The Effect of Chiropractic Treatment on Biomechanical Imbalances and Pain Response in Horses

by
Taylor Prichard

A THESIS

Submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Biology
(Honors Scholar)

Presented December 4, 2019
Commencement June 2020

AN ABSTRACT OF THE THESIS OF

Taylor Prichard for the degree of Honors Baccalaureate of Science in Biology presented on December 4, 2019. Title: The Effect of Chiropractic Treatment on Biomechanical Imbalances and Pain Response in Horses

Abstract approved: ____
Katja F. Duesterdieck-Zellmer

Chiropractic treatment is used to reduce stiffness and pain. While more thoroughly studied in humans, it has been shown to be effective in horses, but relatively little evidence exists to quantify the benefits. To address this shortcoming, four methods were used to assess the effects of chiropractic treatment in horses in this study. Pressure algometry was used to assess pain by applying pressure at predetermined landmarks, proximately 10 cm lateral to the midline. The Lameness Locator was used to assess lameness by applying three sensors to the horse to determine relative asymmetry of the poll and croup. Video analysis was used to quantify performance by measuring the hock amplitude throughout the stride as an approximation for hock flexion, and gait evenness was measured by comparing diagonal limb pairs in the trot when the limbs were fully extended. Finally, owner surveys were used to assess general attitude, soreness and willingness to perform.

Manually applied chiropractic treatment was effective at increasing mechanical nociceptive thresholds and quality of gait at a trot 6-8 days after treatment. However, it does not appear as though lameness, as detected by the Lameness Locator, changed 6-7 days post-treatment. Furthermore, the owner survey also revealed that owners did not notice a significant change in their horses' attitude, appetite, soreness, swelling, willingness to perform under saddle or on the ground in hand.

Key words: equine, chiropractic, spinal manipulation, gait analysis, lameness locator, pressure algometry

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes the release of my project to any reader upon request.

Taylor Prichard, Author

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Introduction

Chiropractic treatment is used in both human and veterinary medicine to reduce musculoskeletal pain and stiffness (Taylor and Romono 1999). The treatment involves applying a high velocity, low amplitude thrust to the joint in question to activate mechanical and neurophysiological reflexes (Haussler 2016) with the intent of increasing mobility and decreasing pain. While anecdotal evidence exists to support the use of chiropractic treatment in horses when correctly applied, there is relatively little quantitative evidence on the benefits of chiropractic treatment (Haussler et. al. 1999). To address this shortcoming, four methodologies were used to assess the effects of chiropractic treatment in horses in the present study. Pressure algometry was used to assess pain by applying pressure to various predetermined landmarks of the back to measure the force at which the horse displayed pain, as determined by the horse moving away from the device (Haussler and Erb 2006a). The Lameness Locator was used to assess lameness. This involved applying inertial sensors to the horse to determine the relative symmetry of the horse's gait and therefore quantify lameness (Keegan et. al. 2011). Video analysis was used to assess movement quality. The quality of the trot was measured by documenting the relative position of the hock throughout a stride to estimate the degree of hock flexion. Additionally, the maximal distance for the two diagonal limb pairs was measured and compared to estimate evenness of left and right stride lengths. Finally, owners were surveyed regarding their perception of treatment effect by analyzing their assessment of their horse's general attitude, soreness and willingness to perform.

Literature Review

History of Chiropractic Adjustments

Spinal manipulation has been used for centuries in many cultures, as summarized by Devocht (2006). The earliest evidence of spinal manipulation was found in China, dating back to 2700 BC (Taylor and Romono 1999). However, modern chiropractic treatment was not developed until the 19th century (Taylor and Romono 1999). At the time, chiropractic care was a treatment that was only performed on humans, but by the 20th century, reports emerged of chiropractic care being successfully applied to animals, as summarized by Taylor and Romono (1999). Currently, animal chiropractic care is predominantly performed on cats, dogs and horses (Taylor and Romono 1999). While the effectiveness of chiropractic manipulations in humans has been widely documented (Gaumer 2006, Leaver et. al. 2007, Hurwitz et. al. 2006), the use of chiropractic techniques in horses is to date limited to studies using relatively few horses (Haussler et. al. 1999, Haussler 1999). The American Veterinary Medical Association (AVMA) stated that there was enough clinical evidence to indicate that veterinary chiropractic care could be beneficial and recommended that further research should be done on the subject (Guidelines for Alternative and Complementary Veterinary Medicine 1996). Given the increasing evidence in favor of chiropractic care for animals, it seems justifiable to consider it as a valid therapy for treatment of equine back problems, either alone or in conjunction with other methods (Haussler et. al. 1999). Incidentally or reflecting this, there has been a recent increase in owners' desire for their horses to receive chiropractic care (Haussler 1999, Guidelines for Alternative and Complementary Veterinary Medicine 1996).

Application of Chiropractic Care

Chiropractic care is a complimentary health modality currently used in veterinary medicine to aid in the prevention, diagnosis and treatment of musculoskeletal impairments (Haussler 1999, Haussler 1997, Guidelines for Alternative and Complementary Veterinary Medicine 1996). Chiropractic care specializes in evaluating and addressing joint and spinal related disorders to improve deficits in posture, biomechanical gait imbalances and performance problems (Haussler 1999). Haussler summarized that chiropractic care is applied with the intent of producing physiological effects on sensory and motor components of the neuromuscular and skeletal system to bring about behavioral change and reduce disobedience caused by pain, such as bucking, failing to move forward, or picking up the wrong lead in the canter (2016).

Impairments in performance are often caused by back pain, which is a common health problem in horses (Landman et. al. 2004, Jeffcott 1980, Jeffcott 1979, Rooney 1982, Cauin 1997, Jeffcott et. al. 1985, Martin and Klide 1999, Haussler 1999), and can thus have a significant negative economic impact (Riccio et. al. 2018). Additionally, it has been hypothesized that all horses in active work exhibit some form of mild back soreness (Sullivan et. al. 2008, Haussler and Erb 2003, Jeffcott 1979). Clinical manifestation of back pain often includes decreased flexion and extension in the thoracic-lumbar area (Wennerstrand et. al. 2004), among other rather non-specific behavioral changes, such as bucking, bolting, rearing or unwillingness to move forward, or pain on palpation (García-López and José 2018). Problems in the pelvis can also present as poor performance, lack of impulsion, or low-grade, chronic hind end lameness (Dyson and Murray 2003).

Non-specific back pain is generally attributed to functional impairment rather than a structural problem, and thus the pain is often caused by soft tissue irritation and joint dysfunction, resulting in a loss of range of motion, as summarized by Haussler (2016). In response to chronic stiffness and pain, new movement patterns can be adapted by the horse to reduce pain, and these movement patterns often persist even after the original noxious stimulus is resolved and can predispose horses to secondary injuries (Haussler 1997, Wennerstrand et. al. 2004). This can lead to subsequent lameness, which comes with a high economic cost (National Economic Cost of Lameness, Colic, and Equine Protozoal Myeloencephalitis (EMP) in the United States 2001). Overall, back problems are not a new phenomenon in horses (Jeffcott, 1979), but it is unclear if this trend is due to increased back problems or simply due to better awareness of the existence of these problems (Haussler et. al. 1999). Chiropractic care is one complimentary medicine modality used to treat back pain in horses, and although clinical studies are still somewhat limited, preliminary results are promising (Haussler and Erb 2003, Haussler et. al. 1999).

Prior to chiropractic treatment, manual palpation and mobilization are typically used to determine the areas of hypomobility that are subsequently treated with chiropractic manipulations (Taylor and Romono 1999). Mobilization is characterized by moving a joint through its full range of motion without employing impulsive thrusts, as summarized by Haussler (2016). The elastic barrier at the end of the full range of motion is evaluated by applying rhythmic oscillations to the joint; within the center of the physiologic range of motion the joint will move fluidly and become more restrictive when the maximal joint range of motion is reached (Haussler 1999). Chiropractic adjustments can then be applied to restricted joints, moving the joint past the elastic barrier and into the paraphysiologic space (Figure 1), which is considered manipulation (Haussler 2010).

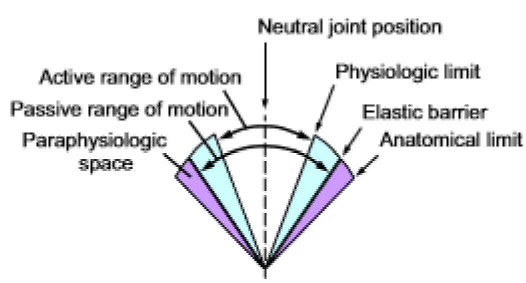


Figure 1: Joint mechanics relating to the active and passive range of motion of the joint (Haussler 2010)

A chiropractic adjustment is defined as any manipulation that utilizes controlled force, direction, leverage and amplitude to induce a beneficial change in a specified anatomical region (Haussler 1997). It utilizes high velocity, low amplitude thrusts, applied at the end of the passive range of motion (Taylor and Romono 1999) either manually or mechanically, again, with the intent to reduce pain and increase mobility (Maigne and Vautravers 2003, Haussler 1999a). In horses, manually applied adjustments have been more thoroughly studied than instrument-assisted adjustment methods (Sullivan 2008, Haussler and Erb 2003, Haussler 1999, Acutt et. al. 2018). However, in humans, both have been proven to be effective methods of reducing pain (Wood et. al. 2001, Shearar et. al. 2005). In horses, manual methods have been reported to improve spinal mobility (Haussler et. al. 1999, Haussler 1999), modulate pain response (Haussler 2010, Haussler 2016, Haussler and Erb 2003, Haussler 1999) and reduce spinal documented to improve muscle and connective tissue function (Haussler 1999). Connective tissue dysfunction typically presents as trigger points, or areas of hyper-irritability, often seen on taut skeletal muscle, that result in pain and tenderness (Vanderweeën et. al. 1996). By decreasing areas of pain, chiropractic adjustments can also correct abnormal gait patterns in horses (Pickar 2002, Collaca et. al. 2003, Haussler 2016). However, there is little scientific evidence exploring the optimal protocol for chiropractic adjustments, which can be modified by the number of joints treated, the force applied or the frequency of the treatment, as summarized by Haussler (2016). Therefore, horses are usually treated on an individual basis at the discretion of the clinician (Haussler 2016). While chiropractic care has aided in some chronic pain cases where other treatment modalities have been exhausted, it is more effective as preventative care or when used in the beginning stages of disease (Haussler 1999a, Haussler 1997, Haussler 2016). This is because chiropractic treatment cannot reverse degenerative processes once damage has occurred (Haussler 1997).

Chiropractic treatment is currently being used to treat horses ranging from companion to performance animals, but there is lack of objective, quantitative evidence for this technique as a method to reduce pain and increase performance. Pressure thresholds have been used to measure pain in horses through a technique called pressure algometry (Haussler and Erb 2003, Pongratz and Licka

2017, Varcoe-Cocks et. al. 2006), which was used in the present study. Objective quantification of lameness has been achieved using the Lameness Locator, which uses inertial sensors to determine gait asymmetries (Keegan et. al. 2011, Keegan et. al. 2012, Keegan et. al. 2013), which was also utilized in the present study. Finally, performance can be assessed through video analysis comparing the movement of horses to the ideals described in competition (Chapter DR Dressage Division 2007).

Pressure Algometry

Pressure algometry is a useful technique to objectively measure pain response for diagnosis and evaluation of treatment results (Varcoe-Cocks et. al. 2006, Vanderweeën et. al. 1996, De Heus et. al. 2010, Haussler et. al. 2007b) but applying pressure in a consistent manner can be difficult (Nussbaum and Downes 1998). A pressure algometer is a tool to measure the level of pain at different locations along the axial skeleton (Haussler and Erb 2006a). Pain is measured by recording mechanical nociceptive thresholds (MNTs), which indicate the minimum amount of pressure required to produce a pain response and is commonly expressed in kg/cm^2 or N (Newton)/cm^2 (De Heus et. al. 2010, Pongratz and Licka 2017). Higher MNTs are indicative of lower pain thresholds, while lower MNTs indicate a painful site (Haussler and Erb 2003, Fisher 1986). Pain in animals, as defined by Zimmerman (1986) is "an aversive sensory experience that elicits protective motor actions, results in learned avoidance and may modify species-specific traits of behavior including social behavior". As tenderness is a major factor of most musculoskeletal pain, pressure algometry offers an objective, non-invasive, repeatable method when compared to manual palpation, which was the traditional method for assessing pain (Vanderweeën et. al. 1996, Haussler and Erb 2003). It can both identify and quantify tenderness at various locations (Vanderweeën et. al. 1996) and has been shown to be highly correlated with subjective palpation scores (Varcoe-Cocks et. al. 2006).

To determine MNTs, steadily (10 $kg/cm^2/s$) increasing amounts of pressure is applied to various anatomical landmarks until a local avoidance reaction is noted (De Heus et. al. 2010). Avoidance reactions can include behaviors such as swishing of the tail, rearing, bucking, unruliness, whole body contraction and moving away from the pressure (Wennerstrand et. al. 2004) Despite high pressure occasionally being tolerated by the horse, bruising after repeated measurements has not yet been seen (Haussler and Erb 2006a), though bruising may be difficult to detect due to hair and dark skin. While pressure algometry has proven to be an effective measure of pain response in horses (Pöntinen 1998, Ohrbach and Gale 1989, Varcoe-Cocks et. al. 2006, Nussbaum and Downes 1998), the reliability of the device also depends on the experience of the examiner (Pöntinen 1998, Nussbaum and Downes 1998).

Previous studies have shown that chiropractic treatment was effective at producing significant increases in MNT values over a period of seven days (Sullivan et. al. 2008, Haussler 2010, Haussler and Erb 2003, Sullivan et. al. 2007). Additionally, at locations where pain was not initially present, median MNT values did not change between initial and final measurements (Haussler and Erb 2006b). In a study done by Haussler and Erb, the median MNT value in the cervical, thoracic and lumbar region was 9 kg/cm^2, 12 kg/cm^2 and 13 kg/cm^2 respectively, with higher MNT values for non-thoroughbred horses (2006a). Geldings also tend to have higher MNT values than mares, and it's hypothesized that behavioral or hormonal differences account for these findings (Haussler et. al. 2007b).

Lameness Locator

Back pain can lead to lameness (Haussler 1997) thus an objective assessment of gait asymmetries may gauge the effects of chiropractic treatment. Studies indicate that there is a relationship between back pain and limb function (Haussler et. al. 1999). Lameness in the hindlimbs has been reported to affect the flexion-extension and axial rotation of the spine (Pourcelot et. al. 1998) which can lead to back pain and stiffness (Landman et. al. 2004). Alternatively, back pain and stiffness can lead to gait abnormalities as the horse alters its movement to protect painful areas (Landman et. al. 2004, Haussler 1997). No causal relationship has been established yet, but a clear connection between back problems and lameness have emerged (Landman et. al., 2004).

Even among experts, detecting subtle lameness is difficult and often inaccurate (Keegan et. al. 1998, Keegan et. al. 2010), even if visual lameness analysis is one of the most frequently used methods to detect lameness in practice (Hewetson 2006). This may be in part due to the subjectivity associated with numeric scales, which range from not lame to non-weight bearing lame in relatively few numeric steps (Keegan et. al. 1998). This can make it difficult to compare pre- and post-treatment values. Objective methods, such as stationary force plates may be used instead, and are currently the gold standard for detection of mild lameness (Keegan et. al. 2012). While potentially less accurate and with more limitations, inertial systems, such as the Lameness Locator (Equinosis), also play a role (Keegan et. al. 2012). While it is still difficult to detect bilateral lameness with the Lameness Locator, the small size of the unit and ability for wireless transmission of data makes it much more practical for clinical use (Keegan et. al. 2012).

The Lameness Locator relies on small sensors affixed to the pole, croup and right forelimb that are designed to be small and light as to not change to a horse's normal movement pattern (Keegan et. al. 2011). The head and pelvic sensors are uniaxial accelerometers that sample vertical head and pelvic acceleration at 200 Hz that are responsible for measuring lameness (Equinosis LLC 2017). The right forelimb sensor acts as a uniaxial gyroscope that determines angular velocity on the sagittal plane at 200 Hz, which measures stride phase (Equinosis LLC 2017). This is used to determine the stance phase of the gait (Equinosis LLC 2017). To detect lameness, the sensors measure the asymmetry of both the head and pelvic movement at the trot in a straight line to calculate a lameness score (Keegan et. al. 2011). This is done by calculating the head and pelvic height differences between the right and left half of the stride (Equinosis LLC 2017). When the horse is trotting, there exist two maximums and two minimums for head height and height of the pelvis (Equinosis LLC 2017). In a sound horse, the head and pelvis should reach the same maximum and minimum heights throughout the cycle of the stride (Equinosis LLC 2017). The Lameness Locator uses a threshold of difference of ± 6 mm for the head height and ± 3 mm for the pelvic height, and values above this indicate that the horse's gait is asymmetric, or lame (Equinosis LLC 2017). Using these sensors, the Lameness Locator can identify lameness at a lower sole pressure than the consensus of three experienced veterinarians for both forelimbs and hindlimbs when inducing lameness via pressure to the sole of the hoof (McCrackenet. al. 2012). Thus, systems like the Lameness Locator are non-invasive, easy to use, provide real time data collection and analysis of gait asymmetry (Keegan et. al. 2011, Keegan et. al. 2012). Trials have been shown to be repeatable, with high correlation between trials, to the degree that it can be useful in clinical practice (Keegan et. al. 2011, Keegan et. al. 2012).

Assessment of Gait Quality

Many studies have shown that spinal manipulation in horses has the possibility of increasing spinal motion and therefore decreasing stiffness (Haussler et. al. 1999, Faber et. al. 2003) which could lead to improved performance. Furthermore, it has been reported that chiropractic care can promote more balanced movement (Taylor and Romono 1999), and chiropractic studies in humans have shown that adjustments can enhance athletic performance when compared to control groups as summarized by Taylor and Romono (1999). It has also been shown to elicit slight but significant changes in thoracolumbar and pelvic kinematics, which may improve gait (Faber et. al. 2003, Haussler et. al. 1999). Horses suffering from back pain often show signs of altered gait kinematics (Pourcelot et. al. 1998, Cauin 1997). They present with poor general gait quality, stiffness, abnormal movement in the back or pelvis, reduced flexion of the hind limb, loss of gait amplitude, reluctance to turn and an inability to track up while trotting (Cauin 1997, Rooney 1982, Riccio et. al. 2018).

Horses used for English sports (dressage, jumping, eventing) are expected to move in certain ways to achieve the highest scores in competitions. The United States Dressage Federation (USDF) indicated that the quality of the trot should be judged upon the elasticity, cadence, impulsion and engagement of the gait (Chapter DR Dressage Division 2007). Elasticity refers to the smooth stretching and contracting of muscles, which gives a quality of springiness to the gait (Chapter DR Dressage Division 2007). Cadence is marked by the steady rhythm and regularity of the gait (Chapter DR Dressage Division 2007). Impulsion involves the thrust from the hind legs, which releases the energy stored in the moment of suspension of the gait (Chapter DR Dressage Division 2007). Engagement refers to an increase in flexion in the joints of the hind limbs during the weight-bearing phase of the stride. This increased flexion is what allows for the upward thrust of the gait that translates into impulsion (Chapter DR Dressage Division 2007). Horses with back pain tend to perform less well due to a lack of impulsion and suppleness (Cauin 1997) but chiropractic care can treat back pain and improving symmetry (Haussler et. al. 1999). Clinical indications for chiropractic care in horses include altered gait not associated with overt lameness, restricted range of motion (Haussler 2010, Haussler 2016) or some of the gait qualities discussed above, such as difficulty with impulsion or collection (Taylor and Romono 1999). Collection refers to the horse moving in a way that engages the hindquarters and shortens the step, resulting in the lightening of the forehand (2019 USDF Glossary of Judging Terms 2019).

Objective, Hypothesis and Aims

The objective of this study is to determine how chiropractic adjustments affect horses' pain thresholds, gait and owner-perceived performance. The purpose of this study is to provide quantitative evidence for or against the clinical efficacy of manual chiropractic manipulations in horses to alleviate back pain and reduce biomechanical imbalances. We hypothesized that individualized chiropractic treatment in horses would decrease back sensitivity, improve lameness, increase gait quality and owners' perception of their horse's performance. To test our hypothesis, we measured pain thresholds, using pressure algometry, at various predetermined locations along the horse's back to determine how much pressure they would tolerate before and after chiropractic treatment. We used the Lameness Locator as a quantitative assessment of lameness, and we used video gait analysis to quantitatively analyze the quality of the gait via measurement of hock amplitude throughout the stride and the evenness of distances of diagonal limb pairs at the trot; before and after chiropractic treatment. Owners' perception of horse performance and attitude before and after treatment was also obtained in the form of a survey.

Methods and Materials

Horses

Twenty-four horses were included in the study after approval from the Animal Care and Use Committee of Oregon State University. All horses used in the study were stabled at the same boarding barn for the duration of data collection to maintain similar environmental conditions. All owners sought chiropractic care from the clinician, who was a licensed veterinarian, certified in equine spinal manipulation, with 4 years of clinical experience in equine chiropractic therapy. The clinician had treated some of the horses previously, but others were new patients. For horses to be included in the study, they had to be visually sound, as assessed by a licensed veterinarian, and have no contraindications to chiropractic treatment, such as acute injury or hypermobility. If horses were on medications that might influence the outcome variables prior to chiropractic treatment, they had to remain on the same medication regime throughout the study. Horses that were on no medications at the beginning of the study were not allowed to be administered any medications throughout the study. Three horses were excluded from the study due to inability to tolerate chiropractic treatment without sedation (n = 2) and for being given phenylbutazone prior to the follow up due to reasons unrelated to the study (n = 1). The remaining 21 horses included 14 geldings and 7 mares aged (mean ± s.d.) 12.0 ± 5.5 years (range 3 to 22 years). Breeds included 1 Appendix Quarter Horse, 2 Arabian crosses, 1 Anglo Arabian, 1 Fjord, 2 Gypsy Vanners, 2 Oldenburger, 2 Quarter Horses, 8 Thoroughbreds, and 2 Thoroughbred crosses. Athletic activities included English lesson horse (n = 6), low level dressage (intro, training, first level) (n = 10), lower level eventing (beginner novice, novice) (n = 5), upper level eventing (preliminary) (n = 2), and trail riding (3). One horse was not in work. Some horses were used for more than one activity, hence the number of activities being larger than the number of horses.

Experimental Set-up

At the beginning of the study, each horse was walked in both directions at the testing site to familiarize them with the setting prior to data collection to aid in the prevention of spooking due to unfamiliar elements in the environment. Then, all pre-treatment data was collected. First, video for video analysis to determine gait quality was obtained. Simultaneously, the Lameness Locator (Equinosis) was used for analysis of lameness. Videos and Lameness Locator data was always taken before pressure algometry data to prevent the possibility of the horses being sore due to the application of pressure on the muscles of the back. Following, the pressure algometer (Wagner Instruments) was used for measurement of pain on the back region. For more details on analyses, see below.

Horses were then assessed by the clinician and given scores for pain and stiffness along the axial and appendicular skeleton. A pain score of 0 indicated that there was no reaction to mobilization of the joint/spinal segment and a pain score of 1 indicated that there was a mild withdrawal reflex elicited at the end of the range of motion. A pain score of 2 indicated that there was a moderate withdrawal at the end of the range of motion whereas a pain score of 3 indicated that there was a moderate withdrawal reflex with any applied mobilization. A pain score of 4 indicated complete avoidance and evasion to any applied mobilization. As for stiffness, a stiffness score of 0 indicated no restrictions with free and fluid motion of the examined joint/spinal segment. A stiffness score of 1 indicated mild stiffness, a stiffness score of 2 indicated moderate stiffness, and a stiffness score of 3 indicated severe stiffness of the examined joint/spinal segment. Pain was scaled on a scale of 0 through 4 instead of 0 through 3, as was done with stiffness, to allow for consideration of severity and location of pain. All scores for all locations were then summed up to obtain a score for total pain and total stiffness, respectively. Areas of hypomobility were then treated with chiropractic adjustments.

Horses were returned to their normal stabling accommodations post-treatment. These accommodations included a box stall, a stall with a run, and a pasture. For horses 1-8, follow-up data was collected 8 days post treatment, for horses 9-20, follow-up data was collected 7 days post treatment, and for horses 21-24, follow-up data was collected 6 days post treatment. Follow-up data collection consisted of video-recording of the gait at a trot, lameness locator recording at a trot and pressure algometry. Subjective scoring of pain and stiffness by the clinician was not performed for follow-up data collection.

Owners were provided with the written survey on the day of treatment and asked to complete it on a daily basis.

Treatment

Horses were restrained with a halter and lead rope by an experienced horse handler, but not by the horse's owner. At locations of hypomobility, each horse received high velocity, low amplitude, manually applied thrusts until the hypomobility had resolved. The thrusts were applied in a specific direction, which was depended on the anatomy of the joints being treated and the exam findings by the clinician. Table 1 details the direction of the adjustment at all sites considered in this study.

Table 1: Direction of chiropractic adjustment based on location

Location	Direction
Cervical vertebra 1	Dorsal, ventral, caudal
Cervical vertebra 2	Not directly adjusted
Cervical vertebrae 3, 4, 5, 6	Left or right oblique
Thoracic vertebrae 3, 4, 5, 6, 7, 8	Left or right in a lateral direction
Thoracic vertebrae 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, Lumbar vertebrae 1, 2, 3, 4, 5, 6	Ventral, or ventral oblique in left or right direction
Hemi pelvises	Ventral or dorsal
Sacrum	Ventral, left or right lateral
Intertransverse joints (L4-L5, L5-L6, L6-S1,)	Ventral
Ribs (T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18)	Ventral
Carpus	Ventral or caudal
Humerus	Medial or lateral
Scapula	Dorsal

Mechanical Nociceptive Thresholds (Pressure Algometry)

All horses were restrained with a halter and lead rope by an experienced handler, although the handler varied between trials. The pressure algometer model FPX 50 (Wagner Instruments) with a 1 cm^2 rubber tip and a calibrated range of 0 to 245 N/cm^2 was used by a single examiner (same clinician who performed the chiropractic exam and treatments) in all cases to determine the mechanical nociceptive thresholds (MNTs) in each horse. The examiner practiced on one horse to become accustomed to the pressure algometer, but at the beginning of the data collection phase, the examiner had less than 10 hours of experience with the device. Pressure was applied perpendicularly to the skin surface at 8 sites on each side of the horse (exact locations described below; Figure 2), although the locations of measurement were not directly associated with sites of chiropractic treatment. Pressure with the algometer was applied until avoidance was noted by the examiner. This included reactions such as skin twitching, whole body muscle contraction, striking or stepping away. At that point, pressure was immediately released, and the corresponding MNT value was recorded automatically by the device. All measurements were performed consecutively in triplicates to increase reliability, resulting in a total of 48 measurements per horse. The examiner was aware of the MNT value after each trial but could not see the MNT value while pressure was being applied.

The MNT value was recorded approximately 10 cm lateral to the dorsal midline at the rhomboideus muscles at the level of the 3rd thoracic vertebra, the thoracic spinalis muscle at the level of the 9th thoracic vertebra, the thoracic longissimus muscle at the level of the 13th and 18th thoracic vertebrae, and the gluteal muscles at the level of the 3rd and 6th lumbar and the 2nd sacral vertebrae vertebra; adapted from Sullivan et. al. (2008). Measurements were always taken in a cranial to caudal order, starting on the left side and then moving to the right side of the horse. If the pressure algometer slipped off the desired anatomical landmark, or the horse was obviously distracted (spooking, calling), the measurement was discarded and taken again. The rate of pressure increased was not controlled, although an attempt to do so in a consistent manner was made.

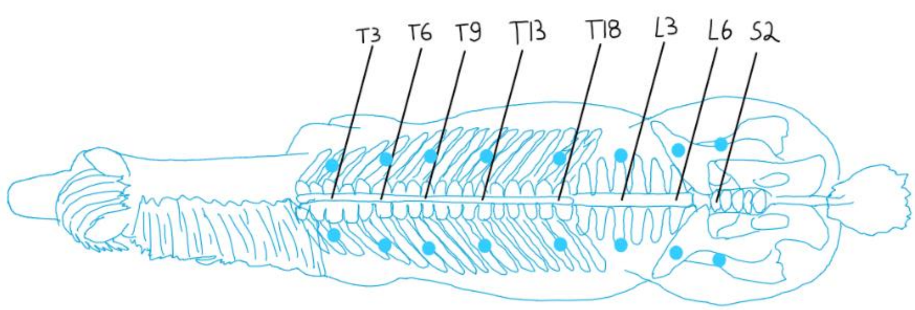


Figure 2: Approximate location of pressure algometry readings marked by blue circles

Lameness Locator

Horses were trotted in the same location before and after treatment over an approximately flat stretch of grass. The stretch of grass was long enough to allow for at least 15 continuous strides.

The Lameness Locator is a piece of equipment designed to objectively detect lameness in horses. The vertical accelerometer sensors were placed on the poll directly on the midline, and over the tuber sacrale on the dorsal midline at the highest level of the pelvis (Equinosis LLC 2017). The gyroscopic sensor was placed on the dorsal midline of the right pastern (Equinosis LLC 2017). The stride selection criterion was set to include all strides that had similar acceleration.

Two variables were considered to determine forelimb lameness: maximum and minimum mean difference in head height. The lameness locator determines the maximum difference in head height (max diff head) by subtracting the maximum height of the head just before the left fore is weight bearing from the maximum height of the head just before the right fore is weight bearing (Equinosis LLC 2017). The minimum difference in head height (min diff head) is determined by subtracting the minimum height of the head during left front mid-stance from the minimum height of the head during right front mid-stance (Equinosis LLC 2017). Detection of forelimb lameness is dependent on both maximum and minimum difference in head height (Equinosis LLC 2017), and thus they were considered together by calculating the total difference in head height (or also called vector sum) as follows (Equinosis LLC 2017): $total\ diff\ head = \sqrt{\max diff\ head^2 + \min diff\ head^2}$ Two independent measures were taken into account to determine hindlimb lameness. The maximum difference in pelvis height was determined by subtracting the maximum height of the pelvis before the left front is weight bearing from the maximum height of the pelvis from before the right front is weight bearing (Equinosis LLC 2017). Then the minimum difference in pelvis is determined by subtracting the minimum height of the pelvis during left front mid-stance from the minimum height of the pelvis during right front mid-stance (Equinosis LLC 2017). The maximum and minimum difference in pelvis height are independent indicators for hindlimb lameness, and thus they were considered separately (Equinosis LLC 2017).

Figure 3: Location of lameness locator sensors (Equinosis LLC 2017)

As illustrated in Figures 4 and 5, horses were considered sound if total diff head was below the threshold of ± 8.5 mm for the forelimbs, and/or if mean values for both diff max pelvis and diff min pelvis were below a threshold of +/- 3 mm for the hindlimbs, regardless of the value of the standard deviation. A horse was considered to have too variable of a gait if one or both mean values for diff max head or diff min head was above the threshold of ± 6 mm for the forelimbs, and/or if one or both mean values for diff max pelvis and/or diff min pelvis were above the threshold of +/- 3 mm for the hindlimbs, but the standard deviation was greater than the absolute value of the respective mean for all of the measurements above threshold. A horse was considered to be lame if one or both mean values for diff max head and/or diff min head was above the threshold of ± 6 mm for the forelimbs, and/or if one or both mean values for diff max pelvis and/or diff min pelvis were above the threshold of +/- 3 mm for the hindlimbs and the standard deviation was equal to or smaller than the absolute value of the mean for at least one measurement above the threshold. The decision trees are illustrated in Figure 4 for the forelimbs and Figure 5 for the hindlimbs.

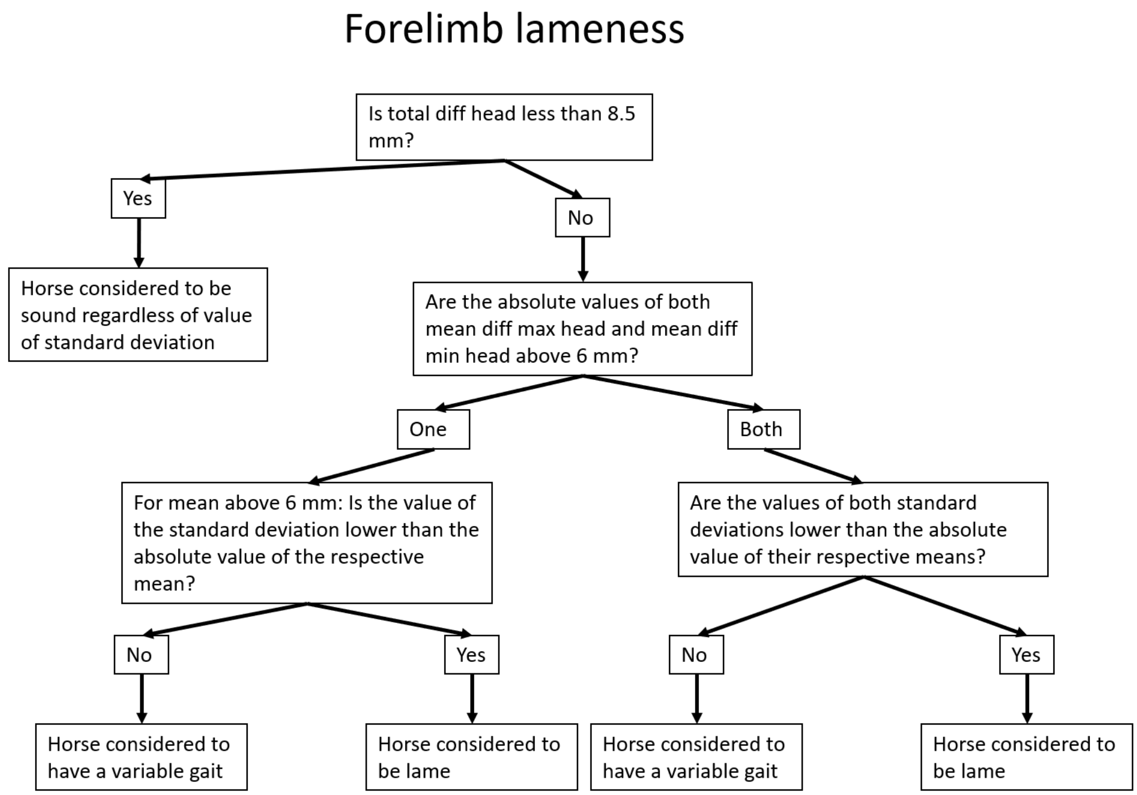


Figure 4: Determination of forelimb lameness using data from the Lameness Locator.

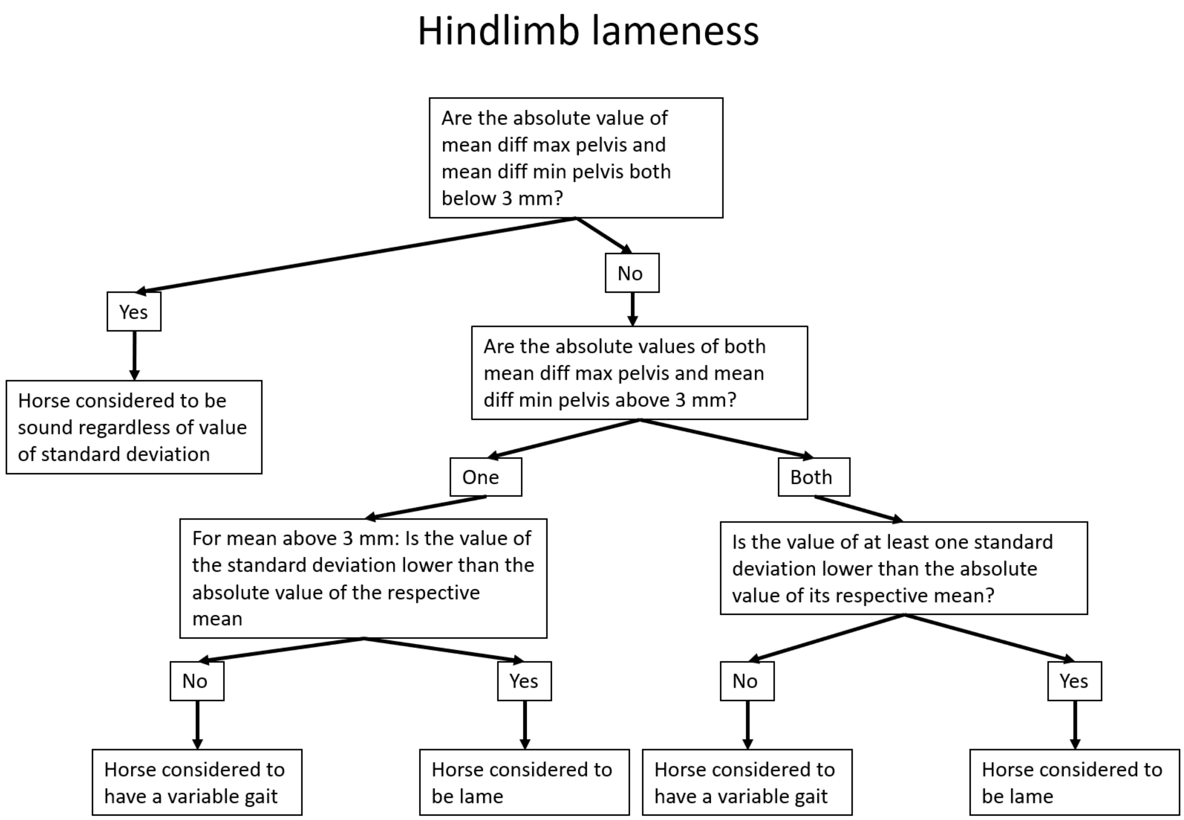


Figure 5: Determination of hindlimb lameness using data from the Lameness Locator.

Analysis of Hock Angle and Stride Symmetry

Video recordings of the horses were made at the trot in a straight line, simultaneously with the Lameness Locator recordings. Each horse was trotted at its own preferred speed six times in each direction. Each trial was recorded by an iPhone XR which was positioned stationary approximately 10 meters away, perpendicular to the horse, allowing for two to four complete strides to be captured for each trial. The camera allowed for the capture of 1920 x 1080-pixel resolution at 30 frames per second.

All videos were imported to LoggerPro 3.8.7 (Vernier) for analysis. A standard coordinate system was used to analyze the motion of each horse. Blinding the analysis was not possible due to one person trotting the horses prior to treatment, and two different people trotting the horses 6-8 days post treatment.

To normalize measurements made for hock amplitude and gait evenness on the video frames for each horse, the height of each horse was measured from the withers to the ground on a video frame when the inside forelimb was perpendicular to the ground and that measurement was scaled to a value of one (Figure 6). All following distance measurements were then expressed as a fraction of the horse's measured height.

The quality of the trot was measured based upon two main factors: hock amplitude throughout the stride as an estimate for hock angle, which may be an indicator for degree of loading of the rear limb and the evenness of distances of diagonal limb pairs at the trot, according to what the United States Dressage Federation considers an ideal trot (2019 USDF Glossary of Judging Terms 2019).

To measure hock amplitude, as an estimation of hock flexion, the amplitude of the hock was measured at the highest and lowest points in one stride (Figure 7), using the point of the hock as landmark. The values measured were expressed as a fraction of the horse's height, scaled to a value of one. The beginning of each stride was taken to be when the inside hind leg struck the ground. The position of the hock nearest the camera was manually marked in each frame of the video, which corresponded to approximately 35 frames analyzed per stride

The evenness of the stride was determined by subtracting the distance between the diagonal limb pairs for the same stride (Figure 8), using the heels as landmarks. The values obtained were also expressed as a fraction of the horse's height, scaled to a value of one. The point of the stride or specific video frame for measurement was chosen based on maximum extension of the limbs. The limb pair with the lowest value was subtracted from the limb pair with the highest value, and therefore, a value closest to zero means the horse was moving symmetrically. Following, to determine the change in gait evenness before and after treatment, the value determined after treatment was subtracted from the value obtained before treatment. Thus, a positive difference indicates improvement.

Only strides in which the necessary landmarks to make the described measurements were clearly visible were used for analysis. If multiple strides fit these criteria, strides were preferentially chosen from the middle of the field of view of the camera to prevent possible distortion. If the horse tripped, slipped, spooked, or violently tossed its head, a different stride was chosen for analysis.

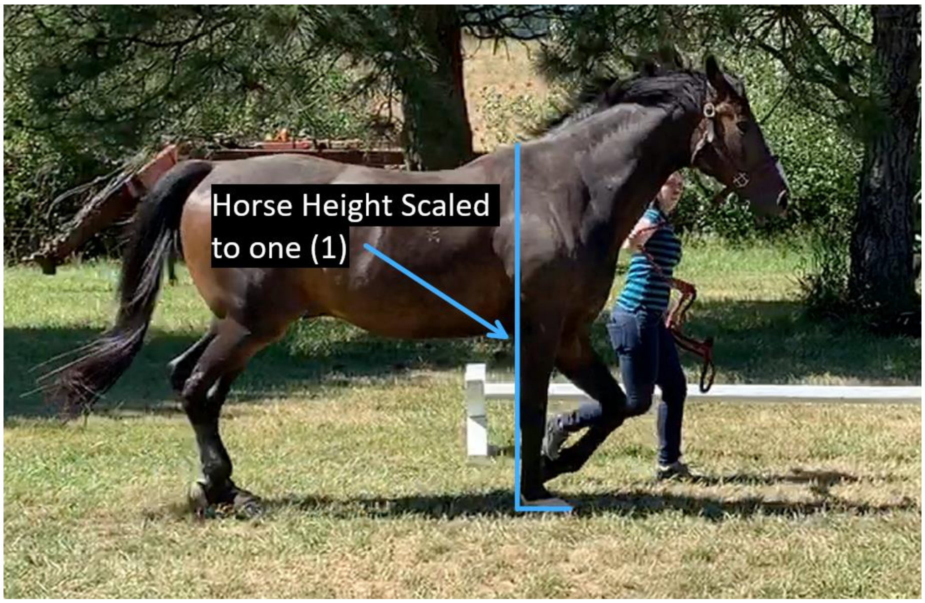


Figure 6: Scaling of video for analysis

Figure 7: Determining hock amplitude

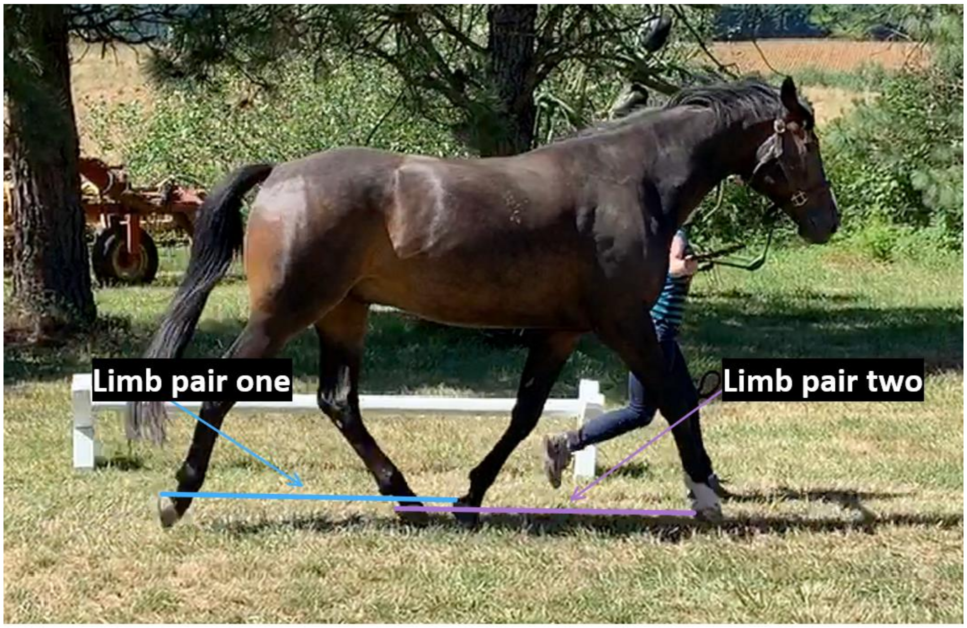


Figure 8: Determining stride evenness

Owner Survey

Owners were handed a paper survey questionnaire (Appendix 6: Owner survey) on the day of treatment and instructed to fill it out daily for seven days after treatment, with the initial treatment day being the first day. Owners were asked to rank their horses' attitude, appetite, soreness, swelling, willingness to perform under saddle and willingness to perform on the ground in hand on a scale of 1 to 10, with a score of 1 being the worst and a score of 10 being the best.

Statistical Analyses

All statistical analyses were performed using RStudio (https://rstudio.com/) with significance set at $p < 0.05$. For video analysis, the Lameness Locator and owner surveys, data is summarized as mean and standard deviation. For pressure algometry, the median of the 3 measurements for each location was determined for each horse, followed by generating the mean and standard deviation to summarize the data for all horses. Paired t-tests were used to detect differences in the pre- and post-treatment for the pressure algometry data, the lameness locator data and video analysis data. The Bonferroni Multiple Comparison method was used to adjust the significance level for t-tests used to determine differences in owner survey responses. Twenty-one pairwise comparisons were made, resulting in a new α of 0.00238. The bootstrap method with 10,000 trials was employed to determine the p-value.

Results

Treatment

The examiner examined all locations on each of the 21 horses included in this study, graded the horses on subjective pain and stiffness, and provided treatment where necessary. The number and location of treatment sites varied according to the needs of each individual horse, ranging from 8 to 29 total treatment sites per horse. Each site was treated until improvement in mobilization was achieved, which ranged from one to three high velocity, low amplitude thrusts per site. Pain was scored on a scale of 0 to 4, where a zero indicates no pain and a score of four indicates complete avoidance and evasion to any applied mobilization. Stiffness was scored on a scale of 0 to 3 where zero indicates free and fluid motion while a four indicates severe stiffness. Between all horses, the total possible number of sites treated was 39. Thus, the maximum total pain would have been 156 and the maximum total stiffness would have been 117.

Table 2: Results of Chiropractic Exam

Horse	Total Pain score	Total Stiffness score	Average Pain per abnormal segment	Average Stiffness per abnormal segment	Locations of Treatment
1	20	48	1.8	2.3	T3-7, T14, T17-18, L1-4, Sacrum, Left and Right Carpus, Scapula, C3-6, C1
2	0	36	0.0	2.6	T3-5, T13, T15-16. L2-4, Hemi Pelvis, Sacrum, C3-4, C6
4	3	39	1.5	2.4	T4-5, T17-18, L1-4, Left Hemi Pelvis, Right and Left Scapula, C3-6, C1
5	5	45	1.7	2.1	T3-8, T13-17, L2-4, Left Hemi Pelvis, Sacrum, Right T13 rib, Left carpus, right scapulohumeral joint, Left and Right scapula, C4, C6
6	0	14	0.0	1.8	T4, T13, T16, L3, Right Hemi Pelvis, C3, C5, C1
7	0	38	0.0	2.4	T3-4, T15-16, L1-2, L4, Right and Left Hemi Pelvis, Sacrum, Left T15 rib, Left scapulohumeral joint, Right scapula, C3-4, C6
8	0	35	0.0	2.3	T3, T5-7, T17-18, L1, L3-4, Sacrum, Right and Left Scapula, C3, C5, C1
9	0	18	0.0	1.8	T3-4, L1, Left and Right Hemi Pelvis, Sacrum, Right Carpus, Left and Right Scapula, C4

10	5	20	1.23	1.7	T3-5, T16, L3-4, Right Hemi Pelvis, Right Scapula, C3, C5-6, C1
11	4	21	2.0	1.6	T3-5, T15, T17-18, L4, Left Hemi Pelvis, Sacrum, Left Carpus, Left Scapula, C5-6
12	0	25	0.0	1.5	T3-6, T15, T17, L1-2, Left and Right Hemi Pelvises, Sacrum, L6s1, Left and Right Carpus, C3-4, C6
13	2	20	2.0	1.7	T3-6, T15, T17, L3, Left and Right Hemi Pelvises, Sacrum, C3, C6
15	20	51	2.5	2.4	T3-6, T12, T17, L2, L4, Left and Right Hemi Pelvises, Sacrum, Right T9 rib, Right T16 Rib, Right scapulohumeral joint, Left and Right Scapula, C3-6, C1
16	3	24	1.5	1.7	T3-4, T13, T15, T17, L1, L3, Sacrum, Right Pastern, Right Carpus, Left and Right Scapula, C4, C6
17	5	43	1.7	2.1	T4-6, T8-9, T15, T17-18, L1, L4, Left and Right Hemi Pelvises, Sacrum, L6s1, Right Carpus, Right scapulohumeral joint, C3-6, C1
18	5	33	1.7	2.2	T4-6, T14, T18, L1, L3, Left Hemi Pelvis, Sacrum, Right scapulohumeral joint, Left and Right Scapula, C3-4, C6
19	0	27	0.0	1.6	T4-5, T16-18, L1, L3, Left and Right Hemi Pelvis, Sacrum, L6s1, Left and Right scapulohumeral joint, C3-4, C6, C1
20	3	32	1.5	2.7	T3-5, L3-4, Right Hemi Pelvis, Sacrum, Left and Right Carpus, Left Scapula, C3-4
21	4	17	1.3	1.7	T4-6, T17-18, Sacrum, Right scapulohumeral joint, C3-4, C6
22	14	71	2.0	2.5	T3-7, T13, T16-18, L3, Left and Right Hemi Pelvises, Sacrum, L6s1, Left and Right T8 rib, Right T9 rib, Left and Right T13 rib, Right T14-15 rib, Left and Right Carpus, Left scapula, C3-6, C1
23	2	29	1.00	1.93	T5-6, T13, T17-18, L3-4, Left and Right Hemi Pelvises, Sacrum, Right scapulohumeral joint, C3-4, C6, C1

Pressure Algometry

Pressure algometry readings of the left side did not significantly differ from those on the right side ($p=0.5$), thus, readings from the left side were pooled with those from the right side for each location and time point. Readings ranged from 79.2 to 133.8 N/cm^2. When using data from all horses, chiropractic treatment was associated with an increase in pain tolerance 7 days after treatment at the level of T18 ($p=0.046$), but not at any other spinal level (one sided p-values for comparison of values prior to treatment to after treatment at spinal levels T3, T9, T13, L3, L6 and S2 were 0.957, 0.999, 0.843, 0.449, 0.099, and 0.080, respectively).

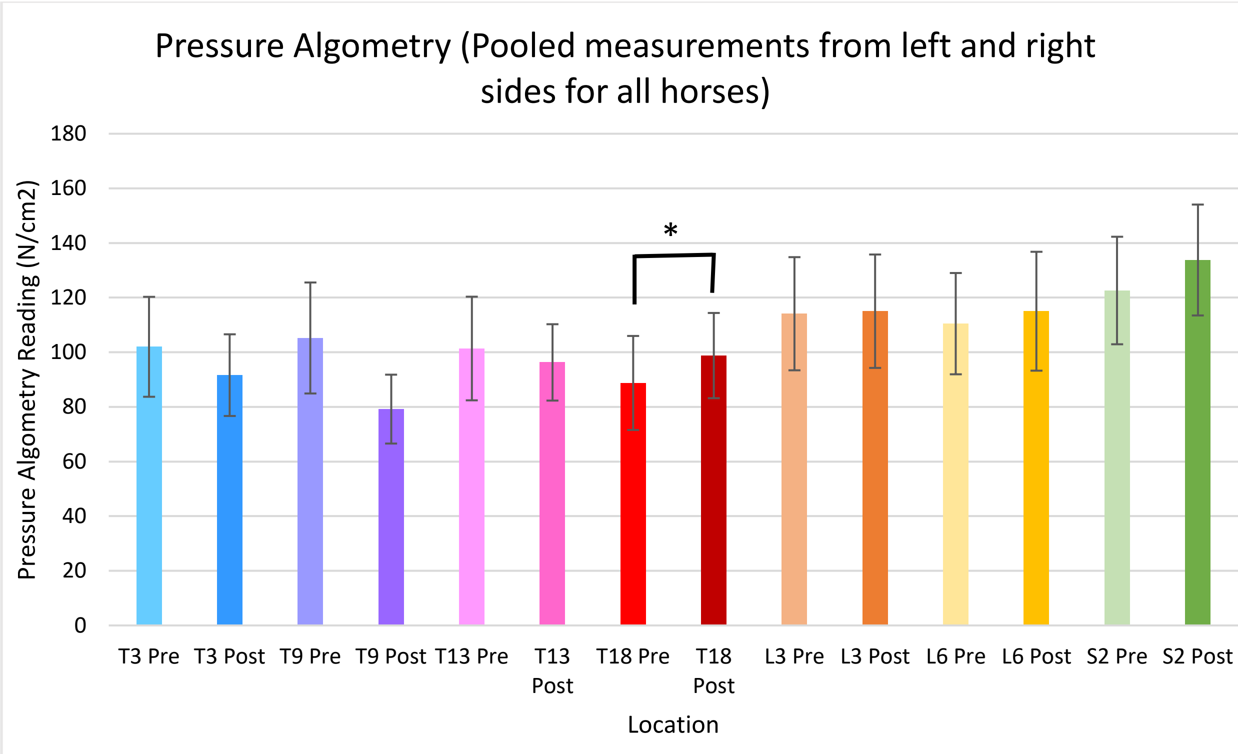


Figure 9: Mean values for pressure algometry, prior to (Pre) and 6 to 8 days after (Post) chiropractic treatment for all horses (n=21). Measurements at each spinal level were made in triplicates and on both sides of the spine, before being pooled to generate an average value for each horse for each spinal level. Error bars represent standard deviation. Bars with the same superscript are significantly different from each other.

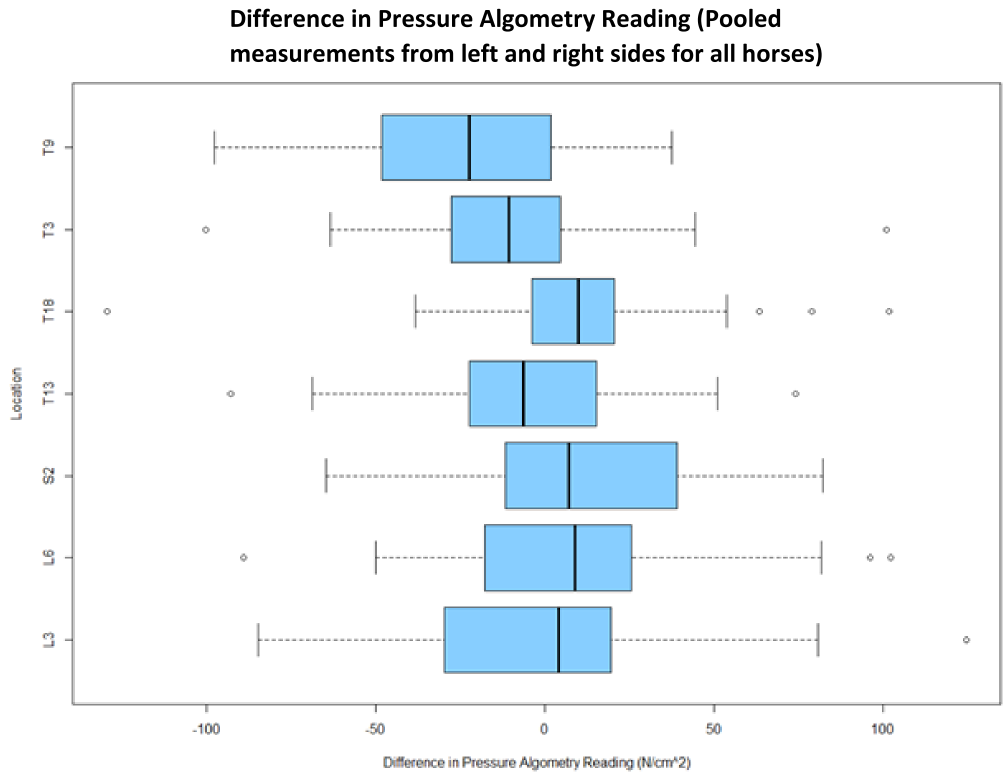


Figure 10: Mean differences in pressure algometry reading before and 6 to 8 days after chiropractic treatment for all horses (n = 21). Pressure algometry readings taken prior to chiropractic treatment were subtracted from readings taken 6 to 8 days after treatment. Thus, a positive difference indicates improvement. The distribution looks approximately normal for all locations, however, both extremely small and extremely big outliers exist.

Because the veterinarian performing the investigation felt that he was getting more consistent and reliable (possibly due to an improvement in his technique with increased practice), pressure algometry readings in the last 9 horses enrolled in the study were also compared separately.

Pressure algometry readings of the left side did not significantly differ from those on the right side (p=0.3), thus, readings from the left side were pooled with those from the right side for each location and time point. Readings ranged from 91.4 to 140.3 N/cm^2 and were lowest at the thoracic regions and increased through the lumbar and sacral regions. When using data from the last nine horses, chiropractic treatment was associated with an increase in pain tolerance 7 days after treatment at the level of T18 (p=0.0037) and L3 (p=0.047), but not at any other spinal level (one sided p-values for comparison of values prior to treatment to after treatment at spinal levels T3, T9, T13, L6 and S2 were significant (0.686, 0.582, 0.150, 0.061, and 0.151, respectively).

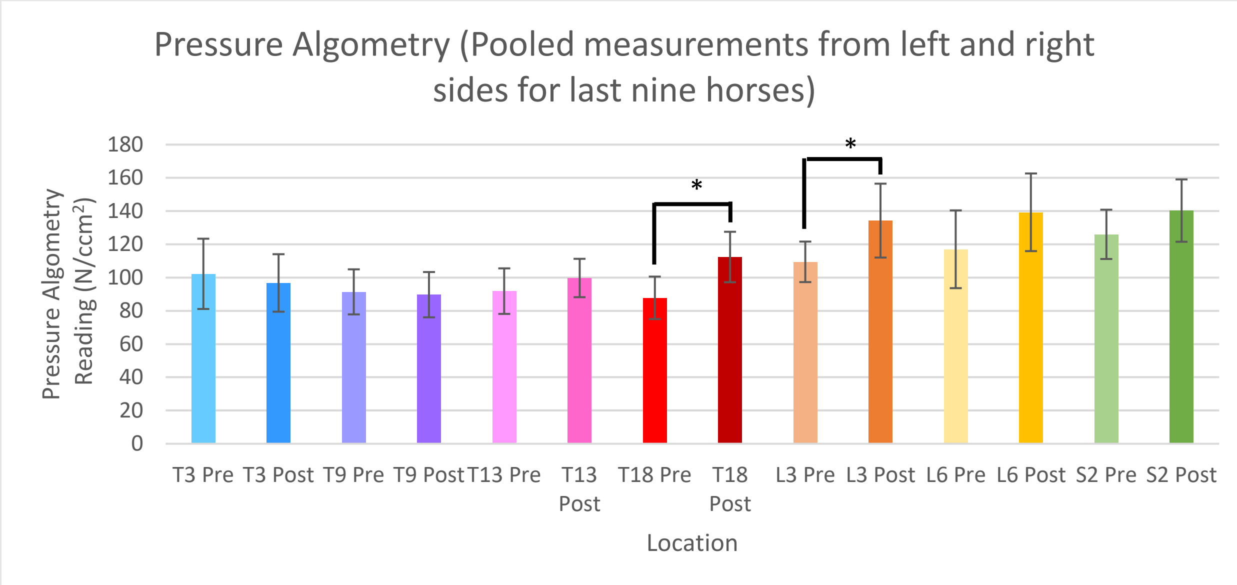


Figure 11: Mean values for pressure algometry, prior to (Pre) and 6 to 7 days after (Post) chiropractic treatment for the last 9 horses. Measurements at each spinal level were made in triplicates and on both sides of the spine, before being pooled to generate an average value for each horse for each spinal level. Error bars represent standard deviation. The asterisks over the bars indicate that they are significantly different from each other.

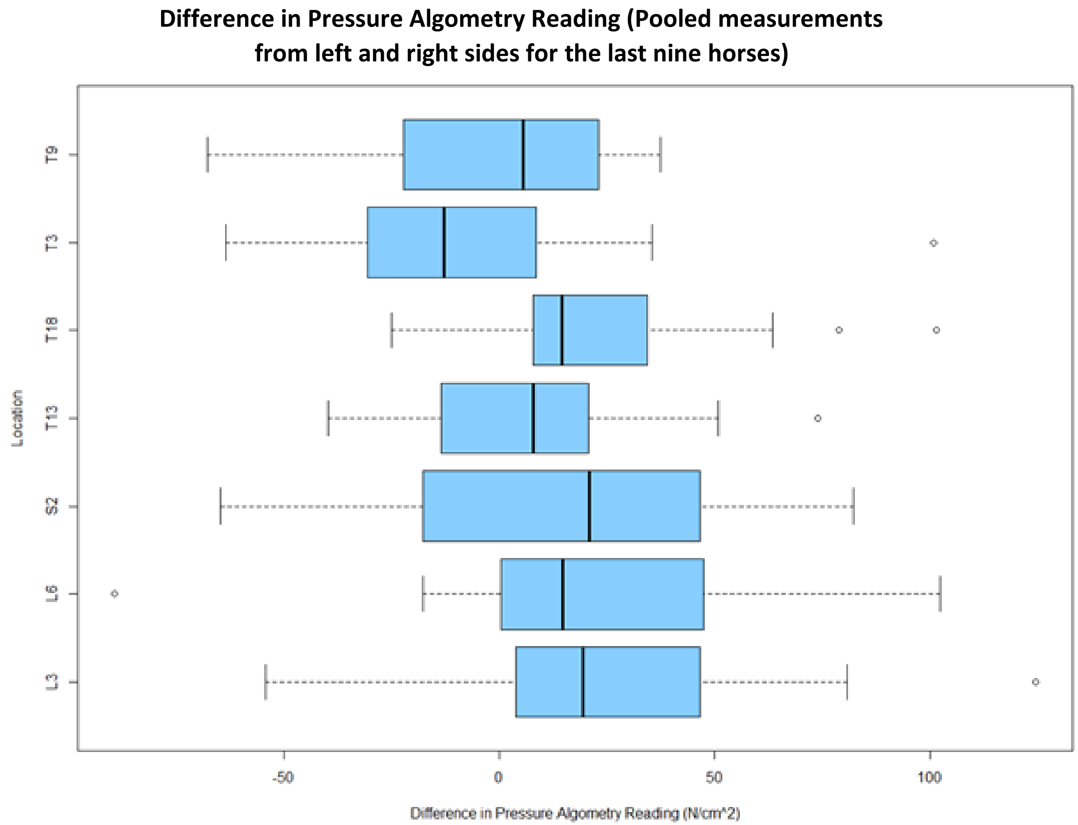


Figure 12: Mean differences in pressure algometry reading before and 6 to 7 days after chiropractic treatment for the last nine horses. Pressure algometry readings taken prior to chiropractic treatment were subtracted from readings taken 6 to 7 days after treatment. Thus, a positive difference indicates improvement. The distribution looks approximately normal for all locations, however, both extremely small and extremely big outliers exist.

Lameness Locator

The Lameness Locator was only used on horses 15-23 due to lack of availability for the first 14 horses. These horses included 5 geldings and 4 mares aged (mean ± s.d.) 10.44 ± 5.46 years (range 3 - 22 years). Breeds included 1 Appendix Quarter Horse, 1 Anglo Arabian, 1 Arabian cross, 1 Fjord, 1 Quarter Horse and 4 Thoroughbreds. Athletic activities included low level dressage (intro, training, some first level), lower level eventing (beginner novice, novice), and trail riding.

The Lameness Locator did not reveal any significant differences in lameness in horses prior to compared to after chiropractic treatment. For the forelimbs, lameness improved in a total of two horses, it remained constant in four horses, and lameness worsened in three horses. For improvement, one horse (# 16) went from lame to sound and 1 horse (# 20) went from variable gait to sound. For no change, 2 horses (#17 and 21) remained sound and two horses (#15 and #18) maintained a variable gait. For the horses that worsened, 2 (# 22 and 23) went from sound to lame, and 1 horse (# 19) went from sound to variable gait. A one-sided p-value of 0.601 indicated chiropractic treatment did not affect forelimb lameness. For the hindlimbs, lameness improved in one horse, it remained constant for two horses, and lameness worsened in six horses. For improvement, 1 horse (# 17) went from a variable gait to sound and two horses (# 16 and 23) maintained a variable gait. Five horses worsened (# 15, 18 through 22), going from a variable gait to lame. Mean diff max pelvis and mean diff min pelvis were considered separately. A one-sided p-value of 0.434 and 0.931 for mean diff max pelvis and mean diff min pelvis, respectively, indicates no evidence of change due to chiropractic treatment.

Table 3: Values of change in lameness for the front limbs

	Pre-chiropractic treatment				Post-chiropractic treatment			
Horse #	Total Diff Head (mm)	Mean Diff Max Head (mm) +/- SD	Mean Diff Min Head (mm) +/- SD	Classification of gait	Total Diff Head (mm)	Mean Diff Max Head (mm) +/- SD	Mean Diff Min Head (mm) +/- SD	Classification of gait
15	12.1	-5.2 +/- 14.5	-10.9 +/- 21.5	Variable gait	8.9	-3.0 +/- 16.2	-8.4 +/- 15.0	Variable gait

16	10.3	3.5 +/- 8.4	-9.7 +/- 9.7	Lame (LF)	3.7	3.1 +/- 7.1	-2.1 +/- 6.7	Sound
17	2.0	-1.4 +/- 12.2	1.4 +/- 11.7	Sound	7.1	-5.7 +/- 22.8	-4.3 +/- 18.7	Sound
18	21.6	8.6 +/- 13.2	19.8 +/- 15.4	Variable	14.4	-3.3 +/- 17.7	14.0 +/- 38.0	Variable gait
19	7.0	0.4 +/- 13.4	7.0 +/- 14.5	Sound	8.8	2.1 +/- 11.7	8.5 +/- 25.5	Variable gait
20	10.8	-10.4 +/- 10.7	2.9 +/- 12.3	Variable gait	5.2	-1.0 +/- 6.5	5.1 +/- 7.0	Sound
21	0.4	0.3 +/- 7.9	0.2 +/- 8.5	Sound	4.1	-0.7 +/- 4.8	4.0 +/- 7.4	Sound
22	4.7	4.5 +/- 9.7	-1.2 +/- 12.9	Sound	14.6	2.7 +/- 7.4	-14.3 +/- 11.3	Lame (LF)
23	7.1	4.9 +/- 13.7	-5.1 +/- 13.0	Sound	16.9	16.4 +/- 14.2	-4.1 +/- 8.8	Lame (RF)

Table 3: Mean total diff head was calculated by taking the square root of the mean diff max head squared plus the mean diff min head squared. Values above 8.5 mm indicate forelimb lameness, unless the gait was very variable (indicated by a SD ≥ mean diff max or mean diff min head). A one-sided p-value of the comparison of pre-total diff head and post-total diff head of 0.601 indicates that there is no evidence to suggest front-end lameness changed as a result of chiropractic treatment.

Table 1: Values of change in lameness for the hind limbs

	Pre-chiropractic treatment			Post-chiropractic treatment		
Horse #	Mean Diff Max Pelvis (mm) +/- SD	Mean Diff Min Pelvis (mm) +/- SD	Classification of gait	Mean Diff Max Pelvis (mm) +/- SD	Mean Diff Min Pelvis (mm) +/- SD	Classification of gait
15	3.6 +/- 6.4	8.1 +/-11.4	Variable gait	2.9 +/- 5.7	15.3 +/- 9.4	Lame (RH)
16	-3.2 +/- 7.1	3.6 +/- 8.1	Variable gait	-1.0 +/- 3.2	3.1 +/- 5.1	Variable gait
17	1.7 +/- 5.0	5.2 +/- 8.3	Variable gait	1.9 +/- 8.3	3.0 +/- 8.4	Sound
18	1.8 +/- 8.9	-5.4 +/- 8.1	Variable gait	0.4 +/- 4.8	-7.5 +/- 4.4	Lame (LH)
19	0.4 +/- 6.2	5.4 +/- 11.4	Variable gait	7.7 +/- 5.1	8.9 +/- 12.1	Lame (RH)
20	7.6 +/- 9.1	1.0 +/- 11.3	Variable gait	3.8 +/- 2.7	2.2 +/- 7.6	Lame (RH)
21	5.7 +/- 7.2	-2.2 +/- 6.2	Variable gait	7.7 +/- 4.4	-0.9 +/- 6.3	Lame (RH)
22	-4.8 +/- 5.3	4.2 +/- 7.2	Variable gait	-9.0 +/- 6.6	-0.1 +/- 8.1	Lame (LH)
23	12.2 +/- 62.5	3.2 +/- 13.8	Variable gait	4.5 +/- 5.3	4.2 +/- 9.1	Variable gait

Table 4: A one-sided p-value of 0.434 indicates that there is no evidence to suggest mean diff max pelvis changed as a result of chiropractic treatment. A one-sided p-value of 0.913 indicates that there is no evidence to suggest mean diff min pelvis changed as a result of chiropractic treatment.

Video analysis

The differences in hock amplitude and gait evenness from the right and left sides were not significant in any case, thus data from the left and right were pooled for analysis. The analysis for difference in hock amplitude showed that there was strong evidence to suggest that hock amplitude increased as a result of chiropractic treatment, with a p-value of less than 0.0001. An improvement in gait evenness was also noted. This was measured by subtracting the distance between the diagonal limb pairs for the same stride during the phase of maximum extension of the limbs, with lower values indicating an increase in symmetry. With a p-value of less than 0.001, there was strong evidence to indicate that the evenness between outside hind to inside fore and inside hind to outside fore increased in association with chiropractic treatment.

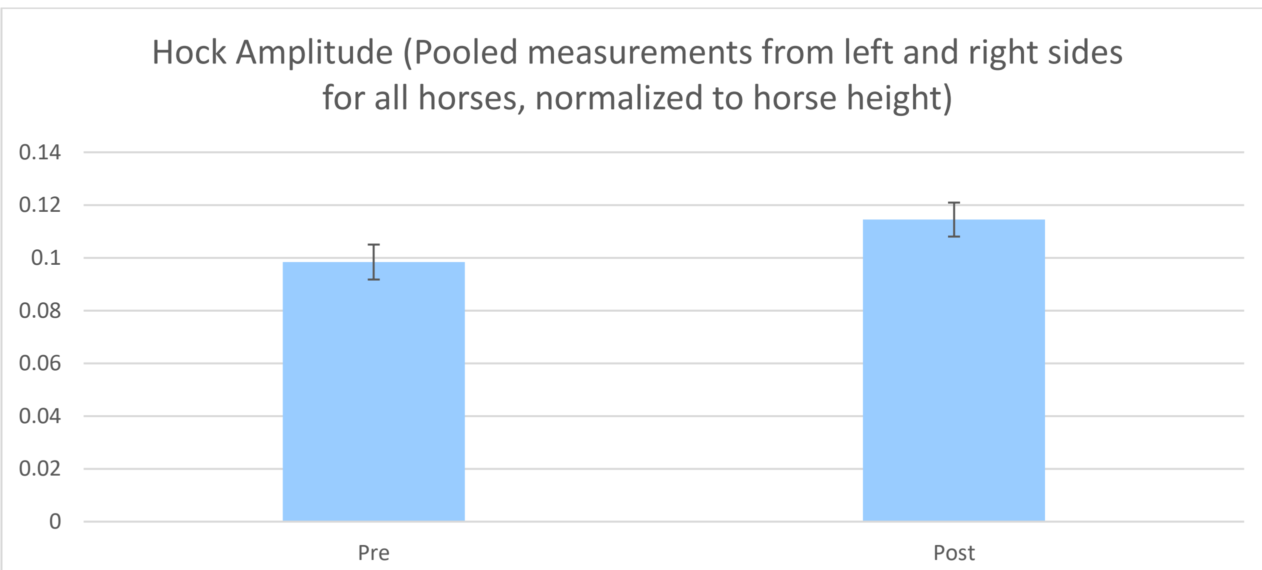


Figure 4: The mean values of hock amplitude for both sides, for all horses. Hock amplitude was determined by measuring the lowest to the highest point of the hock in the stride. Three trials per horse were averaged and right and left averages were pooled for this data set, because the analysis of differences between the right and left sides resulted in a p-value greater than 0.41, indicating that there is no evidence to suggest that the values from the right and left sides were different. Standard deviation was used for error bars. A t-value of 9.825 on 41 degrees of freedom results in a p-value of less than 0.0001, indicating that there is strong evidence to suggest that hock amplitude increased as a result of chiropractic treatment.

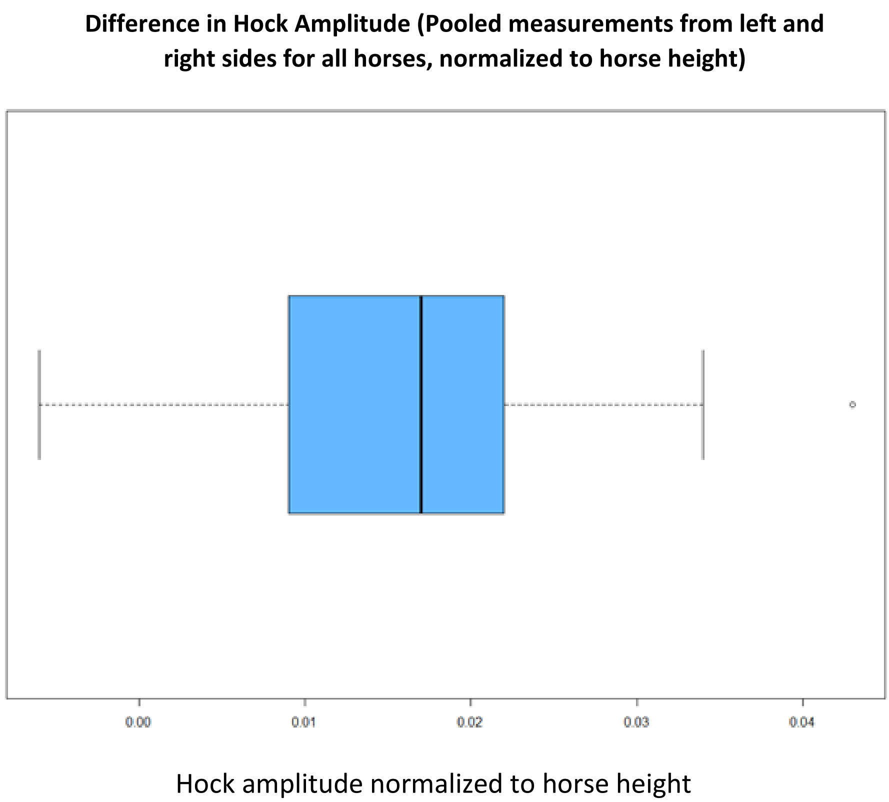


Figure 54: Distribution of the difference in hock amplitude on both sides, normalized to horse height at the withers, for all horses (n=21), of post-treatment value minus pre-treatment value. Hock amplitude was determined by measuring the lowest to the highest point of the hock in the stride. Three trials per horse were averaged and right and left averages were pooled for this data set, because the analysis of differences between the right and left sides resulted in a p-value greater than 0.4, indicating that there is no evidence to suggest that the values from the right and left sides were different. The distribution looks approximately normal with one outlier on the far right. The outlier corresponds to the left side of horse 16.

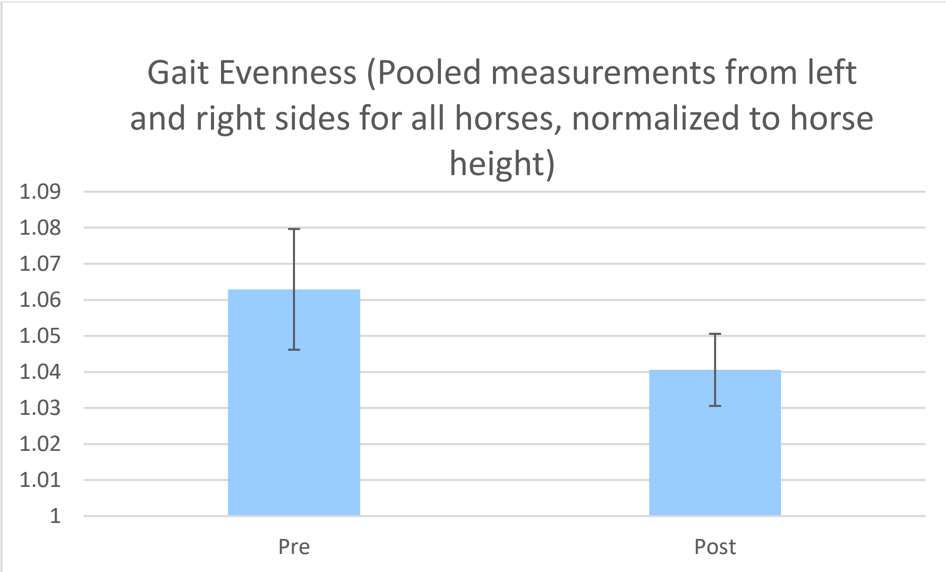
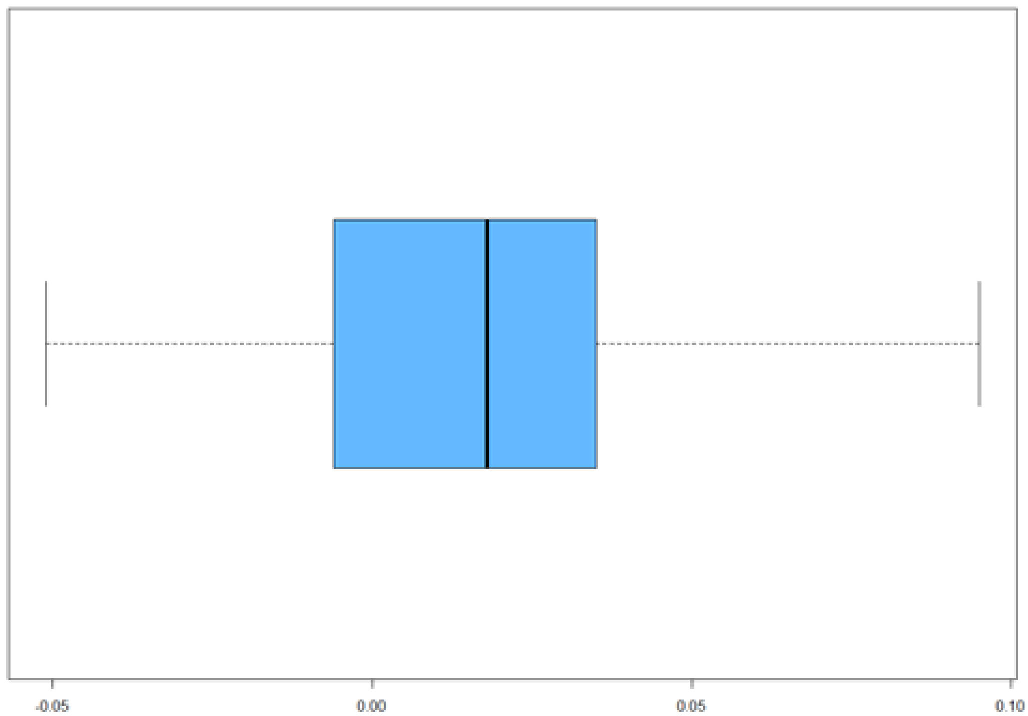


Figure 6: The mean values for gait evenness, for both sides, for all horses (n=21). Higher values indicate less evenness of the stride length of the diagonal limb pairs. Three replicates as seen from the right and three replicates as seen from the left were used to generate two averages for each horse. were included in the data set, as measured from the right and left sides. The difference between differences had a p-value greater than 0.2, thus there was no evidence to suggest that the differences as taken from the right and the left were different. Gait evenness was determined by measuring the distance from the inside hind to outside fore and inside fore to outside hind. Standard deviation was used for error bars. A t-value of 3.78 on 41 degrees of freedom resulted in a p-value of less than 0.001, indicating that there is strong evidence to suggest that gait evenness improves as a result of chiropractic treatment.

Difference in Gait Evenness (Pooled measurements from left and right sides for all horses, normalized to horse height)



Gait evenness normalized to horse height

Figure 16: *Distribution of the difference in gait evenness on both sides, normalized to horse height at the withers, for all horses (n=21), of post-treatment value minus pre-treatment value. Gait evenness was determined by measuring the distance from the inside hind to outside fore and inside fore to outside hind. Three trials per horse were averaged and right and left averages were pooled for this data set, because the analysis of differences between the right and left sides resulted in a p-value greater than 0.21 indicating that there is no evidence to suggest that the values from the right and left sides were different. The distribution looks approximately normal.*

Owner Survey

Owners were surveyed to assess any changes they perceived in their horses throughout the seven-day period after chiropractic care. They were asked about their horses' attitude, appetite, soreness, swelling, willingness to perform under saddle and willingness to perform on the ground. Higher numbers indicated that the horse was doing better, while lower numbers indicated that the horse was doing worse. When the Bonferroni Multiple Comparison method was used for 21 pairwise comparisons, a new α of 0.00238 was obtained for the 0.05 significance level. None of the six categories showed a significant change between day one and day seven.

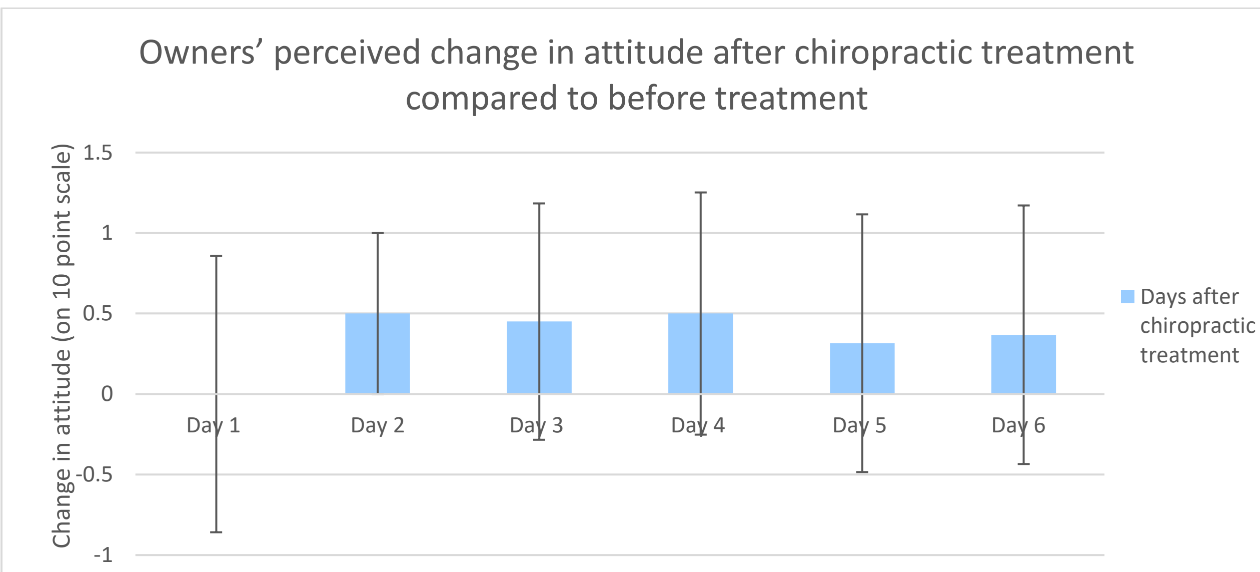


Figure 177: The mean change in values from the owner survey on the opinions of attitude throughout the week post chiropractic treatment. Positive values indicate an improvement in attitude, whereas negative values represent worsening in attitude. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for 21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.165 for day 1 to 7, indicating that there is no evidence that owners noticed an improvement in attitude on day seven post treatment when compared to day one post treatment at the 0.05 significance level.

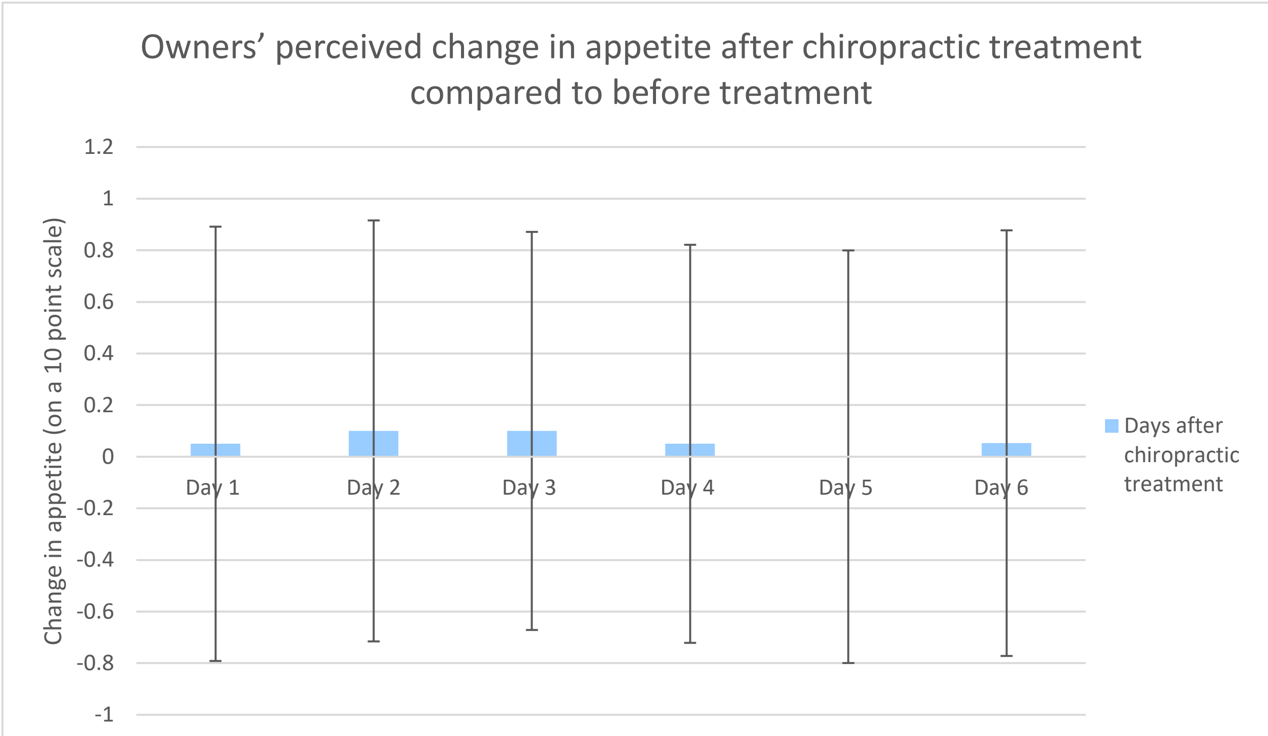


Figure 18: The mean change in values from the owner survey on the opinions of appetite throughout the week post chiropractic treatment. Positive values indicate an improvement in appetite, whereas negative values represent a worsening in appetite. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for 21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.289 for day 1 to 7, indicating that there no evidence that owners noticed an improvement in appetite on day seven post treatment when compared to day one post treatment at the 0.05 significance level.

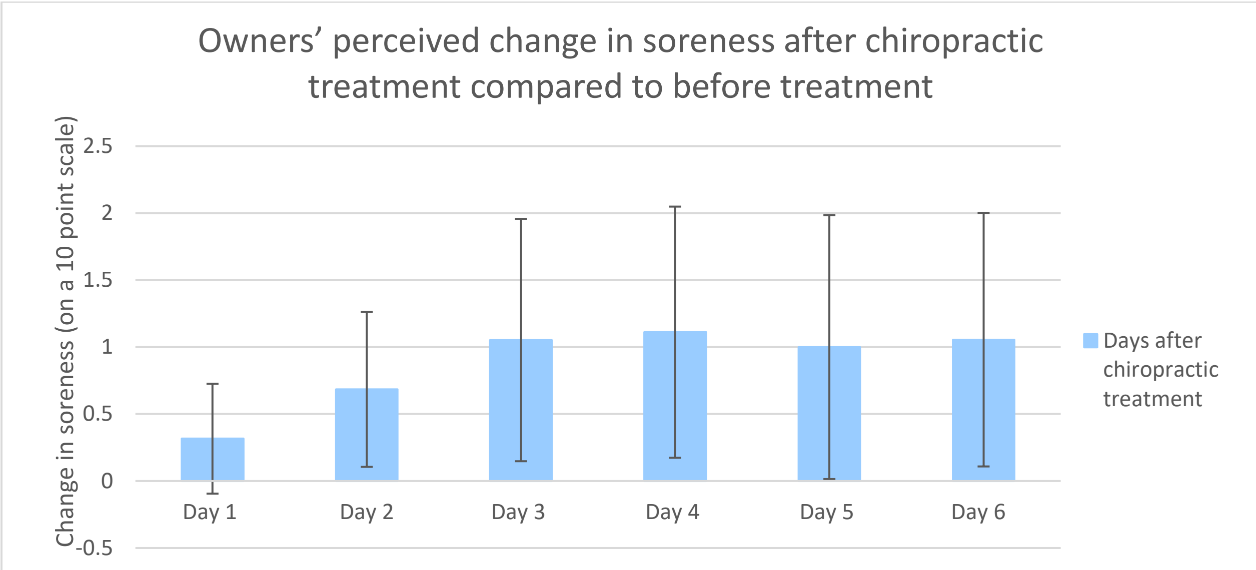


Figure 198: The mean change in values from the owner survey on the opinions of soreness throughout the week post chiropractic treatment. Positive values indicate an improvement in soreness, whereas negative values represent the soreness getting worse. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for 21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.014 for day 1 to 7, indicating that there is no evidence that owners noticed a decrease in soreness on day seven post treatment when compared to day one post treatment at the 0.05 significance level

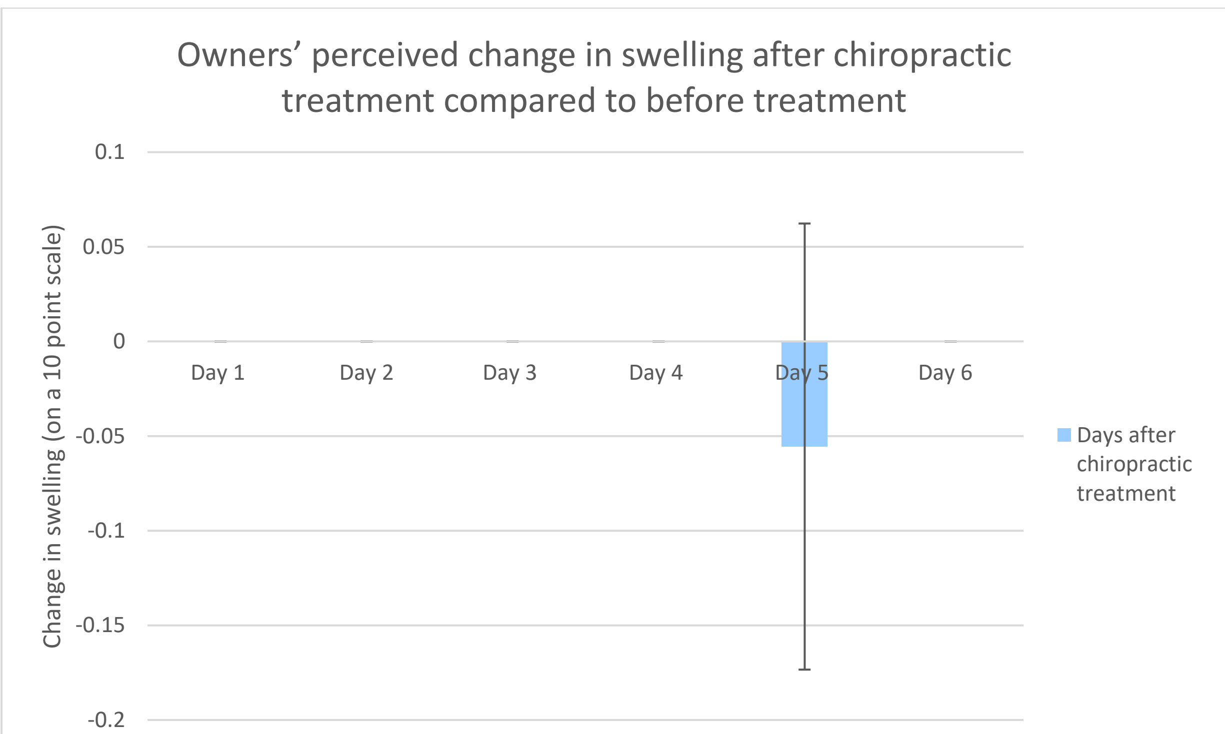


Figure 20: The mean change in values from the owner survey on the opinions swelling throughout the week post chiropractic treatment. Positive values indicate decrease in swelling, whereas negative values represent an increase in swelling. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for

21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.999 for day 1 to 7, indicating that there no evidence that owners noticed an improvement in swelling on day seven post treatment when compared to day one post treatment at the 0.05 significance level.

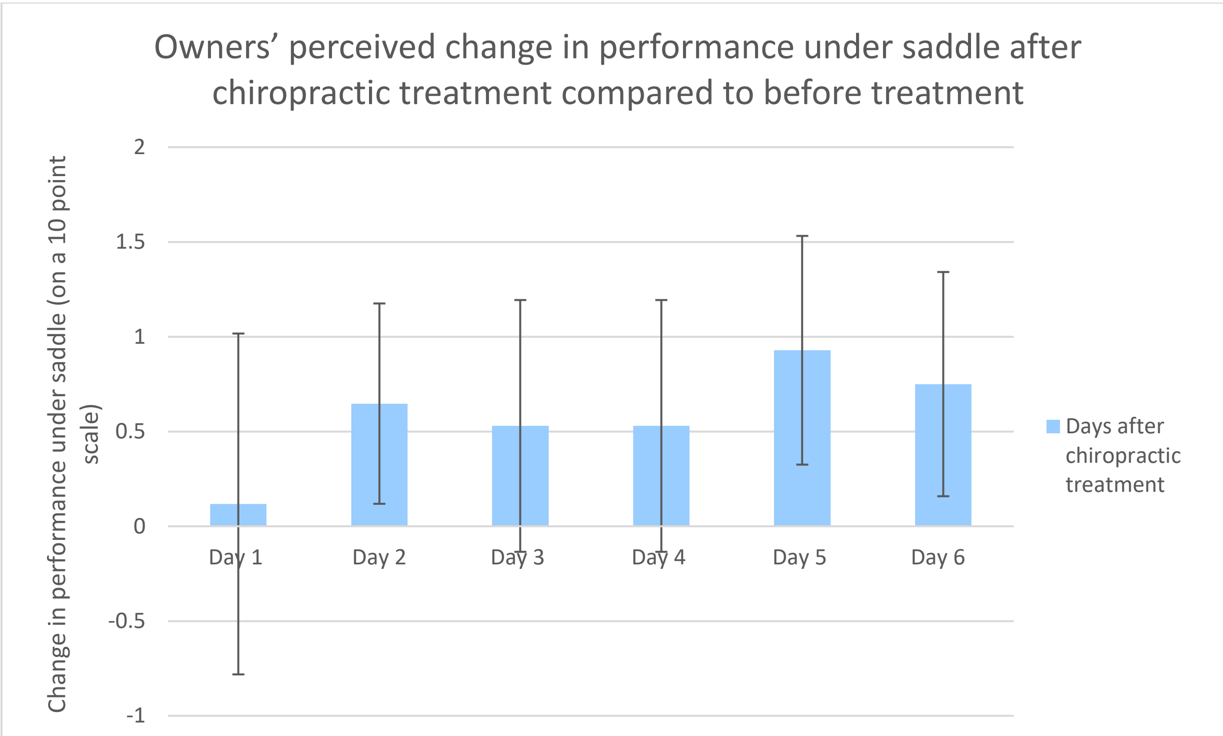


Figure 21: *The mean change in values from the owner survey on the opinions of performance under saddle throughout the week post chiropractic treatment. Positive values indicate an improvement in performance under saddle, whereas negative values represent a decrease in on performance under saddle. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for 21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.0125 for day 1 to 7, indicating that there no evidence that owners noticed an increase in performance under saddle on day seven post treatment when compared to day one post treatment at the 0.05 significance level.*

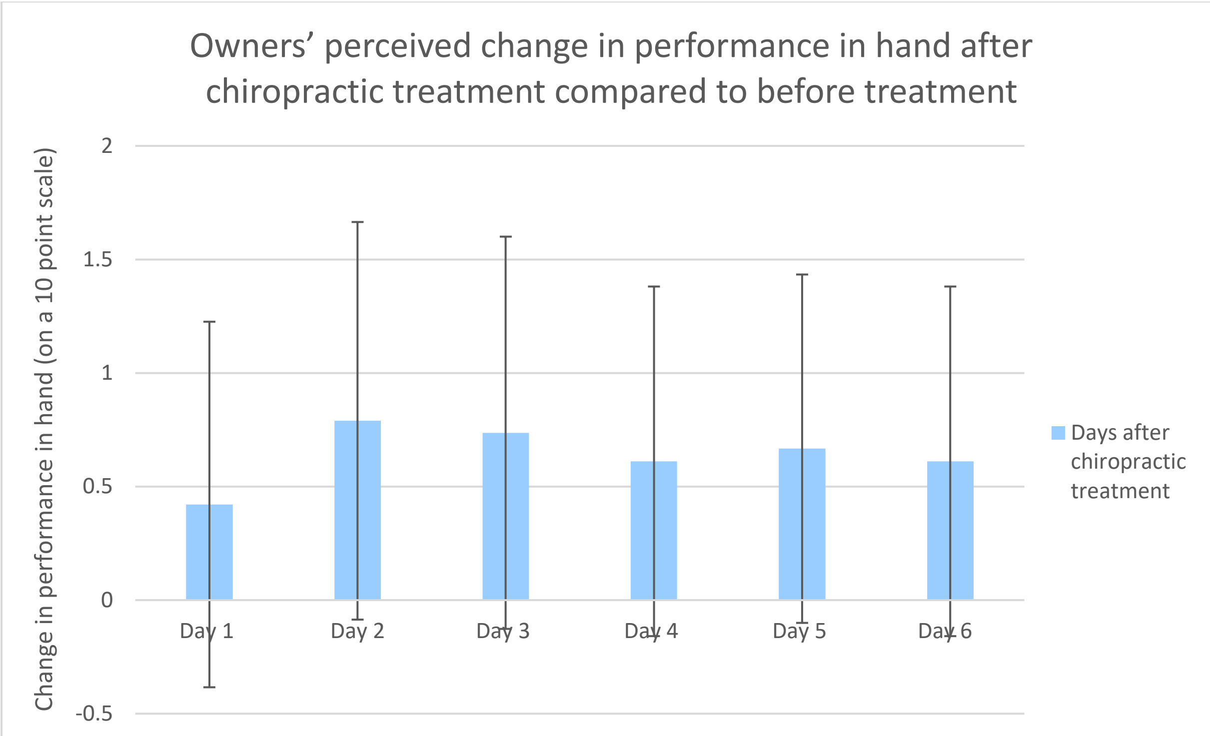


Figure 92: The mean change in values from the owner survey on the opinions of performance on the ground throughout the week post chiropractic treatment. Positive values indicate an improvement in performance on the ground, whereas negative values represent a decrease in on performance on the ground. Error bars represent standard deviation. The Bonferroni Multiple Comparison Method was employed for 21 pairwise comparisons, resulting in a new α equal to 0.00238. A bootstrapped p-value with 10,000 trials resulted in a value of 0.0851 for day 1 to 7, indicating that there no evidence that owners noticed an increase in performance in hand on day seven post treatment when compared to day one post treatment at the 0.05 significance level.

Discussion

Manually applied chiropractic treatment was effective at increasing mechanical nociceptive thresholds, as measured by the pressure algometer, and quality of gait, as measured by hock amplitude and gait evenness in the trot, 6-8 days after treatment. However, it does not appear as though lameness, as detected by the Lameness Locator, changed 6-7 days post treatment. Furthermore, the owner survey also revealed that owners did not notice a significant change in their horses' attitude, appetite, soreness, swelling, willingness to perform under saddle or on the ground in hand. Thus, we are rejecting the parts of our hypothesis stating that manual, individualized chiropractic treatment in horses would improve lameness and owners' perception of their horse's performance.

Pressure algometry applies increasing pressure to the point of pain. However, manual therapies including chiropractic treatment, are known to increase pain thresholds through the release of endorphins and serotonin within the body (Imamura et. al. 2008). It is also hypothesized that pain perception can be influenced through physical or mental relaxation brought about by the treatment (Imamura et. al. 2008). It is therefore worth considering decreased effectiveness of chiropractic treatment by stressing horses or causing them to tighten muscles in the anticipation of the painful stimulus of the pressure algometer. It was noted by the veterinarian that horses seemed more agitated than normal during chiropractic treatment after the use of the pressure algometer. However, since no explicit control group was used for this study, no conclusions can be drawn from this observation.
As of now, no studies have been done to look at the effects of pressure algometry on the effectiveness of chiropractic treatment, but further research is recommended in this area. Additionally, data was collected one week prior to a recognized three-day event at the stables where the horses were kept. If horses were participating in the competition, training regimens may have been changed in anticipation of the competition, possibly resulting in more stiffness or soreness than would have occurred otherwise.

Previous studies utilizing pressure algometry to determine pain responses before and after chiropractic treatment used instrument-assisted adjustments (Sullivan et. al. 2008, Sullivan et. al. 2007), rather than manually applied adjustments. As both studies obtained similar results, this provides more evidence that both manual and instrument-assisted adjustment methods are viable treatment paths. Pressure algometry readings were always taken during the day, but time of day varied between pre- and post-treatment algometry readings. Additionally, no record was kept as to the last time the horse was ridden. It is unknown how either of these factors may have affected the results. Furthermore, temperature ranged from 56° F to 83° F during the days of data collection. Horses may have been more sluggish on hot days and thus accepted more pressure before evasion, or the rubber tip may have had more elasticity, leading to skewed results.

Pressure algometry is non-invasive, but not completely objective, as it depends on the experience and consistency of the examiner and the reaction of the horse to the application of pressure (Ylinen 2007). While there was an attempt to apply pressure in a consistent manner, it was not controlled in the present study. Horses with different sensitivities will react to pain differently even if they are experiencing the same level of pain. As found in other studies (Haussler and Erb 2006a, De Heus et. al. 2010, Haussler and Erb 2003), there does not seem to be a significant difference between right and left pressure algometry values at the same location, and thus values from both sides were considered together. Additionally, as described by Haussler and Erb (2006a), MNT values gradually increase moving in the cranial to caudal direction. When data from all horses were considered, significance was only found at T18, but when only the last nine horses were analyzed, there was a significant decrease in pain at both T18 and L3. Another study has shown significant improvement at T13, T18, L3, L6 and S2 seven days post chiropractic treatment (Sullivan et. al. 2008). Interestingly, both studies tend to find more significant differences in the caudal thoracic and cranial lumbar regions, as opposed to cranial thoracic regions. It is possible that specific anatomical features, such as increased ability for extension and flexion, as opposed to lateral bending, of the vertebral segments, may make this region more responsive to treatment.

The present study found pressure algometry readings ranging from 9.0 kg/cm^2 to 14.3 kg/cm^2, whereas Sullivan et. al. obtained a range of 10.1 kg/cm^2 to 15.5 kg/cm^2 (2008). We suspect that significant differences were found at more sites for the last nine horses due to the examiner applying pressure and noticing evasive behavior more consistently as he gained experience with the instrument. Interestingly, previous studies indicated that once horses were accustomed to the pressure algometer, they would stand quietly while the pressure was being applied, but consistently respond once a pain threshold was reached (Haussler and Erb 2003). In this study, most horses would not stand quietly for the initial pressure algometry readings, especially during the pre-treatment data collection phase. This raises the question as to whether pressure was applied too quickly, which may have skewed the results. In the present study, 15 measurements taken with the pressure algometer exceeded the calibrated range of 0 to 245 N/cm^2, and of the total 314 triplicates measured, 61 exceeded the examiner's ability to apply more pressure. Literature suggests that pressure should be applied at a rate of 10 kg/cm^2/s (De Heus et. al. 2010), thus measuring the rate of pressure increase would help decrease variability caused by pressure being applied too quickly. To help achieve a constant rate of pressure, one could possibly practice with the device over a force plate to measure rate of pressure application.

Overall, results from the Lameness Locator showed that there was no change in lameness before and after chiropractic treatment, but data collected in this experiment had high variability, as reflected in high standard deviations of the mean differences in head or pelvic height. Such variable data may be originating from several sources (Equinosis LLC 2017), such as sensors not being affixed tightly enough to the horse due to oversized halters, uneven ground or horses misbehaving. Additionally, one wrap used to secure the sensor to the pastern (center, figure 3) was prone to rotation. It is unknown how this rotation could have affected the gyroscopic sensors. In some cases, it was impossible to get the horses to trot in a straight line, and it is possible that this affected the results. A second straight line test was not performed after the initial test to stabilize lameness. In the present study, horses were not warmed up before recording Lameness Locator data. Thus, it is possible that, if a horse was lame, the lameness was changing during data collection. Future studies should include a warm-up period for horses before collecting lameness locator data. It may also help to have horses trot on concrete or asphalt, rather than grass. This could reduce uncertainty caused by uneven ground or stepping on a rock. The stride selection criterion was set to more strides when possible, which may have increased variability of the gait.

The quality of the gait at a trot increased significantly 6-8 days after chiropractic treatment with horses showing a more even stride length between the two diagonal limb pairs and exhibiting a higher hock amplitude. Only relative values were used for determining hock amplitude and gait evenness. Initially, we intended to use the cavaletti behind the horse (Figure 6) to scale the video to the actual size. However, it was impossible to trot all horses equidistance from the cavaletti. Instead the height of each horse was scaled to a value of one (1). This most likely decreased variance of hock amplitude between horses, as 14.2 hand horses and 18 hand horses were treated as the same height. Increase in evenness of the gait may have been biased by our inability to blind the person who performed measurements on the video frames for the time point of when the video was taken (before or after treatment). This may have induced bias, especially as there were no visible markers placed onto the anatomic landmarks of the horses for the videos. Instead, measurements were made from heel bulb of one limb to the heel bulbs of the other limb, which is not as precise a methodology compared to measurements based on body markers. Furthermore, the frame rate of the camera used was only 30 frames per second, and it is possible that frames used for measurements did not reflect the maximal stride length due to this. However, distances between the diagonal limb pairs were measured in the same video frame, making this less of a risk for bias. We utilized hock amplitude as an estimate for hock angle, which in turn, can be a measure for how much weight the horse takes up on that limb (during the stance phase) and how much the horse flexes the limb during the swing phase. Thus, measuring hock amplitude is not a direct indicator for how much the horse "carries itself from behind", but it is a good measure for how animated the gait is. Alternatively, we could have measured the hock angle on the video frames during mid-stance, which may have given us a better indication for weight-bearing on that limb as described in the USDF Glossary of Judging Terms.

Interestingly, the data from the owner survey was also quite variable. We had expected that owners would either see a true improvement in their horses performance or attitude, or that they would show a placebo effect, meaning they would believe there was an improvement because they believed that chiropractic treatment is clinically efficacious in treating the problems perceived in their horse. Data from owner surveys are inherently difficult to interpret, because their opinion may have been influenced by unknown external factors. Furthermore, some of these owners had chiropractic treatments performed on their horses by the same clinician on previous occasions, whereas others had not. It is possible that the owners who had experienced effects of chiropractic treatments on their horse before may have been more likely to judge their horse's reaction to the treatment as positive, as they sought to repeat a previous treatment. Thus, if owner surveys are going to be used in future studies, it may be prudent to strive for including horses of owners who do not have any experience with chiropractic treatments in horses at all. However, no significant changes were shown in the owner survey for any of the categories. This could point towards the conclusion that owners simply cannot detect subtle changes in their horses' behavior, but owners have also been reported praising chiropractic treatment for positive changes in their horses (Haussler 1999a, Guidelines for Alternative and Complementary Veterinary Medicine 1996). Therefore, this could be an error in how data was collected in this study. In our study, some owners assigned a value of five for all days to indicate that no change occurred, whereas others had consistent scores of 10s across seven days to indicate no change. This resulted in large standard deviations. Another problem with our data from the owner surveys may be the fact that owners did not return all surveys shortly after the conclusion of the study. This may have been due to them having forgotten to fill out the daily questionnaire, and only completing it after being prompted several times after conclusion of the study. Only two of twenty-one surveys were collected at the seven-day recheck. The last survey wasn't collected until 29 days after initial treatment. Thus, memory of the events of each day may have been skewed, resulting in scores that do not accurately represent the horses' behavior on each day.

Not all horses tolerated the treatment procedures well, and thus, 3 horses were excluded from the study. Horse 3 exhibited signs of bucking, rearing, striking and biting when chiropractic treatment started, and was given 0.37 mg/kg xylazine intravenously as a mild sedative. After five minutes, treatment was re-initiated, but was stopped due to the horse still objecting to the manipulations. It has been shown that aggressive behavior can be a result of pain (Ashley et al. 2010) and it is possible that this was the case in this horse. It is worth considering that pressure algometry prior to treatment may have contributed to the violent behavior, as it may have increased the horse's sensitivity in the area of the back. While this horse would possibly have benefited from treatment, safety of the examiner was paramount, hence why treatment was ceased. Horse 14 would not allow the chiropractic block to be positioned adjacent to him to proceed with treatment, and thus was given 0.37 mg/kg xylazine intravenously. Chiropractic treatment then proceeded. While manipulation can be combined with sedation to increase relaxation and decrease muscle guarding in humans (Kohlbeck et. al. 2002), controlled studies in horses on the effect of sedatives on chiropractic treatment are lacking (Ahern 1994). The data collected from horse 14 was therefore removed from the study. Finally, horse 24 was on a regular regimen for injections into the back (locations and type of drug were not known to us), but it did not receive a scheduled injection a few days after the chiropractic treatment. Instead, the owner gave the horse 1 to 1.5 g phenylbutazone daily after the chiropractic treatment. As the addition of phenylbutazone could affect the MNT values collected at follow up, this horse was excluded from the study.

All horses included in this study had some degree of back pain or stiffness as shown by the chiropractic examination. The use of a randomized control group that did not receive chiropractic care but were analyzed using video analysis, the lameness locator and pressure algometry would have helped negate any uncertainty regarding data collection methods altering results or inexperience with data collection methods altering results, but was not done in this study. The horses were trotted faster on the post-treatment data collection days due to different handlers, but it is unknown how the results may have been affected by this.

While other factors, such as overall gait appearance, elasticity and cadence were not measured in this study, the measures analyzed indicated that gait quality improved with chiropractic care. Video analysis was carried out over grass rather than on a firmer, even surface, which may have increased variability in the gait of the horses and limited the number of strides that could be used for analysis. However, it was not feasible to use a paved, even surface for the present study due unavailability of such surface at the facility. Analysis was not blinded as intended. Originally, the same person was to trot the horses on pre- and post-treatment data collection days, but due to unrelated circumstances, this was not possible. As it could clearly be seen in the video who was trotting the horses, it was easy to determine if the video was from pre- or post-treatment. None of the measurements were truly subjective, as the position of the hock was tracked based on the video. However, due to the video only being captured in 1080p at 30 frames per second, there was blurring of the hock that occurred occasionally, and thus the examiner had to make an estimate of the position of the hock at that instance. Using a high-speed camera and placing a clearly visible marker onto the point of the hock may increase the accuracy of this analysis. In addition, it would also be of interest to have a panel of trained dressage judges assign scores to the quality of the trot. These results could then be compared to the results of the video analysis to determine if there is a correlation.

Conclusion

A single chiropractic treatment was associated with a decrease in pain threshold in the lower back and increased quality of movement at the trot. The degree of soundness and owner evaluation of the horse's behavior did not appear to change with chiropractic treatment. Our data suggest that the practitioner should have sufficient time to practice with the pressure algometry prior to collecting data and more stringent protocols should be used when assessing lameness with the Lameness Locator (ascertaining the lameness has stabilized; using a firm, even, level surface; accustoming horses more to their surroundings). Additionally, when surveys are used, it may be more desirable to use an online questionnaire that prompts the owner for their responses daily, rather than waiting until day seven to request the survey be returned. Alternatively, owners could be required to do a post treatment interview to be included in the study to obtain the information. More research should be done on quality of gait after chiropractic treatment, as it is unknown if the values measured correlate to improved performance.

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Abbreviations

MNTs - Mechanical nociceptive thresholds
USDF - United States Dressage Federation
AVMA - American Veterinary Medical Association
On the bit - Acceptance of contact (without resistance or evasion) with a stretched topline and with lateral and longitudinal flexion as required. The horse's face line is, as a rule, slightly in front of the vertical.
Track up - The hind feet step into the prints of the forefeet.

Appendices

Appendix 1: Horse Variability

All data collected on the demographics of the horses used in the study, including breed, age, sex, activities and current medications. Medications did not change throughout the seven-day time period of the study. Each horse name was associated with a number that would henceforth be used as an identifier. Data on the weight of each animal was not collected.

Number	Breed	Age	Sex	Activities	Current medication	Notes
1	Thoroughbred	20	Gelding	Dressage and jumping lessons 3-6 days a week	Cosequin, occasional Bute	
2	Thoroughbred	22	Gelding	Dressage and jumping lessons 3-6 days a week	Cosequin	
3	Quarter Horse	21	Mare	Dressage and jumping lessons 3-6 days a week		Not used for study, would not tolerate treatment
4	Quarter Horse	15	Gelding	Stall Rest		
5	Arabian cross	15	Gelding	Dressage and jumping lessons 3-6 days a week		
6	Thoroughbred cross	18	Mare	Dressage and jumping lessons 3-6 days a week		
7	Oldenburg	7	Mare	Preliminary 3-Day Event horse	Regumate monthly injections	
8	Oldenburg	8	Gelding	Preliminary 3-Day Event horse		
9	Gypsy Vanner	9	Gelding	Training Level Dressage horse		
10	Gypsy Vanner	11	Gelding	Training Level Dressage horse, kids lesson horse		
11	Thoroughbred	6	Gelding	Beginner Novice Event Horse	Adequan	
12	Thoroughbred	7	Gelding	2'6 Jumping, Training Level Dressage	Adequan	
13	Thoroughbred/Friesian	15	Mare	2nd Level Dressage horse		
14	Oldenburg	5	Gelding	Novice 3-Day Event Horse		Not used for study, would not tolerate treatment without sedation
15	Thoroughbred	10	Gelding	Training Level Dressage Horse		Lameness Locator used

16	Thoroughbred	15	Gelding	Novice 3-Day Event Horse, 1st Level dressage		Lameness Locator used
17	Thoroughbred	3	Gelding	Training Level Dressage horse		Lameness Locator used
18	Quarter Horse	8	Gelding	Trails, non-competitive dressage		Lameness Locator used
19	Arabian/ Thoroughbred	10	Mare	Trails, non-competitive dressage		Lameness Locator used
20	Appendix	22	Gelding	Ridden lightly 4-5 times a week		Lameness Locator used
21	Fjord	11	Mare	Western Pleasure, Reining, trail riding, dressage		Lameness Locator used
22	Thoroughbred	6	Mare	Low level 3-Day Eventing		Lameness Locator used
23	Arabian cross	9	Mare	Low level 3-Day Eventing		Lameness Locator used
24	Warmblood	16	Mare	Low level Dressage	Daily Equinox	Not used for study, given Bute before follow-up

Appendix 2: Treatment

Details on treatment for each horse, and subjective grades of pain and stiffness, carried out by a veterinarian with 15 years of experience. Pain was scored on a scale of 0-4, where a zero indicates no pain and a score of four indicates complete avoidance and evasion to any applied mobilization. Stiffness was scored on a scale of 0-3 where zero indicates free and fluid motion while a four indicates severe stiffness. Between all horses, the total possible number of sites treated was 39. Thus, the maximum total pain is 156 and the maximum total stiffness is 117.

Horse	Total Pain	Total Stiffness	Number of Painful Sites	Number of Sites Treated	Average Pain per Painful site	Average Stiffness per Treated site	Locations of Treatment
1	20	48	11	21	1.82	2.29	T3-7, T14, T17-18, L1-4, Sacrum, Left and Right Carpus, Scapula, C3-6, C1
2	0	36	0	14	0.00	2.57	T3-5, T13, T15-16. L2-4, Hemi Pelvis, Sacrum, C3-4, C6
3				No treatment			
4	3	39	2	16	1.50	2.44	T4-5, T17-18, L1-4, Left Hemi Pelvis, Right and Left Scapula, C3-6, C1
5	5	45	3	23	1.67	2.05	T3-8, T13-17, L2-4, Left Hemi Pelvis, Sacrum, Right T13 rib, Left carpus, right Humerus, Left and Right scapula, C4, C6
6	0	14	0	8	0.00	1.75	T4, T13, T16, L3, Right Hemi Pelvis, C3, C5, C1
7	0	38	0	16	0.00	2.38	T3-4, T15-16, L1-2, L4, Right and Left Hemi Pelvis, Sacrum, Left T15 rib, Left Humerus, Right scapula, C3-4, C6
8	0	35	0	15	0.00	2.33	T3, T5-7, T17-18, L1, L3-4, Sacrum, Right and Left Scapula, C3, C5, C1
9	0	18	0	10	0.00	1.80	T3-4, L1, Left and Right Hemi Pelvis, Sacrum, Right Carpus, Left and Right Scapula, C4
10	5	20	4	12	1.25	1.67	T3-5, T16, L3-4, Right Hemi Pelvis, Right Scapula, C3, C5-6, C1
11	4	21	2	13	2.00	1.62	T3-5, T15, T17-18, L4, Left Hemi Pelvis, Sacrum, Left Carpus, Left Scapula, C5-6
12	0	25	0	17	0.00	1.47	T3-6, T15, T17, L1-2, Left and Right Hemi Pelvises, Sacrum, L6s1, Left and Right Carpus, C3-4, C6
13	2	20	1	12	2.00	1.67	T3-6, T15, T17, L3, Left and Right Hemi Pelvises, Sacrum, C3, C6
14	2	24	2	13	1.00	1.85	T4, T13, T15-16, T18, L1, L4, Right and Left Hemi Pelvises, Sacrum, Right T11 rib, Right T17 rib, Left carpus, Right and Left scapula
15	20	51	8	21	2.50	2.43	T3-6, T12, T17, L2, L4, Left and Right Hemi Pelvises, Sacrum, Right T9 rib, Right T16 Rib, Right Humerus, Left and Right Scapula, C3-6, C1

16	3	24	2	14	1.50	1.71	T3-4, T13, T15, T17, L1, L3, Sacrum, Right Pastern, Right Carpus, Left and Right Scapula, C4, C6
17	5	43	3	21	1.67	2.05	T4-6, T8-9, T15, T17-18, L1, L4, Left and Right Hemi Pelvises, Sacrum, L6s1, Right Carpus, Right Humerus, C3-6, C1
18	5	33	3	15	1.67	2.20	T4-6, T14, T18, L1, L3, Left Hemi Pelvis, Sacrum, Right Humerus, Left and Right Scapula, C3-4, C6
19	0	27	0	17	0.00	1.59	T4-5, T16-18, L1, L3, Left and Right Hemi Pelvis, Sacrum, L6s1, Left and Right Humerus, C3-4, C6, C1
20	3	32	2	12	1.50	2.67	T3-5, L3-4, Right Hemi Pelvis, Sacrum, Left and Right Carpus, Left Scapula, C3-4
21	4	17	3	10	1.33	1.70	T4-6, T17-18, Sacrum, Right Humerus, C3-4, C6
22	14	71	7	29	2.00	2.45	T3-7, T13, T16-18, L3, Left and Right Hemi Pelvises, Sacrum, L6s1, Left and Right T8 rib, Right T9 rib, Left and Right T13 rib, Right T14-15 rib, Left and Right Carpus, Left scapula, C3-6, C1
23	2	29	2	15	1.00	1.93	T5-6, T13, T17-18, L3-4, Left and Right Hemi Pelvises, Sacrum, Right Humerus, C3-4, C6, C1
24	6	30	5	18	1.20	1.67	T4-6, T16, T18, L2-4, Left Hemi Pelvis, Sacrum, Left T9 rib, Right Humerus, Right scapula, C1, C3-6

Appendix 3: Pressure algometry

All data collected on MNT thresholds for all horses, for T3, T6, T9, T13, T18, L3, L6 and S2. Three trials were taken per site per side. Highlighted in blue are the median values for the three trials. Median was used rather than mean due to high variability within trials. Highlighted in green are values at which no avoidance reaction was noted, despite the examiner using as much force as was possible. Values left blank indicated that the data was lost.

Horse	Location	Side	Trial	Pre-Pressure Algometry Reading	Post-Pressure Algometry Reading
1	T3	Right	1	113.1	87.4
1	T3	Right	2	72.9	51.3
1	T3	Right	3	64.7	61.5
1	T3	Right	Median	**72.9**	**61.5**
1	T3	Left	1	87.7	63.3
1	T3	Left	2	99.1	64.9
1	T3	Left	3	94.9	74.2
1	T3	Left	Median	**94.9**	**64.9**
1	T9	Right	1	87.0	34.0
1	T9	Right	2	96.0	48.0
1	T9	Right	3	79.5	59.2
1	T9	Right	Median	**87.0**	**48.0**
1	T9	Left	1	101.2	55.7
1	T9	Left	2	105.3	57.1
1	T9	Left	3	112.6	67.9
1	T9	Left	Median	**105.3**	**57.1**
1	T13	Right	1	87.0	47.4
1	T13	Right	2	70.1	72.0
1	T13	Right	3	96.8	76.3
1	T13	Right	Median	**87.0**	**72.0**
1	T13	Left	1	95.5	61.4
1	T13	Left	2	105.9	66.4
1	T13	Left	3	102.5	77.0
1	T13	Left	Median	**102.5**	**66.4**
1	T18	Right	1	108.0	81.0
1	T18	Right	2	91.5	99.1
1	T18	Right	3	101.6	109.4
1	T18	Right	Median	**101.6**	**99.1**
1	T18	Left	1	73.9	74.9
1	T18	Left	2	91.7	57.3
1	T18	Left	3	101.8	73.7
1	T18	Left	Median	**91.7**	**73.7**
1	L3	Right	1	123.3	101.7
1	L3	Right	2	156.9	109.6
1	L3	Right	3	144.9	110.4
1	L3	Right	Median	**144.9**	**109.6**
1	L3	Left	1	76.0	72.2
1	L3	Left	2	49.7	67.6
1	L3	Left	3	67.8	77.1
1	L3	Left	Median	**67.8**	**72.2**
1	L6	Right	1	131.0	83.3
1	L6	Right	2	116.1	108.7
1	L6	Right	3	156.7	126.7
1	L6	Right	Median	**131.0**	**108.7**
1	L6	Left	1	109.6	90.5
1	L6	Left	2	90.8	119.3
1	L6	Left	3	112.6	144.5
1	L6	Left	Median	**109.6**	**119.3**
1	S2	Right	1	122.8	119.0
1	S2	Right	2	96.1	137.0

1	S2	Right	3	118.3	125.4
1	S2	Right	Median	**118.3**	**125.4**
1	S2	Left	1	120.6	130.8
1	S2	Left	2	118.8	119.3
1	S2	Left	3	102.6	114.5
1	S2	Left	Median	**118.8**	**119.3**
2	T3	Right	1	113.2	141.3
2	T3	Right	2	125.0	84.9
2	T3	Right	3	135.1	150.0
2	T3	Right	Median	**125.0**	**141.3**
2	T3	Left	1	193.8	160.6
2	T3	Left	2	193.0	181.4
2	T3	Left	3	175.7	137.2
2	T3	Left	Median	**193.0**	**160.6**
2	T9	Right	1	76.8	97.8
2	T9	Right	2	103.7	94.1
2	T9	Right	3	105.0	109.2
2	T9	Right	Median	**103.7**	**97.8**
2	T9	Left	1	108.9	84.2
2	T9	Left	2	110.1	82.3
2	T9	Left	3	111.6	94.9
2	T9	Left	Median	**110.1**	**84.2**
2	T13	Right	1	98.0	116.1
2	T13	Right	2	66.8	106.4
2	T13	Right	3	82.0	105.9
2	T13	Right	Median	**82.0**	**106.4**
2	T13	Left	1	122.4	93.6
2	T13	Left	2	110.8	95.5
2	T13	Left	3	114.1	102.3
2	T13	Left	Median	**114.1**	**95.5**
2	T18	Right	1	73.5	122.7
2	T18	Right	2	66.7	106.9
2	T18	Right	3	61.1	120.5
2	T18	Right	Median	**66.7**	**120.5**
2	T18	Left	1	116.8	97.4
2	T18	Left	2	90.9	104.7
2	T18	Left	3	64.1	95.6
2	T18	Left	Median	**90.9**	**97.4**
2	L3	Right	1	152.0	73.3
2	L3	Right	2	132.8	92.4
2	L3	Right	3	90.8	86.5
2	L3	Right	Median	**132.8**	**86.5**
2	L3	Left	1	134.2	98.2
2	L3	Left	2	153.1	88.6
2	L3	Left	3	134.3	98.9
2	L3	Left	Median	**134.3**	**98.2**
2	L6	Right	1	146.5	115.3
2	L6	Right	2	138.0	101.5
2	L6	Right	3	143.6	123.7
2	L6	Right	Median	**143.6**	**115.3**
2	L6	Left	1	144.4	82.5
2	L6	Left	2	105.4	99.6
2	L6	Left	3	117.6	98.1
2	L6	Left	Median	**117.6**	**98.1**
2	S2	Right	1	187.7	133.3
2	S2	Right	2	201.8	157.6
2	S2	Right	3	175.8	154.3
2	S2	Right	Median	**187.7**	**154.3**
2	S2	Left	1	213.9	150.0
2	S2	Left	2	210.8	163.2
2	S2	Left	3	221.4	138.4
2	S2	Left	Median	**213.9**	**150.0**
3	T3	Right	1	67.8	
3	T3	Right	2	63.2	
3	T3	Right	3	68.3	
3	T3	Right	Median	**67.8**	

3	T3	Left	1	72.1	62.3
3	T3	Left	2	83.6	48.7
3	T3	Left	3	111.9	
3	T3	Left	Median	**83.6**	**55.5**
3	T9	Right	1	75.1	
3	T9	Right	2	58.9	
3	T9	Right	3	73.8	
3	T9	Right	Median	**73.8**	
3	T9	Left	1	86.8	
3	T9	Left	2	97.8	
3	T9	Left	3	80.4	
3	T9	Left	Median	**86.8**	
3	T13	Right	1	69.6	
3	T13	Right	2	74.4	
3	T13	Right	3	76.9	
3	T13	Right	Median	**74.4**	
3	T13	Left	1	124.5	
3	T13	Left	2	96.0	
3	T13	Left	3	103.2	
3	T13	Left	Median	**103.2**	
3	T18	Right	1	114.7	
3	T18	Right	2	102.4	
3	T18	Right	3	73.9	
3	T18	Right	Median	**102.4**	
3	T18	Left	1	163.0	
3	T18	Left	2	157.9	
3	T18	Left	3	146.6	
3	T18	Left	Median	**157.9**	
3	L3	Right	1	113.3	
3	L3	Right	2	112.9	
3	L3	Right	3	100.9	
3	L3	Right	Median	**112.9**	
3	L3	Left	1	144.1	

3	L3	Left	2	66.3	
3	L3	Left	3	89.2	
3	L3	Left	Median	**89.2**	
3	L6	Right	1	107.3	
3	L6	Right	2	89.6	
3	L6	Right	3	97.9	
3	L6	Right	Median	**97.9**	
3	L6	Left	1	85.9	
3	L6	Left	2	82.7	
3	L6	Left	3	71.1	
3	L6	Left	Median	**82.7**	
3	S2	Right	1	123.9	
3	S2	Right	2	112.5	
3	S2	Right	3	109.9	
3	S2	Right	Median	**112.5**	
3	S2	Left	1	120.4	
3	S2	Left	2	87.5	
3	S2	Left	3	81.5	
3	S2	Left	Median	**87.5**	
4	T3	Right	1	48.1	49.5
4	T3	Right	2	75.9	47.5
4	T3	Right	3	59.0	60.9
4	T3	Right	Median	**59.0**	**49.5**
4	T3	Left	1	90.7	58.6
4	T3	Left	2	69.1	80.9
4	T3	Left	3	63.2	73.9
4	T3	Left	Median	**69.1**	**73.9**
4	T9	Right	1	40.5	57.5
4	T9	Right	2	63.8	58.4
4	T9	Right	3	97.5	84.4
4	T9	Right	Median	**63.8**	**58.4**
4	T9	Left	1	72.8	43.8
4	T9	Left	2	59.4	52.7

4	T9	Left	3	88.4	42.8
4	T9	Left	Median	**72.8**	**43.8**
4	T13	Right	1	71.8	59.4
4	T13	Right	2	81.6	78.6
4	T13	Right	3	90.2	89.5
4	T13	Right	Median	**81.6**	**78.6**
4	T13	Left	1	54.4	61.1
4	T13	Left	2	67.0	66.9
4	T13	Left	3	62.0	51.4
4	T13	Left	Median	**62.0**	**61.1**
4	T18	Right	1	62.1	84.2
4	T18	Right	2	51.6	94.4
4	T18	Right	3	48.8	94.6
4	T18	Right	Median	**51.6**	**94.4**
4	T18	Left	1	55.0	86.3
4	T18	Left	2	54.3	48.5
4	T18	Left	3	65.2	62.6
4	T18	Left	Median	**55.0**	**62.6**
4	L3	Right	1	74.5	86.1
4	L3	Right	2	74.7	95.4
4	L3	Right	3	76.3	90.1
4	L3	Right	Median	**74.7**	**90.1**
4	L3	Left	1	113.7	132.5
4	L3	Left	2	114.1	133.6
4	L3	Left	3	124.0	147.2
4	L3	Left	Median	**114.1**	**133.6**
4	L6	Right	1	116.0	126.0
4	L6	Right	2	96.1	145.3
4	L6	Right	3	101.0	147.9
4	L6	Right	Median	**101.0**	**145.3**
4	L6	Left	1	135.2	91.9
4	L6	Left	2	104.0	97.4
4	L6	Left	3	116.7	100.0

4	L6	Left	Median	**116.7**	**97.4**
4	S2	Right	1	200.0	171.2
4	S2	Right	2	200.0	162.4
4	S2	Right	3		166.6
4	S2	Right	Median	**200.0**	**166.6**
4	S2	Left	1	196.1	238.0
4	S2	Left	2	213.0	194.0
4	S2	Left	3		
4	S2	Left	Median	**204.6**	**216.0**
5	T3	Right	1	78.5	66.7
5	T3	Right	2	56.7	61.3
5	T3	Right	3	63.7	50.3
5	T3	Right	Median	**63.7**	**61.3**
5	T3	Left	1	72.8	89.6
5	T3	Left	2	57.8	71.8
5	T3	Left	3	63.9	74.1
5	T3	Left	Median	**63.9**	**74.1**
5	T9	Right	1	46.7	78.8
5	T9	Right	2	77.0	77.9
5	T9	Right	3	89.1	117.7
5	T9	Right	Median	**77.0**	**78.8**
5	T9	Left	1	51.5	44.9
5	T9	Left	2	58.7	36.2
5	T9	Left	3	54.1	47.2
5	T9	Left	Median	**54.1**	**44.9**
5	T13	Right	1	99.8	85.8
5	T13	Right	2	88.3	89.0
5	T13	Right	3	141.3	86.7
5	T13	Right	Median	**99.8**	**86.7**
5	T13	Left	1	58.0	76.1
5	T13	Left	2	68.5	65.9
5	T13	Left	3	72.0	74.1
5	T13	Left	Median	**68.5**	**74.1**

5	T18	Right	1	71.7	79.5
5	T18	Right	2	62.4	76.1
5	T18	Right	3	69.6	93.1
5	T18	Right	Median	**69.6**	**79.5**
5	T18	Left	1	40.8	71.9
5	T18	Left	2	50.5	51.8
5	T18	Left	3	50.4	62.6
5	T18	Left	Median	**50.4**	**62.6**
5	L3	Right	1	114.4	94.2
5	L3	Right	2	107.5	68.2
5	L3	Right	3	106.8	81.0
5	L3	Right	Median	**107.5**	**81.0**
5	L3	Left	1	78.0	87.4
5	L3	Left	2	87.4	77.5
5	L3	Left	3	100.9	97.8
5	L3	Left	Median	**87.4**	**87.4**
5	L6	Right	1	59.2	70.8
5	L6	Right	2	48.6	68.2
5	L6	Right	3	50.2	81.0
5	L6	Right	Median	**50.2**	**70.8**
5	L6	Left	1	107.5	87.4
5	L6	Left	2	100.3	101.8
5	L6	Left	3	121.7	111.8
5	L6	Left	Median	**107.5**	**101.8**
5	S2	Right	1	182.0	110.1
5	S2	Right	2	221.7	133.3
5	S2	Right	3	217.9	233.0
5	S2	Right	Median	**217.9**	**133.3**
5	S2	Left	1	144.8	129.1
5	S2	Left	2	170.4	185.1
5	S2	Left	3	150.5	200.7
5	S2	Left	Median	**150.5**	**185.1**
6	T3	Right	1	199.0	106.3

6	T3	Right	2	203.0	98.8
6	T3	Right	3		100.6
6	T3	Right	Median	**201.0**	**100.6**
6	T3	Left	1	155.0	97.3
6	T3	Left	2	200.0	88.5
6	T3	Left	3	170.0	96.3
6	T3	Left	Median	**170.0**	**96.3**
6	T9	Right	1	142.1	91.7
6	T9	Right	2	189.0	100.2
6	T9	Right	3	188.0	92.3
6	T9	Right	Median	**188.0**	**92.3**
6	T9	Left	1	170.5	86.0
6	T9	Left	2	193.0	77.6
6	T9	Left	3	183.8	96.3
6	T9	Left	Median	**183.8**	**86.0**
6	T13	Right	1	168.2	159.9
6	T13	Right	2	177.3	163.5
6	T13	Right	3	188.3	144.4
6	T13	Right	Median	**177.3**	**159.9**
6	T13	Left	1	260.0	99.1
6	T13	Left	2	216.0	124.0
6	T13	Left	3		113.9
6	T13	Left	Median	**238.0**	**113.9**
6	T18	Right	1	207.5	127.5
6	T18	Right	2	190.4	102.8
6	T18	Right	3	232.8	114.7
6	T18	Right	Median	**207.5**	**114.7**
6	T18	Left	1	209.6	144.3
6	T18	Left	2	225.0	116.3
6	T18	Left	3		146.0
6	T18	Left	Median	**217.3**	**144.3**
6	L3	Right	1	172.8	113.7
6	L3	Right	2	164.5	98.9

6	L3	Right	3	170.3	113.1
6	L3	Right	Median	**170.3**	**113.1**
6	L3	Left	1	157.7	125.7
6	L3	Left	2	193.0	126.3
6	L3	Left	3	190.0	145.9
6	L3	Left	Median	**190.0**	**126.3**
6	L6	Right	1	152.3	132.9
6	L6	Right	2	138.4	141.0
6	L6	Right	3	160.0	130.2
6	L6	Right	Median	**152.3**	**132.9**
6	L6	Left	1	125.2	185.5
6	L6	Left	2	159.0	208.4
6	L6	Left	3	153.0	200.8
6	L6	Left	Median	**153.0**	**200.8**
6	S2	Right	1	200.0	196.0
6	S2	Right	2	200.0	126.6
6	S2	Right	3		135.7
6	S2	Right	Median	**200.0**	**135.7**
6	S2	Left	1	188.2	243.0
6	S2	Left	2		237.0
6	S2	Left	3		
6	S2	Left	Median	**188.2**	**240.0**
7	T3	Right	1	173.4	208.0
7	T3	Right	2	179.6	86.7
7	T3	Right	3	196.0	174.0
7	T3	Right	Median	**179.6**	**174.0**
7	T3	Left	1	141.2	91.0
7	T3	Left	2	112.8	76.3
7	T3	Left	3	127.1	74.5
7	T3	Left	Median	**127.1**	**76.3**
7	T9	Right	1	190.0	189.9
7	T9	Right	2	119.4	188.8
7	T9	Right	3	207.0	202.0

7	T9	Right	Median	**190.0**	**189.9**
7	T9	Left	1	124.6	181.0
7	T9	Left	2	153.6	191.0
7	T9	Left	3	213.9	177.0
7	T9	Left	Median	**153.6**	**181.0**
7	T13	Right	1	128.1	122.4
7	T13	Right	2	113.0	109.9
7	T13	Right	3	130.0	141.8
7	T13	Right	Median	**128.1**	**122.4**
7	T13	Left	1	101.6	113.0
7	T13	Left	2	120.2	80.7
7	T13	Left	3	126.7	123.0
7	T13	Left	Median	**120.2**	**113.0**
7	T18	Right	1	105.3	114.2
7	T18	Right	2	114.1	100.2
7	T18	Right	3	121.7	121.7
7	T18	Right	Median	**114.1**	**114.2**
7	T18	Left	1	49.5	73.4
7	T18	Left	2	87.8	63.4
7	T18	Left	3	95.0	102.9
7	T18	Left	Median	**87.8**	**73.4**
7	L3	Right	1	88.3	113.0
7	L3	Right	2	132.6	128.7
7	L3	Right	3	113.9	129.7
7	L3	Right	Median	**113.9**	**128.7**
7	L3	Left	1	87.7	97.2
7	L3	Left	2	103.0	106.3
7	L3	Left	3	93.6	111.9
7	L3	Left	Median	**93.6**	**106.3**
7	L6	Right	1	114.0	132.1
7	L6	Right	2	115.8	148.7
7	L6	Right	3	122.3	147.8
7	L6	Right	Median	**115.8**	**147.8**

7	L6	Left	1	76.8	94.4
7	L6	Left	2	96.2	121.8
7	L6	Left	3	103.9	182.2
7	L6	Left	Median	**96.2**	**121.8**
7	S2	Right	1	143.7	117.8
7	S2	Right	2	134.2	129.0
7	S2	Right	3	134.1	148.3
7	S2	Right	Median	**134.2**	**129.0**
7	S2	Left	1	101.2	169.2
7	S2	Left	2	95.1	101.7
7	S2	Left	3	119.0	118.2
7	S2	Left	Median	**101.2**	**118.2**
8	T3	Right	1	73.4	86.7
8	T3	Right	2	112.1	68.2
8	T3	Right	3	96.0	59.8
8	T3	Right	Median	**96.0**	**68.2**
8	T3	Left	1	80.3	80.2
8	T3	Left	2	65.6	81.8
8	T3	Left	3	92.3	71.1
8	T3	Left	Median	**80.3**	**80.2**
8	T9	Right	1	89.5	42.4
8	T9	Right	2	87.7	37.1
8	T9	Right	3	94.3	45.1
8	T9	Right	Median	**89.5**	**42.4**
8	T9	Left	1	104.4	30.6
8	T9	Left	2	193.7	25.3
8	T9	Left	3	163.8	39.3
8	T9	Left	Median	**163.8**	**30.6**
8	T13	Right	1	76.5	42.4
8	T13	Right	2	52.3	45.2
8	T13	Right	3	82.4	47.9
8	T13	Right	Median	**76.5**	**45.2**
8	T13	Left	1	136.7	70.0

8	T13	Left	2	70.8	53.7
8	T13	Left	3	67.7	52.8
8	T13	Left	Median	**70.8**	**53.7**
8	T18	Right	1	44.1	39.7
8	T18	Right	2	61.4	53.3
8	T18	Right	3	42.0	41.9
8	T18	Right	Median	**44.1**	**41.9**
8	T18	Left	1	57.7	47.0
8	T18	Left	2	68.1	48.4
8	T18	Left	3	70.4	57.3
8	T18	Left	Median	**68.1**	**48.4**
8	L3	Right	1	42.2	46.4
8	L3	Right	2	48.0	57.5
8	L3	Right	3	63.8	51.5
8	L3	Right	Median	**48.0**	**51.5**
8	L3	Left	1	42.0	41.5
8	L3	Left	2	53.9	49.3
8	L3	Left	3	61.0	67.4
8	L3	Left	Median	**53.9**	**49.3**
8	L6	Right	1	85.6	68.8
8	L6	Right	2	84.3	63.1
8	L6	Right	3	85.8	57.2
8	L6	Right	Median	**85.6**	**63.1**
8	L6	Left	1	110.9	53.8
8	L6	Left	2	80.8	63.4
8	L6	Left	3	67.8	66.4
8	L6	Left	Median	**80.8**	**63.4**
8	S2	Right	1	91.8	74.3
8	S2	Right	2	113.8	75.0
8	S2	Right	3	81.4	65.6
8	S2	Right	Median	**91.8**	**74.3**
8	S2	Left	1	88.9	87.0
8	S2	Left	2	79.8	90.7

8	S2	Left	3	76.9	87.0
8	S2	Left	Median	**79.8**	**87.0**
9	T3	Right	1	117.0	88.7
9	T3	Right	2	116.1	74.5
9	T3	Right	3	85.4	89.0
9	T3	Right	Median	**116.1**	**88.7**
9	T3	Left	1	156.9	99.8
9	T3	Left	2	119.2	93.0
9	T3	Left	3	118.2	93.2
9	T3	Left	Median	**119.2**	**93.2**
9	T9	Right	1	95.9	81.8
9	T9	Right	2	108.2	88.9
9	T9	Right	3	133.4	80.3
9	T9	Right	Median	**108.2**	**81.8**
9	T9	Left	1	172.0	66.4
9	T9	Left	2	146.9	84.2
9	T9	Left	3	169.6	84.1
9	T9	Left	Median	**169.6**	**84.1**
9	T13	Right	1	170.3	93.3
9	T13	Right	2	183.9	117.4
9	T13	Right	3	182.0	113.2
9	T13	Right	Median	**182.0**	**113.2**
9	T13	Left	1	173.5	126.2
9	T13	Left	2	174.1	139.8
9	T13	Left	3	161.6	135.2
9	T13	Left	Median	**173.5**	**135.2**
9	T18	Right	1	211.1	97.8
9	T18	Right	2	225.4	80.8
9	T18	Right	3	183.6	81.7
9	T18	Right	Median	**211.1**	**81.7**
9	T18	Left	1	119.7	104.4
9	T18	Left	2	142.7	101.7
9	T18	Left	3	158.7	117.4
9	T18	Left	Median	**142.7**	**104.4**
9	L3	Right	1	203.8	133.4
9	L3	Right	2	227.1	148.4
9	L3	Right	3	214.0	126.5
9	L3	Right	Median	**214.0**	**133.4**
9	L3	Left	1	123.5	144.0
9	L3	Left	2	136.8	157.6
9	L3	Left	3	156.1	167.6
9	L3	Left	Median	**136.8**	**157.6**
9	L6	Right	1	250.0	215.2
9	L6	Right	2	253.0	213.4
9	L6	Right	3		219.1
9	L6	Right	Median	**251.5**	**215.2**
9	L6	Left	1	235.0	171.9
9	L6	Left	2	194.0	183.8
9	L6	Left	3	200.0	206.2
9	L6	Left	Median	**200.0**	**183.8**
9	S2	Right	1	225.0	220.7
9	S2	Right	2	205.9	221.3
9	S2	Right	3	243.1	173.2
9	S2	Right	Median	**225.0**	**220.7**
9	S2	Left	1	217.2	172.8
9	S2	Left	2	198.4	208.2
9	S2	Left	3	188.8	237.2
9	S2	Left	Median	**198.4**	**208.2**
10	T3	Right	1	125.0	139.9
10	T3	Right	2	124.2	124.5
10	T3	Right	3	118.5	124.8
10	T3	Right	Median	**124.2**	**124.8**
10	T3	Left	1	159.3	78.3
10	T3	Left	2	126.2	159.5
10	T3	Left	3	145.4	146.1
10	T3	Left	Median	**145.4**	**146.1**

10	T9	Right	1	167.3	83.0
10	T9	Right	2	171.7	107.7
10	T9	Right	3	150.6	94.6
10	T9	Right	Median	**167.3**	**94.6**
10	T9	Left	1	98.4	91.2
10	T9	Left	2	190.9	105.1
10	T9	Left	3	178.7	87.7
10	T9	Left	Median	**178.7**	**91.2**
10	T13	Right	1	114.8	81.5
10	T13	Right	2	122.0	83.0
10	T13	Right	3	128.6	89.6
10	T13	Right	Median	**122.0**	**83.0**
10	T13	Left	1	245.7	100.6
10	T13	Left	2	193.4	96.6
10	T13	Left	3	145.4	101.3
10	T13	Left	Median	**193.4**	**100.6**
10	T18	Right	1	107.0	93.8
10	T18	Right	2	105.3	115.0
10	T18	Right	3	138.5	112.5
10	T18	Right	Median	**107.0**	**112.5**
10	T18	Left	1	145.7	104.4
10	T18	Left	2	108.9	92.1
10	T18	Left	3	91.1	104.1
10	T18	Left	Median	**108.9**	**104.1**
10	L3	Right	1	234.0	104.1
10	L3	Right	2	247.0	133.0
10	L3	Right	3		136.4
10	L3	Right	Median	**240.5**	**133.0**
10	L3	Left	1	202.3	104.5
10	L3	Left	2	219.6	118.8
10	L3	Left	3	203.5	125.1
10	L3	Left	Median	**203.5**	**118.8**
10	L6	Right	1		125.0

10	L6	Right	2		137.2
10	L6	Right	3		189.9
10	L6	Right	Median		**137.2**
10	L6	Left	1	300.0	222.2
10	L6	Left	2		257.0
10	L6	Left	3		210.0
10	L6	Left	Median	**300.0**	**222.2**
10	S2	Right	1	269.0	164.8
10	S2	Right	2	290.0	212.2
10	S2	Right	3		216.0
10	S2	Right	Median	**279.5**	**212.2**
10	S2	Left	1	278.0	161.0
10	S2	Left	2		171.9
10	S2	Left	3		185.7
10	S2	Left	Median	**278.0**	**171.9**
11	T3	Right	1	120.0	76.3
11	T3	Right	2	113.4	63.2
11	T3	Right	3	117.8	66.5
11	T3	Right	Median	**117.8**	**66.5**
11	T3	Left	1	88.6	82.0
11	T3	Left	2	60.8	79.2
11	T3	Left	3	94.0	63.9
11	T3	Left	Median	**88.6**	**79.2**
11	T9	Right	1	90.8	84.3
11	T9	Right	2	117.9	65.6
11	T9	Right	3	95.6	80.8
11	T9	Right	Median	**95.6**	**80.8**
11	T9	Left	1	157.6	66.0
11	T9	Left	2	93.7	54.4
11	T9	Left	3	140.6	67.1
11	T9	Left	Median	**140.6**	**66.0**
11	T13	Right	1	75.8	91.7
11	T13	Right	2	64.5	75.6

11	T13	Right	3	69.0	79.6
11	T13	Right	Median	**69.0**	**79.6**
11	T13	Left	1	70.3	80.4
11	T13	Left	2	144.5	79.5
11	T13	Left	3	99.5	
11	T13	Left	Median	**99.5**	**80.0**
11	T18	Right	1	48.4	113.0
11	T18	Right	2	58.1	84.8
11	T18	Right	3	59.9	94.3
11	T18	Right	Median	**58.1**	**94.3**
11	T18	Left	1	80.0	83.4
11	T18	Left	2	83.0	93.5
11	T18	Left	3	53.5	89.8
11	T18	Left	Median	**80.0**	**89.8**
11	L3	Right	1	60.4	85.9
11	L3	Right	2	66.5	92.2
11	L3	Right	3	87.2	106.2
11	L3	Right	Median	**66.5**	**92.2**
11	L3	Left	1	112.6	76.5
11	L3	Left	2	130.9	98.2
11	L3	Left	3	106.5	94.9
11	L3	Left	Median	**112.6**	**94.9**
11	L6	Right	1	65.6	82.5
11	L6	Right	2	67.3	78.2
11	L6	Right	3	77.4	88.1
11	L6	Right	Median	**67.3**	**82.5**
11	L6	Left	1	102.7	79.5
11	L6	Left	2	110.1	39.5
11	L6	Left	3	108.8	58.8
11	L6	Left	Median	**108.8**	**58.8**
11	S2	Right	1	76.6	142.8
11	S2	Right	2	81.7	150.5
11	S2	Right	3	83.8	149.2

11	S2	Right	Median	**81.7**	**149.2**
11	S2	Left	1	141.6	102.3
11	S2	Left	2	134.5	104.6
11	S2	Left	3	92.5	96.4
11	S2	Left	Median	**134.5**	**102.3**
12	T3	Right	1	92.0	132.2
12	T3	Right	2	79.5	74.2
12	T3	Right	3	74.0	123.8
12	T3	Right	Median	**79.5**	**123.8**
12	T3	Left	1	95.8	118.7
12	T3	Left	2	65.8	94.4
12	T3	Left	3	86.4	101.1
12	T3	Left	Median	**86.4**	**101.1**
12	T9	Right	1	69.5	63.7
12	T9	Right	2	73.0	44.4
12	T9	Right	3	49.4	58.4
12	T9	Right	Median	**69.5**	**58.4**
12	T9	Left	1	51.3	28.7
12	T9	Left	2	41.1	28.9
12	T9	Left	3	56.7	37.4
12	T9	Left	Median	**51.3**	**28.9**
12	T13	Right	1	70.4	82.7
12	T13	Right	2	57.2	78.9
12	T13	Right	3	60.7	55.6
12	T13	Right	Median	**60.7**	**78.9**
12	T13	Left	1	51.6	62.5
12	T13	Left	2	46.8	45.3
12	T13	Left	3	48.6	70.7
12	T13	Left	Median	**48.6**	**62.5**
12	T18	Right	1	62.3	46.3
12	T18	Right	2	54.2	45.1
12	T18	Right	3	52.8	77.1
12	T18	Right	Median	**54.2**	**46.3**

12	T18	Left	1	69.6	65.2
12	T18	Left	2	46.8	60.7
12	T18	Left	3	48.6	61.5
12	T18	Left	Median	**48.6**	**61.5**
12	L3	Right	1	63.2	63.9
12	L3	Right	2	44.7	50.1
12	L3	Right	3	74.5	67.9
12	L3	Right	Median	**63.2**	**63.9**
12	L3	Left	1	71.5	72.4
12	L3	Left	2	75.7	66.9
12	L3	Left	3	70.0	44.0
12	L3	Left	Median	**71.5**	**66.9**
12	L6	Right	1	84.2	89.7
12	L6	Right	2	73.6	84.2
12	L6	Right	3	67.6	96.1
12	L6	Right	Median	**73.6**	**89.7**
12	L6	Left	1	80.3	72.4
12	L6	Left	2	74.4	66.9
12	L6	Left	3	78.6	92.8
12	L6	Left	Median	**78.6**	**72.4**
12	S2	Right	1	68.4	136.1
12	S2	Right	2	71.7	130.5
12	S2	Right	3	65.0	149.5
12	S2	Right	Median	**68.4**	**136.1**
12	S2	Left	1	78.4	59.2
12	S2	Left	2	52.3	60.1
12	S2	Left	3	61.7	82.9
12	S2	Left	Median	**61.7**	**60.1**
13	T3	Right	1	122.8	90.3
13	T3	Right	2	107.1	94.3
13	T3	Right	3	92.4	114.3
13	T3	Right	Median	**107.1**	**94.3**
13	T3	Left	1	101.8	71.0
13	T3	Left	2	100.9	83.3
13	T3	Left	3	170.0	107.8
13	T3	Left	Median	**101.8**	**83.3**
13	T9	Right	1	124.9	90.6
13	T9	Right	2	156.0	81.2
13	T9	Right	3	134.9	103.5
13	T9	Right	Median	**134.9**	**90.6**
13	T9	Left	1	180.8	95.0
13	T9	Left	2	168.4	85.0
13	T9	Left	3	192.2	81.1
13	T9	Left	Median	**180.8**	**85.0**
13	T13	Right	1	108.4	146.4
13	T13	Right	2	88.0	157.2
13	T13	Right	3	134.0	147.1
13	T13	Right	Median	**108.4**	**147.1**
13	T13	Left	1	159.8	141.3
13	T13	Left	2	166.7	152.6
13	T13	Left	3	170.5	135.6
13	T13	Left	Median	**166.7**	**141.3**
13	T18	Right	1	131.0	159.3
13	T18	Right	2	105.6	137.4
13	T18	Right	3	139.6	147.4
13	T18	Right	Median	**131.0**	**147.4**
13	T18	Left	1	128.8	100.4
13	T18	Left	2	136.2	133.2
13	T18	Left	3	150.2	157.4
13	T18	Left	Median	**136.2**	**133.2**
13	L3	Right	1	156.2	164.7
13	L3	Right	2	248.0	160.1
13	L3	Right	3	201.0	175.8
13	L3	Right	Median	**201.0**	**164.7**
13	L3	Left	1	182.8	163.2
13	L3	Left	2	175.8	188.0

13	L3	Left	3	206.8	189.6
13	L3	Left	Median	**182.8**	**188.0**
13	L6	Right	1	136.8	82.3
13	L6	Right	2	118.3	104.7
13	L6	Right	3	105.5	105.6
13	L6	Right	Median	**118.3**	**104.7**
13	L6	Left	1	220.0	174.7
13	L6	Left	2		232.0
13	L6	Left	3		194.0
13	L6	Left	Median	**220.0**	**194.0**
13	S2	Right	1	132.7	159.9
13	S2	Right	2	209.5	161.5
13	S2	Right	3	213.6	232.0
13	S2	Right	Median	**209.5**	**161.5**
13	S2	Left	1	247.0	197.8
13	S2	Left	2	172.0	200.5
13	S2	Left	3	200.0	185.1
13	S2	Left	Median	**200.0**	**197.8**
14	T3	Right	1	94.8	74.9
14	T3	Right	2	85.9	91.3
14	T3	Right	3	132.7	112.5
14	T3	Right	Median	**94.8**	**91.3**
14	T3	Left	1	120.2	149.0
14	T3	Left	2	92.9	110.9
14	T3	Left	3	95.3	154.9
14	T3	Left	Median	**95.3**	**149.0**
14	T9	Right	1	88.5	96.3
14	T9	Right	2	111.6	95.6
14	T9	Right	3	112.5	116.3
14	T9	Right	Median	**111.6**	**96.3**
14	T9	Left	1	108.0	104.4
14	T9	Left	2	76.0	110.5
14	T9	Left	3	115.4	123.0

14	T9	Left	Median	**108.0**	**110.5**
14	T13	Right	1	104.6	136.5
14	T13	Right	2	113.6	99.2
14	T13	Right	3	107.3	108.0
14	T13	Right	Median	**107.3**	**108.0**
14	T13	Left	1	188.0	96.5
14	T13	Left	2	169.5	93.4
14	T13	Left	3	199.1	103.0
14	T13	Left	Median	**188.0**	**96.5**
14	T18	Right	1	74.1	100.5
14	T18	Right	2	101.7	110.2
14	T18	Right	3	122.7	123.2
14	T18	Right	Median	**101.7**	**110.2**
14	T18	Left	1	126.9	87.8
14	T18	Left	2	97.4	104.2
14	T18	Left	3	108.7	85.1
14	T18	Left	Median	**108.7**	**87.8**
14	L3	Right	1	204.0	108.8
14	L3	Right	2	176.0	114.2
14	L3	Right	3	188.0	113.0
14	L3	Right	Median	**188.0**	**113.0**
14	L3	Left	1	146.8	121.5
14	L3	Left	2	155.0	117.0
14	L3	Left	3	175.0	133.5
14	L3	Left	Median	**155.0**	**121.5**
14	L6	Right	1	124.2	93.6
14	L6	Right	2	141.6	108.0
14	L6	Right	3	124.3	101.7
14	L6	Right	Median	**124.3**	**101.7**
14	L6	Left	1	174.5	96.4
14	L6	Left	2	210.0	110.1
14	L6	Left	3	203.0	110.9
14	L6	Left	Median	**203.0**	**110.1**

14	S2	Right	1	128.6	95.0
14	S2	Right	2	108.6	105.4
14	S2	Right	3	127.3	132.1
14	S2	Right	Median	**127.3**	**105.4**
14	S2	Left	1	119.2	124.2
14	S2	Left	2	150.8	130.9
14	S2	Left	3	155.8	122.5
14	S2	Left	Median	**150.8**	**124.2**
15	T3	Right	1	16.0	51.4
15	T3	Right	2		23.6
15	T3	Right	3		51.8
15	T3	Right	Median	**16.0**	**51.4**
15	T3	Left	1	136.7	105.3
15	T3	Left	2	76.1	80.4
15	T3	Left	3	71.6	57.5
15	T3	Left	Median	**76.1**	**80.4**
15	T9	Right	1	49.8	65.2
15	T9	Right	2	37.8	76.4
15	T9	Right	3	45.0	59.6
15	T9	Right	Median	**45.0**	**65.2**
15	T9	Left	1	67.2	60.1
15	T9	Left	2	85.9	51.7
15	T9	Left	3	91.6	42.9
15	T9	Left	Median	**85.9**	**51.7**
15	T13	Right	1	48.8	91.0
15	T13	Right	2	66.1	65.6
15	T13	Right	3	82.6	69.7
15	T13	Right	Median	**66.1**	**69.7**
15	T13	Left	1	66.5	79.5
15	T13	Left	2	50.0	91.1
15	T13	Left	3	65.0	96.4
15	T13	Left	Median	**65.0**	**91.1**
15	T18	Right	1	68.6	73.5
15	T18	Right	2	69.0	81.9
15	T18	Right	3	73.0	90.4
15	T18	Right	Median	**69.0**	**81.9**
15	T18	Left	1	64.8	72.2
15	T18	Left	2	55.2	63.9
15	T18	Left	3	47.4	72.0
15	T18	Left	Median	**55.2**	**72.0**
15	L3	Right	1	77.3	93.2
15	L3	Right	2	124.2	97.7
15	L3	Right	3	126.6	91.0
15	L3	Right	Median	**124.2**	**93.2**
15	L3	Left	1	193.9	63.9
15	L3	Left	2	123.6	95.1
15	L3	Left	3	118.4	100.2
15	L3	Left	Median	**123.6**	**95.1**
15	L6	Right	1	95.5	104.6
15	L6	Right	2	67.8	91.1
15	L6	Right	3	65.4	117.6
15	L6	Right	Median	**67.8**	**104.6**
15	L6	Left	1	124.5	80.3
15	L6	Left	2	103.2	85.4
15	L6	Left	3	94.0	92.4
15	L6	Left	Median	**103.2**	**85.4**
15	S2	Right	1	86.5	127.6
15	S2	Right	2	75.5	129.1
15	S2	Right	3	86.8	148.5
15	S2	Right	Median	**86.5**	**129.1**
15	S2	Left	1	168.6	116.9
15	S2	Left	2	82.7	142.3
15	S2	Left	3	95.7	134.7
15	S2	Left	Median	**95.7**	**134.7**
16	T3	Right	1		180.0
16	T3	Right	2		190.0

16	T3	Right	3		
16	T3	Right	Median	**no data**	**185.0**
16	T3	Left	1	187.0	192.0
16	T3	Left	2		179.9
16	T3	Left	3		134.0
16	T3	Left	Median	**187.0**	**179.9**
16	T9	Right	1		74.5
16	T9	Right	2		65.5
16	T9	Right	3		77.5
16	T9	Right	Median	**no data**	**74.5**
16	T9	Left	1	72.5	101.9
16	T9	Left	2	100.8	114.8
16	T9	Left	3	113.0	112.7
16	T9	Left	Median	**100.8**	**112.7**
16	T13	Right	1		76.4
16	T13	Right	2		72.0
16	T13	Right	3		76.0
16	T13	Right	Median	**no data**	**76.0**
16	T13	Left	1	93.2	93.1
16	T13	Left	2	120.8	89.8
16	T13	Left	3	106.6	101.0
16	T13	Left	Median	**106.6**	**93.1**
16	T18	Right	1		87.3
16	T18	Right	2		89.9
16	T18	Right	3		83.4
16	T18	Right	Median	**no data**	**87.3**
16	T18	Left	1	104.7	106.2
16	T18	Left	2	128.8	103.3
16	T18	Left	3	110.2	96.7
16	T18	Left	Median	**110.2**	**103.3**
16	L3	Right	1		134.4
16	L3	Right	2		125.3
16	L3	Right	3		133.8
16	L3	Right	Median	**no data**	**133.8**
16	L3	Left	1	98.3	129.8
16	L3	Left	2	110.4	109.1
16	L3	Left	3	114.1	135.6
16	L3	Left	Median	**110.4**	**129.8**
16	L6	Right	1		136.6
16	L6	Right	2		110.1
16	L6	Right	3		130.2
16	L6	Right	Median	**no data**	**130.2**
16	L6	Left	1		182.4
16	L6	Left	2		223.5
16	L6	Left	3		164.8
16	L6	Left	Median	**no data**	**182.4**
16	S2	Right	1		243.0
16	S2	Right	2		211.0
16	S2	Right	3		
16	S2	Right	Median	**no data**	**227.0**
16	S2	Left	1		240.0
16	S2	Left	2		250.0
16	S2	Left	3		
16	S2	Left	Median	**no data**	**245.0**
17	T3	Right	1	134.6	141.0
17	T3	Right	2	147.4	109.2
17	T3	Right	3	138.4	122.1
17	T3	Right	Median	**138.4**	**122.1**
17	T3	Left	1	174.8	126.2
17	T3	Left	2	150.2	77.3
17	T3	Left	3	162.1	138.6
17	T3	Left	Median	**162.1**	**126.2**
17	T9	Right	1	123.6	125.9
17	T9	Right	2	119.0	125.9
17	T9	Right	3	96.2	138.5
17	T9	Right	Median	**119.0**	**125.9**

17	T9	Left	1	100.9	72.4
17	T9	Left	2	82.5	109.8
17	T9	Left	3	81.3	105.0
17	T9	Left	Median	**82.5**	**105.0**
17	T13	Right	1	125.8	73.7
17	T13	Right	2	94.8	105.3
17	T13	Right	3	115.4	100.7
17	T13	Right	Median	**115.4**	**100.7**
17	T13	Left	1	87.0	72.4
17	T13	Left	2	76.0	109.8
17	T13	Left	3	92.5	105.0
17	T13	Left	Median	**87.0**	**105.0**
17	T18	Right	1	100.9	91.4
17	T18	Right	2	79.5	89.6
17	T18	Right	3	80.8	90.8
17	T18	Right	Median	**80.8**	**90.8**
17	T18	Left	1	61.7	93.4
17	T18	Left	2	86.5	116.8
17	T18	Left	3	70.6	101.1
17	T18	Left	Median	**70.6**	**101.1**
17	L3	Right	1	149.1	81.4
17	L3	Right	2	123.3	67.2
17	L3	Right	3	134.4	80.2
17	L3	Right	Median	**134.4**	**80.2**
17	L3	Left	1	225.0	98.0
17	L3	Left	2	223.0	111.9
17	L3	Left	3		92.6
17	L3	Left	Median	**224.0**	**98.0**
17	L6	Right	1	125.6	111.1
17	L6	Right	2	137.4	114.5
17	L6	Right	3	132.2	119.8
17	L6	Right	Median	**132.2**	**114.5**
17	L6	Left	1	164.2	159.9

17	L6	Left	2	152.6	166.1
17	L6	Left	3	159.5	136.6
17	L6	Left	Median	**159.5**	**159.9**
17	S2	Right	1	107.6	115.1
17	S2	Right	2	159.2	109.8
17	S2	Right	3	158.1	115.5
17	S2	Right	Median	**158.1**	**115.1**
17	S2	Left	1	212.5	104.8
17	S2	Left	2	165.9	108.5
17	S2	Left	3	173.2	128.2
17	S2	Left	Median	**173.2**	**108.5**
18	T3	Right	1	89.6	99.7
18	T3	Right	2	129.1	91.8
18	T3	Right	3	81.7	98.2
18	T3	Right	Median	**89.6**	**98.2**
18	T3	Left	1	142.1	62.7
18	T3	Left	2	117.2	89.0
18	T3	Left	3	126.2	60.5
18	T3	Left	Median	**126.2**	**62.7**
18	T9	Right	1	85.8	96.3
18	T9	Right	2	83.0	109.5
18	T9	Right	3	104.8	111.1
18	T9	Right	Median	**85.8**	**109.5**
18	T9	Left	1	103.3	95.4
18	T9	Left	2	108.9	64.0
18	T9	Left	3	91.9	105.3
18	T9	Left	Median	**103.3**	**95.4**
18	T13	Right	1	100.4	203.5
18	T13	Right	2	90.6	158.1
18	T13	Right	3	85.1	164.6
18	T13	Right	Median	**90.6**	**164.6**
18	T13	Left	1	108.9	152.1
18	T13	Left	2	72.2	88.8

18	T13	Left	3	84.3	126.4
18	T13	Left	Median	**84.3**	**126.4**
18	T18	Right	1	138.9	170.9
18	T18	Right	2	81.3	197.3
18	T18	Right	3	92.0	145.7
18	T18	Right	Median	**92.0**	**170.9**
18	T18	Left	1	79.9	160.9
18	T18	Left	2	67.5	194.3
18	T18	Left	3	88.3	181.5
18	T18	Left	Median	**79.9**	**181.5**
18	L3	Right	1	105.7	204.2
18	L3	Right	2	123.0	180.4
18	L3	Right	3	99.3	157.4
18	L3	Right	Median	**105.7**	**180.4**
18	L3	Left	1	95.9	219.0
18	L3	Left	2	83.4	208.0
18	L3	Left	3	74.2	179.9
18	L3	Left	Median	**83.4**	**208.0**
18	L6	Right	1	133.3	216.2
18	L6	Right	2	84.1	213.3
18	L6	Right	3	113.9	237.1
18	L6	Right	Median	**113.9**	**216.2**
18	L6	Left	1	98.5	138.9
18	L6	Left	2	76.7	172.9
18	L6	Left	3	69.5	196.1
18	L6	Left	Median	**76.7**	**172.9**
18	S2	Right	1	142.3	268.0
18	S2	Right	2	200.0	250.0
18	S2	Right	3	215.0	
18	S2	Right	Median	**200.0**	**259.0**
18	S2	Left	1	91.9	161.5
18	S2	Left	2	92.1	198.0
18	S2	Left	3	109.0	159.8

18	S2	Left	Median	**92.1**	**161.5**
19	T3	Right	1	163.7	103.2
19	T3	Right	2	161.0	86.9
19	T3	Right	3	123.2	119.6
19	T3	Right	Median	**161.0**	**103.2**
19	T3	Left	1	73.0	179.0
19	T3	Left	2	72.1	132.3
19	T3	Left	3	83.1	173.9
19	T3	Left	Median	**73.0**	**173.9**
19	T9	Right	1	113.2	50.5
19	T9	Right	2	80.1	54.0
19	T9	Right	3	113.5	68.0
19	T9	Right	Median	**113.2**	**54.0**
19	T9	Left	1	74.5	159.0
19	T9	Left	2	73.7	209.0
19	T9	Left	3	120.5	170.0
19	T9	Left	Median	**74.5**	**170.0**
19	T13	Right	1	89.0	80.2
19	T13	Right	2	91.7	76.4
19	T13	Right	3	135.3	90.3
19	T13	Right	Median	**91.7**	**80.2**
19	T13	Left	1	94.4	79.6
19	T13	Left	2	90.8	111.5
19	T13	Left	3	104.1	102.3
19	T13	Left	Median	**94.4**	**102.3**
19	T18	Right	1	115.7	113.6
19	T18	Right	2	126.1	131.6
19	T18	Right	3	121.1	156.7
19	T18	Right	Median	**121.1**	**131.6**
19	T18	Left	1	53.9	82.2
19	T18	Left	2	72.3	93.9
19	T18	Left	3	69.6	110.0
19	T18	Left	Median	**69.6**	**93.9**

19	L3	Right	1	236.0	143.3
19	L3	Right	2	257.0	142.6
19	L3	Right	3		150.0
19	L3	Right	Median	**246.5**	**143.3**
19	L3	Left	1	101.3	247.7
19	L3	Left	2	106.9	271.0
19	L3	Left	3	124.4	
19	L3	Left	Median	**106.9**	**259.4**
19	L6	Right	1	224.0	132.0
19	L6	Right	2	216.7	134.8
19	L6	Right	3	225.1	165.0
19	L6	Right	Median	**224.0**	**134.8**
19	L6	Left	1	86.1	282.0
19	L6	Left	2	155.7	228.0
19	L6	Left	3	211.4	
19	L6	Left	Median	**155.7**	**255.0**
19	S2	Right	1	196.0	196.9
19	S2	Right	2	217.0	245.0
19	S2	Right	3		
19	S2	Right	Median	**206.5**	**221.0**
19	S2	Left	1	97.0	253.0
19	S2	Left	2	160.2	259.7
19	S2	Left	3	136.1	
19	S2	Left	Median	**136.1**	**256.4**
20	T3	Right	1	64.8	56.8
20	T3	Right	2	59.8	76.3
20	T3	Right	3	89.8	63.4
20	T3	Right	Median	**64.8**	**63.4**
20	T3	Left	1	193.0	118.1
20	T3	Left	2	112.8	114.6
20	T3	Left	3	134.1	96.6
20	T3	Left	Median	**134.1**	**114.6**
20	T9	Right	1	48.8	48.7
20	T9	Right	2	56.5	51.7
20	T9	Right	3	73.2	81.0
20	T9	Right	Median	**56.5**	**51.7**
20	T9	Left	1	126.0	64.4
20	T9	Left	2	116.8	54.3
20	T9	Left	3	134.8	58.4
20	T9	Left	Median	**126.0**	**58.4**
20	T13	Right	1	86.5	95.8
20	T13	Right	2	79.4	87.9
20	T13	Right	3	76.2	106.1
20	T13	Right	Median	**79.4**	**95.8**
20	T13	Left	1	104.0	103.6
20	T13	Left	2	118.2	75.5
20	T13	Left	3	109.5	81.4
20	T13	Left	Median	**109.5**	**81.4**
20	T18	Right	1	78.6	87.9
20	T18	Right	2	77.6	112.0
20	T18	Right	3	75.5	113.0
20	T18	Right	Median	**77.6**	**112.0**
20	T18	Left	1	96.7	86.4
20	T18	Left	2	121.3	81.0
20	T18	Left	3	111.3	96.1
20	T18	Left	Median	**111.3**	**86.4**
20	L3	Right	1	51.9	103.8
20	L3	Right	2	54.2	77.9
20	L3	Right	3	55.5	78.5
20	L3	Right	Median	**54.2**	**78.5**
20	L3	Left	1	66.0	81.1
20	L3	Left	2	87.3	95.6
20	L3	Left	3	86.3	100.8
20	L3	Left	Median	**86.3**	**95.6**
20	L6	Right	1	76.9	73.2
20	L6	Right	2	61.7	75.4

20	L6	Right	3	66.6	82.8
20	L6	Right	Median	**66.6**	**75.4**
20	L6	Left	1	54.9	78.6
20	L6	Left	2	65.1	72.6
20	L6	Left	3	79.1	70.1
20	L6	Left	Median	**65.1**	**72.6**
20	S2	Right	1	87.0	94.7
20	S2	Right	2	105.3	91.5
20	S2	Right	3	114.9	94.2
20	S2	Right	Median	**105.3**	**94.2**
20	S2	Left	1	120.4	85.7
20	S2	Left	2	108.9	115.5
20	S2	Left	3	108.8	97.1
20	S2	Left	Median	**108.9**	**97.1**
21	T3	Right	1	150.7	129.2
21	T3	Right	2	151.6	179.0
21	T3	Right	3	157.0	206.0
21	T3	Right	Median	**151.6**	**179.0**
21	T3	Left	1	209.0	115.1
21	T3	Left	2	187.5	95.8
21	T3	Left	3		119.8
21	T3	Left	Median	**198.3**	**115.1**
21	T9	Right	1	88.6	112.0
21	T9	Right	2	166.4	83.3
21	T9	Right	3	142.7	109.0
21	T9	Right	Median	**142.7**	**109.0**
21	T9	Left	1	75.1	87.8
21	T9	Left	2	82.6	126.1
21	T9	Left	3	83.9	120.0
21	T9	Left	Median	**82.6**	**120.0**
21	T13	Right	1	147.2	107.5
21	T13	Right	2	138.0	93.8
21	T13	Right	3	160.1	133.7

21	T13	Right	Median	**147.2**	**107.5**
21	T13	Left	1	212.4	96.6
21	T13	Left	2	150.4	115.2
21	T13	Left	3	140.9	117.4
21	T13	Left	Median	**150.4**	**115.2**
21	T18	Right	1	170.1	131.1
21	T18	Right	2	128.1	121.7
21	T18	Right	3	145.7	147.7
21	T18	Right	Median	**145.7**	**131.1**
21	T18	Left	1	113.7	131.5
21	T18	Left	2	127.2	149.9
21	T18	Left	3	123.5	117.7
21	T18	Left	Median	**123.5**	**131.5**
21	L3	Right	1	123.7	177.0
21	L3	Right	2	154.4	201.8
21	L3	Right	3	141.8	188.4
21	L3	Right	Median	**141.8**	**188.4**
21	L3	Left	1	195.5	268.0
21	L3	Left	2	177.9	251.0
21	L3	Left	3	140.2	
21	L3	Left	Median	**177.9**	**259.5**
21	L6	Right	1	133.3	219.9
21	L6	Right	2	229.3	200.2
21	L6	Right	3	188.8	203.6
21	L6	Right	Median	**188.8**	**203.6**
21	L6	Left	1	123.5	237.0
21	L6	Left	2	208.7	220.0
21	L6	Left	3	184.5	
21	L6	Left	Median	**184.5**	**228.5**
21	S2	Right	1	166.5	332.9
21	S2	Right	2	234.9	319.6
21	S2	Right	3	223.0	
21	S2	Right	Median	**223.0**	**326.3**

21	S2	Left	1	128.3	230.0
21	S2	Left	2	251.0	212.0
21	S2	Left	3	138.8	
21	S2	Left	Median	**138.8**	**221.0**
22	T3	Right	1	99.2	127.8
22	T3	Right	2	102.3	109.2
22	T3	Right	3	93.1	124.0
22	T3	Right	Median	**99.2**	**124.0**
22	T3	Left	1	138.8	124.8
22	T3	Left	2	99.7	97.2
22	T3	Left	3	147.6	108.2
22	T3	Left	Median	**138.8**	**108.2**
22	T9	Right	1	102.0	122.9
22	T9	Right	2	90.5	119.4
22	T9	Right	3	82.6	124.3
22	T9	Right	Median	**90.5**	**122.9**
22	T9	Left	1	118.2	109.9
22	T9	Left	2	107.0	94.1
22	T9	Left	3	91.6	96.5
22	T9	Left	Median	**107.0**	**96.5**
22	T13	Right	1	61.9	115.8
22	T13	Right	2	64.9	107.8
22	T13	Right	3	67.7	118.4
22	T13	Right	Median	**64.9**	**115.8**
22	T13	Left	1	71.6	103.8
22	T13	Left	2	88.5	84.3
22	T13	Left	3	84.0	96.6
22	T13	Left	Median	**84.0**	**96.6**
22	T18	Right	1	78.3	128.6
22	T18	Right	2	56.3	138.4
22	T18	Right	3	65.6	129.0
22	T18	Right	Median	**65.6**	**129.0**
22	T18	Left	1	63.6	90.0

22	T18	Left	2	60.0	111.2
22	T18	Left	3	44.9	121.9
22	T18	Left	Median	**60.0**	**111.2**
22	L3	Right	1	112.7	151.7
22	L3	Right	2	102.5	133.9
22	L3	Right	3	97.0	138.9
22	L3	Right	Median	**102.5**	**138.9**
22	L3	Left	1	144.4	100.1
22	L3	Left	2	132.6	136.5
22	L3	Left	3	119.8	139.0
22	L3	Left	Median	**132.6**	**136.5**
22	L6	Right	1	108.3	130.9
22	L6	Right	2	100.3	119.6
22	L6	Right	3	111.8	122.9
22	L6	Right	Median	**108.3**	**122.9**
22	L6	Left	1	100.8	122.2
22	L6	Left	2	102.3	148.6
22	L6	Left	3	101.1	160.7
22	L6	Left	Median	**101.1**	**148.6**
22	S2	Right	1	106.0	116.2
22	S2	Right	2	120.9	144.2
22	S2	Right	3	118.9	127.8
22	S2	Right	Median	**118.9**	**127.8**
22	S2	Left	1	148.8	203.8
22	S2	Left	2	142.4	156.4
22	S2	Left	3	122.8	175.5
22	S2	Left	Median	**142.4**	**175.5**
23	T3	Right	1	81.1	56.1
23	T3	Right	2	79.8	64.8
23	T3	Right	3	59.2	72.5
23	T3	Right	Median	**79.8**	**64.8**
23	T3	Left	1	72.1	73.0
23	T3	Left	2	54.4	61.4

23	T3	Left	3	89.7	58.5
23	T3	Left	Median	**72.1**	**61.4**
23	T9	Right	1	69.0	65.3
23	T9	Right	2	60.4	70.8
23	T9	Right	3	64.1	68.3
23	T9	Right	Median	**64.1**	**68.3**
23	T9	Left	1	72.2	88.9
23	T9	Left	2	49.9	67.7
23	T9	Left	3	57.3	89.0
23	T9	Left	Median	**57.3**	**88.9**
23	T13	Right	1	65.6	80.7
23	T13	Right	2	81.6	72.8
23	T13	Right	3	74.0	78.8
23	T13	Right	Median	**74.0**	**78.8**
23	T13	Left	1	47.7	71.2
23	T13	Left	2	50.5	63.3
23	T13	Left	3	70.7	81.4
23	T13	Left	Median	**50.5**	**71.2**
23	T18	Right	1	71.4	88.8
23	T18	Right	2	81.8	88.2
23	T18	Right	3	81.7	99.2
23	T18	Right	Median	**81.7**	**88.8**
23	T18	Left	1	67.2	81.3
23	T18	Left	2	78.5	96.7
23	T18	Left	3	81.7	93.1
23	T18	Left	Median	**78.5**	**93.1**
23	L3	Right	1	88.6	157.0
23	L3	Right	2	102.8	183.5
23	L3	Right	3	116.8	194.2
23	L3	Right	Median	**102.8**	**183.5**
23	L3	Left	1	124.9	100.0
23	L3	Left	2	114.4	177.2
23	L3	Left	3	121.0	137.2

23	L3	Left	Median	**121.0**	**137.2**
23	L6	Right	1	91.0	143.0
23	L6	Right	2	117.3	149.5
23	L6	Right	3	121.3	140.1
23	L6	Right	Median	**117.3**	**143.0**
23	L6	Left	1	81.9	195.4
23	L6	Left	2	124.0	243.9
23	L6	Left	3	113.7	177.2
23	L6	Left	Median	**113.7**	**195.4**
23	S2	Right	1	140.8	136.1
23	S2	Right	2	104.4	244.9
23	S2	Right	3	126.1	176.7
23	S2	Right	Median	**126.1**	**176.7**
23	S2	Left	1	186.0	119.9
23	S2	Left	2	138.9	155.9
23	S2	Left	3	165.8	142.3
23	S2	Left	Median	**165.8**	**142.3**
24	T3	Right	1	57.8	65.8
24	T3	Right	2	60.8	40.3
24	T3	Right	3	73.7	50.3
24	T3	Right	Median	**60.8**	**50.3**
24	T3	Left	1	53.7	82.7
24	T3	Left	2	47.4	89.6
24	T3	Left	3	55.8	72.6
24	T3	Left	Median	**53.7**	**82.7**
24	T9	Right	1	64.5	51.7
24	T9	Right	2	79.7	51.5
24	T9	Right	3	90.3	65.1
24	T9	Right	Median	**79.7**	**51.7**
24	T9	Left	1	77.6	26.1
24	T9	Left	2	57.5	36.0
24	T9	Left	3	57.7	41.0
24	T9	Left	Median	**57.7**	**36.0**

24	T13	Right	1	85.9	69.0
24	T13	Right	2	88.6	85.8
24	T13	Right	3	94.3	95.6
24	T13	Right	Median	**88.6**	**85.8**
24	T13	Left	1	106.3	57.6
24	T13	Left	2	131.6	64.8
24	T13	Left	3	126.4	63.1
24	T13	Left	Median	**126.4**	**63.1**
24	T18	Right	1	65.1	75.8
24	T18	Right	2	69.7	78.5
24	T18	Right	3	82.2	68.7
24	T18	Right	Median	**69.7**	**75.8**
24	T18	Left	1	108.5	61.9
24	T18	Left	2	101.3	63.3
24	T18	Left	3	83.2	75.3
24	T18	Left	Median	**101.3**	**63.3**
24	L3	Right	1	67.3	101.5
24	L3	Right	2	73.1	82.5
24	L3	Right	3	81.1	77.5
24	L3	Right	Median	**73.1**	**82.5**
24	L3	Left	1	113.0	45.3
24	L3	Left	2	118.2	41.8
24	L3	Left	3	134.7	48.7
24	L3	Left	Median	**118.2**	**45.3**
24	L6	Right	1	79.1	66.5
24	L6	Right	2	104.9	63.5
24	L6	Right	3	101.8	76.1
24	L6	Right	Median	**101.8**	**66.5**
24	L6	Left	1	87.9	57.7
24	L6	Left	2	114.3	73.7
24	L6	Left	3	134.7	73.4
24	L6	Left	Median	**114.3**	**73.4**
24	S2	Right	1	212.6	103.0
24	S2	Right	2	227.0	110.8
24	S2	Right	3	223.1	107.0
24	S2	Right	Median	**223.1**	**107.0**
24	S2	Left	1	69.1	83.6
24	S2	Left	2	106.2	86.6
24	S2	Left	3	103.9	91.5
24	S2	Left	Median	**103.9**	**86.6**

Appendix 4: Lameness Locator

All data collected from the Lameness Locator for the last nine horses. If the value for Mean Diff Max Head and Mean Diff Min Head were within ± 6 mm, the horse was sound in the front limbs, regardless of the standard deviation. Similarly, if the value for Mean Diff Max Pelvis and Mean Diff Min Pelvis were within ± 3 mm, the horse was sound in the hind limbs, regardless of the standard deviation. If Diff Max and Diff Min were above threshold (± 6 mm for head, ± 3 mm for pelvis), but the standard deviation was above the mean, the horse had a variable gait. If Diff Max and Diff Min were above threshold (± 6 mm for head, ± 3 mm for pelvis), and the standard deviation was below the mean, the horse was lame.

Horse	Time	Mean Diff Max Head (mm)	s.d. Diff Max Head	Mean Diff Min Head (mm)	s.d. Diff Min Head	Mean Diff Max Pelvis (mm)	s.d. Diff Max Pelvis	Mean Diff Min Pelvis (mm)	s.d. Diff Min Pelvis
15	Pre	-5.2	14.5	-10.9	21.5	3.6	6.4	8.1	11.4
15	Post	-3.0	16.2	-8.4	15.0	2.9	5.7	15.3	9.4
16	Pre	3.5	8.4	-9.7	9.7	-3.2	7.1	3.6	8.1
16	Post	3.1	7.1	-2.1	6.7	-1.0	3.2	3.1	5.1
17	Pre	-1.4	12.2	1.4	11.7	1.7	5.0	5.2	8.3
17	Post	-5.7	22.8	-4.3	18.7	1.9	8.3	3.0	8.4
18	Pre	8.6	13.2	19.8	15.4	1.8	8.9	-5.4	8.1
18	Post	-3.3	17.7	14.0	38.0	0.4	4.8	-7.5	4.4
19	Pre	0.4	13.4	7.0	14.5	0.4	6.2	5.4	11.4
19	Post	2.1	11.7	8.5	25.5	7.7	5.1	8.9	12.1
20	Pre	-10.4	10.7	2.9	12.3	7.6	9.1	1.0	11.3
20	Post	-1.0	6.5	5.1	7.0	3.8	2.7	2.2	7.6
21	Pre	0.3	7.9	0.2	8.5	5.7	7.2	-2.2	6.2
21	Post	-0.7	4.8	4.0	7.4	7.7	4.4	-0.9	6.3
22	Pre	4.5	9.7	-1.2	12.9	-4.8	5.3	4.2	7.2
22	Post	2.7	7.4	-14.3	11.3	-9.0	6.6	-0.1	8.1
23	Pre	4.9	13.7	-5.1	13.0	12.2	62.5	3.2	13.8
23	Post	16.4	14.2	-4.1	8.8	4.5	5.3	4.2	9.1

Appendix 5: Gait Analysis

All data collected from analysis of video (1080p, 30 frames per second) in LoggerPro 3.8.7. Three trials were done for each side, and the mean is shown in blue. The mean was used rather than the median in this case as all data was similar. Hock amplitude is a measure of the height at which the hock traveled in one stride. Limb pair one and limb pair two refers to the distance between the inside fore and outside hind, and the outside fore and inside hind. Limb pair one was always the pair with the longer distance, and limb pair two was always the pair with the shorter distance. Gait evenness was determined by dividing limb pair one by limb pair two. The closer the value is to one (1), the greater evenness the stride possessed.

Horse	Side	Trial	Pre-Hock Amplitude	Post-Hock amplitude	Pre-Limb Pair 1	Pre-Limb Pair 2	Post-Limb Pair 1	Post-Limb Pair 2	Pre-Gait Evenness	Post-Gait Evenness
1	Right	1	0.056	0.069	0.819	0.746	0.780	0.753	1.098	1.036
1	Right	2	0.061	0.061	0.789	0.748	0.794	0.791	1.055	1.004
1	Right	3	0.070	0.098	0.804	0.728	0.842	0.812	1.104	1.037
1	Right	Mean	0.062	0.076	0.804	0.741	0.805	0.785	1.086	1.025
1	Left	1	0.089	0.097	0.849	0.744	0.789	0.745	1.141	1.059
1	Left	2	0.079	0.100	0.844	0.712	0.832	0.745	1.185	1.117
1	Left	3	0.061	0.092	0.790	0.736	0.805	0.734	1.074	1.097
1	Left	Mean	0.076	0.096	0.828	0.731	0.809	0.741	1.133	1.091
2	Right	1	0.093	0.107	0.922	0.881	0.783	0.773	1.047	1.013
2	Right	2	0.096	0.089	0.823	0.767	0.788	0.772	1.073	1.021
2	Right	3	0.116	0.106	0.823	0.762	0.802	0.791	1.080	1.014
2	Right	Mean	0.102	0.101	0.856	0.803	0.791	0.779	1.066	1.016
2	Left	1	0.090	0.090	0.831	0.786	0.831	0.786	1.057	1.057
2	Left	2	0.089	0.089	0.808	0.789	0.808	0.789	1.024	1.024
2	Left	3	0.086	0.086	0.802	0.774	0.802	0.774	1.036	1.036
2	Left	Mean	0.088	0.088	0.814	0.783	0.814	0.783	1.039	1.039
4	Right	1	0.102	0.114	0.800	0.753	0.839	0.795	1.062	1.055
4	Right	2	0.100	0.131	0.854	0.822	0.776	0.772	1.039	1.005
4	Right	3	0.103	0.113	0.808	0.787	0.760	0.746	1.027	1.019
4	Right	Mean	0.102	0.119	0.821	0.787	0.792	0.771	1.042	1.027
4	Left	1	0.098	0.089	0.861	0.855	0.781	0.774	1.007	1.009

4	Left	2	0.105	0.097	0.846	0.822	0.867	0.824	1.029	1.053
4	Left	3	0.093	0.095	0.793	0.764	0.860	0.807	1.038	1.066
4	Left	Mean	0.099	0.094	0.833	0.814	0.836	0.802	1.024	1.043
5	Right	1	0.122	0.136	0.848	0.786	0.815	0.781	1.079	1.044
5	Right	2	0.109	0.150	0.866	0.717	0.860	0.808	1.208	1.064
5	Right	3	0.100	0.114	0.827	0.731	0.822	0.802	1.131	1.025
5	Right	Mean	0.110	0.133	0.847	0.745	0.832	0.797	1.137	1.044
5	Left	1	0.092	0.091	0.836	0.785	0.794	0.778	1.065	1.021
5	Left	2	0.090	0.110	0.791	0.776	0.762	0.757	1.019	1.007
5	Left	3	0.089	0.116	0.791	0.782	0.811	0.807	1.012	1.005
5	Left	Mean	0.090	0.106	0.806	0.781	0.789	0.781	1.032	1.011
6	Right	1	0.068	0.100	0.817	0.805	0.799	0.755	1.015	1.058
6	Right	2	0.099	0.116	0.804	0.742	0.811	0.781	1.084	1.038
6	Right	3	0.105	0.114	0.876	0.783	0.814	0.782	1.119	1.041
6	Right	Mean	0.091	0.110	0.832	0.777	0.808	0.773	1.072	1.046
6	Left	1	0.084	0.109	0.799	0.768	0.822	0.782	1.040	1.051
6	Left	2	0.083	0.107	0.807	0.789	0.818	0.742	1.023	1.102
6	Left	3	0.102	0.119	0.825	0.804	0.781	0.772	1.026	1.011
6	Left	Mean	0.090	0.112	0.810	0.787	0.807	0.765	1.030	1.054
7	Right	1	0.103	0.114	0.857	0.780	0.841	0.835	1.099	1.007
7	Right	2	0.082	0.115	0.824	0.805	0.864	0.825	1.024	1.047
7	Right	3	0.109	0.141	0.815	0.799	0.821	0.793	1.020	1.035
7	Right	Mean	0.098	0.123	0.832	0.795	0.842	0.818	1.047	1.030
7	Left	1	0.110	0.135	0.916	0.795	0.850	0.833	1.152	1.020
7	Left	2	0.118	0.155	0.935	0.886	0.895	0.851	1.055	1.052
7	Left	3	0.112	0.150	0.875	0.845	0.902	0.826	1.036	1.092
7	Left	Mean	0.113	0.147	0.909	0.842	0.882	0.837	1.079	1.055
8	Right	1	0.076	0.125	0.844	0.727	0.912	0.891	1.161	1.024
8	Right	2	0.088	0.098	0.810	0.757	0.787	0.786	1.070	1.001
8	Right	3	0.105	0.130	0.785	0.782	0.817	0.850	1.004	0.961
8	Right	Mean	0.090	0.118	0.813	0.755	0.839	0.842	1.076	0.996
8	Left	1	0.110	0.126	0.836	0.804	0.847	0.815	1.040	1.039
8	Left	2	0.123	0.116	0.813	0.806	0.848	0.840	1.009	1.010

8	Left	3	0.119	0.115	0.777	0.761	0.831	0.795	1.021	1.045
8	Left	Mean	0.117	0.119	0.809	0.790	0.842	0.817	1.023	1.031
9	Right	1	0.114	0.106	0.842	0.830	0.782	0.769	1.014	1.017
9	Right	2	0.114	0.133	0.815	0.803	0.856	0.795	1.015	1.077
9	Right	3	0.124	0.119	0.843	0.825	0.841	0.805	1.022	1.045
9	Right	Mean	0.117	0.119	0.833	0.819	0.826	0.790	1.017	1.046
9	Left	1	0.106	0.148	0.860	0.810	0.801	0.799	1.062	1.002
9	Left	2	0.094	0.126	0.804	0.728	0.854	0.848	1.104	1.007
9	Left	3	0.119	0.135	0.874	0.745	0.825	0.791	1.173	1.043
9	Left	Mean	0.106	0.136	0.846	0.761	0.827	0.813	1.112	1.017
10	Right	1	0.117	0.131	0.769	0.692	0.787	0.717	1.111	1.098
10	Right	2	0.129	0.119	0.790	0.734	0.740	0.722	1.076	1.025
10	Right	3	0.125	0.132	0.783	0.724	0.784	0.772	1.081	1.016
10	Right	Mean	0.124	0.127	0.781	0.717	0.770	0.737	1.089	1.045
10	Left	1	0.064	0.107	0.747	0.733	0.826	0.793	1.019	1.042
10	Left	2	0.091	0.110	0.772	0.749	0.798	0.752	1.031	1.061
10	Left	3	0.111	0.128	0.783	0.756	0.776	0.742	1.036	1.046
10	Left	Mean	0.089	0.115	0.767	0.746	0.800	0.762	1.029	1.049
11	Right	1	0.086	0.102	0.888	0.849	0.848	0.844	1.046	1.005
11	Right	2	0.096	0.117	0.886	0.855	0.908	0.862	1.036	1.053
11	Right	3	0.112	0.123	0.890	0.847	0.861	0.826	1.051	1.042
11	Right	Mean	0.098	0.114	0.888	0.850	0.872	0.844	1.044	1.034
11	Left	1	0.121	0.103	0.883	0.800	0.885	0.803	1.104	1.102
11	Left	2	0.103	0.147	0.880	0.851	0.863	0.841	1.034	1.026
11	Left	3	0.111	0.126	0.866	0.837	0.898	0.870	1.035	1.032
11	Left	Mean	0.112	0.125	0.876	0.829	0.882	0.838	1.057	1.053
12	Right	1	0.107	0.116	0.878	0.825	0.824	0.796	1.064	1.035
12	Right	2	0.119	0.114	0.866	0.795	0.795	0.793	1.089	1.003
12	Right	3	0.099	0.117	0.868	0.862	0.809	0.790	1.007	1.024
12	Right	Mean	0.108	0.116	0.871	0.827	0.809	0.793	1.052	1.021
12	Left	1	0.087	0.096	0.871	0.849	0.809	0.774	1.026	1.045
12	Left	2	0.092	0.110	0.833	0.760	0.777	0.761	1.096	1.021
12	Left	3	0.078	0.107	0.813	0.792	0.833	0.753	1.027	1.106

12	Left	Mean	0.086	0.104	0.839	0.800	0.806	0.763	1.048	1.057
13	Right	1	0.122	0.122	0.985	0.949	0.822	0.795	1.038	1.034
13	Right	2	0.086	0.122	0.893	0.835	0.823	0.820	1.070	1.003
13	Right	3	0.088	0.111	0.959	0.902	0.854	0.788	1.063	1.084
13	Right	Mean	0.099	0.118	0.946	0.895	0.833	0.801	1.056	1.040
13	Left	1	0.092	0.117	0.905	0.929	0.835	0.826	0.974	1.011
13	Left	2	0.085	0.093	0.841	0.754	0.920	0.901	1.115	1.021
13	Left	3	0.080	0.122	0.859	0.840	0.917	0.887	1.023	1.034
13	Left	Mean	0.086	0.111	0.868	0.841	0.891	0.871	1.033	1.022
15	Right	1	0.116	0.114	0.821	0.790	0.812	0.790	1.039	1.028
15	Right	2	0.119	0.124	0.865	0.863	0.816	0.792	1.002	1.030
15	Right	3	0.109	0.113	0.795	0.767	0.797	0.736	1.037	1.083
15	Right	Mean	0.115	0.117	0.827	0.807	0.808	0.773	1.025	1.046
15	Left	1	0.115	0.103	0.777	0.754	0.766	0.723	1.031	1.059
15	Left	2	0.089	0.111	0.824	0.751	0.785	0.760	1.097	1.033
15	Left	3	0.097	0.099	0.864	0.716	0.694	0.658	1.207	1.055
15	Left	Mean	0.100	0.104	0.822	0.740	0.748	0.714	1.110	1.049
16	Right	1	0.089	0.133	0.847	0.768	0.885	0.878	1.103	1.008
16	Right	2	0.096	0.118	0.841	0.815	0.842	0.787	1.032	1.070
16	Right	3	0.118	0.116	0.859	0.782	0.822	0.808	1.098	1.017
16	Right	Mean	0.101	0.122	0.849	0.788	0.850	0.824	1.077	1.031
16	Left	1	0.079	0.139	0.816	0.787	0.822	0.805	1.037	1.021
16	Left	2	0.102	0.121	0.823	0.810	0.840	0.791	1.016	1.062
16	Left	3	0.084	0.133	0.836	0.798	0.830	0.793	1.048	1.047
16	Left	Mean	0.088	0.131	0.825	0.798	0.831	0.796	1.033	1.043
17	Right	1	0.103	0.123	0.801	0.769	0.744	0.727	1.042	1.023
17	Right	2	0.105	0.120	0.793	0.766	0.772	0.706	1.035	1.093
17	Right	3	0.097	0.115	0.854	0.730	0.764	0.732	1.170	1.044
17	Right	Mean	0.102	0.119	0.816	0.755	0.760	0.722	1.081	1.053
17	Left	1	0.114	0.120	0.783	0.737	0.764	0.750	1.062	1.019
17	Left	2	0.088	0.124	0.756	0.702	0.774	0.735	1.077	1.053
17	Left	3	0.102	0.114	0.799	0.720	0.783	0.752	1.110	1.041
17	Left	Mean	0.101	0.119	0.779	0.720	0.774	0.746	1.083	1.038

18	Right	1	0.093	0.110	0.819	0.809	0.808	0.804	1.012	1.005
18	Right	2	0.099	0.097	0.834	0.823	0.798	0.778	1.013	1.026
18	Right	3	0.103	0.113	0.820	0.793	0.889	0.842	1.034	1.056
18	Right	Mean	0.098	0.107	0.824	0.808	0.832	0.808	1.020	1.029
18	Left	1	0.096	0.109	0.919	0.874	0.856	0.839	1.051	1.020
18	Left	2	0.091	0.112	0.928	0.866	0.879	0.850	1.072	1.034
18	Left	3	0.107	0.097	0.926	0.796	0.957	0.877	1.163	1.091
18	Left	Mean	0.098	0.106	0.924	0.845	0.897	0.855	1.093	1.049
19	Right	1	0.122	0.123	0.842	0.745	0.818	0.815	1.130	1.004
19	Right	2	0.103	0.134	0.910	0.767	0.797	0.781	1.186	1.020
19	Right	3	0.121	0.129	0.908	0.822	0.798	0.773	1.105	1.032
19	Right	Mean	0.115	0.129	0.887	0.778	0.804	0.790	1.140	1.019
19	Left	1	0.108	0.139	0.872	0.792	0.793	0.825	1.101	0.961
19	Left	2	0.108	0.133	0.834	0.791	0.841	0.778	1.054	1.081
19	Left	3	0.128	0.125	0.812	0.731	0.792	0.789	1.111	1.004
19	Left	Mean	0.115	0.132	0.839	0.771	0.809	0.797	1.088	1.014
20	Right	1	0.079	0.109	0.835	0.829	0.861	0.848	1.007	1.015
20	Right	2	0.082	0.112	0.874	0.849	0.849	0.795	1.029	1.068
20	Right	3	0.079	0.110	0.871	0.867	0.841	0.791	1.005	1.063
20	Right	Mean	0.080	0.110	0.860	0.848	0.850	0.811	1.014	1.048
20	Left	1	0.121	0.111	0.848	0.810	0.845	0.830	1.047	1.018
20	Left	2	0.137	0.123	0.844	0.792	0.900	0.778	1.066	1.157
20	Left	3	0.112	0.118	0.856	0.852	0.866	0.755	1.005	1.147
20	Left	Mean	0.123	0.117	0.849	0.818	0.870	0.788	1.038	1.105
21	Right	1	0.089	0.121	0.905	0.832	0.885	0.829	1.088	1.068
21	Right	2	0.094	0.095	0.911	0.824	0.885	0.825	1.106	1.073
21	Right	3	0.102	0.099	0.918	0.862	0.827	0.804	1.065	1.029
21	Right	Mean	0.095	0.105	0.911	0.839	0.866	0.819	1.086	1.057
21	Left	1	0.095	0.114	0.879	0.820	0.872	0.840	1.072	1.038
21	Left	2	0.082	0.116	0.864	0.830	0.862	0.836	1.041	1.031
21	Left	3	0.091	0.129	0.860	0.859	0.868	0.828	1.001	1.048
21	Left	Mean	0.089	0.120	0.868	0.836	0.867	0.835	1.037	1.039
22	Right	1	0.100	0.121	0.858	0.764	0.832	0.792	1.123	1.051

22	Right	2	0.102	0.101	0.813	0.734	0.813	0.749	1.108	1.085
22	Right	3	0.069	0.105	0.835	0.812	0.776	0.772	1.028	1.005
22	Right	Mean	0.090	0.109	0.835	0.770	0.807	0.771	1.085	1.047
22	Left	1	0.079	0.094	0.805	0.781	0.823	0.787	1.031	1.046
22	Left	2	0.073	0.086	0.773	0.742	0.820	0.791	1.042	1.037
22	Left	3	0.080	0.105	0.778	0.717	0.784	0.781	1.085	1.004
22	Left	Mean	0.077	0.095	0.785	0.747	0.809	0.786	1.052	1.029
23	Right	1	0.098	0.118	0.852	0.783	0.847	0.794	1.088	1.067
23	Right	2	0.105	0.091	0.855	0.787	0.786	0.752	1.086	1.045
23	Right	3	0.084	0.116	0.847	0.821	0.831	0.757	1.032	1.098
23	Right	Mean	0.096	0.108	0.851	0.797	0.821	0.768	1.068	1.070
23	Left	1	0.095	0.110	0.868	0.804	0.733	0.730	1.080	1.004
23	Left	2	0.106	0.114	0.878	0.762	0.813	0.787	1.152	1.033
23	Left	3	0.091	0.126	0.727	0.710	0.880	0.825	1.024	1.067
23	Left	Mean	0.097	0.117	0.824	0.759	0.809	0.781	1.087	1.036

Appendix 6: Owner Survey

Pre- and Post-Chiropractic Treatment Form

Owner Name: _____________________
Horse Name: _____________________

Please fill out the following prior to initial chiropractic treatment.

Use and Performance history:

____
____
____
____
____

Current Medications:

____
____
____
____

Problem history:

____
____
____
____

Please complete the following short form daily starting from the day of initial treatment until the recheck by writing the number you feel to be the most appropriate in each category. Please only use a scale of 1 through 10. Consider a score of one (1) to be the worst and a score of ten (10) to be the best.

Day	1	2	3	4	5	6	7
Attitude							
Appetite							
Soreness							
Swelling							
Willingness to perform under saddle							
Willingness to perform on the ground							

Appendix 7: Owner Survey Data

Owners were surveyed regarding their horses' attitude, appetite, soreness, swelling, performance under saddle and performance on the ground. Owners were told to rank their horses on a scale of one to ten, with ten being the best and zero being the worst.

Horse	Day	Attitude	Appetite	Soreness	Swelling	Performance under saddle	Performance on the ground
1	1	5	10	5	10	5	5
1	2	4	10	4	10	4	5
1	3	5	10	5	10	5	5
1	4	4	10	6	10	5	5
1	5	4	10	5	10	N/A	5
1	6	5	10	5	10	5	5
1	7	5	10	5	10	6	5
2	1	8	10	7	10	7	8
2	2	8	10	7	10	8	8
2	3	9	10	8	10	7	8
2	4	8	10	7	10	6	8
2	5	9	10	7	10	N/A	8
2	6	8	10	8	10	7	8
2	7	8	10	7	10	7	8
3	1	10	10	10	10	10	10
3	2	10	10	10	10	10	10
3	3	10	10	10	10	10	10
3	4	10	10	10	10	10	10
3	5	8	10	10	10	10	10
3	6	7	10	10	10	N/A	N/A
3	7	7	10	3	10	N/A	N/A
4	1	10	10	N/A	N/A	N/A	10
4	2	10	10	N/A	N/A	N/A	10
4	3	10	10	N/A	N/A	N/A	10
4	4	10	10	N/A	N/A	N/A	10

4	5	10	10	N/A	N/A	N/A	10
4	6	10	10	N/A	N/A	N/A	10
4	7	10	10	N/A	N/A	N/A	10
5	1	10	10	8	10	10	10
5	2	10	10	8	10	10	10
5	3	10	10	10	10	10	10
5	4	10	10	10	10	10	10
5	5	10	10	10	10	10	10
5	6	10	10	10	10	10	10
5	7	10	10	10	10	10	10
6	1	5	10	5	10	5	5
6	2	5	10	5	10	5	5
6	3	5	10	5	10	5	5
6	4	5	10	5	10	5	5
6	5	5	10	5	10	5	5
6	6	5	10	5	10	5	5
6	7	5	10	5	10	5	5
7	1	4	7	3	10	1	10
7	2	3	7	3	10	1	10
7	3	5	8	3	10	1	10
7	4	4	8	2	10	2	10
7	5	3	7	3	10	2	10
7	6	3	8	2	10	3	10
7	7	3	8	3	10	2	10
8	1	5	10	3	10	3	9
8	2	5	10	4	10	4	9
8	3	5	10	3	10	3	9
8	4	5	10	3	10	3	8
8	5	5	10	4	10	4	9
8	6	5	10	3	10	3	9
8	7	5	10	3	10	3	9
9	1	7	10	6	10	7	9
9	2	10	10	8	10	8	10

9	3	10	10	9	10	9	10
9	4	10	10	10	10	10	10
9	5	10	10	10	10	10	10
9	6	10	10	10	10	10	10
9	7	10	10	10	10	10	10
10	1	10	10	10	10	10	10
10	2	10	10	10	10	10	10
10	3	10	10	10	10	10	10
10	4	10	10	10	10	10	10
10	5	10	10	10	10	10	10
10	6	10	10	10	10	10	10
10	7	10	10	10	10	10	10
11	1	3	9	2	10	4	4
11	2	5	9	2	10	4	4
11	3	6	9	5	10	7	7
11	4	8	9	8	10	8	7
11	5	8	9	8	10	8	7
11	6	8	9	8	10	8	7
11	7	8	9	8	10	8	7
12	1	9	5	3	10	N/A	N/A
12	2	9	5	5	10	N/A	7
12	3	8	5	5	10	N/A	7
12	4	7	5	6	10	N/A	7
12	5	7	5	7	10	N/A	6
12	6	6	5	7	10	N/A	6
12	7	6	5	7	10	N/A	6
13	1	5	10	5	10	4	8
13	2	5	10	5	10	5	8
13	3	5	10	4	10	5	9
13	4	5	10	5	10	4	8
13	5	5	10	5	10	5	8
13	6	5	10	4	10	4	9
13	7	5	10	5	10	5	8

14	1	4	10	6	10	4	10
14	2	4	10	7	10	4	10
14	3	3	10	6	10	5	10
14	4	4	10	6	10	4	10
14	5	4	10	7	10	4	10
14	6	3	10	6	10	5	10
14	7	4	10	7	10	4	10
15	1	9	10	9	10	9	9
15	2	9	10	9	10	9	9
15	3	9	9	9	10	9	9
15	4	9	9	9	10	9	9
15	5	9	9	9	10	9	9
15	6	9	9	9	10	9	9
15	7	9	9	9	10	9	9
16	1	10	7	10	10	N/A	N/A
16	2	10	8	10	10	10	N/A
16	3	10	9	10	10	10	10
16	4	10	9	10	10	10	N/A
16	5	10	9	10	10	10	N/A
16	6	10	7	10	10	N/A	N/A
16	7	10	8	10	10	10	N/A
17	1	10	10	10	10	10	10
17	2	4	10	10	10	4	10
17	3	10	10	10	10	10	10
17	4	10	10	10	10	10	10
17	5	10	10	10	10	10	10
17	6	10	10	10	10	10	10
17	7	10	10	10	10	10	10
18	1	9	10	10	10	9	10
18	2	10	10	10	10	10	10
18	3	10	10	10	10	10	10
18	4	10	10	10	10	8	10
18	5	10	10	10	10	10	10

18	6	9	10	10	10	10	10
18	7	10	10	10	10	10	10
19	1	8	10	8	8	8	7
19	2	8	10	8	8	9	7
19	3	8	10	8	8	8	9
19	4	8	10	8	8	8	8
19	5	9	10	8	8	9	8
19	6	8	10	8	8	9	8
19	7	8	10	8	8	8	8
20	1	5	5	5	5	5	5
20	2	5	5	5	5	5	5
20	3	5	5	5	5	5	5
20	4	5	5	5	5	5	5
20	5	5	5	5	5	5	5
20	6	5	5	5	5	5	5
20	7	5	5	5	5	5	5
21	1	7	10	6	0	5	8
21	2	9	10	8	0	8	9
21	3	8	10	8	0	8	10
21	4	8	10	8	0	7	10
21	5	9	10	N/A	0	N/A	N/A
21	6	N/A	N/A	N/A	N/A	N/A	N/A
21	7	N/A	N/A	N/A	N/A	N/A	N/A
22	1	N/A	N/A	N/A	N/A	N/A	N/A
22	2	N/A	N/A	N/A	N/A	N/A	N/A
22	3	N/A	N/A	N/A	N/A	N/A	N/A
22	4	N/A	N/A	N/A	N/A	N/A	N/A
22	5	N/A	N/A	N/A	N/A	N/A	N/A
22	6	N/A	N/A	N/A	N/A	N/A	N/A
22	7	N/A	N/A	N/A	N/A	N/A	N/A
23	1	8	9	7	10	8	9
23	2	8	9	7	10	8	9
23	3	9	9	8	10	9	9

23	4	10	9	10	10	9	10
23	5	9	9	10	10	9	10
23	6	10	9	10	9	9	10
23	7	10	9	10	10	9	10
24	1	6	10	5	10	6	8
24	2	N/A	10	N/A	N/A	N/A	N/A
24	3	7	10	5	10	6	8
24	4	6	10	5	10	5	7
24	5	6	10	5	10	3	7
24	6	7	10	5	10	4	7
24	7	N/A	N/A	N/A	N/A	N/A	N/A