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The Effect of Weight Carried and Time Ridden on Back Pain in Horses Ridden During Horse Shows as Determined by Pressure Algometry

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THE EFFECT OF WEIGHT CARRIED AND TIME RIDDEN ON BACK PAIN IN HORSES RIDDEN DURING HORSE SHOWS AS DETERMINED BY PRESSURE ALGOMETRY

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In Partial Fulfillment

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By

Meghan L. Mothershead

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THE EFFECT OF WEIGHT CARRIED AND TIME RIDDEN ON BACK PAIN IN HORSES RIDDEN DURING HORSE SHOWS AS DETERMINED BY PRESSURE ALGOMETRY

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Master of Natural and Applied Science

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ABSTRACT

The objective of this study was to determine the effects of weight carried (rider + tack) on back pain in horses used in riding classes and a series of intercollegiate horse shows. Sixteen school horses (431-649 kg) were ridden consistently over a semester. Cross sectional images were used to measure width and put in a mapping program to figure total area. Back pain scores were determined using a pressure algometer on predetermined points over the horses back. Pain scores were recorded over five periods, including 28 d into the semester (P1) and during the show period on three consecutive Fridays from October 30-November 13 (P2-P4). The second and third period (P2-P3) measurements were followed by two days of shows, and (P4) measurements were taken five days after the last show. As a result, horses were tested the Friday before each show. Final pain scores were taken 21 d (P5) after the last show. Percent horse weight carried averaged 16% (range 10-27%). Pain was lowest in P1 and highest in P4 ($P<0.05$), and decreased ($P<0.05$) in P5. When entered as covariates, % horse weight carried, wither area (cm^2), loin width 5cm, and P1 had a negative relationship on back pain scores. Wither width 10cm ventrally from the medial line increased back pain scores. Research with a wider range of weight carried and alternative measurements may elucidate factors contributing to equine back pain.

KEYWORDS: horses, algometry, weight carried, back pain, horse shows

This abstract is approved as to form and content

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Gary W. Webb, PhD
Chairperson, Advisory Committee
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INTRODUCTION

In 1876, back problems in horses were among the most common and least understood of equine afflictions (Lupton and Mayhew, 1876). Back pain is still prevalent in horses. A substantial amount of research has been conducted, and is still ongoing, to gain a better understanding into the etiology of this common malady.

Poor performance, or a change in performance, and change in behavior are the most common signs of back pain in the horse (Jeffcott, 1980; Martin and Klide, 1999; Findley and Singer, 2015). In the past, diagnosis was based upon clinical observation only. While these early professionals were expert horsemen, opinions were numerous and varied. Many of the old veterinary textbooks lacked detailed descriptions and facts on back disorders (Jeffcott, 1999). Present-day technology now offers new imaging techniques including radiography, nuclear scintigraphy, and ultrasonography to evaluate the horse's back. Unfortunately, these diagnostic tools are expensive and not readily available to the general practitioner or horsemen (Burns et al., 2016).

Causes of equine back pain are multifarious. Commonly encountered causes can be grouped into either primary or secondary. Primary sources of pain include skin or muscle lesions, spinal trauma, disease, an imbalanced rider, ill-fitting tack, and incorrect training. Back pain may also develop secondarily due to lameness (Greve and Dyson, 2012). The type of work a horse performs correlates with the type and location of pain experienced (Fonseca et al., 2006). Horses used in riding schools are known to have various levels of back pain. In one study 59 riding school horses were evaluated by an equine chiropractic practitioner for back pain and classified as severely affected, slightly affected, or totally unaffected. Results showed that 73% (n=43) of horses appeared to be severely affected. Severely affected horses were those with at least two severely affected vertebrae. Moreover, 12% (n=7) of horses were slightly affected, with one affected vertebrae, and 15% (n=9) were unaffected (Fureix et al., 2010).

While diagnostic imaging has improved significantly over the last thirty years and diagnosis of back problems are being recognized, the relationship between pain and loss of performance is still unexplained (Burns et al., 2016). For the sake and well-being of the horse, as they are asked and expected to perform to their full potential, understanding equine back pain and its implications is critical for any horse owner or professional.

Working horses are subject to injury like any athlete. Horses used in riding instruction programs and therapeutic programs are likely candidates for back disorders. Due to being ridden by inexperienced riders who lack balance, riders of differing sizes, and poor fitting tack. Little research has been done in a riding program on the effects of weight carried and time ridden, or equine back pain. This particular information could be relevant for a stable manager and the overall welfare of horses in a riding program.

The objective of this study was to determine the effects of weight carried (rider + tack) and time ridden on back pain in horses used in different riding classes and a series of intercollegiate horse shows. It is hypothesized that as horses are ridden throughout the semester, time ridden and weight carried will not have an impact on back pain in horses as measured by pressure algometry.

Due to height and weight restrictions put on some horses at the intercollegiate horse shows, percent horse weight carried rarely reached greater than 20%. Therefore, effect of weight carried was minimized. Also, due to the limited number of horses used in this study, observation of the effects of weight carried and time ridden may not fully reflect the horse population as a whole.

LITERATURE REVIEW

Equine Anatomy

The axial skeleton of the horse is comprised of the skull, vertebral column, sternum, and ribs. Various muscles and ligaments work together to stabilize and support these structures.

Both head and neck of the horse play an extensive roll in the overall balance of the horse, as the horse carries more weight on his forequarters. The head joins the neck at the poll, followed by seven cervical vertebrae. Helping to support these structures is the *nuchal* ligament, running dorsally from the poll to the spinous processes at the withers (Higgins, 2009).

Thoracic and lumbar vertebrae constitute the largest part of the spine of the equine back. Three principle functions of the vertebral column of the back are: 1) protection of the spinal cord and nerves, 2) support for bearing weight, and 3) assistance with locomotion (Haussler, 1999). Consisting of 18 thoracic and six lumbar vertebrae, this area of the spine is very rigid, with very little movement between joints (Higgins, 2009). Spinal variation can occur between breeds. Arabian and Prjevalsky horses have shown to have the greatest variations between the thoracic and lumbar vertebrae (Stecher, 1962). While Arabian horses have a tendency to have 17 thoracic and occasionally five lumbar vertebrae, a small number of prjevalsky horses examined had 19 thoracic vertebrae and an equal number had either five or six lumbar vertebrae. Attached to the last lumbar vertebrae is the sacrum. Consisting of five vertebrae that fuse together by the time a horse is five years of age. Where the lumbar and sacral vertebrae meet is known as the lumbo-sacral junction. A very flexible region of the spine, injury can also occur here (Lesimple et al., 2013). Beyond the sacrum, are 15-25 coccygeal vertebrae that extend into the tail, with an average of 18.

Three main ligaments support the back, *supraspinous* ligament*, ventral longitudinal* ligament*,* and *interspinous* ligament. Laying dorsal and attached to each spinous process from the withers to the sacrum is the *supraspinous* ligament*,* which supports and stabilizes the back by keeping the vertebrae in place. Attached ventrally to the vertebral bodies and only existing between the T5 vertebrae and other caudal vertebrae, is the *ventral longitudinal* ligament. Supporting the spine in this area of the back, whenever the horse's back is hollowed; the ventral longitudinal ligament stretches. Between spinous processes is the *interspinous* ligament, offering additional support to the spine (Higgins, 2009).

A series of deep muscles function together to protect and support the spine. Medially along the spinous processes from the axis to the tail runs the short back muscle, *multifidus.* This composite muscle is made up of separate units, allowing it to isolate its action on a specific part of the spine. Distal to the *multifidus* runs the long back muscles, l*ongissimus* and *iliocostalis*. Running the entire length of the back, these muscles contract on both sides and hollow the back. They are also used in turning, rearing, kicking, and jumping (Higgins, 2009; Clayton, 2011). Other muscles not located on the back, but offer additional support and assist with the transfer of motion include the hypaxial muscles, or flexor muscles. Namely, the *internal* and *external oblique* muscles, *transverse abdominal*, and *rectus abdominis* (Higgins, 2009).

A horse's back is well represented by the "bow and string" theory, suggested by Slijper in 1946 (Figure 1). The bow represents the thoracolumbar (TL) spine and epaxial muscles, including the *longissimus dorsi* and *multifidus*, which provide stability and locomotion. The bow is kept under pressure by the string, which represents the sternum and abdominal muscles (Jeffcott, 1979, Burns et al., 2016). Contracting the abdominal muscles will tense the bow as will protraction of the forelegs and retraction of the hind legs, flexing or rounding the back. When the forelegs are retracted and the hind legs are protracted, a decrease in the tension of the bow causes the back to extend or hollow (Townson, 2012).

For the horse to effectively carry the weight of a rider, it is critical that he has a strong core. The rider wants to keep the "bow" tense, or the spine flexed by making the horse engage his abdominal muscles by retracting his hind legs and bringing them underneath him (Higgins, 2009). There have been suggestions that poor stride quality could be improved in horses that performed specific exercises designed to recruit and strengthen the core and locomotor musculature while moving joints through a wide range of motion (Oliveira et al., 2015).

Gymnastic training exercises (GYM), known for stretching and strengthening muscles and preventing injury in humans were adapted for hippotherapy horses (Oliveira et al., 2015). Dynamic mobilization exercises (DMEs) were paired with GYMs to recruit and strengthen abdominal muscles and pelvic stabilizing muscles. Nine healthy and sound horses who had been used in hippotherapy sessions for at least three years, with no signs of muscle lesions upon clinical observation were randomly assigned to three groups: sedentary, DMEs, and DMEs plus GYM. Horses performed exercises for three months, three times a week, while still performing hippotherapy sessions. DME exercises involved cervical flexion (e.g. chin to chest), a cervical extension exercise, and lateral cervical bending to the left and right (e.g. chin to flank). Pelvic tilting, backing up, walking around tight circles, and stepping over obstacles at a walk constituted GYM exercises.

Results showed a significant difference in stride length and tracking distance over the period of the study, indicating improvement of stride quality and hind limb engagement. DME and DME plus GYM horses both had significant increases in their *multifidus* muscle. Possibly preventing instability of intervertebral joints during locomotion and protecting against future injury (Oliveira et al., 2015).

Head and neck position are equally important to the strength and stability of the horse's back. Lowering the head and neck causes the nuchal ligament to stretch, allowing the *supraspinous* ligament attached to the spinous processes of the thoracic vertebrae at the withers to pull apart. With this action, the other spinous processes of the thoracic and lumbar vertebrae are pulled, and the back and ribcage is lifted (Figure 2). However, when the head and neck are high, the nuchal ligament slackens and the back becomes hollow and weakens (Higgins, 2009).

Head and neck positions of 19 horses from two different schools were observed during two lesson periods in which a beginner riders (less than 50 hours of riding) were observed. In addition spinal exams were conducted on by a chiropractor (Lesimple et al., 2010). Vertebral disorders evaluated by the chiropractor were correlated with postural elements seen during work. A negative correlation was found between rider posture and horse's neck position. The more time the rider spent with low hands and a longer rein the less time the horse spent with a high or hollowed neck. Lower heels were correlated to a lower neck as well. Contrarily, where high hands, shorter reins, and higher heels implied tension and unbalance. On average, riders spent more time with low hands (elbow angle >100º), but with medium heels (ankle angle 80º-100º) and medium reins (1/2-1 horse's neck). Suggesting that improper riding posture may have a strong impact on the horse's posture, potentially leading to vertebral problems (Lesimple et al., 2010).

Pain Assessment

The International Association for the Study of Pain defines human pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage" (Merskey and Bogduk, 1994). Likewise, not being able to physically or vocally communicate does not discredit the notion that an individual is experiencing pain. The latter definition implies that pain is always subjective. Nonetheless, this definition cannot be directly applied to animals because it entails that we know how that animal feels, and or that animal can verbally communicate their personal experiences to us. Therefore, the most commonly used definition for animal pain is "an unpleasant sensory experience caused by actual or potential injury that brings to bout protective and vegetative reactions, results in learned behavior, and may modify species specific behavior" (Sneddon, 2004).

In other words, an animal will move away and avoid any noxious stimuli by exhibiting some kind of change in behavior that will protect the animal from any further pain or injury. Most spinal or back disorders can be classified under three categories: soft tissue, osseous, or neurological (Haussler, 1999). Soft tissue back disorders can come from an improper fitting saddle or even sore muscles from being over worked, as the muscles atrophy. Soreness can also occur secondarily from asymmetrical movement, such as a lame horse trying to compensate for a sore limb, therefore using back muscles incorrectly. Osseous back disorders are due to various factors. Developmental issues and normal wear and age are problematic. These problems generally take time to show up (Smith-Thomas et al., 2014)

Neurophysiology of Pain. Pain perception is highly complex. Stimuli are processed and sent to the brain through the nervous system by special neural pathways (Daglish and Mama, 2016). Nociceptors are a type of sensory receptor that respond to potentially tissue damaging stimuli, called noxious stimuli. Noxious stimuli includes, but not limited to, thermal, chemical, or mechanical stimulants. These receptors are free nerve endings found widespread through the peripheral in the superficial layers of the skin. Action potentials, or nerve impulses, are elicited as the cell becomes depolarized. Depolarization occurs as the cell membrane potential increases towards the zero level, and voltage gated ion channels open, allowing an influx of (Na^+). Two types of afferent fibers relay information to the spinal cord. Fast-sharp, pricking, pain is sent to the via alpha delta (Aδ) fibers. These are medium sized myelinated nerve fibers sending signals at a velocity of 30 m/sec. Slow-chronic pain is transmitted by C fibers. These fibers are small and unmyelinated, sending signals at velocities of 0.5 – 2 m/sec (Guyton, 1991).

Cell bodies are located in the dorsal root ganglion, and information is sent into the spinal cord via the dorsal horn. Depending on fiber type, neurotransmitters glutamate (Aδ) and substance P (C-fiber) are transmitted, exciting postsynaptic receptors. These second order neurons actually cross over in the spinal cord, and continue to carry the action potential up to the brain through the spinothalamic tract. (Guyton, 1991).

Fast-pain fibers terminate in the thalamus of the brain, and pain perception can be easily localized, especially if tactile receptors have been activated as well. Slow fibers terminate widespread through the hindbrain, very few making it to the thalamus. Slow-pain localization is very poor, thus a dull, burning, throbbing type pain is perceived.

Acute pain is often characterized as that of short duration and localized to the area of injury or surrounding tissues. Pain follows injury as the body's response is intended to promote removal of injured cells and minimize further damage (Daglish and Mama, 2016).

Chronic pain results from an acutely painful episode that persists beyond the expected period of tissue healing. This state of discomfort is believed to be the result of abnormal signaling from injured tissues, alterations occurring in both peripheral and central nervous systems. Pain may persist or recur for months (Hall et al., 2002). In some cases pain perception is altered, injury and inflammation result in increased sensitivity to non-noxious stimuli (allodynia) and noxious stimuli (hyperalgesia). Nociception can vary according to age, sex, weight, race, and exercise activity (Haussler and Erb, 2006b).

Subjective vs Objective Testing. Objective assessments are based on fact, and are quantifiable and measurable. Objectively testing for pain in animals is challenging due to the nature of pain and the fact that an animal cannot verbally express their feelings (Love et al., 2011). Adding to the difficulty, many objective methods of quantifying pain and back problems in horses are expensive, limited, and difficult to apply to field study (Lesimple et al., 2010). Subjective assessments are more open to different interpretations based on personal feelings and emotions of the individual evaluator. Interpreting behavior of an animal requires basic understanding of that animal's normal behavior (Taylor et al., 2002).

Physiologic Measurements. Heart rate, respiration rate, temperature, beta-endorphins, and corticosteroid levels are objective parameters commonly associated with pain. However shock, stress, medication, and exercise have been recognized to have an influence on these measurements as well (Daglish and Mama, 2016; Taylor et al., 2002).

In female dogs undergoing an ovariohysterectomy, heart rate did not differ in those that received the pain medicine oxymorphone, compared to those who did not. Lack of change in heart rate could was assumed to be from not enough stimulus provided, or a modifying effect of the drug used had occurred (Hansen et al., 1997). In an alternative study, heart rates in horses that had undergone arthroscopic surgery and received phenylbutazone did not differ from horses that had undergone surgery and received no pain medication (Raekallio et al., 1997). Stress can also play a role in the fluctuation of heart rate. Laboratory monkeys had a significantly increased heart rate in response to routine cage change in a laboratory scenario (Balcombe et al., 2004). In consideration, pain may be present in any animal without elevated heart rates (Taylor et al., 2002).

Beta-endorphins are neurotransmitters naturally produced in the body that have an analgesic property. They are produced in response to certain stimuli, especially to stress, pain, or fear. It has been established that the pituitary secretes the beta-endorphins into the blood circulation along with adrenocorticotropic hormone (ACTH) in response to stress (Höllt et al., 1979). Therefore, making it difficult to identify the degree of pain the animal is in, and levels differ between each individual. No significant differences were found in plasma beta-endorphin levels in horses given phenylbutazone and those given the placebo undergoing arthroscopic surgery (Raekallio et al., 1997). Howbeit, individual response to arthroscopy surgery seemed to be higher in horses that were not treated with the NSAID.

An indicator of stress, adrenal corticosteroids can be used in conjunction with other objective measures of pain. However, it is not suggested to solely use cortisol as a measure of pain. Due to the multitude of outside stressors that can have an effect on concentrations, besides just pain (Taylor et al., 2002). In sheep with chronic foot rot, differing cortisol concentrations between two studies were associated with survival, as one flock was larger than another. The smaller flock of sheep had less cortisol, due to food and water resources being easier to access (Ley et al., 1991; Ley et al., 1994). When cows were acutely exposed to moderate heat conditions (30˚C), plasma cortisol significantly increased within the first 20 minutes, and peaked at 2h. Although under chronic conditions, after weeks of exposure, cattle became acclimated to conditions, and cortisol levels fell (Christison and Johnson, 1972). When horses were ran on a treadmill and acclimated to hot humid conditions, a reduction in cortisol levels was not seen (Williams et al., 2002). Cortisol did not correlate with expected pain in horses undergoing arthroscopy surgery. However, concentrations were higher, although not significantly, in the placebo group horses (Raekallio et al., 1997).

Behavior Evaluation. Behavior based pain assessment is subjective and limited by the knowledge and experience of the observer and time making the observations. Horses are a flight or fight animal, therefore it can be difficult to establish whether they are experiencing pain or some other unpleasant sensation. Behavioral signs affecting pain scores in any animal encompasses temperament, vocalization, posture, locomotion, and other behavioral changes (Bufalari et al., 2007). Behaviors recognized as indicating pain or at least discomfort in horses include: restlessness, excitement, head tossing, tail swishing, ear pinning, stamping feet, and in severe cases kicking or biting (Taylor et al., 2002, Lesimple et al., 2010). Specifically, horses experiencing back pain may show resentment towards the saddle, back sinking when a rider mounts, failure to give to riding aids, bolting, and bucking (Taylor et al., 2002).

Pain scoring systems for animals can be partitioned into three different tests: visual analog scales, numeric rating scales, and simple descriptive scales.

Visual analog scales consist of an observer making observations of an animal's behavior and physiologic parameters, and marking them on a scale from "no pain" to "worst pain possible" often a 0-100 scale. Numeric rating scales assess pain through different parameters such as heart rate and behavior, on a scale from 0-10 with 10 being the maximum pain felt. Numbers are added together in some form of intricate scoring system. Weighting different scores to a particular set of conditions being observed would allow for a more linear scale (Taylor et al., 2002). For example, the Melbourne pain scale consists of six categories, each category contains four levels, and levels are allotted scores (Hansen, 2003). Simple descriptive scales use a numeric scale combined with a behavioral description. Oftentimes, subjective assessments are paired with objective assessments to evaluate animal pain (Taylor et al., 2002).

Horse Grimace Scale. Facial expressions have been used to assess pain and other emotional states in humans who could not verbally communicate such as neonates

(Grunau and Craig, 1987). Pain assessment using facial expressions of rabbits and rodents has recently been published (Sotocina et al., 2010; Keating et al., 2012). There are a number of advantages to using species-specific grimace scales. Advantages to using include learnability, safety of the observer, as well as using basic human nature to focus on the face when looking at an animal in pain (Costa et al., 2014).

The horse grimace scale was developed using 40 stallions of different breeds undergoing routine castration. The scale is comprised of six facial units, on a scale of 0-2, from not present to obviously present. Subjects in the study were allowed an acclimation period to adjust to their new surroundings. Video sequences were recorded pre-procedure and eight hours post-procedure. Behavior states and frequency were recorded. Images were compared by a blind observer experienced in assessing facial expressions in other species, based on these the horse grimace scale was developed. To test the scale, 126 images were scored by five observers all from different backgrounds (e.g. veterinary surgeons, welfare researchers). Individual accuracy among participants ranged 68-78%. High inter-observer reliability was demonstrated. Although lacking in physiologic observations, the horse grimace scale was compared to a composite pain scale. Positive correlation was observed between scores (Costa et al., 2014). This method of pain assessment as well as other methods are limited by thought that prey species have the ability to mask obvious signs of pain under certain circumstances, such as being in the presence of a predator like a human (Taylor et al., 2002; Costa et al., 2014).

Pressure Algometry. Response to pressure using a quantifiable force applied to a part of the body is a prevalent method for determining pain thresholds (Taylor et al., 2002). Pressure algometry (PA) uses a mechanical device to quantify the subjective assessment of pain pressure thresholds. Attached to a small rubber tip, the pressure gauge, measured in kg/cm^2, is pressed against a predetermined landmark until a perceived noxious reaction is produced (Haussler and Erb, 2006b). This method provides a non-invasive, easy to use, repeatable method for pain measurement in horses (Haussler and Erb, 2003). Mechanical nociceptive thresholds (MNTs) are described as the minimum pressure that induces a pain response. Therefore, a high MNT score would indicate a higher pain tolerance compared to a low MNT score, indicating a low pain tolerance (Haussler and Erb, 2003). Pressure algometry has been used to detect musculoskeletal pain in both humans and horses (Vanderweeën et al., 1996, Heus et al., 2010; Haussler and Erb, 2006a).

In a pilot study conducted over two consecutive years in 2000 and 2001, 20 clinically sound and healthy horses with induced back pain were used to assess the ability of PA to identify a known musculoskeletal injury. Two fixation half-pins were placed in the dorsal spinous processes of two adjacent vertebrae. Overall, consistent responses to the applied pressure were easily identified at all sites. Researchers were able to recognize the exact placement of the pins as a result of dramatic and localized decreases in MNTs at and adjacent to pin-placement sites.

Similarly PA has been used to establish a pressure pain threshold within the axial skeleton and evaluate differences among individuals (Haussler and Erb, 2006b). Sixty-two midline and bilaterally symmetrical sites including bony and soft tissue landmarks, and apices of dorsal spinous processes were used. Thirty-six mature horses (10 non-ridden and 26 actively ridden) of various breeds, ages, and weights were assessed. Interestingly, there seemed to be a tendency for a higher threshold tolerance in young, heavy, non-Thoroughbred, castrated male horses. However, these results were not significant. In horses, differences in nociception might occur due to behavioral issues like adaptation, response to environmental stimuli, or mental alertness. Consistent and substantial increases in MNT scores of the actively ridden horses were observed. Possibly due to the variability between years or the type and duration of exercise (Haussler and Erb, 2006b).

Inter-examiner reliability was found to be good, and intra-examiner reliability was found to be moderate to good in a study using Icelandic horses (Menke et al., 2016). Intra-examiner reliability was lower possibly due to a lack of experience by one handler. Further research is needed to evaluate whether reliability is influenced by experience. Possible limitations to PA include a learning effect or increased sensitivity, described in one study, as some horses started shaking their head in anticipation before the algometer was applied (Heus et al., 2010). Albeit in this particular study, two measurement sessions were performed on the same day. Lower MNT scores in the evenings were possibly due to sensitization of measurement locations.

Visual Assessment. Lameness can be directly correlated to back problems. Lameness originating from a limb may have a significant impact on the motion of the horses back likely causing secondary back problems. Prevalence of lameness in horses with back problems was studied in a population of 805 horses with orthopedic problems from a mixed background of work (Landmann et al., 2004). Work background included dressage (70%), show jumpers (20%), and trotters (10%). Lame horses were defined based on the American Association of Equine Practitioners lameness score based on a scale of 1-5. Horses with at least two at the trot and/or who improved by at least 50%

after a nerve block were labeled as lame. Out of the 805 horses, 434 (53.9%) were lame without a back problem, 72 (8.9%) had a back problem but sound, 208 (25.8%) were lame and had a back problem, and 91 (11.3%) were sound and did not have a back problem.

Saddle Design

Historically saddle designs were made by memory, knowledge, experience, and feel (Greve and Dyson, 2012). Generally, saddle makers start with a rigid frame, referred to as the tree of the saddle. When well fitted, the tree is meant to distribute the load on the horse's back. Unfortunately, it cannot change shape with the horse. Padding, air bags, and flexible trees have been used to help alleviate some of this stress. More recently, tree-less saddles have been constructed to fit a wider range of horses and void pressure points underneath an ill-fitting saddle. Allowing flexibility, these saddles unfortunately do not distribute the load like a saddle with a tree would (Greve and Dyson, 2012).

In a 2012 study comparing pressure distribution under a conventional dressage saddle compared to a treeless dressage saddle, eight clinically sound Arabian riding school horses were ridden by a single rider of an experienced level (Belock et al., 2012). One brand and model of conventional and tree-less saddles were used on all eight horses using traditional girthing systems. Pressure measurements were made using an electronic mat underneath the saddle and five consecutive strides were analyzed using custom software. Locomotion changes total force between the saddle and back of the horse with limb movements between each gait. Force distribution was more uniform under the conventional saddle than the treeless saddle, which had focal areas of pressure beneath the rider's seat bones and resulted in higher forces under the middle third of the saddle. Consistently high pressure (>11kPa) throughout the horse's stride occurred over the epaxial musculature. This particular area is susceptible to pressure induced pain (Belock et al., 2012). Mean pressure of (>11kPa) was found to be a point for stimulation of back pain (Byström et al., 2010).

Saddle Fit. Ill-fitting saddles can do irreparable damage to a horse's back. Physical evidence of a poor fitting saddle includes sores, white hairs, temporary swelling, scars or hard spots, and muscle atrophy (Harman, 2004). Saddle fitting is an intricate process and must fit the horse's back, whose shape is constantly changing at different gaits. Additionally, the saddle must fit the rider, allowing them to stay balanced and in synch with their horse. Unfortunately, there is no standardized method to saddle fitting. Generally horse owners must place the saddle on the horse's back to check position, then palpating underneath for pressure points and tree clearance (Harman, 2004).

Mean pressure values of >11 kPa are thought to be detrimental. Focal pressure in the cranial saddle region was compared in normal horses and horses with dry spots and muscle soreness or swelling at a walk, trot, and canter. In the control group, mean pressure values ranged from 7.8 kPa at a walk and 10.9 kPa at a canter. Horses with muscle soreness and swelling had mean pressure points twice as much than the control group (Greve and Dyson, 2012).

Saddle pressure pads provide for an objective method of measurement for determining pressures on the horses back while standing and moving (Meschan et al., 2007). Horses not only carry the weight of a rider plus tack, but also a dynamic load when moving, which can be as great as 380N, discovered after ground reaction forces were measured (Clayton et al., 1999). In a study evaluating pressure distribution under an English saddle at a walk, trot, and canter, maximum overall force increased as gait increased (Fruehwirth et al., 2004).

Force applied to the horse's back increases with rider load and increased velocity. Consequently, focal concentration of forces beneath riders, induced by a poor fitting saddle is cause for concern with heavier riders, especially at high forward gaits (Greve and Dyson, 2012).

Saddle Pads. Oftentimes, if the horse's back pain can be referred back to an ill-fitting saddle, riders will place a thicker pad underneath the saddle. Symptoms may disappear temporarily, but typically return. Due to the fact that pressure points do not disappear, but shift to a new location with the different pad (Harman, 2004). Saddle pads were tested to see if they helped fitting an excessively wide saddle by reducing forces and pressure. Four different types of saddle pads were used in this study; gel, foam, leather, and reindeer fur (Kotschwar et al., 2009). No significant difference was found between pads during trials. At a walk, the foam pad had the lowest force value while at a trot, the gel pad had the lowest force value. However, when assessing pad effects per horse, at least one saddle pad for each horse reduced maximal overall force.

Girth/cinch Placement. In a 2010 study, six warmblood horses, each ridden by three different riders ranging in weight from 53-66 kg were used to test the influence of girth strap placement on the pressure pattern that occurs during riding. An experimental custom saddle built on a jumping saddle tree was used and the saddle had exchangeable panels fastened with screws and two sets of girth straps. One set of straps were located where they traditionally are on a jumping saddle, while the other set consisted of a cranial strap attached to the point of the tree and a caudal strap with a sliding attachment to a sling fastened over the midline and posterior parts of the tree of the saddle. The latter set of girth straps are referred to as a v-system. Saddle fit was found to be sufficient in all six horses, but not perfect. A sensor mat was used to measure the pressure at both a sitting and rising trot, and rising canter. Traditional girthing was found to be equally good if not better than the v-system. Increased peak pressures were observed using the v-system under the anterior portion of the saddle possible due to the cranial girth strap being placed farther forward developing a leverage type action and pulling the saddle down more (Byströ̃m et al., 2010).

Weight Carrying Capacity

Many horse owners and riders go by the 20% rule in regards to weight carrying capacity of horses which is thought to have originated from the 1920 US Cavalry Horseman & Horsemanship Manual. An evaluation of the indicators of weight carrying capacity was assessed using eight riding horses ranging in weight from 391-625 kg and from 6-18 years of age. Monitoring heart rates, respiration rates, rectal temperatures, plasma lactate and creatine kinase concentrations, muscle soreness, and muscle tightness. Measurements were taken before and after horses performed a submaximal standard exercise test mimicking a 45-minute working session of a riding lesson horse. Researchers found that heart rates, respiration rates, and rectal temperatures differed significantly when horses carried 25 and 30% of their body weight compared to 15 and 20% body weight. Plasma lactate and serum creatine kinase concentrations were both significantly higher immediately after workout sessions when horses carried 30% of their body weight. Creatine kinase levels remained elevated at 24 and 48 hours as well. The most significant change in muscle soreness and tightness was observed when horses were measured 24 and 48 hours after exercises, carrying 25 and 30% of their body weight. Given the results of this study, the authors concluded that a horse should not carry a load in excess of 20% of their body weight (Powell et al., 2008)

Effects of weight load was also observed using heart rate, cortisol, and behavior as parameters. An exercise protocol of moderate work intensity was performed at 15, 20, 25, and 30% of each horse's body weight. Treatments were not significant, although a negative correlation between weight and behavior was seen. As weight increased, behavior scores decreased. Results of this study differed from similar studies. Speculation indicated that a difference in pre-study fitness as well as exercise intensity could have effected results (Ernst et al., 2015).

Whether or not live weight versus dead weight affected a horse was observed in one study (Oldruitenborgh-Oosterbaan et al., 1995). Nine warmblood horses were worked on a treadmill carrying 90 kg of weight either with a rider or without. Horses ranged in weight from 550-714 kg. No differences were found in HR and plasma lactate in horses regardless of weight carried. However, fetlock extension and movement increased with dead weight.

Animal Welfare

Back problems in horses occur regularly in horses, particularly riding school horses (Lesimple et al., 2010; Fureix et al., 2010). Often they go undetected, given that objective assessment is limited to the common horse owner, and behavior is often blamed on other factors. In a 2013 study, owners/caretakers from 17 riding schools were asked if the horses (n=161) in their care, suffered from chronic back pain, lameness, or any other chronic health problem during the past year (Lesimple et al., 2013). Back pain was assessed by manual palpation from an experienced chiropractor and static surface electromyogram (sEMG) testing was also used. Out of the 59 horses with severely affected backs (at least 2 vertebral sites affected), only 22% (n=13) were reported by their owners/caretakers as having back pain. Although given the opportunity to answer on the questionnaire, none of the respondents reported anything concerning possible causes of back pain or how back pain is identified.

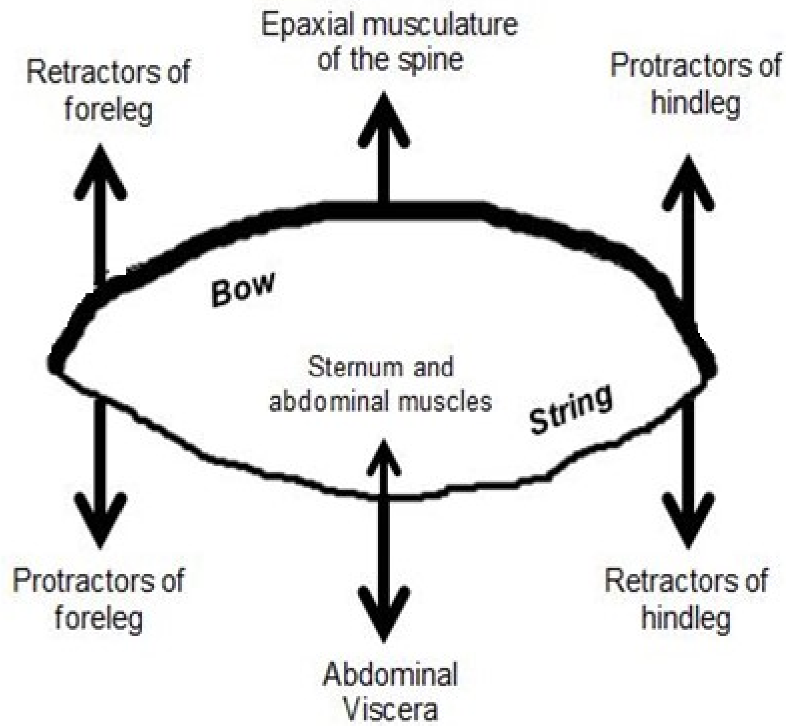

Figure 1. Illustration of the "bow and string" theory (Slijper, 1946; Jeffcott, 1979).

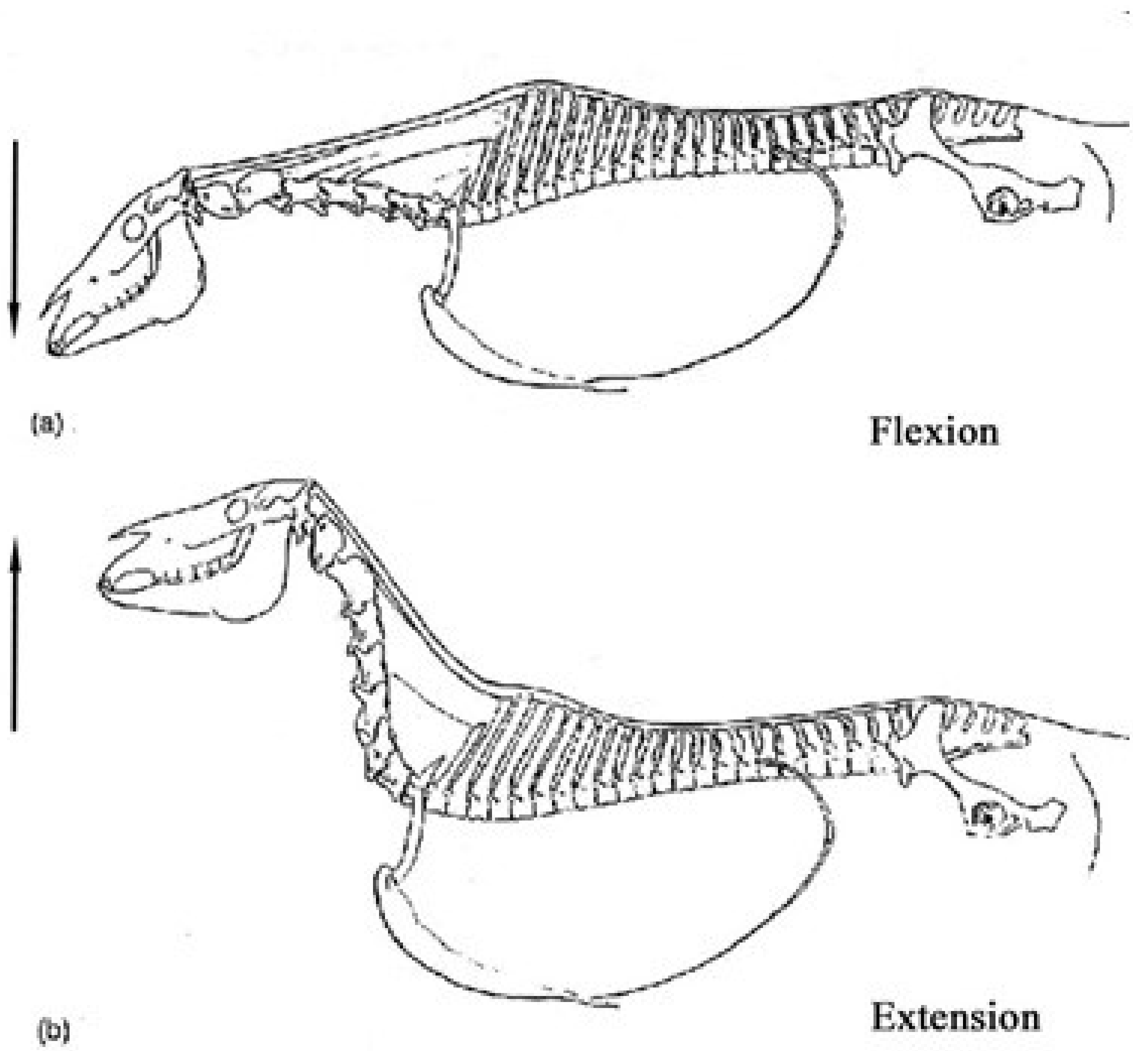

Figure 2. Nuchal ligament and its actions on the withers (Denoix, 1987; Townson, 2012).

MATERIALS AND METHODS

Animals

Fourteen quarter horses (6 geldings and 8 mares) and two quarter horse x thoroughbred crosses (1 gelding and 1 mare) ranging in age from 3-22 years old and in weight from 471-649 kg (mean of 570 kg) were ridden in a university riding program at Missouri State University's Pinegar Arena during the fall 2015 semester (Table 1). Additionally horses performed in two consecutive collegiate horse shows during this time. Time during the semester was divided into five periods (Table 2) and rider weight, and tack, were both recorded.

Horses were not fed special diets during this project; most (n=12) were kept on pasture and supplemented fescue hay and grain as needed in an effort to maintain weight and body condition scores. Horses kept in stalls (n=3), one 3.6m x 10.8m and two 3.6m x 6.6m, were fed hay and grain twice a day and turned out in an arena on a regular basis each week for exercise. While one horse was housed in a 35m x 35m outdoor arena and fed hay and grain twice a day. Weights were taken once, before the project began, then during each period through the project. Average of these values was calculated and recorded, and used to calculate the percent horse weight ridden during the project. All procedures involving the use, care, and management of horses in this project was approved by the Institutional Animal Care and Use committee of Missouri State University (IACUC protocol # 16-001.0-A). This project was funded by the USDA-NLGCA Capacity Building Grant (#102387).

As part of the Missouri State University equine program, horses were used in various riding classes during the semester including introduction to riding, horse training, and riding for instruction classes. Additionally horses were also used in competitive equestrian team practices including: western horsemanship, hunt seat equitation, jumping, and ranch horse. Amount of work done in each class varied, for example, an introduction to riding class featuring beginner riders with minimal experience, would normally consist of an approximate 30-40 minute walk/trot riding lesson Where a competitive practice class with riders of various levels of experience usually consists of a 60-90 minute lesson at a walk/trot/lope and pattern work. On average horses in this project were ridden five times a week (range: 0-13), excluding the two horse show weekends. Horse's skill set and tolerance were taken into consideration when assigned to classes each week.

Collegiate Horse Shows

The Intercollegiate Horse Show Association (IHSA) is a non-profit organization that promotes competition for riders of all skill levels. Riders compete individually and as teams at regional, zone, and national levels. Within regions, schools travel to shows at hosting colleges (Appendix A). In an effort to match rider skill with horse, horses are assigned to a class, and riders from that class randomly draw for a horse. Rider height/weight limits are set for some horses for different reasons (Appendix B). Various reasons for this practice include age, wither height, and health of the horse. Limits for height/weight are set at each show by the hosting college or owner of the horses. As a result, horses are paired more closely to riders the hosting college deems of an appropriate size.

During the experimental period, Missouri State University hosted two IHSA shows held over consecutive weekends. The first of which was a western show (Oct. 31-Nov. 1), followed by a hunt seat show the next weekend (Nov. 7-Nov 8). Saddles were weighed before each show and assigned a number. Therefore, one individual could stand in the paddock area and record the saddle each horse originated with and any following tack changes throughout the show. Warm-up riders were weighed either before or after warming up their horse. Weights had to be estimated for some riders, since these riders were from other universities and did not provide official weights. IHSA riders were asked to voluntarily stand on a scale fully dressed with show clothes either before they mounted, or after they finished their class. Howbeit, some riders denied this request. Thus an average weight was calculated from previously documented weights and recorded for these riders instead. Rider weights were recorded under horse's names to remain anonymous. Another individual sat in the spectator stands and recorded warm up times for each horse and class times. Use of human subjects in this research project was approved by IRB protocol (IRB-FY2017-197).

Back Measurements

Pain scores were determined using the FPK 60 pressure algometer (Wagner Instruments, Greenwich, CT) by applying pressure to predetermined points on the horse's withers, back, and loin. This nonelectrical pressure algometer has a 1 cm^2 rubber tip and can hold a maximum reading of 30 kg. A force of 5 kg of pressure was found to be efficient enough to elicit a response in a previous study where the median pressure pain thresholds at surgical sites was 5.5 kg/cm^2 (Haussler and Erb, 2006a). Pain was scored based on the Pain Scoring System (Appendix C) as adapted from a previous study (Heus et al., 2010), as well as the Horse Grimace Scale (Appendix D) as adapted from a previous study (Costa et al., 2014). Measurements were repeated three times consecutively, and an average score was recorded and used for data analysis. On measurement days, horses were brought into the stock tie areas in pairs. All doors to the area were shut to limit outside distractions. A soft flat ruler was taped to the horse's back, starting from the beginning of the withers back caudally to the loin, in an effort to improve accuracy and precision. To limit inconsistence in measurements examiners remained the same through the duration of the project.

Back pain scores were recorded over five periods (Table 1). Including 28 days into the semester (P1), and during the show period on three consecutive Fridays from October 30 – November 13 (P2 – P4). The first and second of which (P2 – P3) measurements were followed by two days of horse shows on Saturday and Sunday, and the last (P4) measurement was taken five days after the last show. As a result, horses were tested the Friday before and after each show. Final pain scores were taken 21 days (P5) after the last show.

Back measurement locations were chosen based on other research (Haussler and Erb, 2006b; Heus et al., 2010) as well as taking various saddles placed on the horse's back and manually palpating underneath for contact areas. Without an official protocol existing to measure saddle fit, it was determined that using both the shortest and longest western and hunt seat saddles on the bare back of the horse would give an acceptable representation of pressure points. A total of 26 measurement sites were selected; 12 on both sides of the horse, and two midline measurements (Figure 3 and Table 3).

Total back area was compared by measuring two positions on the horse's back (withers, loin) once at the beginning of the project and at the end. Area was measured by shaping a flexible ruler (Goldstar Tools, Los Angeles, CA) into position on each horse at 7.62cm caudal from the start of the withers, and 58.42cm caudal from the start of the withers. Shape of the ruler was traced onto graph paper, and drawings were digitalized and ran through a mapping program (ArcGIS 10.2.2, Esri, Redlands, CA) to determine left, right, and total area. Scales were set within the program to measure square inches instead of square miles. Measurements were later converted to centimeters squared for analysis. To compare back shapes of each horse relative to where the bars of the saddle tree would hit, back tracings on graph paper were measured 5 cm and 10cm from the most dorsal point on both the withers and loin.

Statistical Analyses

The effects of weight carried and time ridden on back pain scores for horses and periods were assessed using a general linear model (GLM) analysis of variance (ANOVA) procedures of Minitab 17 (Penn State, State College, PA). All inferences were made based on a type-III error rate of 0.05. Model included wither and loin area, width measurements at the withers and loin, time ridden, percent horse weight carried, horse and period. All variables except for horse and period were ran as covariates. For all analyses period was treated as a fixed factor and horse was treated as a random factor. All effects and interactions were considered significant when ($P < 0.05$). When the F test showed significance ($P<0.05$) means were separated using Tukey-Kramer procedure for multiple comparisons. Regression analysis was run on Microsoft Excel, with pain totals as the dependent variable.

Table 1. Breed[1], gender[2], age, and average weight for each horse used during the project.

Horse	Breed	Gender	Age	Average Weight (kg)
1	Appendix	Gelding	17	613
2	QH	Gelding	16	649
4	QH	Gelding	19	612
5	QH	Mare	8	563
8	Appendix	Mare	10	585
14	QH	Mare	13	503
16	QH	Gelding	3	578
17	QH	Mare	16	518
18	QH	Mare	10	543
19	QH	Mare	10	571
20	QH	Mare	15	554
21	QH	Gelding	4	564
22	QH	Mare	22	471
24	QH	Mare	7	579
25	QH	Gelding	15	644
26	QH	Gelding	15	571
Average	-	-	13	571

[1] Quarter Horse x Thoroughbred Cross (Appendix), Quarter Horse (QH)
[2] Castrated Male (Gelding), Intact female (Mare)

Table 2. Dates and descriptions of periods during the experiment.

Period	Date	Description
1	Sep 4 – Oct 2	Beginning of semester, horses out of shape
2	Oct 3 – Oct 30	Horses being ridden consistently, getting in shape for western show
3	Oct 31 – Nov 6	Western show (Oct 31 – Nov 1), horses still get ridden, getting ready for hunt seat show
4	Nov 7 – Nov 13	Hunt seat show (Nov 7 – Nov 8), some horses get 1 or 2 day break, classes continue
5	Nov 14 – Dec 4	End of semester, horses still worked in classes

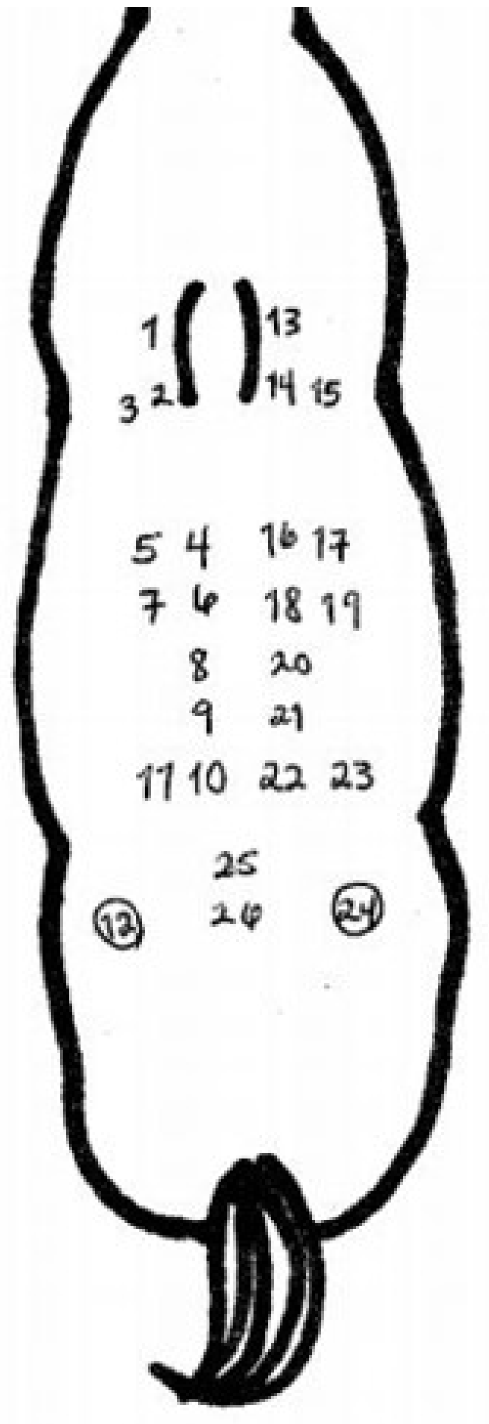

Figure 3. Pressure algometry measurement sites on the horses back.

Table 3. Anatomical location of pressure algometry measurement sites over the horse's back.

Numerical Abbreviation	Anatomical Location
1,13	7.62 cm caudal from start of wither, 7.62 cm off midline
2,14	15.24 cm caudal from start of wither, 7.62 cm off midline
3,15	15.24 cm caudal from start of wither, 15.24 cm off midline
4,16	35.56 cm caudal from start of wither, 7.62 cm off midline
5,17	35.56 cm caudal from start of wither, 15.24 cm off midline
6,18	43.18 cm caudal from start of wither, 7.62 cm off midline
7,19	43.18 cm caudal from start of wither, 15.24 cm off midline
8,20	50.8 cm caudal from start of wither, 7.62 cm off midline
9,21	58.42 cm caudal from start of wither, 7.62 cm off midline
10,22	68.58 cm caudal from start of wither, 7.62 cm off midline
11,23	68.58 cm caudal from start of wither, 7.62 cm off midline
12	Left Hip
24	Right Hip
25	76.2 cm caudal from start of wither, on midline
26	83.82 cm caudal from start of wither, on midline

RESULTS AND DISCUSSION

Results

Descriptive analysis of each period was recorded (Table 4). Riding concentration was calculated by dividing minutes ridden by number of days in each period. Period one had the second highest number of recorded rides (n=252), with the largest riding concentration. During the show period (P3-4), riding concentration, minutes ridden, and number of rides were substantial compared to the number of days in each period. Period five had the least number of rides (n=114) with a smaller riding concentration compared to other periods.

When treated as covariates, loin width measurement at 5cm ventrally from the midline, wither width measurement at 10cm ventrally from the midline, wither area measured in December, period, and percent horse weight carried all had a significant effect ($P<0.05$) on total pain scores (Table 5). Period also had an effect ($P<0.05$) on the change of pain scores between period and period prior. Tukey pairwise comparisons (Table 6) showed total pain scores for P1 and P4 were significantly different ($P<0.05$) than pain scores in periods two, three, and five. Pain scores being significantly less in P1 and significantly greater in P4. Change in pain score from P4 to P5 decreased significantly $P<0.05$) than the change in pain score observed during any other period. Regression analysis was recorded for covariate variables that showed significance in the ANOVA test (Table 7). The r^2 values explain very little of the variation of the variables effect on pain scores. Overall mean percent horse weight carried over this project was 16% ± 4%, with a range of 10 – 26%, with each horse averaging 69 rides (Table 8). Changes in weight were compared to wither and loin area measurements from September and December (Table 9) and wither and loin width measurements from September to December (Table 10 & 11). No obvious relationships between change in weight and change in area or width could be found.

Discussion

Mean total pain scores gradually increased as the project progressed and decreased significantly in the last period. These findings coincide with period descriptions (Table 2). As P1 is close to the beginning of the semester, and after having a summer off on pasture, a lower pain score was expected. Pain scores increased as the semester continued and horses were ridden more consistently. Although not significant, the increase in pain between P1 and P2 was considerable, possibly due to muscle fatigue as horses were becoming more fit, preparing for the first horse show. Period four was after two contiguous weekends of horse shows. Horses were ridden more frequently by a large number of different riders during a relatively short time span. There were approximately 182 rides over the weekend of the western show, and 119 rides at the hunt seat show. Mean total pain scores were highest during this period. Change in pain scores from P4 and P5 significantly decreased, most likely due to the fact that horses were not being ridden as consistently or intensely. Period 5 had the least number of rides. Consequently because of the 18 days included in this period, there were approximately only eight days of riding. This was due to another horse show out of town, therefore there were no riders, and a week of holiday break.

Mean percent horse weight carried did not vary much between periods. It was thought that horses might carry more weight more often at the western horse show during the project due to the variety of riders, added weight of show clothing, and random draw. Nonetheless, with a weight protocol set, this was not seen. While there is no official weight carrying protocol for IHSA shows, a limit is set by each hosting college or owner of the horse. At both shows, height/weight limits were set at (>170 cm and/or >75 kg). This meaning that any horse with a height/weight limit set for them could not carry these riders. Therefore, horses carried an average of 16% of their body weight during the show period, no different than the overall mean for the entire project. There was only 28 occurrences of horses carrying 20% of their body weight or greater. Horses did nevertheless carry more weight at the western show compared to the hunt seat show, but this was expected due to difference in weight of tack. Percent horse weight carried had a negative relationship on back pain total scores. As percent horse weight carried increased, pain total scores decreased. This negative relationship is likely a consequence of outliers and the immense variation between horses. Horses 2 and 8 consistently had high pain score totals compared to other horses. This was even with horse 8 having height/weight restrictions on her during the horse shows. Where horses 1 and 4, who did not have height/weight restrictions and were ridden just as often if not more, had very low pain score totals. Period 1 had a negative relationship with the covariates compared to periods 2, 3, and 4. Likely due to P1 being one of the longest periods and having the heaviest riding concentration.

Changes in weight were compared to wither and loin area measurements from September and December (Table 9) and wither and loin width measurements from September to December (Table 10 & 11). No obvious relationships between change in weight and change in area or width could be found. For example, horse 24 lost 20 kg of weight but gained area and width in both withers and loin. It has been suggested that a 16 – 20 kg change in weight could be enough to change BCS in a horse (Heusner, 1993). December measurements were in the winter time when the weather was cold, and most horses did have noticeably thicker hair with their winter coats. This factor could possibly have had a small effect on measurement differences. Nonetheless wither area at the end of the project, wither width measured 10cm ventrally from the medial line, and loin width measured 5cm ventrally from the medial line were shown to have a significant effect on back pain totals. Regression was run on these covariates, and while the numbers were low, these variables do have some impact on pain scores. Wither area and loin width both had a negative relationship with back pain total scores. As area and width increased, pain scores decreased. In contrast, wither width had a positive relationship with pain score totals. As wither width increased, pain scores increased. The latter positive relationship could be explained by saddle fit, or lack thereof. Narrow saddles being placed on wider horses. Wither area is a common problem area when dealing with horses (Harman, 2004, Peinen et al., 2010). Particularly when looking at saddle fit. It is certainly plausible that ill-fitting tack could explain some of these findings. Particularly when saddles are not assigned to horses, and this decision is left to the knowledge and choice of student riders. Further research would be needed to confirm this assumption.

Immense variability between horses can be seen in number of rides, time ridden, and pain total scores (Table 8). Difference between number of rides and time ridden between horses can be justified by the horse's skill set and tolerance level. Horses like 18, 24, and 26 were used in every riding class and practice due to their knowledge and easy demeanor. These classes and practices include the introduction to riding class, competition equitation practice, and ranch horse practice. Five horses were used for the western equitation show only, and not in the hunt seat show. Explaining some of the great variability in number of times ridden.

Pain is felt differently in every individual (Sneddon, 2004; Taylor et al., 2002). Some are more sensitive than others. Furthermore, some horses in this project were known to have had a hypersensitive back in previous semesters prior to this study. This can account for some variability in pain score totals. Horses 2, 8, and 17 had shown signs consistent with sensitivity in the back in the past. Signs included aggressive tail swishing and head shaking both while being groomed and being ridden, especially at a trot and lope. Also, these horses would show other signs of resentment while being groomed and saddled such as ear pinning, foot stomping, and at times trying to bite (Taylor et al., 2002; Findley and Singer, 2015).

Table 4. Descriptive statistics of each period including days in period, mean percent horse weight carried, number of rides, and minutes ridden.

Period	Number of Days in Period	Mean Percent Horse Weight Carried	Number of Rides	Minutes Ridden	Riding Concentration
1	19	0.17 ± 0.03	252	16441	865.3
2	27	0.17 ± 0.03	335	19938	738.4
3	7	0.17 ± 0.03	225	4099.5	585.6
4	7	0.15 ± 0.03	190	5171.5	738.8
5	18	0.16 ± 0.03	114	7075	393.1

* ± st. deviation

Table 5. ANOVA for December wither area (cm^2), wither width 10cm ventrally from medial line, loin width 5cm ventrally from medial line, %HW carried, and period effect on total pain scores.

Source	DF	SS	MS	F	P
Loin width (5cm)	1	106.46	106.46	9.06	0.004
Wither width (10cm)	1	205.29	205.29	17.47	0.000
Wither area (cm^2)	1	681.26	681.26	57.98	0.000
% HW carried	1	87.46	87.46	7.44	0.008
Period	4	135.60	33.90	2.89	0.029
Error	70	822.5	11.75		
Total	79				

Table 6. Tukey-Kramer procedure for multiple comparisons of total back pain scores for each period and the change in back pain score from period prior.

Period	Total pain score	Score difference from previous period
1	3.21 ± 0.99[a]	0.25 ± 0.58[a]
2	5.65 ± 1.42[ab]	2.44 ± 0.63[a]
3	6.52 ± 1.37[ab]	0.88 ± 0.57[a]
4	7.29 ± 1.62[b]	0.77 ± 0.86[a]
5	4.65 ± 1.30[ab]	-2.65 ± 0.78[b]

[a,b] Values are different ($P<0.05$)

Table 7. Regression analysis for total back pain score versus wither width 10cm ventrally from medial line, loin width 5cm ventrally from medial line, wither area in December, and percent horse weight carried.

	R^2	F-Statistic	P-Value
Wither width (10cm)	0.16	14.49	0.0003
Loin width (5cm)	0.14	12.31	0.0007
Wither area (cm^2)	0.12	10.76	0.002
%HW carried	0.12	10.31	0.002

Table 8. Overall mean %HW carried, number of rides, minutes ridden, and back pain score total for each horse during the research period.

Horse	Mean %HW carried	Range of %HW carried	Number of rides	Minutes ridden	Pain Totals
1	0.15	0.11 - 0.22	87	3947.5	1.7
2	0.15	0.10 - 0.23	97	3905.3	47.3
4	0.16	0.10 - 0.26	79	2723.6	6.7
5	0.20	0.12 - 0.25	73	4351.2	14.3
8	0.14	0.11 - 0.21	73	3788.2	90.0
14*	0.19	0.15 - 0.23	31	1510.0	62.7
16	0.16	0.11 - 0.24	55	2387.5	14.7
17	0.16	0.12 - 0.20	74	3441.3	26.0
18*	0.17	0.11 - 0.25	97	4698.5	15.0
19*	0.16	0.10 - 0.25	53	3068.0	0.7
20	0.17	0.11 - 0.22	46	2644.0	25.3
21*	0.15	0.11 - 0.21	37	2006.0	38.3
22	0.18	0.13 - 0.24	52	2220.1	6.7
24	0.17	0.11 - 0.23	105	4503.5	6.0
25*	0.15	0.12 - 0.21	41	2374.0	49.3
26	0.16	0.11 - 0.25	109	5162.5	32.3
Average	0.16	-	69	3295.3	27.3 ± 25.0**

* Horses that competed in western equitation competition only
** ± st. deviation

Table 9. Wither and loin area (cm^2) in September vs. December compared to body weight change (kg).

Horse	Weight Change (kg)	Wither			Loin		
		September	December	Wither Change	September	December	Loin Change
1	-18	447.8	432.3	-15.5	318.2	335.5	17.3
2	-2	465.3	421.8	-43.5	333.0	342.6	9.6
4	-45	475.7	459.9	-15.8	398.5	379.3	-19.2
5	-43	367.5	364.9	-2.7	314.9	308.7	-6.2
8	-48	333.3	333.6	0.3	314.3	302.1	-12.2
14	5	373.8	374.3	0.5	344.6	330.6	-14
16	32	426.0	403.7	-22.3	329.8	355.3	25.5
17	16	355.7	385.4	29.7	304.3	326.3	22.0
18	-39	432.1	426.5	-5.6	307.9	349.1	41.2
19	-7	445.7	470.8	25.1	420.2	631.6	211.4
20	-16	408.5	416.2	7.7	377.3	341.9	-35.4
21	-5	443.0	383.4	-59.6	309.5	340.1	30.6
22	-14	458.2	428.9	-29.3	378.1	355.1	-23.0
24	-20	471.5	490.0	18.5	311.7	348.8	37.1
25	-7	461.2	388.6	-72.7	361.8	363.1	1.3
26	-2	359.5	373.9	14.4	295.5	313.2	17.7

Table 10. Wither width measurements (cm) compared to weight change (kg) from September to December.

Horse	Weight (kg)	Withers					
		5cm			10cm		
		September	December	Change in width (5cm)	September	December	Change in width (10cm)
1	-18	18.5	15.5	-3	30.5	29.6	-0.09
2	-2	21.3	17.1	-4.2	31.4	30.5	-0.9
4	-45	20.0	19.9	-0.1	31.5	32.8	1.3
5	-43	13.5	13.5	0	24.5	24.3	-0.2
8	-48	12.2	11.5	-0.7	22.6	23.1	0.5
14	5	16.8	15.4	-1.4	26.7	26.7	0
16	32	18.2	17.8	-0.4	29.4	28.5	-0.9
17	16	13.7	13.1	-0.6	25.8	25.1	-0.7
18	-39	17	16.5	-0.5	28.9	28.6	-0.3
19	-7	19.5	19.1	-0.4	31.2	32.3	1.1
20	-16	16.8	17	0.2	27.6	28.9	1.3
21	-5	18.6	14.2	-4.4	28.9	26.2	-2.7
22	-14	19	19.5	-3.2	30.8	29.1	-1.7
24	-20	22.5	23.2	0.7	32.2	34.0	1.8
25	-7	18.2	15	-3.2	31.9	28.0	-3.9
26	-2	12.3	13.1	0.8	24.7	25.0	0.3

Table 11. Loin width measurements (cm) compared to weight change (kg) from September to December.

Horse	Weight (kg)	Loin					
		5cm			10cm		
		September	December	Change in width (5cm)	September	December	Change in width (10cm)
1	-18	32.5	33.5	1	45.6	46.7	1.1
2	-2	33.2	32.9	-0.3	44.1	45.1	1
4	-45	36.9	36.5	-0.4	49.7	48.4	-1.3
5	-43	30.4	30.6	0.2	40.4	39.9	-0.5
8	-48	29.5	29.0	-0.5	46.1	44.0	-2.1
14	5	33.0	33.3	0.3	45.8	45.4	-0.4
16	32	33.5	35.0	1.5	46.4	47.5	1.1
17	16	31.4	32.9	1.5	41.5	43.0	1.5
18	-39	31.8	33.1	1.3	42.9	43.5	0.66
19	-7	36.8	34.3	-2.5	47.8	44.4	-3.4
20	-16	34.5	33.7	-0.8	48.5	45.5	-3
21	-5	30.0	34.0	4	41.3	45.1	3.8
22	-14	34.5	33.5	-1	42.6	44.6	2
24	-20	31.5	33.4	1.9	42.1	44.9	2.8
25	-7	35.8	36.4	0.6	47.2	47.0	-0.2
26	-2	27.1	30.9	3.8	45.7	47.2	1.5

CONCLUSION

In this study weight carried, wither area and width, and loin width had some effect on back pain. It also appears increasing riding frequency had an effect on back pain scores. Further research using alternative methods for measuring back area and width are warranted to further elucidate or confirm the findings of this study. Using a flexible ruler left room for possible inaccuracy if not shaped well, and had the potential to flare out. Explaining some of the inconsistencies seen when compared to weight change. In further research, it is also suggested that body condition score be observed and recorded, as well as subcutaneous fat and *longissimus dorsi* thickness at the loin.

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APPENDICES

Appendix A. Variation in height (Ht.) and weight (Wt.) of riders in a class at an IHSA horse show.

Name	School	Class	Ht	Wt
Rider 1	University 1	12A	5’8”	130
Rider 2	University 2	12A	5’1”	125
Rider 3	University 2	12A	5’4”	125
Rider 4	University 3	12A	5’0”	230
Rider 5	University 4	12A	5’9”	240
Rider 6	Universtiy 3	12A	5’2”	122

Key	
>5’7” <165lbs	Ht
>5’7” >165lbs	Ht +Wt
<5’7” >165lbs	Wt
	Neither

Appendix B. Example of a horse list used at the draw table for IHSA competition.

11. Intermediate 1 Sec 1	12. Open Sec 1
1.Leo*	1.CMT
2.Kidd	2.Sunny
3.Alf	3.Tuff
4.Clyde	4.Judy
5.Visionary	5.Precious*
6.Suzie*	6.
Alt 1. Trouble	Alt 1. Trouble
Alt 2. Rock	Alt 2. Rock

* asterisk denotes a horse with a height/weight limit set on it, or who cannot carry riders who meet or exceed height/weight limits.

Appendix C. Pain scoring system[1] used to record pain response to pressure algometry.

Pain Score	Classification	Description
0	Pain Free	No reaction observed
1	Mild	Nose wrinkling, ear flattening, slight spasm upon palpation without related movement
2	Moderate	Head jerk, bearing teeth, tail lashing, stamping foreleg, (aggressive) tail flattening, rising hind leg, spasm upon palpation with related local movement (e.g. pelvic tilt)
3	Severe	Kicking, biting, rearing, sour attitude, restlessness, moving away from the hand

[1] adapted from (Heus et al., 2010)

Appendix D. Horse grimace scale.

[1] adapted from (Costa et al., 2014)