EVALUATING MUSCLE TENSION SCORES AS AN INDICATOR OF STRESS
IN RIDING HORSES

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Dedication

My aunt and uncle, Vickie and Ted Frisbee, of Boise, Idaho pulled me through my life’s darkest time. I wouldn’t be here completing this dream without their compassion. I haven’t been around much these past few years, but I hope this emphasizes my interminable gratitude. Madre and Padre, I am happiest in your company, especially when we’re relaxing together at Priest Lake.
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Abstract

Correlations between muscle tone and pain are limited in equine research, lagging behind human studies. Previous studies done in humans involving tension-type headaches (TTH) and increased muscle tension (MT) post exercise have correlated muscle firmness with soreness (Leistad et al., 2005; Whitehead et al., 2001). Muscle dysfunction is known to reduce performance and welfare in horses (McGowan and Goff, 2016). Increased stress is associated with elevated cortisol concentrations in equids, allowing opportunistic researchers to evaluate underlying causes, such as abnormal muscle tension. Therefore, the purpose of this study was to evaluate correlations between serum cortisol concentrations (SCC) and increased muscle tension in horses. It was hypothesized that increased MT would correlate with increased cortisol concentrations. Two experiments were conducted: experiment 1 studied 17 therapeutic riding horses over 2 eight-week long riding sessions, and experiment 2 studied 25 horses enrolled in 2 beginner level riding courses. Serum cortisol was collected and subjective MT evaluations based on previously published research were recorded (Chen et al., 2017). Serum cortisol concentrations declined from Pre to Post to 30 minutes post exercise, but increased over time in experiment 1, while seeming to correspond with work demands in experiment 2. Changes in MT were observed in riding horses for the following muscles: facial, quadriceps femoris, and semitendinosus. Quadriceps femoris and triceps tended to be tenser on the left versus right side in this study. Interestingly, longissimus dorsi and trapezius did not change in experiment 2 over time. Some muscles followed SCC patterns throughout the study indicating a possible link between increased muscle tension and elevated cortisol concentrations in horses.
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Correlations between muscle tone and pain are limited in equine research, unlike human studies. Previous studies done in humans involving tension type headaches and increased muscle tension post exercise have correlated muscle firmness with soreness (Leistad et al., 2005; Whitehead et al., 2001). Muscle pain has a known impact on equine performance (Simons and Mense, 1998; Lesimple, et al., 2010). Varcoe-Cocks et al. (2006) showed a correlation between sacroiliac dysfunction and muscle soreness in racehorses.

Simply asking human patients how they feel using pain scales helps when assessing muscle discomfort and soreness. Animal pain is more difficult to assess and evaluate (McGowan and Goff, 2016; Weary et al., 2006). Behavior indicators of stress are typically used and are species specific; horses present stress-related behaviors that include lameness, restlessness, nostril flaring, sweating, rigid posture, head tossing, tail swishing, aggression, and more (Wagner, 2010). Without physiological indicators of stress, like cortisol, the behavior can be hard to interpret. As prey animals, horses often hide their pain as a survival trait, and training can change the horse’s natural behavior. Physiological evidence should back up interpretations of behavioral signs to responsibly justify inferences (Hall et al., 2013). Periods of increased stress levels in horses are
associated with elevated cortisol concentrations (Aurich, et al., 2015; Helseki, et al., 2002; Kedzierski et al., 2014; Kedzierski et al., 2013; McKeever and Malkinowski, 1999; Visser et al., 2008). The described physiologic stress markers enable equine researchers an opportunity to find correlations involving less evaluated origins of stress, such as muscle tension. Although published studies have discussed correlations between equine behavior and cortisol concentrations, a correlation between SCC and MT has not been thoroughly investigated in horses.

Therefore, the purpose of this study was to evaluate correlations between serum cortisol concentrations, a biochemical marker of stress, and muscle tension in horses. It was hypothesized that increased muscle tension would correlate with increased cortisol, an indicator of stress. Results from this muscle scoring system could be influenced by the type of work or program the horse is involved in, so horses in two different disciplines were evaluated. The significance of this study could establish a framework for a universal muscle tension grading scale which might be used to analyze equine stress. Equine massage therapists could familiarize themselves with the scale to develop consistency and, in turn, provide a service to individuals and organizations managing working horses. Evaluations by equine massage therapists could serve as an alternative to costlier means of identifying equine stress such as heart rate monitoring, which requires equipment and computer software, or cortisol testing, which requires laboratory analysis.
Chapter Two - Literature Review

Introduction

Detecting stress in animals is complicated, particularly when it is related to the impact of their jobs on their muscles. Research involving the connection between MT and equine stress has not been thoroughly investigated. Available methods to evaluate MT include electromyography (EMG), pressure algometers, palpometers, and subjective scoring which can be compared to accepted stress markers, such as cortisol concentrations, behavior evaluations, or heart rate variability. Research involved with this study evaluated MT in riding horses using a previously published subjective scale and serum cortisol (Chen et al., 2017). The subsequent literature review includes information relevant to understanding general muscle tension, equine muscles relevant to this study, how cortisol serves as an indicator of equine stress, subjective scoring in the medical field, and using massage therapists as resources for MT evaluations. The information provides relevancy and background for the experiments conducted in this study.

Muscle Tension Comprehension

The influence of movements on muscles has been discussed as early as 350 BC when Aristotle wrote that “the organ of movement must be capable of expanding and contracting (Aristotle, 350 BC).” Since his time, there have been generations of research
conducted to better understand muscle anatomy and physiology. The foundational understanding of muscular tone was developed in 1957 by Dr. Basmajian. Muscle tone involves any amount of contraction by skeletal muscles (Basmajian, 1957; Scanlon and Sanders, 2014). A muscle’s level of tone can be influenced by individual structure, intramuscular pressure, pain, temperature, preceding rest or exercise, disease, and medication, and has been reviewed extensively (Bennet, 1985; Murayama et al., 2012; Mustalampi et al., 2013; Simons and Mense, 1998; Yanagisawa et al., 2015). Postural tone involves a low level of continuous or intermittent neuromuscular activity to hold different parts of the skeleton in proper relation to the various and constantly changing attitudes and postures of the body. Postural tone is different than resting tone, which is a muscle at rest with no neuromuscular activity. Skeletal muscles associated with standing have a general tone identifiable by elastic stiffness and characterized by contractile activity. Contractile activity occurs in three forms: electrogenic stiffness, pathological involuntary electrogenic spasm, and contracture arising endogenously within the muscle fibers independent of electromyography activity. The first two forms are identifiable EMG activity because ‘electrogenic’ refers to activity of alpha - motor neuron and the neuromuscular endplate. Electromyography is the study of motor unit action potentials associated with muscle activity during movement.

Muscle tone can be understood as a measurable stiffness as a result of neural inputs. Changes in muscle stiffness can be recognized with palpation (Hourdebaigt, 2007). Elastic stiffness is the steady force required to produce unit displacement (Thewlis, 1979). Resistance of muscle against perpendicular pressure has been considered the definition for muscle hardness (Murayama et al., 2005; Murayama et al.,
2012). This is helpful for evaluators palpating a muscle searching for changes in tone, but it is as yet unknown how underlying physiological mechanisms influence muscle hardness. A disruption involving muscle fiber architecture is known as a muscle strain and is different than sore muscles. The latter is attributed to damage on the cellular level and is usually attributed to structural damage with only the contractile elements (Robinson, 1997). Significant positive correlations between a muscle’s increasing tension and muscle hardness have been reported in previous studies (Murayama et al., 2005). The tension of a muscle is related to four distinctions: basic viscoelastic tone, physiological contracture, voluntary contracture, and muscle spasm. Any increase in muscle tone is known as hypertonia (Simons and Mense, 1998). Various conditions can be associated with hypertonia, including spasticity, rigidity, dystonia, and muscle contraction.

Causes of inadvertent MT are established as psychological distress or anxiety, overload from sustained contraction or repetitive activity, and untrained use of muscles (Murayama et al., 2012; Simons and Mense, 1998). Intended increases in muscle tension do not usually have painful consequences unless they occur for abnormal or extended periods of time. Whether the tension is intended or not, the results lead to increased stress from engaged muscles. Stress from activated muscles can be positive or negative, causing the hypothalamus to react, influencing the autonomic nervous system. The hypothalamus also engages the pituitary gland to release hormones, such as cortisol, into the circulatory system. During this process, skeletal muscles shorten which increases tension (Assc. Applied Psychophys. and Biofeedback, Inc., 2011). Prolonged stress and MT result in changes that can also cause positive or negative changes to the body. Positive changes include increased strength or speed, but negative consequences can result in tension or
fatigue that can cause myofascial pain (Scanlon and Sanders, 2014; Waldman, 2013).

Diagnosing myofascial pain can be difficult, but migraines and tension-type headaches are recognized as one type of muscle tension in head and neck muscles (Leistad et al., 2005; Simons and Mense, 1998). Patients that experience migraines report higher pain responses in the splenius and temporalis muscles than control subjects. Likewise, TTH sufferers reported markedly higher pain responses in the temporalis and frontalis muscles, as well as trends toward higher pain responses in the trapezius and splenius muscles (Leistad et al., 2005). Increased MT and exercise has also been studied at length. Muscle soreness occurring post exercise resulting from increased muscle tone has been confirmed (Macgregor, et al., 2016; Niitsu et al., 2010; Whitehead et al., 2001). This data followed research from Murayama et al. (2000) indicating exercise induced hardening of muscles occurs two days after the event. It is also important to note that muscle atrophy can result in muscle pain. Additionally, joint pain can reverberate into surrounding muscles causing pain (Brooks, 2011).

Job stressors can influence musculoskeletal disorders and are usually strongly associated with low back pain in humans. Identifying demographic or physical influencers is important when identifying job stressors as biomechanical and psychophysiological processes influence musculoskeletal pain (Greiner and Krause, 2006). Correlations between office work and increased muscle tone and/or pain from lengthy computer or general desk work have associated these activities with localized pain in neck and shoulder muscles. The static work positions are believed to reduce blood flow and increased accumulation of Ca^{2+} in the affected areas resulting in muscle tenderness (Brandt et al., 2014; Waldman, 2013). In 2004, Wahlstöm, et al. reviewed
perceived MT as an independent risk factor for neck pain among computer users. Results showed a strong correlation between perceived muscular tension and risk for developing neck pain. Identifying an established connection between work and MT related pain in human research is important for making connections to how job related stressors might also impact muscle tension for horses.

**Relevant Equine Muscle Anatomy**

The highly elastic skeletal muscles have several important functions. They enable the body to support and protect the skeleton; create movement and control range of motion; maintain joint stability and posture; and contribute to thermoregulation. Deep muscles, responsible for posture and stability, attach directly to the bone and are located close to joints. They have a high number of nerve endings making them sensitive to postural alignment. Superficial muscles, located between deep muscles and skin, vary in shape and size and enable movement (Higgins and Martin, 2013). Relevant to this study, ten muscles or muscle groups were evaluated equally on both sides of the horse: a group of four facial muscles, Figure 1: Facial muscles were evaluated as a group of four different muscles on both sides of the face: (a) orbicularis oris, (b) levator labii superioris, (c) zygomaticus, and the (d) masseter muscles. Included in this closeup are the (e) brachiocephalicus and (f) rhomboideous muscles. Drawing by M. Davidson, 2018.
brachiocephalic, rhomboideus, trapezius, triceps, longissimus dorsi, gluteal muscles, biceps femoris, quadriceps, and semitendinosus (Appendix C).

Facial muscles, sometimes known as mimetic muscles, are responsible for facial expressions. Specifically, the orbicularis oris, levator labii superioris, and zygomaticus are superficial face muscles related to lip movement (Wathan et al., 2015) (Figure 1: a-c). Similarly located on the skull, superficial masseter muscles move the lower jaw to the side for mastication and allows for movement to open and close the jaws (Figure 1: d). Problems with the masseter muscle might result in difficulty chewing or bridling, excessive yawning, and/or head tossing.

The brachiocephalicus muscle extends from the wings of the atlas along the side of the neck to the arm allowing for flexion (Figure 1 and Figure 2: e). It also enables the horse to move the forelimbs forward when the head and neck are still. Soreness in this muscle results in tightness in the shoulder and an instability of the scapulohumeral joint (Reigel and Hakola, 2001). Horses with soreness in this muscle will struggle with circles as their flexion is limited (Hourdebaigt, 2007).

Rhomboideus muscles lie deep beneath the trapezius muscle and aid in elevation of the head and neck (Reigel and Hakola, 2001) (Figure 1 and Figure 2: f). They attach the cervical and thoracic vertebrae to the scapula allowing it to raise the shoulder blade or move it forward. Rhomboideus muscles are important for stabilization during locomotion (Zsoldos and Licka, 2015). Muscular issues might cause the horse to react negatively when the girth is tightened from soreness in the withers. There might also be soreness along the top of the neck that might lead to a shortened stride or problems picking up or changing leads (Reigel and Hakola, 2001). Riders can impact rhomboid muscle function
through improper saddle fit, excessive rein pulling, or bouncing in the saddle (Zsoldos and Licka, 2015).

Superficial equine trapezius muscle helps to move the scapula and joining the foreleg to the body (Reigel and Hakola, 2001) (Figure 2: g). Similar to the rhomboids, the cervical portion pulls the scapula forward while the thoracic portion moves it backwards. Trapezius muscles allow for protraction, retraction, adduction, and abduction of the foreleg. The cervical portion also supports neck extension. Tight trapezius muscles can result in reduced flexibility in shoulder movement and reactions to girth tightening. A poorly fitted saddle can result in inflammation across the muscle (Hourdebaigt, 2007).

Triceps brachii muscles are superficial and are important for forelimb retraction (Figure 2: h). They also help make up the stay apparatus which allows the horse to sleep while standing, and cope with the stance phase of locomotion using minimal exertion (Reigel and Hakola, 2001; McGowan and Goff, 2016). The stay apparatus supports standing during extended rest periods relying on two front limbs and one forelimb (Schuurman et al., 2003). Horses with problems in the triceps may keep weight of the affected side by standing on the opposite leg. They may have a shortened stride and might be lame at the extended trot. Jumpers might hang an afflicted leg lower as they move over the obstacle (The Horse Curator, http://www.horsecurator.com/equine-triceps-brachii-muscle/, 20180303).

The deep longissimus dorsi muscle supports the vertebral column and allows for extension and lateral flexion (Figure 2: i). As the largest and longest muscle in the body it runs long the spine from the withers to the point of the croup. Tightness can lead to
uncomfortable movement and poor coordination. Extended periods of tension may result in soreness during palpation, grooming and/or riding (Hourdebaigt, 2007).

Equine gluteal muscles have three distinct muscles, but the deep gluteus medius is relevant to muscle evaluation in this study (Figure 2: j.). The gluteus medius is the largest equine muscle and is responsible for concentric contraction through extension of the hip joint and abducting the hind limb (Zsoldos et al., 2018). It attaches to the back of the femur for initiating hind leg retraction, abduction, and adduction (Reigel and Hakola, 2001; Hourdebaigt, 2007). The gluteus medius helps power the horse forward during locomotion and stabilizes the limb while standing quietly (Zsoldos et al., 2018). It is susceptible to the development of myofascial pain in humans as a result of repetitive microtrauma from overuse or improper activation (Waldman, 2013).

Superficial biceps femoris muscle has a complex action allowing extension of the hip and hock, as well as flexing of the stifle during locomotion (Figure 2k.). Biceps femoris is the strongest

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**Figure 2:** The remaining nine muscle groups evaluated in sequential order on both sides as follows: (e) brachiocephalic, (f) rhomboideus, (g) trapezius, (h) triceps, (i) longissimus dorsi, (j) gluteus medius, (k) biceps femoris (part of the hamstring muscle group), (l) quadriceps, (m) and the semitendinosus (part of the hamstring muscle group).
part of the hamstring muscle group, allowing the horse to rear, kick, and move the leg away from the body. It is also important to patella function: pulling the patella to the side and releasing it from the femoral trochlea, both of which enable the locking mechanism of the stifle joint as part of the hindlimb contribution to the stay apparatus (McGowan and Goff, 2016). Problems with the biceps femoris can lead to toe dragging and shortened protraction of the affected limb. When asked to collect, the horse may have difficulty holding its positions during forward movement (Longhurst, 2016).

Quadriceps is a group of four deep muscle heads enabling movement of the stifle and hip joints, as well as supporting the function of the stay apparatus (Schuurman et al., 2003) (Figure 2l). An intentional contraction of the quadriceps is necessary to unlock the patella from a locked stifle when horses rest (McGowan and Goff, 2016). The stifle can be the weakest joint in the horse even though it is most complex (Reigel and Hakola, 2001). Therefore, quadriceps strength and endurance are important for normal stifle function. Horses with poor quadriceps musculature might have a shortened stride in the hind end while the front end moves correctly at the trot. They may have difficulty picking up and holding correct leads during a canter. They may also drag the toe in the affected limb (Brooks, 2011).

The superficial hamstring muscle group provides most of the power for hind leg retraction, but specific to this study, the long semitendinosus is evaluated for tension (Figure 2m). The muscle group supports the stay mechanism. The semitendinosus muscles also supports extension of the hip and hock joints; flexion of the stifle, and rotation of the hind limb inward (Reigel and Hakola, 2001). Chronic stretching from sliding stop motions in reining and rodeo horses leads to fibrotic lesions which can lead
to an abnormal gait. Most observable at a walk, the cranial phase is shortened and the
caudal phase is lengthened. In advanced stages, the palpation of the semitendinosus will
reveal a hardened mass (Reigel and Hakola, 2001).

**Equine Muscle Tension**

A concern for equine managers is how work influences the welfare of their
animals. Regardless of the type of work a horse performs, it serves as a job for their
human counterpart. Horses have jobs that commonly result in back or neck issues
including localized or generalized pain, pressure sores, and spinal injuries (Bertuglia, et
al., 2014; Hausberger et al., 2009; Jeffcott, 1980; Lesimple et al., 2010). Most difficulties
interfering with training horses can be traced to pain in those areas (Robinson, 1997).
Longissimus dorsi issues are a common cause of poor or reduced performance and
originate from overexertion, soreness, falls, poorly fitted equipment, unbalanced riders,
or traumatic incidents. Abnormal MT may be present in the longissimus dorsi muscle.
Horses with poor fitting saddles or unbalanced riders are at risk for developing
brachiocephalic soreness at the base of the neck (Robinson, 1997). Assessment for such
issues can be tricky due to spontaneous recoveries and because physiologically the horse
is not fully relaxed in the standing position (Jeffcott, 1980; McGowan and Goff, 2016;).

Traditionally, clinical evaluation of musculoskeletal pain in horses has used
palpation which has limited accuracy. Although veterinarians and physiotherapists rely
on palpation for muscular evaluations, subjectivity issues remain. Currently, few studies
exist involving increased equine muscle tension and soreness that might impact welfare.
Research studying equine muscle tension has used EMG as it is a helpful tool for
investigating function. A review by Williams (2017) identified three areas of focus using EMG in equine research: muscle recruitment, muscle activity during exercise, and fatigue. Interpreting data from horses is complicated by a lack of comprehensive research involving fatigue-induced muscle recruitment leading to abnormal MT and pain. The use of treadmills or riders during research further complicates EMG research as treadmills contribute to alterations in normal locomotion and riders have great influence on overall performance of the horse. A rider’s skill and their control during exercise can therefore impact results. Further research is needed specific to manual evaluation of MT by palpation and a possible connection to increased EMG activity prior to the evaluation.

Equine research has not yet studied this type of data interpretation (Tabor and Williams, 2017). Mechanical measurement tools have been developed to overcome subjectivity problems associated with manual palpation evaluation. Pressure algometry has been used for quantitative evaluations in previous studies (Hausler and Erb, 2006; Loon, 2012). Associated training or practice requirements reduce usefulness for average equine managers (Varcoe-Cocks et al., 2006).

**Cortisol as an Indicator of Equine Stress**

Currently, a correlation between accepted markers of equine stress and muscle tension has not been identified. In humans, increased MT has been associated with elevated cortisol levels. While it is often associated with negative effects on the body from stress, secretion of cortisol is important to coping with stress. Coping or coping strategies are understood to be the behavioral and physiological adjustments of an animal in stressful scenarios. Cortisol secretions occur with physiological changes in the body
related to stress. Adrenocorticotropic hormone regulates the release of cortisol by the adrenal cortex when the hypothalamus. Increased cortisol concentrations are accepted as quantitative and objective measures of stress response and the general mental condition of an animal. Non-protein-bound cortisol promptly circulates into saliva and salivary cortisol concentrations which mirrors variations of free cortisol in blood plasma (Ille, et al., 2013). Storing serum cortisol for processing enables equine researchers an opportunity to find correlations involving muscle tension. Serum cortisol concentrations remain stable with little change occurring when stored at 4°C or room temperature (22 - 24°C) for 72h (Reimers et al., 1983).

Equine cortisol levels are naturally influenced by circadian rhythm, aging, season, pain, and generalized disease (Aurich, et al., 2015; Cordero et al., 2012; Kedzierski et al., 2013; McKeever and Malkinowski, 1999; Peeters et al, 2011). Research has shown that horses have a circadian rhythm associated with cortisol that can be disrupted by persistent stress (Irvine and Alexander, 1994). It is also important to recognize that aged horses have decreased cortisol variability as a result of decreased adrenal gland capabilities (Cordero et al., 2012). Seasonal influences could result from anticipations of food availability shortages or extreme temperatures.

Increased cortisol levels have been connected to management stressors such as housing, exercise, or transportation, and slaughter procedures (Roy et al., 2015). Domesticated horses are often housed in stalled environments that are abnormal to evolutionary behaviors. Research shows that horses confined to stalls have more atypical behaviors and cortisol changes than those managed as a group in a paddock or group housing. Horses in paddocks spend more time moving and grazing, similar to feral
behaviors. In group housing, horses spend more time eating (Hoffmann, et al., 2012; (Rivera et al., 2002; Visser et al., 2008). It has been shown that as training becomes more intricate cortisol increases accordingly (Hall et al., 2013). Horses are known to endure stress when traveling alone and over long distances. Fortunately for equine managers, Fazio et al. (2016) showed that coping mechanisms seem to work for horses enduring transportation stress as previous experiences reduced peak cortisol concentrations. Additionally, that research found a connection to the quality of handling, which influenced peak cortisol concentrations, indicating humans can impact the stress levels in domestic horses. Increases in cortisol have also been connected to exercise (Becker-Birck et al., 2013; Casella et al., 2016; Kedzierski et al., 2013; Kedzierski et al., 2014). Interestingly, enhanced performance during competition is associated with increased cortisol levels (Munk et al., 2016; Peeters et al., 2011). Peak cortisol levels in competition horses in research by Munk et al. (2016) were below concentrations in other research evaluating cortisol levels from stressors such as transportation, perhaps indicating horses in the study were experiencing positive influences from exercise stress related to competition. It is also important to note that the horses studied were not influenced physiologically by stressed riders, who had correlations between increased cortisol levels and more frequent penalties (Peeters et al, 2011).

**Subjectivity and Medical Scoring**

Historically, manual assessments of tension, stiffness, and pain have not proven to be reliable. Generally, manual analyses of pain are more reliable than analyses of muscle tension (Maher and Adams, 1994). Scoring systems are a recognized tool to evaluate the
health and welfare of human and animal species. In the equine industry, body condition, behavior, lameness, injuries, pain, muscle tension, and gastric ulcers can all be evaluated using scoring systems (Alzola Domingo et al., 2017; Chen et al., 2017; Dalla Costa et al., 2016; Hall et al., 2013; Macallister et al., 1997; Mejdell et al., 2010; Mottet et al., 2009; Starke and May, 2017; Sutton and Bar, 2016; Walker et al., 2016). Scoring pain has involved both recognizing pain symptoms to assign scores as well as quantifying changes in the frequency or magnitude of pain leading to three types of assessments: simple descriptive scales, visual analogue scales, and numerical rating scales (NRS) (Loon, 2012; Weary et al., 2006). Simple descriptive scales identify pain using terms such as none, mild, moderate, and severe. Visual analogue scales do not force examiners to adhere to specific categories, but rather run along a numerical set of values, like NRS. Examples of simple descriptive scales include: the revised Equine Acute Abdominal Pain Scale (EAAPS), the Obel grading system, the Horse Grimace Scale, and the injury scoring system (Dalla Costa et al., 2016; Mejdell et al., 2010; Sutton and Bar, 2016).

Behavioral traits have been assessed to determine personality traits or temperaments in horses using scoring systems. Tests to score reactivity to stimuli have generally been developed using simple descriptive scales. Abnormal behavior related to pain has been evaluated and documented at length (Hall et al., 2013). There has been a positive correlation between assigned pain scores and cortisol as a physiological validation of pain scoring as a marker of underlying stress resulting from colic (Lawson et al., 2017).

Effects of massage on equine behavior has been interpreted using behavioral scores and heart rate data. On a scale of 1 to 5 where 1 represented high negative
responses and 5 represented high positive responses, horses presented the highest scores at normal allogrooming locations. The behavioral scoring system presented an effective way to judge the effects of massage on the experimental group (McBride et al., 2004).

Muscle scores given during equine clinical examinations related to back kinematics at a collected trot. Horses were scored on a NRS of 1 to 5 and half scores were allowed. Six areas on the horse were evaluated and definitions for pressure, muscle tone, and muscle tension were imperative to the understanding and application of the scoring system. Thirty-five horses were evaluated by a veterinarian and an experienced clinician. The repeatability of the developed system was rated from moderate to very good, and was suggested to be an early identifier of asymmetry or imbalances in muscle development. (Walker et al., 2016).

The success of a scoring system can depend on the total equine experience or practice of the scoring system by the raters. A training program was established to educate evaluators of bovine BCS. A one-week training program accomplished excellent understanding between trainers and trainees that was maintained over a six-month evaluation period. A high repeatability achieved by training in the bovine BCS system could improve the outlook of the results being sought in this study (Vasseur et al., 2013). This study suggests that proper training by evaluators can improve accuracy and repeatability; familiarization is an important first step to the success of a scoring system.

**Massage Therapists as a Resource**

There are more than 600 muscles arranged around the human skeleton and approximately 700 in the horse’s body (Scanlon and Sanders, 2014). The unique passive
and continuous tension or tone of those many muscles allow the body to maintain a position (Campbell and Lakie, 1998; Loram et al., 2007). The normal feel of skeletal muscle is determined by its normal tissue turgor and its immediate reflex response to stimuli or palpation (Basmajian, 1957; Scanlon and Sanders, 2014; Simons and Mense, 1998). General muscle tone varies between individual horses and breeds; it is also influenced by a horse’s mood or health status. Healthy epaxial muscles are relaxed and malleable in a quietly standing horse (Hinchcliff et al., 2013). Massage therapists, part of a growing network of complementary and alternative medicine (CAM) providers, must understand the normal feel and reflex of muscles to relieve pain, relax muscles, and reduce swelling. They accomplish their goals through a strong foundation of education in gross anatomy, physiology, pathology, historical context, and practical application (Fritz, 2017). The intent of therapeutic massage is to use one or more forms of touch, usually using a nonspecific approach, to return homeostasis to the body. According to Encyclopedia Britannica (2018), there are three forms of manual manipulation used to aid healing processes in therapeutic massage: effleurage (light and/or hard stroking); petrissage (compression including kneading, squeezing and friction); and tapotement (percussion using the sides of the hands to strike the surface of the client in rapid succession). These forms work to relax muscles in direct blood flow toward the heart, improve mobility, and improve circulation, respectively (Massage, 2018). Palpation outside of CAM can be a useful technique to identify soft tissues changes in texture, mobility, or resistance. Soft tissue layers are evaluated from superficial to deep layers by increasing digital pressure. Horses do not typically avoid deep muscle palpations and
exaggerated resistance to a manual evaluation is considered abnormal (Hinchcliff et al., 2013).

In the equine industry, the use of CAM seems to be influenced by veterinarian support or recommendation (Bergenstrahle and Nielsen, 2016; Thirkell and Hyland, 2017). In turn, veterinarians strongly favor a standardized education and licensing system for CAM providers (Bergenstrahle and Nielsen, 2016). It could be assumed that if a symbiotic relationship between veterinarians and equine massage therapists existed, more owners would consider using the intervention. Consequently, there is an opportunity for massage therapists and veterinarians to work together for improved patient care. Given the knowledge proficiency required to be a successful massage therapist, they could be trusted in the same way experts in any other field are counted on to give advice and provide educational input. An extensive review by Cuthbert and Goodheart, Jr. (2007) concluded that manual muscle testing performed by physical therapists was a clinically useful tool. Although they noted the practice needed further scientific validation, they emphasized that manual testing was an appropriate approach to muscle evaluation. Similarly, manual palpation of nerve tissue in examinations of lower back pain was supported with strong reliability and validity in a 2009 study by Walsh and Hall. Collaborating by medical professionals is seen more commonly in human supportive treatment, but for equine owners and managers it could provide a more feasible solution to studying osteopathy than more mechanical solutions which require proficiency and lack interpretation. Mechanical devices simply provide statistical data; the owner or manager would then be required to interpret the statistical data and make decisions. In contrast, a trained massage therapist could provide feedback from a manual muscle test
and provide recommendations on the direction of possible treatment. This is the first study known to the author covering equine massage therapists as subjective evaluators of muscle tension.

**Summary**

While there is limited support for manual evaluation of muscle tension, recent studies have provided a positive outlook on a fresh approach to the method. The cost and necessary training for mechanical methods of MT evaluation limits feasibility providing sensible reasoning to develop a reliable manual method. Manual evaluation methods may require a training program for physiotherapists to achieve widespread success and high repeatability. Equine owners and managers could work with experienced physiotherapists to improve welfare in animals with stress as a result of increased MT.
Chapter Three - Methodology

Horses participating in this study were involved in two different experiments. The first group included 17 horses from a therapeutic riding program in the Midwest participating in eight-week programs year-round. Horses were of mixed genders, ages, and breeds. The second group of horses included 25 horses from Murray State University’s equine program. It included mixed genders, ages, and breeds, working nine months a year for riding classes and competition teams.

Pilot Study

A scoring system was developed with an experienced massage therapist based on former muscle scoring systems (Chen et al., 2017). Horses were evaluated in a squared stance, but the evaluator may have asked a handler to step a horse forward or backwards to reassess a muscle that is not initially recognizable. A female massage therapist with 12 years of experience practiced with the scale for 6 months, participated in a pilot study, and then evaluated horses in these experiments. The therapist practiced with her own clients and three horses not participating in the main study were used in the pilot study, assuring she was unfamiliar with the horses beforehand. However, a larger study was needed to further validate the accuracy of the muscle scoring system.
Experiment 1

Horses

Seventeen healthy adult horses, mean age of 14.7±10 years, participating in equine assisted activities and therapies (EAAT) at a therapeutic riding center (TRC) were used in this study. There were 15 geldings and 2 mares of mixed light horse breeding, the majority of which were Quarter Horses. All horses had been owned by the TRC for at least three years prior to start of the study and regularly participated in riding activities. Horse management, including feeding, turnout, and routine health care, was not changed during the study. Also, no horses were removed from, nor did any new horses arrive at the facility during this time.

Riders

Although this study was deemed exempt from IRB oversight, legal consent was granted from riders or parents/legal guardians of all riders of horses involved. All riders at the TRC had some degree of physical, mental, or psychological disability. Disability type was identified by the following identifiers: ADHD (attention-deficit/hyperactivity disorder), AS (Asperger’s), AU (Autism), CP (cerebral palsy), DS (Down’s syndrome), EP (Epilepsy), MR (mental retardation), Other (various health impaired disabilities), and SPD (sensory processing disorders). Standard practice at the TRC required each rider to have a handler for their horse during the entire lesson to ensure safety of the participant. Some horse-rider pairs also required one or two additional assistants, referred to as sidewalkers, to provide additional support for the rider depending on the nature of the rider’s disability. Nine different disability types were observed during the duration of the study.
Riding Program

The riding program consisted of two consecutive 8-week riding sessions between January and May 2017, referred to as session A and B. Horses were allowed a 4-week recovery period between December 2016 and January 2017 before starting session A. Upon completing session A, horses were allowed a 2-wk rest period before starting session B. During each riding session, horses were used in 3 riding lessons per week. Each 1.5-hour riding session included approximately 45 min for tacking and untacking and 45 min for riding. Data was collected during weeks 1, 5, and 8 of session A and B. All riding lessons and data collections were held in a climatic controlled indoor riding arena. Horses were assessed and data collected in accordance with standard operating procedures at the TRC during actual riding classes; no changes other than data collections were made to the lessons.

Manual Muscle Testing

Manual muscle testing, which scored muscle tension on a scale between 1.5 and 2.5, was based on previously published research (Chen et al., 2017). The massage therapist began each evaluation by approaching the horse, untying it, and allowing for an “introductory period” to allow the horse to return to a relaxed state (Figure 3a & b).
intent of the slow, purposeful greeting was to ensure the horse was not bracing in anticipation of palpation. She would “ask” the horse to relax, if needed, by pushing against their neck until it would move freely and calmly instead of pushing back against her pressure. A recorder stood off to the side, out of the way, to record the scores she assigned as she moved through the 10 established muscle groups (Figures 1 and 2). The

Figure 3: A collage of images showing the "introductory meeting" allowing the horse to return to a relaxed state (left) and different types of pressure used to evaluate muscle tension (right). The therapist adjusted pressure based on initial feel of the muscle. Photos by S. Porr; editing by M. Hovey.
amount of pressure used to assign a score was dependent on the muscle being evaluated and the initial tone of the muscle (Figure 3: c-e). After grading all 10 locations on each side, the massage therapist would move to the next horse and the steps were repeated until all horses had been evaluated. Enthusiastic owners and handlers were requested not to share information with the massage therapist that would influence grading bias.

**Blood Collection**

Jugular blood samples were collected to determine equine stress based on changes in serum cortisol concentrations. Blood samples were collected using 20-gauge needles and anticoagulant free 5 ml vacutainer tubes (Monoject™ blood collection tubes, Covidien LLC, Mansfield, MA, USA) before tacking (Pre), immediately following dismount of riders (Post), and 30 min post exercise (30-Min) on alternate sides of the neck at each observation period during weeks 1, 5, and 8 of session A and B. Samples were allowed to clot at room temperature for 20 minutes before centrifugation at 2000 g for 10 minutes (ThermoFischer Scientific, Waltham, MA, USA). Serum was then pipetted into 1.7 mL microcentrifuge tubes (Argos Technologies, Vernon Hills, IL, USA), stored on ice, and transported to the Murray State University Breathitt Veterinary Center in Hopkinsville, KY. Determination of serum cortisol concentrations was conducted within 24 hours of collection using a bench top immunoassay analyzer (IMMULITE 1000 Immunoassay System, Siemens Healthcare GmbH, Erlangen, Germany).
Statistics and Analysis

Statistical analysis was performed using SAS (SAS Inst. Inc., Cary, NC). The Mixed procedure was used to determine the following: 1) differences in cortisol concentrations over time (pre, post, and 30 min), 2) effects of disability type of the rider on cortisol concentrations post and 30 min after riding, 4) changes in overall muscle scores throughout the study, and 5) effects of disability of the rider on changes in overall muscle scores. Variables of interest included cortisol concentrations and muscle scores for each muscle group evaluated, and overall muscle soreness scores. Fixed effects included disability type of the rider, age category and gender of the horses. The repeated measure was horse within riding season. Data is reported as least square means and significance declared at $P \leq 0.05$, and trends at $P \leq 0.10$.

Experiment 2

Horses

Twenty-five healthy adult horses participating in an equitation classes at Murray State University (MSU) were used. There were 21 geldings and 4 mares of mixed light horse breeding, the majority of which were Quarter Horses. Age of horses ranged between 8 to 20 years, with a mean age of 14 years. Horses had been owned or used in the MSU equine program for 5 to 20 years. At the start of the experiment, horses were returning from an approximate six-week break between the fall and spring semesters.
Riders

Participants in Experiment 2 consisted of MSU students enrolled in two equitation classes during the spring semester of 2017. To ensure rider safety, student skill level was determined prior to the start of the semester. Riders were classified according to their self-reported equine experience and riding abilities on a scale from 1 to 9, where 1 indicated very little equine experience and a 9 indicated advanced experience. Rider scores were further evaluated retrospectively and simplified into three groups with riders in group 1 being inexperienced riders (Beginners, n=6), group 2 being intermediate riders (Intermediate, n=2), and group 3 being advanced riders (Advanced, n=2).

Riding Program

This study was conducted during a regular 16-week academic semester: January through May of 2017. Data was collected during weeks 1, 9, and 15. Horses were ridden in 1 to 5 riding classes per week with each class lasting approximately 1.5 hr. Roughly thirty minutes of the allotted time involved tacking and untacking the horse while the remaining hour involved riding. All horses were also used during evening or weekend practices for the University equestrian team. Horses were ridden an average of 7 to 10 hours a week, but were handled by students approximately 22 hours per week in total for grooming, tacking, and intermittent course laboratory work (S. Porr, personal communication, April 2018).
Manual Muscle Testing

Manual muscle testing done with the University horses was performed as in Experiment 1. Murray State University horses were scored at the start of the riding course (week 1), at the midterm (week 9), and again at completion (week 15).

Statistics and Analysis

Statistical analysis was performed as described in Experiment 1. Variables of interest included cortisol concentrations and muscle scores for each muscle group evaluated, and overall muscle soreness scores. Fixed effects included experience level of the rider, age category and gender of the horses. Because this experiment was conducted during one academic semester instead of two riding sessions, session was removed from analysis. Data is reported as least square means and significance declared at $P \leq 0.05$, and trends at $P \leq 0.10$. 
Chapter Four – Results and Discussion

Understanding how muscle tensions scores might correlate with increased physiological indicators of stress is critical to recognizing how muscle tension might impact the welfare of the animal. Recognition of the relationship between muscle tension and equine stress would support physiotherapists seeking improved welfare. The subjective muscle tension scale could reduce the need for owners to purchase and train with mechanical devices, such as pressure algometers, to evaluate the impact of muscle tension on muscular dysfunction. In this chapter, MT scores are evaluated as an average of each muscle for each experiment group. Evaluating how muscle scores might correlate with SCCs is important as cortisol is a recognized indicator of stress. Equine stress correlates to elevated cortisol concentrations (Peeters et al., 2011). Normal equine serum cortisol concentrations were based on reference ranges from the laboratory used are 3 to 10 µg/dL (P. Godwin, personal communication, October 2017). Equally important is reviewing what variables might impact the animal’s muscle scores or cortisol concentrations, such as age and disability or riders’ skill levels.
Experiment One

**Session by Time.** The first session for the TRC horses followed a four week break over the holiday season and the second session started after a regularly scheduled two-week break. A session by time interaction existed for rhomboideus (P = 0.0028), trapezius (P = 0.0017), gluteal (P = 0.0261), and tended to exist for brachiocephalic (P = 0.0761; Table 1). The interaction means that effects of session could not be separated from effects of time.

As shown in Table 1, highest MT scores in the rhomboideus were observed in horses before starting session one (1.91, scale range 1.5-2.5) and were different from those after session one and before starting session two (1.84 and 1.77, respectively; P ≤ 0.0366). In regards to the trapezius muscle, the highest scores were observed before starting session one (1.8750; P ≤ 0.0254), but were similar to scores the after session one, as well as before and after session two (1.7917, 1.79692, and 1.8123, respectively; P ≥ 0.1301). Gluteal muscles showed the highest MT score before starting session one (1.8393). These scores were different from those observed before starting session two (1.7596; P = 0.0028), which were similar to those observed after session one and two (1.7917 and 1.7937, respectively; P ≤ 0.1942). However, MT scores tended to differ before and after session one (1.8393 and 1.7917, respectively; P = 0.0606) and before session one and after session two (1.8393 and 1.7937, respectively; P = 0.0780). Brachiocephalic MT scores were similar before and after session one (1.9333 and 1.9196, respectively; P = 0.6771), but different before and after session two (1.75 and 1.8484, respectively; P ≤ 0.0001). Overall, the lowest brachiocephalic muscle scores were
observed before starting session two, which differed from those of the end of the eight-week riding session \((P = 0.0047)\) (Appendix D).

Table 1: Muscle tension scores were impacted by time interactions for the included muscle groups in horses used in a therapeutic riding program over two different eight-week riding sessions.

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Time</th>
<th>Session 1</th>
<th></th>
<th>Session 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Rhomboideus</td>
<td>1.9107(^a)</td>
<td>1.8417(^a)</td>
<td></td>
<td>1.7692(^c)</td>
<td>1.8484(^a,b)</td>
</tr>
<tr>
<td>Trapezius</td>
<td>1.8750(^a)</td>
<td>1.7917(^b)</td>
<td></td>
<td>1.7692(^b)</td>
<td>1.8123(^b)</td>
</tr>
<tr>
<td>Gluteal</td>
<td>1.8393(^a)</td>
<td>1.7917(^a,b)</td>
<td></td>
<td>1.7596(^b)</td>
<td>1.7937(^a,b)</td>
</tr>
<tr>
<td>Brachiocephalic</td>
<td>1.9196(^a)</td>
<td>1.9333(^a)</td>
<td></td>
<td>1.7500(^c)</td>
<td>1.8484(^b)</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically.

**Session by Side.** A session by side interaction was observed for biceps femoris (Table 2). During session one, horses tended to be more tense on the left versus the right side \((1.91 \text{ vs. } 1.84; \quad P = 0.0736)\), but were similar throughout the rest of the experiment. Therefore, both session and side influenced MT scores in the biceps muscles of the TRC horses.

Table 2: Muscle tension scores were impacted by side for the biceps.

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>1</td>
<td>1.9055(^*)</td>
</tr>
<tr>
<td>Right</td>
<td>2</td>
<td>1.8742(^*)†</td>
</tr>
<tr>
<td>Left</td>
<td>2</td>
<td>1.8430(^*)†</td>
</tr>
<tr>
<td>Right</td>
<td>1</td>
<td>1.8366†</td>
</tr>
</tbody>
</table>

Different symbols within the same row tend to differ < 0.1.
Main Effects – Tension Scores.

Muscle tension scores differed before and after riding sessions for facial muscles (1.7839 vs 1.8609, respectively; \( P = 0.0262 \)), longissimus dorsi (1.9106 vs 1.8244, respectively; \( P = 0.0040 \)), and quadriceps (1.8007 vs 1.7655; \( P = 0.0413 \)) (Table 3). Facial muscles were observed to be highest at the end of the sessions, which indicates there was some influence by the equipment and/or riders’ rein tension. The increase in facial MT supports the findings of Chen et al. (2017) which found that scores increased before and after a singular riding session. This experiment extends those findings, suggesting that equipment and/or rider rein pressure can affect facial MT over a longer period of time because evaluations were conducted at least 12 hours after horses had been ridden. A 2009 study by Manfredi et al., showed that increased rein tension correlated with oral behaviors. TRC riders generally used rein tension to direct the horse more than leg pressure, but horses were ridden with and without bits. This suggests that regardless of the use of a bit, pulling on the face might lead to bracing behaviors which could influence facial MT. Longissimus dorsi and quadriceps muscles had higher MT scores before the sessions versus those recorded at the end suggesting that the length of the break prior to the sessions did not influence MT scores for those muscles. Longissimus dorsi and quadriceps muscles are both deep muscles which can make evaluations difficult (Groesel et al., 2010). As the largest muscle in the equine back, the longissimus dorsi has the important role of supporting the weight of the thorax. Exercise can help a horse carry itself appropriately to avoid muscle soreness or atrophy. The TRC horses in this experiment were evaluated after detraining totaling four and two weeks, respectively.
Equine muscles maintain fitness levels longer than humans and a break of a couple weeks should not necessarily impact MT scores, but considering flexibility degrades much faster the impact of the break on the loaded longissimus dorsi muscles should not be ruled out. Detraining is considered to be the period of time after complete cessation of a training program or a marked decrease in the level of intensity. A rule of thumb for horses returning to work after a lay-off is to allow a horse half the time it had off to return to its previous level of work (Marlin and Nankervis, 2002). Considering the highest MT scores for longissimus dorsi were at the start of the study could support the idea that by the end of the eight-week session their muscles had returned to the necessary suppleness for their jobs. Similarly to the longissimus dorsi, it is possible that the quadriceps femoris muscles were impacted by the inactivity. The quadriceps femoris must contract to support stabilization of the hock and stifle joints (Schuurman et al., 2003). Therefore it is possible that as the quadriceps femoris returned to a regular exercise schedule they became more supple and flexible resulting in a lower MT score assigned by the evaluator.

In contrast, MT scores were similar before and after sessions for biceps (1.8748 and 1.8403; $P = 0.5279$), triceps (1.8563 and 1.8403; $P = 0.5279$), and semitendinosus (1.8155 and 1.7818; $P = 0.0994$) (Table 3). These three muscle groups were determined to have consistent muscle tension from the start of the experiment to the end. Evaluated as a group average, TRC horses had higher muscle tension scores in the biceps and triceps brachii than in the semitendinosus.
Table 3: Muscle tension scores in therapeutic riding horses over two eight-week long riding sessions

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Before</th>
<th>After</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial</td>
<td>1.7839</td>
<td>1.8609</td>
<td>0.0262</td>
</tr>
<tr>
<td>Longissimus</td>
<td>1.9106</td>
<td>1.8244</td>
<td>0.0040</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>1.8007</td>
<td>1.7655</td>
<td>0.0413</td>
</tr>
<tr>
<td>Biceps</td>
<td>1.8748</td>
<td>1.8548</td>
<td>0.4714</td>
</tr>
<tr>
<td>Triceps</td>
<td>1.8563</td>
<td>1.8403</td>
<td>0.5279</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>1.8155</td>
<td>1.7818</td>
<td>0.0994</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically.

Muscle tension scores were similar between left and right sides for facial, brachiocephalic, rhomboids, trapezius, gluteal, longissimus, hamstring, and triceps, but different for quadriceps. Left quadriceps tended to be tenser than right throughout the study (1.7982 vs. 1.7679; P = 0.0795) (Figure 4). Quadriceps help power the hind end of the horse enabling movement through the hip to the stifle and allow the horse to stand while sleeping as part of stay mechanism. If the horses were not exercised equally to the right and left, it is possible their quadriceps were tenser from either right or left directional exercise. In a right circle around the arena, the left quadriceps would help propel the horse forward and would be stretched further in the stride. The continued right patterns could require adaptation to accommodate the work. The muscle adaptation for prolonged propulsion to the right could have been interpreted as tension. Stretching has shown to induce muscle hypertrophy and if this was occurring as a result of the exercises, it could have been interpreted as tension (Coutinho et al., 2004). In contrast, a left pattern around the arena would require a shortened swing phase by the left foreleg. This might result in tenser muscles from improper use resulting in soreness that was interpreted as tension by the evaluator if the horse reacted to her pressure. Time spent exercising in one
direction versus the other was not monitored in this study. Inclusion of directional influences on muscle tension might be helpful in future research. Additionally, mounting consistently from the left side may have influenced the quadriceps. Unbalanced engagement of the left quadriceps muscle more than the right for mounting could have resulted in a slightly more developed structure that might have been interpreted as increased tension by the evaluator. Finally, it is important to clarify that while every attempt was made to ensure horses were standing evenly balanced on all four legs, it is possible horses were leaning more on their left hind legs as quadriceps are an important part of the stay mechanism.

Muscle tension scores were different for the longissimus muscle and tended to differ for the hamstrings between session one and two (Table 4). Therapeutic riding center horses had higher longissimus MT scores overall during session one compared to

Figure 4 Therapeutic riding center horses tended to have different muscle tension scores on the left versus right side in the quadriceps femoris muscles (1.7982 vs. 1.7679; P = 0.0795).
session two (1.9067 and 1.8283; P = 0.0088). Higher longissimus dorsi muscle tension scores during session one could relate to the idea that horses in regular exercise would have greater flexibility and suppleness than inactive horses. However, higher semitendinosus scores were observed in session two versus session one, which works against that principle (1.8165 and 1.7808; P = 0.0811). Considering that the semitendinosus muscle helps the horse propel forward during the weight-bearing portion of a stride, it is possible that this muscle would be more defined after almost 16 weeks of consecutive exercise. The two-week break between session one and two would not have cause the muscle to begin catabolism. Incorrect use of the hind end can result in overdeveloped semitendinosus muscles which could have been interpreted as increased muscle tension. Development of individual muscles might be worth investigating in future studies to see if it influences MT scores. No differences were observed between session one and two for facial, triceps, and quadriceps muscles (P ≥ 0.4600).

Table 4: Muscle tension scores influenced by session in therapeutic riding horses over two eight-week long riding sessions.

<table>
<thead>
<tr>
<th></th>
<th>Session One</th>
<th>Session Two</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus</td>
<td>1.9067a</td>
<td>1.8283b</td>
<td>0.0088</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>1.7808†</td>
<td>1.8165*</td>
<td>0.0811</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically. Different symbols within the same row tended to differ statistically.
Effect of Disability Type on Muscle Tension.

Able-bodied riders can send mixed signals as they ride, whether they are learning new skills or pleasure riding. Riders who have mental, physical, or psychological disabilities may not be able to control their physical movements easily, or may be unaware of their impact on the animal. This can be met with resistance or irritation by the animals being directed. Therefore, the riders may lose sight of the goal to have a balanced seat and soft touch. Multiple studies have shown that this does not have a negative impact on the animal in regards to behavior or physiologically, but there is no known investigation into this impact on muscle soreness. Results from experiment one in this study showed that overall MT scores were not affected by disability type and did not differ from the left to right side ($P \geq 0.3858$). Further research would be needed to validate these results. In this study, TRC horses had multiple riders of varying disability types each week. It would be helpful to track all rider-horse pairs used during the evaluated period, or even assign riders of like disabilities to particular horses. Furthermore, MT evaluations were not done on the same days as the riding sessions were occurring. It would be advantageous to evaluate MT scores on the same day as riding sessions.

Effect of disability type on cortisol changes.

The highest cortisol concentrations in experiment one were observed immediately after dismount of horses with AU riders which differed from horses assigned riders with DS, CP, EP, and other disabilities (2.1131, 1.6392, 1.5033, 0.9525, & 1.2712, respectively; $P \leq 0.0372$), but were similar to horses with ADHD, Asperger’s Syndrome,
mental retardation, and SPD riders (1.9230, 1.7989, 1.6960, and 1.6633, respectively; $P \geq 0.1003$) (Table 5).

**Table 5: Serum cortisol concentrations by disability type in TRC horses at the end of two eight-week long riding sessions.**

<table>
<thead>
<tr>
<th>Disability Type</th>
<th>Serum cortisol concentration (µg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autism (AU)</td>
<td>2.1131$^a$</td>
</tr>
<tr>
<td>Attention deficit/hyperactivity disorder (ADHD)</td>
<td>1.9230$^{a,b}$</td>
</tr>
<tr>
<td>Asperger’s Syndrome (AS)</td>
<td>1.7989$^{a,b}$</td>
</tr>
<tr>
<td>Mental Retardation (MR)</td>
<td>1.6960$^{a,b}$</td>
</tr>
<tr>
<td>Sensory Processing Disorders (SPD)</td>
<td>1.6633$^{a,b}$</td>
</tr>
<tr>
<td>Down’s Syndrome (DS)</td>
<td>1.6392$^b$</td>
</tr>
<tr>
<td>Cerebral Palsy (CP)</td>
<td>1.5033$^b$</td>
</tr>
<tr>
<td>Various health impaired disabilities (Other)</td>
<td>1.2717$^b$</td>
</tr>
<tr>
<td>Epilepsy (EP)</td>
<td>0.9525$^b$</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically.

**Serum cortisol concentration changes over time.**

Cortisol concentrations changed between collection times, but values were within or slightly below normal ranges as previously described. The highest cortisol concentrations were observed in horses before riding began (2.0625 µg/dL) and differed from that observed Post and 30 min after ride ended ($P \leq 0.02$) (Table 6). Horses having higher cortisol concentrations prior to riding might have been anxiously anticipating the unknown. It is also possible they may have been unhappy about leaving their preferred environment or companions. The lowest cortisol concentrations were observed 30 min after riding and differed from Post ride values (1.4830 and 1.7860 µg/dL, respectively; $P = 0.0107$). Since cortisol concentrations remained within or slightly below normal ranges and declined during riding sessions in TRC horses suggesting horses were not negatively stressed due the riding experience. Serum cortisol concentrations were similar between
session one and two (1.7878 and 1.8011 µg/dL; P = 0.8831). Therefore, horses were not increasingly stressed during one session over the other. Average SCCs differed between weeks for both eight week-long riding sessions. The lowest concentration was observed in week 1 and was different than concentrations observed in weeks 5 and 8 (1.4863, 1.9035, and 1.9937 µg/dL, respectively; P ≤ 0.0002). Average SCC observed in week 5 was similar to week 8 (1.9035 and 1.9937, respectively; P = 0.4304). The gradual increase in SCC was below normal ranges provided by Breathitt Veterinary Center of 3 to 10 µg/dL, but indicated the length of the two eight-week sessions might influence cortisol concentrations. Further investigation of longer sessions would be needed to see how long SCC might continue to rise. It also indicates detraining periods between sessions do benefit TRC horse welfare as concentrations were lower following both a four-week and two-week break.

Table 6: Serum cortisol concentrations in horses used in an equine therapeutic riding program.

<table>
<thead>
<tr>
<th>Serum Cortisol Concentration by Collection Time (µg/dL)</th>
<th>PRE</th>
<th>POST</th>
<th>30MIN</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0625&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7860&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.4830&lt;sup&gt;c&lt;/sup&gt;</td>
<td>P&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Serum Cortisol Concentration by Week of Collection (µg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>1.4863&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Data presented as least squares means. Different letters within the same row differ statistically.
Experiment Two

Main effects – tension scores over time.

**Facial Muscles.** Muscle tension scores appeared to differ over time ($P = 0.0433$). The highest MT was observed in horses during the middle semester compared to the beginning (1.8625 and 1.7778, respectively; $P = 0.0144$). Values were similar ($P = 0.4841$) at the end of the semester to those observed midways. Although MS scores had declined by the end of the semester, values tended to be slightly higher than those observed at the start (1.8382 and 1.7778; $P = 0.0908$). Horses at the University ride with bits in their mouths and it is possible that the muscles were adapting for pulling by the rider. Horses observed in experiment two were carrying riders of various skill levels, so some may be leaning more heavily than others. The effect of the bit on the equine facial muscle tension has not been studied, but it could be assumed that extended or exaggerated inputs by the rider might require the horses to resist, and ultimately adapt to, chronic pull by the riders. Once the semester had concluded the horses may have been able to relax the tension in their facial muscles.

**Brachiocephalic.** University horses’ MT scores appeared to change over the course of the semester in the brachiocephalic muscles ($P = 0.0022$). The highest MT was observed in horses at the middle of the semester compared to scores taken after course completion (1.9375 vs 1.8456; $P = 0.0013$). Values were similar at the beginning of the semester to values at the end of the semester ($P = 0.5862$). Similarly to the facial muscles, the brachiocephalic muscles can be affected by rider pressure on the reins (Cook, 1999). As riders ask the horse to collect itself in higher than usual head carriage, it is possible the muscles were adapting to demands midway through the semester. Riders in
experiment two began each class with stretching exercises. Some of those exercises require the rider to reach out over the horses’ necks, which would require the horse to brace against the shifting rider weight. It is possible brachiocephalic muscles were adapting to the stretching exercises in the middle of the semester, but had become more relaxed by the time they were given their break from riding. The brachiocephalic muscles are shown to have more EMG activity during the stance phase of a stride suggesting that it is possible that the horses’ brachiocephalic muscles were engaged more than other muscles during the evaluation (Zellner et al., 2017). A study by Kienapfel (2014) showed that horses engaged in hyperflexed positions had more EMG activity indicating the position required activation by the brachiocephalicus. Experienced riders could be asking horses to collect into a hyperflexed position for advanced riding. Inexperienced riders could be asking for hyperflexion, too, and could be doing so correctly or incorrectly. Whether or not inexperienced riders were asking the horses to collect into hyperflexion correctly, their actions could have been impacting the horses negatively.

Rhomboideus. Tension scores differed over time for the rhomboid muscles in the MSU horses (P = 0.0374). Scores were highest at the beginning of the experiment and differed from values observed midway (1.9097 vs 1.8438; P = 0.02). The rhomboid muscles became tenser as the semester progressed from week 9 to 15 (1.8438 vs 1.9044; P = 0.0370) with the before and after values being similar at the end of the experiment (P = 0.8572). The rhomboid muscles help raise the neck and enable dynamic movement of the scapula. It is possible that the muscle flexibility had been impacted by the six-week break prior to the start of the semester (The Horse Curator, http://www.horsecurator.com/equine-rhomboid-cervicis-and-rhomboid-thoracalis-
muscles/, 20180325). It is also possible that muscle contraction and catabolism had started to impact the feel of the rhomboid muscles in the MSU horses due to the length of detraining. The potential for subjective error on the scoring should also be considered when reviewing the scores of the average overall rhomboid muscles because of its deep location beneath the triceps.

*Trapezius.* Muscles were not affected by time or side over the course of the semester in the Murray State horses and appeared to have no change in tension (P = 0.6720 vs P = 0.7205). Trapezius muscles cover the withers and it is noteworthy they were seemingly not impacted by equipment or riders throughout the semester. Some research supports equine laterality, but that research does not investigate muscle tension (Kuhnke et al., 2010). Merriam-Webster defines laterality as a “preference in use of homologous parts on one lateral half of the body over the other,” (https://www.merriam-webster.com/medical/laterality, 20180415). If the tension were to be evaluated immediately after riding it is possible a rise in tension would have been observed (Chen, et al., 2017). Instead, this experiment studied university horses over a longer period of time and the horses were not ridden on the day of evaluation.

*Longissimus Dorsi.* There appeared to be no difference for time or side affecting the back muscles in the MSU horses over the course of the semester (P = 0.8329 and P = 0.3523, respectively). It is interesting that the back muscles were not impacted over time throughout this experiment. There is extensive equine research examining back pain and its connection to riding, but the correlation of muscle tension and back issues is less so (Groesel, et al., 2010). As this muscle is essential to supporting the vertebral column, no changes in MT indicate that the horses were not negatively affected by rider weight. The
lack of change indicates that individual horses with higher longissimus dorsi MT scores remained unchanged over the course of the semester.

**Gluteus medius.** Muscle tension scores appeared to differ over time (P = 0.0383). The highest MT was observed in horses at the end of the semester compared to scores midway through the semester (1.8162 vs 1.7625; P = 0.0246). Muscle tension scores also seemed to differ from the beginning of the semester to midway scores (1.8125 vs 1.7625; P = 0.0333). Values were similar at the beginning of the semester to those at the end of the semester (P = 0.0879). At the start of the semester in week 1, the horses had detrained for approximately six weeks; it is interesting that week 1 MT scores were similar to those after 15 weeks of regular exercise. Weight bearing exercises correlate with peak gluteus medius activity in humans (Baggen et al., 2017). Horses carrying just 10% of their body weight experience physiological changes, therefore it is possible that adaptations required for exercise demands of MSU horses resulted in increased tone (Powell et al., 2008). In humans, weak gluteus medius muscles are associated with nonspecific low back pain, especially with increased body weights as seen in pregnant women (Cooper et al., 2016). This connection was not investigated in this study, but it would seem the MSU horses were not suffering from underdeveloped gluteus medius muscles.

**Biceps Femoris.** There appeared to be a difference in MT scores over time (P = 0.0417). The highest MT scores were determined to be at the start of the semester compared to scores recorded in the middle (1.9028 vs 1.8375; P = 0.0234). Muscle tension scores also appeared to differ between the end and the middle of the semester (1.8971 vs 1.8375; P = 0.0412). Values were similar at the start of the semester to those at the end (P = 0.8469). The biceps femoris might be tricky to evaluate in this study
because it is subdivided into three parts and each has different EMG recordings at different phases of the walk, trot, or canter gaits (Tokuriki and Aoki, 1995). It is hard to determine why tenser scores were recorded in week one rather than later in the semester. Further investigation is needed to provide insight into the biceps femoris muscle tension scores.

**Quadriceps Femoris.** Muscle tension scores tended to differ for quadriceps femoris MT scores during the semester in University horses (P = 0.0949). The lowest MT scores occurred midway through the semester which was similar to those at the start of the semester (1.7750 vs 1.7917; P = 0.4498), but differed from scores observed after the semester ended (1.8235; P = 0.0318). Muscle tension scores were similar at the end of the semester compared to scores from the beginning of the riding course (1.8235 vs 1.7917; P = 0.1665). The quadriceps muscles help adduct and extend the equine hip (Payne et al., 2005). It also helps to extend the stifle and it is possible that the 15 weeks of regular work during the semester resulted in increased tonicity interpreted as higher tension than recordings at the start of the semester. Tyler et al. (1998) reported that morphological adaptations in skeletal muscles were mostly completed by 16 weeks of training. Therefore, quadriceps femoris muscles may have been tenser as a result of required muscle adaptation to exercise to meet University work demands.

**Semitendinosus.** The lowest muscle scores were observed before the riding period began and were similar to scores observed midway through the semester at week 9 (1.7917 and 1.8313; P = 0.1506), but differed from scores observed after the riding period ended (1.8824; P = 0.0019). However, scores observed mid-semester, tended to be similar to those observed at the end of the study (1.8313 and 1.8824; P = 0.0684).
Semitendinosus muscles power the leg in locomotion and are susceptible to adaptation in response to exercise. Semester long development of this superficial muscle could have been interpreted as increased tension by the massage therapist.

Table 7: Muscle tension scores of Murray State University horses over a semester long beginner riding course

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Time</th>
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<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 9</td>
<td>Week 15</td>
</tr>
<tr>
<td>Facial</td>
<td>1.7778&lt;sup&gt;b&lt;/sup&gt;&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.8625&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8382&lt;sup&gt;a&lt;/sup&gt;&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td>Brachiocephalic</td>
<td>1.8611</td>
<td>1.9375</td>
<td>1.8456</td>
</tr>
<tr>
<td>Rhomboideus</td>
<td>1.9097&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8438&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.9044&lt;sup&gt;a&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trapezius</td>
<td>1.8333</td>
<td>1.8438</td>
<td>1.8162</td>
</tr>
<tr>
<td>Longissimus</td>
<td>1.9097</td>
<td>1.9375</td>
<td>1.9191</td>
</tr>
<tr>
<td>Gluteal</td>
<td>1.8125&lt;sup&gt;a&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.7625&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.8162&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Biceps</td>
<td>1.9028&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8375&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.8971&lt;sup&gt;a&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>1.7917</td>
<td>1.7750</td>
<td>1.8235</td>
</tr>
<tr>
<td>Hamstrings</td>
<td>1.7917</td>
<td>1.8313</td>
<td>1.8824</td>
</tr>
</tbody>
</table>

Different letters within the same row differ by P ≤ 0.05.
Different symbols within the same row differ by P ≤ 0.09.

Main effects – tension scores by side.

Triceps. Other than triceps, no MT scores differed on the left or right side. In MSU horses, triceps muscle tension scores on the left side tended to be tenser than the right side (1.9044 vs 1.8589; P = 0.0562) (Figure 5). The triceps muscles allow movement in the shoulder and elbow. They are also subjected to direct stress by the riders during mounting and dismounting as the pull from the rider is resisted by the tissues and muscles underneath the saddle. Therefore, it would be reasonable to assume that riders impacted the amount of tension in the MSU horses. While the students do typically use blocks for mounting, the blocks do not totally eliminate the abrupt jarring motion caused
by stepping into the stirrup and swinging of the right leg over the horses’ back, especially for shorter riders. There is a moment of imbalance resulting in uneven pressure by the riders. Considering the increased work demands of the MSU horses over the TRC herd, it is possible to imagine their trapezius muscles adapted in a way that led the evaluator to score them higher on the muscle tension grading scale.

Figure 5 MSU horses tended to be tenser on the left versus right in triceps brachii muscles (1.9044 vs 1.8589; P = 0.0562).
Cortisol concentration changes by collection time.

Average SCC was highest when horses were removed from their stalls or pastures prior to tacking, but were similar to cortisol concentrations observed immediately upon rider dismount (2.9606 and 2.6880 µg/dL; P = 0.1893). Thirty min after rider dismount, cortisol concentrations declined and differed from Pre and Post concentration (2.1314 µg/dL; P < 0.0079) (Figure 6). Normal serum cortisol concentrations for horses based on reference ranges for the laboratory used are 3 to 10 µg/dL (P. Godwin, personal communication, October 2017). Values in experiment two were often higher than 2 µg/dL, but lower than 3 µg/dL. Serum cortisol being higher at Pre and Post as compared to 30 Min (P = 0.0004) suggested that horses experienced some level of stress by being brought from pastures or stalls, and during riding. However, all SCCs were within normal range, so MSU horses in the riding class did not appear to be enduring unmanageable stress. The higher Pre cortisol concentration could have resulted from horses anticipating the exercise or from leaving their housing areas. It is possible they were experiencing “good” stress as cortisol concentrations overall stayed in healthy ranges.

Table 8: Average serum cortisol concentrations in MSU horses used in two beginner riding courses.

<table>
<thead>
<tr>
<th>Serum Cortisol Concentration by Collection Time (µg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE</td>
</tr>
<tr>
<td>2.9606&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically.
Cortisol concentration changes over time.

Average SCC was highest during week 9 and similar to week 15, (2.9709 µg/dL and 2.9054 µg/dL, respectively; P = 0.7499) (Table 9). Serum cortisol was lowest in week one and different than both weeks 9 and 15 (1.9039 µg/dL, 2.9709 µg/dL and 2.9054 µg/dL, respectively; P ≤ 0.0001). Lower concentrations in week 1 suggests that horses were less stressed at the start of the semester which followed their detraining over the holiday break. This coincides with the activity level of the riding class where increased demand is placed on the horses as the semester progresses. Horses used in college program were only asked to do very simple movements during week 1, but more intense exercise was required as the course progressed. When reviewing the video recordings, horses were only asked to walk in week 1, but were asked to walk, trot, and canter during weeks 9 and 15. Therefore, the difference in cortisol concentrations between week 1 and weeks 9 and 15 (P < 0.001) may have been caused by the increased amount of exercise and would be considered a normal increase and not a response to negative stress.

<table>
<thead>
<tr>
<th>Table 9: Average serum cortisol concentrations in horses used in two MSU beginner riding courses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum Cortisol Concentration by Week (µg/dL)</td>
</tr>
<tr>
<td>Week 1</td>
</tr>
<tr>
<td>1.9039&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different letters within the same row differ statistically.
Effect of experience level of riders on cortisol changes.

Experience level of the rider had no effect on SCCs, but a difference was observed based on week and collection. As a group average, the highest SCC was seen in week 15 which were similar to concentrations collected in week 9 (2.4887 and 2.3327, respectively; P = 0.5992). These levels were different than those taken in week 1 (1.5679; P ≤ 0.01). Cortisol concentrations observed were lower than the normal serum references range previously described, but a notable increase in scores indicates the horses were enduring greater levels of stress as the semester progressed. Horses were seemingly less stressed following their six-week break between semesters, therefore the break might be considered a necessary part of their annual schedule for enhanced welfare. The levels observed in weeks 9 and 15 do not indicate the care of the horses should be altered to improve welfare as they were slightly below normal ranges that would be deemed unhealthy.

Comparison of Experiments One and Two.

Although data was not combined for Experiment one and two due to differences in management, participants, and facilities, there are still comparisons to be made worth discussing. Facial muscles were impacted in both experiments over time with the highest average MT scores recorded at the end of the semester for experiment one while in experiment two, the highest average MT scores were annotated in week 9 (midway through the semester). Regardless of whether the highest average scores occurred at the end of a session or midway through a semester, the changes indicate an impact by the equipment and/or the rider. It supports training objectives focused on responsiveness to
leg pressure as opposed to requiring direct input through the reins in order to alleviate negative impact on smaller facial muscles. The longissimus dorsi muscles were highest at the start of the sessions in experiment one, but were not impacted over time in experiment two. Work requirements for TRC horses are less demanding than MSU horses and it is possible that they are therefore more susceptible to detraining periods between riding sessions as they may have less muscle development in longissimus dorsi. Further investigation into muscle thickness would need to be investigated with EMG to evaluate whether or not the fitness levels of the longissimus dorsi yielded different results.

Quadriceps femoris muscles had highest levels of tension in experiment one at the start of sessions versus those at the end and tended to be tenser on the left versus right side. This is somewhat similar to experiment two where the highest in week 15 (end of semester), but those scores were similar to those taken in week 1 (start of semester). It is possible that if the sessions ran longer in experiment two that the scores would have had comparable measurements at the end. It also indicates that the MSU horses might be worked more evenly in both directions allowing for balanced muscle development.

Murray State University riding instructors emphasize the importance of exercise to the right and left and are able to do so because their riders do not need special considerations (C. Colston, personal communication, March 2018). This does not mean the TRC horses have degraded welfare, but rather it emphasizes the differences in focus between the two facilities: therapeutic riding facilities must understandably put the needs of their riders first, while university riding programs must put their horses first due to increased work demands. For experiment one, MT scores were similar before and after the sessions for biceps, semitendinosus, and triceps. Biceps muscles in experiment two followed a similar
pattern where MT scores were similar to those at the end. Semitendinosus muscles differed from week 1 to 15 where the highest MT scores were recorded at the start. Triceps muscles tended to be tenser on the left versus right side for MSU horses which was not found in TRC horses. Other muscles could not be compared between experiments at length because of session by time interactions (brachiocephalic, rhomboideus, trapezius, and gluteal), and session by side interactions (biceps).

Both the TRC session and MSU class evaluated in this study had horses with low cortisol concentrations, which is generally associated with more relaxed states. Higher cortisol concentrations at Pre-collections could have been related to unhappiness about being removed from their stalls or pastures. Cortisol concentrations being lowest at the 30 Min collection indicated the work was not overwhelmingly stressful in either experiment or that horses were calmer when they recognized their duty was finished. Most of the horses in this study had been involved in the programs for more than three years; they were familiar with their routines. Studies show that horses adapt to stress and the more experienced they are, the less stressed they became (Budzyńska, 2014).
Chapter Five - Conclusion and Implications

This study showed that changes in subjective muscle tension scores were observed in riding horses for the following muscles: facial, quadriceps femoris, and semitendinosus. A difference also tended to appear between the left and right side for MT scores in quadriceps femoris muscles throughout experiment one. Three-way interactions prevented further investigation in TRC horses for brachiocephalic, rhomboideus, trapezius, gluteal, and biceps femoris, but longissimus dorsi MT was higher at the start of the study than at the end. In contrast, trapezius, longissimus dorsi, and triceps brachii muscles had no changes over time during experiment two, but were observed in all other muscles. Triceps brachii muscles tended to be tenser on the left versus right side in MSU horses. Future studies involving muscle tension could include multiple therapists to investigate possible inter-rater reliability. Evaluating inter- and intra-observer variability is important to confirm the reliability of such measures. Reliability among therapists could strengthen the argument that grading muscle tension is appropriate for welfare discussions. Research into whether scores are affected by massage treatment could replicate findings from human research for equine patients. Using treatment and control groups to evaluate muscle scores changed with interval massage treatments over time would expand research done by Birt et al., (2015). The study showed Flowtrition, a specific style of massage, produced more stereotypic behaviors associated with relaxation and a decrease in heart rate during and after the massage treatments (Birt et al., 2015).
To add to the quality of data in that study, it would be helpful to evaluate muscles using EMG before, and possibly during, evaluation. Overall, efficacy of massage therapy is controversial as studies provide mixed results, but some data suggest supportive evidence is growing (Ernst et al., 2007; Crawford, et al., 2016; Kinkead, et al., 2018). Regardless of the opinions of the scientific community, equine massage therapy is a widely-used type of complementary and alternative medicine (Lange et al., 2017; Thirkell and Hyland, 2017). More research will be needed to confirm whether massage therapists using this subjective scale could improve welfare options for owners looking to treat animals that have symptoms of muscle dysfunction. Their trust in massage therapists as a resource would likely increase if veterinarians directed owners to them as necessary for perceived muscle tension.

Neither disability type nor experience level of University riders affected SCCs in this study, but changes were observed between collection times and over time. Serum cortisol concentrations were highest at Pre-collection time and declined over time with differences observed between Pre and 30 min collections. In contrast, serum cortisol increased over time from the start of each experiment to the end of each riding session and course. Highest cortisol levels were observed in week 8 in experiment one and week 15 for experiment two, which were both different than week 1 in their respective experiments. While there were differences from start to finish, all SCCs were below normal levels of 3 to 10 µg/dL indicating the horses in this study were not physiologically stressed. Further research might benefit from pulling serum cortisol on the day of muscle tension evaluations. Studying horses under higher intensity work might also provide insight into a correlation between muscle tension and serum cortisol as the
horses used in this study were not worked hard enough to increase cortisol levels from pre to post to 30 min post exercise.
Works Cited


Appendix A: Definitions

Abduct – moving a limb away from body’s midline
Adduct – moving a limb toward body’s midline
Cortisol - a steroid hormone (glucocorticoid) produced in the adrenal gland and released in response to stress by the hypothalamus
Detrain - physiologic adaptations occurring as a result of significant inactivity
Epaxial – muscles situated on the dorsal side of the body
Equine Massage Therapist – professional trained to methodically manipulate muscles and other soft tissues on a horse to enhance wellbeing
Hypertonicity – a state of abnormally high muscle tone or tension
Laterality - a preference of using one homologous parts on one lateral side of the body over the other
Muscle Tension - variable tightness of individual muscles
Myofascial Pain - produced by muscular irritation radiating from trigger points throughout muscle tissue
Osteopathy - a drug free, non-invasive form of medicine using a whole-body approach focusing on joints, muscles, and the spine
Palpation – evaluating muscle with varying degrees of digital pressure to determine tonicity and feel for inflammation or pain
Physiotherapist - a professional trained to treat disease, injury, or deformity through physical techniques, such as massage, exercise, and thermotherapy or cryotherapy

Stereotypic Behaviors - repetitive, abnormal behavior pattern without a useful purpose

Stress - emotional strain from pressure or tension exerted by adverse circumstances

Tone/Tonicity - Throughout this article it is measured as muscle elastic or viscoelastic stiffness with contractile activity
## Appendix B

### Muscle Scoring Form

<table>
<thead>
<tr>
<th>Date</th>
<th>Evaluator</th>
<th>Time</th>
<th>Week</th>
<th>Session</th>
<th>Muscle Score</th>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Home</th>
<th>Side</th>
<th>Facial Tension</th>
<th>Brachiocephalic</th>
<th>Rhomboidalis</th>
<th>Trapezius</th>
<th>Triceps</th>
<th>Longissimus</th>
<th>Gluteus</th>
<th>Biceps</th>
<th>Quadriceps</th>
<th>Hamstring</th>
<th>Overall Score</th>
<th>Average</th>
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Figure 1: Muscle evaluation patterns established by a massage therapist numbered 1 through 10.
Figure 2: Muscle evaluation patterns established by a massage therapist numbered 1 through 10.
Figure 3: Muscle evaluation patterns established by a massage therapist numbered 1 through 10.
Figure 4: Muscle evaluation patterns established by a massage therapist numbered 1 through 10.
This appendix includes charts for visual references to data collected during this study.

Figure 1: Therapeutic riding center serum cortisol concentrations by disability type (µg/dL). The disability types included: autism (AU), attention deficit/hyperactivity disorder (ADHD), Asperger’s (AS), mental retardation (MR), sensory processing disorders (SPD), Down’s syndrome (DS), cerebral palsy (CP), other limiting disorders, epilepsy (EP). Disability types were not found to impact serum cortisol concentration levels during two eight-week riding courses.
Figure 2: Average muscle tension scores observed in therapeutic riding horses evaluated over two eight-week riding sessions.
Figure 3: Average serum cortisol concentrations for University horses involved in two beginner-level riding courses were not impacted by riders’ experience level.
Figure 4: Average muscle tension scores for horses used in two University beginner-level, semester-long riding courses.
Figure 5: Average muscle tension scores for riding horses. Therapeutic riding center horses, shown in blue, before and after two eight-week riding sessions. Murray State University horses, shown in yellow, at the start of two semester-long beginner level riding courses (week 1), at week 9, and again in week 15.
Average serum cortisol concentrations for therapeutic riding horses over two eight-week long riding sessions.

Figure 7: Average serum cortisol concentrations for both riding sessions differed between weeks. The lowest concentration was observed in week 1 and was different than concentrations observed in weeks 5 and 8 (1.4863, 1.9035, and 1.9937 µg/dL, respectively; P ≤ 0.0002). Average serum cortisol concentration observed in week 5 was similar to week 8 (1.9035 and 1.9937, respectively; P = 0.4304).

Figure 6: Average serum cortisol concentration differed between collection times. The highest cortisol concentrations were observed in horses before riding began (2.0625) and differed from that observed Post and 30 min after ride ended (P ≤ 0.02).
Average serum cortisol concentrations for Murray State University horses over two semester-long, beginner riding courses.

Figure 8: Average serum cortisol concentrations were highest at Pre-collection time, but were similar to Post-collection time (2.9606 and 2.6880 µg/dL; P = 0.1893). Thirty min after rider dismount, cortisol concentrations declined and differed from Pre and Post concentration (2.1314 µg/dL; P < 0.0079).

Figure 9: Cortisol concentration was highest during week 9 and similar to week 15, (2.9709 µg/dL and 2.9054 µg/dL, respectively; P = 0.7499). Serum cortisol in was lowest in week one and different than both weeks 9 and 15 (1.9039 µg/dL, 2.9709 µg/dL and 2.9054 µg/dL, respectively; P ≤ 0.0001).
Appendix E: IACUC Acceptance Letter

February 13, 2017

Dr. Shea Poir
Animal/Equine Science
Murray State University
Murray, KY 42071

Dear Dr. Poir:

It is with pleasure I inform you that the Murray State University Institutional Animal Care and Use Committee (IACUC) has approved your research protocol, “Evaluation of Behavior and Stress in Horses used in University Equine and Therapeutic Riding Programs.”

The protocol timeline is approved through August 31, 2017. Please use the Animal Use Report (attached) to keep up-to-date information about the animals. At the termination of the protocol, you will need to complete the Conclusion Report (attached) and list final information concerning the animals.

The IACUC sincerely wishes you the best in your teaching pursuits. If you have any questions, please contact me at 270-809-3534.

Sincerely,

Kristi Stockdale
IACUC Coordinator

cc:
IACUC File