of work the horse is being prepared for may determine the most accurate measurements to take regarding fitness. When evaluating recreational riding or schooling type horses, the most common workload is likely to be light to moderate intensity exercise. The National Research Council classifies light exercise as 1-3 hours of riding per week with 90% of the riding to be at a walk or trot and the remaining 10% of exercise to be at the canter. Moderate exercise would include 3-5 hours of exercise per week with 85% of that exercise at the walk and trot, 10% canter and 5% specified skill work (Nutrient Requirements of Horses, 2007). Using specific measurements in standardized exercise tests allows for researchers to determine the current level of fitness, and thus the horse's ability to perform the work.

Heart Rate

Heart rate can represent an estimate of the amount of oxygen used by the animal during the light to moderate work (Evans et al., 2006). The typical range of resting heart rates for light horses is 28-40 beats per minute (Physick-Sheard, 1985). Recording a horse's normal resting heart rate prior to and throughout training/conditioning may provide insight on the physical condition of the individual. Resting heart rates of horses that are conditioned compared to those that are in a state of disuse might vary on an individual basis, but overall, rarely will the heart rates differ significantly between conditioned or nonconditioned groups (Lindner et al., 2020). Some researchers suggest that the more physical conditioning a horse goes through will result in a lower resting heart rate (Physick-Sheard, 1985). In a study performed by Kuwahara and associates, researchers evaluated the heart rates of 24, 2-year-old thoroughbreds via Holter electrocardiogram close to 24 hours a day as the horses were in training. There was adequate data to suggest that physical training of young thoroughbred racehorses can lower their resting heart rates (Kuwahara et al., 1999). A more recent study performed with similar protocol as Kuwahara's study but on a larger sample of untrained Standardbred racehorses also confirmed their findings (Nissen et al., 2022). On the contrary, researchers evaluating resting heart rate of adult standardbred horses who were subject to varied exercise programs did not find that increased fitness had any significant effect on heart rate (Bayly et al., 1983). Therefore, the current data on how fitness affects resting heart rate is mixed.

Recovery heart rates have long been thought of as a fitness parameter, but understanding how resting heart rate can affect recovery is important to understand. In a study evaluating endurance horses, researchers found that the recovery heart rate was reached in shorter time intervals when the horses resting heart rate was lower. For this group of horses, the range of resting heart rates was from 26 – 37 bpm. The difference in resting heart rates was not due to varying degrees of fitness between horses. Thus, reaching a set recovery heart rate can be attained in a shorter interval of time if the animal has a lower natural resting heart rate (Lindner et al., 2020).

When monitoring a horse's heart rate, it is important to make note of any data that does not fit in the normal range. Specifically, if a horse's resting heart rate is elevated above the normal range, the horse may be experiencing pain or an external stimulus consequently causing additional stress that results in elevated heart rates, making resting a heart rate a difficult parameter to evaluate when considering horse fitness (Evans and Young, 2010). To avoid having skewed results due to external stimuli, research to evaluate resting heart rate is often recorded over a period of minutes in a relaxed environment (Lindner et al., 2020).

Recording a horse's maximal heart rate during exercise is a common parameter in equine fitness studies. Standardbred and Thoroughbred racehorses are a heavily studied subgroup when assessing heart rate during submaximal and maximal exercise. Depending on the degree of exercise the horse is doing, heart rates during exercise typically range from 140 - 200 beats per minute, and only in intense exercise conditions will the heart rate exceed 210 beats per minute. (Physick-Sheard, 1985; Evans et al., 2006; Hodgson, 2014). Maximal heart rates greater than 210 beats per minute are typically seen in racing horses, whereas peak heart rates recorded in reining horses during competition averaged 181 beats per minute (Physick-Sheard, 1985; Kastner et al., 1999). Many studies choose to measure the velocity at which the maximal heart rate of a horse is reached; at this point, the heart rate will no longer increase, even when velocity continues to rise (Evans and Young, 2010). The velocity at which maximal heart rate (HR_{max}) is reached is likely to differ between horses based on age, type of training, etc. (Physick-Sheard, 1985). As training progresses, it would be expected that the horse would reach a higher velocity before reaching its maximal heart rate. This would be indicative of the horse using less energy at the initial velocity at which the maximal heart rate was achieved. The best use of HR_{max} in research is to allow each horse to act as its own control, as each individual will have varying initial HR_{max} that would not be represented accurately using other cohorts (Evans and Young, 2010).

To gather more information about fitness during the time of exercise, researchers often use the velocity at which a heart rate reaches 140 or 200 beats per minute (V_{140} or V_{200})(Evans and Young, 2010). This measurement is best used for individual horses to track changes made over the training period, similar to velocity at maximal heart rate (Evans and Young, 2010). If the horse is becoming more fit, the velocity at which 140 or 200 bpm is reached should be higher, meaning that the horse is not working as hard to reach a higher velocity.

Heart rate may be a misleading variable, as environmental stress can impact heart rate substantially. Making sure horses are acclimated to the tools used for research and exercise can assure that the most accurate measurement is being recorded. For horses that have not been trained prior to a study for the purpose of research, the heart rates may appear higher upon the start of the study, but the reasons for the elevated heart rate during exercise could be caused by environmental stress rather than the exercise alone (Munsters et al., 2013).

Muscling

A horse’s muscling is variable depending on the amount and type of exercise the horse is asked to perform, as well as breed characteristics, and age. It is also understood that a lack of movement and exercise will cause a reduction in the level of muscling a horse has (Graham-Thiers and Bowen, 2013).

Circumference of the gaskin is a conventional and easily obtained muscle measurement on horses. The gaskin, located on the hind leg between the stifle and hock, is a heavily muscled area that is simple for researchers to measure compared to post-mortem analysis, biopsy, or the use of ultrasound. Additionally, the gaskin size is not predisposed to change with fluctuations in fat cover (Henneke et al., 1983; O'Connor et al., 2002). The gaskin area is also one of the best tools to calculate the gluteal muscle size, with a correlation of 0.97, thus making this muscle group indicative of muscle strength and fitness in horses (McCann et al., 1988).

Gaskin circumference has been found to change in response to resistance training. This type of training has been proven to increase muscle mass in both horses and humans (Starkey et al., 1996; O'Connor et al., 2002). Resistance training for horses would most often involves carrying a saddle and rider which can result in a change of forearm and gaskin circumference. In a study that compared horses being exercised with no added weight to horses carrying 45.4 kg on their back researchers evaluated the horses as they exercised at a walk and trot on treadmills in a counterclockwise manner for 78 days, although weights were not added to the treatment horses until day 60. Horses carrying weight mimicking a light-weight rider and tack while exercising were found to have smaller right gaskin circumference than the control horses, while the left side remained unchanged. These findings are likely attributed to the counterclockwise travel which had a greater effect on the right side in addition to the non-strenuous exercise the horses were participating in and the light weight the horses were carrying for only 18 days (O'Connor et al., 2002). Another study evaluating ponies carrying much heavier weights until the point of fatigue found an increase in both forearm and gaskin circumferences (Heck et al., 1996). Thus, demonstrating that the type of exercise and resistance added will result in mixed results for muscle measurements.

The increase in muscle size as a result of exercise is due to the hypertrophy of the individual muscle myofibers, rather than increase in the amount of muscle fibers. Additionally, the type of myofiber will also affect the size of the muscle. (Rivero, 2007) When analyzing the muscle composition of a horse, it is important to note that breed and breed function often plays a large part in muscle type based on the selective breeding and training the horses have been subject to, i.e. endurance, speed, draft etc. (Heck et al., 1996; O'Connor et al., 2002). Along with biomarkers analyzed from muscle biopsies, the measurement of muscles, in the form of ultrasound or measurement of the circumference of the muscle, can be a helpful indicator of fitness, as these areas are not subject to significant changes in fat composition (Henneke et al., 1983).

Three different muscle fiber types have been identified in mature horse skeletal muscle (Rivero and Piercy, 2008). After the phase of skeletal muscle hypertrophy, the muscle can still become specialized for the training it is subject to via changing the fiber type (Rivero, 2007). Each fiber type has unique properties from one another, and depending on the purpose of the muscle, the fiber contents may further explain the primary purpose of the muscle. The first is type I, this is a slow twitch muscle fiber that has low ATPase enzyme activity and glycolytic capacity, but high oxidative capacity, thus making it less prone to fatigue. Type I myofibers are the smallest in size. (Herbison et al., 1982; Petersen et al., 2013). Horses used for endurance type events, such as Arabians, will have a greater concentration of type I muscle fibers. Due to the relatively small size of these muscle fibers, horses that have the greatest concentration of type I myofibers will have the lightest appearance of muscling.

Type IIA muscle fibers are characterized by elevated ATPase activity and high glycolytic and oxidative capacity. These fast twitch muscles are more resistant to fatigue than that of the type IIB muscle fibers, the third individual muscle fiber (Herbison et al., 1982). Similar to the type IIA fibers, type IIB are also fast twitch with high ATPase activity and glycolytic capacity, yet they differ in having low oxidative capacity and a tendency to fatigue most rapidly (Herbison et al., 1982). Type IIA myofibers will be larger than type I myofibers, and type IIB muscle fibers are the largest of the myofibers discussed. The type II fibers are found in greater amount percentage of total muscle in short distance speed type horses such as racing Thoroughbred and Quarter Horses (Petersen et al., 2013).

Understanding the properties of muscle fiber types provides understanding as to how each muscle functions. For example, slow twitch muscles are vital for aerobic exercise due to the high oxidative capacity. Additionally, these muscles are able to be used for longer periods of time but are not as strong as other muscle types. On the other hand, fast twitch muscles are utilized during anerobic exercise. These muscles are stronger but cannot be used for long bouts of time (Petersen et al., 2013). Given this, it makes sense that horses who were bred and selected for endurance properties likely have more type I and IIA muscle fibers. Whereas short distance racehorses are likely to have the largest percent of type IIB fibers. Furthermore, the myofiber composition of a horse can change as training progresses. For example, a horse going through race training will likely start with a greater percentage of type I myofibers, yet at the conclusion of training will have a greater percentage of type IIB myofibers. Horses subject to endurance training will have a greater ration of type I and IIA myofibers (Rivero and Piercy, 2008; Petersen et al., 2013). Breeding of the horses can also alter the type of muscle fibers a horse has, as it has been found that horses bred for many years for sprinting are more likely to have more type II myofibers than type I (Petersen et al., 2013).

Body Weight and Body Condition Score

Measuring the body weight of a horse is a frequently used technique to track changes when starting a conditioning program, but the BCS of the animal may be more telling. Similar to humans, as a horse becomes more fit, it would not be uncommon for the animal to gain weight from muscle hypertrophy during the training period (O’Connor et al., 2002). Body condition scores aid in measuring the fitness of the animal because it analyzes the subcutaneous fat cover. Body condition score for horses ranges from 1 (emaciated) to 9 (very obese) and evaluates the areas on the body most prone to change in fat composition. The six areas that must be evaluated with a hands-on exam to determine BCS are the crest of the neck, area behind the shoulder, wither, loin, area over ribs, and tailhead (Henneke et al., 1983). A BCS of 5 is ideal because it allows for enough fat composition for all essential bodily functions to occur, without an excess of fat that may be harmful to the animal. When evaluating BCS, it is important to palpate and differentiate soft, squishy fat versus a toned muscle to give an accurate assessment of the fat cover. By using body weight and BCS, muscle and fat changes can be tracked in relation to training or conditioning.

Training and nutrition can greatly affect a horse's body weight and BCS. For the average mature horse in submaximal exercise, BCS should remain around 5, but if the horse were to enter a period of disuse it would likely lose overall body weight from the loss of muscle, yet should maintain the body condition score of 5. In a study evaluating changes in BCS, body weight, and muscle mass in response to feeding elevated levels of amino acids with moderate exercise found that the horses fed a higher concentration had an increase in muscle mass. The increase in muscle mass for the horses supplemented with amino acids was also associated with a decreased BCS, yet no change was detected in body weight (Graham-Thiers and Kronfeld, 2005). This concludes that an increase in muscle mass as a factor of fitness can have an inverse reaction with fat cover, with no changes in body weight.

Oxygen Uptake

Oxygen uptake is another measurement that can aid in defining the degree of fitness a horse is in. The maximal oxygen uptake in horses can increase by much as 25-29% as a result of training, with 15% of that increase occurring after just 7 weeks of endurance training. The average maximal oxygen uptake prior to training and exercise is 117 $ml \cdot kg^{-1} \cdot min^{-1}$. When in an exercise program for 16 weeks, maximal oxygen uptake can reach 151 $ml \cdot kg^{-1} \cdot min^{-1}$ (Tyler et al., 1996). With the improvement of maximal oxygen uptake associated with submaximal exercise, a lower heart rate during exercise is expected (Evans et al., 2006). For example, when tracking a horse's fitness via maximal oxygen uptake, as the horse becomes more fit, the lower heart rate in association with increased maximal oxygen uptake shows that the horse is performing similar exercise as it was when the animal was not conditioned yet is exerting less energy.

In the case of disuse, where horses are rested in paddocks, it is estimated that in 2-3 weeks the maximal oxygen uptake will return to pre-training levels. In other instances, where horses have access to small paddocks rather than stalls, it took 6 weeks of disuse to notice a slight reduction in maximal oxygen uptake (Tyler et al., 1996). However, if the horses are turned out to pasture for 8 hours/day while in a 10-week period of disuse, maximal oxygen uptake can remain the same, or increase, from the levels reached during training (Mukai et al., 2006).

Management Style

During times of disuse, where a horse is not subject to any forced exercise (McKeever and Lehnhard, 2014), horses are usually subject to pasture turn out, stall confinement, or a mix of the two. The style of management may help or hinder a horse when they resume exercise. Deciding which management style is best for a horse is likely based on the environment of the facility the horse is housed at and the reason for time off exercise.

Horses turned out to pasture are more likely to maintain fitness over horses who are kept in stalls (Graham-Thiers and Bowen, 2013). In a group of horses stalled for 14 weeks with no exercise, when exercise resumed, plasma lactate was elevated during and after exercise when compared to their levels previous to their time of disuse. Researchers attributed the accumulation of plasma lactate would likely be the result of poor aerobic capacity, associated with decreased fitness. The other cohort of horses used in the study had access to large pasture turnout, these horses had lower heart rates 1-minute post-exercise and 10 minutes post-exercise as well as lower rectal temperatures than that of stalled horses. Researchers concluded that the pastured horses had a higher degree of fitness than stalled horses based on the lower plasma lactate levels during exercise, lower recovery heart rates and body temperature (Graham-Thiers and Bowen, 2013).

By allowing horses to be housed in a situation that allows for free movement, the health of bones has been found to increase. Bone mineral content as a measurement of bone density has been rigorously studied in horses subject to various confinement situations. Growing horses benefit most from pasture turn out over stall confinement. If pasture is not available, dynamic, high-speed exercise can also increase the bone mineral content in growing and mature horses (Hoekstra et al., 1999; Hiney et al., 2004b; Hiney et al., 2004a).

Conclusion

Horses in training or conditioning programs display adaptations to a variety of physical parameters that can be measured to assess the fitness of the animal. A conditioned horse is likely to have more efficient oxygen uptake and a lower accumulation of plasma lactate. Additionally, conditioning a horse after a period of disuse may elicit a response to resting heart rates, increased velocity at peak or maximal heart rates, and varied results in BCS, muscle mass, and body weight. Horses who are not able to perform in-hand or ridden exercise regularly but have an environment that allows for freedom of movement, such as pasture access, can aid in the maintenance of fitness.

CHAPTER II: COMPARISON OF CONDITIONED AND NON-CONDITIONED UNIVERSITY HORSES AFTER SEMESTER BREAK

Introduction

Ensuring a horse is fit for the work they are expected to perform is essential for the animal's welfare and to prevent injury from occurring. Physical re-conditioning studies often evaluate horses returning to work from an injury-related or stall rest scenario (Essen-Gustavsson et al., 1989; Tyler et al., 1996; Hoekstra et al., 1999; McGowan et al., 2002; Mukai et al., 2006). Another method researchers use is to induce a period of de-training/disuse after a period of exercise to measure how fitness changes between being in work (Essen-Gustavsson et al., 1989; Tyler et al., 1996; McGowan et al., 2002; Mukai et al., 2006). In non-injury related scenarios, horses are often subject to pasture turnout while in disuse due to climate or owner/rider availably. If a major injury or illness is not the cause of the disuse, pasture is ideal due to the freedom of movement that may result in better physical condition (Hoekstra et al., 1999; Graham-Thiers and Bowen, 2013). Besides the risk of injury upon reintroducing ridden work for horses, loss of muscle mass may be of concern as well when considering prolonged periods of disuse. Additionally, horses not in work will also likely have decreased aerobic capacities when compared to those in moderate to high amounts of ridden work (Mukai et al., 2006). The current study aims to evaluate the fitness of mature, university horses after a 3-month period of disuse while turned-out on pasture when compared to a similar cohort that remained in light to moderate exercise. Based on previous research it was hypothesized that university horses not conditioned during a break would have a lower level of fitness, compared to horses remaining in work, when returning to use in the fall semester

Material and Methods

Horses

Twelve mature, healthy Paint and Quarter Horses were selected from the Middle Tennessee State University (MTSU) Horse Science herd with approval from MTSU Institutional Animal Care and Use Committee (23-2002). Researchers determined twelve horses should be used for this study using alpha = 0.05 and power (1-B) = 0.80. Of the twelve horses included in the study, five were geldings and seven were mares aged 16.4 ± 5 years old. Horses were divided into two even groups of six horses based on their summer exercise load. The first group, referred to as the non-conditioned group, were not subject to any riding over the duration of the summer. The second group, the conditioned group, was subject to light-to-moderate work 3-5 d/wk during the summer.

Animal Management

Horses were fed prairie grass hay and a commercial pelleted concentrate (Purina Strategy) to meet National Research Council dietary requirements. Horses had access to *ad libitum* water. Prior to the study, all horses had access to pasture, with some of the horses housed in stalls overnight due to pasture availability. The beginning of the study coincided with the beginning of ridden classes and team practices during the Fall semester. At the start of the study, all horses were stalled on weekdays and turned out to pasture over the weekends. For the one-month duration of the study, all horses were subject to submaximal exercise 4-5 times per week via general horsemanship lessons and classes and measurements were gathered on every 2 weeks, starting on d 0 and continuing on d 14 and d 28.

Data Collection

Horse heart rates during rest and submaximal exercise were collected with heart rate monitors (Polar Equine H10) on d 0, 14, and 28. Data was recorded using the Polar Beat mobile device application. Resting heart rate was gathered in the horse's stall within 24 hours of exercise as an average of five minutes at rest. To obtain peak heart rate during submaximal exercise, a heart rate monitor was placed under each horse's saddle and data was recorded for the duration of the class or team practice session.

Body weights and body condition scores were gathered within 24 hours of exercise data. Weights were recorded using a digital scale (Transcell TI-500 Industrial Scale, Trancell Technology, INC, Buffalo Grove, IL). Body condition scores were measured by two trained researchers using the Henneke scoring system (Henneke et al., 1984).

To assess changes to muscling, researchers measured forearm circumference, gaskin circumference, and topline score. Forearm circumference was measured in the middle of the elbow joint and the knee and gaskin circumference was measured at the largest portion of the muscle (O'Connor et al., 2002). Topline scoring was conducted by two trained researchers by assigning a value from 1 (poor muscle mass and definition) to 5 (excellent muscle mass and definition) to describe the longissimus dorsi muscle, with consideration to breed standards (Graham-Thiers and Kronfeld, 2005).

Statistical Analysis

Data were analyzed using SAS Ver. 9.4 (SAS Stat. Inc., Cary, NC). After verifying that data were normally distributed using the Shapiro-Wilk statistic, a mixed model with repeated measures was used to compare the effects of group (fit vs unfit) and day (0, 14, and 28 days after returning to work) on all variables (body weight, body condition score, resting heart rate, maximum heart rate, topline score, and the left, right, and average circumferences of forearm and gaskin), using horse as the individual subject and day as the repeated effect. Pearson's correlation coefficients were used to examine relationships between all variables.

A P-value of $P < 0.05$ was considered significant, while $0.05 < P < 0.10$ was considered a trend. Correlation coefficients were interpreted as follows: $r > 0.90$ were considered very strong; r between 0.70 to 0.90 as strong; r between 0.50 to 0.70 as moderate; r between 0.30 to 0.50 as weak, and $r < 0.30$ were negligible correlations.

Results

All horses and riders completed all procedures in this study without difficulty. The maximum temperature on collection days ranged from 30.5°C to 43.6°C (National Centers for Environmental Information - Past Weather). Most data collections took place during lessons and class laboratories in an indoor arena, but some data were collected in an outdoor arena. No significant changes in BCS or body weight were found in either group, so the amount of feed was not changed for the groups during times of disuse or exercise.

Peak heart rate during submaximal exercise between groups was not different ($P = 0.17$) but did increase as the study progressed ($P = 0.04$, Figure 1). There was no significant day and group interaction for peak heart rate ($P=0.72$). Resting heart rate in conditioned horses tended to be lower than the non-conditioned horses ($P = 0.08$). The conditioned horses had an average resting heart rate of 37 ± 1.1 bpm, whereas the non-conditioned horses had an average of 40 ± 1.1 bpm.

The average body weight for non-conditioned horses tended to be heavier ($P = 0.07$) with a mean of 552.7 ± 21.4 kg. The mean weight of conditioned horses was 492.3 ± 21.4 kg. Weights did not change as the study progressed ($P = 0.38$) and no group and day interaction was detected ($P = 0.33$). No difference in BCS was detected between groups ($P = 0.22$) or day ($P = 0.30$). There was no interaction between day and group for BCS ($P = 0.33$).

Topline muscling scores were significantly different between groups ($P = 0.02$, Table 1), with the conditioned horses scores being higher. A trend toward increased topline muscling scores was detected as the study progressed ($P = 0.07$, Table 1). There was no interaction between day and group ($P = 0.93$).

Mean gaskin circumference for the non-conditioned horses was 42.5 ± 1.0 cm and 39.2 ± 1.0 cm for conditioned horses (Figure 2). Gaskin circumference was found to be strongly correlated ($r = 0.85$, $P < 0.0001$) with body weight. Gaskin circumference for non-conditioned horses was larger than conditioned horses ($P = 0.05$). As the study progressed, gaskin circumference of both groups increased ($P = 0.04$, Figure 2) although there was no interaction between day and treatment ($P = 0.20$). Forearm circumference was not different between groups ($P = 0.26$) or day ($P = 0.13$), and no group and day interaction was detected ($P = 0.66$). Forearm circumference was moderately correlated ($r = 0.66$, $P < 0.0001$) with body weight.

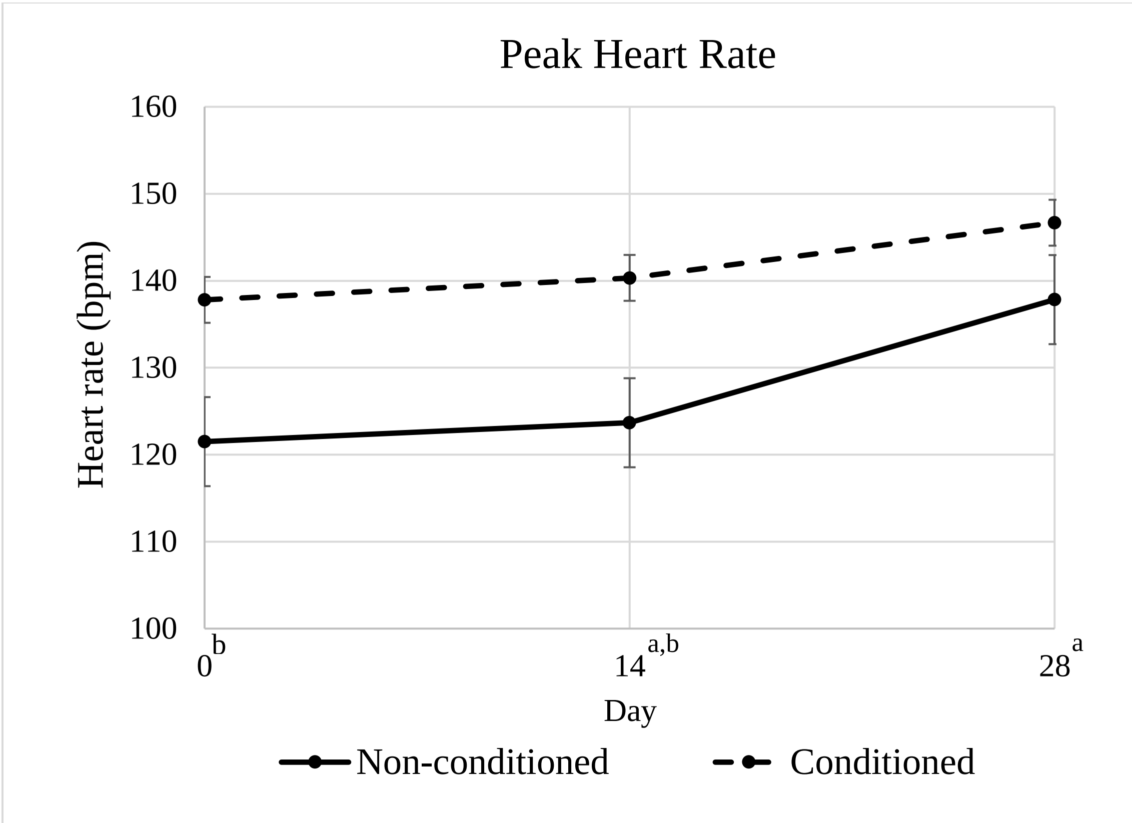

Figure 1. Peak heart rate (mean ± SE) during exercise for conditioned and non-conditioned horses throughout a 28-day return-to-work study period.

[a,b] Days lacking common superscript differ (P = 0.04).

Topline Muscling Scores

	Non-Conditioned [a]	Conditioned [b]
Day 0 [y]	2.5	3.2
Day 14 [xy]	2.7	3.4
Day 28 [x]	2.8	3.5

Table 1. Mean topline muscling score of conditioned and non-conditioned horses throughout a 28-day return-to-work study period.

[x,y] Days lacking common superscript tend to differ (P = 0.07; SEM = 0.2)

[a,b] Treatments lacking common superscript differ (P = 0.022; SEM = 0.2)

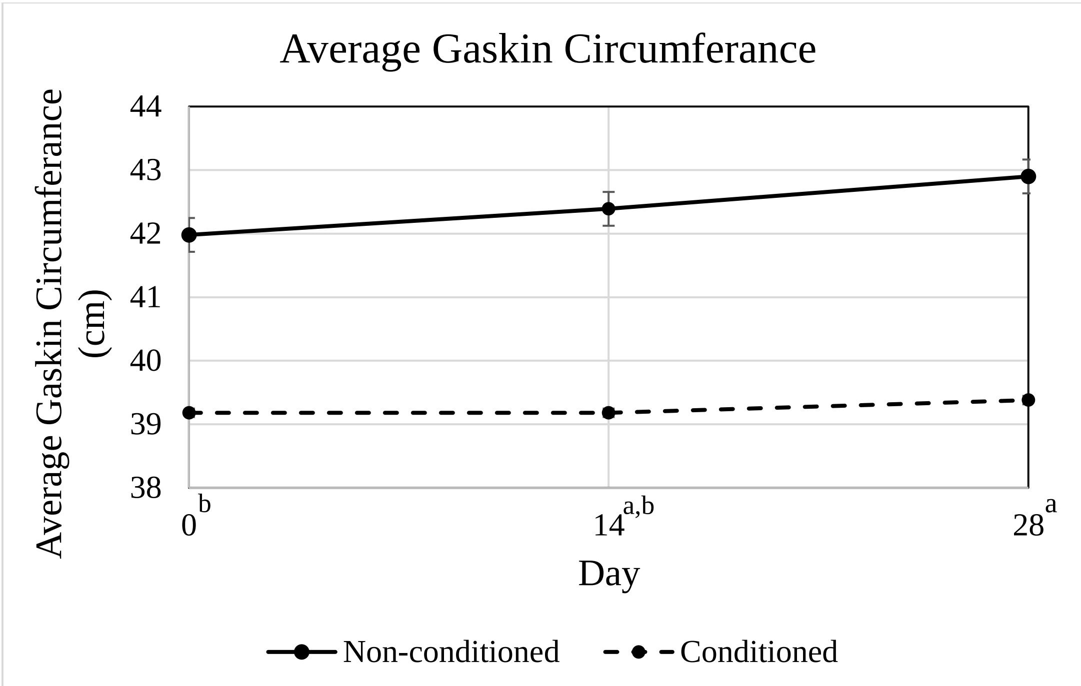

Figure 2. Gaskin circumference (mean ± SE) was higher in non-conditioned compared to conditioned horses (P = 0.05) throughout a 28-day return-to-work study period.

[a,b] Days lacking common superscript differ (P = 0.04).

Discussion

In this study, allowing horses access to pasture while in a period of disuse likely aided in limiting the amount of fitness lost. Many studies conclude that fitness can be greatly reduced when horses are confined in stalls (Esse-Gustavsson et al., 1989; Hoekstra et al., 1999; Graham-Thiers and Bowen, 2013). Additionally, horses that are previously physically conditioned may be predisposed to maintain fitness (Mukai et al., 2006; Graham-Thiers and Bowen, 2013).

Many studies have found that human-mandated and/or ridden exercise aids in the hypertrophy of muscles (Esse-Gustavsson et al., 1989; Starkey et al., 1996; Rivero, 2007; Rivero and Piercy, 2008; Castejon-Riber et al., 2017; Pallesen et al., 2023). In this study, the difference of topline scores between the conditioned or non-conditioned groups was very telling of the effect of disuse. The use of a topline scoring system is a convenient way to measure the muscling of the horse's dorsal muscles along the back because this method considers breed characteristics that strongly affect the muscling of the horses on an individual basis, as opposed to measuring the physical width and length of the muscles (Graham-Thiers and Kronfeld, 2005). With the conditioned horses having greater topline scores, it could be suggested that continued exercise aids in the growth and maintenance of the topline muscles. Even with the non-conditioned horses having complete freedom of movement and voluntary exercise in their pastures, this movement did not keep their topline muscling as high as the horses that remained in work. Additionally, ages between the groups were not significantly different, confirming that age did not interfere with the results of this study.

Both the conditioned and non-conditioned horses tended to increase topline muscling scores as the days of the study progressed. This suggests performing submaximal exercise is likely a variable that influences the growth of the topline muscles. These results agree with Pallesen et al. (2023) who found that horses that were ridden in a continuous training program had larger muscling over the topline when evaluated using ultrasonography (Pallesen et al., 2023). The limitation of these comparisons is that topline muscle scoring is a limited, and minimally invasive technique (Graham-Thiers and Kronfeld, 2005), while other studies more commonly have used ultrasound (O’Connor et al., 2002; Pallesen et al., 2023) and muscle biopsies (Rivero, 2007) to estimate muscle responses to conditioning.

Although the topline scores were higher for the horses who were conditioned, similar findings were not observed for gaskin circumference. The gaskin circumference was larger on the non-conditioned horses, but this may be attributed to a larger frame, as gaskin circumference and body weight were strongly correlated. While BCS was similar between groups, the non-conditioned horses tended to have higher body weight and were larger framed animals. Likewise, the difference in average gaskin circumference on day one was potentially not a response to treatment, but rather a variation in overall body size of horses between groups, although both groups were found to have increased gaskin circumference as the study progressed. These findings do not align with the results of O’Connor et al. (2002) who found that low-level resistance training for 78 days of horses in moderately exercised horses had either no change or a reduced size of gaskin muscles (O’Connor et al., 2002). Compared to the current study, the exercise duration used by O’Connor et al. (2002) was over 2.75-times longer. Horses in the O’Connor et al. (2002)

study were theorized to have lost gaskin circumference due to either loss of fat and/or loss of muscle via an alteration in amino acid status over the longer study period, because an additional treatment group supplemented with amino acids did have increased gaskin and forearm size. Another study that used intensive resistance training techniques in ponies did find an increase in forearm muscle size (Heck et al., 1996). Considering the varied findings in this study and previous reports, any changes in gaskin or forearm circumference in response to exercise training should not be viewed as a stand-alone effect but evaluated with respect to frame size, diet, BCS or body fat assessment, and type of muscling related to training and breed.

The heart rate of both groups on average increased as the study progressed. This is an anticipated response as the level of difficulty and intensity while riding both groups of horses increased as the semester progressed, as students gained experience and strength as riders. Many studies have concluded that heart rate increases with the difficulty of the exercise while remaining in submaximal work (Kastner et al., 1999; Evans, 2008; Hodgson, 2014; Younes et al., 2016). Day 0 of the study was the first day of fall semester classes. During that time, it is important to note that classes were mostly focusing on safety, refreshing skills in riders, and acclimation of riders to the demands of proper equitation. Horses spent most of their under-saddle time walking with brief bouts of trot and canter included. As the study and semester progressed to day 28, riders had experienced at least 4 classes or lessons on horseback (at least one ride per week). In comparison to mostly walking at day 0, by day 28, riders were focusing on developing their trot and canter with walking primarily used to warm up and cool down horses. A higher peak heart rate may reflect that the horses were working harder by day 28, or it may be a result of increased fitness and willingness to increase the difficulty of maneuvers in both groups of riding horses as the semester progressed. Future research in this area would benefit from the use of a standard exercise test at the beginning and end of the study to better assess changes in peak heart rate.

Conclusion

Horses continuously conditioned over a semester break had mixed improvement in fitness, based on resting heart rate and topline muscling. The nature of university classes at the beginning of the Fall semester allows for safe and effective reintroduction of horses to exercise, based on the measured parameters in this cohort. Pasture confinement may be a substantial aid in maintaining fitness over a summer break, as university horses appeared to retain a certain degree of fitness during a 3-month period of rest on pasture turn-out. Additionally, the horses subject to pasture confinement were previously in a higher degree of fitness, so a horse’s previous level of fitness may have aided in the retention of fitness during disuse. These findings support the health of university horses over short periods of disuse over a summer break and subsequent reconditioning as classes resume.

LITERATURE CITED

Bayly, W. M., A. A. Gabel, and S. A. Barr. 1983. Cardiovascular effects of submaximal aerobic training on a treadmill in Standardbred horses, using a standardized exercise test. Am J Vet Res. 44:544–53.

Castejon-Riber, C., C. Riber, M. D. Rubio, E. Agüera, and A. Muñoz. 2017. Objectives, Principles, and Methods of Strength Training for Horses. J Equine Vet Sci. 56:93–103. doi:10.1016/j.jevs.2017.04.011.

Essen-Gustavsson, B., D. McMiken, K. Karlstrom, A. Lindholm, S. Persson, and J. Thornton. 1989. Muscular adaptation of horses during intensive training and detraining. Equine Vet J. 21:27–33. doi:10.1111/j.2042-3306.1989.tb02085.x.

Evans, D. 2008. Exercise testing in the field. In: Equine Exercise Physiology. p. 12–27.

Evans, D. L., L. B. Jeffcott, and P. K. Knight. 2006. Performance-related problems and exercise physiology. The Equine Manual. 1059–1104. doi:10.1016/B978-0-7020-2769-7.50021-6.

Evans, D. L., and L. Young. 2010. Cardiac Responses to Exercise and Training. In: Cardiology of the Horse. W.B. Saunders. p. 35–47.

Graham-Thiers, P. M., and L. K. Bowen. 2013. Improved Ability to Maintain Fitness in Horses During Large Pasture Turnout. J Equine Vet Sci. 33:581–585. doi:10.1016/j.jevs.2012.09.001.

Graham-Thiers, P. M., and D. S. Kronfeld. 2005. Amino acid supplementation improves muscle mass in aged and young horses. J Anim Sci. 83:2783–2788. doi:10.2527/2005.83122783x.

Heck, R. W., K. H. McKeever, S. E. Alway, W. K. Auge, R. Whitehead, A. L. Bertone, and J. A. Lombardo. 1996. Resistance training-induced increases in muscle mass and performance in ponies. Med Sci Sports Exerc. 28:877–83. doi:10.1097/00005768-199607000-00015.

Henneke, D. R., G. D. Potter, J. L. Kreider, and B. F. Yeates. 1983. Relationship between condition score, physical measurements and body fat percentage in mares. Equine Vet J. 15:371–372. doi:10.1111/j.2042-3306.1983.tb01826.x.

Herbison, G. J., M. M. Jaweed, and J. F. Ditunno. 1982. Muscle Fiber Types. Archives of Physical Medicine and Rehibilitation. 63:227–230.

Hiney, K. M., B. D. Nielsen, and D. Rosenstein. 2004a. Short-duration exercise and confinement alters bone mineral content and shape in weanling horses. J Anim Sci. 82:2313–2320. doi:10.2527/2004.8282313x.

Hiney, K. M., B. D. Nielsen, D. Rosenstein, M. W. Orth, and B. P. Marks. 2004b. High-intensity exercise of short duration alters bovine bone density and shape. J Anim Sci. 82:1612–1620. doi:10.2527/2004.8261612x.

Hodgson, D. R. 2014. The Cardiovascular System: Anatomy, Physiology, and Adaptations to Exercise and Training. In: The Athletic Horse: Principles and Practice of Equine Sports Medicine: Second Edition. W.B. Saunders. p. 162–173.

Hoekstra, K. E., B. D. Nielsen, M. W. Orth, D. S. Rosenstein, H. C. Schott, and J. E. Shelle. 1999. Comparison of bone mineral content and biochemical markers of bone metabolism in stall vs. pasture-reared horses. Equine Vet J. 30:601–604. doi:10.1111/j.2042-3306.1999.tb05292.x.

Kastner, S. B. R., K. Feige, Weishaupt. M. A., and J. A. Auer. 1999. Heart rate and hematological responses of Quarter Horses to a reining competition. J Equine Vet Sci. 19:127–131.

Kuwahara, M., A. Hiraga, M. Kai, H. Tsubone, and S. Sugano. 1999. Influence of training on autonomic nervous function in horses: evaluation by power spectral analysis of heart rate variability. Equine Vet J Suppl. 30:178–180. doi:10.1111/j.2042-3306.1999.tb05213.x.

Lindner, A., M. Esser, R. López, and F. Boffi. 2020. Relationship Between Resting and Recovery Heart Rate in Horses. Animals. 10. doi:10.3390/ani10010120.

McCann, J. S., J. C. Heird, C. Boyd Ramsey, and R. A. Long. 1988. Skeletal bone and muscle proportionality in small- and large- framed mature horses of different muscle thickness. J Equine Vet Sci. 8:255–261.

McGowan, C. M., L. C. Golland, D. L. Evans, D. R. Hodgson, and R. J. Rose. 2002. Effects of prolonged training, overtraining and detraining on skeletal muscle metabolites and enzymes. Equine Vet J. 257–263. doi:10.1111/j.2042-3306.2002.tb05429.x.

McKeever, K., and R. Lehnhard. 2014. Age and Disuse in Athletes: Effects of Detraining, Spelling, Injury, and Age. In: The Athletic Horse. p. 243–252.

Mukai, K., H. Ohmura, A. Hiraga, D. Eto, T. Takahashi, Y. Asai, and J. H. Jones. 2006. Effect of detraining on cardiorespiratory variables in young Thoroughbred horses. Equine Vet J. 38:210–213. doi:10.1111/j.2042-3306.2006.tb05541.x.

Munsters, C. C. B. M., J. van den Broek, R. van Weeren, and M. M. Sloet van Oldruitenborgh-Oosterbaan. 2013. A prospective study on fitness, workload and reasons for premature training ends and temporary training breaks in two groups of riding horses. Prev Vet Med. 108:199–208. doi:10.1016/j.prevetmed.2012.08.005.

National Centers for Environmantal Information - Past Weather. National Oceanic and Atmospheric Administration. Available from: https://www.ncei.noaa.gov/access/past-weather/Murfreesboro%2C%20Tennessee

Nissen, S. D., R. Weis, E. K. Krag-Andersen, E. M. Hesselkilde, J. L. Isaksen, H. Carstensen, J. K. Kanters, D. Linz, P. Sanders, C. Hopster-Iversen, T. Jespersen, S. Pehrson, and R. Buhl. 2022. Electrocardiographic characteristics of trained and untrained standardbred racehorses. J Vet Intern Med. 36:1119–1130. doi:10.1111/jvim.16427.

Nutrient Requirements of Horses. 2007. National Academies Press, Washington, D.C.

O'Connor, C. I., B. D. Nielsen, H. C. Schott, and H. M. Clayton. 2002. Effects of weight carrying, exercise and a myo-anabolic supplement on growth and muscle. Equine Vet J. 34:178–181. doi:10.1111/j.2042-3306.2002.tb05414.x.

Pallesen, K., K. Gebara, C. Hopster-Iversen, and L. C. Berg. 2023. Development of an equine muscle condition score. Equine Vet Educ. doi:10.1111/eve.13777.

Petersen, J. L., J. R. Mickelson, A. K. Rendahl, S. J. Valberg, L. S. Andersson, J. Axelsson, E. Bailey, D. Bannasch, M. M. Binns, A. S. Borges, P. Brama, A. da Câmara Machado, S. Capomaccio, K. Cappelli, E. G. Cothran, O. Distl, L. Fox-Clipsham, K. T. Graves, G. Guérin, B. Haase, T. Hasegawa, K. Hemmann, E. W. Hill, T. Leeb, G. Lindgren, H. Lohi, M. S. Lopes, B. A. McGivney, S. Mikko, N. Orr, M. C. T. Penedo, R. J. Piercy, M. Raekallio, S. Rieder, K. H. Røed, J. Swinburne, T. Tozaki, M. Vaudin, C. M. Wade, and M. E. McCue. 2013. Genome-Wide Analysis Reveals Selection for Important Traits in Domestic Horse Breeds. PLoS Genet. 9:e1003211. doi:10.1371/journal.pgen.1003211.

Physick-Sheard, P. W. 1985. Cardiovascualr Responce to Exercise and Training in the Horse. Veterinary Clinics of North America: Equine Practice. 1:383–417.

Rivero, J. L. L. 2007. A scientific background for skeletal muscle conditioning in equine practice. Journal of Veterinary Medicine Series A: Physiology Pathology Clinical Medicine. 54:321–332. doi:10.1111/j.1439-0442.2007.00947.x.

Rivero, J.-L. L., and R. J. Piercy. 2008. Muscle physiology: responses to exercise and training. In: Equine Exercise Physiology.

Starkey, D. B., M. L. Pollock, Y. Iahida, M. L. A. Welsch, W. F. BRECHUE, J. E. Graves, and M. S. Feigenbaum. 1996. Effect of resistance training volume on strength and muscle thickness. Med Sci Sports Exerc. 28:1311–1320. doi:10.1097/00005768-199610000-00016.

Tyler, C. M., L. C. Golland, D. L. Evans, D. R. Hodgson, R. J. Rose, and R. J. R. Changes. 1996. Changes in maximum oxygen uptake during prolonged training, overtraining, and detraining in horses. J Appl Physiol. 81:2244–2249.

Younes, M., C. Robert, E. Barrey, and F. Cottin. 2016. Effects of Age, Exercise Duration, and Test Conditions on Heart Rate Variability in Young Endurance Horses. Front Physiol. 7. doi:10.3389/fphys.2016.00155.