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DEPARTMENT OF VETERINARY AND BIOMEDICAL SCIENCES

PAIN RELIEF OF KINESIOLOGY TAPE ON THE THORACOLUMBAR REGION OF EQUINE REHABILITATION PATIENTS

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ABSTRACT

Back pain is a significant cause of loss of performance in equine athletes. To manage back pain, there are both pharmacological and interventional therapy treatment options. Kinesiology tape (KT) is an interventional therapy often used for pain relief and mechanical support in human medicine. In horses, KT is used primarily for analgesic effects. However, there is little to no research to prove the efficacy of kinesiology tape usage for analgesia in horses. The objective of this study was to determine if there is an analgesic effect from kinesiology taping the thoracolumbar region of the horse. It was hypothesized that when compared to a control, the KT would have a greater reduction in pain levels. Nineteen horses of varying breeds received an application of either control tape or KT; after tape removal, horses underwent a washout period of 7 days, followed by the application of the second type of tape. Pressure algometry was used to measure changes in pain levels from a baseline measurement done before each taping, immediately following tape removal, and 24- and 48-hours post-tape removal. A mixed analysis of variance was used to analyze data, with significance set at $P<0.05$. Results revealed a significant improvement ($P<2e-16$) in pain levels for the KT compared to the control regardless of the order of application of control and KT. Significant interactions ($P<0.05$) were found between the order of treatments and the type of treatment, and between the time measurements were taken and the treatment. There is a possible impact of the confounding variables of desensitization or sensitization to the pressure algometer. Further research is necessary to investigate the longevity and mechanism of the analgesic effect of KT. Although the findings are preliminary, these results suggest that KT may be an additional tool to help treat thoracolumbar pain in the equine athlete.

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Chapter 1

Literature Review

1.1 Back Pain in the Horse

Back pain is a significant cause of loss of performance in equine athletes. The International Association for the Study of Pain definition of pain is “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”.[1] It can manifest as acute or chronic which can lead to poor performance, lameness, and behavioral changes.[2] It is common to find pain in the lumbar region of the spine of horses that participate in events such as reining, cutting, barrel racing, and roping cue to the demand for high speed with abrupt stops and changes in direction in these events. However, horses suffering from back pain are still found throughout the horse industry, encompassing all disciplines in both Western and English style sports.[3] Depending on the specialty and type of veterinary practice surveyed, reports of the prevalence of equine back pain range from 0.9 to 94%.[4] Even though there is limited research on the impact of back pain, it is expected to have significant welfare and economic impacts on the horse industry.

Back pain can be classified as primary or secondary. Primary back pain is the anatomical point where the pain is being caused, whereas secondary back pain is when the pain has manifested due to some other ailment in a different region of the body—such as a limb lameness (Table 1).[5]

Type of back pain	General category	Specific problem
Primary back pain	Soft tissue injury	Muscle strain
		Ligament sprain
		Exertional rhabdomyolysis
		Non-specific soft tissue injury
	Osseous injury	Conformational abnormality
		Osteoarthritis
		Vertebral fracture
	Tack associated	Poor saddle fit or excessive pressure
Secondary back pain		Lameness (forelimb or hindlimb)
		Neck problems
		Sacroiliac injury
		Pelvic fracture

Table 1. Differential diagnoses for horses with back problems.
Adapted from: LB Jeffcott, KK Haussler. Back and pelvis. KW Hinchcliff, AJ Kaneps, RJ Geor (eds). Equine sports medicine and surgery (1st edition), Vol. 1, WB Suanders Philadelphia, PA (2004), pp. 433-474.

1.2 Anatomy of the Equine Back

The vertebral column of the horse includes osseous structures for structural support, spinal musculature for complex movements, and spinal ligaments for stability of the vertebral column.[6] The portion of the vertebral column that consists of the back of the horse starts with the more cranial thoracic region, and ends with the more caudal lumbar region. Together, this portion of the vertebrae is known as the thoracolumbar region.

The skeleton of the horse can be divided into the axial and appendicular skeleton. The axial skeleton consists of the skull, vertebrae, ribs, and sternum, while the appendicular skeleton includes the shoulder, limbs, and pelvis. The osseous structures of the vertebral column are composed of the vertebrae. The thoracic region is made up of 18 vertebrae, each of which attaches to a set of ribs. The lumbar region consists of six vertebrae which run from the end of the ribs to the start of the pelvis (Figure 1). The lumbosacral junction is where maximal intervertebral motion in the back occurs.[7]

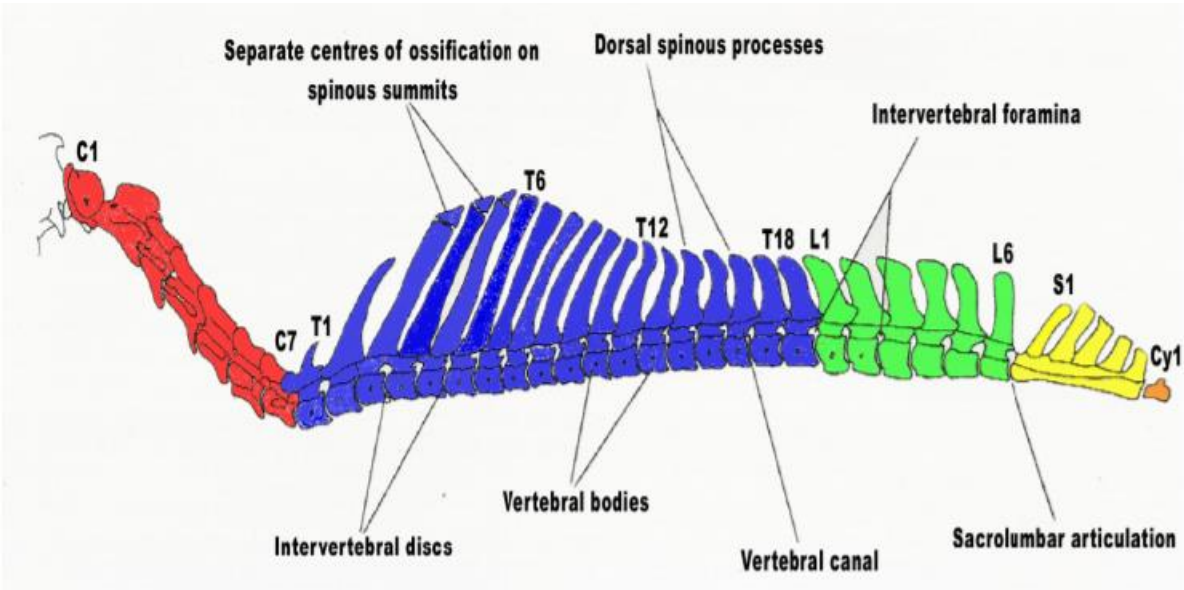


Figure 1. Regions of the equine vertebral column. Thoracic vertebrae (T) are blue and lumbar vertebrae (L) are green.
Retrieved from: LB Jeffcott, G Dalin. Natural rigidity of the horse's backbone. Equine Veterinary Journal, 12 (3) (1980), pp. 101-108.

The muscles of the vertebral column can be classified as intrinsic or extrinsic spinal muscles. Intrinsic spinal muscles only attach to the axial skeleton, with the largest group including the iliocostalis, longissimus, and spinalis muscle groups (Figure 2).[6] The iliocostalis muscles attach the angle of the ribs to the tips of the lumbar transverse processes. The longissimus muscles (the largest and longest group of back muscles) attach to the dorsal spinous and transverse processes in the thoracolumbar region and the wing of the ilium—they are important in supporting the weight of a rider and saddle.[6] The spinalis muscles cover the spinous processes of the withers.

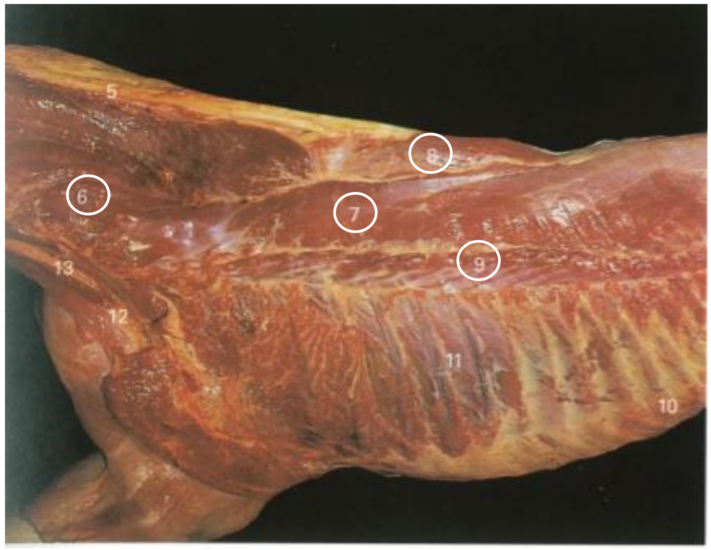


Figure 2. Deep dissection of the thoracic wall of a foal, lateral view, showing the intrinsic spinal muscles: iliocastilis (9), longissimus muscles (6,7), and spinalis (8).
Retrieved from: H Clayton, P Flood, D Rosenstein. Clinical anatomy of the horse. (1st edition) Elsevier Ltd, London (2005), pp. 32.

Extrinsic spinal muscles have attachments on the axial skeleton as well as the proximal limbs with the general functions of inducing proximal limb motions or assisting vertebral mobility. These can be broadly grouped into muscles of the shoulder girdle, which suspend the forelimbs from both the neck and the trunk, and the pelvic girdle muscles that attach to the hindlimbs. The shoulder girdle muscles that attach to the thoracolumbar spine include the trapezius, rhomboideus, cutaneous trunci, latissimus dorsi, subclavius, and the thoracic serratus ventralis (Figure 3).[8] The pelvic girdle muscle that attaches to the thoracolumbar spine is the iliopsoas.[8]

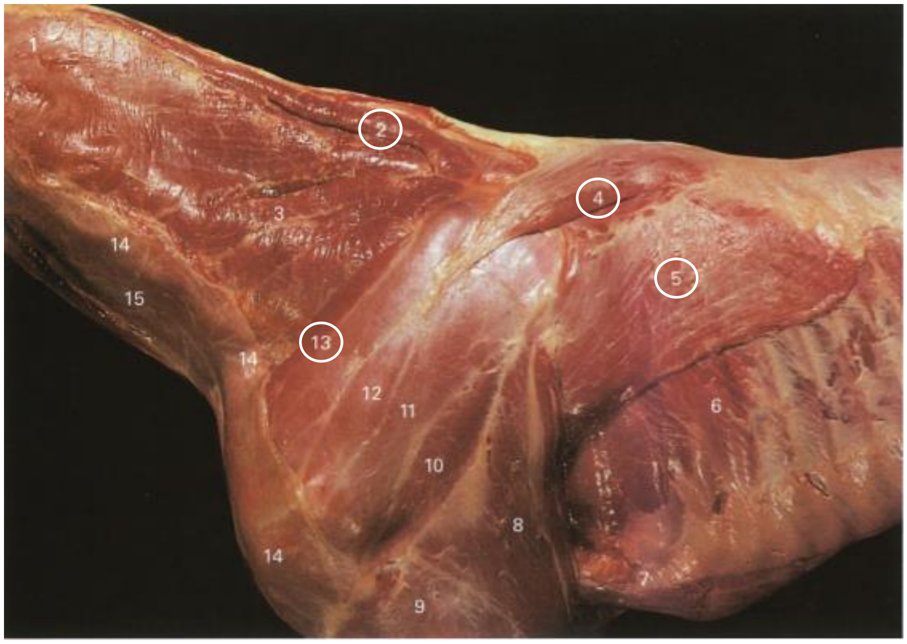


Figure 3. Superficial dissection of the musculature of the shoulder and thoracic wall of a foal, lateral view, showing the extrinsic spinal muscles of the shoulder girdle: trapezius (4), rhomboideus (2), latissimus dorsi (5), and subclavius (13).
Retrieved from: H Clayton, P Flood, D Rosenstein. Clinical anatomy of the horse. (1st edition) Elsevier Ltd, London (2005), pp. 33.

The ligament that provides stability to the thoracolumbar spine is the supraspinous ligament, a continuation of the nuchal ligament from the cervical vertebral region.[6] Additionally, there are dorsal and ventral longitudinal ligaments that reinforce the intervertebral disks as well as short spinal ligaments for segmental vertebral stability and inter spinous ligaments which connect adjacent spinous processes.[9]

1.3 The Physiology of Pain

The perception of pain depends upon the differential processing of stimuli by various and specialized neural pathways.[10] A potentially damaging or noxious stimulus, whether it be chemical, thermal, or mechanical, is received by sensory receptors specific to pain called nociceptors that transduce and encode that stimulus.[11] Normally, acute pain is essential and plays a protective role, alerting the animal to a potentially damaging stimuli and allowing them to react in a manner that will minimize the effects of the stimulus.[12] However, clinical pain is considered truly pathologic with no benefit to the patient. Clinical pain is typically chronic and can include damage to the nervous system, so it is also known as neuropathic pain.[12]

The first step in the pain pathway is the identification of a stimulus by nociceptors on the primary sensory neurons. The primary sensory neuron is a highly specialized receptive neuron that has terminals located in peripheral tissues and relays sensory input from the tissues to the dorsal horn of the spinal cord. These neurons transduce the chemical, thermal, or mechanical stimulus from the nociceptors into action potentials that can then be projected through ascending pathways into the dorsal root ganglia, through the spinal cord, and into the higher brain centers of the animal.[10]

The dorsal horn is regulated by various excitatory and inhibitory receptors (primarily glutamate, GABAergic, and glycinergic receptors), which act as nociceptive pathway neuropeptides.[13] The transmission through the spinal cord is then controlled by intrinsic neurons and other regulators from the brain.[14]

Once the action potential reaches the brain it is processed in multiple regions. The somatosensory cortices are associated with the perception of the pain and the cerebellum is associated with the responses to the stimulation. Once a response to the noxious stimulus is determined, it is then transmitted to the area of pain via a descending pathway.[15,16] The descending pathways transmit motor control and responses from the brain to the body. Those that are associated with the pain response are classified as inhibitory and transmit the signal from the brain to the peripheral tissues. They can be modulated by the concentrations of various compounds, including endogenous opioids, neurotensin, acetylcholine, cholecystokinin, serotonin, alpha-2-adrenergic agonists, and cannabinoids.[17]

Due to the neural and local effects at the site of the injury, an upregulation of vasoactive compounds and neuropeptides will occur[18], stimulating epidermal and immune cells, leading to vasodilation, plasma extravasation, and smooth muscle contraction.[10] In the case of acute pain, there is tissue healing and termination of nociception that results in the end of the pain process. However, in chronic pain there is no termination of nociception and altered neurophysiology, which then causes persistent and chronic pain.[19] This chronic pain can then lead to welfare issues and economic losses in the equine industry leading to a need for the management of the pain.

1.4 Assessment of Pain

Assessing pain in the horse is difficult as objective assessments are rare and techniques used in human medicine rarely translate well to the horse.[10,20] There are a variety of subjective assessments that are commonly utilized in the horse, including behavioral changes, physical examinations with diagnostic palpation, and semi-objective lameness examinations among others.[5] Radiographs are not commonly used as the pathologic findings identified, if any, rarely correlate with the clinical findings.[21]

One objective way to measure musculoskeletal pain is through a pressure algometer that determines the mechanical nociceptive threshold (MNT)—the amount of applied pressure necessary to produce pain.[20] A pressure algometer has a gauge that measures the amount of pressure (in lb/cm^2) applied with a 1 cm^2 rubber plunger tip. Pressure is applied perpendicularly over a site for approximately 2-3 seconds until a local avoidance reaction is noted. The pressure algometer values have an inverse relationship with pain levels—larger values recorded on the pressure algometer indicate lower pain levels as the horse can tolerate greater amounts of pressure before demonstrating a local avoidance reaction. Smaller values indicate a greater amount of pain at the site of pressure. Pressure algometry has been shown to provide valid and reliable measures of MNT and is used increasingly in research studies that investigate pain and has been suggested for application in the clinical evaluation of pain in the axial skeleton.[22, 23, 24]

1.5 Pharmacologic Treatment of Pain

There are a variety of pharmacologic options that can be used to treat back pain. Pharmacologic options are commonly used in equine medicine, ranging from every day oral administration to intra-articular injections on a more annual basis. These are often the preferred methods for treating back pain in the horse and are often used in tandem with other types of therapy. Pharmacologic options most often utilized in medicine include nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids, and gabapentin.[10]

NSAIDs

The NSAIDs legal for use in the United States include phenylbutazone, flunixin meglumine, firocoxib, ketoprofen, aspirin, and diclofenac.[10] Phenylbutazone is the most common NSAID used and is administered orally. Additionally, NSAIDs can also be used via intravenous routes. They create an anti-inflammatory effect by inhibiting cyclooxygenase and thus reducing the concentration of prostaglandins, while also dampening the peripheral sensitization.[10] Prostaglandins, produced by cyclooxygenase, are considered sensitizing agents that can reduce the nociceptive threshold and cause tenderness, thus a reduction in concentration will lead to analgesia.[25] Analgesic efficacy of NSAIDs alone or in combination with other pharmacologic agents in horses has been reported.[26, 27] There can be adverse effects from the use of NSAIDs in horses, including nephrotoxicity, hepatotoxicity, and gastrointestinal tract ulceration (the last most commonly in foals).[10]

Corticosteroids

Corticosteroids, such as triamcinolone and methylprednisolone, are administered intra-articularly to reduce inflammation by inhibition of phospholipase A_2 (a compound that releases arachidonic acid—an important precursor of inflammatory mediators).[10, 28] When used correctly, these drugs are effective in management of pain, but there are serious adverse effects that need to be considered. Laminitis,[29] immunosuppression, and systemically reduced glycosaminoglycan concentrations in joints,[30] can all occur with intra-articular injection of corticosteroids.

Gabapentin

Gabapentin is an anticonvulsant drug administered orally that is used in the treatment of neuropathic pain in human and small animal patients. The exact method of analgesia is not known. In the horse it is rapidly absorbed, and although there is limited experience in horses, there have been reports of possible benefits.[10] There are no known side effects in the horse.

1.5 Interventional Therapy Treatment of Pain

Interventional therapy is a broad term that encompasses a variety of treatments that do not require pharmacological options for analgesic effects. Due to recent advances in sports medicine research in both the human and equine field, interventional therapies are becoming much more common.[10] These include, but are not limited to, manual therapy, acupuncture, therapeutic ultrasound, transcutaneous electrical nerve stimulation (TENS), shockwave, laser therapy, and kinesiotaping. Although these therapies are commonly used with clinically perceived effects, many are still lacking documented scientific basis for treatment in the horse.

Manual Therapy

Manual therapy exercises are specific to the function of the injured tissue and result in pain modulation in addition to proprioceptive and motor retraining.[31] Modalities that fall into the broad group of manual therapy include chiropractic, massage, physiotherapy, and therapeutic exercises such as hand walking, hill work, and walking over poles.

Chiropractic

Chiropractic treatment of the back includes high-velocity yet low-amplitude thrusts along the spine to restore proper mobility and function of the joints between the vertebrae.[32] It has been shown to reduce spinal pain in horses.[23] In one study there was a 27% increase in MNTs for up to 7 days when compared with a baseline in a clinical trial that compared changes in MNTs in response to pharmacologic and nonpharmacologic therapies.[33] Although influences on biomechanical, neurologic, physiologic, and psychological mechanisms have been proposed,[34] the exact analgesic mechanism is not well known.

Massage

Tissue manipulation through massage induces changes in neurologic signaling that relate to pain processing and motor control[35] and upregulates the signaling within large-diameter nerve fibers which provides inhibition of the ascending nociceptive signals.[36] Clinical observations have shown an improvement in pain after massage[10] and studies have demonstrated an increase in MNTs along the thoracolumbar region.[33] Massage can improve the blood flow and viability of damaged tissue, thus reducing the pain.[37]Physiotherapy

Physiotherapy is characterized by passive or assisted active movements utilized to aid impairments found in various systems such as the muscular, neural, and articular systems.[35]

Many of these movements reproduce the movements of the joint that could be carried out voluntarily by the horse, such as flexion of the neck and lateral movement of the spine. While the specific method for analgesia is not known, ongoing research suggests that it produces hypoalgesia by activating afferent neurons and stimulating neural inhibitory systems at multiple levels along the spine.[38]

Therapeutic Exercises

Therapeutic exercises can include those such as hand walking, backing, hill work, and walking over poles, all with the aim of returning the bones and associated soft tissues to their normal physical capacity. Although there are analgesic effects of therapeutic exercise[31] after an injury, alternative measures for pain control may also be required to ensure the exercises are executed in a correct and optimal manner.[10]

Acupuncture

Acupuncture treats pain through the release of locally active neuropeptides. These neuropeptides initiate a systemic analgesic response that is then mediated by endogenous opioid peptides, dopamine, serotonin, and norepinephrine once the needle is placed.[39] In the horse, increased concentrations of endogenous opioids in plasma and cerebrospinal fluid following acupuncture treatment have been documented.[40] Electroacupuncture has also been shown to resolve chronic thoracolumbar spine pain in horses in a series of three treatments.[41]

Therapeutic ultrasound

Use of therapeutic ultrasound in the horse is increasing in popularity as studies in human and small animals have shown beneficial treatment effects.[10] Ultrasound waves produce both thermal and nonthermal effects on tissues, which is theorized to improve local circulation, enhancing collagen extensibility, reducing muscle spasm, and increasing cell membrane permeability.[42, 43]

Transcutaneous Electrical Nerve Stimulation (TENS)

Electrotherapy has analgesic effects through the transduction of electrical current into the body to depolarize sensory neurons and thus suppress pain.[42] Although the analgesic efficacy is variable, it has been demonstrated in humans to provide beneficial short-term relief from chronic pain. It is used in the horse with similar perceived effects, but the scientific basis for treatment is undocumented.[10]

Shockwave

Extracorporeal shockwave applies shockwaves to areas of pain to promote revascularization and stimulate the healing process of connective tissues.[44] In humans, extracorporeal shockwave therapy has been successful at reducing chronic low back pain.[44] In horses, shockwave therapy has been shown to have modifying effects in induced carpal osteoarthritis models with short-term analgesic effect and a longer duration of improvements in lameness score and range of motion.[45]

Laser therapy

Laser therapy includes the application of low-level wavelengths with various laser modes (continuous or pulsed), power levels, power density, and energy levels. In humans, when the recommended low-level laser therapy guidelines were followed, a positive analgesic effect on osteoarthritis was seen.[46] In horses there are low-level laser therapy protocols for muscle soreness, osteoarthritis, treatment of wounds, tendinitis, and desmitis.[10]

Kinesiotaping

Kinesiology tape (KT) techniques were developed in the 1970s by chiropractor Dr. Kenso Kase.[47] Kinesiology tape is an elastic therapeutic tape that has been used in the treatment of sports injuries and for relieving pain in humans and is being used increasingly in horses. It can be applied almost anywhere on the body with various levels of tension to facilitate release of pressure and increased lymphatic flow. In humans it is used in the treatment of various neuro-musculoskeletal disorders and sports injuries and can improve muscle strength and activity, range of motion, force sensing, scar healing, lymphatic flow, and reduce pain.[48,49,50,51,52,53,54,55]

Although the specific analgesic mechanism for KT is not known, there are some proposed processes. Taping provides release of pressure on tissues from the skin and increases space for the movement of lymphatic fluid, which in turn also releases the pressure on tissues.[56] It is also proposed that KT provides consistent mechanical stimulation which will downregulate the nociceptive transmission.[57] While there is increasing research on kinesiology tape in humans, its use and effect in horses has not been studied.

The purpose of this study was to investigate if there is an analgesic component to kinesiology taping the thoracolumbar region of the horse. It is hypothesized that that when compared to a control, the kinesiology tape will have a greater reduction in pain levels.

Chapter 2

Pain Relief of Kinesiology Tape on the Thoracolumbar Region of Equine Rehabilitation Patients

2.1 Materials and Methods

2.1.1 Horses

This study was performed in accordance with Colorado State University's Animal Care and Use Committee recommendations and all horses were enrolled in the study with client consent. This study started with 6 horses at the Colorado State University (CSU) Veterinary Teaching Hospital Equine Rehabilitation Center but was broadened to include an additional 16 horses from barns in the surrounding Fort Collins area for a total of 22 horses. The horses included 5 mares and 17 geldings with a median age of 10.55 ± 6.54 years. The breeds included 15 Warmbloods, 4 Thoroughbreds, 1 Irish Sport Horse, 1 Andalusian Thoroughbred cross, and 1 Quarter Horse. Of the 22 horses in the trial, 9 horses were in rehabilitation for various limb associated lameness (but were previously training for eventing, dressage, or trail), 11 horses were in full training for either dressage or eventing, 1 horse was semi-retired from dressage, and 1 horse was fully retired from eventing. The 6 horses from CSU were measured and treated at the CSU Rehab Center, while the 16 horses from other barns were measured and treated at their own barn.

Nineteen of the 22 horses completed the experiment in full. Of the three that did not complete the full experiment, one horse only received the KT treatment before leaving the rehab center, and two other horses received complete KT treatment values but only partial control values; one due to leaving the barn and the other due to colic.

2.1.2 Experimental Procedure- Pressure Algometry

All horses were restrained quietly with a halter in their stall. A pressure algometer (Model FDK 40, Wagner Instruments Inc., Greenwich, Connecticut, USA) with a 1 cm^2 rubber plunger tip and calibrated to range 0-44 lb/cm^2 was used to determine MNTs. Pressure was applied perpendicularly over predetermined sites at approximately 20 $lb/cm^2/sec$ over 2-3 seconds until a local avoidance reaction was noted. Pressure was immediately stopped once the reaction was noted and the corresponding value was recorded. A local avoidance reaction was defined as any of the following actions: skin twitching, local muscular contractions, or stepping away. The examiner did not view the readings during application of the pressure to limit any potential bias. The instrument automatically recorded the highest pressure applied and once the value was recorded it was reset to zero after each measurement. Three consecutive measurements at each site at 3-4 second intervals apart were recorded and the average of the three was determined and used as the site-specific MNT for that set of measurements for that horse. Each measurement session lasted approximately 10-15 minutes. A single examiner (H.P.) performed all measurements to limit variability in pressure applied. Horses were done at varying times throughout the day.

Pressure algometry was used at 5 sites on the right and left side of the back. The sites for these were thoracic vertebrae 14 and 16, and lumbar vertebrae 1, 3, and 6 (Figure 4). Each site was found via palpation and then marked with a dot of white out to ensure each measurement was done at the exact site each time. The pressure was applied 4 in laterally from the apices of the dorsal spinous processes at each site. All sites were tested in a cranial-to-caudal order starting on the left side and ending on the right side. Bilateral site comparisons were also used to determine whether bilateral MNTs could be pooled into a combined median value for each site.

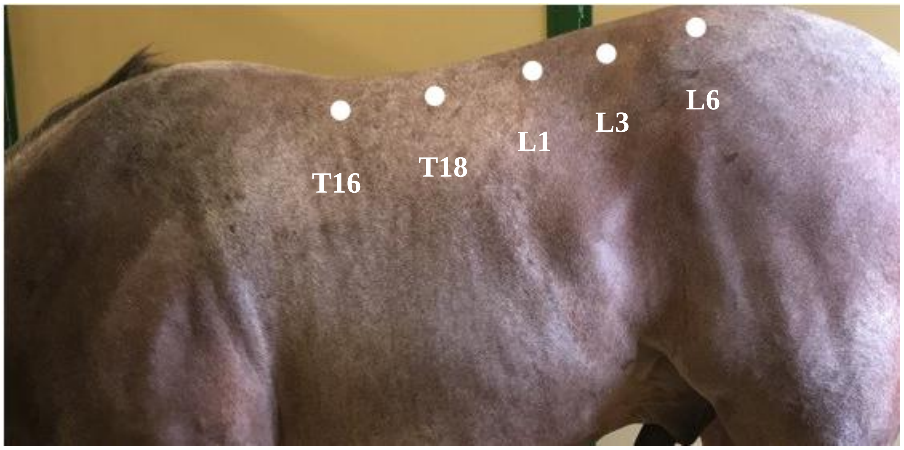


Figure 4. Location of sites for measurements on the left- these same sites will also be measured on the right side of the horse's back.

In order to assess repeatability, the examiner did three complete sets of measurements on a one horse within a day. This was used to determine the intra-day variability of the examiner. Additionally, 1 measurement per day for 5 days was done on the same horse to determine the intra-day variability of the examiner. This horse was then washed out for seven days before being used in the trial.

2.1.3 Experimental Procedure- Taping

Each horse acted as its own control—receiving both kinesiology tape (KT) and a control tape. The KT used was 2 in Equine Rock Tape® while the control was 2 in Johnson & Johnson® White Zonas Porous Adhesive Tape. Horses were randomly assigned to either order 1 or order 2 with a 7-day washout period between tape applications (Figure 7b). Order 1 was receiving the control tape application first followed by KT application and order 2 was receiving the KT application first followed by the control tape application.

A complete set of pressure algometry measurements were conducted before any tape was applied to determine the baseline for that horse. Since this was done before each type of tape was applied, each horse had 2 separate baselines to compare post-taping results (of KT or control tape) to the corresponding baseline. Tape was then immediately applied to the back of the horse. All taping was done by a veterinarian.

Treatment Tape- KT

Each horse was taped following the same protocol. The back of the horse was brushed off and cleaned of dirt and debris before application. Before application of the tape, the edges of each piece of tape were rounded to allow them to stick better. A strip of tape was first placed dorsally along the center of the back, starting from the withers and ending at the sacroiliac joint. This was applied with no tension in order to act as an anchor for subsequent pieces of tape. All tape that was applied to the back was then rubbed in order to activate the adhesive. A series of 5-7 pieces of tape (depending on the size of the horse and thus the length of the back) were then placed laterally across the back spanning the width of the epaxial muscles (Figure 5). These were placed in identical manners to each other and spaced uniformly 4 in apart from each other. The first of these was started 4 in from the top of the anchor strip of tape. The protective backing was removed from the middle of the strip to attach it to the anchor strip, and then it was placed one side at a time by applying 30% tension down the strip until only 1-2 in of tape remained. The remaining 1-2 in of tape was then applied to the back with no tension. This portion of tape was then rubbed with a flat hand to activate the adhesive and the same procedure was used on the opposite side of that piece of tape. This was then repeated for the remaining pieces of tape. There was no set time limit for the tape to remain on the back, thus the time the tape stayed on varied from horse to horse (2-7 days).

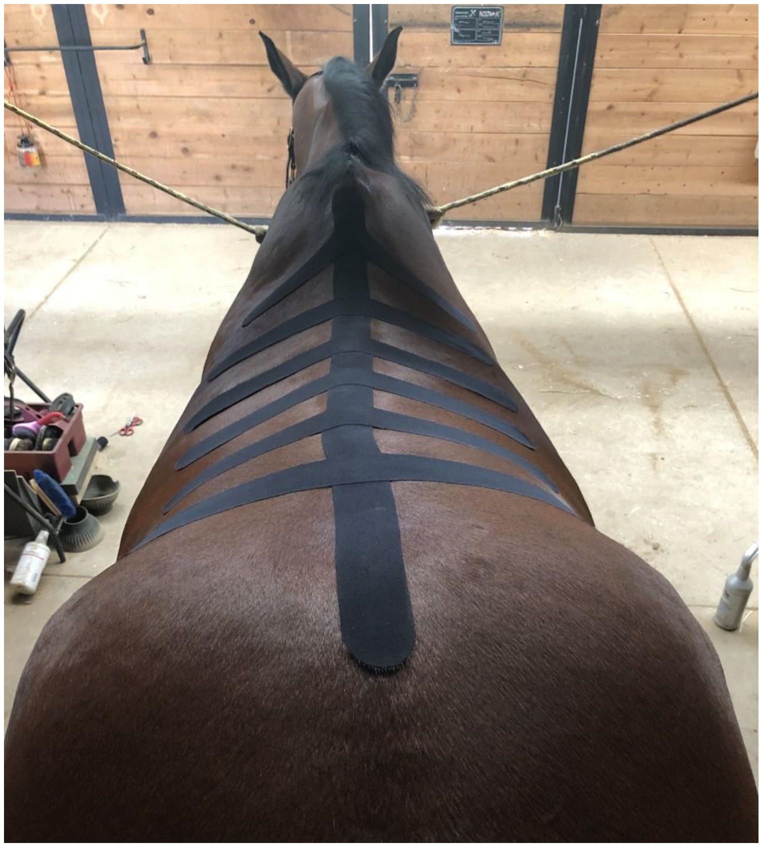


Figure 5. Placement of the KT including the dorsal anchor piece and 6 lateral strips.

Control Tape- White Tape

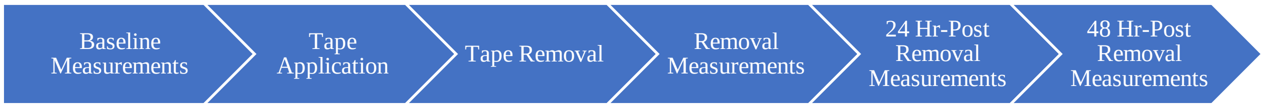
The control tape was applied in an almost identical manner but there were a few inherent differences. The white tape has no elasticity to it, which is why it was chosen as a control tape. It cannot be stretched like the KT, so the lateral pieces could not be applied with any tension. Additionally, as the tape does not come with a protective backing it could not be applied in the exact manner of one side at a time but it was applied as similarly as possible (Figure 6). All of the tape was rubbed in the same way as with the KT tape. The control tape stayed on the back of each horse for approximately 24 hours.

Figure 6. Placement of the control tape including the dorsal anchor piece and 5 lateral strips.

2.1.4 Experimental Procedure- Additional Measurements

Three additional complete sets of MNT measurements were taken for each taping procedure. Tape was then removed and discarded. Once the tape was completely removed a “tape removal” set of MNT measurements was done. Two more complete sets of MNT measurements were taken in the next 2 days, one for 24 hours post tape removal and one for 48 hours post tape removal, to determine the longevity of any affect the tape may have had (Figure 7a).

7a.



7b.

Figure 7. a. Timeline of a horse through a single application of tape (control or KT), indicating when measurements were taken. b. Timeline of a single horse through an order in the experiment. The first tape application was either control tape or KT and the second tape application was then the one that was not done for the first application.

2.1.5 Mixed ANOVA Analysis

Impact on pain levels with control tape versus KT was examined using a mixed analysis of variance for repeated measures for each site on the back (RStudio version 3.6.1, RStudio Inc., Boston, MA). The model included the effects of treatment type, order of treatments, left or right side of the back, and time (time represents the time post tape removal) as well as all interactions. Horse was included as a random effect. Effects were measured in percent difference from the baseline measurement pre-tape application for each treatment. Interactions were examined at the highest order. The mixed analysis of variance for repeated measures was run again within each order of treatment at each site to determine the significance levels of any interactions. Statistical significance was set at $P<0.05$.

2.2 Results

2.2.1 Improvement in Pain Levels with Kinesiology Tape in Comparison to Control

A total of 19 horses completed tests with both the control tape and KT. When looking at each individual horse, the percent difference found with the pressure algometer did not have a significant difference ($P>0.05$) from left to right side for any horse, so the results for each side were pooled. The post-tape removal measurements were compared to the baseline and a percent difference for each site was determined (Figure 8). A significant difference ($P<2e-16$) when comparing the percent difference of control to its baseline and then KT to its baseline was found at each site. The KT values ranged from 15-26% difference from baseline while the control values ranged from -4% to 8% difference from baseline. The KT values 24 hours post-tape removal were the highest of any value (control and KT), ranging from 19-26% difference ($P<0.05$). The control tape values 48 hours post-tape removal were the highest of the control values, ranging from 1-8% difference ($P<0.05$). The lowest value for the experiment was the control tape removal, which ranged from -4% to 1% difference from baseline ($P<0.05$).

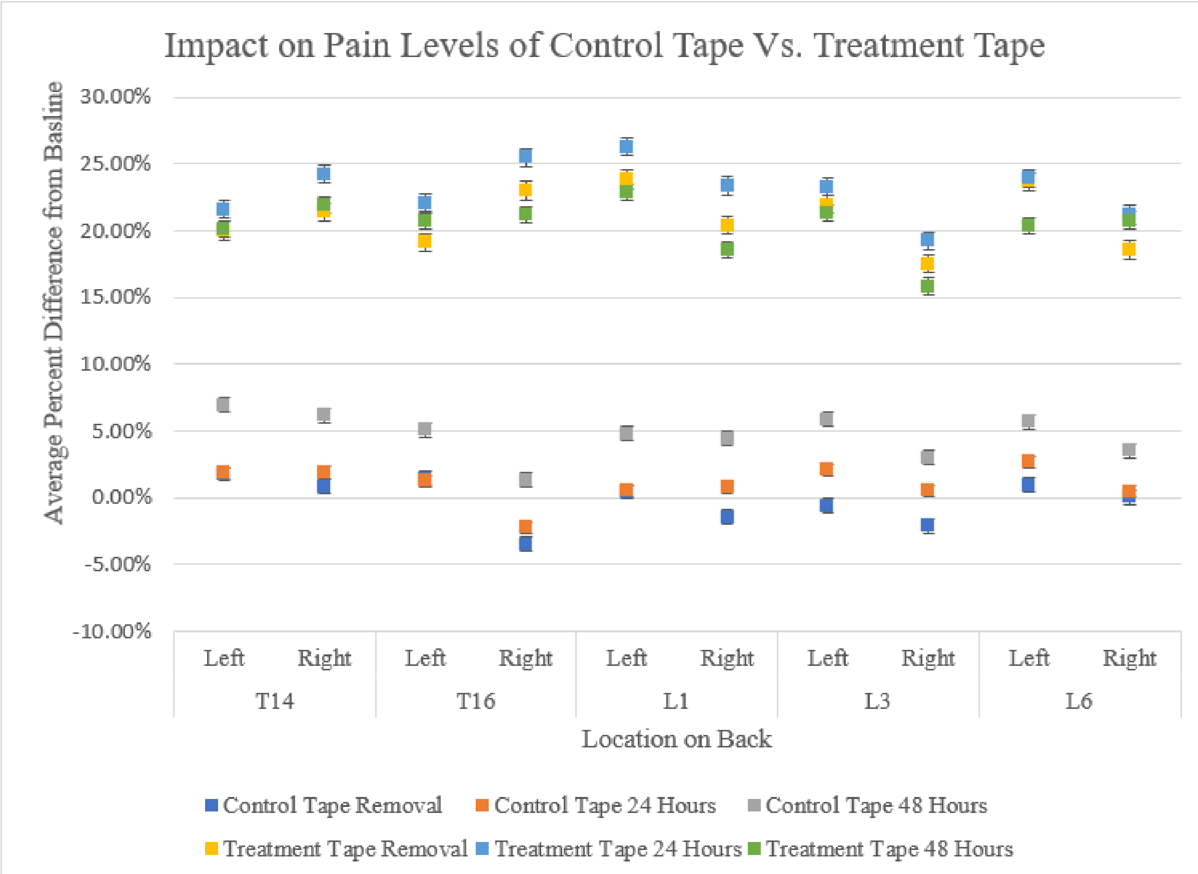
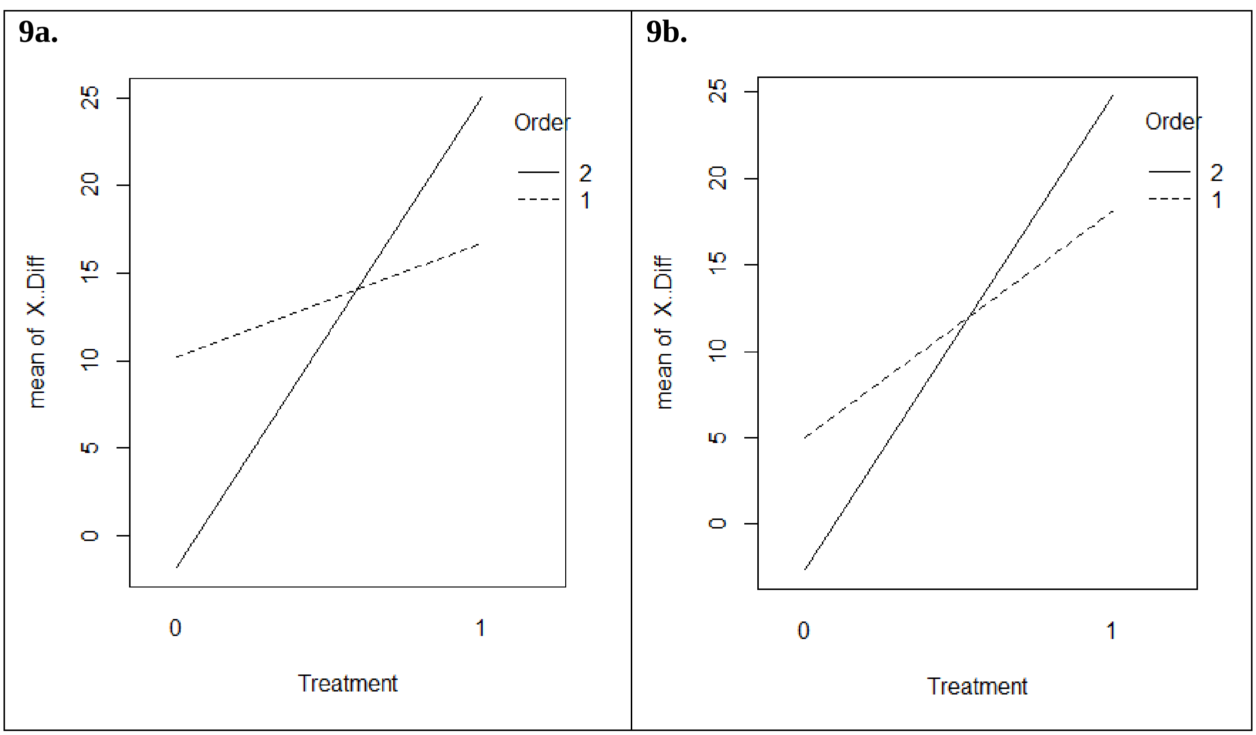


Figure 8. Average of all horses' measurements at each site for both control and treatment tape (KT). KT values ranged from a positive 15-26% increase from the baseline measurements across the back on both the left and right. Control tape values ranged from a -4% decrease to a positive 8% increase from the baseline measurements. On average, the KT values 24-hours post-tape removal (light blue) were about 1-3% higher than the removal (yellow) and 1-5% higher than the 48 hour post-tape removal (green) values (P<0.05). The control tape values 48 hours post-tape removal (grey) were between 2-5% higher than the removal (dark blue) and 24 hours post-tape removal (orange) values (P<0.05).

The order of treatments and time post-tape removal both had significant interaction (P<0.05) with the type of treatment. No significant difference in the percent change from baseline with either control or KT was found between the post-tape removal measurements for all sites except T16 (P=0.0417).

2.2.2 Interaction Between the Order of Treatments and Improvement in Pain Levels

Each site measured had a significant interaction (P<0.05) between the order of treatments and the treatment itself. An interaction plot was created for each site (Figure 9). If there was no interaction, the lines for order 1 and 2 would be parallel with no intercept. If there was an interaction the lines would intercept, which was the case at each site, and the closer the lines were to perpendicular the stronger the interaction. Overall values for KT, regardless of order, were still higher than for control tape despite the interaction between order and treatment. For each site, the KT values were higher for order 2 than for order 1 (P<0.05). For each site, the control values were higher for order 1 than for order 2 (P<0.05). While a significant difference (P<0.05) was still found for the percent difference from baseline for the kinesiology tape when compared to the control, there was greater significance (P<2e-16) when kinesiology tape was the first applied versus when the control tape was the first applied (Table 2).



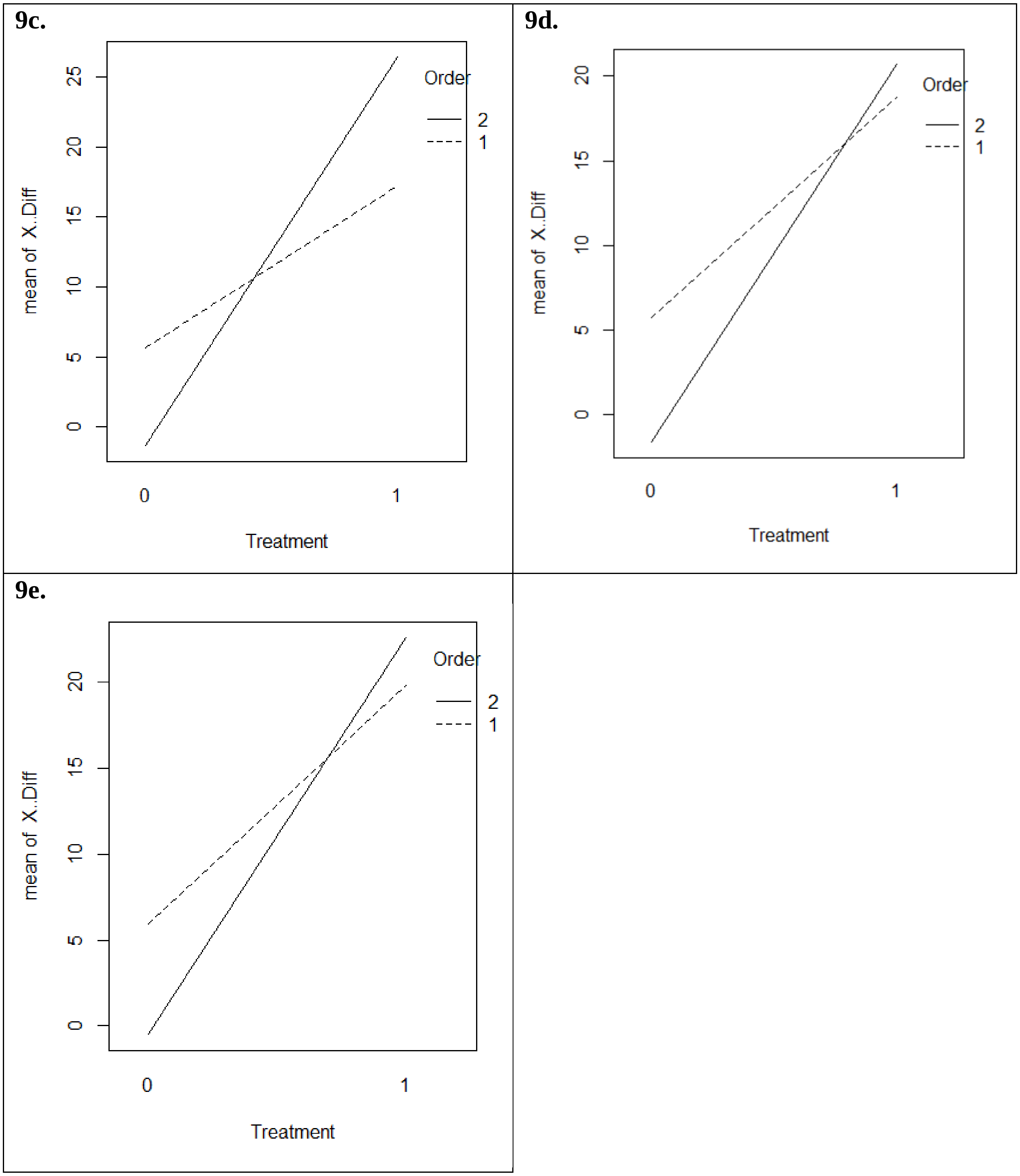


Figure 9. Interaction plots of the type of treatment and the order of treatment for a. T14; b. T16; c. L1; d. L3; and e. L6. Treatment 0 refers to control; treatment 1 refers to kinesiology tape. Order 1 (dashed line) is control tape first then kinesiology tape; order 2 (solid line) is kinesiology tape first then control tape. Mean of X..Diff refers to percent difference from baseline. The closer the lines are to parallel, the weaker the interaction. The closer the lines are to perpendicular, the stronger the interaction.

Site	Order	P-Value for Treatment:Order
T14	1	0.00983
	2	<2e-16
T16	1	1.57e-11
	2	<2e-16
L1	1	3.83e-09
	2	<2e-16
L3	1	1.46e-10
	2	<2e-16
L6	1	3.51e-10
	2	<2e-16

Table 2. P-values for the interaction between treatment and order at each site analyzed within each order. Order 1 is control tape first then KT; order 2 is KT first then control tape. The P-values at each site for order 2 were much smaller than the P-values for order 1.

2.2.3 Interaction Between Time and Improvement in Pain Levels

A significant interaction (P=0.0373) between the time post-tape and the treatment was found at one of the five sites: L3. At T16, time had a significant impact on the percent difference from baseline (P=0.0417), but there was no significant interaction (P>0.05) between treatment and time. An interaction plot was made for L3 (Figure 10). At each time point the values for KT were higher than for control (P<0.05). The values for KT ranged from 18-21% while the values for control tape ranged from -2% to 5%. The values for the control tape increased by about 3% between each measurement post-tape removal post-tape removal. The values for KT increased by about 1% from tape removal to 24 hours post-tape removal and then decreased by about 3%

from 24 hours post-tape removal to 48 hours post-tape removal. A significance (P=0.0373) was found with time only within order 1:control tape followed by KT (Table 3).

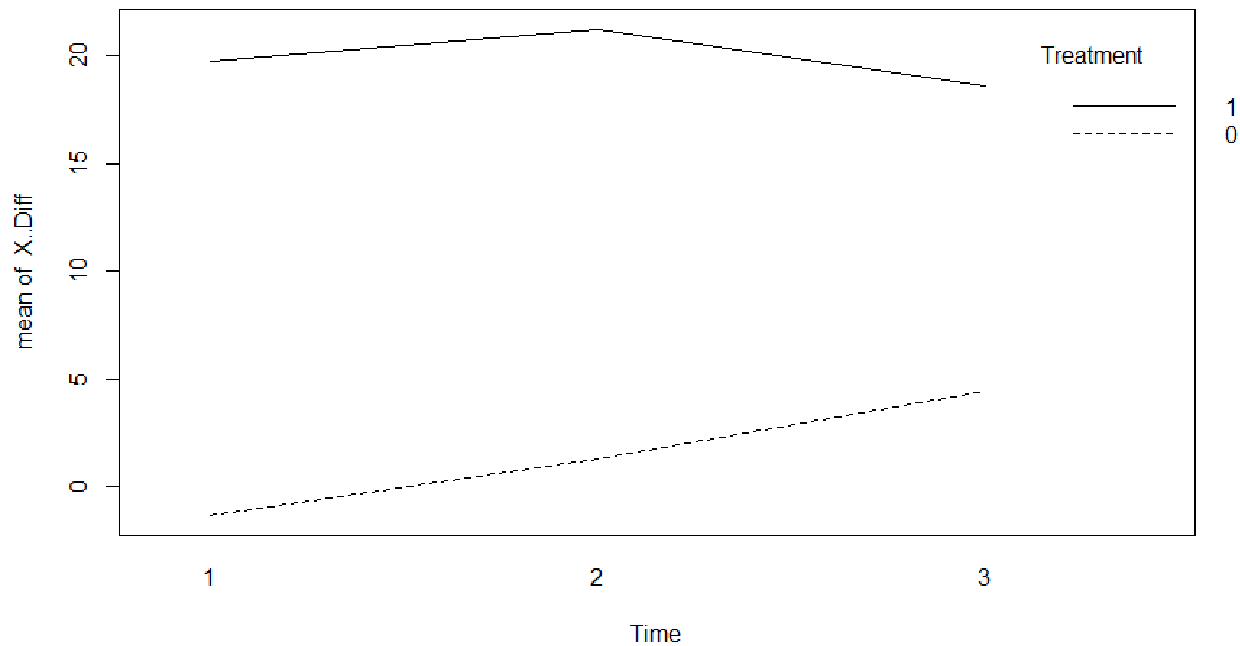


Figure 10. Interaction plot between the time post-tape removal and the type of treatment for L3. Time 1 is immediately following tape removal; time 2 is 24 hours post-tape removal; and time 3 is 48 hours post-tape removal. Treatment 0 (dashed line) is the control tape; treatment 1 (solid line) is the kinesiology tape. Mean of X..Diff is percent difference from baseline. Control values were lower at each time point than KT values, but increased with increasing time post-tape removal from around -2% to 5%. The values for KT remained in the 18-21% range across each time point.

Site	Order	P-Value for Treatment:Time
L3	1	0.0373
	2	0.251

Table 3. P-values for the interaction between the type of treatment and the time post-tape removal at L3. A significant value was reported for order 1—control tape first—but not for order 2.

2.3 Discussion

Back pain is a major welfare and economic issue for horses. At this time, there are no other equine studies that have studied the use of kinesiology tape for the management of back pain. The current study was conducted to evaluate the analgesic effect of kinesiology tape on the thoracolumbar region of the equine back when compared to a control tape. Results showed a significant improvement in pain levels ($P<2e-16$) when KT was used in comparison to the control tape. However, there were interactions between the treatment type and the order of treatment as well as the treatment type and time post-tape removal, and some limitations of the study. This study demonstrated the need for future studies to determine the longevity of the analgesic effect of KT.

There was a significant ($P<2e-16$) increase in algometer measurements from baseline to post-tape removal measurements with the KT when compared to the control. This indicates a larger decrease in pain levels with the kinesiology tape, but there was still some decrease in pain levels with the control tape as well. Human studies using KT have found immediate improvement in pain-free shoulder motion[55] and cervical pain relief in patients with acute whiplash injury[50]. In the study by Gonzalez-Iglesias et al., the short-term effects of KT on cervical pain and range of motion immediately after KT application and 24 hours post-application were studied. Patients received either KT or a placebo KT that was applied without tension and those receiving the actual KT had a significant decrease in pain immediately following application and 24 hours post-application (both $P<0.001$).[50] Additional, patients in the experimental group had a significant improvement in range of motion when compared to the control group ($P<0.001$).[50] In the current study, the greatest analgesic impact seems to be at 24 hours post-tape removal with KT. T16 and L6 had the lowest KT values at tape removal, but

T14, L1, and L3 had the lowest value at 48 hours post-tape removal, indicating that the pain relief starts to decrease as time goes on. As there were no measurements taken immediately following tape application it is difficult to determine when the analgesic impact starts, warranting further research.

There is currently some debate on how exactly KT reduces pain in mammals. It is difficult to say if KT reduces pain through promoting lymphatic flow and drainage, downregulating nociceptive transmission, a combination of the two, or some other mechanism due to the limited research on KT in any species. In a study with rabbits[53], researchers demonstrated a significant increase (P=0.0317) in lymph flow rate with KT applied to the ankle and foot and a linear increase in rate with an increase in the area of tape (P=0.0017) in rabbits[53]. The rabbits had lymph collected at rest or during passive exercise. During passive exercise, the lymph flow rate was increased (P=0.0317) by deforming the skin[53]. In the current study, lymph flow rate was not measured, but it is speculated that since the horses treated with KT had a reduction in pain, the lymph flow rate may have increased. Additional research needs to be done in horses and other species to determine the analgesic mechanism of KT.

In the current study, regardless of the order of treatments there was a significance (P<0.05) in the percent difference from baseline for KT compared to from baseline to control. However, there was a significant interaction (P<0.05) between the type of treatment and the order of treatments. With order 1 there was a 7-12% higher percent change from baseline to control than with order 2 at each site. Additionally, with order 1 the percent change from baseline to control was positive whereas with order 2 there was a negative percent change from baseline to control. This discrepancy could be caused by desensitization to the algometer. The horses could produce increasing values from the algometer if they become adapted to the algometer and can thus tolerate more pressure, regardless of their pain levels, if they were skittish or wary of the tool to start. This could explain why the control tape produced positive percent differences when applied first and the KT did as well when it was applied first. A study by Haussler et al. using pressure algometry to determine the effects of chiropractic treatment on the equine back did not demonstrate desensitization[23], but it is still a confounding variable that should be recognized. The chiropractic study measured the pain level at 52 anatomic locations along the axial skeleton on 26 Warmblood horses, Quarter Horses, and a variety of crosses all in English riding training, with no horses demonstrating sensitization or desensitization.[23] In the current study, the horses may have become desensitized to the algometer which contradicts the results Haussler et al. found.[23] This discrepancy illustrates the need for additional research to determine if horses can become sensitized or desensitized to the algometer.

In the current study, the negative percent change indicates that the horses had higher pain levels following the control tape removal when compared to the baseline, but the pain levels decreased as the time post-tape removal increased. These findings may suggest that the control tape actually exacerbated the back pain of the horses in order 2, but without further research it is not possible to draw that conclusion. The negative values could also be explained by sensitization to the measurements (a decrease in algometer values from applying too much pressure or being overly forceful) but the increase in values in subsequent measurements post-tape removal make this unlikely.

A seven-day washout period between application of the first tape and application of the second tape was selected for this study. No prior research has been done in any species to determine the appropriate washout period between taping protocols. The negative percent change with control tape in order 2 indicates that the analgesic effects from the KT did not carry over to the second taping and that the seven-day washout period was sufficient. It would be interesting to see if in future work a shorter washout period would be sufficient when comparing KT and a control tape and their effects on analgesia in horses.

A significant interaction (P=0.0373) between the time post-tape removal and the treatment was found at L3, but only with the control tape. The KT values were higher at all time points, with an increase of about 1% from tape removal to 24 hours later, and a decrease of about 3% from 24 hours to 48 hours post-tape removal. This could be the start of the decrease in the analgesic effect of the KT, but this decrease was not found to be significant (P>0.05) at any site measured except T16 (P=0.0417). In contrast, time post-tape removal influenced the control tape values at site L3. The percent difference increased by about 3% between each measurement, starting from -2% and going up to 5% at 48 hours post-tape removal. When analyzed further within the 2 orders, the significant interaction (P=0.0373) was only found within order 1(control tape followed by KT). Again, this could be explained by desensitization to the algometer, but that is unlikely as there was no significant interaction (P>0.05) between time and treatment with order 2 which would be expected if desensitization was occurring. Another proposed explanation is that other therapeutic modalities, such as hand walking or other manual therapy exercises done for those horses in rehab (9 out of the 22 horses), contributed to the pain relief with the increasing time post-control tape removal. For the horses not in rehab, perhaps simply every day movement contributed to the pain relief. This pain relief could be minute in comparison to that found with the KT, making its impact indistinguishable except when there was seemingly no pain relief from the control tape. However, there is no data to support this with the control tape at other sites on the back or with order 2, making it improbable as well.

This study had several limitations. The first limitation was that there was no set amount of time for the tape to remain on the patient's back. The study was performed in a clinical setting with 9 of the 22 horses being treated for sports medicine-related injuries. As there was believed to be the potential for the tape to have an analgesic effect, it was determined that it should stay on as long as possible to improve the wellbeing of the patients with only minor trimmings of any loose corners. The time the tape stayed on the back thus varied from horse to horse with a range of 2-7 days, which was longer than the time the control tape stayed on the back of the horse. The control tape only stayed on 24 hours for each horse before the adhesive was no longer sufficient. It was still believed to act as an appropriate control as the application of the tape was the same as the KT and it didn't immediately fall off. A second limitation was the time frame of the study; if the study had run for a year or longer it would have been possible to give each horse additional KT treatments to determine if the analgesic effect is similar each time. It is also difficult to compare the results to other studies as the pain levels were measured with different systems and were more subjective in human studies.

Further research could be done on the impact of time the KT tape remains on the horse to determine the effect on pain relief. For example, if there is a difference if the KT is on the horse for 2 days versus 4 days. Additionally, further research into different control tapes that would hopefully stay on the back longer is needed in order to have a properly designed experiment. Post-tape measurements were also only taken up to 48 hours after removal, so additional research following the effects of taping over multiple weeks or even months should be done to assess the effect of KT on pain relief Additional research could also be done using pressure algometry to determine if the decrease in pain levels is comparable to that from other treatment methods, such as NSAIDs and various pharmacological options or even other treatment methods along with combining treatments to see if the analgesic effect increases.

2.4 Conclusion

Back pain is a significant problem in the equine industry which can lead to poor performance, lameness, and behavioral changes. There are pharmacological and interventional therapy options for the treatment of back pain, including kinesiology tape. The overall goal of this study was to determine if there was an analgesic effect of KT on the thoracolumbar region of equine patients. While research has been done in human medicine and rabbits, this study is the first to use KT on the horse. The significant (P<2e-16) percent difference from baseline measurements found supports the hypothesis that KT has a greater reduction in pain levels when compared to a control. However, despite the fact that an analgesic effect has been demonstrated with KT, additional research needs to be conducted on the longevity of that effect.

Interactions between the order of treatments and the type of treatment, as well as between the time measurements were taken and the treatment, raise questions as to the impact of the confounding variables of desensitization or sensitization to the pressure algometer. Regardless of the order of treatments, a significant (P<2e-16) decrease in pain levels was found with the KT, but further study is needed to determine the mechanism of it. Although these findings are preliminary, these results suggest that kinesiology tape may be another form of interventional therapy that can be used to help treat thoracolumbar pain in the equine athlete.

Future research into the longevity of the analgesic effect and comparison of that effect to that of various pharmacological treatments is necessary to determine if KT is a viable alternative in the treatment of back pain. Pharmacological treatments can become expensive and more labor intensive as many of them need to be given daily or even multiple times per day and many are associated with severe adverse effects or potential side effects. Other pharmacological options, such as the intra-articular injection of various corticosteroids, are invasive and can be high risk.

In contrast, KT is more economical and less labor intensive as it only requires one taping session for multiple days of pain relief. It is also a safer, non-invasive, approach to back pain with no documented side effects, making it a promising treatment.

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PROFESSIONAL EXPERIENCE

Pennsylvania State University Horse Barns *January 2020-May 2020*

- Managed all of the basic needs of horses of various ages and reproductive status, including feeding, cleaning waters, vaccinating pregnant brood mares, treating foals, and administering medication when needed
- Assisted the veterinarian and barn manager with various procedures

Colorado State University Veterinary Hospital Equine Rehab Center *June 2017-Present*

- Managed all of the basic needs of the horses to ensure their health, including feeding, cleaning waters, grooming, mucking stalls, collecting fecal samples, and maintaining the cleanliness of the barn
- Assisted the veterinarians and performed daily rehab treatments and stretches
- Sterilized stalls after each horse to prevent the spread of infection and contamination

Taft Hill Dairy *May 2017-July 2017*

- Brought the cows in to the milking parlor every morning to be milked
- Washed and dried all of the udders to prevent contamination of the milk or the spread of infections
- Fed all of the cattle on the property, as well as the horse and chickens
- Cleaned all the milk bottles and transferred the fresh milk to them
- Sanitized the milking parlor and holding pen

STUDENT ORGANIZATIONS

- Collegiate Horseman's Association at Penn State *Fall 2019-May 2020*
- Penn State Western Equestrian Team *Fall 2018-May 2020*
- Penn State Equine Research Team *Fall 2017-May 2020*

Honors/Awards:

American Quarter Horse Congress Intercollegiate Judging Competition- 3rd Place *2019*

American Quarter Horse Lucas Oil World Show Intercollegiate Judging Competition- 6th Place *2019*