Subjective and objective gait analysis describing the effects of diagnostic analgesia in naturally occurring equine lameness

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Dedication

To my parents, Jeff and Kay, for their ever-present encouragement and support

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ABSTRACT

INTRODUCTION: Lameness in horses is a clinical sign of musculoskeletal pain. Use of objective gait analysis could aid in the evaluation of lameness and monitoring the response to diagnostic analgesia in addition the traditional equine subjective clinical lameness exam.

OBJECTIVE: The objective of this study was to describe the effects of diagnostic analgesia on the kinematic and kinetic variables in cases of naturally-occurring lameness and to describe the compensatory changes in the other limbs in response to diagnostic analgesia in the primary lame limb.

METHODS: Eight horses from the teaching herd at the University of Minnesota were evaluated for lameness. Objective gait analysis was performed at the time of subjective exam. Kinematic evaluation was performed using a body mounted inertial sensor system (BMISS) at the trot and 2D sagittal plane extension of the fetlock at the walk. Kinetic evaluation was performed using an in-ground force plate at the walk and trot. Diagnostic analgesia with a local anesthetic was performed based on subjective evaluation. Subjective evaluation was repeated to determine if diagnostic analgesia improved lameness. Objective analysis was repeated after diagnostic analgesia and analyzed retrospectively after completion of the exam and diagnostic imaging. Diagnostic imaging of the identified region was performed after diagnostic analgesia was deemed successful for localizing the source of pain.

RESULTS: All eight horses were found to have musculoskeletal pain. Diagnostic analgesia was performed in the forelimbs in four horses and in the hindlimbs of four horses. Two horses had lameness that was localized to feet of the forelimbs. One horse had lameness localized to a single forelimb fetlock and one horse had lameness localized to a single carpus. Three horses had lameness localized to the distal tarsal joints bilaterally and one horse had lameness localized to the medial femorotibial joints bilaterally. BMISS data showed alterations in head and pelvis asymmetry in response to diagnostic analgesia. Head asymmetry was decreased in the single forelimb lameness cases after diagnostic analgesia and head asymmetry switched between forelimbs after diagnostic analgesia of the lame limb in cases of bilateral forelimb lameness. Changes in asymmetry of the pelvis were variable in cases where hindlimb diagnostic analgesia was performed. There were increases in peak vertical force and vertical impulse at the trot in the lame limb in response to diagnostic analgesia. There was increase an in vertical impulse at the walk in the forelimb in response to diagnostic analgesia. There was an alteration in the distribution of force between the heel and midstance phases of the stride at the walk-in response to diagnostic analgesia in the hindlimb.

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CHAPTER 1

1.1 Introduction

Lameness in horses is a clinical sign of musculoskeletal pain. It is the alteration of the gait as an adaptation to decrease the load on a limb or limbs in response to a structural or functional disorder in the locomotor system (Baxter 2020). Injury to joints are a major cause of lameness and impact performance (Goodrich 2006). It is estimated that 60% of lameness is attributable to osteoarthritis (McIlwraith 2012). There is a significant economic impact of lameness in the equine industry starting with the cost of diagnosis and treatment. There is an estimated yearly cost of $3,000 for maintenance of a horse with osteoarthritis including lameness evaluations by a veterinarian, intra-articular, intravenous or intramuscular treatments and oral nutraceuticals (Oke 2010).

In addition, lameness is a significant factor in the number of days lost in training and competition for horses. This contributes to further financial losses in earnings lost in missed competitive events. In the 2015 USDA APHIS NAHMS Equine Survey, 67.1% of equine operations had at least 1 lame horse in the 12 months preceding and 38.7% of operations had at least 1 lame horse on the day of questionnaire. Only 46.8% of the lame horses had fully recovered within the year and 15% of horses got worse or showed no improvement. Twelve percent of horses improved, but then lameness recurred (USDA 2017). This highlights how lameness can negatively impact the equine industry demonstrating the importance of a timely and accurate diagnosis. Lameness can be difficult to diagnose, especially when it is subtle (van Weeren 2013; Baxter 2020). This has led researchers and clinicians to investigate more reliable methods for identifying lameness. This thesis will apply objective gait analyses to naturally-occurring lameness to detail the effect of diagnostic analgesia on the lameness to determine if, and where, objective analyses might benefit the clinical exam to achieve an accurate diagnosis.

1.2 Subjective lameness evaluation

A subjective lameness exam has been used traditionally as the method of lameness identification in horses (Baxter 2020; Keegan 2020a). In this type of exam, the horse is subjectively evaluated by the veterinarian while it undergoes a series of locomotive tasks to gather information about the lameness (van Weeren 2013; Clayton 2013; Baxter 2020). A passive palpation of the horse's musculoskeletal structures is first performed to identify asymmetries or pain; then, the horse proceeds to the active examination, which includes observation of the horse walking and trotting in hand on a straight line, followed by circles. At the walk, the clinician may evaluate the horse walking away from them, walking towards them and from the side. Parameters that may be evaluated are hoof flight arc, fetlock extension, the cranial phase of the stride, cadence and hoof ground contact during the stance phase (Baxter 2020). Even though asymmetry of fetlock extension can used as an indication of lameness at a walk, asymmetric fetlock hyperextension may be caused by unbalanced dorsal hoof angles of contralateral hooves, such as an under-run heel on one foot and a club-foot on the other (Weishaupt 2004). At the trot, the clinician evaluates the horse trotting away from them and then trotting towards them. Asymmetrical movements can be most consistently observed in the sacrum and tuber coxae in a hindlimb lameness and in the vertical displacement of the head in a forelimb lameness (Weishaupt 2008). To assess hindlimb lameness at the trot, the clinician observes the asymmetry of the vertical and rotational displacement of the tuber coxae where the side with a greater drop or greater overall excursion is considered to be the lame limb (Weishaupt 2008). To assess forelimb lameness at the trot, the head is raised when the lame limb is in the stance phase and the head is then lowered when the sound limb is in the stance phase. This decreases the weight on the lame leg by offsetting the weight of the head and neck on to the sound limb (Weishaupt 2008). The veterinarian can also watch the horse in circles to gather more information about the asymmetry. This can aid in the identification of bilateral lameness as the limb on the inside of the circle has a greater amount of weight placed on it, which can exacerbate lameness. Finally, the veterinarian performs flexion tests to elicit pain in related regions in an attempt to narrow the region of focus for the source of pain (Baxter 2020). Subjective lameness is numerically graded such that the higher the number on the scale, the greater the severity of lameness present for either multiple aspects of the exam or the complete exam (Keegan 2020a). There are two different scales depending upon where a clinician is trained (USA or Europe). In the United States, the American Association of Equine Practitioners (AAEP) scale of 1 to 5 is used to define lameness (Swanson 1984). After the lame leg(s) have been identified, then the clinician can use perineural and/or intra-articular diagnostic analgesia to systematically desensitize regions of the limb to determine if the lameness improves. This is usually based on a percent improvement from the baseline lameness. Typically, a seventy-five to eighty percent improvement in the lameness is considered substantial improvement to discontinue blocking. This is because there may be some residual lameness as a result of soreness in musculature or habituation in pattern of movement as a result of lameness that cannot be overcome with diagnostic analgesia.

The main advantage of using the subjective lameness exam is that it requires no specialized equipment and can be readily performed in any location provided there is a flat area of ground for the horse to trot. However, it does require training and practice to develop skill in lameness diagnosis and evaluation, and as such is dependent on individual ability to observe and interpret the lameness because it is a subjective evaluation. Previous publications have investigated whether there is agreement between subjective evaluations by experienced clinicians (Donnell 2015; Keegan 2010). Based on the idea that for any given lameness evaluation there is a 50% chance of picking the correct lame leg, the agreement for all forelimb lameness was 22-26% above chance (72-76% agreement for the correct lame leg), and the agreement for all hindlimb lameness was 14-19% above chance (64-69% agreement between clinicians for the correct leg) (Keegan 2010). Agreement was higher for lameness grades above 1.5 out of 5 on the AAEP scale. (Keegan 2010). This study by Keegan, et al. highlighted important limitations of the subjective lameness exam demonstrating a large amount of disagreement between experienced clinicians, especially with hindlimb lameness. In addition, there was greater difficulty in diagnosing lameness when it was subtle, when multi-limb lameness was present, and when bilateral lameness was present. Multiple limb lameness is not uncommon in the horse, but it is challenging to distinguish primary lameness as opposed to compensatory lameness when using the subjective exam. A primary lameness is a gait adaptation that is the result of pain or mechanical dysfunction in that limb. A compensatory lameness is a gait adaptation that is secondary to pain in another limb but is not reflective of pain in that limb. For instance, there is evidence available that in cases of ipsilateral forelimb and hindlimb lameness, the hindlimb is most likely to be the primary source of lameness, whereas in a contralateral forelimb and hindlimb lameness, the forelimb is most likely to be the primary source of lameness (Weishaupt 2008). Because of these limitations of the subjective lameness exam, investigators in equine lameness have worked to determine if there were more objective ways to characterize lameness that could be more reliable and repeatable, especially with subtle and multi-limb lameness.

1.3 Objective lameness evaluation

Objective assessment of movement can be divided into two branches of quantification, kinematics and kinetics. Kinematic quantification is the measurement of position, velocity and acceleration of a point or segment in space (Winter 2009). Kinetics is the quantification of external and internal forces acting on a body (Winter 2009). Estimations of internal forces can be made through the use of inverse dynamics from the measurement of external forces, but these measurements involve invasive methods that are not as clinically practical or applicable in horses as they are in humans (Clayton 2013; Winter 2009). Objective measurements that are used in the horse are meant to provide higher spatial and temporal resolution of kinematic and kinetic parameters that could be clinically useful for lameness interpretation even if the clinician does not have significant experience with the technology.

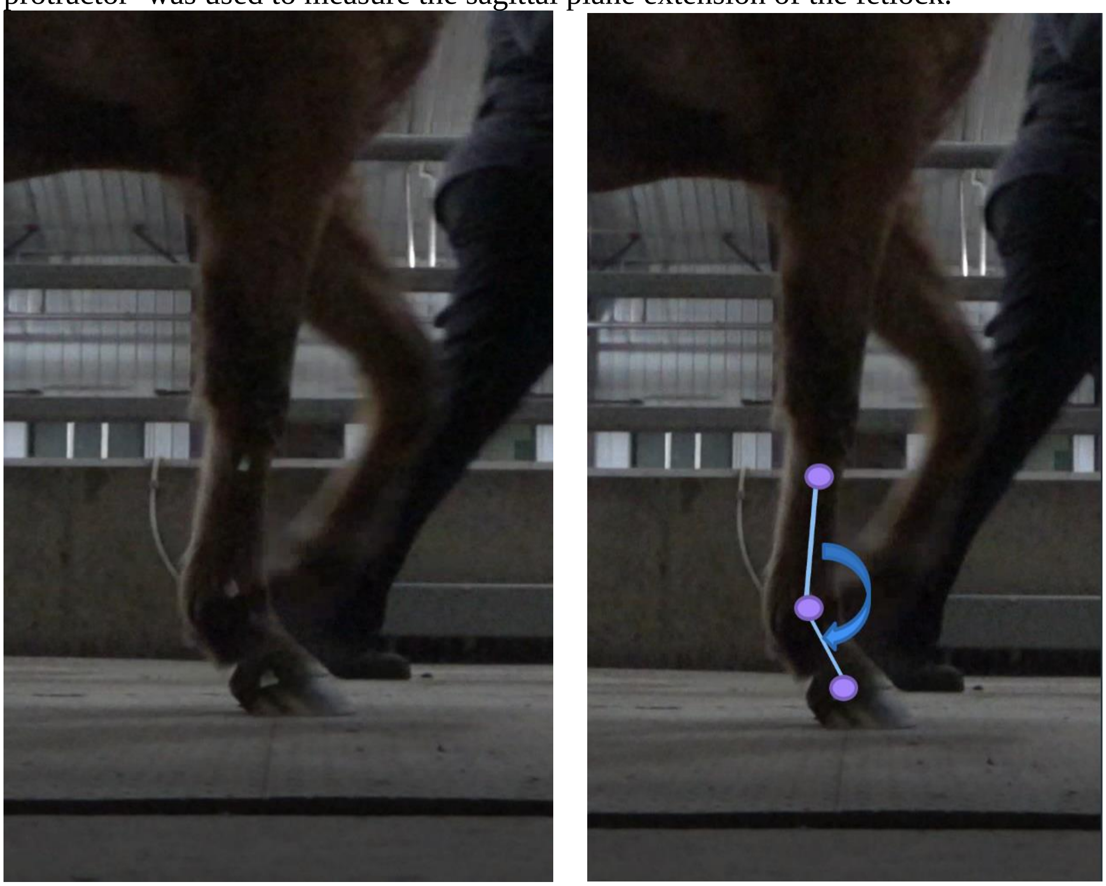
Subjective examination was compared to objective methods in an experimentally-induced lameness using the unilateral carpal osteochondral fragment in the middle carpal joint of 16 horses (Donnell 2015). They compared the outcomes for subjective lameness evaluations (blinded and unblinded), force platforms (kinetic measurements) and an inertial sensor system (kinematic measurements) that were all used to detect lameness at the trot at four time points. Their findings demonstrated that blinded subjective evaluation and inertial sensor systems had higher agreement (50%, mild positive correlation) than subjective evaluation and force plate exams (38%), with mild negative correlations between inertial sensor systems and force plate. However, this agreement was similar to agreement between clinicians. It should be noted that this does not mean the force plate exam was unable to determine lameness as they reported a 3.6% decrease in mean peak vertical force (PVF) at day 15 in the osteochondral fragment limb of all horses compared to baseline, indicating greater lameness due to less force being placed on the limb (Donnell 2015). To the authors' knowledge, this is the only equine study that has compared multiple objective measurement systems to each other in addition to subjective evaluation between clinicians. It demonstrates that in an injury model, all lameness measurement modalities can play a role depending on the type of injury being evaluated. This could be especially important in naturally-occurring osteoarthritis where there is a multitude of etiologies that could make one modality better than another for diagnosis of pathology in certain joints. Each objective measurement system used in the horse will be explained in further detail below.

1.3.1 Kinematic evaluation – 2- and 3-dimensional analysis

Optical kinematic evaluation can occur in either 2- or 3-dimensions (2-D and 3-D, respectively). The main difference between the systems is the number of cameras used to collect data; 2-D only needs one camera whereas 3-D usually requires a minimum of 4 cameras. Briefly, an optical motion camera(s) can be used to track the position of markers placed on a subject (Figure 1.3.1.1) while they perform a task over time in a defined space (Winter 2009). The most accurate calculations come from 3-D analyses where a space is defined during calibration prior to data collection (Winter 2009, Clayton 2013) For example, a wand with retroreflective markers placed in known distances can be used for calibration to allow each camera to calculate the marker position and orientation in space. This establishes an absolute reference of origin and orientation that then allows for reconstruction of 3-D positions of captured motion of the markers from at least two cameras at all time. Ideally, the subject must be outfitted with retroreflective markers where each landmark requires 3 non-collinear markers to define coordinate system, position and orientation (Winter 2009), or else accuracy will be lost. For these reasons, 3-D measurement systems are difficult to achieve in the equine clinical setting as it is necessary to have a large capture space that can be detected by multiple cameras in order for the movement of the horse to be captured. In addition, markers should be placed over bony landmarks to accurately identify limb segments that surround a joint, which has been shown to be difficult in to achieve in the upper limb of a horse due to skin displacement (Van Weeren 1990).

Depending on the joint and activity of interest, a simplified system using a single camera system can be used to calculate 2-D kinematics. This has been used in equine gait analysis as many of the joints of interest have their greatest degree of motion in a single plane. This is true of the fetlock joint (Figure 1.3.1), whose greatest motion of interest for lameness determination is flexion and extension in the sagittal plane. Lameness, age, conformation, gait, capsulitis and osteoarthritis have all been noted to influence flexion and extension (Clayton 2007; Hodson 2001). For instance, in a model of sole pressure induced lameness, the maximal fetlock extension in the lame limb decreased by 3.3% and increased in the other limbs at the trot (Serra Bragança 2021). Combined, these studies demonstrate that 2-D analysis has the potential to identify the lame limb via a lack of fetlock extension compared to the other limbs. The potential advantages of using 2-D fetlock extension to visually identify the lame limb in a research study is that it is possible for a clinician to incorporate visual inspection of fetlock extension at a walk into their lameness evaluation without the requirement of specialized equipment. However, the disadvantage to using this method is that 3-D motion is not quantified, so there is a loss of information in the other planes of motion and a simplification of methods by using human performed semi-quantitative measurement over optical motion capture and computer tracking of markers (Clayton 2007). There is also the potential for the addition of parallax artifact when the fetlock is not in the center of the field of view (Winter 2009).

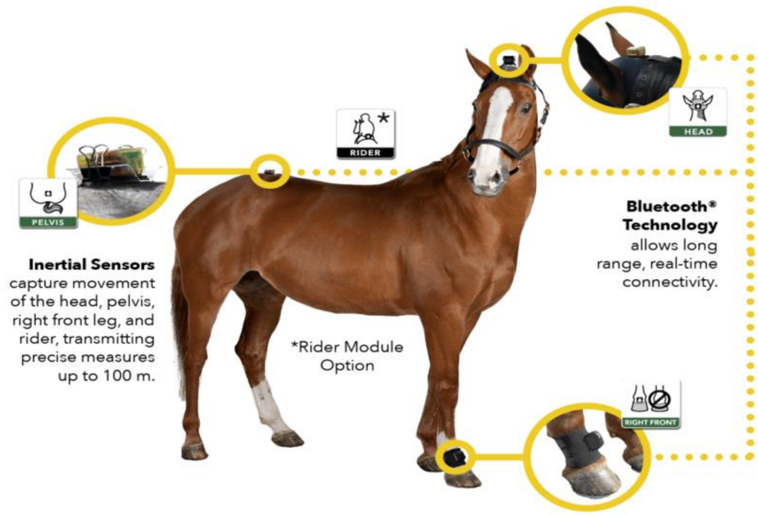
Figure 1.3.1.1: Image of the fetlock that was acquired from the study described in this thesis. The still frame was acquired from a video from a high-speed camera[a] at 120 frames per second. The frame was chosen at the midstance phase of the stride. This is when the full weight of the animal is placed on the limb and the contralateral limb is in mid-swing phase. The landmarks for skin marker placement were identified by palpation and marked using Aluspray[b]. Three markers were placed on the dorsopalmar midpoint medially and laterally of the proximal third metacarpal bone at the level of the head of the second metacarpal/tarsal and fourth metacarpal bone respectively, the dorsopalmar midpoint medially and laterally of the coronary band, and medial and lateral distal epicondyle of the third metacarpal or metatarsal bone. The image on the left shows the marker placement on the lateral aspect of the right forelimb for measurement of fetlock angle. The image on the right depicts the segments constructed for measurement and the angle of measurement for sagittal fetlock extension. The blue arrow indicates the angle of measurement. A screen protractor[c] was used to measure the sagittal plane extension of the fetlock.



1.3.2 Kinematic evaluation – body mounted inertial sensor system

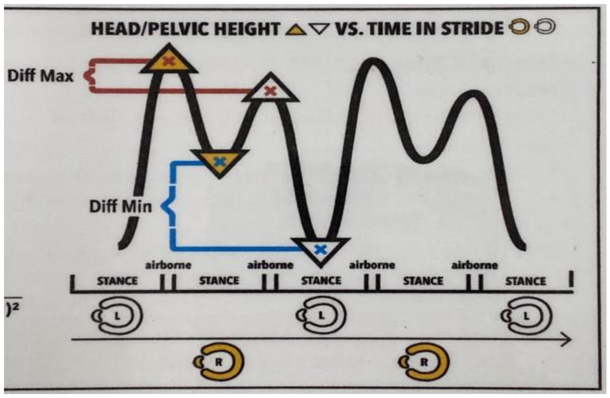
Body mounted inertial sensor system (BMISS) is a method of kinematic measurement that uses the combination of accelerometers, gyroscopes, and magnetometer to describe the movement pattern. These can be used to measure displacement, acceleration in two or three dimensions and momentum. A BMISS was initially developed for use in humans and uses inertial measurement units to quantify the position of different points on a body over time (Winter 2009). A BMISS has also been developed for the horse, called the Lameness Locator®[d] (Figures 1.3.2.1 and 1.3.2.2) (Keegan 2004; Keegan 2011; Keegan 2012; Keegan 2013; Bell 2016), which is commercially available and will be briefly described below. Three inertial measurement units are placed on the horse. This specific system uses accelerometers and gyroscopes to describe the movement of the head and pelvis of the horse. An accelerometer is placed on the poll in a helmet that attaches to the halter (Figure 1.3.2.1). This measures the vertical displacement of the head during the trot. Another accelerometer is placed on the highest point of the pelvis to measure vertical displacement of the pelvis (Figure 1.3.2.1). A uniaxial gyroscope is placed on the pastern of the right forelimb to serve as a stride marker and differentiate the position measurements during the left and right sides of the gait cycle at the trot only (Figure 1.3.2.1). A minimum collection of 25 strides is recommended for analysis per trial. The information is transmitted by wireless signal to a tablet device. This device provides an assessment with a trial aide to help with interpretation of findings that indicates severity of lameness and degree of evidence (Equinosis Lameness Locator® Manual 2019).

Figure 1.3.2.1: This figure shows the three inertial measurement units (IMU) and their placement on the horse. The helmet contains a pocket for an IMU that sits at the point of the poll. This measures the vertical acceleration and displacement of the head. An IMU is placed at the highest point of the pelvis to measure vertical acceleration and displacement of the pelvis. An IMU is placed on the pastern of the right forelimb that serves as a stride marker to distinguish data collected from the right and left side. The data is transmitted wirelessly to a tablet and the Equinosis software algorithm analyzes the data. This image is reproduced from the Lameness Locator® Manual.



Calculations for the Lameness Locator® are defined in the manual and is reproduced here (Figure 1.3.2.2) (Equinosis Lameness Locator ® Manual 2019). The minimum position of the head is measured for left and right sides when the respective forelimb is in the stance phase. The maximum vertical position of the head is measured for the left and right sides when the respective forelimb is in the swing phase. The "Diff min" is calculated by subtracting the minimum position of the head during the stance phase of the right forelimb from the minimum position of the head during the stance phase of the left forelimb. The "Diff max" of the head is calculated by subtracting the maximum position of the head during the swing phase of the right forelimb from the maximum position of the head during the swing phase of the left forelimb. Since the Diff max and Diff min are both vector quantities, they are considered together to determine the direction and magnitude of forelimb lameness. The Diff max is plotted on the x-axis and the Diff min is plotted on the y-axis, and the Pythagorean theorem is used to calculate the hypotenuse between these two vector quantities, called the vector sum. This gives the limb (right or left) and the timing of the lameness (impact, midstance or push off). The "Diff min" of the pelvis is calculated by subtracting the minimum position of the pelvis during the stance phase of the right hindlimb from the minimum position of the pelvis during the stance phase of the left hindlimb. This provides the impact lameness score. The “Diff max” of the pelvis is calculated by subtracting the maximum position of the pelvis during the swing phase of the right hindlimb from the maximum position of the pelvis during the swing phase of the left hindlimb. This provides a push off lameness score.

Figure 1.3.2.2: This figure illustrates the displacement of the head/pelvis during the stride cycle. Diff Max represents the difference between the maximum height of the head or the pelvis on the left and right sides during the swing phase of the stride. Diff min represents the difference between the minimum height of the head or the pelvis on the left and right sides during the stance phase of the stride. The stride marker on the right forelimb relays to the system to which side (left or right) the measurements correspond. This image is reproduced from the Lameness Locator® Manual.



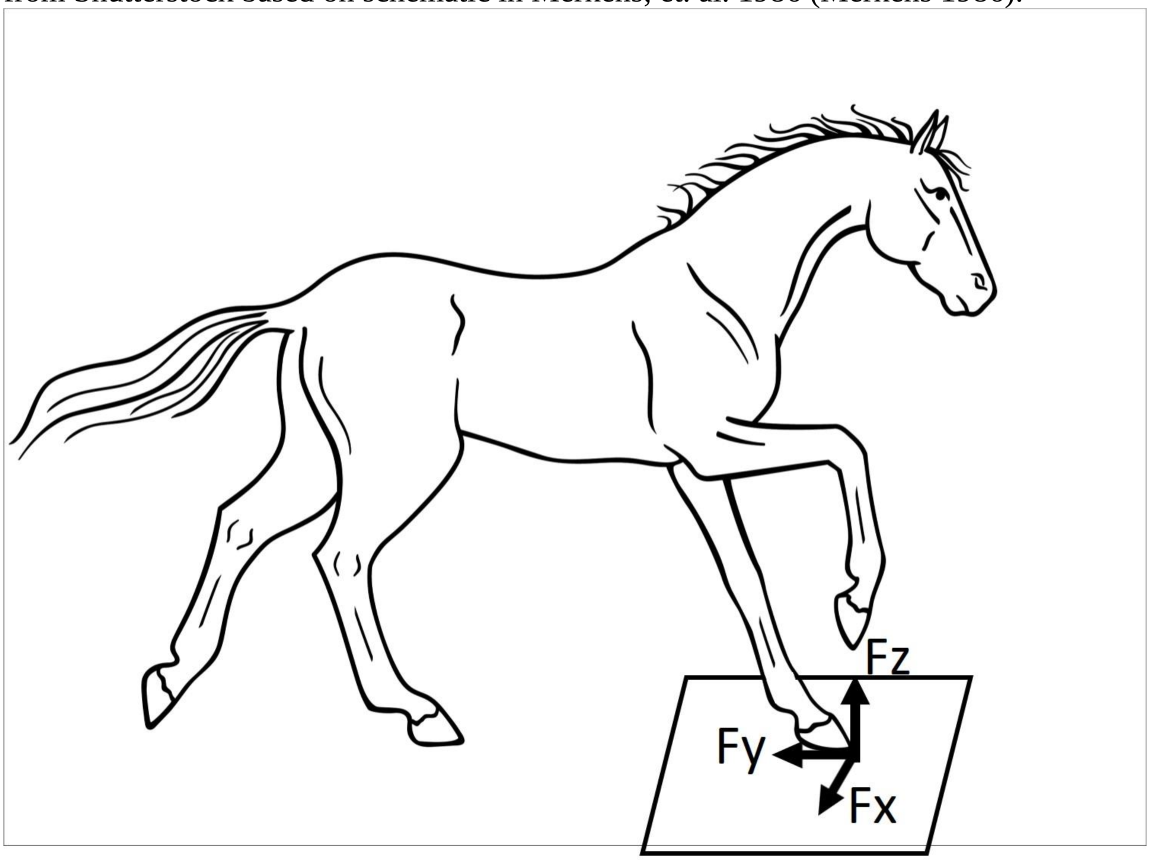
The Lameness Locator® has been compared previously to subjective evaluation (McCracken 2012; Keegan 2013). Keegan, et. al. (Keegan 2013) demonstrated a positive and significant correlation between lameness evaluation of horses with an inertial sensor system and subjective lameness examinations, but they did not show strong agreement (difference of minimum head height and subjective evaluation had an R^2 value of 0.511; subjective evaluation and difference of minimum pelvic height had an R^2 value of 0.1037; subjective evaluation and difference of maximum pelvic height had an R^2 value of 0.3179). Overall, studies have shown this tool to be valuable when used objectively to assess improvement with diagnostic analgesia (Egan 2019; Maliye 2013; Phutthachalee 2021; Reed 2020).

There are several limitations associated with this technology. A recent study defined a total of 8 different patterns of combined forelimb and hindlimb lameness and compared these to their definitive diagnostic findings (Reed 2020). This study found that although a combined forelimb and hindlimb lameness was the most common pattern observed, horses with this pattern were least likely to obtain a definitive diagnosis. In conclusion, it was noted that the initial sensor results often did not align with the definitive diagnosis in multiple limb lameness, but could be useful in planning the lameness exam (Reed 2020). This fits with other previous statements that the inertial sensor-based evaluation could aid in lameness evaluation of horses, but it is not sufficient to replace the subjective lameness examination by a veterinarian (Keegan 2013).

1.3.3 Kinetic evaluation – in ground force plate

Kinetics is the division of biomechanics that quantifies the forces acting on a subject (Winter 2009). The stationary force plate has been considered the gold standard of objective lameness quantification (Keegan 2020b), and in equine lameness, force plates have been used to measure the ground reaction forces (GRFs) acting on a limb(s) (Clayton 2005). The principle behind this device is that the applied force causes a given amount of strain within the transducer that then produces an electrical signal that is proportional to the applied force (Winter 2009). GRFs are quantified in three planes (Figure 1.3.3.1): vertical (Fz), horizontal (Fy), and transverse (Fx) (Merkens 1986). Horses traverse the force plate at the desired gait, and five trials are necessary for each limb to achieve statistical power due to the low variability between trials for a given horse at a particular gait at a consistent speed (Clayton 2005; Weishaupt 2010). The horse is led by a handler across a runway overlaying the force plate and the limbs must smoothly strike the plate near the center with no excess motion of the head or body.

Figure 1.3.3.1: Schematic of a horse striking the force plate with the left forelimb. Ground reaction forces in three axes are shown. Fz represents the vertical axis ground reaction force. Fy represents the horizontal axis ground reaction force (braking and propulsion). Fx represents the transverse axis ground reaction force (medial and lateral). Image modified from Shutterstock based on schematic in Merkens, et. al. 1986 (Merkens 1986).



In the assessment of equine lameness, kinetic gait analysis has primarily focused on the analysis of vertical (Fz) and horizontal braking and propulsion (Fy) ground reaction forces and their impulses (the distribution of force over time), as well as the duration of the stance phase (Clayton 2004; Clayton 2013; Keegan 2020b). Force plate measurements have been described in sound Warmblood horses at the walk (Merkens 1986) and trot (Merkens 1993). In addition, numerous studies have been performed using the force plate to evaluate equine gait at the trot in sound and induced lameness (Merkens 1986; Merkens 1988; Merkens 1993; Weishaupt 2006; Back 2007; Keegan 2012; Donnell 2015; Serra Bragança 2021). It has been shown that at a trot peak vertical force (PVF) and vertical impulse (VI) decrease with increasing severity of lameness, indicating less direct force of a lame limb and a shorter amount of time that the limb is loaded in the stance phase (Clayton 2004).

Horizontal forces and impulses have also been quantified but are not as reliable as vertical forces and impulses as indicators of lameness (Clayton 2004; Clayton 2013).

Examples of the vertical force output at the walk and trot are demonstrated in Figures 1.3.3.2 and 1.3.3.3, respectively. At the walk, there are three discrete force values of the stance phase that are used in the analysis. The first is the peak reached when the weight is primarily loaded on the heel region. Then there is a decrease in force as it moves toward the midstance phase, followed by a second peak when the weight is primarily loaded in the toe region. The peak vertical forces are greater in the forelimbs compared to the hindlimbs. In the forelimbs, the heel PVF is less than the toe PVF. Symmetry between the discrete values for forelimbs or between hindlimbs for peak vertical forces has been reported to be between 94 and 99 percent for sound Dutch Warmbloods (Merkens 1986). The trot has only one peak vertical force. Vertical impulse can be calculated as the area under the curve for the walk and trot, which accounts for force over time (Merkens 1986).

Figure 1.3.3.2: Walk data from an in-ground strain gauge force plate[e]. The ipsilateral forelimb and hindlimb strike the plate during the same trial at different times. For each foot, there are two peaks recorded. The first peak represents peak vertical force on the heel region of the foot. The second peak represents peak vertical force on the toe region of the foot. There is a trough between the two peaks that represents the peak vertical force at the midstance phase. The vertical forces are recorded in Newtons per kilogram to standardize the findings to the size of the horse. The vertical impulse is the shaded area under the curve that is calculated by the amount of force placed on the limb during the stance phase over time and is recorded in Newton seconds per kilogram.

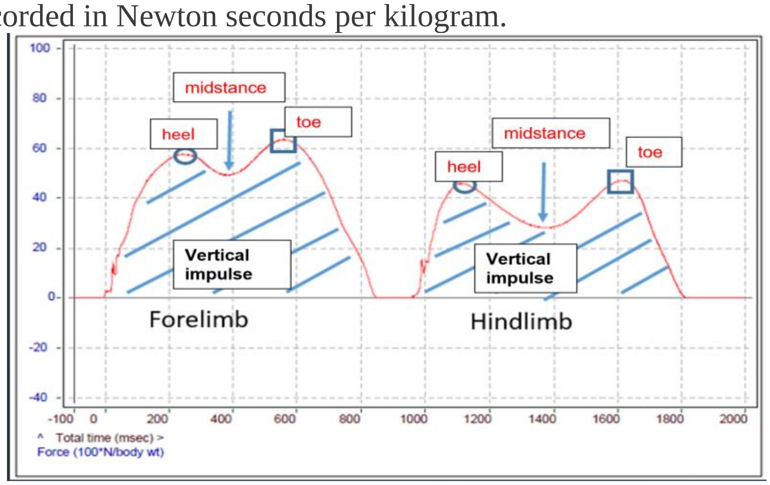
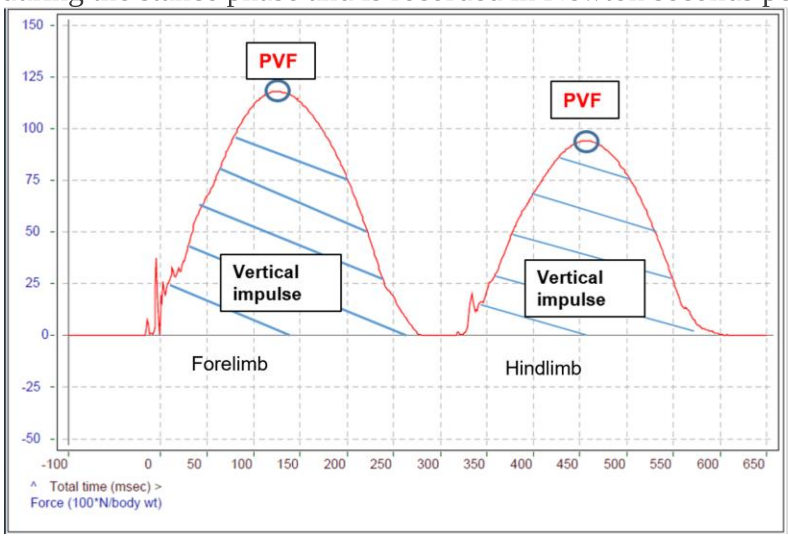


Figure 1.3.3.3: Trot data from an in-ground strain gauge force plate[e]. Ipsilateral forelimb and hindlimb strike the plate during a single trial. As opposed to the walk, each foot only has one peak recorded due to the increased force at the trot. The peak vertical force (PVF) is the maximum force recorded for the limb in the vertical axis and is reported in Newtons per kilogram (N/kg) to standardize the findings to the size of the horse. The vertical impulse (VI) is the shaded area under the curve that calculates the amount of force placed on the limb over time during the stance phase and is recorded in Newton seconds per kilogram.



The force plate exam in naturally-occurring lameness has several potential benefits. It can be used to provide information about the forces applied to the limbs instead of only the resulting kinematic movements. Force plate outcomes for the normal walk and trot have been quantified and reported in Dutch Warmblood horses (Merkens 1986; Merkens 1993). Experimentally-induced lameness has been quantified using the force plate at the trot (Merkens 1988; Merkens 1993; Clayton 2005; Erkert 2005; Ishihara 2005; Weishaupt 2006; Dakin 2011; Boyce 2013; Donnell 2015; Swaab 2015; Bell 2016; Serra Bragança 2021). Combined, these studies demonstrate that one advantage of using the force plate to quantify lameness is that the force on each limb can be measured individually. The additional benefit of adding the walk to the exam is that the walk shows detailed distribution of force within a limb during the stance phase of the stride, which could provide more information about how lameness impacts how the horse uses the lame limb and the sound limbs in compensation for a primary lameness (Merkens 1986). However, there is a greater investment in the time to collect data. In one study, it was reported that attempts at collecting data ranged from 16-72 attempts to successfully capture the data (Merkens 1986). Changes in kinetic parameters at the walk and trot have been studied in a collection of related studies with a solar pressure model to induce single forelimb and single hindlimb lameness at the walk and trot (Weishaupt 2004; Weishaupt 2006; Weishaupt 2008; Serra Bragança 2021). These studies noted that the reduction of peak vertical force and vertical impulse in the lame limb were the most significant changes. A small amount of published data is available providing data on naturally-occurring lameness and responses to diagnostic analgesia (Bidwell 2004; Radtke 2020; Leelamonkong 2020; Phutthachalee 2021).

An important factor to consider in the extrapolation of these studies to this thesis is the difference in our patient populations. This thesis enrolled eight Quarter Horse mares as the study participants, whereas the foundational papers describe normal force plate values for Warmblood horses. Breed differences in ground reaction forces in lame and sound Warmbloods and Quarter Horses have been described where Warmblood horses had higher peak vertical forces compared to Quarter Horses with the same grade of lameness (Back 2007). This led to the need for reference values in sound Quarter Horses for the purposes of evaluating naturally-occurring lameness compared to sound horses.

1.3.3.1 Pilot study data

Considering this information, it was necessary to establish reference ranges for kinetic parameters in sound Quarter Horses for the purposes of the study described in this thesis. This data collection was used to establish reference ranges that could be applied to all four feet for a horse, which allowed for the analysis of the effects of induced lameness and compensation on the remaining sound limbs. The induced lameness was used to improve the understanding of multiple lameness and the resulting compensatory effects. We could then apply this information to cases of naturally- occurring lameness described in Chapters 2 and 3 of this thesis.

Twenty-two (n=22) clinically normal adult Quarter Horses served as the control population to determine reference intervals for the values of key kinetic parameters at the trot (Table 1.3.3.1.1) and walk (Table 1.3.3.1.2). This control population data was taken from baseline (week 0 time point) measurements recorded from a previous study (Boyce 2013). Multiple kinetic parameters were analyzed included peak vertical force (PVF, N/kg), vertical impulse (VI, N/kg s), duration (s), and braking and propulsive impulse (BI and PI, respectively). The peak vertical force was divided into its toe, midstance, and heel counterparts for the walk data. Multiple intra- and inter-limb ratios were calculated and symmetry scores for the forelimb and hindlimb were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Symmetry scores less than 1 indicate a left sided asymmetry and scores greater than 1 indicate a right sided asymmetry.

Table 1.3.3.1.1: Reference values for twenty-two sound Quarter Horses at the trot including the mean, standard deviation (SD), and interquartile range (IQR) for each parameter. Ratios between forelimbs and hindlimbs were calculated by dividing the value for the parameter for the hindlimb by the value for the forelimb. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the right limb. Symmetry scores less than 1 indicate a left sided asymmetry and scores greater than 1 indicate a right sided asymmetry. PVF=peak vertical force; VI=vertical impulse; N=Newtons; kg=kilograms; s=seconds

	Parameter	**Mean**	**SD**	**IQR**
Fore	Fore PVF (N/kg)	9.494	0.675	9.150-9.776
	Fore VI (Ns/kg)	1.799	0.110	1.741-1.870
	Fore Duration (s)	0.323	0.042	0.306-0.335
	Fore Breaking Impulse (Ns/kg)	0.078	0.021	0.067-0.088
	Fore Propulsive Impulse (Ns/kg)	0.075	0.004	0.066-0.084
Hind	Hind PVF (N/kg)	8.087	0.577	7.650-8.519
	Hind VI (Ns/kg)	1.377	0.079	1.322-1.425
	Hind Duration (s)	0.302	0.020	0.287-0.316
	Hind Breaking Impulse (Ns/kg)	0.035	0.012	0.026-0.044
	Hind Propulsive Impulse (Ns/kg)	0.097	0.025	0.081-0.107
Ratios	Ipsilateral Hind: Fore PVF	0.856	0.065	0.817-0.887
	Ipsilateral Hind: Fore VI	0.767	0.032	0.746-0.784
	Ipsilateral Hind: Fore Duration	0.940	0.053	0.909-0.973
	Contralateral Hind: Fore PVF	0.854	0.066	0.813-0.897
	Contralateral Hind: Fore VI	0.767	0.043	0.741-0.796
	Contralateral Hind: Fore Duration	0.938	0.077	0.906-0.983
Forelimb Symmetry	Fore PVF	1.006	0.062	0.968-1.050
	Fore VI	1.000	0.050	0.975-1.038
	Fore Duration	0.984	0.073	0.964-1.036
Hindlimb Symmetry	Hind PVF	1.002	0.035	0.983-1.029
	Hind VI	0.992	0.047	0.974-1.018
	Hind Duration	0.986	0.053	0.973-1.012

Table 1.3.3.1.2: Reference values for twenty-two sound Quarter Horses at the walk including the mean, standard deviation (SD), and interquartile range (IQR) for each parameter. Ratios between forelimbs and hindlimbs were calculated by dividing the value for the parameter for the hindlimb by the value for the forelimb. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the right limb. Symmetry scores less than 1 indicate a left sided asymmetry and scores greater than 1 indicate a right sided asymmetry. PVF=peak vertical force; VI=vertical impulse; N=Newtons; kg=kilograms; s=seconds

	Parameter	**Mean**	**SD**	**IQR**
Fore	Heel PVF (N/kg)	5.085	0.749	4.914-5.436
	Midstance PVF (N/kg)	5.045	0.726	4.919-5.341
	Toe PVF (N/kg)	5.841	0.830	5.731-6.115
	VI (Ns/kg)	3.046	0.481	2.913-3.273
	Heel VI (Ns/kg)	1.347	0.209	1.217-1.470
	Duration (s)	0.777	0.133	0.728-0.838
	Breaking Impulse (Ns/kg)	0.170	0.038	0.150-0.192
	Propulsive Impulse (Ns/kg)	0.163	0.038	0.145-0.185
	Midstance: Heel PVF	0.994	0.047	0.975-1.018
Hind	Heel PVF (N/kg)	4.149	0.628	3.912-4.485
	Midstance PVF (N/kg)	2.978	0.469	2.786-3.251
	Toe PVF(N/kg)	4.169	0.541	4.040-4.412
	VI (Ns/kg)	2.273	0.312	2.176-2.409
	Heel VI (Ns/kg)	1.207	0.135	1.120-1.289
	Duration (s)	0.761	0.125	0.720-0.810
	Breaking Impulse (Ns/kg)	0.123	0.028	0.107-0.143
	Propulsive Impulse (Ns/kg)	0.182	0.034	0.165-0.197
Ratios	Midstance: Heel PVF	0.730	0.137	0.625-0.834
	Ipsilateral Hind: Fore Heel PVF	0.817	0.109	0.752-0.888
	Ipsilateral Hind: Fore Toe PVF	0.717	0.041	0.689-0.747
	Ipsilateral Hind: Fore VI	0.745	0.046	0.715-0.766
	Ipsilateral Hind: Fore Duration	1.205	0.355	0.962-1.423
	Ipsilateral Hind: Fore Midstance	0.662	0.141	0.573-0.738
	Contralateral Hind: Fore Heel PVF	0.816	0.092	0.757-0.873
	Contralateral Hind: Fore Toe PVF	0.716	0.038	0.693-0.743
	Contralateral Hind: Fore VI	0.745	0.038	0.715-0.776
	Contralateral Hind: Fore Duration	0.984	0.075	0.950-1.009
	Contralateral Hind: Fore Midstance PVF	0.591	0.058	0.549-0.632
Forelimb Symmetry	Heel PVF	1.012	0.057	0.981-1.030
	Heel VI	0.993	0.072	0.938-1.047
	VI	1.008	0.037	0.987-1.033
	Midstance PVF	1.001	0.033	0.977-1.025
	Duration	1.026	0.080	0.978-1.045
Hindlimb Symmetry	Heel PVF	1.018	0.071	0.985-1.049
	Heel VI	1.008	0.047	0.964-1.053
	VI	1.003	0.035	0.976-1.031
	Midstance PVF	0.991	0.062	0.956-1.021
	Duration	1.007	0.059	0.968-1.033
Forelimb Ratios	Fore Heel: Toe PVF	0.873	0.071	0.819-0.916
	Toe Peak with respect to total time	0.614	0.048	0.589-0.640
Hindlimb Ratios	Heel/Toe Duration	1.136	0.317	0.993-1.236
	Toe Peak with respect to total time	0.755	0.091	0.749-0.776
	Hind Heel: Toe PVF	0.990	0.095	0.925-1.044

In a previous study conducted by our lab, placement of circumferential hoof clamps was shown to be a viable method for inducing consistent, reproducible, and reversible lameness in an experimental setting (Swaab 2015). Using this model of lameness, additional pilot data was gathered from 8 Quarter Horses where a grade 2 out of 5 (on the AAEP scale) single limb lameness or multi-limb lameness was induced. Combinations of induced lameness included single forelimb, single hindlimb, contralateral fore and hindlimb, ipsilateral fore and hindlimb, bilateral forelimbs, and bilateral hindlimbs. Data were analyzed to look for compensation patterns (trends) in ground reaction forces that were consistent between horses for a given lameness at the walk and trot.

Briefly, for all of the following descriptions, the forces being discussed are being compared to the control limbs where clamps were applied to the limb(s) but not tightened. At the walk, the application of a single forelimb clamp resulted in a trend for a decreased midstance PVF on the clamped forelimb and an increase in contralateral hind heel impulse, while at the trot there was decreased PVF and VI on the clamped limb with an increase in the vertical impulse on the contralateral fore. For the single forelimb clamp, there was a positive correlation between the decrease in clamped fore trot VI and walk VI. Similarly, the application of a single hindlimb clamp at a walk resulted in decreased midstance PVF on the clamped hindlimb and an increased contralateral forelimb heel PVF. In addition, there was a decreased hind toe PVF and heel PVF on the clamped hindlimb with an increase in the ipsilateral fore midstance PVF and propulsion impulse, and a decrease in hind propulsive impulse on the contralateral hind. At the trot, there was also a decreased PVF and VI on the clamped hindlimb with an additional decrease in braking impulse at the trot. For the single hindlimb clamp, there was a positive correlation between decrease in clamped hind trot VI and walk VI.

In a concurrent ipsilateral forelimb and hindlimb lameness, there were several trends observed at the walk. There was an increase in the clamped fore heel VI, but a decrease in the clamped forelimb heel and midstance PVF. There was a decrease in the clamped hind heel PVF. Additionally, there was an increase in the contralateral fore and hind midstance

PVF and increase in contralateral forelimb heel PVF. At the trot there was decreased clamped forelimb PVF and VI and decreased clamped hind PVF and VI. For the ipsilateral forelimb and hindlimb clamps, there was a positive correlation between the decrease observed in the clamped fore and hind trot VI and walk VI.

In the contralateral forelimb and hindlimb clamped scenario, at the walk, there was decreased hind heel PVF, toe PVF, and an increased ratio of the midstance PVF to the hind heel PVF on the clamped hind. At the trot, there was a decrease in the clamped forelimb PVF, VI and braking impulse and a decrease in the clamped hindlimb PVF and VI. There was increased forelimb duration bilaterally and an increased ratio of hindlimb to forelimb PVF for the clamped fore and sound hind at the trot. There was a positive correlation between the decrease in trot VI and walk VI for the clamped forelimb, but for the clamped hindlimb there was a negative correlation between the trot PVF and walk midstance PVF. This means that while the PVF of the clamped hind is decreasing at the trot, the midstance PVF increases on the clamped hind at the walk. This suggests the compensatory role of the clamped hind for the contralateral forelimb still exists despite the application of a clamp.

Combined, this pilot data demonstrated some key kinetic parameters that were utilized in Chapters 2 and 3 of this thesis that could indicate lameness and/or compensation when forces are collected at a walk or trot. The vertical forces (PVF and VI) appear to be the most informative compared to the horizontal forces, which is similar to findings in other published studies (Weishaupt 2004; Weishaupt 2006). However, it has been described that the horizontal breaking forces also decrease with lameness (Clayton 2004; Clayton 2013). Our pilot data also indicates that examining kinetic data at a walk could be of great value in determining lameness as there were consistent changes to the midstance and heel PVF regardless of what leg, or combination of limbs were affected. These findings are similar to the data presented by Merkens and Schamhardt where they recorded walk data after the induction of lameness using the solar pressure model (Merkens 1988). In that study, they found that there were decreases in the heel PVF and increases in midstance PVF that had a greater magnitude of change with increasing lameness. This has not been confirmed in naturally-occurring lameness, nor have the compensatory effects in naturally-occurring been described. Symmetry scores and comparison of ipsilateral forelimbs and hindlimbs may also be helpful in cases of naturally-occurring lameness where no baseline is available.

In a prospective clinical case (Dobbs 2017), we applied the information learned from these pilot studies to determine if changes could be identified to the GRFs at the walk in response to diagnostic analgesia and treatment. A 19-year-old Warmblood gelding with an AAEP grade 3/5 right forelimb lameness and history of chronic navicular disease was monitored over three months with the owner's consent. With bilateral forelimb foot and pastern MRI, he was diagnosed with extensive severe tendinopathy within the deep digital flexor tendon in the pastern region and moderate chronic navicular bursitis of the right forelimb. At baseline, there was decreased weight bearing on the heel region. Perineural analgesia was performed and demonstrated an increase in heel PVF and forelimb VI (Figure 1.3.3.1.1). The effect of the cumulative treatments along with shoeing changes resulted in the closest match to abaxial block GRFs indicating increased weight bearing on the heel (Figure 1.3.3.1.2). This case study supported our thoughts that using force plate data at a walk can provide relevant data that could aid in the diagnosis and treatment of horse with naturally-occurring musculoskeletal disease.

Figure 1.3.3.1.1: Right walk trials on the force plate from a 19-year-old Warmblood gelding with right fore deep digital flexor tendinitis and navicular bursitis. Baseline is shown in red, post palmar digital nerve block is shown in orange and post abaxial nerve block is shown in blue indicating an increased heel PVF after analgesia.

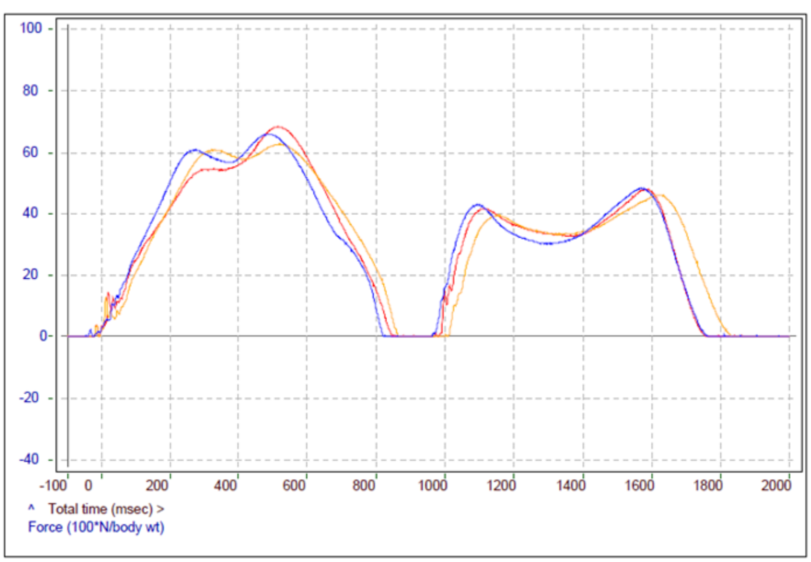
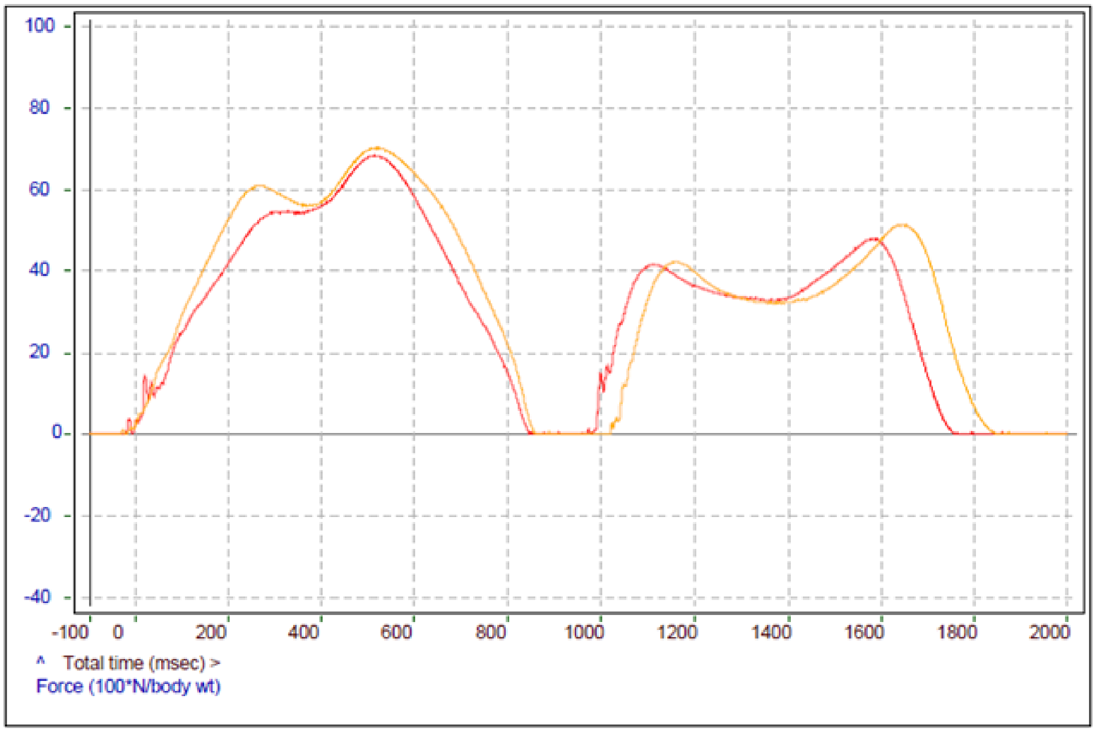


Figure 1.3.3.1.2: Right walk trials from a from a 19-year-old Warmblood gelding with right fore deep digital flexor tendinitis and navicular bursitis. Baseline is shown in red and post shoeing with and Equine Digit Support System (EDSS) shoe with a low rail is shown in orange indicating an increased heel PVF after treatment.



1.4 Gap in Knowledge

In an overview of trends in equine movement analysis, research trends, limitations and opportunities across the available equine gait analysis literature have been recently described (Egan 2019). This study found observational research, as opposed to experimental research, to be used the most. While the body mounted inertial sensor system use has been increasing in recent years, other methods of data collection, such as the force plate or 3-D optical motion capture technologies, have reached a plateau or decreased in use. The main limitation identified in these studies are the sample size, with most having between 6-10 horses enrolled in a study. The most common challenge in these studies has been the challenge of transferability of the research results to the clinical setting. Part of the reason for this is that most of the studies published were methodological studies that examined things such as: tool validation, the reliability or validity of experiments of testing and set up of equipment, or comparison of methods. The top three research opportunities identified were clinical interventions, specifically the effect of diagnostic analgesia and treatments, clinical exercise interventions, such as rehabilitative exercise and performance, or training interventions, which includes the effect of weighted boots or specific ridden protocols on performance outcomes and injury prevention.

As described throughout this chapter, objective measures of lameness evaluation are primarily used in the research setting at this time and have mostly focused on sound horses or in those with experimentally-induced lameness. Limited studies have been performed using force plate gait analysis to evaluate perineural analgesia. These studies have performed only one or two levels of palmar digital perineural analgesia and/or abaxial sesamoid perineural analgesia (Bidwell 2004; McGuigan 2001). Therefore, there is a gap of knowledge on the objective evaluation of perineural and intra-articular diagnostic analgesia in naturally-occurring lameness where the origin of lameness is unknown. This is a critical step that is needed to apply objective gait analyses techniques to the clinical setting.

1.5 Objective and Hypothesis

The objective of this thesis is to describe the effects of diagnostic analgesia on the kinematic and kinetic variables in cases of naturally-occurring lameness that are clinically assessed using traditional subjective methods. We hypothesize that the application of diagnostic analgesia will alter kinetic and kinematic values at the walk and trot in naturally-occurring lameness. The resulting effect of diagnostic analgesia will indicate a sound horse if the structure causing pain is desensitized. For kinetic methods, this equates to increased PVF on the lame limb in response to diagnostic analgesia. For kinematic analysis, this equates to decreased asymmetry in measured parameters. Additionally, we hypothesize that the application of diagnostic analgesia will result in the reversal of compensatory changes in the non-lame limbs, and lastly, we hypothesize that in horses with the same diagnosis, there will be similar patterns in their response to diagnostic analgesia

CHAPTER 2

2.1 Introduction

Lameness is a clinical sign of musculoskeletal pain and is the alteration of the gait as an adaptation to decrease the load on a limb or limbs in response to a structural or functional disorder in the locomotor system (Weishaupt 2008; Baxter 2020). Movements indicating lameness can be most consistently observed as changes in the vertical displacement of the head in forelimb lameness and in sacrum and tuber coxae in hindlimb lameness (Weishaupt 2008; Keegan 2020a).

In a clinical lameness exam, the horse is subjectively evaluated by the veterinarian while it undergoes a series of locomotive tasks to gather information about the lameness. Please see Chapter 1 for more specific detail about a subjective exam. In addition, objective analysis can also be performed to evaluate lameness at a walk and trot; they have the potential to provide more detail for the clinician, especially in subtle or multi-limb lameness. Please see Chapter 1 for more specific detail about objective techniques. Briefly, 2-dimensional analysis can easily be performed in a clinical setting as can a body mounted inertial sensor system (BMISS), whereas collection of ground reaction forces (GRFs) requires use of a specialized force plate. Once a limb(s) has been identified, then perineural and/or intra-articular diagnostic analgesia is used to narrow the region of focus for the source of pain and the response can be identified using both subjective and objective lameness techniques.

The objective of this study is to describe the effects of diagnostic analgesia on the kinematic and kinetic variables in cases of naturally-occurring lameness that are clinically assessed using traditional subjective methods. This chapter focuses on the individual exams for each horse and how the subjective and objective measures compare and contrast within an exam.

2.2 Materials and Methods

Eight Quarter Horse teaching mares at the University of Minnesota participated in this study. The age of the horses ranged from 8-20 years of age, and all have been previously subjectively evaluated in lameness rotations to teach professional veterinary students lameness. All procedures performed on the horses were approved by the University of Minnesota Institutional Animal Care and Use Committee (#1902-36738A).

The lameness for each horse was clinically evaluated and the source of lameness was identified using a traditional subjective lameness exam aided by the use of peri-neural and/or intra-articular analgesia. Kinematic and kinetic objective measures were also collected throughout the exam, as appropriate, but were not examined real-time so that they could not be used to influence the direction of the exam. The general flow of an exam was as follows. The horse was initially palpated to determine any areas of swelling or soreness. They were then walked and trotted in a straight line on a hard surface and a subjective AAEP lameness grade for the forelimbs and/or hindlimbs was determined by the student and advisor via mutual agreement. The horse was then outfitted with a commercially available body mounted inertial sensor system (BMISS), the Lameness Locator®[d] and trotted in the same straight line. If the horse was trained to lunge, and was not too lame, circles in each direction were performed on arena footing while subjective and BMISS data was collected. A second straight line baseline was observed after lunging to ensure that the lameness had not been affected after circling. Next, force plate data was collected at the walk and then the trot[e], if the horse was able to do so depending on the lameness. A high-speed camera[a] was placed perpendicular to the center of the force plate approximately 8 inches off the ground on a tripod and video of all walk trials were recorded for the measurement of fetlock extension, noting which trials were acceptable for the force plate. Then, flexion tests were performed and evaluated subjectively. Perineural or intra-articular analgesia were performed based on palpation and the cumulative subjective exam. All perineural and joint blocks were performed using traditionally described approaches and volumes (Moyer 2007) using bupivacaine because of the length of time required to perform objective data collection, as well as the unknown duration of each horse's lameness exam and unknown number of blocks that would be performed for each horse. After palpable confirmation that the area was desensitized for perineural analgesia or 20 minutes for intra-articular analgesia, the subjective exam and objective data collection was repeated. Then, diagnostic analgesia was repeated in order from distal to proximal along the limb until 60-70% subjective improvement was achieved.

2.2.1 Objective data collection and analyses

2.2.1.1 Body mounted inertial sensor system

A body mounted inertial sensor system (Lameness Locator®)[d] was used to record kinematic data at the trot as described in Chapter 1. Inertial sensors were placed on the poll, highest point of the pelvis, and the right front fetlock according to the company protocol (please see Chapter 1 for more detail). A minimum of 25 strides were collected for each trial. Two straight line trials were collected at baseline. The sensors transmit the data to a tablet preloaded with software algorithm that calculates mean head movement asymmetry and pelvic movement asymmetry. The following values were calculated and reported based on an average of at least 25 strides, mean and standard deviation for vector sum for forelimb lameness determination, minimum difference of the pelvis between left and right sides for the determination of impact lameness, and the maximum difference of the pelvis for right and left sides for the determination of push off lameness (please see Chapter 1 for more detail). The software also provides a calculation of percent improvement in asymmetry based on the baseline value of asymmetry subtracted from the value of asymmetry after diagnostic analgesia, then divided by the baseline value of asymmetry.

2.2.1.2 Force plate data collection and analysis

Kinetic data was recorded at both the walk and trot using an in-ground force plate[e] and corresponding recording software[f]. Horses were led by a handler on the left side of the horse. To be considered a good trial, the horse had to walk at a speed of 0.9-1.7 m/s with acceleration limited to ± 0.1 m/s^2. At the trot, the speed of the trial had to be 2.8–3.3 m/s with an acceleration limited to ± 0.3 m/s^2. A minimum of five trials were collected for each limb. Ground reaction forces (GRFs) were measured in 3 directions, including the vertical, horizontal, and transverse, but based on previous pilot data (please see Chapter 1), only GRFs in the vertical direction were analyzed further for this study. Mean peak vertical force values and standard deviation were calculated for the heel, midstance and toe regions of the stance phase and the associated vertical impulse (VI) for forelimbs and hindlimbs at a walk, while the peak vertical force and associated vertical impulse were calculated for forelimbs and hindlimbs at the trot. For the walk, ratios of midstance PVF to heel PVF were also calculated within each limb. For the walk and trot data, ipsilateral hindlimb to forelimb ratios for PVF and VI were calculated for each trial and the mean and standard deviation were reported. For the walk and trot, symmetry sores for the PVF and VI of forelimbs and hindlimbs were also calculated from the mean of the 5 trials. Symmetry scores were calculated by dividing the value for the parameter for the left limb divided by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Percent improvement with diagnostic analgesia was calculated by subtracting the baseline GRF value from the GRF after diagnostic analgesia, then divided by the baseline value of the GRF parameter.

2.2.1.3 Two-dimensional fetlock extension

Prior to collection of the walk data on the force plate, three reflective markers[b] were placed on the dorsopalmar midpoint medially and laterally of the proximal third metacarpal bone at the level of the head of the second metacarpal/tarsal and fourth metacarpal bone respectively, the dorsopalmar midpoint medially and laterally of the coronary band, and medial and lateral distal epicondyle of the third metacarpal or metatarsal bone. As described in Chapter 1, the video data of the fetlock at the walk was recorded as the horse traverses the force plate at the walk to measure fetlock angle of extension. The video camera[a] was placed at the level of the fetlock (approximately 8 inches off the ground on a tripod placed perpendicular to the center of the force plate) and set to high-speed recording mode at 120 frames per second. The video recordings of viable trials were examined frame by frame until the limb of interest was in the mid stance phase where the contralateral limb was in mid swing phase. On the chosen image, lines were drawn connecting the 3 surface markers creating 2 segments that coursed proximal and distal from the fetlock. A screen protractor[c] was then used to measure the dorsal angle of the sagittal plane extension. Only viable force plate trials were used for fetlock extension analysis, so a minimum of five trials were collected from each limb, and the mean and standard deviation were calculated. Percent improvement with diagnostic analgesia was calculated by subtracting the baseline fetlock extension from the fetlock extension after diagnostic analgesia, then divided by the baseline value of fetlock extension.

2.3 Results and Discussion

2.3.1 Horse 1

Signalment and use:

Horse 1, an 18-year-old Quarter Horse mare, is used as a teaching horse at the University of Minnesota. She was previously used as the treadmill demonstration horse, until her lameness prevented her from performing this task.

Passive exam findings:

Forelimbs: On the right forelimb, there was mild coffin joint effusion and mild middle carpal joint effusion. On the left forelimb, there was mild coffin joint effusion, mild to moderate middle carpal joint effusion. The medial aspect of the left middle carpal joint had firm thickening that was sensitive to palpation along the medial aspect.

Hindlimbs: Mild to moderate medial femorotibial effusion was present bilaterally. Churchill test for the distal hocks were negative bilaterally. There was mild sensitivity to palpation of the epaxial musculature in the thoracolumbar region.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 3 LF and Grade 1 RH

Lunging: The left forelimb lameness was exacerbated in the left circle. The left forelimb lameness was present in the right circle, but to a lesser degree than the left circle.

Baseline after lunging: Grade 3 LF and Grade 1 RH

<u>*Baseline Lameness Locator® exam findings:*</u>

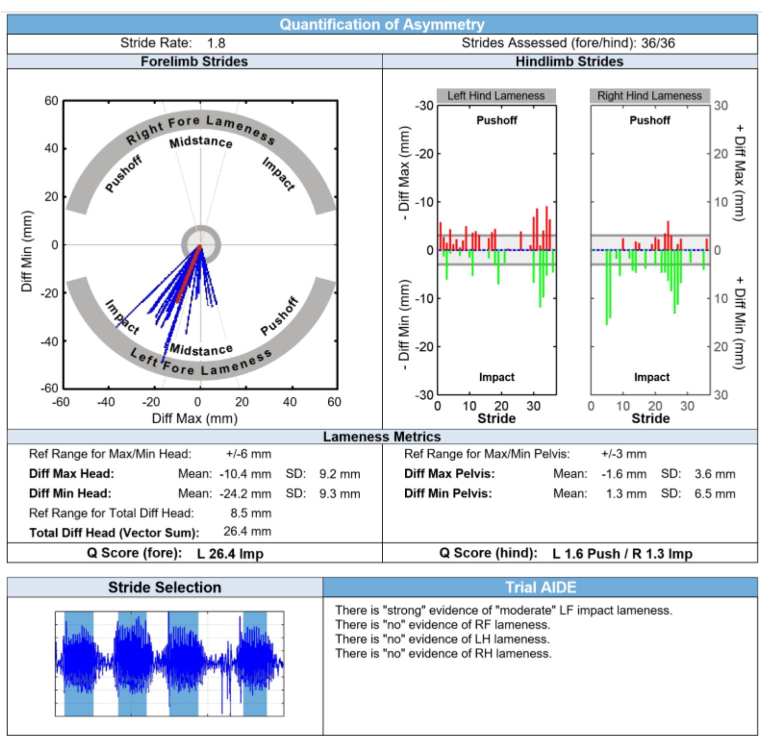
Straight line: There was strong evidence of a moderate LF impact lameness. Hindlimb lameness measurements were within normal limits (Table 2.3.1.1 and Figure 2.3.1.1).

Table 2.3.1.1: Horse 1 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	Trial 2	Baseline (Mean ± SD)
Vector Sum (mm)	26.4 (L)	33.4 (L)	29.9 ± 5 (L)
Diff min pelvis (mm)	1.3 ± 6.5 (R)*	1.7 ± 6.5 (R)*	1.5 ± 0.3 (R)*
Diff max pelvis (mm)	1.6 ± 3.6 (L)*	2.3 ± 3.4 (L)*	2.0 ± 0.5 (L)*

*Below the 3mm threshold for lameness

Figure 2.3.1.1: Horse 1 baseline Lameness Locator® summary from Trial 1 in a straight line.



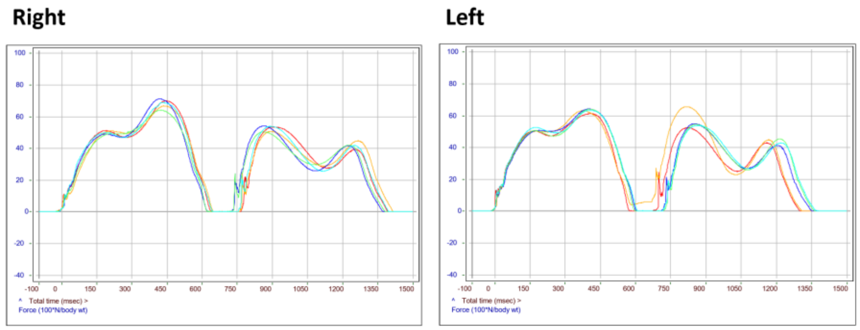
Baseline Force Plate Exam Findings (after lunge):

Walk: Five trials were analyzed for each limb (Table 2.3.1.2 and Figure 2.3.1.2). Forelimb midstance (Ms)PVF was decreased compared to normal controls (5.045 ± 0.726 N/kg) bilaterally. Forelimb toe PVF was increased relative to the average of normal controls (5.841 ± 0.830 N/kg) bilaterally. LF toe PVF and VI were decreased compared to the RF, indicating a LF lameness. Hindlimb heel PVF was increased compared to normal controls (4.149 ± 0.628 N/kg) bilaterally. Hindlimb heel PVF was greater than forelimb heel PVF bilaterally. LH heel PVF was greater than the RH heel PVF. The RH midstance PVF was greater than the LH midstance PVF. This indicates a RH lameness. Ipsilateral hindlimb VI to forelimb VI (left hindlimb to forelimb was 0.85 ± 0.06 and right hindlimb to forelimb VI was 0.78 ± 0.02) was increased compared to normal control horses (0.75 ± 0.05). This indicates that the hindlimbs had a greater amount of force compared to a normal horse, which supports that Horse 1 had a forelimb lameness and the hindlimbs had a compensatory role.

Table 2.3.1.2: Horse 1 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	4.924 ± 0.106	4.698 ± 0.131	6.698 ± 0.277	2.746 ± 0.069
Left	5.014 ± 0.095	4.772 ± 0.135	6.208 ± 0.115	2.562 ± 0.079
Symmetry	1.02	1.02	0.93	0.93
HIND				
Right	5.170 ± 0.176	2.698 ± 0.167	4.128 ± 0.188	2.138 ± 0.029
Left	5.530 ± 0.517	2.500 ± 0.156	4.276 ± 0.162	2.162 ± 0.142
Symmetry	1.07	0.93	1.04	1.01

Figure 2.3.1.2: Horse 1 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.

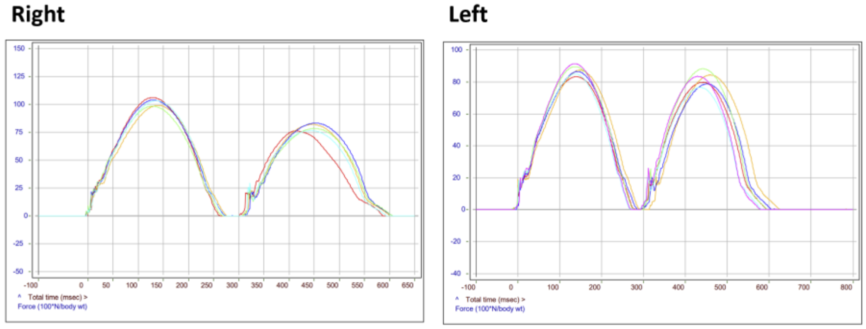


Trot: Six trials were analyzed for the left limbs, and five trials were analyzed for the right limbs (Table 2.3.1.3 and Figure 2.3.1.3). The left forelimb PVF and VI were decreased compared to the right forelimb with moderate asymmetry for both PVF and VI. The right hindlimb PVF and VI were decreased compared to the left hindlimb. The left hindlimb to left forelimb PVF and VI ratio (PVF: 0.94, VI: 0.91) were increased compared to control horses (PVF: 0.86 ± 0.06, VI: 0.77 ± 0.03). The right hindlimb to right forelimb PVF ratio (0.78) was decreased compared to control horses (PVF: 0.86 ± 0.06). This is indicative of a left forelimb and right hindlimb lameness.

Table 2.3.1.3: Horse 1 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind:Fore PVF	Ipsilateral Hind:Fore VI	Contralat Hind:Fore PVF	Contralat Hind:Fore VI
Right	10.032 ± 0.322	1.668 ± 0.041	7.792 ± 0.313	1.330 ± 0.082	0.78	0.80	0.91	0.90
Left	8.562 ± 0.288	1.478 ± 0.049	8.037 ± 0.420	1.350 ± 0.096	0.94	0.91	0.80	0.81
Symmetry	0.85	0.89	1.03	1.02				

Figure 2.3.1.3: Horse 1 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at a walk: There were 5 unobstructed video trials for each limb (Table 2.3.1.4). The LF fetlock extension was less that the RF fetlock extension. The RH fetlock extension was greater that the LH. This is indicative of a left forelimb lameness and the right hindlimb is playing a greater compensatory role than the left hindlimb based on increased extension in the right hindlimb fetlock.

Table 2.3.1.4: Horse 1 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	**LF**	**RH**	**LH**
Baseline angle (degrees)	137.18	139.97	147.67	149.69
SD	1.42	2.78	2.45	2.92

Flexion test responses:

Forelimbs:

RF distal limb: negative, worse LF.

RF carpus: negative, worse LF.

LF distal limb: negative.

LF carpus: moderate positive.

Hindlimbs:

RH distal limb: negative.

RH full limb: mild to moderate positive.

LH distal limb: negative.

LH full limb: mild positive.

Diagnostic Analgesia:

First block performed: Left middle carpal joint intra-articular analgesia

Subjective lameness exam post first block:

There was an 80% improvement in the LF lameness after the left middle carpal joint block.

Lameness Locator® exam post first block:

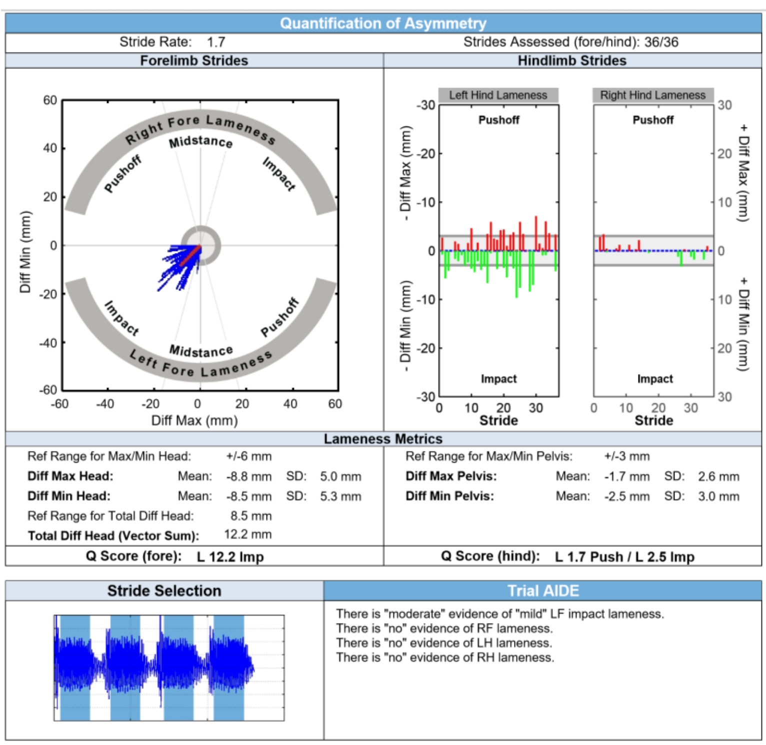
There was moderate evidence of a mild LF lameness, but there was a 59% improvement in the left forelimb lameness compared to baseline (Table 2.3.1.5 and Figure 2.3.1.4). Hindlimb lameness measurements were within normal limits.

Table 2.3.1.5: Horse 1 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post L middle carpal joint block. The lame limb is highlighted in the parentheses.

	Baseline	**Post L middle carpal joint block**	**Percent change (%)**
Vector Sum (mm)	29.9 ± 5 (L)	12.2 (L)	-59
Diff min pelvis (mm)	1.5 ± 0.3 (R)*	2.5 ± 3.0 (L)*	*
Diff max pelvis (mm)	2.0 ± 0.5 (L)*	1.7 ± 2.6 (L)*	*

*Below the 3mm threshold for hindlimb lameness

Figure 2.3.1.4: Horse 1 Lameness Locator® summary in a straight-line post L middle carpal joint block.



Force plate exam post first block

Walk: Five trials were analyzed for all limbs (Tables 2.3.1.6–2.3.1.7 and Figure 2.3.1.5). LF midstance PVF and VI increased from baseline indicating that the application of diagnostic analgesia has improved the lameness. LH and RH midstance PVF increased and heel PVF decreased compared to baseline. The greatest change was a 13% decrease in the LH heel PVF and 14% increase in the left hindlimb midstance PVF. This is consistent with the pattern observed for a hindlimb lameness at the walk. This suggests that the left hindlimb was playing a substantial compensatory role in accommodating the left forelimb lameness. It is important to consider that the left forelimb lameness may have been masking a left hindlimb lameness that is elucidated after improvement in the left forelimb lameness post diagnostic analgesia.

Table 2.3.1.6: Horse 1 force plate ground reaction forces at a walk (mean ± SD) post L middle carpal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.004 ± 0.104	4.874 ± 0.059	6.262 ± 0.291	2.736 ± 0.052
Left	5.102 ± 0.056	5.020 ± 0.100	6.140 ± 0.218	2.758 ± 0.063
Symmetry	1.02	1.03	0.98	1.01
HIND				
Right	4.828 ± 0.194	2.822 ± 0.129	4.244 ± 0.109	2.226 ± 0.071
Left	4.798 ± 0.151	2.856 ± 0.169	4.310 ± 0.084	2.220 ± 0.022
Symmetry	0.99	1.01	1.02	0.99

Figure 2.3.1.5: Horse 1 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post L middle carpal joint block. Vertical impulse is the area under the curve.

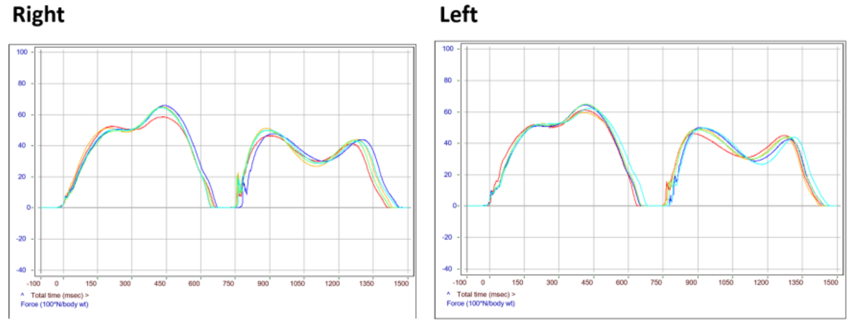


Table 2.3.1.7: Horse 1 force plate ground reaction forces at a walk (mean) comparing baseline and post LF middle carpal joint block measurements. Ms=Midstance.

	RF baseline	**RF post LF middle carpal joint block**	**Percent change (%)**	**LF baseline**	**LF post LF middle carpal joint block**	**Percent change (%)**
Heel PVF (N/kg)	4.924	5.004	2	5.014	5.102	2
MsPVF (N/kg)	4.698	4.874	4	4.772	5.02	5
Toe PVF (N/kg)	6.698	6.262	-7	6.208	6.140	-1
VI (Ns/kg)	2.746	2.736	0	2.562	2.758	8
	RH baseline	**RH post LF middle carpal joint block**	**Percent change (%)**	**LH baseline**	**LH post LF middle carpal joint block**	**Percent change (%)**
Heel PVF (N/kg)	5.170	4.828	-7	5.530	4.798	-13
MsPVF (N/kg)	2.698	2.822	5	2.500	2.856	14
Toe PVF (N/kg)	4.128	4.244	3	4.276	4.31	1
VI (Ns/kg)	2.138	2.226	4	2.162	2.220	3

Trot: Five trials were analyzed for each limb (Tables 2.3.1.8–2.3.1.9 and Figure 2.3.1.6). The left forelimb PVF increased by 9% from baseline and the VI increased by 11%. The RF PVF decreased 4% from baseline. There was greater symmetry between forelimbs. This indicates improvement in the left forelimb lameness. The right hindlimb PVF and VI increased compared to baseline. Hindlimb PVF symmetry also improved. This is suggestive that the initial right hindlimb lameness was due to compensation. Overall, bilaterally hindlimb PVF and VI is increased relative to the forelimbs compared to normal controls (PVF: 0.85 ± 0.065, VI: 0.77 ± 0.032), which supports that the forelimb lameness is not completely resolved as the hindlimbs still have a greater amount of force applied to them.

Table 2.3.1.8: Horse 1 force plate ground reaction forces at a trot (mean ± SD) post left middle carpal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	9.614 ± 0.152	1.696 ± 0.030	8.178 ± 0.212	1.450 ± 0.035	0.85	0.86	0.88	0.88
Left	9.334 ± 0.242	1.644 ± 0.063	8.110 ± 0.246	1.394 ± 0.029	0.87	0.85	0.84	0.82
Symmetry	0.97	0.97	0.99	0.96				

Figure 2.3.1.6: Horse 1 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post left middle carpal joint block. Vertical impulse is the area under the curve.

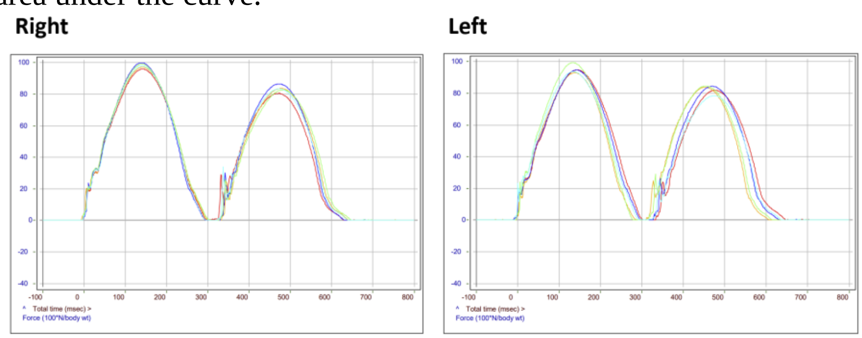


Table 2.3.1.9: Horse 1 force plate ground reaction forces at a trot (mean) comparing baseline and post LF middle carpal joint block measurements.

	RF baseline	**RF post LF middle carpal joint block**	**Percent change (%)**	**LF baseline**	**LF post LF middle carpal joint block**	**Percent change (%)**
PVF (N/kg)	10.032	9.614	-4	8.56	9.334	9
VI (Ns/kg)	1.668	1.696	2	1.48	1.644	11
	RH baseline	**RH LF middle carpal joint block**	**Percent change (%)**	**LH baseline**	**LH LF middle carpal joint block**	**Percent change (%)**
PVF (N/kg)	7.792	8.178	5	8.037	8.110	1
VI (Ns/kg)	1.330	1.450	9	1.350	1.394	3

Semi-quantitative fetlock extension at a walk post first block: There were 5 unobstructed video trials for each limb (Table 2.3.1.10). There was minimal change in the forelimb fetlock extension. There was slightly less extension in RH fetlock extension. This may be reflective of compensatory change where there was greater extension into the RH fetlock at baseline because force was shifted from the primary lame limb (LF) to the contralateral hindlimb (RH). After the LF lameness improved, force was shifted away from the RH resulting in decreased fetlock extension.

Table 2.3.1.10: Horse 1 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post left middle carpal joint block with comparison to baseline.

	RF	**LF**	**RH**	**LH**
Angle post L middle carpal joint block	137.80 ± 2.15	139.65 ± 1.45	152.31 ± 2.57	151.36 ± 3.15
Baseline angle	137.18	139.97	147.67	149.69
Percent change (%)	1	0	3	1

Subjective clinical assessment of 1st block:

There was significant improvement with the left middle carpal joint block. Based on gross palpable changes and flexion responses, it is likely that residual pain was a result of subchondral bone pain. However, there was a recent historical report of improvement of this horse after a left forelimb abaxial nerve block. Therefore, a LF abaxial sesamoidean nerve block was performed to rule out other contributions. Only subjective and Lameness Locator® data were collected after this block.

<u>*Second block performed*</u>*:* LF abaxial nerve block

Subjective lameness exam post second block:

There was no further improvement in the left forelimb lameness after the LF abaxial nerve block.

Lameness Locator® exam post second block:

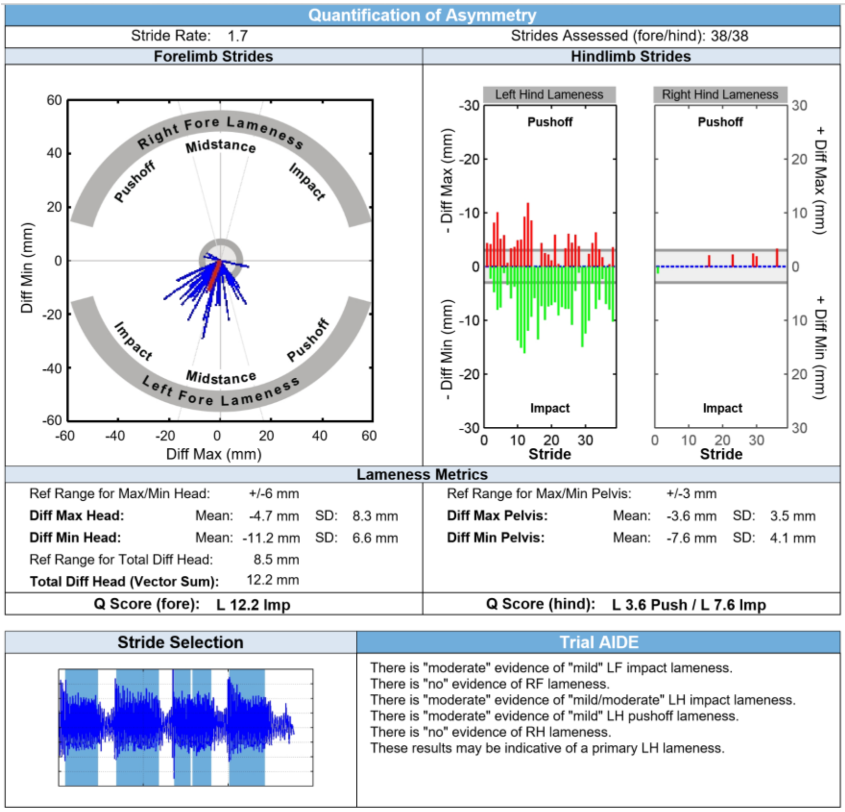
There was moderate evidence of a mild LF lameness, which is unchanged from the first block. There was also moderate evidence of a mild to moderate LH impact lameness. There was moderate evidence of a mild LH push-off lameness. This may be indicative of a primary LH lameness (Table 2.3.1.11 and Figure 2.3.1.7).

Table 2.3.1.11: Horse 1 Lameness Locator® data in a straight line (mean ± SD) comparing post LF abaxial block to post L middle carpal joint block (percent change calculated). Baseline data is included for convenience. The lame limb is highlighted in the parentheses.

	Baseline	**Post L middle carpal joint block**	**Post LF abaxial sesamoid**	**Percent change (%)**
Vector Sum (mm)	29.9 (L)	12.2 (L)	12.2 (L)	0
Diff min pelvis (mm)	1.5 (R)*	2.5 ± 3.0 (L)*	7.6 ± 4.1 (L)	204*
Diff max pelvis (mm)	2.0 (L)*	1.7 ± 2.6 (L)*	3.6 ± 3.5 (L)	111*

*Below the 3mm threshold for lameness

Figure 2.3.1.7: Horse 1 Lameness Locator® summary in a straight-line post LF abaxial sesamoid perineural block.



Subjective clinical assessment of 2^{nd} *block*:

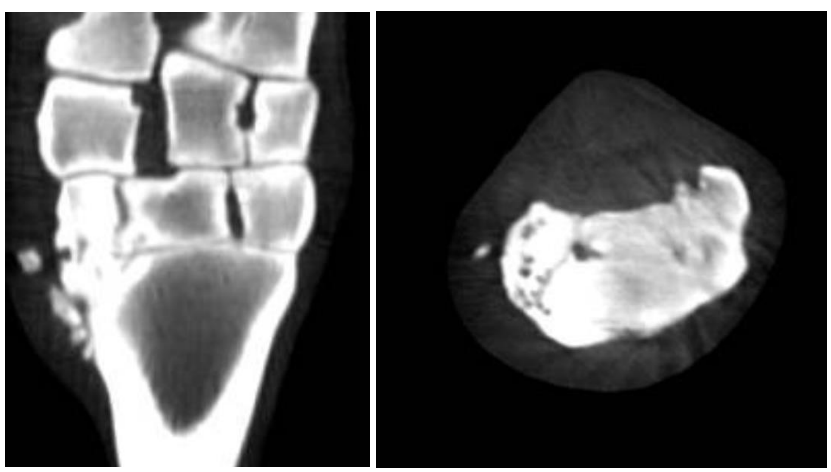
The greatest subjective improvement was seen after the left forelimb middle carpal joint block. No additional improvement was observed after abaxial nerve block on the left forelimb above the middle carpal joint block. Improvement was significant enough to proceed to imaging of the left carpus. Hindlimb lameness was minimal throughout so no diagnostic analgesia of the hindlimbs was performed.

Diagnostic Imaging:

Forelimb CT (Figure 2.3.1.8)*:*

On the left second carpal bone there was sclerosis at the level of the middle carpal joint. There was a small invaginated defect at the caudal lateral aspect of the second carpal bone, and a small circular lucent area at the caudal aspect extending distally. There were smaller circular lucent areas at the dorsal surface of the second carpal bone extending distally. Distally, there was a larger circular lucent area at the dorsomedial aspect of the bone with a small fragment at the medial border of the second carpal bone. On the left third carpal bone, there was an irregular surface and projections along the dorsal and dorsomedial aspect of the third carpal bone. There was sclerosis of the third carpal bone at the level of the carpometacarpal joint. There were semi-circular lucent areas at the articulation of the second and third carpal bones, with increased opacity in the surrounding bone. There was bridging of increased opacity between the second and third carpal bones dorsally, that extends distally resulting in fusion of the bones at the most distal aspect. There was also bridging of increased opacity between the third and second metacarpal bones with a spiculated appearance that extended to the proximal metaphysis of the third metacarpal bone. These changes appeared to be in the location of the medial collateral ligaments of the carpus. There was proliferative change where the ligament inserts and there was bone change to the medial splint bone and the second carpal bone with collapse of the joint space of the carpometacarpal joint.

Figure 2.3.1.8: CT images in the frontal (left image) and transverse (right image) planes demonstrating osseous change in the 2nd and 3rd carpal bones mostly at the level of the carpometacarpal joint of the left forelimb. Medial is on the left side of each image, and the dorsal aspect is on the bottom of the transverse image which is at the level of the carpometacarpal joint.



Diagnosis:

Carpometacarpal joint partial ankylosis and osteoarthritis, left forelimb

Comparison of subjective and objective lameness exam findings:

There was agreement between the subjective lameness exam, Lameness Locator® exam, and force plate exam at the walk and trot in the initial lameness evaluation and all these methods identified that there was a significant improvement in the lameness with intra-articular analgesia of the middle carpal joint (which communicates with the carpometacarpal joint).

Main points for clinical gait analysis from Horse 1:

In addition to the agreement between the exam at the trot, the force plate exam at the walk highlighted changes to the hindlimbs in response to blocking that may be representative of compensatory changes.

The force plate at the walk showed a greater increase in vertical impulse of the left forelimb in response to the intra-articular analgesia of the middle carpal joint. After this forelimb block, the force plate at the walk also showed an increase in left hindlimb heel PVF and decreased midstance PVF, which may be indicative of an underlying left hindlimb lameness.

Based on the changes in the left hind limb following the left forelimb blocks on the Lameness Locator® and force plate at the walk, there may have been an underlying secondary lameness in the left hindlimb. It is also possible that the remaining left forelimb lameness could be confounded by compensation for an ipsilateral hindlimb lameness. A limitation to this hypothesis is that no further force plate data was collected after the left forelimb abaxial nerve block.

2.3.2 Horse 2

Signalment and use:

Horse 2, an 11-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings:

Forelimbs: On the right forelimb, there was mild-moderate coffin joint effusion, mild sensitivity to palpation of proximal suspensory ligament, sensitivity to palpation of the deep digital flexor tendon between the heel bulbs (medially greater than laterally). On the left forelimb, there was mild to moderate coffin joint effusion, mild sensitivity to the proximal suspensory ligament, and mild sensitivity to palpation of the palmar pastern. She was negative to hoof testers bilaterally.

Hindlimbs: On the right hindlimb, there was mild effusion of the medial femorotibial joint effusion, mild femoropatellar effusion. On the left hindlimb, there was mild medial femorotibial, mild femoropatellar and mild tibiotarsal effusion. There was mild fetlock effusion. The LH pastern had mild sensitivity to palpation. There was a mild to moderate positive on the RH and a mild to moderate positive on the LH to the Churchill distal hock test. There was mild sensitivity to palpation of epaxial muscles along the left side at the thoracolumbar junction. There was also sensitivity to palpation of the lumbar epaxial muscles on the right side.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 1- 2 RF (worsened as continued exam), grade 1-2 LH

Baseline Lameness Locator® exam findings in a straight line:

There was moderate evidence of a mild RF midstance lameness and moderate evidence of mild LH push-off lameness (Table 2.3.2.1 and Figure 2.3.2.1). The impact lameness in the

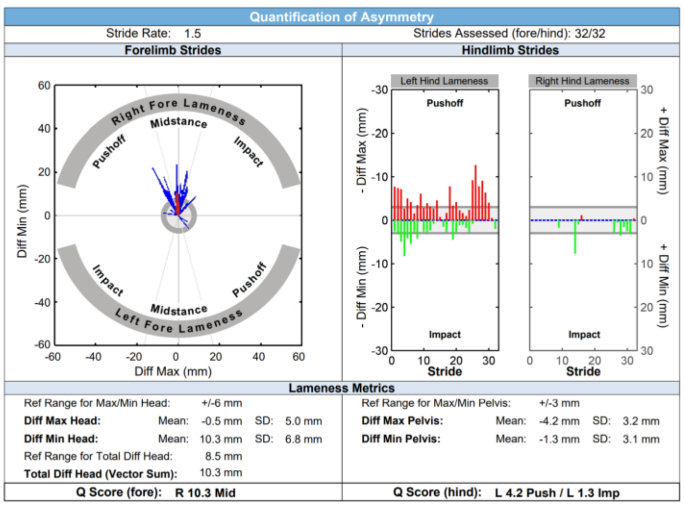
LH was within normal limits (< 3mm). The trial aid indicated there was insufficient evidence to suggest which limb is primary.

Table 2.3.2.1: Horse 2 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	**Trial 2**	**Baseline (Mean ± SD)**
Vector Sum (mm)	11.1 (R)	10.3 (R)	10.7 ± (R)
Diff min Pelvis (mm)	2.4 ± 2.1 (L)*	1.3 ± 3.1 (L)*	1.9 ± 2.6 (L)*
Diff max Pelvis (mm)	5.5 ± 2.5 (L)	4.2 ± 3.2 (L)	4.9 ± 2.9 (L)

*Below the 3mm threshold for lameness

Figure 2.3.2.1: Horse 2 baseline Lameness Locator® summary from Trial 2 in a straight line.



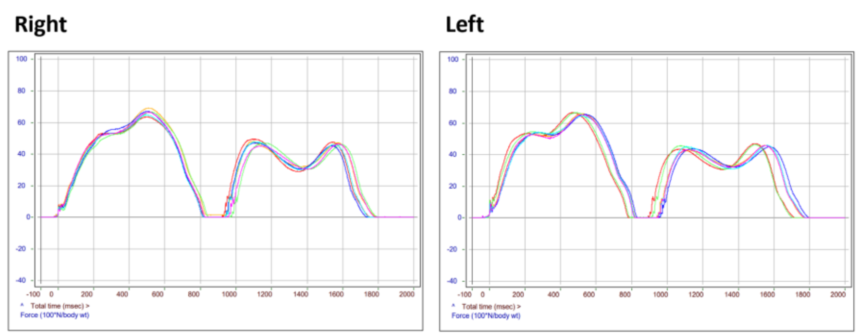
<u>*Baseline force plate exam findings (after lunge)*</u>*:*

Walk: There were 6 walk trials analyzed for all four limbs (Table 2.3.2.2 and Figure 2.3.2.2). The RF midstance PVF was increased relative to the heel PVF compared to the contralateral forelimb. The right forelimb heel PVF was decreased compared to the heel PVF on the left forelimb, suggesting a right forelimb lameness. The left hindlimb had decreased heel PVF, increased MsPVF and decreased VI compared to the contralateral hindlimb. This is supportive of a left hindlimb lameness.

Table 2.3.2.2: Horse 2 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.248 ± 0.114	5.243 ± 0.128	6.505 ± 0.187	3.512 ± 0.082
Left	5.273 ± 0.079	5.093 ± 0.112	6.448 ± 0.083	3.518 ± 0.042
Symmetry	1.00	0.97	0.99	1.00
HIND				
Right	4.673 ± 0.141	2.987 ± 0.097	4.570 ± 0.079	2.672 ± 0.060
Left	4.325 ± 0.120	3.088 ± 0.083	4.513 ± 0.062	2.603 ± 0.040
Symmetry	0.93	1.03	0.99	0.97

Figure 2.3.2.2: Horse 2 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=6) and left (n=6) limbs at baseline. Vertical impulse is the area under the curve.

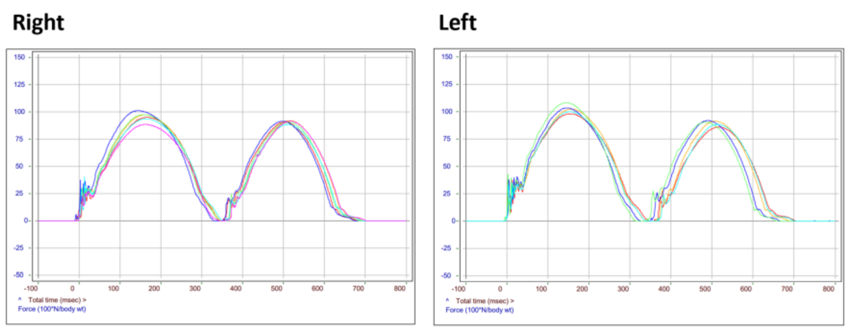


Trot: There were six trials analyzed for the right limbs and 5 trials analyzed for the left limbs (Table 2.3.2.3 and Figure 2.3.2.3). The RF had decreased PVF and VI compared to the LF. The symmetry scores supported the presence of a RF and LH limb lameness. The symmetry score for the forelimb PVF was 93%, where the RF was less than the LF, and the fore VI was 98% where the RF was less than the LF. The hindlimb symmetry scores were 99% for PVF and 97% for VI, where the LH <RH. Additionally, the fore to hind ratios increased for the right limbs. The PVF of the right hind was increased relative to the right forelimb. The combination of these findings suggests a right forelimb lameness.

Table 2.3.2.3: Horse 2 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	9.387 ± 0.418	1.993 ± 0.077	8.922 ± 0.121	1.602 ± 0.029	0.95	0.80	0.89	0.78
Left	10.066 ± 0.381	2.034 ± 0.036	8.798 ± 0.239	1.556 ± 0.015	0.87	0.77	0.94	0.78
Symmetry	1.07	1.02	0.99	0.97				

Figure 2.3.2.3: Horse 2 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=6) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at a walk: Six unobstructed video trials were analyzed for each limb (Table 2.3.2.4). The fetlock extension for the forelimbs and hindlimbs were symmetrical, respectively, which would suggest that the horse is sound.

Table 2.3.2.4: Horse 2 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	**LF**	**RH**	**LH**
Baseline Angle (degrees)	140.73	140.34	147.38	146.90
SD	1.07	1.28	2.05	1.81

Flexion test responses:

Forelimbs:

RF distal: mild positive.

LF distal: negative, worse lameness RF.

RF carpus: mild positive.

LF carpus: negative, worse lameness RF.

Hindlimbs:

RH distal limb: negative.

LH distal limb: negative.

RH full limb: mild positive.

LH full limb: mild positive.

Diagnostic Analgesia:

First block performed: RF palmar digital nerve (PDN) block

Subjective lameness exam post first block:

No improvement: worsening of the RF lameness as the exam continued.

Lameness Locator® exam post first block:

Lameness Locator® indicated a worsening of the right forelimb lameness and worsening of the left hindlimb lameness (Table 2.3.2.5).

Table 2.3.2.5: Horse 2 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post RF PDN block. The lame limb is highlighted in the parentheses.

	Baseline	**Post RF PDN**	**Percent change (%)**
Vector Sum (mm)	10.7 (R)	23.8 (R)	+122
Diff min Pelvis (mm)	1.9 (L)*	3.2 ± 1.5 (L)	+ 65*
Diff max Pelvis (mm)	4.9 (L)	7.2 ± 2.5 (L)	+ 47

*Below the 3mm threshold for lameness

Force plate exam post first block:

Force plate was not performed due to the worsening lameness.

Semi-quantitative fetlock extension at a walk post first block:

Fetlock extension was not performed due to the worsening lameness.

Second block performed: RF abaxial sesamoid nerve block

Subjective lameness exam post second block:

There was no improvement in the right forelimb lameness from the RF palmar digital nerve block.

Lameness Locator® exam post second block:

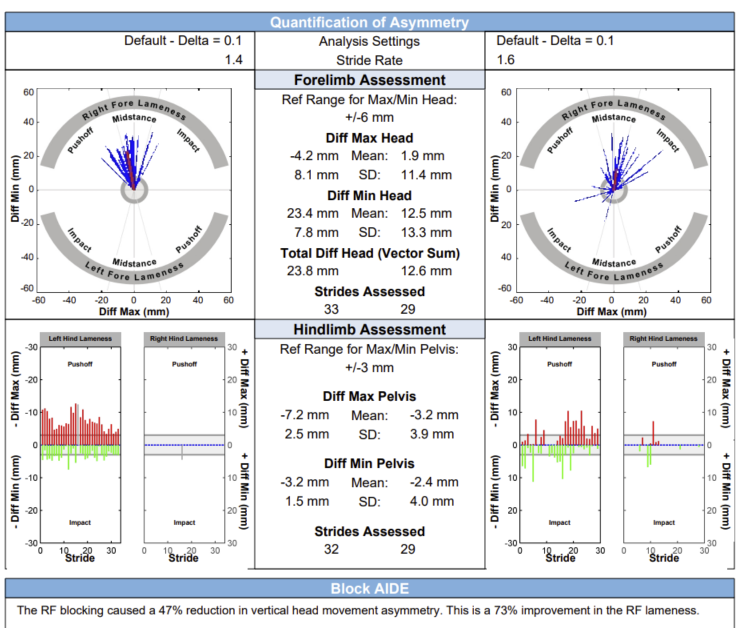
There was significant improvement with the RF abaxial block compared to the RF palmar digital nerve block, (Table 2.3.2.6 and Figure 2.3.2.4) but not the original baseline (mean vector sum of 10.7 mm on the R). There was also significant improvement in the left hindlimb lameness compared to the RF palmar digital nerve block.

Table 2.3.2.6: Horse 2 Lameness Locator® data in a straight line (mean ± SD) comparing post RF abaxial block to post RF PDN block. The lame limb is highlighted in the parentheses.

	Post RF PDN	Post RF Abaxial	Percent change (%)
Vector Sum (mm)	23.8 (R)	12.6 (R)	- 47
Diff min Pelvis (mm)	3.2 ± 1.5 (L)	2.4 ± 4.0 (L)*	-25*
Diff max Pelvis (mm)	7.2 ± 2.5 (L)	3.2 ± 3.9 (L)	-55

*Below the 3mm threshold for lameness

Figure 2.3.2.4: Horse 2 Lameness Locator ® block summary in a straight-line comparing post RF PDN block (left side of image) and post RF abaxial sesamoid perineural block (right side of image).



Force plate exam post second block:

Force plate was not performed due to the degree of lameness.

Semi-quantitative fetlock extension at a walk post second block:

Fetlock extension was not performed due to the degree of lameness.

Third block performed: RF low 4-point perineural block

Subjective lameness exam post third block:

There was a 50% improvement of RF lameness from the RF abaxial nerve block .

Lameness Locator® exam post third block:

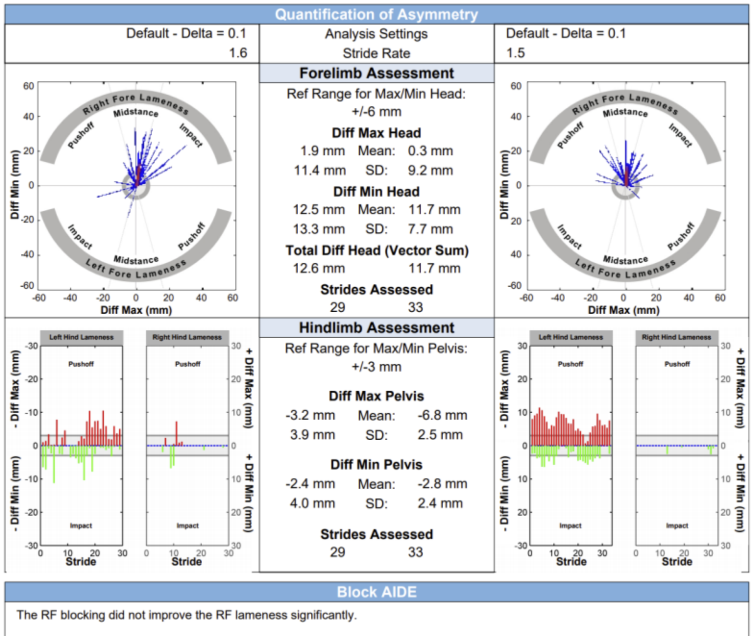
After the RF low four-point block, there was moderate evidence of mild RF midstance lameness. There was weak evidence of very mild LH impact asymmetry. There was also strong evidence of mild to moderate LH push-off lameness. There was insufficient evidence to suggest which limb was primary. There was no obvious improvement from the original baseline or following the RF abaxial nerve block (Table 2.3.2.7 and Figure 2.3.2.5). However, there was significant improvement compared to the right forelimb palmar digital nerve block. The left hindlimb lameness worsened compared to post RF abaxial nerve block.

Table 2.3.2.7: Horse 2 Lameness Locator® data in a straight line (mean) comparing post RF low 4-point block to post RF abaxial block (percent change calculated). Baseline data is included for convenience. The lame limb is highlighted in the parentheses.

	Baseline	**Post RF Palmar Digital**	**Post RF abaxial**	**Post RF low 4-point block**	**Percent change (%)**
Vector Sum (mm)	10.7 (R)	23.8 (R)	12.6 (R)	11.7 (R)	-7
Diff min Pelvis (mm)	1.9 (L)*	3.2 ± 1.5 (L)	2.4 (L)*	2.8 (L)*	*
Diff max Pelvis (mm)	4.9 (L)	7.2 ± 2.5 (L)	3.2 (L)	6.8 (L)	113

*Below the 3mm threshold for lameness

Figure 2.3.2.5: Horse 2 Lameness Locator® block summary in a straight-line comparing RF abaxial sesamoid perineural block (left side of image) and post RF low 4-point block (right side of image).



Force plate exam post third block:

Walk: Seven trials were analyzed for the right forelimb and hindlimb. Five trials were analyzed for the left forelimb and hindlimb (Tables 2.3.2.8-2.3.2.9 and Figure 2.3.2.6). The most significant changes were an increase in LF heel PVF and decreased midstance PVF of the RF compared to baseline. There is decreased midstance PVF of the right forelimb relative to the heel PVF compared to baseline, suggesting an improvement in the distribution of force. There was a decreased VI on both forelimbs compared to baseline. There is an increased heel PVF and decreased midstance PVF on both hindlimbs. This indicates a shift of forces within the hindlimbs that is closer to the distribution observed in a sound horse.

Table 2.3.2.8: Horse 2 force plate ground reaction forces at a walk post RF low 4-point block (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.230 ± 0.161	4.940 ± 0.159	6.534 ± 0.146	3.306 ± 0.077
Left	5.506 ± 0.130	4.918 ± 0.190	6.562 ± 0.132	3.292 ± 0.057
Symmetry	1.05	1.00	1.00	1.00
HIND				
Right	4.849 ± 0.174	2.786 ± 0.108	4.590 ± 0.099	2.513 ± 0.086
Left	4.658 ± 0.129	2.806 ± 0.104	4.612 ± 0.092	2.456 ± 0.078
Symmetry	0.96	1.01	1.00	0.98

Figure 2.3.2.6: Horse 2 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=7) and left (n=5) limbs post RF low 4-point block. Vertical impulse is the area under the curve.

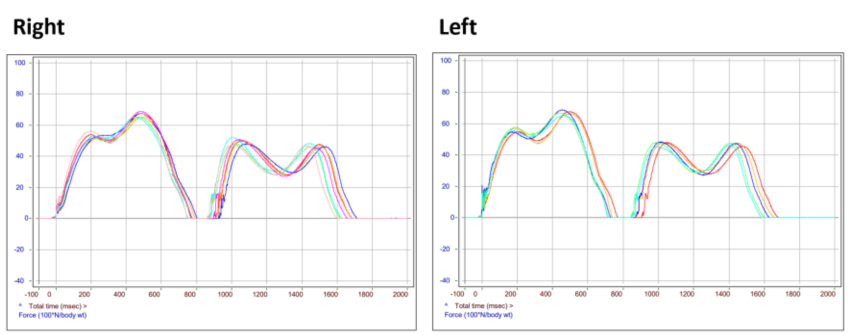


Table 2.3.2.9: Horse 2 force plate ground reaction forces at a walk (mean) comparing baseline and post RF low 4-point block measurements. Ms=Midstance.

	RF Baseline	RF post RF Low 4-point block	Percent change (%)	LF Baseline	LF post RF Low 4-point block	Percent change (%)
Heel PVF(N/kg)	5.248	5.230	0	5.273	5.506	4
Midstance PVF (N/kg)	5.243	4.940	-6	5.093	4.918	-3
Toe PVF (N/kg)	6.505	6.534	0	6.448	6.562	2
VI (Ns/kg)	3.512	3.306	-6	3.518	3.292	-6
	RH Baseline	**RH post RF Low 4-point block**	**Percent change**	**LH Baseline**	**LH post RF Low 4-point block**	**Percent change**
Heel PVF(N/kg)	4.673	4.849	4	4.325	4.658	8
Midstance PVF (N/kg)	2.987	2.785	-7	3.088	2.806	-9
Toe PVF (N/kg)	4.570	4.590	0	4.513	4.612	2
VI (Ns/kg)	2.672	2.513	-6	2.603	2.456	-6

Trot: Five trials were analyzed for all four limbs (Tables 2.3.2.10 – 2.3.2.11 and Figure 2.3.2.7). There was an increased RF PVF after low four-point nerve block compared to baseline (trot data was not collected with the other blocks). Symmetry scores were altered compared to baseline. The PVF symmetry between the forelimbs increased. The fore PVF symmetry suggested a left forelimb lameness. The right forelimb vertical impulse remained lower than the left forelimb. The hindlimb symmetry was similar to baseline.

Table 2.3.2.10: Horse 2 force plate ground reaction forces at a trot (mean ± SD) post RF low point block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	9.878 ± 0.252	1.882 ± 0.057	9.018 ± 0.165	1.520 ± 0.087	0.91	0.81	0.93	0.78
Left	9.690 ± 0.367	1.958 ± 0.056	8.768 ± 0.304	1.548 ± 0.036	0.91	0.79	0.89	0.82
Symmetry	0.98	1.04	0.97	1.02				

Figure 2.3.2.7: Horse 2 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post RF low 4-point block. Vertical impulse is the area under the curve.

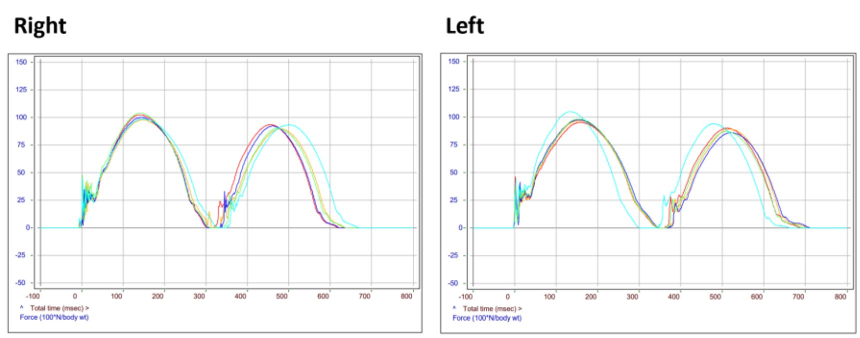


Table 2.3.2.11: Horse 2 force plate ground reaction forces at a trot (mean) comparing baseline and post RF low 4-point block measurements.

	RF Baseline	RF post RF Low 4-point block	Percent change (%)	LF Baseline	LF post RF Low 4-point block	Percent change (%)
Fore PVF (N/kg)	9.386	9.878	5	10.066	9.690	-4
Fore VI (Ns/kg)	1.993	1.882	-6	2.034	1.958	-4
	RH Baseline	**RH post RF Low 4-point block**	**Percent change (%)**	**LH Baseline**	**LH post RF Low 4-point block**	**Percent change (%)**
Hind PVF (N/kg)	8.922	9.018	1	8.798	8.768	0
Hind VI (Ns/kg)	1.602	1.520	-5	1.556	1.548	-1

Semi-quantitative fetlock extension post third block: Five unobstructed video trials were analyzed for the left forelimb and hindlimb. Seven unobstructed video trials were analyzed for the right forelimb and hindlimb (Table 2.3.2.12). There was decreased fetlock extension in the LF after the RF low four-point block, but the fetlock extension in the RF remained similar. There was also decreased fetlock extension in the left hindlimb. This is suggestive of compensatory shift when combined with the other technology measurements. The decreased fetlock extension in the left forelimb aligns with the decreased force in the left forelimb after blocking the right forelimb.

Table 2.3.2.12: Horse 2 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post RF low 4-point block with comparison to baseline.

	RF	LF	RH	LH
Angle Post RF low 4-point block	141.12 ± 1.48	143.98 ± 2.06	147.96 ± 1.64	149.25 ± 3.12
Baseline angle	140.73	140.34	147.38	146.90
Percent change (%)	0	3	0	2

<u>Subjective clinical assessment for the third block:</u>

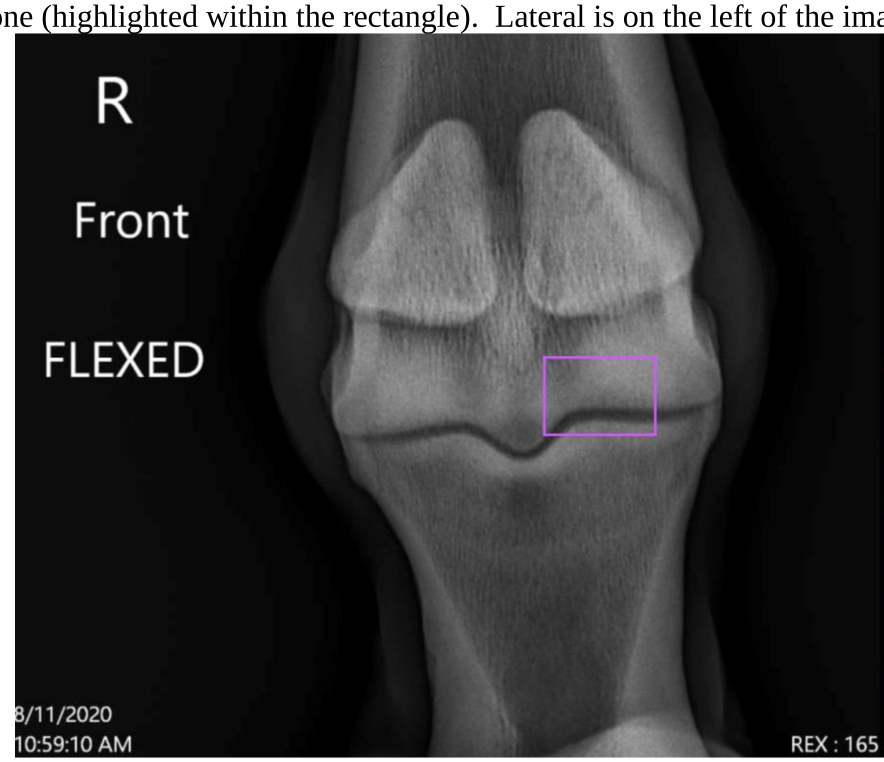
The subjective clinical assessment of the RF low four-point block was a 50% improvement in the RF limb lameness. This level of improvement was deemed significant based on the degree of subjective improvement after an initial worsening of lameness during the initial right forelimb palmar digital nerve block. The fetlock was identified as the region of interest for diagnostic imaging due to the improvement gained between the abaxial nerve block and low four-point block.

<u>Diagnostic Imaging:</u>

Radiographs:

<u>RF fetlock series</u>: Decreased semi-circular opacity at the axial aspect of the medial condyle of the right front third metacarpal bone on the flexed dorsopalmar view (Figure 2.3.2.8).

Figure 2.3.2.8: Flexed (125-degree) dorsopalmar radiographic view of RF fetlock with decreased semilunar opacity at the axial aspect of the medial condyle of the right front third metacarpal bone (highlighted within the rectangle). Lateral is on the left of the image.

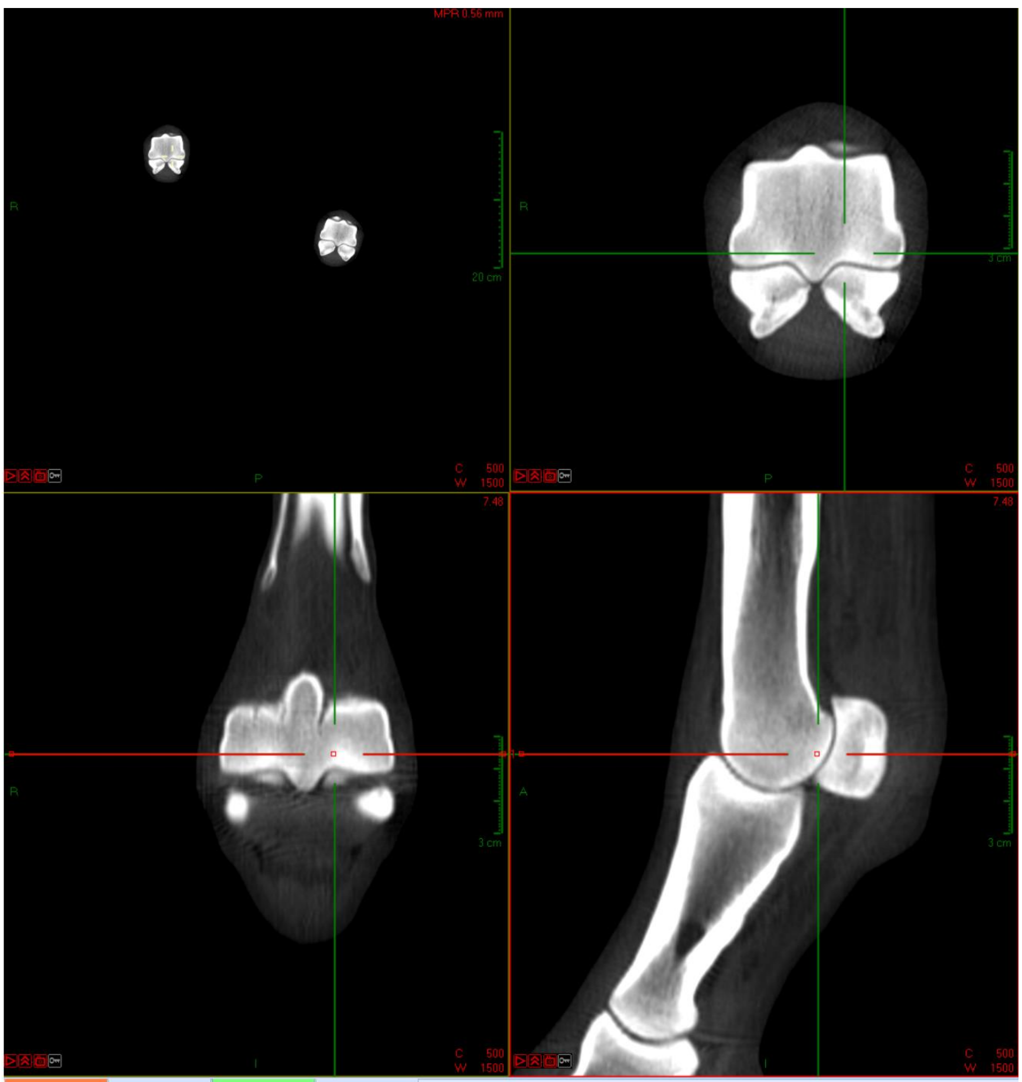


Bilateral hock series: There was a small medial osteophyte on central tarsal bone over the distal intertarsal joint bilaterally. The remainder of radiographs were within normal limits.

Computed Tomography:

Bilateral forelimb CT: Sclerosis at the axial aspect of the medial condyle of the right front third metacarpal bone (Figure 2.3.2.9).

Figure 2.3.2.9: CT of right forelimb fetlock in the transverse plane (upper 2 images), frontal plane (lower left image) and sagittal plane (lower right image) with crosshairs centered on the axial medial condyle demonstrating sclerosis.



<u>Diagnosis:</u>

Subchondral semicircular demineralization (hypodensity) and surrounding sclerosis of the third metacarpal medial condyle, right forelimb.

Comparison of subjective and objective lameness exam findings:

The subjective lameness exam determined there was a 50% improvement in the RF lameness after the low four-point block. The force plate findings support this improvement of the RF lameness from baseline with an increase in the RF PVF at the trot and the walk after the low four-point block. However, the Lameness Locator® findings did not show an improvement in the RF lameness compared to baseline. Instead, it demonstrated improvement after the abaxial nerve block when compared to the worsening lameness after the PDN block, but not to baseline. It also indicated a worsening of the LH lameness after the RF low four-point block. This is supported by the decreased PVF at the trot in the left hindlimb after the RF low four-point block compared to baseline.

Main points for clinical gait analysis from Horse 2:

There was agreement in subjective assessment and the Lameness Locator® data in the worsening of the RF lameness as the exam continued despite the initial blocking. However, the Lameness Locator® showed the greatest improvement in the lameness after the abaxial nerve block on the right forelimb. The Lameness Locator® did not support the subjectively noted improvement in the RF lameness after the RF low four-point block. There was agreement between subjective assessment and the objective kinetic data. Force plate data supported the improvement in the RF lameness after the RF low four-point block with both an increased in RF PVF at the trot and improvement in distribution of force between the heel, midstance and toe at the walk.

Although the fetlock extension in the RF remained similar, there was less fetlock extension in the LF after the RF low four-point block compared to baseline. However, the small degree of change makes this interpretation difficult.

A major limitation in this exam is that the force plate exam was not performed for the initial two blocks. However, welfare of the horse was prioritized, and investigators elected not to perform the lengthy force plate exam with a worsening forelimb lameness. The force plate may have been helpful in this case because of the ultimate diagnosis of a subchondral bone demineralization with surrounding sclerosis. There could be additional musculoskeletal soreness from compensation secondary to the duration and severity of lameness that contributed to a residual right forelimb lameness in the kinematic data when comparing that to the kinetic data. This could explain the greater improvement in the pure forces applied to the limb when compared to symmetry of movement.

2.3.3 Horse 3

Signalment and use:

Horse 3, a 19-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings: Shoes on all 4 feet with bubble pads.

Forelimbs: There was mild sensitivity to palpation of the proximal suspensory ligament, and mild coffin joint effusion bilaterally

Hindlimbs: There was mild-moderate effusion of the tibiotarsal joint bilaterally. On the LH, there was mild fetlock effusion and mild digital flexor tendon sheath effusion. Mild sensitivity over the trochanteric bursa was present bilaterally (Left greater than right). The Churchill test for distal hock pain was mildly positive bilaterally. She had mild sensitivity to palpation of the epaxial muscles in the thoracic through lumbar region and mild sensitivity to palpation of gluteal muscles bilaterally, but the response on the right side was greater than left side.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 2 RF and Grade 2 LH

Baseline Lameness Locator® exam findings:

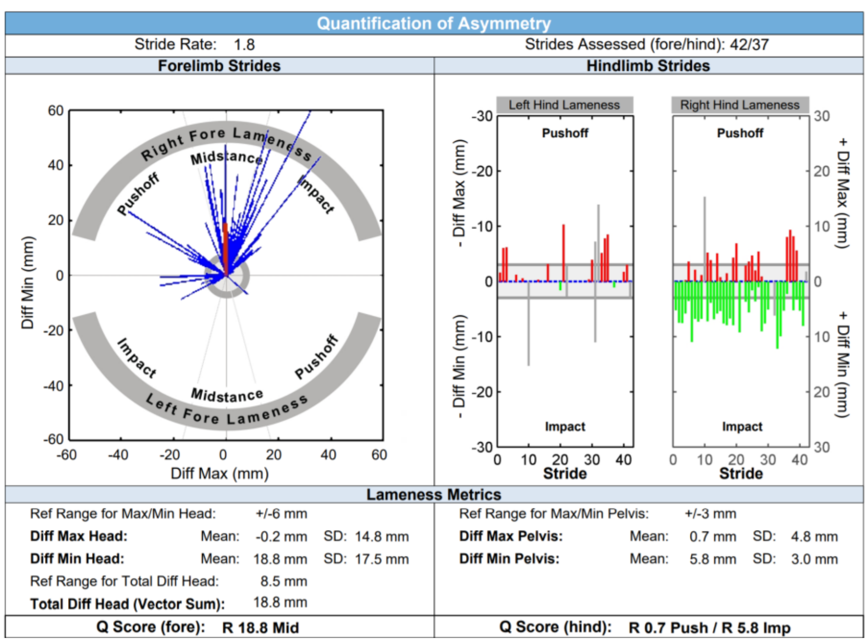
Straight line: On trial 1, there was moderate evidence of a mild RF lameness (Table 2.3.3.1 and Figure 2.3.3.1). There was weak evidence of a mild RH impact lameness. On the second trial, there was moderate evidence of a mild to moderate RF midstance lameness. There was moderate evidence of mild RH impact lameness. For both trials, the trial aide indicated that there was insufficient evidence to suggest which limb is primary.

Table 2.3.3.1: Horse 3 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	Trial 2	Mean baseline
Vector sum (mm)	16.6 (R)	18.8 (R)	17.7 ± 1.56 (R)
Diff min pelvis (mm)	3.4 ± 4.4 (R)	5.8 ± 3.0 (R)	4.6 ± 3.70 (R)
Diff max pelvis (mm)	1.1 ± 4.1 (R)*	0.7 ± 4.8 (R)*	0.9 ± 4.45 (R)*

*Asymmetry is below 3mm threshold for hindlimb lameness

Figure 2.3.3.1: Horse 3 baseline Lameness Locator® summary from Trial 2 in a straight line.



Baseline force plate exam findings:

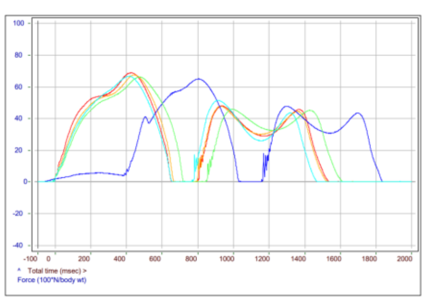
Walk: Five trials were analyzed for all limbs (Table 2.3.3.2 and Figure 2.3.3.2). The right front had a decreased heel PVF and increased midstance PVF relative to heel PVF. The left front had an increased heel PVF and midstance PVF compared to reference ranges. These findings are suggestive of a right forelimb lameness. Right hind had an increased heel PVF and decreased ratio of midstance PVF to heel PVF. The left hind had increased heel PVF. These findings are suggestive of compensatory changes on the hindlimb to compensate for the forelimb lameness. The symmetry scores for forelimb heel PVF, midstance PVF and VI are supportive of a RF lameness.

Table 2.3.3.2: Horse 3 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

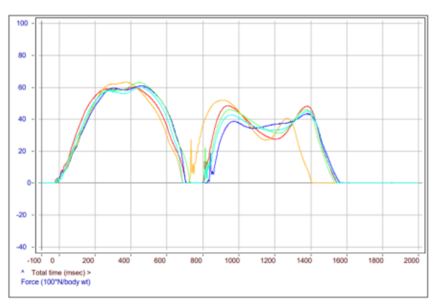
FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.340 ± 0.219	5.410 ± 0.207	6.562 ± 0.141	2.960 ± 0.111
Left	5.836 ± 0.147	5.744 ± 0.205	6.032 ± 0.162	2.976 ± 0.100
Symmetry	1.09	1.06	0.92	1.01
HIND				
Right	4.740 ± 0.196	2.910 ± 0.234	4.638 ± 0.209	2.322 ± 0.113
Left	4.486 ± 0.499	3.000 ± 0.315	4.392 ± 0.285	2.350 ± 0.076
Symmetry	0.95	1.03	0.95	1.01

Figure 2.3.3.2: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.

Right Walk Baseline



Left Walk Baseline

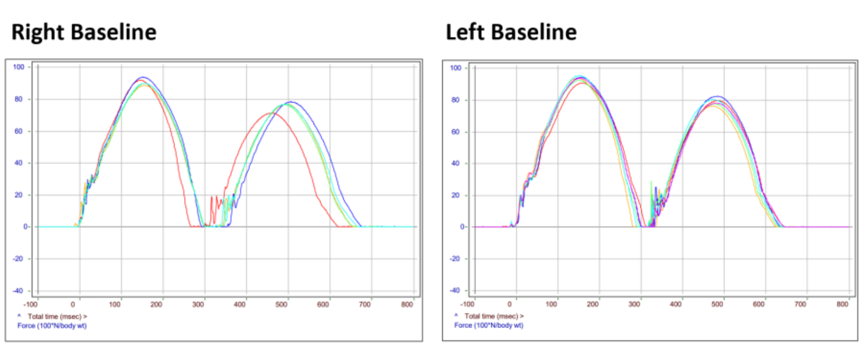


Trot: Six trials of the left forelimb and hindlimb and five trials of the right forelimb and hindlimb were analyzed (Table 2.3.3.3 and Figure 2.3.3.3). The RF had decreased PVF and VI compared to the left forelimb. There was increased hind VI relative to forelimb VI bilaterally compared to control horses (0.77 ± 0.03) . This suggests that there is a bilateral forelimb lameness. Symmetry scores indicated a right forelimb and right hindlimb lameness.

Table 2.3.3.3: Horse 3 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	8.916 ± 0.200	1.646 ± 0.066	7.464 ± 0.267	1.388 ± 0.075	0.84	0.84	0.81	0.80
Left	9.168 ± 0.164	1.738 ± 0.033	7.758 ± 0.216	1.422 ± 0.060	0.85	0.82	0.87	0.86
Symmetry	1.03	1.06	1.04	1.02				

Figure 2.3.3.3: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at a walk: There were 5 unobstructed video trials for the right limbs and for the left hind limb. There were 4 unobstructed video trials for the left forelimb (Table 2.3.3.4). The forelimbs had symmetrical fetlock extension.

Table 2.3.3.4: Horse 3 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	LF	RH	LH
Baseline angle (degrees)	136.55	137.11	144.96	143.72
SD	4.86	2.15	2.81	3.41

Diagnostic Analgesia:

First block performed: Right forelimb palmar digital nerve (PDN) block

Subjective lameness exam post first block:

The horse switched from a RF lameness to Grade 2 LF lameness. No hindlimb lameness was noted.

Lameness Locator® exam post first block:

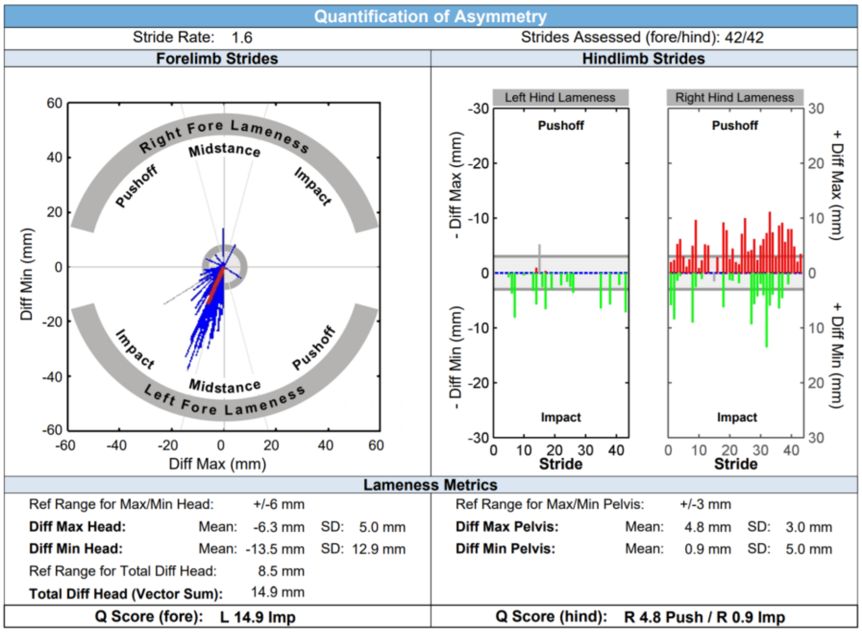
There was moderate evidence of a mild LF impact lameness and there was also moderate evidence of a mild RH push-off lameness. No impact lameness was indicated (Table 2.3.3.5 and Figure 2.3.3.4). The most predominant lameness was a left forelimb lameness meaning that the primary lameness switched to the contralateral forelimb after the RF palmar digital nerve block.

Table 2.3.3.5: Horse 3 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post RF PDN block. The lame limb is highlighted in the parentheses.

	Baseline	Post RF PDN block	Percent change (%)
Vector sum (mm)	17.7 (R)	14.9 (L)	^
Diff min pelvis (mm)	4.6 (R)	0.9 ± 5.0 (R)*	-80*
Diff max pelvis (mm)	0.9 (R)*	4.8 ± 3.0 (R)	433*

*Asymmetry was below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb

Figure 2.3.3.4: Horse 3 Lameness Locator® summary in a straight-line post RF palmar digital nerve block.



Force plate exam post first block

Walk: Five trials were analyzed for all limbs (Tables 2.3.3.6–2.3.3.7 and Figure 2.3.3.5). The right forelimb had increased VI with the RF PDN compared to baseline. The right forelimb had minimally decreased heel and midstance PVF from baseline. Left forelimb had minimally decreased heel and MS PVF from baseline that was similar in magnitude to the changes in the right forelimb. Although the values for the forelimb PVF decreased from baseline, the forelimb heel and midstance PVF symmetry scores were maintained from baseline. This is indicating that there is remaining abnormal force distribution in both forelimbs. The symmetry score for forelimb VI indicated a LF lameness. The right hindlimb had decreased heel PVF and midstance PVF compared to baseline. The left hindlimb had decreased heel PVF and increased VI compared to baseline. This is suggestive of a compensatory shift as there was decreased force in the hindlimbs after the primary forelimb lameness improved with the RF palmar digital nerve block.

Table 2.3.3.6: Horse 3 force plate ground reaction forces at a walk (mean ± SD) post RF palmar digital nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.224 ± 0.176	5.204 ± 0.185	6.492 ± 0.212	3.144 ± 0.121
Left	5.696 ± 0.211	5.586 ± 0.158	6.050 ± 0.084	3.058 ± 0.051
Symmetry	1.09	1.07	0.94	0.97
HIND				
Right	4.530 ± 0.117	2.870 ± 0.172	4.514 ± 0.117	2.338 ± 0.162
Left	4.238 ± 0.189	3.098 ± 0.066	4.532 ± 0.101	2.448 ± 0.041
Symmetry	0.94	1.08	1.00	1.05

Figure 2.3.3.5: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post RF palmar digital nerve block. The vertical impulse is the area under the curve.

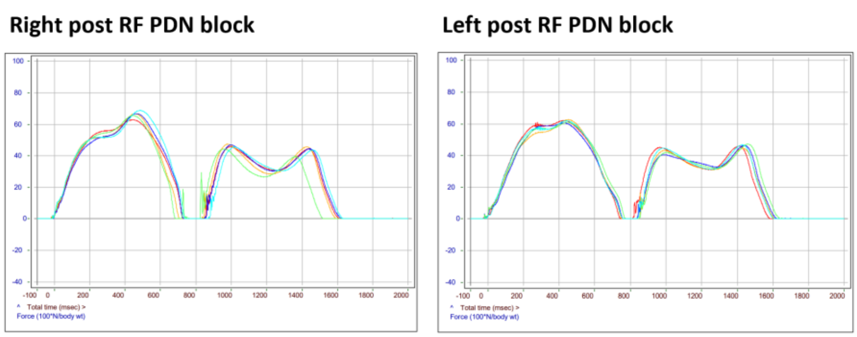


Table 2.3.3.7: Horse 3 force plate ground reaction forces at a walk (mean) comparing baseline and post RF palmar digital nerve block measurements. Ms=Midstance.

	RF Baseline	**RF post RF PDN block**	**Percent change (%)**	**LF Baseline**	**LF post RF PDN block**	**Percent change (%)**
Heel PVF (N/kg)	5.342	5.224	-2	5.836	5.696	-2
MsPVF (N/kg)	5.414	5.204	-4	5.744	5.586	-3
Toe PVF (N/kg)	6.562	6.492	-1	6.032	6.05	0
VI (Ns/kg)	2.960	3.144	6	2.976	3.058	3
	RH Baseline	**RH post RF PDN block**	**Percent change (%)**	**LH Baseline**	**LH post RF PDN block**	**Percent change (%)**
Heel PVF (N/kg)	4.740	4.526	-5	4.486	4.238	-6
MsPVF (N/kg)	2.910	2.874	-1	3.000	3.098	3
Toe PVF (N/kg)	4.638	4.514	-3	4.392	4.532	3
VI (Ns/kg)	2.322	2.338	1	2.350	2.448	4

Trot: Six trials were analyzed for the left limbs and five trials were analyzed for the right limbs (Tables 2.3.3.8–2.3.3.9 and Figure 2.3.3.6). The RF had markedly increased PVF and VI after the RF PDN compared to baseline indicating that the right forelimb lameness improved with the RF palmar digital nerve block. This indicated The LF had minimal change from baseline. Both hindlimbs had increased PVF from baseline supporting that there is still forelimb lameness and there is increased PVF as a result of compensation for the forelimb lameness. Forelimb symmetry scores supported a left forelimb lameness. Additionally, the hindlimb to forelimb PVF ratios supported a left forelimb lameness as the hindlimb PVF was a greater percentage of the left forelimb PVF compared to the ratio of hindlimb to right forelimb force. Symmetry scores for hindlimb PVF and VI support a right hindlimb lameness.

Table 2.3.3.8: Horse 3 force plate ground reaction forces at a trot (mean ± SD) post RF palmar digital nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	10.128 ± 0.234	1.754 ± 0.047	7.866 ± 0.119	1.360 ± 0.037	0.78	0.78	0.86	0.80
Left	9.165 ± 0.200	1.705 ± 0.063	8.067 ± 0.028	1.445 ± 0.048	0.88	0.84	0.80	0.82
Symmetry	0.90	0.97	1.03	1.06				

Figure 2.3.3.6: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs post RF palmar digital nerve block. Vertical impulse is the area under the curve.

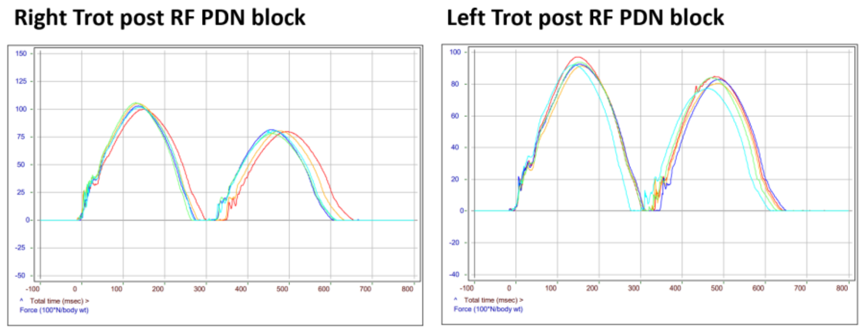


Table 2.3.3.9: Horse 3 force plate ground reaction forces at a trot (mean) comparing baseline and post RF palmar digital nerve block measurements.

	RF Baseline	**RF post RF PDN block**	**Percent change (%)**	**LF Baseline**	**LF post RF PDN block**	**Percent change (%)**
PVF (N/kg)	8.916	10.128	14	9.168	9.165	0
VI (Ns/kg)	1.646	1.754	7	1.738	1.705	-2
	RH Baseline	**RH post RF PDN block**	**Percent change (%)**	**LH Baseline**	**LH post RF PDN block**	**Percent change (%)**
PVF (N/kg)	7.464	7.866	5	7.758	8.067	4
VI (Ns/kg)	1.388	1.360	-2	1.422	1.445	2

Semi-quantitative Fetlock extension at a walk post first block: There were 5 unobstructed video trials of all four limbs (Table 2.3.3.10). There was an increased fetlock extension of the RF, with similar fetlock extension for the LF, RH and LH compared to baseline. This is supportive of improvement in the right forelimb lameness, but it must be acknowledged that there is a high standard deviation for all measurements.

Table 2.3.3.10: Horse 3 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post RF palmar digital nerve block with comparison to baseline.

	RF	LF	RH	LH
Post RF PDN block	133.38 ± 2.48	137.68 ± 2.59	143.28 ± 2.73	143.14 ± 3.36
Baseline (degrees)	136.55	137.11	144.96	143.72
Percent change (%)	-2	0	-1	0

<u>Subjective clinical assessment for 1st block</u>:

The first block switched the lameness from a RF lameness to a LF lameness. Due to the degree of lameness exhibited in the left forelimb, blocking of the left forelimb was indicated because there was suspicion of a bilateral forelimb disease process. The next block performed was a left forelimb palmar digital nerve block.

<u>Second block performed</u>: LF palmar digital nerve (PDN) block.

Subjective lameness exam post second block:

The horse switched to grade 2/5 RF and 1/5 RH lameness.

Lameness Locator® exam post second block:

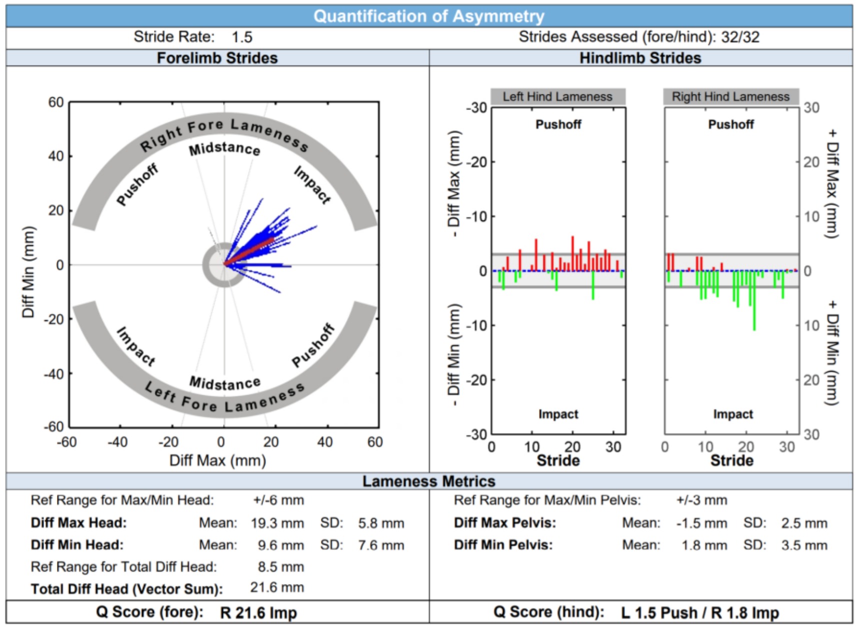
There was moderate evidence of a mild to moderate RF impact lameness (Table 2.3.3.11 and Figure 2.3.3.7). There was no evidence of a hindlimb lameness.

Table 2.3.3.11: Horse 3 Lameness Locator ® data in a straight line (mean ± SD) comparing post LF PDN block to post RF PDN block. The lame limb is highlighted in the parentheses.

	Post RF PDN block	Post LF PDN block	Percent change (%)
Vector sum (mm)	14.9 (L)	21.6 (R)	^
Diff min pelvis (mm)	0.9 ± 5.0 (R)*	1.8 ± 3.5 (R)*	100%*
Diff max pelvis (mm)	4.8 ± 3.0 (R)	1.5 ± 2.5 (L)*	*^

*Below 3mm threshold for lameness
^Lameness switched to contralateral limb

Figure 2.3.3.7: Horse 3 Lameness Locator® summary in a straight-line post LF PDN block.



Force plate exam post second block

Walk: Five trials were analyzed for all four limbs (Tables 2.3.3.12–2.3.3.13 and Figure 2.3.3.8). With the LF PDN block, the RF had decreased heel PVF, MsPVF, toe PVF and decreased VI compared to the RF PD. The RF midstance to heel PVF ratio increased from 99.6% to 103% from the previous block data. This indicates that the weight is shifted toward the midstance phase from the heel. The LF had a decreased midstance to heel PVF ratio compared to the RF PDN block. The RH VI increased compared to the RF PDN. The LH heel PVF decreased and the midstance PVF increased. This is supportive of a right forelimb and left hindlimb lameness.

Table 2.3.3.12: Horse 3 force plate ground reaction forces at a walk (mean ± SD) post LF palmar digital nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	4.984 ± 0.323	5.120 ± 0.204	6.236 ± 0.080	2.980 ± 0.024
Left	5.620 ± 0.221	5.500 ± 0.176	5.952 ± 0.103	3.040 ± 0.079
Symmetry	1.13	1.07	0.95	1.02
HIND				
Right	4.596 ± 0.167	2.898 ± 0.229	4.566 ± 0.209	2.400 ± 0.057
Left	4.140 ± 0.147	3.138 ± 0.075	4.334 ± 0.103	2.404 ± 0.099
Symmetry	0.90	1.08	0.95	1.00

Figure 2.3.3.8: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post LF palmar digital nerve block. Vertical impulse is the area under the curve.

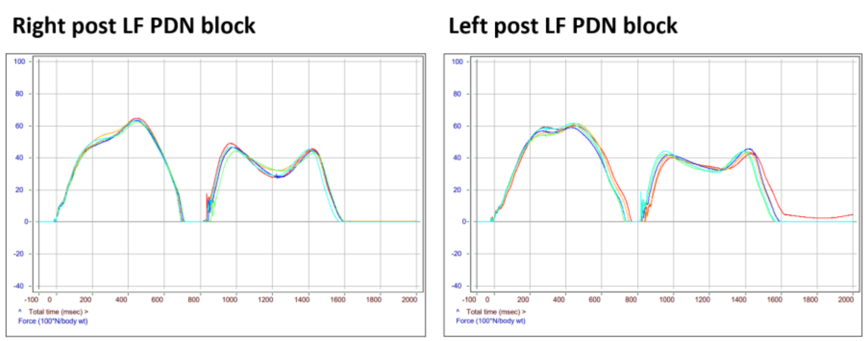


Table 2.3.3.13: Horse 3 force plate ground reaction forces at a walk (mean) comparing baseline, post RF palmar digital nerve block, and post LF palmar digital nerve block measurements. The percent change represents the difference between RF and LF palmar digital nerve blocks. Ms=Midstance.

	RF Baseline	**RF post RF PDN block**	**RF post LF PDN block**	**Percent change (%)**	**LF Baseline**	**LF post RF PDN block**	**LF post LF PDN block**	**Percent change (%)**
Heel PVF (N/kg)	5.342	5.224	4.984	-5	5.836	5.696	5.620	-1
MsPVF (N/kg)	5.414	5.204	5.120	-2	5.744	5.586	5.500	-2
Toe PVF (N/kg)	6.562	6.492	6.236	-4	6.032	6.050	5.952	-2
VI (Ns/kg)	2.960	3.144	2.980	-5	2.976	3.058	3.040	-1
	RH Baseline	**RH post RF PDN block**	**RH post LF PDN block**	**Percent change (%)**	**LH Baseline**	**LH post RF PDN block**	**LH post LF PDN block**	**Percent change (%)**
Heel PVF (N/kg)	4.740	4.526	4.596	2	4.486	4.238	4.140	-2
MsPVF (N/kg)	2.910	2.874	2.898	1	3.000	3.098	3.138	1
Toe PVF (N/kg)	4.638	4.514	4.566	1	4.392	4.532	4.334	-4
VI (Ns/kg)	2.322	2.338	2.400	3	2.350	2.448	2.404	-2

Trot: Five trials were analyzed for both right and left (Table 2.3.3.14–2.3.3.15 and Figure 2.3.3.9). The RF had decreased PVF and VI for the LF PDN compared to the RF PDN block. The LF had increased PVF and VI with the LF PDN block compared to RF PDN block. With the LF PDN, both hindlimbs had decreased PVF and VI compared to RF PDN block. The amalgamation of these findings supports a right forelimb lameness. There is evidence of a remaining hindlimb lameness of similar magnitude based on hindlimb symmetry scores for PVF and VI.

Table 2.3.3.14: Horse 3 force plate ground reaction forces at a trot (mean ± SD) post LF palmar digital nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	8.262 ± 0.152	1.558 ± 0.038	7.504 ± 0.198	1.328 ± 0.030	0.91	0.85	0.76	0.71
Left	9.842 ± 0.209	1.860 ± 0.070	7.916 ± 0.158	1.390 ± 0.038	0.80	0.75	0.96	0.89
Symmetry	1.19	1.19	1.05	1.05				

Figure 2.3.3.9: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post LF palmar digital nerve block. Vertical impulse is the area under the curve.

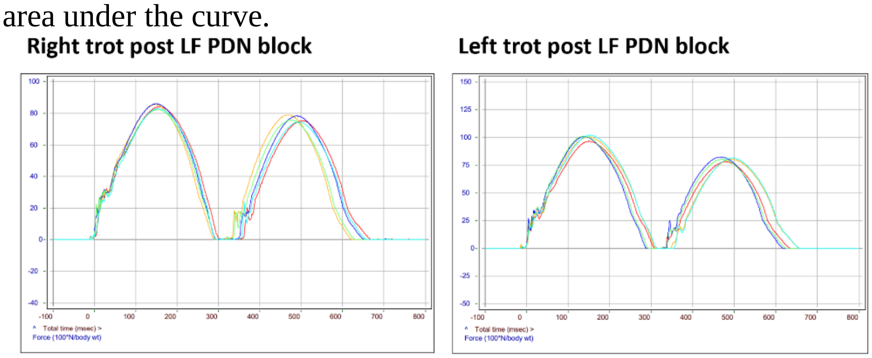


Table 2.3.3.15: Horse 3 force plate ground reaction forces at a trot (mean) comparing baseline, post RF palmar digital nerve block, and post LF palmar digital nerve block measurements. The percent change represents the difference between RF and LF palmar digital nerve blocks.

	RF Baseline	**RF post RF PDN**	**RF post LF PDN**	**Percent change (%)**	**LF Baseline**	**LF post RF PDN**	**LF post LF PDN**	**Percent change (%)**
PVF (N/kg)	8.916	10.128	8.262	-18	9.168	9.165	9.842	7
VI (Ns/kg)	1.646	1.754	1.558	-11	1.738	1.705	1.860	9
	RH Baseline	**RH post RF PDN**	**RH post LF PDN**	**Percent change (%)**	**LH Baseline**	**LH post RF PDN**	**LH post LF PDN**	**Percent change (%)**
PVF (N/kg)	7.464	7.866	7.504	-5	7.758	8.067	7.916	-2
VI (Ns/kg)	1.388	1.360	1.328	-2	1.422	1.445	1.390	-4

Semi-quantitative fetlock extension at walk post second block: There were 4 unobstructed video trials for the right forelimb, 5 unobstructed trials for the right hindlimb and left forelimb, and 6 unobstructed trials for the left hindlimb (Table 2.3.3.16). There was decreased fetlock extension in the RF, increased extension in the LF, decreased extension in the RH and LH. This is indicating a minimal change from the previous block, but slight improvement in the left forelimb lameness.

Table 2.3.3.16: Horse 3 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post LF palmar digital nerve block with comparison to post RF palmar digital nerve block.

	RF	**LF**	**RH**	**LH**
Post RF PDN block	133.38	137.68	143.28	143.14
Post LF PDN block	134.11± 2.38	136.59 ± 1.51	146.80 ± 3.17	145.38 ± 2.44
Percent change (%)	1	-1	2	2

Subjective clinical assessment for second block:

The left forelimb lameness switched back to a right forelimb lameness. A right forelimb abaxial nerve block should be performed next to desensitize structures below the fetlock joint.

<u>Third block performed</u>: RF abaxial block

Subjective lameness exam post third block:

There was a 75% improvement in the right forelimb lameness after the RF abaxial block. A hindlimb lameness was not noted.

Lameness Locator® exam post third block:

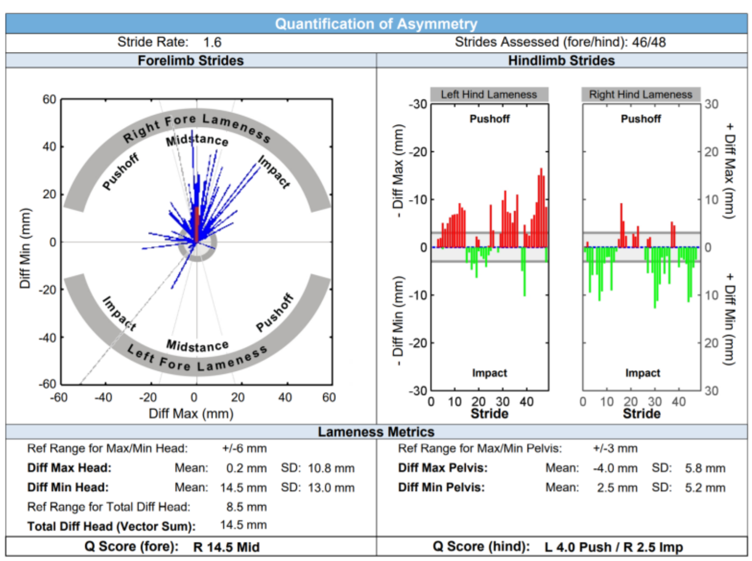
There was moderate evidence of a mild RF midstance lameness that was a 33% improvement in forelimb lameness. There was weak evidence of mild LH push-off lameness (Table 2.3.3.17 and Figure 2.3.3.10).

Table 2.3.3.17 Horse 3 Lameness Locator® data in a straight line (mean ± SD) comparing post RF abaxial block to post LF PDN block. The lame limb is highlighted in the parentheses.

	Post LF PDN block	Post RF abaxial block	Percent change (%)
Vector sum (mm)	21.6 (R)	14.5 (R)	33
Diff min pelvis (mm)	1.8 ± 3.5 (R)*	2.5 ± 5.2 (R)*	*
Diff max pelvis (mm)	1.5 ± 2.5 (L)*	4.0 ± 5.8 (L)	167*

* Asymmetry below 3mm threshold for hindlimb lameness

Figure 2.3.3.10: Horse 3 Lameness Locator® summary in a straight-line post RF abaxial nerve block.



Force Plate Exam Post Third Block

Walk: 5 trials were analyzed for all four limbs (Tables 2.3.3.18–2.3.3.19 and Figure 2.3.3.11). Compared to the LF PDN block, the RF had increased heel PVF, decreased MsPVF, and increased VI. The left forelimb had decreased heel PVF, MsPVF and toe PVF, and increased VI compared to the LF PDN. Heel PVF and midstance are decreased in the RF compared to the LF. The toe PVF and VI are decreased in the LF compared to the RF. The combined observations support an improvement in the right forelimb lameness compared to the previous block data. The hindlimb heel PVF decreased bilaterally and midstance PVF increased. This could be reflective of a compensatory change as the force in the hindlimb heel has decreased in response to forelimb blocking.

Table 2.3.3.18: Horse 3 force plate ground reaction forces at a walk (mean ± SD) post RF abaxial nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.066 ± 0.087	5.058 ± 0.085	6.194 ± 0.223	3.198 ± 0.150
Left	5.312 ± 0.075	5.318 ± 0.061	5.778 ± 0.097	3.120 ± 0.041
Symmetry	1.05	1.02	0.93	0.98
HIND				
Right	4.266 ± 0.258	3.126 ± 0.202	4.300 ± 0.170	2.556 ± 0.081
Left	4.118 ± 0.095	3.068 ± 0.070	4.514 ± 0.055	2.490 ± 0.071
Symmetry	0.97	0.98	1.05	0.97

Figure 2.3.3.11: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post RF abaxial nerve block. Vertical impulse is the area under the curve.

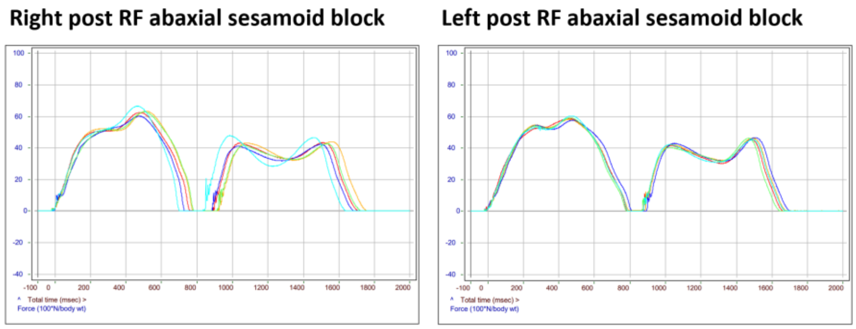


Table 2.3.3.19: Horse 3 force plate ground reaction forces at a walk (mean) comparing baseline, post LF palmar digital nerve block, and post RF abaxial nerve block measurements. The percent change represents the difference between LF palmar digital nerve block and the RF abaxial nerve block. Ms=Midstance.

	RF baseline	**RF post LF PDN block**	**RF post RF abaxial block**	**Percent change (%)**	**LF Baseline**	**LF post LF PDN block**	**LF post RF abaxial block**	**Percent change (%)**
Heel PVF (N/kg)	5.342	4.984	5.066	2	5.836	5.620	5.312	-5
MsPVF (N/kg)	5.414	5.120	5.058	-1	5.744	5.500	5.138	-7
Toe PVF (N/kg)	6.562	6.236	6.194	-1	6.032	5.952	5.778	-3
VI (Ns/kg)	2.960	2.980	3.198	7	2.976	3.040	3.120	3
	RH baseline	**RH post LF PDN block**	**RH post RF abaxial block**	**Percent change (%)**	**LH baseline**	**LH post LF PDN block**	**LH post RF abaxial block**	**Percent change (%)**
Heel PVF (N/kg)	4.740	4.596	4.266	-7	4.486	4.140	4.118	-1
MsPVF (N/kg)	2.910	2.898	3.126	8	3.000	3.138	3.068	-2
Toe PVF (N/kg)	4.638	4.566	4.300	-6	4.392	4.334	4.514	4
VI (Ns/kg)	2.322	2.400	2.556	7	2.350	2.404	2.49	4

Trot: Five trials were analyzed for all four limbs (Tables 2.3.3.20–2.3.3.21 and Figure 2.3.3.12). The RF had an increased PVF and VI with the RF abaxial nerve block compared to the LF PDN block. The LF had a decreased PVF and VI with the RF abaxial nerve block compared to the LF PDN block. The RH had and increased PVF and VI compared to the LF PDN block. The LH VI and PVF values were very similar to the previous block. Symmetry scores for the forelimbs and hindlimbs were improved compared to the left forelimb palmar digital nerve block. This is indicating an improvement in the right forelimb lameness with improved PVF and symmetry score with the left forelimb. The symmetry scores support a very mild left forelimb asymmetry compared to the degree of right forelimb lameness (1.19 symmetry score for a RF lameness after LF palmar digital nerve block).

Table 2.3.3.20: Horse 3 force plate ground reaction forces at a trot (mean ± SD) post RF abaxial nerve block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind: Fore PVF	Ipsilateral Hind: Fore VI	Contralat Hind: Fore PVF	Contralat Hind: Fore VI
Right	9.442 ± 0.093	1.710 ± 0.058	7.994 ± 0.116	1.404 ± 0.044	0.85	0.82	0.88	0.81
Left	9.054 ± 0.452	1.738 ± 0.054	7.846 ± 0.372	1.392 ± 0.014	0.87	0.80	0.83	0.81
Symmetry	0.96	1.02	0.98	0.99				

Figure 2.3.3.12: Horse 3 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post RF abaxial nerve block. Vertical impulse is the area under the curve.

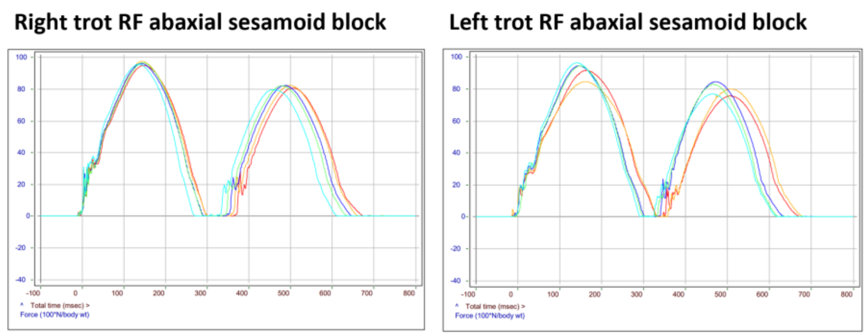


Table 2.3.3.21: Horse 3 force plate ground reaction forces at a trot (mean) comparing baseline, post LF palmar digital nerve block, and post RF abaxial nerve block. The percent change represents the difference between LF palmar digital nerve block and RF abaxial nerve block.

	RF Baseline	**RF post LF PDN block**	**RF post RF abaxial block**	**Percent change (%)**	**LF Baseline**	**LF post LF PDN block**	**LF post RF abaxial block**	**Percent change (%)**
PVF (N/kg)	8.916	8.262	9.442	14	9.168	9.842	9.054	-8
VI (Ns/kg)	1.646	1.558	1.71	10	1.738	1.860	1.738	-7
	RH Baseline	**RH post LF PDN block**	**RH post RF abaxial block**	**Percent change (%)**	**LH Baseline**	**LH post LF PDN block**	**LH post RF abaxial block**	**Percent change (%)**
PVF (N/kg)	7.464	7.504	7.994	7	7.758	7.916	7.846	-1
VI (Ns/kg)	1.388	1.328	1.404	6	1.422	1.390	1.392	0

Semi-quantitative fetlock extension at walk post third block: There were 5 unobstructed video trials of the right limbs and 8 unobstructed trials of the left limbs (Table 2.3.3.22). Measurements indicated an increased fetlock extension of the RF, decreased fetlock extension of the LF, and an increased fetlock extension of the RH and LH (RH is greater than LH). There has been minimal change, but this indicates a slight improvement in the right forelimb lameness. The RH fetlock extension is slightly greater but is symmetrical given the standard deviation present.

Table 2.3.3.22: Horse 3 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post RF abaxial nerve block with comparison to post LF palmar digital nerve block.

	RF	**LF**	**RH**	**LH**
LF PDN block	134.11	136.60	146.80	145.38
RF abaxial	132.45 ± 1.69	138.62 ± 2.31	141.79 ± 2.62	143.76 ± 4.36
Percent change (%)	-1	1	-3	-1

Subjective clinical assessment for 3rd block: There was a significant improvement in the RF lameness after the RF abaxial nerve block. This subjective improvement was sufficient to stop blocking and move to diagnostic imaging of the forelimb foot region bilaterally. A bilateral forelimb foot MRI was indicated based on the response to blocks observed.

Diagnostic Imaging:

Bilateral forelimb foot MRI and navicular series (Figure 2.3.3.13)

The conclusions from the MRI are as follows:

Left fore:

-Mild to moderate synovial invagination enlargement and moderate palmar distal fluid
of navicular bone

-Mild navicular bursitis

-Mild deep digital flexor tendinopathy

-Moderate enlargement and scarring, collateral sesamoidean ligament

-Mild collateral cartilage ossification, distal phalanx

Right fore:

-Severe fluid with probable small flexor surface erosion of navicular bone

-Moderate deep digital flexor tendinopathy

-Mild to moderate navicular bursitis

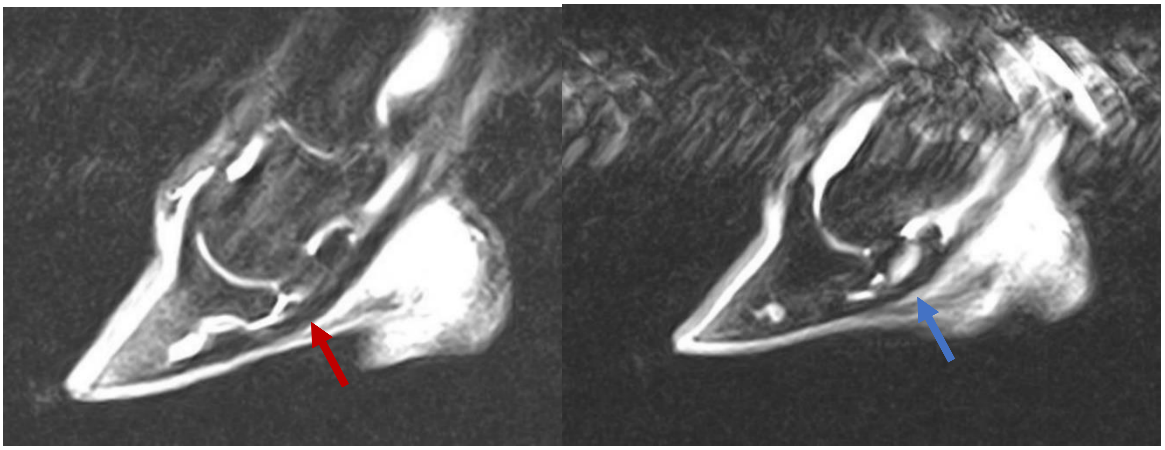
-Mild synovitis, distal interphalangeal joint

-Mild enlargement and scarring, collateral sesamoidean ligament

-Mild to moderate effusion, digital sheath

-Probable magic angle effect, lateral collateral ligament of the distal interphalangeal joint

Figure 2.3.3.13: Mid sagittal plane MRI images of LF (left image) and RF (right image) feet using SITR FSE. Left forelimb moderate palmar distal fluid of navicular bone (red arrow). Right fore severe fluid with probable small flexor surface erosion of navicular bone (blue arrow)



Diagnosis:

Bilateral navicular syndrome characterized by RF navicular bone edema with flexor surface erosion, moderate deep digital flexor tendinopathy, mild to moderate navicular bursitis and LF synovial invagination enlargement, palmar distal fluid of the navicular bone, mild navicular bursitis, and mild deep digital flexor tendinopathy. The findings on the right forelimb are more severe than the left forelimb.

Comparison of subjective and objective lameness exam findings:

The subjective exam findings and the Lameness Locator® exam findings were consistent for the forelimb lameness but differed for the hindlimb lameness. However, the Lameness Locator® trial aide concluded that there was insufficient evidence to determine if the right hindlimb or the right forelimb lameness was primary on baseline exam.

Main points for clinical gait analysis from Horse 3:

The distribution of forces observed at the walk were consistent with palmar heel pain because the heel peak vertical force was decreased, and the force was shifted toward the midstance phase bilaterally.

Although the Lameness Locator® confirmed that a right forelimb lameness was present on baseline, the trial aide stated that there was not strong enough evidence to be identified as the primary lameness. This could be misleading if the operator was depending solely on this technology to identify the lameness and select a limb to start diagnostic analgesia. However, the forelimb was more likely to be primary based on the magnitude of change of vertical displacement of the head compared to the pelvis.

2.3.4 Horse 4

Signalment and use:

Horse 4, a 20-year-old Quarter Horse mare, is used as a teaching horse at the University of Minnesota.

Passive exam findings:

Forelimbs: Horse 4 had contracted heels bilaterally and had steel shoes with a wedge pad bilaterally. On the right forelimb, there was mild coffin joint effusion and mild sensitivity to palpation of the proximal suspensory ligament. There was mild coffin joint effusion on the left forelimb.

Hindlimbs: There was mild tibiotarsal joint effusion bilaterally. There was mild medial femorotibial joint effusion on the left hindlimb. There was mild sensitivity to pressure over the right trochanteric bursa. The Churchill test for distal hock pain was mildly positive on the right hind. It was negative on the left hindlimb.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 2-3 LF and grade 1-2 LH

Lunging: This was not performed due to degree of lameness.

Baseline Lameness Locator® exam findings:

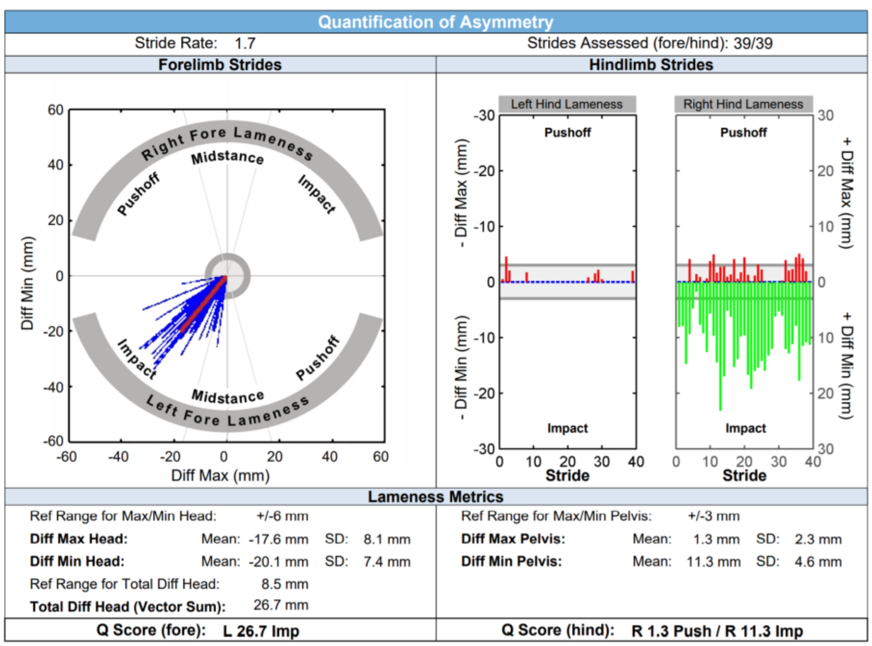
Straight line: There was strong evidence of a moderate LF impact lameness. There was also strong evidence of a moderate RH impact lameness. The trial aide stated that this may be indicative of a primary LF lameness (Table 2.3.4.1 and Figure 2.3.4.1).

Table 2.3.4.1: Horse 4 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	Trial 2	Mean Baseline
Vector sum (mm)	24.9 (L)	26.7 (L)	25.8 ± 1.3
Diff min Pelvis (mm)	9.9 ± 3.1 (R)	11.3 ± 4.6 (R)	10.6 ± 3.85
Diff max Pelvis (mm)	0.7 ± 2.9 (R)*	1.3 ± 2.3 (R)*	1.0 ± 2.6*

* Asymmetry below 3mm threshold for hindlimb lameness

Figure 2.3.4.1. Lameness Locator® data for trial 2 at baseline for Horse 4.



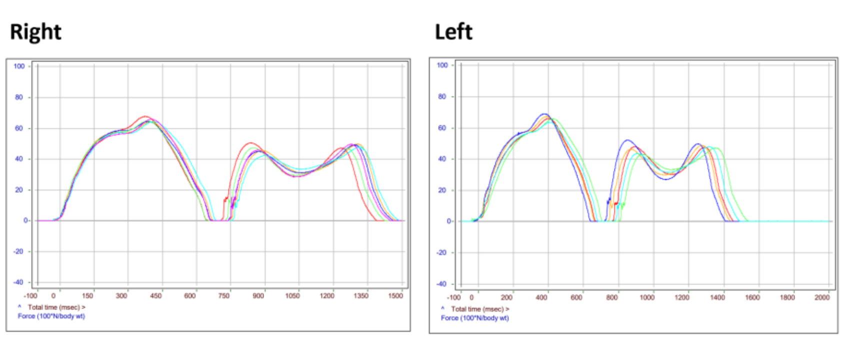
Baseline force plate exam findings:

Walk: Five trials were analyzed for the left limbs and six trials were analyzed for the right limbs (Table 2.3.4.2 and Figure 2.3.4.2). The RF had an increased heel PVF and MsPVF compared to the left forelimb. The RF and LF both had an increased ratio of midstance PVF to heel PVF ratio compared to normal controls (0.99 ± 0.05) . Additionally, the hind to fore VI ratio for right and left sides (R:0.81 ± 0.01, L:0.81 ± 0.01) was increased compared to normal controls (0.75 ± 0.05). The symmetry scores for the forelimbs were close to 1, with the LF slightly less than the RF for heel PVF, MsPVF and VI. Symmetry scores were also close to 1 for the hindlimbs. Because of the bilateral symmetry for fore and hindlimbs, the greatest indication of lameness is that the hind VI is increased relative to the forelimb VI bilaterally. In conjunction with abnormal force distribution in the forelimbs, this is supportive a bilateral forelimb lameness.

Table 2.3.4.2: Horse 4 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.653 ± 0.082	5.661 ± 0.109	6.402 ± 0.132	2.853 ± 0.073
Left	5.574 ± 0.066	5.606 ± 0.035	6.512 ± 0.198	2.834 ± 0.056
Symmetry	0.99	0.99	0.99	1.02
HIND				
Right	4.540 ± 0.265	2.975 ± 0.178	4.760 ± 0.120	2.305 ± 0.067
Left	4.588 ± 0.362	2.976 ± 0.229	4.790 ± 0.192	2.292 ± 0.036
Symmetry	1.01	1.00	1.01	0.99

Figure 2.3.4.2: Horse 4 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=6) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.



Trot: Force plate data at the trot was not performed due to the degree of lameness.

Semi-quantitative fetlock extension at a walk: There were 5 unobstructed video trials analyzed for each limb (Table 2.3.4.3). The forelimbs had a similar degree of fetlock extension. The right hindlimb had greater fetlock extension than the LH. This would suggest a left hindlimb lameness.

Table 2.3.4.3: Horse 4 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	LF	RH	LH
Baseline angle (degrees)	143.16	142.14	145.62	149.36
SD	2.03	2.90	0.94	3.96

Diagnostic Analgesia:

First block performed: Left forelimb palmar digital nerve block

Subjective lameness exam post first block:

The lameness switched to a grade 2/5 RF lameness. No hindlimb lameness was noted.

Lameness Locator® exam post first block:

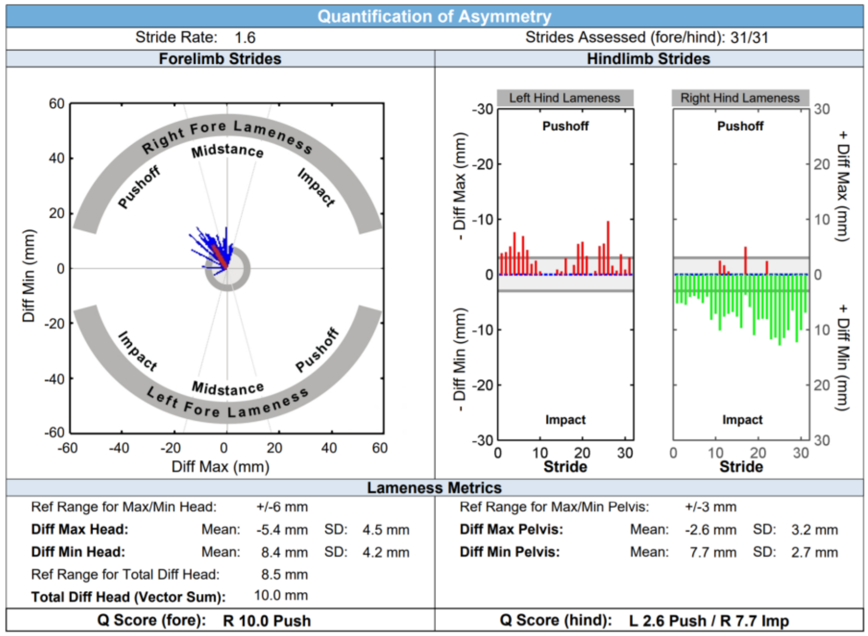
There is moderate evidence of a mild RF push-off lameness. There is strong evidence of a mild to moderate RH impact lameness. The trial aide state that these results may be indicative of a primary RH lameness (Table 2.3.4.4 and Figure 2.3.4.3).

Table 2.3.4.4: Horse 4 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post LF PDN block. The lame limb is highlighted in the parentheses.

	Baseline	Post LF PD Trial 1	Post LF PD Trial 2	Mean Post LF PD	Percent change (%)
Vector sum (mm)	25.8 (L)	10.0 (R)	12.6 (R)	11.3 (R)	^
Diff min Pelvis (mm)	10.6 (R)	7.7 ± 2.7 (R)	9.7 ± 5.0 (R)	8.7 ± 3.9 (R)	- 18
Diff max Pelvis (mm)	1.0 (R)*	2.6 ± 3.2 (L)*	2.2 ± 2.6 (L)*	2.4 ± 2.9 (L)*	*^

*Below the 3mm threshold for lameness
^Lameness switched to contralateral limb

Figure 2.3.4.3. Horse 4 Lameness Locator® data for trial 1 in a straight line (mean ± SD) post LF PDN block.



Force plate exam post first block

Walk: Five trials were analyzed for the left limbs and six trials were analyzed for the right limbs (Tables 2.3.4.5–2.3.4.6 and Figure 2.3.4.4). The LF had decreased heel PVF, MsPVF, and toe PVF, but increased VI compared to baseline. The LF heel to toe PVF ratio increased from 86% to 89% after LF palmar digital nerve block compared to baseline. Similarly, the RF had decreased heel PVF, MsPVF, and toe PVF, but increased VI compared to baseline. Symmetry scores remained within normal limits with the LF heel PVF remaining decreased compared to the RF post LF PDN. VI for the right forelimb is less than the left forelimb, so this could indicate a mild right forelimb lameness. The LH had decreased heel PVF, increased MsPVF, decreased toe PVF, and increased VI compared to baseline. Similarly, RH had decreased heel PVF, increased MsPVF decreased toe PVF, and increased VI compared to baseline. There is evidence of a mild right hindlimb lameness based on symmetry scores. An alternative explanation is that the LH values are increased as a compensatory effect for a contralateral forelimb (RF) lameness.

Table 2.3.4.5: Horse 4 force plate ground reaction forces at a walk post LF palmar digital nerve block (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.513 ± 0.210	5.438 ± 0.227	6.242 ± 0.091	2.908 ± 0.092
Left	5.448 ± 0.083	5.442 ± 0.084	6.154 ± 0.117	2.920 ± 0.064
Symmetry	0.99	1.00	0.99	1.00
HIND				
Right	4.160 ± 0.171	3.127 ± 0.103	4.670 ± 0.137	2.335 ± 0.056
Left	4.242 ± 0.259	3.216 ± 0.194	4.590 ± 0.119	2.354 ± 0.044
Symmetry	1.02	1.03	0.98	1.01

Figure 2.3.4.4: Horse 4 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=6) and left (n=5) limbs post LF palmar digital nerve block. Vertical impulse is the area under the curve.

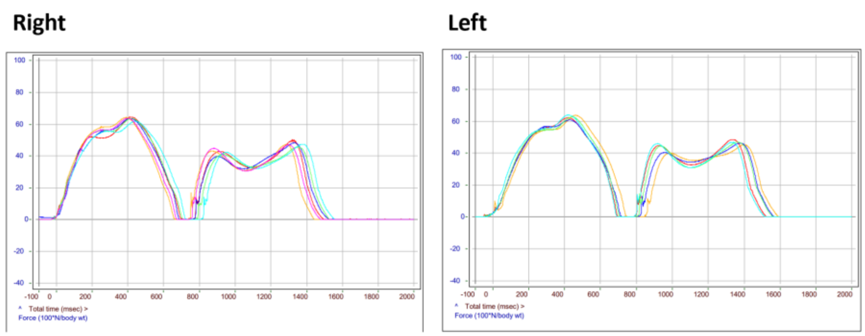


Table 2.3.4.6: Horse 4 force plate ground reaction forces at a walk (mean) comparing baseline and post LF palmar digital nerve block measurements.

	RF Baseline	RF post LF PDN	Percent change (%)	LF Baseline	LF post LF PDN	Percent change (%)
Heel PVF (N/kg)	5.653	5.513	-2	5.574	5.448	-2
Midstance PVF (N/kg)	5.661	5.438	-4	5.606	5.442	-3
Toe PVF (N/kg)	6.402	6.242	-3	6.512	6.154	-6
VI(Ns/kg)	2.853	2.908	2	2.834	2.920	3
	RH Baseline	**RH post LF PDN**	**Percent change (%)**	**LH Baseline**	**LH post LF PDN**	**Percent change (%)**
Heel PVF (N/kg)	4.540	4.160	-8	4.588	4.242	-8
Midstance PVF (N/kg)	2.975	3.127	5	2.976	3.216	8
Toe PVF (N/kg)	4.760	4.670	-2	4.790	4.590	-4
VI(Ns/kg)	2.305	2.335	1	2.292	2.354	3

Trot: Force plate data at the trot was not performed post LF PDN due to the degree of lameness.

Semi quantitative fetlock extension at a walk post first block: Five unobstructed video trials were analyzed for the left limbs and six unobstructed video trials were analyzed for the right limbs (Table 2.3.4.7). There was increased extension in both the RF and LF post LF PDN. There was also a slightly increased extension in the RH and LH post LF PDN. This represents a slight improvement in the LF lameness as there was a 2% increase in fetlock extension. However, this change was minimal with high standard deviation indicating no significant change from baseline.

Table 2.3.4.7: Horse 4 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post LF palmar digital nerve block with comparison to baseline.

	RF	LF	RH	LH
Angle post LF PDN	141.32 ± 3.71	139.44 ± 2.18	143.96 ± 2.64	147.53 ± 3.48
Baseline angle	143.16	142.14	145.62	149.36
Percent change (%)	-1	-2	-1	-1

Subjective clinical assessment on 1st block:

The first block switched the left forelimb lameness to a right forelimb lameness. The right forelimb lameness was severe enough to warrant blocking, as a primary bilateral forelimb disease process was suspected even though the left forelimb lameness was initially greater. As a result, a RF palmar digital nerve block was performed.

Second block performed: RF palmar digital nerve block

Subjective lameness exam post second block:

The lameness switched to a grade1-2 LF and no appreciable subjective hindlimb lameness.

Lameness Locator® exam post second block:

There was strong evidence of a mild to moderate LF impact lameness. There was strong evidence of a mild to moderate RH impact lameness, but not push-off. The trial aide stated that there was insufficient evidence to suggest which limb was primary (Table 2.3.4.8 and Figure 2.3.4.5).

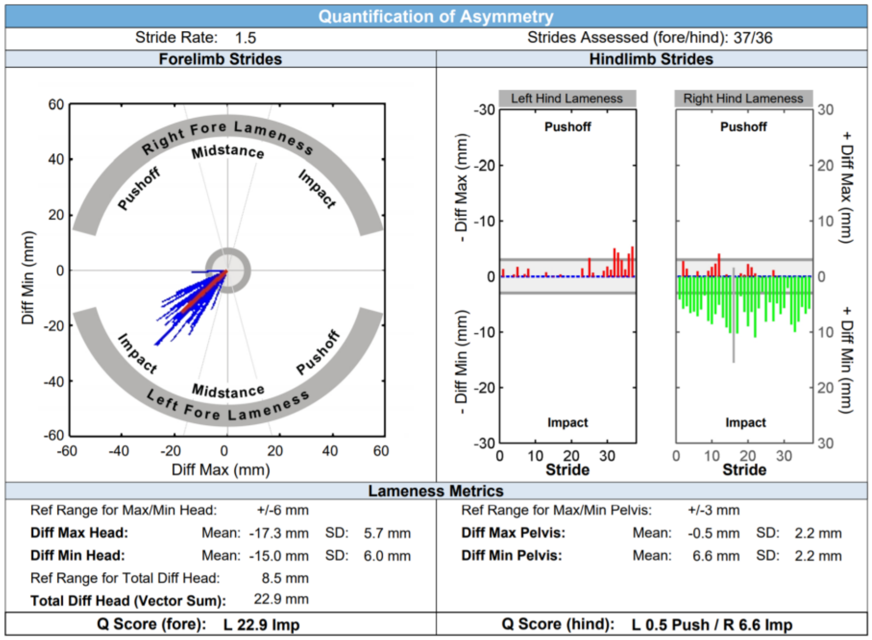
Table 2.3.4.8 Horse 4 Lameness Locator® data in a straight line (mean ± SD) comparing post RF PDN block to post LF PDN block. The lame limb is highlighted in the parentheses.

	Post LF PD	**Post RF PD Trial 1**	**Post RF PD Trial 2**	**Mean Post RF PD**	**Percent change (%)**
Vector sum (mm)	11.3 (R)	22.9 (L)	20.1 (L)	21.5 (L)	^
Diff min Pelvis (mm)	7.7 (R)	6.6 ± 2.2 (R)	7.3 ± 2.2 (R)	7.0 ± 2.2 (R)	-9
Diff max Pelvis (mm)	2.6 (L)*	0.5 ± 2.2 (L)*	0.0 ± 2.6 (L)*	0.3 ± 2.4 (L)*	*

*Below 3mm threshold for lameness

^Lameness switched to contralateral limb

Figure 2.3.4.5. Horse 4 Lameness Locator® data for trial 1 in a straight-line post RF palmar digital nerve block.



Force plate exam post second block

Walk: Five trials were collected for each limb (Tables 2.3.4.9–2.3.4.10 and Figure 2.3.4.6). There was an increased RF VI compared to the LF PDN block. After the RF PDN, the left hindlimb heel PVF increased and the midstance PVF decreased. The opposite change occurred in the right hindlimb, where the heel PVF decreased and midstance PVF increased. The vertical impulse asymmetry indicated a left forelimb lameness. It is interesting to note that for both forelimbs the midstance PVF is less than the heel PVF, which is more consistent with a sound horse, compared to baseline where the midstance PVF was greater than the heel PVF bilaterally. The right hindlimb lameness appeared to worsen based in increased asymmetry with the left hindlimb.

Table 2.3.4.9: Horse 4 force plate ground reaction forces at a walk post RF palmar digital nerve block (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.478 ± 0.090	5.414 ± 0.117	6.152 ± 0.160	3.030 ± 0.166
Left	5.592 ± 0.141	5.500 ± 0.159	6.234 ± 0.036	2.852 ± 0.106
Symmetry	1.02	1.02	1.01	0.94
HIND				
Right	3.958 ± 0.309	3.230 ± 0.245	4.540 ± 0.128	2.442 ± 0.106
Left	4.576 ± 0.142	2.930 ± 0.104	4.838 ± 0.104	2.302 ± 0.052
Symmetry	1.16	0.91	1.07	0.94

Figure 2.3.4.6: Horse 4 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post RF palmar digital nerve block. Vertical impulse is the area under the curve.

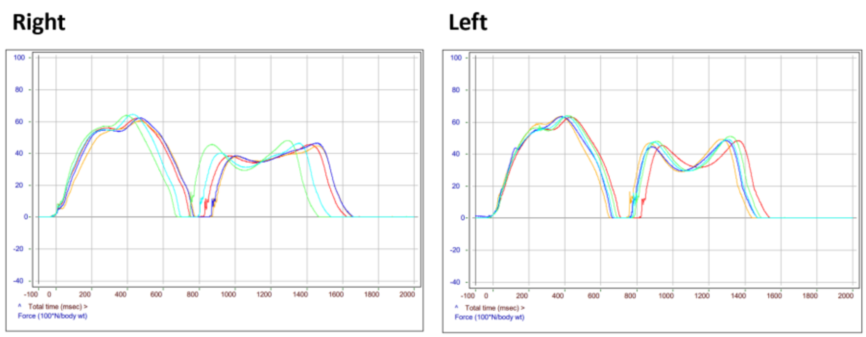


Table 2.3.4.10: Horse 4 force plate ground reaction forces at a walk (mean) comparing post RF palmar digital nerve block to post LF palmar digital nerve block measurements.

	RF post LF PDN	RF post RF PDN	Percent change (%)	LF post LF PDN	LF post RF PDN	Percent change (%)
Heel PVF (N/kg)	5.513	5.478	-1	5.448	5.592	3
Midstance PVF (N/kg)	5.438	5.414	0	5.442	5.500	1
Toe PVF (N/kg)	6.242	6.152	-1	6.154	6.234	1
VI (Ns/kg)	2.908	3.030	4	2.920	2.850	-2
	RH post LF PDN	**RH post RF PDN**	**Percent change (%)**	**LH post LF PDN**	**LH post RF PDN**	**Percent change (%)**
Heel PVF (N/kg)	4.160	3.958	-5	4.242	4.576	8
Midstance PVF (N/kg)	3.127	3.230	3	3.216	2.930	-9
Toe PVF (N/kg)	4.670	4.540	-3	4.590	4.838	5
VI (Ns/kg)	2.335	2.442	5	2.354	2.300	-2

Semi quantitative fetlock extension at a walk post second block: Five unobstructed video trials were analyzed for the left limbs and six unobstructed video trials were analyzed for the right limbs (Table 2.3.4.11). There was decreased fetlock extension in the RF and LF suggesting increased lameness. The RH and LH remained similar to previous measurements. Despite the change in lameness at the trot, the fetlock extension appears relatively unchanged compared to baseline especially with the high standard deviation.

Table 2.3.4.11: Horse 4 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post RF palmar digital nerve block with comparison to LF palmar digital nerve block and baseline. The percent change is comparing RF PDN to LF PDN.

	RF	LF	RH	LH
Angle post RF PDN	145.58 ± 2.86	143.47 ± 3.61	145.26 ± 5.33	148.85 ± 2.88
Angle post LF PDN	141.32	139.44	143.96	147.53
Baseline	143.16	142.14	145.62	149.36
Percent change (%)	3	3	1	1

Subjective clinical assessment for 2nd block:

The lameness switched back to a left forelimb lameness. This lameness was a grade 1-2 whereas the baseline lameness was a grade 2-3. No hindlimb lameness was noted after this block. Bilateral forelimb foot MRI was chosen due to the bilateral improvement to the palmar digital nerve block and the high potential for involvement of soft tissue structures in the foot. Although there was residual left forelimb lameness was present, further blocking was not pursued because of welfare concerns for the horse with continued trotting.

Diagnostic Imaging:

Bilateral forelimb foot MRI and navicular series (Figure 2.3.4.7)

The conclusions from the MRI are as follows:

Left fore:

-Flexor surface erosion, moderate fluid with synovial invagination and/or vascular channel enlargement of the navicular bone

-Mild to moderate chronic navicular bursitis

-Moderate deep digital flexor tendinopathy with possible adhesion formation

-Mild to moderate synovitis and arthrosis, distal interphalangeal joint

-Palmar rotation (10 degrees) with margin flaring and lysis, mild to moderate fluid and diffuse laminar thickening, and mild collateral cartilage ossification distal phalanx

-Mild enlargement and scarring, collateral sesamoidean ligament

-Mild desmopathy, medial collateral ligament of the distal interphalangeal joint

-Mild arthrosis and punctate subchondral bone irregularity, proximal interphalangeal joint

Right fore:

-Flexor surface erosion, sclerosis, and extensive moderate to severe fluid of the navicular bone

-Mild to moderate navicular bursitis

-Moderate deep digital flexor tendinopathy with possible adhesion formation

-Mild to moderate synovitis and arthrosis, distal interphalangeal joint

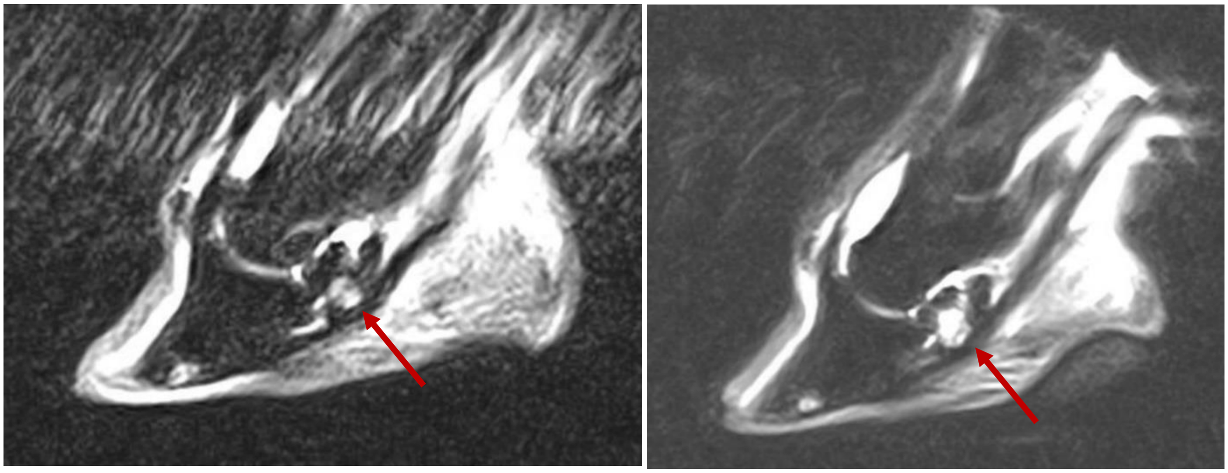
-Palmar rotation (5 degrees), flaring with overlying diffuse laminar thickening, distal phalanx

-Mild to moderate enlargement and scarring, collateral sesamoidean ligament

-Mild arthrosis, proximal interphalangeal joint

-Mild collateral cartilage ossification, distal phalanx

Figure 2.3.4.7: Mid-sagittal plane MRI images of LF (left image) and RF (right image) feet using STIR FSE. Bilateral flexor surface erosions noted with red arrows.



Diagnosis:

Bilateral forelimb navicular syndrome, left forelimb worse than right forelimb

Comparison of subjective and objective lameness exam findings:

There was agreement between subjective lameness exam and the Lameness Locator® with the forelimb lameness switching between blocks and the degree of forelimb lameness observed. There was disagreement with the hindlimb lameness on baseline and throughout the exam.

Main points for clinical gait analysis from Horse 4:

Force plate at the walk

With the palmar digital nerve blocks, the ratio of forelimb midstance to heel PVF shifted subtly, so that the heel PVF increased relative to the MsPVF after blocking. However, symmetry was mostly preserved between forelimbs during blocking.

The primary limitation of this horse's exam is that trot data collection was not possible due to degree of lameness. The force plate data at a trot may have been helpful to compare to the walk data, especially in determining the hindlimb lameness. In addition, the horse had wedges on the front feet at time of exam, so this may have influenced distribution of the forces at the walk.

2.3.5 Horse 5

Signalment and use:

Horse 5, an 8-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings:

Forelimbs: Bilaterally contracted heels. Mild to moderate effusion of the RF coffin joint. Mild sensitivity to palpation of the lateral aspect of the proximal suspensory ligament of the RF. On the left forelimb, there was mild coffin joint effusion, sensitivity to the palpation of the palmar pastern and mild sensitivity to palpation of the proximal suspensory ligament laterally. There was also an exostosis of the second metacarpal bone of the LF.

Hindlimbs: Mild tibiotarsal joint effusion was present on the right hind. Mild to moderate tibiotarsal joint effusion was present on the left hindlimb. Mild digital flexor tendon sheath effusion was present bilaterally on the hindlimbs. The Churchill test for distal hock pain was a mild to moderate positive on the RH and LH.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 1 LF and Grade 2 RH lameness

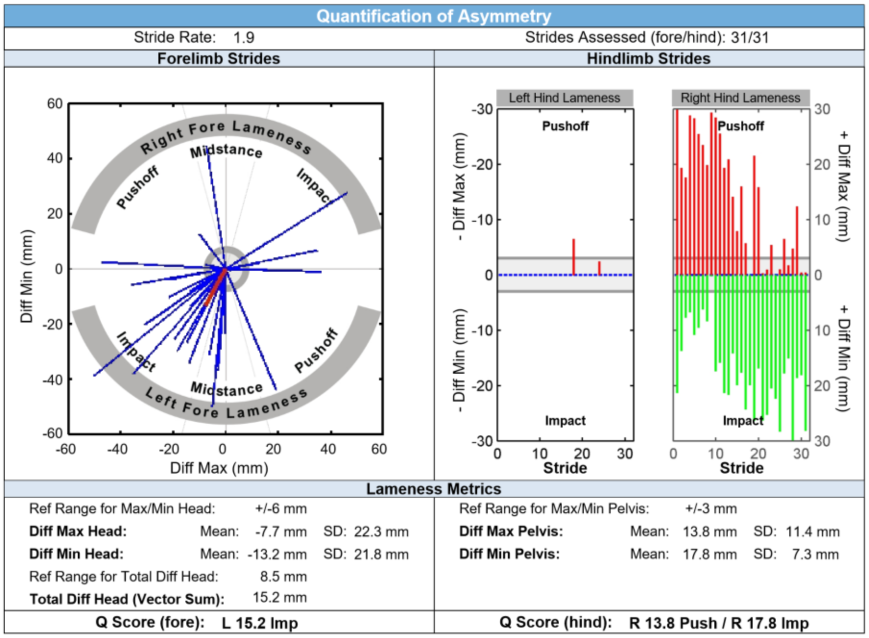
Baseline Lameness Locator® exam findings:

Initial baseline in a straight line: There was weak evidence of a mild LF impact lameness. The trial aide indicated there was moderate evidence of moderate to severe RH push-off lameness and strong evidence of moderate to severe RH impact lameness. The trial aide indicated that there was insufficient evidence to suggest which limb was primary (Table 2.3.5.1 and Figure 2.3.5.1).

Table 2.3.5.1: Horse 5 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	Trial 2	Mean Baseline
Vector sum (mm)	15.2 (L)	16.5 (L)	15.6 (L)
Diff min pelvis (mm)	17.8 ± 7.3 (R)	10.3 ± 6.1 (R)	14.1 ± 6.7 (R)
Diff max pelvis (mm)	13.8 ± 11.4 (R)	10.7 ± 7.6 (R)	12.3 ± 9.5 (R)

Figure 2.3.5.1: Horse 5 baseline Lameness Locator® summary from Trial 1 in a straight line.



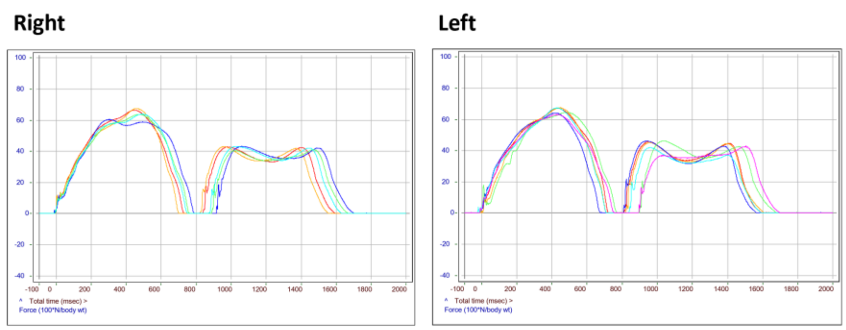
<u>Baseline force plate exam findings (after lunge)</u>:

Walk: Five trials analyzed for the right forelimb and right hindlimb. Five trials were analyzed for the left forelimb and hindlimb (Table 2.3.5.2 and Figure 2.3.5.2). The right hindlimb heel PVF was decreased and the midstance PVF was increased compared to the left hindlimb. The vertical impulse for the right hindlimb was less than that of the left hindlimb. This is suggestive of a right hindlimb lameness. The left forelimb VI was less than the right forelimb VI, which may indicate a left forelimb lameness. However, the PVF for the heel, midstance and toe were slightly increased for the left forelimb relative to the right forelimb. These may be compensatory increases for the hindlimb lameness.

Table 2.3.5.2: Horse 5 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF(N/kg)**	**Toe PVF(N/kg)**	**VI (Ns/Kg)**
Right	5.718 ± 0.270	5.708 ± 0.168	6.292 ± 0.319	3.248 ± 0.101
Left	5.732 ± 0.190	5.790 ± 0.148	6.442 ± 0.186	3.125 ± 0.113
Symmetry	1.00	1.01	1.02	0.96
HIND				
Right	4.188 ± 0.119	3.346 ± 0.072	4.122 ± 0.054	2.380 ± 0.069
Left	4.297 ± 0.359	3.278 ± 0.154	4.165 ± 0.258	2.427 ± 0.123
Symmetry	1.03	0.98	1.01	1.02

Figure 2.3.5.2: Horse 5 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.



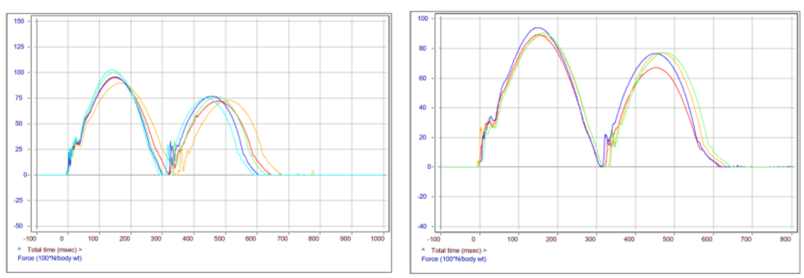
Trot: Five trials analyzed for the right forelimb and right hindlimb. Four trials were analyzed for the left forelimb and hindlimb (Table 2.3.5.3 and Figure 2.3.5.3). The LF PVF and VI are decreased compared to the right forelimb. There is hindlimb asymmetry in the PVF supporting a RH lameness.

Table 2.3.5.3: Horse 5 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind: Fore PVF	Ipsilateral Hind: Fore VI	Contralat Hind: Fore PVF	Contralat Hind: Fore VI
Right	9.486 ± 0.480	1.830 ± 0.049	7.346 ± 0.216	1.346 ± 0.051	0.78	0.74	0.82	0.77
Left	8.903 ± 0.234	1.740 ± 0.032	7.567 ± 0.494	1.353 ± 0.115	0.82	0.75	0.80	0.73
Symmetry	0.94	0.95	1.03	1.01				

Figure 2.3.5.3: Horse 5 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=4) limbs at baseline. Vertical impulse is the area under the curve.

Right Left



Semi-quantitative fetlock extension at a walk: Five unobstructed video trials analyzed for the right forelimb and right hindlimb. Five trials were analyzed for the left forelimb and hindlimb (Table 2.3.5.4). The forelimb fetlock extension was symmetrical. The RH fetlock extension was decreased compared to the LH suggestive of a right hindlimb lameness.

Table 2.3.5.4: Horse 5 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	LF	RH	LH
Baseline angle (degrees)	138.90	138.33	150.28	148.44
SD	2.26	1.97	1.86	4.45

Flexion test responses:

Forelimbs:	*Hindlimbs:*
RF distal: negative	RH distal: mild to moderate positive
RF carpus: negative	RH full limb: moderate positive
LF distal: mild positive	LH distal limb: negative
LF carpus: negative	LH full limb: mild to moderate positive, LF lameness worsened

Diagnostic Analgesia:

First block performed: bilateral distal intertarsal and tarsometatarsal joint block

Subjective lameness exam post first block:

There was a 70% improvement in the right hindlimb lameness with only intermittent RH and LH lameness remaining in the hind end. There were some intermittent LF lame steps, and some RF lame steps present.

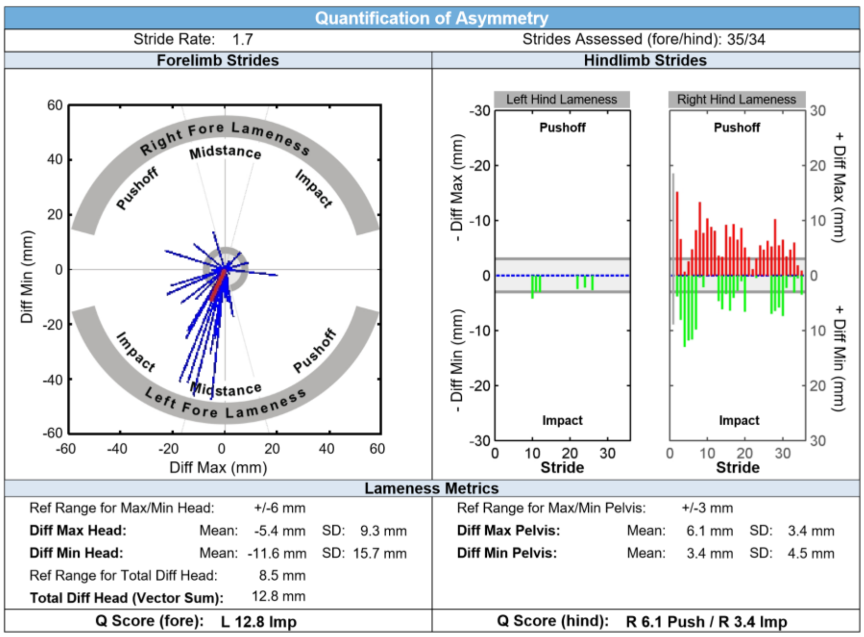
Lameness Locator® exam post first block:

There was an improvement of the forelimb and hindlimb lameness from baseline. The trial aide indicated that there was weak evidence of a mild LF impact lameness, weak evidence of a mild RH impact lameness and moderate evidence of a mild to moderate RH push-off lameness. Based on the Lameness Locator®, the greatest improvement from DIT/TMT block was in the RH impact lameness indicated by the change in the minimum position difference in the pelvis between right and left stance phases of the stride (Table 2.3.5.5 and Figure 2.3.5.4).

Table 2.3.5.5: Horse 5 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post bilateral distal intertarsal and tarsometatarsal joint blocks. The lame limb is highlighted in the parentheses.

	Baseline	Post bilateral DIT/TMT blocks	Percent change (%)
Vector sum (mm)	15.6 (L)	12.8 (L)	-18
Diff min pelvis (mm)	14.1 ± 6.7 (R)	3.4 ± 4.5 (R)	-76
Diff max pelvis (mm)	12.3 ± 9.5 (R)	6.1 ± 3.4 (R)	-50

Figure 2.3.5.4: Horse 5 Lameness Locator® summary in a straight-line post bilateral distal intertarsal and tarsometatarsal joint block.



Force Plate Exam Post First Block

Walk: Five trials were analyzed for all four limbs (Tables 2.3.5.6 – 2.3.5.7 and Figure 2.3.5.5). There was an increase in RH heel PVF and decrease in RH midstance PVF compared to baseline. This indicates that there was improvement in the lameness and shift toward normal force distribution. There was a decrease in LF and RF heel PVF and midstance PVF compared to baseline. This suggests that the increases observed at baseline were compensatory changes for the hindlimb lameness.

Table 2.3.5.6: Horse 5 force plate ground reaction forces at a walk (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/kg)**
Right	5.440 ± 0.263	5.530 ± 0.228	6.476 ± 0.312	3.104 ± 0.086
Left	5.186 ± 0.709	5.576 ± 0.203	6.348 ± 0.192	3.220 ± 0.099
Symmetry	0.95	1.01	0.98	1.04
HIND				
Right	4.260 ± 0.055	3.230 ± 0.082	4.102 ± 0.130	2.344 ± 0.054
Left	4.226 ± 0.182	3.230 ± 0.108	4.140 ± 0.117	2.424 ± 0.061
Symmetry	0.99	1	1.01	1.03

Figure 2.3.5.5: Horse 5 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

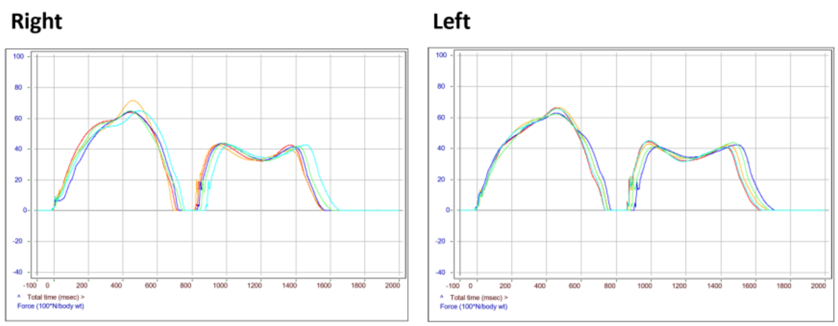


Table 2.3.5.7: Horse 5 force plate ground reaction forces at a walk (mean) comparing baseline and post bilateral distal intertarsal and tarsometatarsal joint block measurements.

	RF baseline	**RF post bilateral DIT/TMT joint blocks**	**Percent change (%)**	**LF baseline**	**LF post bilateral DIT/TMT joint blocks**	**Percent change (%)**
Heel PVF (N/kg)	5.718	5.440	-5	5.732	5.186	-10
Midstance PVF (N/kg)	5.708	5.530	-3	5.790	5.576	-4
Toe PVF (N/kg)	6.292	6.476	3	6.442	6.348	-1
VI (Ns/kg)	3.248	3.104	-4	3.125	3.220	3
	RH baseline	**RH post bilateral DIT/TMT joint blocks**	**Percent change (%)**	**LH baseline**	**LH post bilateral DIT/TMT joint blocks**	**Percent change (%)**
Heel PVF (N/kg)	4.188	4.260	2	4.297	4.226	-2
Midstance PVF (N/kg)	3.346	3.230	-3	3.278	3.230	-1
Toe PVF (N/kg)	4.122	4.102	0	4.165	4.140	-1
VI (Ns/kg)	2.380	2.344	-2	2.427	2.424	0

Trot: Five trials were analyzed for each limb (Tables 2.3.5.8–2.3.5.9 and Figure 2.3.5.6). There was an increase in PVF for the LH and RH compared to baseline. The PVF and VI decreased in the RF compared to baseline. There was remaining PVF asymmetry between LH and RH despite increases in PVF because the increase in LH and RH PVF was similar. The ratio of ipsilateral hind to fore PVF increased compared to baseline. The increase in force in the hindlimbs supports that the intraarticular blocks improved the lameness.

Table 2.3.5.8: Horse 5 force plate ground reaction forces at a trot (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind: Fore PVF**	**Ipsilateral Hind: Fore VI**	**Contralat Hind: Fore PVF**	**Contralat Hind: Fore VI**
Right	9.362 ± 0.445	1.738 ± 0.055	7.518 ± 0.257	1.298 ± 0.060	0.81	0.75	0.85	0.76
Left	8.902 ± 0.112	1.718 ± 0.025	7.864 ± 0.269	1.364 ± 0.052	0.88	0.79	0.84	0.79
Symmetry	0.95	0.99	1.05	1.05				

Figure 2.3.5.6: Horse 5 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

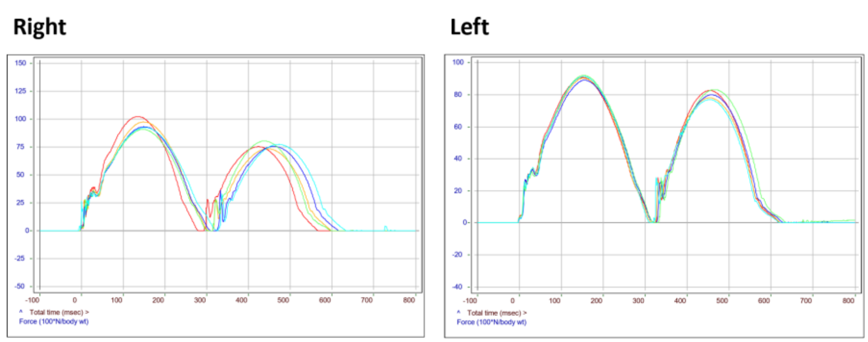


Table 2.3.5.9: Horse 5 force plate ground reaction forces at a trot (mean) comparing baseline and post bilateral distal intertarsal and tarsometatarsal joint block measurements.

	RF baseline	**RF post bilateral DIT/TMT joint blocks**	**Percent change (%)**	**LF baseline**	**LF post bilateral DIT/TMT joint blocks**	**Percent change (%)**
PVF (N/kg)	9.486	9.362	-1	8.903	8.902	0
VI (Ns/kg)	1.830	1.738	-5	1.740	1.718	-1
	RH baseline	**RH post bilateral DIT/TMT joint blocks**	**Percent change (%)**	**LH baseline**	**LH post bilateral DIT/TMT joint blocks**	**Percent change (%)**
PVF (N/kg)	7.346	7.518	2	7.567	7.864	4
VI (Ns/kg)	1.346	1.298	-4	1.353	1.364	1

Semi-quantitative fetlock extension at a walk post first block: Five unobstructed video trials analyzed for the right forelimb and right hindlimb. Five trials were analyzed for the left forelimb and hindlimb (Table 2.3.5.10). There was increased fetlock extension in the RH after the bilateral DIT/TMT block and decreased fetlock extension in the LH. There was a slight decrease in fetlock extension in the RF. This indicates that the block improved the right hindlimb lameness. The decrease in fetlock extension in the right forelimb may represent the reversal of a compensatory change.

Table 2.3.5.10: Horse 5 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post bilateral distal intertarsal and tarsometatarsal joint block with comparison to baseline.

	RF	**LF**	**RH**	**LH**
Angle post bilateral DIT/TMT block	140.42 ± 2.80	138.42 ± 1.94	145.05 ± 2.53	151.192 ± 3.42
Baseline angle	138.90	138.33	150.28	148.44
Percent change (%)	1	0	-3	2

Subjective clinical assessment for 1st block:

There was 70% improvement in the right hindlimb lameness. There was no change to the left forelimb lameness. This improvement was significant enough to proceed diagnostic imaging. Due to the positive response to intra-articular analgesia of the distal intertarsal and tarsometatarsal joints, radiographs of both tarsi were performed as it is the first line imaging for these structures.

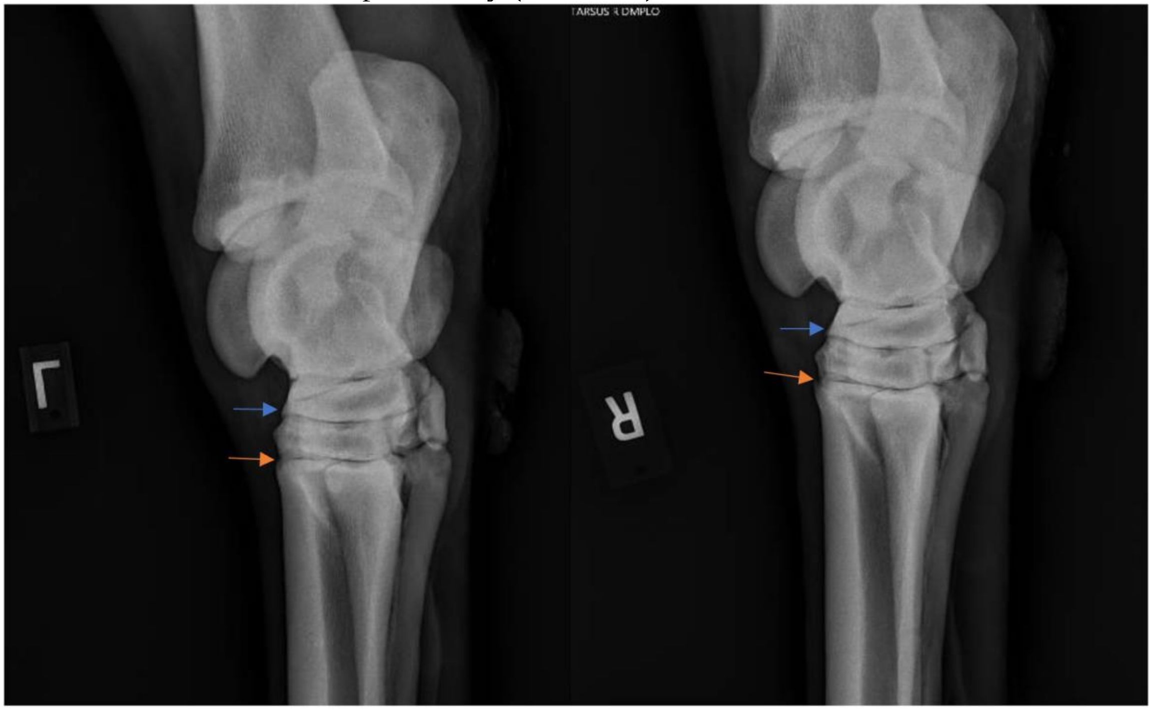
Diagnostic Imaging:

Bilateral tarsus series (Figure 2.3.5.7)*:*

Right tarsus: There are small to medium sized osteophytes present at the proximal dorsolateral aspect of the third tarsal bone and distodorsolateral the central tarsal bone. There are small sized osteophytes at the dorsolateral surface distal third tarsal bone. There is a small sized osteophyte present on the dorsolateral surface of the third metatarsal bone proximally.

Left tarsus: There are small sized osteophytes at the dorsolateral surface of the distal central tarsal bone joint and the proximal third tarsal bone.

Figure 2.3.5.7: Dorsomedial palmar lateral radiographs of the LH (left image) and RH (right image) tarsus. On the left tarsus, there are small sized osteophytes at the dorsolateral surface of the distal central tarsal bone joint (blue arrow) and the distal third tarsal bone (red arrow). On the right tarsus, there are small to medium sized osteophytes present at the proximal dorsolateral aspect of the third tarsal bone and distodorsolateral the central tarsal bone (blue arrow). There are small sized osteophytes at the dorsolateral surface of the distal third tarsal bone, and there is a small sized osteophyte present on the dorsolateral surface of the third metatarsal bone proximally (red arrow).



Diagnosis:

Moderate distal intertarsal and tarsometatarsal joint osteoarthritis of the right hindlimb.

Mild to moderate distal intertarsal and tarsometatarsal joint osteoarthritis of the left hindlimb.

Comparison of subjective and objective lameness exam findings:

There was agreement between the subjective and objective lameness exam findings in the improvement of the right hindlimb lameness. There was also agreement in that there was minimal change in the left forelimb lameness.

Main points for clinical gait analysis from Horse 5:

There was agreement in the degree of improvement in the right hindlimb and left forelimb lameness between the Lameness Locator® and subjective exam. However, the trial aide indicated that there was insufficient evidence to suggest which limb was primary (Table 2.3.5.1 and Figure 2.3.5.1). Subjectively, the right forelimb was determined to be the lameness of greater magnitude.

For the walk, there was a decrease in bilateral forelimb heel and midstance PVF when the DIT and TMT were blocked bilaterally. This may be a representation of compensatory change in the forelimbs because of bilateral hindlimb lameness. The lack of improvement in the left forelimb lameness suggests that there is also a primary left front limb lameness. Ideally, this would be further investigated.

At the trot, the force plate demonstrated increases in PVF for both hindlimbs, but there was a remaining asymmetry because the magnitude of improvement was similar between LH and RH. The hind to forelimb PVF ratios were helpful to demonstrate that the hindlimbs are contributing to a greater proportion of overall force distribution with the bilateral DIT/TMT blocks compared to baseline.

2.3.6 Horse 6

Signalment and use:

Horse 6, an 8-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings:

Forelimbs: There was mild bilateral forelimb coffin joint effusion, mild sensitivity to palpation of the proximal suspensory ligament of the left forelimb and an exostosis on the distal aspect of metacarpus II of the left forelimb that was not sensitive to palpation. Hoof tester examination was negative for both fore feet.

Hindlimbs: There was mild effusion of the medial femorotibial joint bilaterally (LH > RH). The Churchill test for distal hock pain was positive bilaterally. There was a mild to moderate positive response on the right hock and moderate positive response for the left hock There was also sensitivity to palpation of the thoracolumbar epaxial musculature. She also had mild sensitivity to pressure on the trochanteric bursa on the left side.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 1 RF and Grade 2 RH lameness.

Baseline after lunging: Grade 1 LF and Grade 2 LH lameness.

Baseline Lameness Locator® exam findings:

Baseline straight line before the lunge: The Lameness Locator® exam from the straight-line baseline showed weak evidence of mild RF push off lameness and strong evidence of moderate LH push-off lameness. The trial aide tool indicated that this was insufficient evidence to suggest which limb is primary (Table 2.3.6.1 and Figure 2.3.6.1).

Baseline straight line after lunging: This showed weak evidence of a mild LF impact lameness and strong evidence of a moderate LH push-off lameness (Table 2.3.6.1 and Figure 2.3.6.2).

Table 2.3.6.1: Horse 6 baseline Lameness Locator® data (mean ± SD) from trials collected in a straight line before and after lunging. The lame limb is highlighted in the parentheses.

	Before Lunge	After Lunge	Percent change (%)
Vector Sum (mm)	13.0 (R)	14.3 (L)	^
Diff min Pelvis (mm)	2.0 ± 4.5(R)*	1.5 ± 3.4 (R)*	-25*
Diff max Pelvis (mm)	9.8 ± 2.3 (L)	10.1 ± 3.3 (L)	3

*Asymmetry below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb after lunging

Figure 2.3.6.1: Horse 6 baseline Lameness Locator® summary in a straight line before lunging.

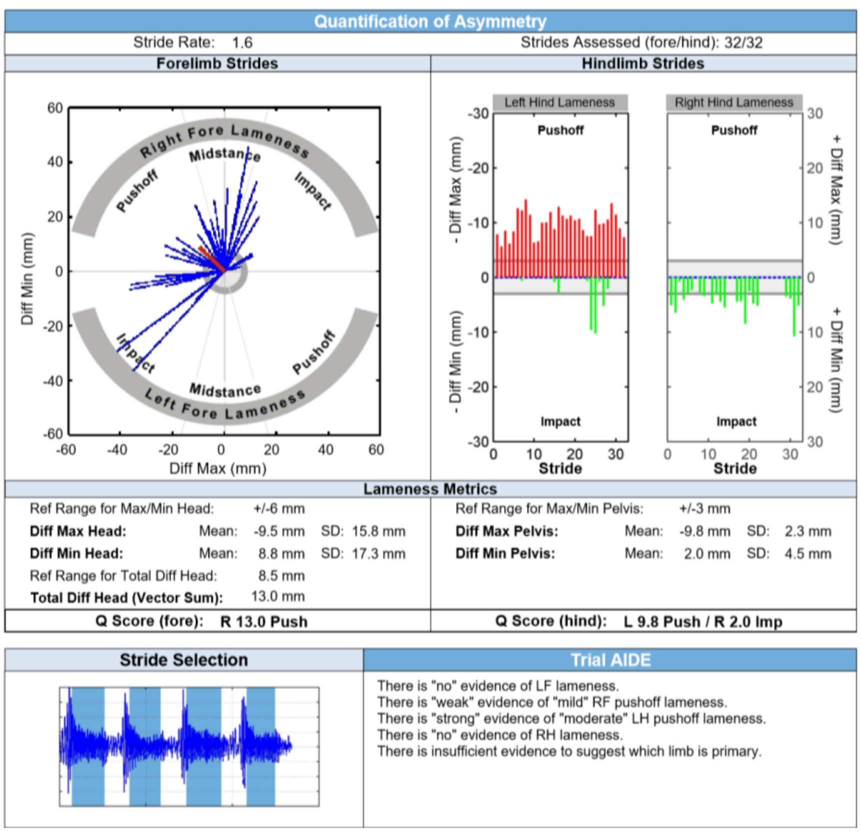
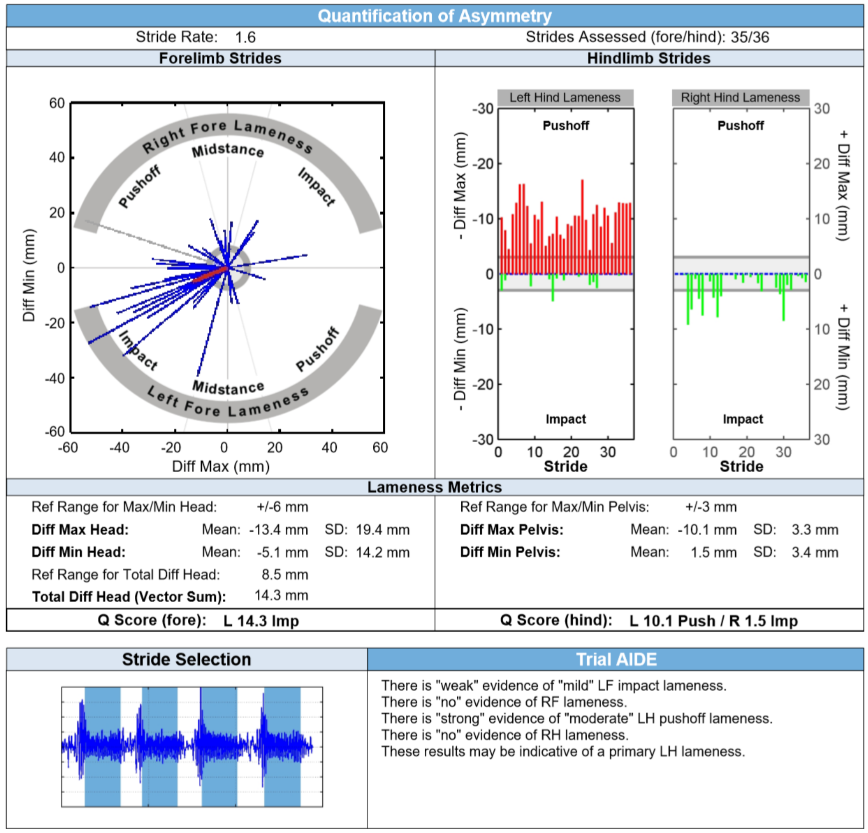


Figure 2.3.6.2: Horse 6 baseline Lameness Locator® summary in a straight line after lunging.



Baseline force plate exam findings (after lunge):

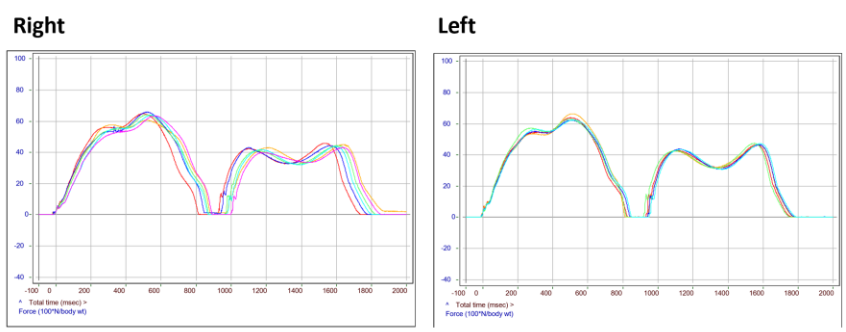
According to the protocol determined, all force plate data was collected after the lunging portion of the exam.

Walk: Five trials were analyzed for the left forelimb and left hindlimb. Six trials were analyzed for the right forelimb and right hindlimb (Table 2.3.6.2 and Figure 2.3.6.3). The force plate exam at a walk showed there was increased heel PVF on the LF compared to the RF and the midstance PVF was increased for the right forelimb compared to the LF. Forelimb PVF symmetry scores were all very close to 1. There was a mild vertical impulse asymmetry where the RF was greater than LF. Heel PVF was decreased in the right hindlimb (RH) and midstance PVF (MsPVF) was increased compared to the left hindlimb. Additionally, the right hind MsPVF increased relative to heel PVF. The toe PVF was also decreased RH compared to the left hindlimb. This is indicative of the right hindlimb lameness and a mild left forelimb lameness.

Table 2.3.6.2: Horse 6 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.407 ± 0.174	5.343 ± 0.144	6.260 ±0.176	3.610 ± 0.106
Left	5.438 ± 0.142	5.308 ± 0.090	6.242 ± 0.166	3.516 ± 0.046
Symmetry	1.01	0.99	0.997	0.97
HIND				
Right	4.120 ± 0.123	3.215 ± 0.054	4.358 ± 0.095	2.662 ± 0.098
Left	4.228 ± 0.058	3.072 ± 0.051	4.594 ± 0.044	2.670 ± 0.014
Symmetry	1.03	0.96	1.05	1.00

Figure 2.3.6.3: Horse 6 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=6) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.

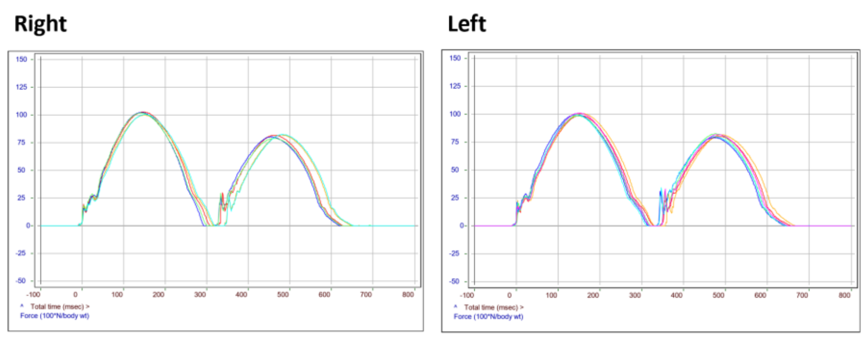


Trot: Six trials were analyzed for the left forelimb and hindlimb. Five trials were analyzed for the right forelimb and right hindlimb (Table 2.3.6.3 and Figure 2.3.6.4). Force plate at the trot revealed decreased LF PVF compared to the right forelimb and decreased RF VI compared to the left forelimb. Symmetry scores for the RF and LF were close to 1. The Hind PVF and VI were also close to 1. These findings are supportive of a mild left forelimb lameness, but a hindlimb lameness is not supported by this data.

Table 2.3.6.3: Horse 6 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	9.968 ± 0.117	1.864 ± 0.029	7.964 ± 0.143	1.422 ± 0.029	0.80	0.76	0.81	0.75
Left	9.790 ± 0.096	1.892 ± 0.049	7.937 ± 0.128	1.420 ± 0.023	0.81	0.75	0.80	0.76
Symmetry	0.98	1.01	1.00	1.00				

Figure 2.3.6.4: Horse 6 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at a walk: There were six unobstructed trials analyzed for the right forelimbs and right hindlimbs, and five unobstructed trials for the left forelimb and hindlimb (Table 2.3.6.4). The forelimb fetlock extension was symmetrical and the hindlimb fetlock extension was also symmetrical. This does not support any specific limb lameness.

Table 2.3.6.4: Horse 6 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	LF	RH	LH
Baseline angle (degrees)	139.77	140.27	147.40	147.48
SD	2.94	1.36	3.07	1.95

Flexion test responses:

Forelimbs:

RF distal: negative

RF carpus: worsened LF lameness (i.e. LF lameness was worse after standing on the LF for the RF carpal flexion)

LF distal: mild positive

LF carpus: mild positive

Hindlimbs:

RH distal: negative

RH full limb: mild to moderate positive

LH distal limb: mild

LH full limb: mild to moderate positive; stifle flexion was also mild to moderate positive

Diagnostic Analgesia:

First block performed: Bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint intra-articular analgesia

Subjective lameness exam post first block:

The hindlimb lameness switched to a grade 1 RH after the block with a grade 1 RF present.

Lameness Locator® exam post first block:

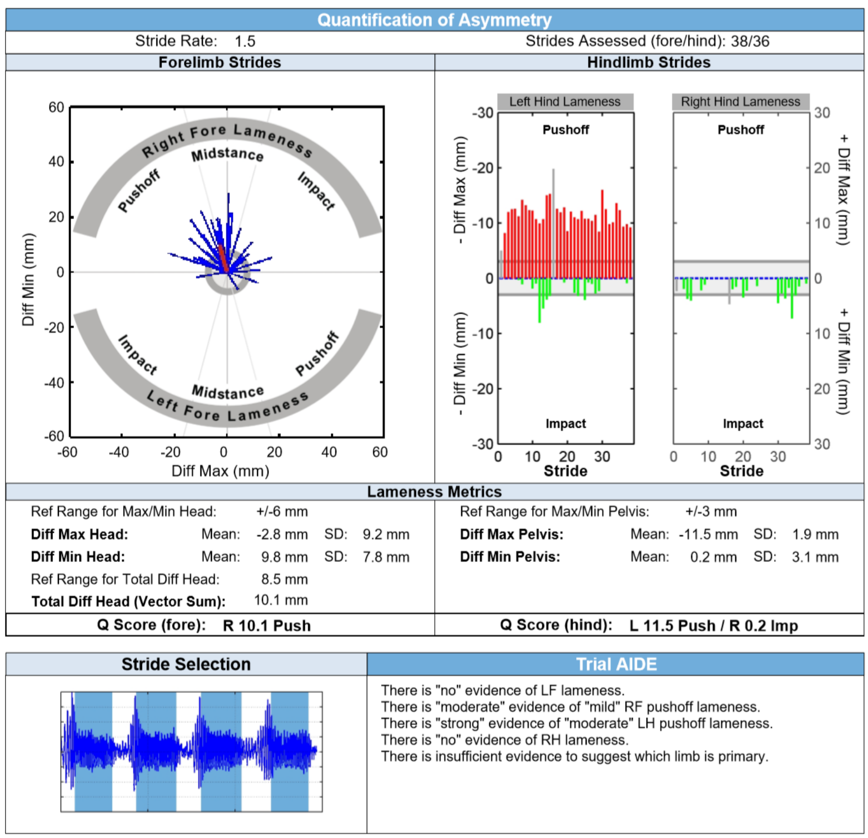
Moderate evidence of mild RF push-off lameness and strong evidence of a moderate LH push-off lameness remained (Table 2.3.6.5 and Figure 2.3.6.5). It was noted that the lameness changed during the force plate exam, so an additional lameness locator trial was performed to document the change observed. The impact lameness remained below the threshold for hindlimb lameness, but the asymmetry switched to the contralateral hindlimb.

Table 2.3.6.5: Horse 6 Lameness Locator ® data in a straight line (mean ± SD) comparing baseline and 20 minutes and 1 hour post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint blocks. The lame limb is highlighted in the parentheses.

	Baseline (after lunge)	20 minutes post bilateral DIT/TMT block	Percent change (%)	1 hour post bilateral DIT/TMT block	Percent change (%)
Vector Sum (mm)	14.3 (L)	10.1 (R)	^	12.0 (R)	19
Diff min Pelvis (mm)	1.5 (R)*	0.2 ± 3.1 (R)*	-87	1.4 ± 2.3 (L)*	^*
Diff max Pelvis (mm)	10.1 (L)	11.5 ± 1.9 (L)	14	9.4 ± 2.5 (L)	-18

*Asymmetry below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb

Figure 2.3.6.5: Horse 6 Lameness Locator® summary in a straight-line 20 minutes post bilateral distal intertarsal and tarsometatarsal joint block.



Force plate exam post first block

Walk: Six trials were analyzed for the left forelimb and left hindlimb. Five trials were analyzed for the right forelimb and right hindlimb (Tables 2.3.6.6–2.3.6.7 and Figure

2.3.6.6). Heel PVF increased in the LF and midstance PVF increased in the RF compared to baseline. Symmetry scores for PVF were close to 1, but the heel asymmetry was the greatest (RF less force than the LF). There was VI asymmetry present where the right forelimb was less than the left forelimb. This is supportive of a mild right forelimb lameness. After the block, the right hindlimb heel PVF increased and midstance PVF decreased compared to baseline. The VI was unchanged from baseline. Symmetry scores for PVF shifted that more force is now being placed on RH. This indicates that the block improved the right hindlimb lameness.

Table 2.3.6.6: Horse 6 force plate ground reaction forces at a walk (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.222 ± 0.158	5.176 ± 0.133	6.246 ± 0.068	3.486 ± 0.123
Left	5.357 ± 0.129	5.252 ± 0.127	6.182 ± 0.167	3.570 ± 0.051
Symmetry	1.03	1.01	0.99	1.02
HIND	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	4.246 ± 0.322	3.092 ± 0.048	4.466 ± 0.042	2.646 ± 0.110
Left	4.162 ± 0.180	3.002 ± 0.078	4.675 ± 0.083	2.650 ± 0.063
Symmetry	0.98	0.97	1.05	1.00

Figure 2.3.6.6: Horse 6 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=6) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

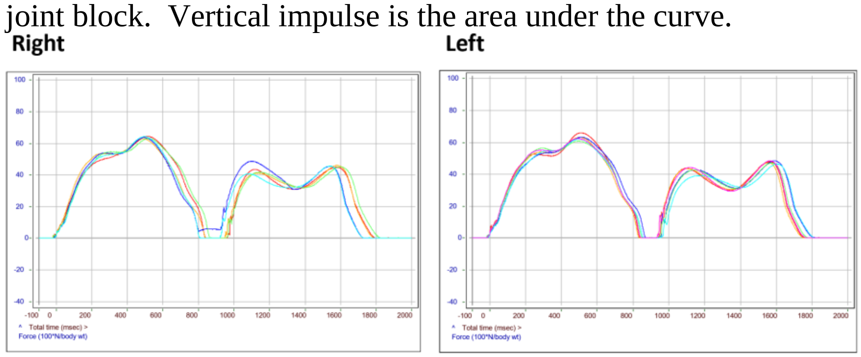


Table 2.3.6.7: Horse 6 force plate ground reaction forces at a walk (mean) comparing baseline and post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint block measurements.

	RF Baseline	**RF post bilateral DIT/TMT block**	**Percent change (%)**	**LF Baseline**	**LF post bilateral DIT/TMT block**	**Percent change (%)**
Heel PVF (N/kg)	5.407	5.222	-3	5.438	5.357	-2
MsPVF (N/kg)	5.343	5.176	-3	5.308	5.252	-1
Toe PVF (N/kg)	6.260	6.246	0	6.242	6.182	-1
VI (Ns/kg)	3.610	3.486	-3	3.516	3.570	2
	RH Baseline	**RH post bilateral DIT/TMT block**	**Percent change (%)**	**LH Baseline**	**LH post bilateral DIT/TMT block**	**Percent change (%)**
Heel PVF (N/kg)	4.120	4.246	3	4.228	4.162	-2
MsPVF (N/kg)	3.215	3.092	-4	3.072	3.002	-2
Toe PVF (N/kg)	4.358	4.466	2	4.594	4.675	2
VI (Ns/kg)	2.662	2.646	-1	2.670	2.650	-1

Trot: Six trials were analyzed for the left forelimb and left hindlimb. Five trials were analyzed for the right forelimb and right hindlimb (Tables 2.3.6.8–2.3.6.9 and Figure 2.3.6.7). Force plate data at the trot showed increased peak vertical force for the RF and LF compared to baseline. PVF was also increased for both the RH and LH compared to baseline. VI was increased from baseline for the RF, LF and RH compared to baseline. Forelimb PVF and VI symmetry scores were closer to 1 compared to baseline. The ratio of hindlimb to forelimb PVF were unchanged from baseline. The ratio of hindlimb to forelimb VI were increased from baseline. The increase in PVF in both hindlimbs compared to baseline supports that the intra-articular block improved the hindlimb lameness compared to baseline.

Table 2.3.6.8: Horse 6 force plate ground reaction forces at a trot (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind:Fore PVF**	**Ipsilateral Hind:Fore VI**	**Contralat Hind:Fore PVF**	**Contralat Hind:Fore VI**
Right	10.158 ± 0.280	1.898 ± 0.051	8.192 ± 0.018	1.492 ± 0.062	0.81	0.79	0.81	0.78
Left	10.058 ± 0.280	1.910 ± 0.037	8.093 ± 0.118	1.462 ± 0.035	0.80	0.77	0.80	0.77
Symmetry	0.99	1.01	0.99	0.98				

Figure 2.3.6.7: Horse 6 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

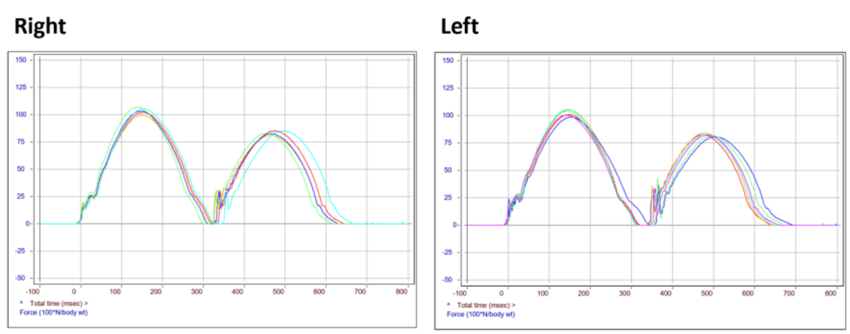


Table 2.3.6.9: Horse 6 force plate ground reaction forces at a trot (mean) comparing baseline and post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint block measurements.

	RF baseline	**RF post bilateral DIT/TMT block**	**Percent change (%)**	**LF baseline**	**LF post bilateral DIT/TMT block**	**Percent change (%)**
Fore PVF (N/kg)	9.968	10.158	2	9.790	10.058	3
Fore VI (Ns/kg)	1.864	1.898	2	1.892	1.910	1
	RH baseline	**RH post bilateral DIT/TMT block**	**Percent change (%)**	**LH baseline**	**LH post bilateral DIT/TMT block**	**Percent change (%)**
Hind PVF (N/kg)	7.964	8.192	3	7.937	8.093	2
Hind VI (Ns/kg)	1.422	1.492	5	1.420	1.462	3

Semi-Quantitative fetlock extension post first block: Four unobstructed trials were analyzed for the RF and RH. There were 6 unobstructed trials were analyzed for the LF and LH (Table 2.3.6.10).

Fetlock extension was greatest for the RF after the block, but the forelimb fetlock extension was unchanged from baseline. The RH and LH fetlock extension were approximately equal after performing blocks, but the fetlock extension was greater than baseline. This indicates that the block improved the hindlimb lameness symmetrically.

Table 2.3.6.10: Horse 6 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint block with comparison to baseline.

	RF	**LF**	**RH**	**LH**
Angle post bilateral DIT/TMT block	139.84 ± 1.55	141.88 ± 2.66	143.42 ± 2.60	144.20 ± 1.96
Baseline angle	139.77	140.27	147.40	147.48
Percent change (%)	0	1	-3	-2

Subjective clinical assessment for 1st block:

The lameness switched to a RH grade 1 lameness and grade 1 right forelimb lameness. The hindlimb lameness was not significant enough to continue blocking. The forelimb lameness was not consistent enough to pursue blocking. The diagnostic imaging chosen was bilateral tarsal radiographs and computed tomography to look for evidence of osteoarthritis.

Diagnostic Imaging:

Radiographs:

Bilateral tarsal series:

Right tarsus: Small osteophytes present at the dorsomedial surface of the distal central tarsal bone and distal third tarsal bone.

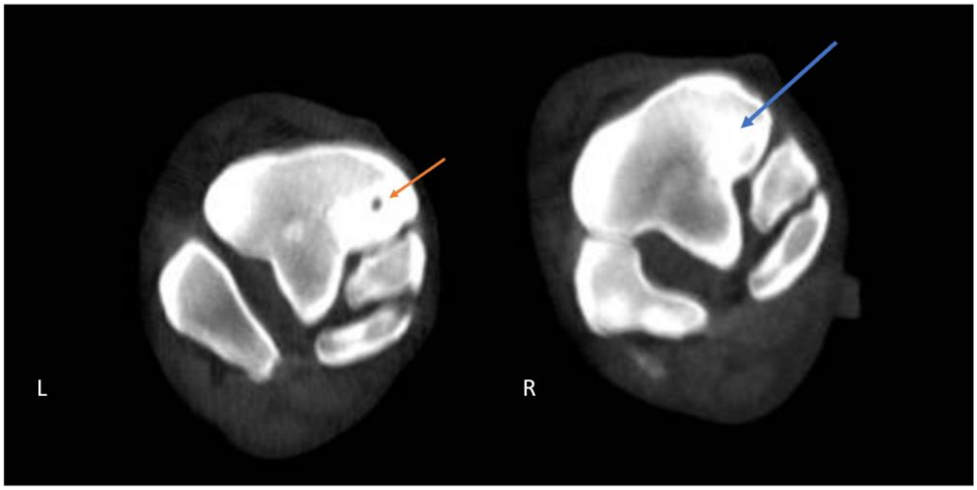
Left tarsus: Small osteophytes present at the dorsomedial surface of the distal central tarsal bone and distal third tarsal bone.

Hind CT (Figure 2.3.6.8)

Right Tarsus: Hyperdensity of the dorsomedial aspect of the proximal third tarsal bone. Minimal periosteal proliferation along the proximal dorsomedial aspect of the third tarsal bone.

Left Tarsus: Hyperdensity of the third and central tarsal bones. There is a circular hypodense area in the medial aspect of the third tarsal bone that is surrounded by hyperdensity.

Figure 2.3.6.8: CT images of the LH (left image) and RH (right image) tarsus in the transverse plane near the proximal aspect of the third tarsal bone. The marker is place on the lateral aspect of the limb. The red arrow highlights the circular hypodense area surrounded by hyperdensity (sclerosis) in the medial aspect of the left third tarsal bone. The blue arrow indicates the region of hyperdensity (sclerosis) in the medial aspect of the right third tarsal bone.



Diagnosis:

Subchondral bone cyst with sclerosis, left third tarsal bone.

Mild bilateral osteoarthritis of the distal intertarsal and tarsometatarsal joints.

Comparison of subjective and objective lameness exam findings:

There was some disagreement between subjective lameness exam and the Lameness Locator® for the hindlimb lameness on initial baseline, but there was agreement for the forelimb lameness. However, there was agreement between the subjective lameness exam and Lameness Locator® on the post lunging baseline. Both indicated a switched forelimb lameness from right forelimb before lunging to left forelimb after the lunge. This is the only method that could compare before and after lunge.

The forelimb walk data follows the subjective and Lameness Locator® for identifying the forelimb lameness. The hindlimb walk data disagreed with the subjective and Lameness Locator® data at baseline, which indicated a right hindlimb lameness on baseline when other methods indicated a left hindlimb lameness after the lunge. However, the subjective baseline prior to lunging indicated a right hindlimb lameness.

Main points for clinical gait analysis from Horse 6:

There was agreement with the subjective exam and the Lameness Locator® in the change in forelimb lameness from right forelimb to left forelimb after the lunging portion of the exam.

There was evidence of agreement between the subjective exam and the force plate data in the improvement of the hindlimb lameness with the bilateral intra-articular analgesia of the distal intertarsal and tarsometatarsal joints. The force plate walk data also indicated improvement in after DIT/TMT blocks with the decrease in hindlimb midstance PVF bilaterally.

There was some disagreement with the Lameness Locator® and the subjective exam on the final lameness status of the horse. The subjective exam indicated that the lameness improved significantly, but there was grade 1 right hindlimb lameness remaining at the end of the exam. However, the lameness was not significant enough to block. The lameness locator indicated there was a residual left hindlimb push-off lameness despite blocking of the distal hock joints. This could be further investigated with continued blocking of the stifles since there was mild effusion of the medial femorotibial joints bilaterally.

2.3.7 Horse 7

Signalment and use:

Horse 7, a 17-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings:

Forelimbs: The horse has contracted and under-run heels and dropped fetlocks bilaterally.

There was mild sensitivity to palpation of the proximal suspensory ligament bilaterally.

Hindlimbs:

For its hindlimb conformation, the horse is straight through the hocks, and has dropped fetlocks bilaterally (greater than forelimbs). On the left hindlimb, there was mild digital flexor tendon sheath effusion. On the right hindlimb, there was mild digital flexor tendon sheath effusion, mild sensitivity to palpation of the pastern. The suspensory branches were thickened bilaterally. The Churchill test for distal hock pain was a mild to moderate positive on the left hind and a moderate positive on the right hind.

Baseline subjective active exam findings:

Initial baseline in a straight line: LF grade 2; LH Grade 3

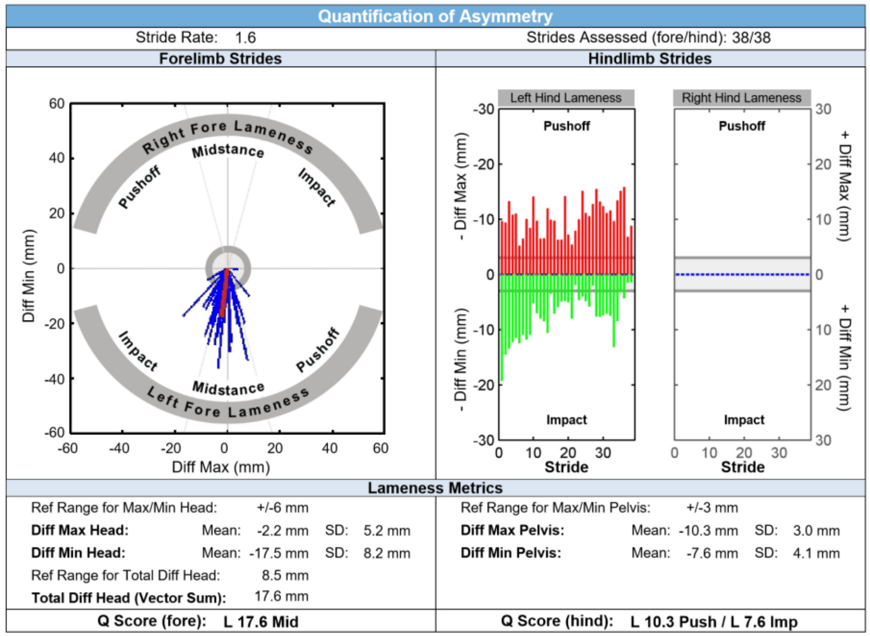
Baseline Lameness Locator® exam findings:

Initial baseline in a straight line: The first trial showed strong evidence of a mild LF midstance lameness. The second trial showed strong evidence of a mild to moderate LF midstance lameness. Both trials showed strong evidence of a mild to moderate LH impact lameness. There is strong evidence of a moderate to severe push-off lameness. The trial aide stated that this may be indicative a primary LH lameness (Table 2.3.7.1 and Figure 2.3.7.1).

Table 2.3.7.1: Horse 7 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	**Trial 2**	**Baseline (Mean ± SD)**
Vector Sum (mm)	16.6 (L)	17.6 (L)	17.1 ± 0.7
Diff min Pelvis (mm)	6.8 ± 3.0 (L)	7.6 ± 4.1 (L)	7.2 ± 0.6
Diff max Pelvis (mm)	12.7 ± 3.7 (L)	10.3 ± 4.1 (L)	11.5 ± 1.7

Figure 2.3.7.1. Horse 7 baseline Lameness Locator® data.



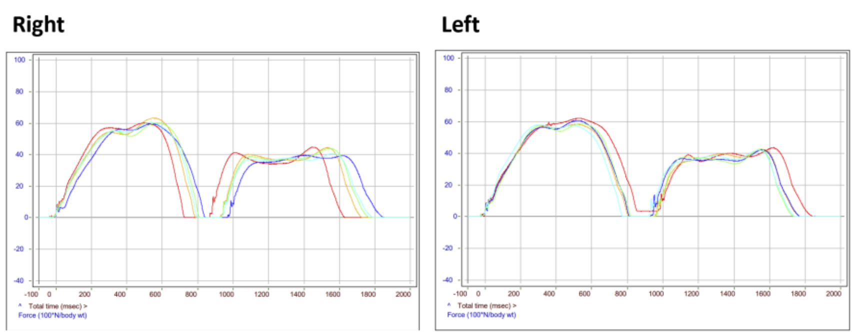
<u>*Baseline force plate exam findings:*</u>

Walk: Five trials were analyzed for each limb (Table 2.3.7.2 and Figure 2.3.7.2). There was decreased VI in the LH compared to RH. The hindlimb midstance PVFs and heel PVFs were symmetrical. There was asymmetry in the vertical impulse, where the RH was less than the LH. The left forelimb heel PVF and midstance PVF were greater than those for the right forelimb. The VI was greater for LF than RF. This is supportive of a left hindlimb lameness and right forelimb lameness. However, there is abnormality in force distribution of both hindlimbs that is supportive of a bilateral hindlimb lameness.

Table 2.3.7.2: Horse 7 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.474 ± 0.099	5.306 ± 0.169	5.964 ± 0.136	3.348 ± 0.102
Left	5.676 ± 0.118	5.478 ± 0.169	5.854 ± 0.171	3.426 ± 0.193
Symmetry	1.04	1.03	0.98	1.02
HIND				
Right	3.794 ± 0.234	3.550 ± 0.123	4.190 ± 0.231	2.550 ± 0.087
Left	3.792 ± 0.140	3.530 ± 0.183	4.180 ± 0.056	2.490 ± 0.129
Symmetry	1	0.99	0.99	0.97

Figure 2.3.7.2: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.

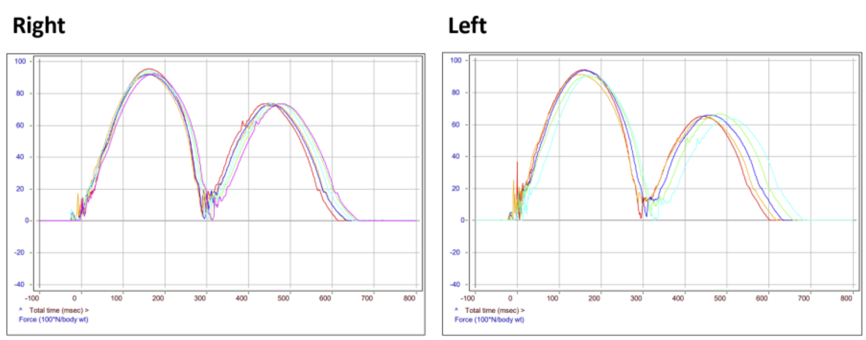


Trot: There were six trials analyzed for the right limbs and five trials analyzed for the left limbs (Table 2.3.7.3 and Figure 2.3.7.3). The PVF and VI were moderately decreased in the left hindlimb compared to the right hindlimb. The hindlimb PVF was decreased compared to normal control horses bilaterally (PVF: 8.087 ± 0.577). Left hindlimb VI was decreased compared to normal control horses (1.377 ± 0.0793). There was decreased ipsilateral hindlimb PVF to forelimb PVF and ipsilateral hindlimb VI to forelimb VI ratios for the left hindlimb to the left forelimb compared to control horses (PVF: 0.86 ± 0.07, VI: 0.77 ± 0.03). There was asymmetry present between hindlimbs, which were both supportive of a left hindlimb lameness. The PVF and VI for the forelimbs were symmetrical indicating no forelimb lameness was present.

Table 2.3.7.3: Horse 7 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind: Fore PVF	Ipsilateral Hind: Fore VI	Contralat Hind: Fore PVF	Contralat Hind: Fore VI
Right	9.155 ± 0.136	1.813 ± 0.039	7.200 ± 0.064	1.430 ± 0.035	0.79	0.79	0.79	0.77
Left	9.054 ± 0.166	1.850 ± 0.036	6.390 ± 0.120	1.244 ± 0.055	0.71	0.67	0.70	0.69
Symmetry	0.99	1.02	0.89	0.87				

Figure 2.3.7.3: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=6) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at the walk: There were five unobstructed video trials analyzed for each limb (Table 2.3.7.4). There was slight increased LF fetlock extension compared to RF. This likely not significant due to the degree of standard deviation. The hindlimb fetlock extension was fairly symmetrical. There is no indication of a hindlimb lameness based on symmetry.

Table 2.3.7.4: Horse 7 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	**LF**	**RH**	**LH**
Baseline angle (degrees)	134.30	128.40	142.63	141.07
SD	2.74	1.28	3.67	1.80

Flexion test responses:

Forelimbs:

Right Distal phalangeal: negative (worse LF)

Right Carpal: Negative

Left Distal phalangeal: mild positive

Left Carpal: Negative (spooked)

Hindlimbs:

Right Distal phalangeal: moderate to marked positive; LF lameness decreased

Right Full Limb: moderate positive

Left Distal phalangeal: moderate to marked positive

Left Full Limb: moderate positive

Diagnostic Analgesia:

First block performed: Bilateral low 6-point nerve block was performed first because of her dropped hind fetlocks bilaterally and moderate to marked response to distal hindlimb flexion.

Subjective lameness exam post first block:

There was no change in her lameness subjectively compared to baseline.

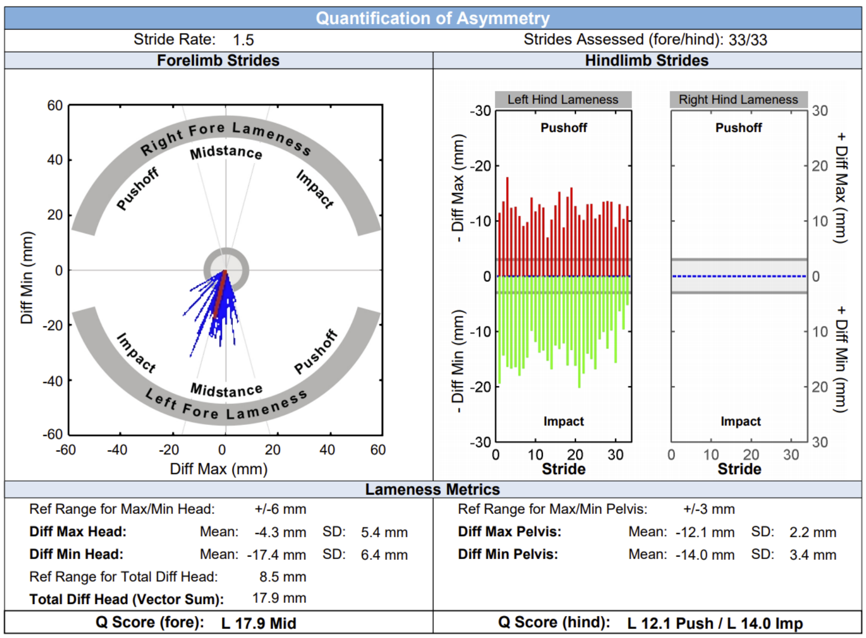
Lameness Locator® exam post first block:

The Lameness Locator® stated there was strong evidence of a mild to moderate LF midstance lameness as well as there was strong evidence of a moderate to severe LH impact and push-off lameness. The trial aide stated that this may be indicative of a primary LH lameness. The trial aide for block comparison stated that blocking did not improve the push off lameness significantly. The trial aide stated that LH blocking worsened the LH impact lameness (Table 2.3.7.5 and Figure 2.3.7.4).

Table 2.3.7.5: Horse 7 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post bilateral low 6-point nerve blocks. The lame limb is highlighted in the parentheses.

	Mean Baseline	Bilateral low 6-point nerve block	Percent Change (%)
Vector Sum (mm)	17.1	17.9 (L)	5
Diff min Pelvis (mm)	7.2	14.0 ± 3.4 (L)	94
Diff max Pelvis (mm)	11.5	12.1 ± 2.2 (L)	5

Figure 2.3.7.4. Horse 7 Lameness Locator® data in a straight line (mean ± SD) 15 minutes post bilateral low 6-point nerve blocks.



Force plate exam post first block

Walk: There were five trials analyzed for all four limbs (Tables 2.3.7.6–2.3.7.7 and Figure 2.3.7.5). There was decreased hindlimb midstance PVF compared to baseline bilaterally. There was increased hindlimb heel PVF compared to baseline bilaterally. This indicates improvement in the hindlimb lameness bilaterally. The LH midstance PVF and VI were less than those for the RH. This supports that there was improvement in both hindlimbs after the low 6-point block. Both forelimbs had decreased heel PVF and midstance PVF, as well as decreased VI compared to baseline. This suggests that the increased heel and midstance PVF at baseline in the forelimbs was a result of compensation as they have decreased in response to the bilateral low 6-point hindlimb blocks. Symmetry scores were all close to 1 except, there was VI asymmetry where the LF was less than the RH.

Table 2.3.7.6: Horse 7 force plate ground reaction forces at a walk (mean ± SD) post bilateral low 6-point nerve blocks. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.276 ± 0.155	5.182 ± 0.150	5.978 ± 0.250	3.218 ± 0.231
Left	5.258 ± 0.129	5.154 ± 0.088	5.916 ± 0.296	3.132 ± 0.180
Symmetry	1.00	0.99	0.99	0.97
HIND				
Right	3.978 ± 0.164	3.368 ± 0.055	4.162 ± 0.128	2.436 ± 0.092
Left	3.994 ± 0.295	3.136 ± 0.098	4.166 ± 0.149	2.286 ± 0.065
Symmetry	1.00	0.93	1.00	0.93

Figure 2.3.7.5: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post bilateral low 6-point nerve block. Vertical impulse is the area under the curve.

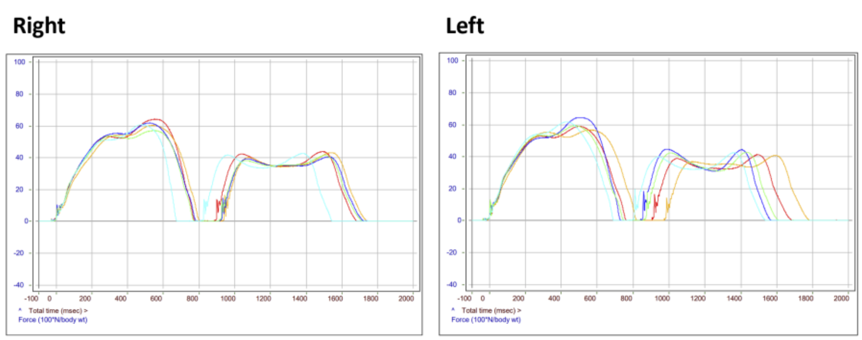


Table 2.3.7.7: Horse 7 force plate ground reaction forces at a walk (mean) comparing baseline and post bilateral low 6-point nerve block measurements.

	RF Baseline	**RF post Bilateral Low 6-point block**	**Percent change (%)**	**LF Baseline**	**LF post Bilateral Low 6-point block**	**Percent change (%)**
Heel PVF (N/kg)	5.474	5.276	-4	5.676	5.258	-7
Midstance PVF (N/kg)	5.306	5.182	-2	5.480	5.154	-6
Toe PVF (N/kg)	5.964	5.978	0	5.854	5.916	1
VI (Ns/kg)	3.348	3.218	-4	3.426	3.132	-9
	RH Baseline	**RH post Bilateral Low 6-point block**	**Percent change (%)**	**LH Baseline**	**LH post Bilateral Low 6-point block**	**Percent change (%)**
Heel PVF (N/kg)	3.794	3.978	5	3.792	3.994	5
Midstance PVF (N/kg)	3.548	3.368	-5	3.534	3.136	-11
Toe PVF (N/kg)	4.190	4.162	-1	4.182	4.166	0
VI (Ns/kg)	2.554	2.436	-5	2.490	2.286	-8

Trot: Five trials were analyzed for the right limbs and six trials were analyzed for the left limbs (Tables 2.3.7.8–2.3.7.9 and Figure 2.3.7.6). There was an increased hindlimb PVF and VI compared to baseline, with a greater increase on the RH. There was greater asymmetry in the PVF and VI between LH and RH compared to baseline, where the LH PVF and VI were less than the RH. The combination of findings indicates improvement in response to low 6-point block despite increased asymmetry. There was increased LF VI compared to baseline. There was VI asymmetry where the LF was greater than the RF VI. This indicates a remaining left hindlimb lameness. The forelimb PVF was symmetrical, but there was a VI asymmetry indicating a right forelimb lameness.

Table 2.3.7.8: Horse 7 force plate ground reaction forces at a trot (mean ± SD) post bilateral low 6-point nerve blocks. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind: Fore PVF	Ipsilateral Hind: Fore VI	Contralat Hind: Fore PVF	Contralat Hind: Fore VI
Right	9.130 ± 0.272	1.813 ± 0.087	8.160 ± 0.060	1.542 ± 0.027	0.89	0.85	0.89	0.80
Left	9.162 ± 0.069	1.917 ± 0.056	6.762 ± 0.204	1.297 ± 0.036	0.74	0.68	0.74	0.72
Symmetry	1.00	1.06	0.83	0.84				

Figure 2.3.7.6: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=6) limbs post bilateral low 6-point nerve block. Vertical impulse is the area under the curve.

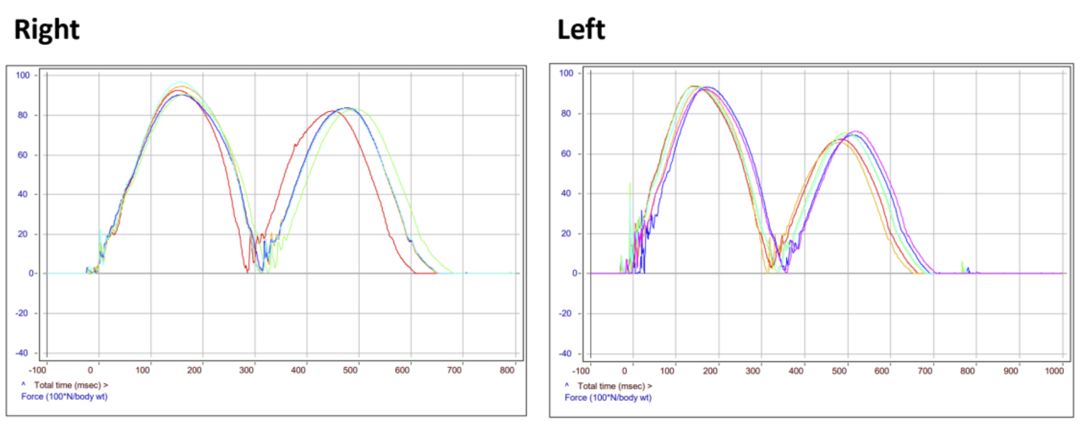


Table 2.3.7.9: Horse 7 force plate ground reaction forces at a trot (mean) comparing baseline and post bilateral low 6-point nerve block measurements.

	RF Baseline	**RF Bilateral Low 6-point block**	**Percent change (%)**	**LF Baseline**	**LF Bilateral Low 6-point block**	**Percent change (%)**
PVF (N/kg)	9.155	9.130	0	9.054	9.162	1
VI (Ns/kg)	1.813	1.800	-1	1.850	1.917	4
	RH Baseline	**RH Bilateral Low 6-point block**	**Percent change**	**LH Baseline**	**LH Bilateral Low 6-point block**	**Percent change**
PVF (N/kg)	7.200	8.160	13	6.390	6.762	6
VI (Ns/kg)	1.430	1.542	8	1.244	1.297	4

Semi-quantitative fetlock extension at the walk post first block: There were five unobstructed video trials analyzed for each limb (Table 2.3.7.10). There was a slight increase in fetlock extension in the right hindlimb. There was a decrease in fetlock extension in both forelimbs. This indicates a very slight improvement in the right hindlimb with bilateral low 6-point nerve blocks.

Table 2.3.7.10: Horse 7 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post bilateral low 6-point nerve blocks with comparison to baseline.

	LF	**RF**	**LH**	**RH**
Angle post Bilateral low 6-point block	130.18 ± 1.01	136.13 ± 1.95	140.74 ± 1.61	141.48 ± 2.36
Baseline angle	128.40	134.30	141.07	142.63
Percent change (%)	1	1	0	-1

Subjective clinical assessment for 1st block:

There was no improvement to the hindlimb lameness subjectively. There was a remaining left hindlimb and left forelimb lameness subjectively. The next block to be performed is bilateral DIT/TMT joint block because of the moderate positive Churchill tests and moderate positive full limb flexion.

Second block performed: Bilateral distal intertarsal/tarsometatarsal (DIT/TMT) joint block

Subjective lameness exam post second block:

After 25 min: 50-60% LH improvement, improvement in forelimb lameness to grade 1 LF.

After 35 min: 70% improvement in LH lameness.

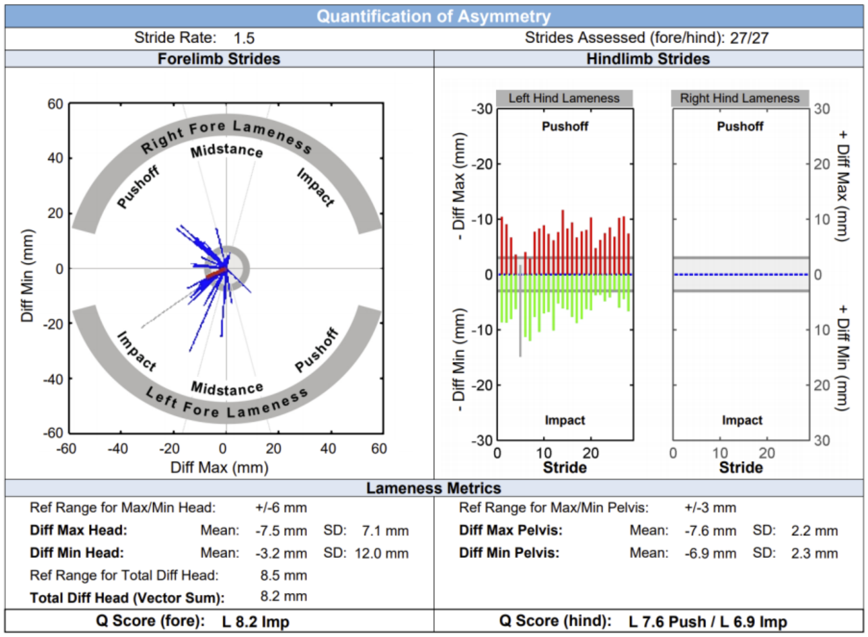
Lameness Locator® exam post second block:

The trial aide stated there was weak evidence of a very mild LF impact asymmetry. There was strong evidence of a mild to moderate LH impact lameness, and strong evidence of a mild to moderate LH push-off lameness. There was improvement in the impact and push-off lameness in the left hindlimb, but the greater improvement was in the impact lameness (Table 2.3.7.11)

Table 2.3.7.11: Horse 7 Lameness Locator® data in a straight line (mean ± SD) comparing post bilateral low 6-point nerve blocks and post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint blocks. The lame limb is highlighted in the parentheses.

	Bilateral low 6-point nerve block	**Bilateral DIT/TMT joint blocks**	**Percent Change (%)**
Vector Sum (mm)	17.9 (L)	8.2 (L)	-54
Diff min Pelvis (mm)	14.0 ± 3.4 (L)	6.9 ± 2.3 (L)	-51
Diff max Pelvis (mm)	12.1 ± 2.2 (L)	7.6 ± 2.2 (L)	-37

Figure 2.3.7.7. Horse 7 Lameness Locator® data in a straight line (mean ± SD) 20 minutes post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint blocks.



Force plate exam post second block

Walk: There were five trials analyzed for each limb (Tables 2.3.7.12–2.3.7.13 and Figure 2.3.7.8). The LH heel PVF decreased compared to the bilateral low 6-point block. There was a decrease in midstance PVF in the RH. This indicates an improvement in the right hind limb lameness and possible slight worsening of the left hindlimb lameness.

Table 2.3.7.12: Horse 7 force plate ground reaction forces at a walk (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	Heel PVF (N/kg)	MsPVF (N/kg)	Toe PVF (N/kg)	VI (Ns/Kg)
Right	5.200 ± 0.096	5.132 ± 0.096	6.204 ± 0.158	3.264 ± 0.046
Left	5.308 ± 0.110	5.170 ± 0.152	5.808 ± 0.214	3.206 ± 0.094
Symmetry	1.02	1.00	0.94	0.98
HIND				
Right	4.068 ± 0.157	3.176 ± 0.105	4.214 ± 0.115	2.422 ± 0.061
Left	3.810 ± 0.174	3.200 ± 0.070	4.154 ± 0.087	2.336 ± 0.060
Symmetry	0.94	1.01	0.99	0.96

Figure 2.3.7.8: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

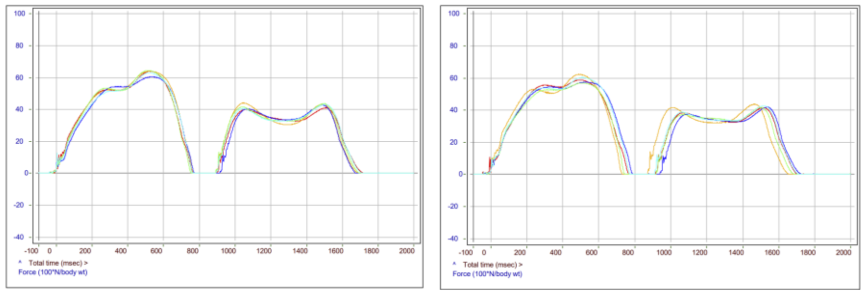


Table 2.3.7.13: Horse 7 force plate ground reaction forces at a walk (mean) comparing post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint blocks to the bilateral low 6-point block measurements.

	RF post bilateral low 6point block	RF post bilateral DIT/TMT block	Percent change (%)	LF post bilateral low 6point block	LF post bilateral DIT/TMT block	Percent change (%)
Heel PVF (N/kg)	5.28	5.2	-1	5.26	5.31	1
Midstance PVF (N/kg)	5.18	5.13	-1	5.15	5.17	0
Toe PVF (N/kg)	5.98	6.20	4	5.92	5.81	-2
VI (Ns/kg)	3.22	3.26	1	3.13	3.21	2
	RH post bilateral low 6point block	**RH post bilateral DIT/TMT block**	**Percent change (%)**	**LH post bilateral low 6point block**	**LH post bilateral DIT/TMT block**	**Percent change (%)**
Heel PVF (N/kg)	3.978	4.068	2	3.994	3.810	-5
Midstance PVF (N/kg)	3.368	3.176	-6	3.136	3.200	2
Toe PVF (N/kg)	4.16	4.21	1	4.17	4.15	0
VI (Ns/kg)	2.436	2.422	-1	2.286	2.336	2

Trot: There were 5 trials analyzed for each limb (Tables 2.3.7.14–2.3.7.15 and Figure 2.3.7.9). The hindlimb symmetry improved, however there was remaining asymmetry between hindlimbs for both PVF and VI where the LH PVF was less than a RH PVF. There was a decrease in right hindlimb PVF compared to the low 6-point block. This is indicative of a remaining left hindlimb lameness. The forelimb symmetry scores are within normal limits.

Table 2.3.7.14: Horse 7 force plate ground reaction forces at a trot (mean ± SD) post bilateral distal intertarsal and tarsometatarsal joint block. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	Fore VI	Hind PVF	Hind VI	Ipsilateral Hind: Fore PVF	Ipsilateral Hind: Fore VI	Contralat Hind: Fore PVF	Contralat Hind: Fore VI
Right	9.178 ± 0.142	1.906 ± 0.049	7.220 ± 0.168	1.450 ± 0.041	0.79	0.76	0.78	0.75
Left	9.138 ± 0.203	1.940 ± 0.062	6.780 ± 0.098	1.370 ± 0.040	0.74	0.71	0.79	0.76
Symmetry	1.00	1.02	0.94	0.94				

Figure 2.3.7.9: Horse 7 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post bilateral distal intertarsal and tarsometatarsal joint block. Vertical impulse is the area under the curve.

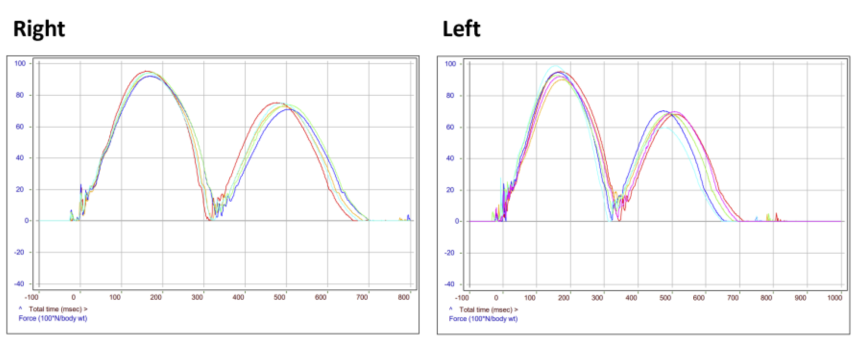


Table 2.3.7.15: Horse 7 force plate ground reaction forces at a trot (mean) comparing post bilateral distal intertarsal (DIT) and tarsometatarsal (TMT) joint blocks to the bilateral low 6-point block measurements.

	RF post bilateral low 6point block	**RF post bilateral DIT/TMT block**	**Percent change (%)**	**LF post bilateral low 6point block**	**LF post bilateral DIT/TMT block**	**Percent change (%)**
PVF (N/kg)	9.130	9.178	1	9.162	9.138	0
VI (Ns/kg)	1.800	1.906	6	1.917	1.940	1
	RH post bilateral Low 6-point block	**RH post bilateral DIT/TMT block**	**Percent change (%)**	**LH post Bilateral Low 6-point block**	**LH post bilateral DIT/TMT block**	**Percent change (%)**
PVF (N/kg)	8.160	7.220	-12	6.762	6.780	0
VI (Ns/kg)	1.542	1.450	-6	1.297	1.370	6

<u>Semi-quantitative fetlock extension at the walk post second block</u>: There were five unobstructed video trials analyzed for each limb (Table 2.3.7.16). There was minimal change in fetlock extension compared to the bilateral low 6-point blocks, with a slight decrease in fetlock extension in the LH, but the hindlimbs are fairly symmetrical when the standard deviation is considered. There is an indication of a right forelimb lameness because of the asymmetry between the forelimbs.

Table 2.3.7.16: Horse 7 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post bilateral distal intertarsal and tarsometatarsal joint blocks with comparison to post bilateral low 6-point nerve blocks.

	RF	**LF**	**RH**	**LH**
Bilateral DIT/TMT	135.78 ± 2.14	130.29 ± 1.98	140.17 ± 2.10	142.46 ± 1.83
Bilateral low 6-point block	136.13	130.18	141.48	140.74
Percent change (%)	0	0	-1	1

<u>Subjective clinical assessment for second block</u>:

There was a significant enough improvement subjectively from this block to proceed to diagnostic imaging. Based on the greatest subjective improvement with diagnostic analgesia of the distal intertarsal and tarsometatarsal joints, bilateral hock radiographs were recommended as the next step. A bilateral MRI of the hindlimb suspensory ligaments was recommended based on the palpable thickening of the suspensory branches bilaterally and marked response to distal hindlimb flexion.

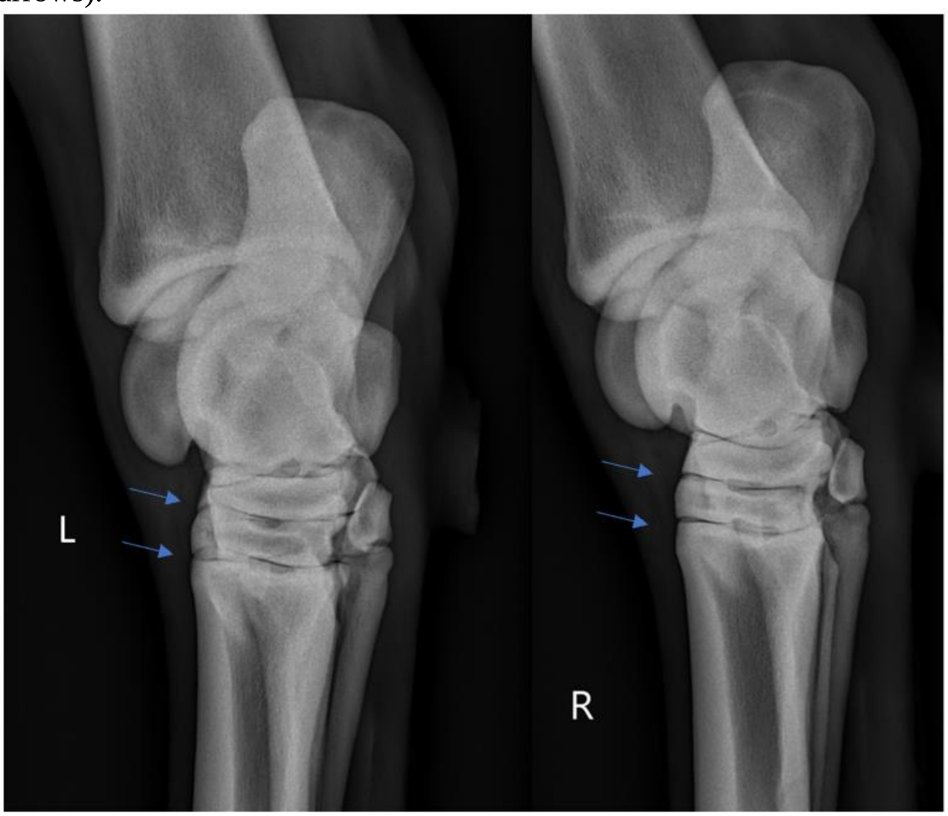
Diagnostic Imaging:

Radiographs: Tarsus, bilateral (Figure 2.3.7.10)

Left tarsus: There are small osteophytes present at dorsolateral surface of the distal central tarsal bone and the distal third tarsal bone.

Right tarsus: There are small osteophytes present at dorsolateral surface of the distal central tarsal bone and the distal dorsolateral third tarsal bone.

Figure 2.3.7.10: Dorsomedial palmar lateral radiographs of the LH (left image) and RH (right image) tarsus. There are small osteophytes present at dorsolateral surface of the distal central tarsal bone and the distal third tarsal bone bilaterally (indicated by blue arrows).



MRI, distal metatarsus and fetlock, bilateral (Figure 2.3.7.11)

The conclusions from the MRI are as follows: The desmopathy affecting the suspensory ligament branches is considered the most significant finding on this study, followed by the metatarsophalangeal joint synovitis.

<u>*Left hind*</u>:

-Extensive moderate desmopathy with severe periligamentous tissue proliferation, lateral suspensory ligament branch.

-Moderate desmopathy with mild to moderate periligamentous tissue proliferation, medial suspensory ligament branch.

-Mild to moderate synovitis and mild arthrosis with synovial membrane thickening, metatarsophalangeal joint.

-Focal subchondral bone irregularity, third metacarpal bone sagittal ridge.

-Mild to moderate diffuse enlargement, metatarsophalangeal joint collateral ligaments.

-Moderate subcutaneous edema, fetlock

-Mild sclerosis, third metacarpal bone

-Mild enlargement, medial oblique sesamoidean ligament

Right hind:

-Moderate desmopathy with possible parasagittal split and moderate periligamentous tissue proliferation, medial suspensory ligament branch

-Mild to moderate desmopathy and mild to moderate periligamentous tissue proliferation, lateral suspensory ligament branch

-Mild to moderate synovitis and arthrosis with synovial membrane thickening, metatarsophalangeal joint

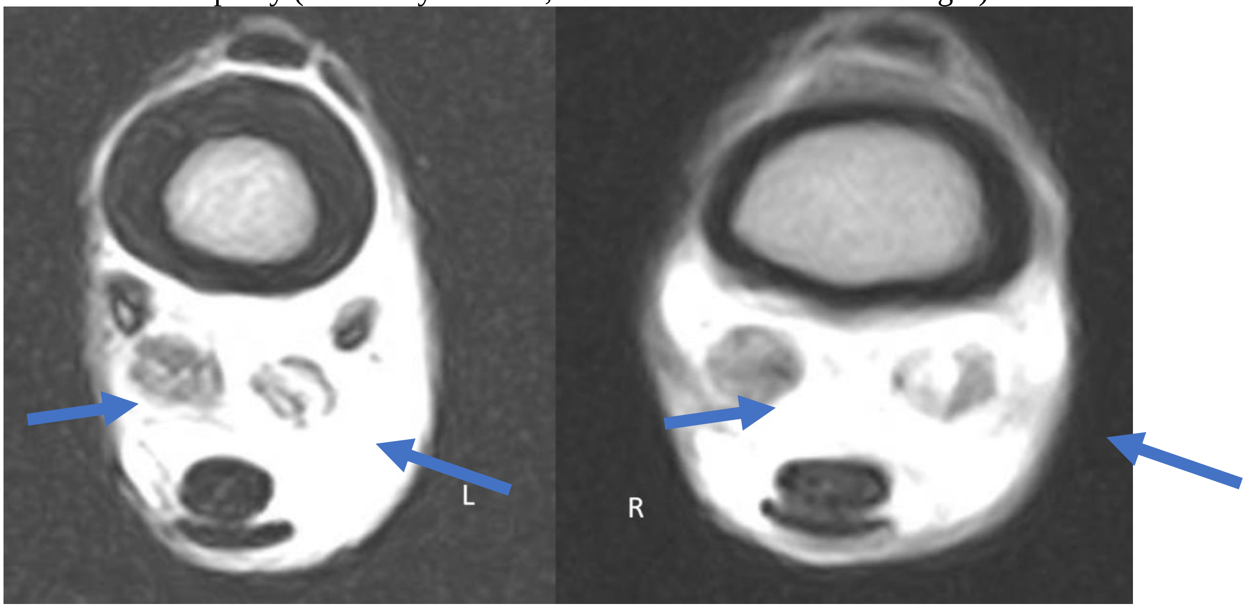
-Focal subchondral bone irregularity, third metacarpal bone sagittal ridge

-Mild to moderate diffuse enlargement, metatarsophalangeal joint collateral ligaments

-Periligamentous tissue proliferation, lateral oblique sesamoidean ligament

-Mild sclerosis, third metacarpal bone

Figure 2.3.7.11: Transverse plane MRI images of the LH (left image) and RH (right image) distal suspensory branches using a T2-weighted technique at the level of the distal diaphysis of the third metatarsal bone. Dorsal is at the top of the image and lateral is marked with the L or R marker. The arrows indicate the suspensory branches affected with moderate desmopathy (bilaterally affected, with the left worse than the right).



Diagnosis:

Suspensory branch desmitis, lateral and medial branches, bilateral hindlimb (left worse than right).

Osteoarthritis, Tarsometatarsal and distal intertarsal joints, bilateral (left worse than right).

Comparison of subjective and objective lameness exam findings:

The Lameness Locator® and the subjective lameness exam were in agreement that the low 6-point block did not improve the lameness. The Lameness Locator® indicated that the impact lameness on the LH worsened. There was disagreement in the force plate data. The force plate at the trot showed an increase in PVF applied to the hindlimbs, but a worsening of asymmetry between the hindlimbs. The low 6-point block bilateral improvement was demonstrated in the distribution of force at the walk on force plate examination. There was improvement at the trot that was observed subjectively, with the force plate at the trot, and the Lameness Locator® after the block of bilateral DIT and TMT joints. There was also additional improvement in the hindlimb walk data in the midstance PVF bilaterally after the block of bilateral distal hock joints.

Main points for clinical gait analysis from Horse 7

Gait analysis findings are consistent with clinical findings as there was improvement in force plate and Lameness Locator® with diagnostic analgesia of both regions where pathological findings were identified on diagnostic imaging modalities.

The force plate at the walk provided the evidence that the low 6-point block provided improvement to the horse's comfort level with the change in distribution of the forces. The force plate at the trot showed an increase in force applied to the hindlimbs after the low 6-point block compared to baseline. However, there was a greater increase in the force applied to the right hindlimb compared to the left hindlimb equating to increased asymmetry. This may provide an explanation for the discrepancy between force plate data at the walk and the subjective and kinematic assessment.

With hindlimb blocks, there were also symmetrical decreases in the forelimb heel and midstance PVF that could be indicative of compensatory changes.

2.3.8 Horse 8

Signalment and use:

Horse 8, a 16-year-old Quarter Horse mare, is used as a teaching and riding horse in classes at the University of Minnesota.

Passive exam findings:

Forelimbs: On the right forelimb, there was a medial exostosis of the third metacarpal that was not sensitive to palpation. There was mild to moderate coffin joint effusion of the RF. There was mild coffin joint effusion of the LF.

Hindlimbs: There was moderate medial femorotibial and femoropatellar joint effusion of the RH. There was moderate medial femorotibial joint effusion and mild femoropatellar effusion of the LH. There was a scar over the medial aspect of the LH metacarpophalangeal joint. The Churchill test for distal hock pain was negative bilaterally. There was mild sensitivity to palpation of the thoracic epaxial muscles.

Baseline subjective active exam findings:

Initial baseline in a straight line: Grade 1 RF and grade 2 LH

Lunging: In the right circle, the RF lameness was like baseline with a decreased cranial phase of the stride on the RH. In the left circle, there was an intermittent LF lameness with a decreased cranial phase of the stride on the LH.

Baseline after lunging: Grade 1 RF and grade 2 LH

Baseline Lameness Locator® exam findings:

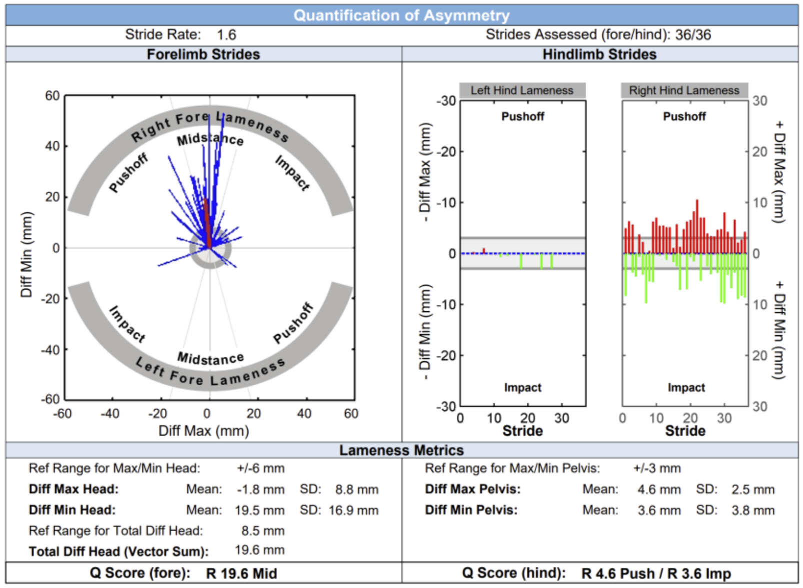
Initial baseline in straight line: There was moderate evidence of a mild RF midstance lameness.

There was moderate evidence of mild RH impact lameness. There was strong evidence of a mild RH push-off lameness. The trial aide stated there was insufficient evidence to determine which limb is primary (Table 2.3.8.1 and Figure 2.3.8.1).

Table 2.3.8.1: Horse 8 baseline Lameness Locator® data (mean ± SD) from 2 trials collected in a straight line. The lame limb is highlighted in the parentheses.

	Trial 1	**Trial 2**	**Mean**
Vector sum (mm)	16.6 (R)	19.6 (R)	18.1
Diff min Pelvis (mm)	3.3 ± 3.1 (R)	3.6 ± 3.8 (R)	3.4 ± 3.5
Diff max Pelvis (mm)	4.6 ± 2.2 (R)	4.6 ± 2.5 (R)	4.6 ± 2.4

Figure 2.3.8.1: Horse 8 baseline Lameness Locator® summary from Trial 2 in a straight line.



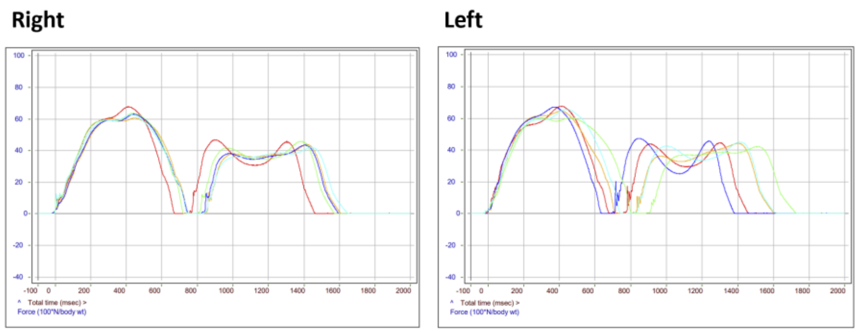
Baseline force plate exam findings (after lunge):

Walk: Five trials were analyzed for all four limbs (Table 2.3.8.2 and Figure 2.3.8.2). For the forelimbs, the symmetry scores were close to 1, which does not support the presence of a forelimb lameness. The midstance PVF for the left hindlimb was decreased compared to the right hindlimb. This is supportive of a right hindlimb lameness.

Table 2.3.8.2: Horse 8 baseline force plate ground reaction forces at a walk (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.834 ± 0.076	5.780 ± 0.050	6.234 ± 0.254	3.116 ± 0.093
Left	5.858 ± 0.223	5.806 ± 0.200	6.392 ± 0.279	3.146 ± 0.269
Symmetry	1.00	1.00	1.03	1.01
HIND				
Right	3.944 ± 0.415	3.345 ± 0.209	4.352 ± 0.183	2.366 ± 0.071
Left	4.078 ± 0.460	3.088 ± 0.426	4.392 ± 0.179	2.310 ± 0.193
Symmetry	1.03	0.92	1.01	0.98

Figure 2.3.8.2: Horse 8 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.

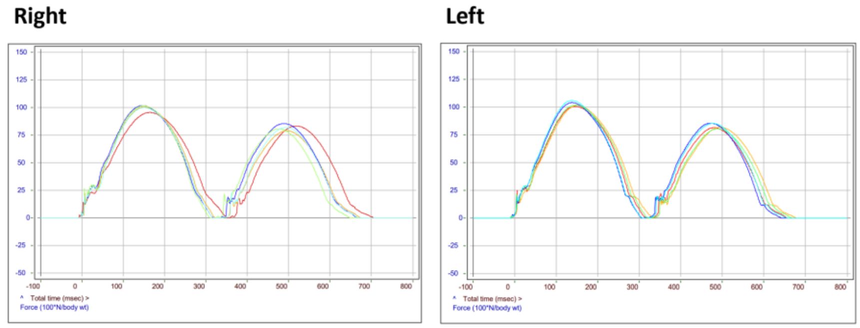


Trot: There were five trials analyzed for all four limbs (Table 2.3.8.3 and Figure 2.3.8.3). The right hindlimb PVF and VI were less than those of the left hindlimb. The PVF was less for the right forelimb compared to the left forelimb. This is suggestive of a right hindlimb and right forelimb lameness.

Table 2.3.8.3: Horse 8 baseline force plate ground reaction forces at a trot (mean ± SD). Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind: Fore PVF**	**Ipsilateral Hind: Fore VI**	**Contralat Hind: Fore PVF**	**Contralat Hind: Fore VI**
Right	9.810 ± 0.252	1.892 ± 0.034	8.062 ± 0.245	1.448 ± 0.071	0.82	0.77	0.80	0.76
Left	10.100 ± 0.210	1.896 ± 0.030	8.148 ± 0.227	1.456 ± 0.039	0.81	0.77	0.83	0.77
Symmetry	1.03	1.00	1.01	1.01				

Figure 2.3.8.3: Horse 8 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs at baseline. Vertical impulse is the area under the curve.



Semi-quantitative fetlock extension at a walk: Five unobstructed video trials were measured for each limb (Table 2.3.8.4). There was increased fetlock extension of the right forelimb compared to the left forelimb, which suggests a possible left forelimb lameness. There was greater fetlock extension in the RH compared to the LH, suggesting a left hindlimb lameness. However, it must be considered that the standard deviation is substantial, which limits the strength of these conclusions.

Table 2.3.8.4: Horse 8 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D), at baseline.

	RF	**LF**	**RH**	**LH**
Baseline angle (degrees)	135.87	137.86	147.27	150.36
SD	3.31	2.02	3.37	2.48

Flexion test responses:

Forelimbs:

LF Distal: negative

LF Carpus: negative

RF Distal: mild

RF Carpus: mild

Hindlimbs:

RH distal limb: negative

RH full limb: mild-moderate

LH distal limb: negative

LH full limb: mild-moderate

Subjective clinical assessment:

Bilateral medial femorotibial joints were blocked based on the evidence of bilateral hindlimb lameness with positive response to full hindlimb flexion and the presence of effusion in the medial femorotibial joint with the absence of a Churchill response.

Diagnostic Analgesia:

First block performed: Bilateral medial femorotibial (MFT) joint blocks

Subjective lameness exam post first block:

There was 70% improvement in the left hindlimb lameness with the bilateral MFT joint blocks. There was no change to the RF lameness.

Lameness Locator® exam post first block:

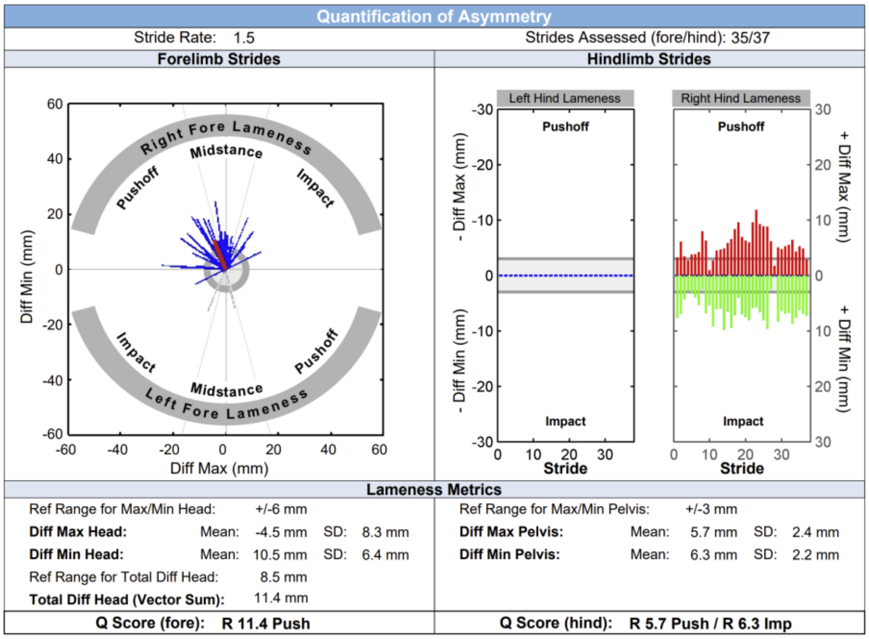
There was moderate evidence of a mild RF push-off lameness and there was strong evidence of a mild-moderate RH impact lameness and a mild RH push-off lameness. The trial aide stated that

results may be indicative of a primary RH lameness (Table 2.3.8.5 and Figure 2.3.8.4).

Table 2.3.8.5: Horse 8 Lameness Locator® data in a straight line (mean ± SD) comparing baseline and post bilateral medial femorotibial (MFT) joint blocks. The lame limb is highlighted in the parentheses.

	Mean Baseline	Post bilateral MFT block	Percent change (%)
Vector sum (mm)	18.1 (R)	11.4 (R)	-37
Diff min Pelvis (mm)	3.45 ± 3.45 (R)	6.3 ± 2.2 (R)	83
Diff max Pelvis (mm)	4.6 ± 2.35 (R)	5.7 ± 2.4 (R)	24

Figure 2.3.8.4: Horse 8 Lameness Locator® summary in a straight-line post bilateral medial femorotibial (MFT) joint blocks.



Force plate exam post first block

Walk: Five trials analyzed for all four limbs (Tables 2.3.8.6–2.3.8.7 and Figure 2.3.8.5). The RF and LF demonstrated decreased heel, midstance and toe PVF compared to baseline. The symmetry scores remained relatively constant compared to baseline except for a slight increase in VI asymmetry, which suggests a mild right forelimb lameness present. The right and left hindlimbs both showed decreased heel PVF, increased MsPVF, decreased toe PVF and increased VI compared to baseline. The midstance PVF was less in the left hindlimb compared to the right hindlimb. This is supportive of a worsening of hindlimb lameness bilaterally.

Table 2.3.8.6: Horse 8 force plate ground reaction forces at a walk (mean ± SD) post bilateral medial femorotibial joint blocks. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

FORE	**Heel PVF (N/kg)**	**MsPVF (N/kg)**	**Toe PVF (N/kg)**	**VI (Ns/Kg)**
Right	5.526 ± 0.160	5.372 ± 0.072	6.066 ± 0.177	3.368 ± 0.151
Left	5.476 ± 0.109	5.388 ± 0.104	6.074 ± 0.148	3.456 ± 0.120
Symmetry	0.99	1.00	1.00	1.03
HIND				
Right	3.654 ± 0.131	3.510 ± 0.056	4.092 ± 0.146	2.474 ± 0.036
Left	3.686 ± 0.131	3.374 ± 0.077	4.112 ± 0.089	2.476 ± 0.091
Symmetry	1.01	0.96	1.00	1.00

Figure 2.3.8.5: Horse 8 graphs of all acceptable vertical (N/kg) force plate trials at a walk for ipsilateral right (n=5) and left (n=5) limbs post bilateral medial femorotibial joint blocks. Vertical impulse is the area under the curve.

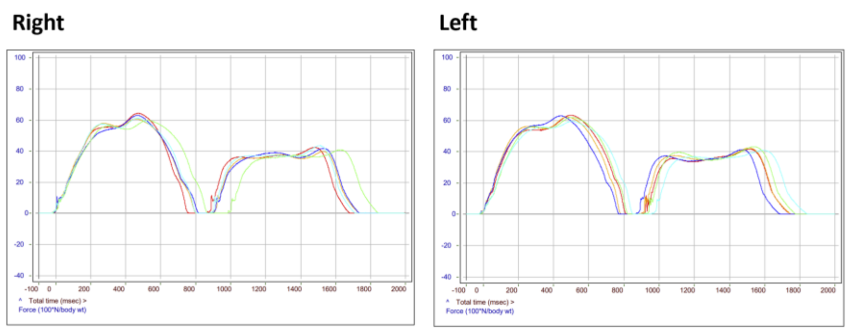


Table 2.3.8.7: Horse 8 force plate ground reaction forces at a walk (mean) comparing baseline and post bilateral medial femorotibial (MFT) joint block measurements.

	RF Baseline	**RF post bilateral MFT joint block**	**Percent change (%)**	**LF Baseline**	**LF post bilateral MFT joint block**	**Percent change (%)**
Heel PVF (N/kg)	5.834	5.526	-5	5.858	5.476	-7
Midstance PVF (N/kg)	5.78	5.372	-7	5.806	5.388	-7
Toe PVF (N/kg)	6.234	6.066	-3	6.392	6.074	-5
VI (NS/kg)	3.116	3.368	8	3.146	3.456	10
	RH Baseline	**RH post bilateral MFT joint block**	**Percent change (%)**	**LH Baseline**	**LH post bilateral MFT joint block**	**Percent change (%)**
Heel PVF (N/kg)	3.944	3.654	-7	4.078	3.686	-10
Midstance PVF (N/kg)	3.345	3.510	5	3.088	3.374	9
Toe PVF (N/kg)	4.352	4.092	-6	4.392	4.112	-6
VI (NS/kg)	2.366	2.474	5	2.31	2.476	7

Trot: Five trials analyzed for all four limbs (Tables 2.3.8.8 -2.3.8.9 and Figure 2.3.8.6). There was an increased PVF for the RF and LF compared to baseline. There was an increased asymmetry between the hindlimbs for PVF and VI, where the right hindlimb had decreased PVF and VI relative to the left hindlimb. This is suggestive of a worsening right hindlimb lameness.

Table 2.3.8.8: Horse 8 force plate ground reaction forces at a trot (mean ± SD) post bilateral medial femorotibial joint blocks. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry. Ratios of hindlimb to forelimb peak vertical force and vertical impulse were calculated by dividing the hindlimb value by the forelimb value.

	Fore PVF	**Fore VI**	**Hind PVF**	**Hind VI**	**Ipsilateral Hind: Fore PVF**	**Ipsilateral Hind: Fore VI**	**Contralat Hind: Fore PVF**	**Contralat Hind: Fore VI**
Right	10.226 ± 0.086	1.916 ± 0.031	8.304 ± 0.243	1.464 ± 0.025	0.81	0.76	0.81	0.77
Left	10.240 ± 0.233	1.892 ± 0.069	8.154 ± 0.222	1.422 ± 0.047	0.80	0.75	0.80	0.74
Symmetry	1.00	1.01	1.02	1.03				

Figure 2.3.8.6: Horse 8 graphs of all acceptable vertical (N/kg) force plate trials at a trot for ipsilateral right (n=5) and left (n=5) limbs post bilateral medial femorotibial (MFT) joint blocks. Vertical impulse is the area under the curve.

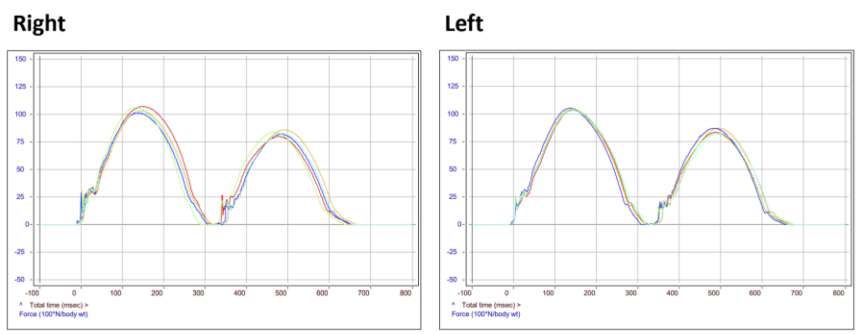


Table 2.3.8.9: Horse 8 force plate ground reaction forces at a trot (mean ± SD) post bilateral distal medial femorotibial (MFT) joint blocks. Symmetry score was calculated

	RF Baseline	RF post bilateral MFT joint block	Percent change (%)	LF Baseline	LF post bilateral MFT joint block	Percent change (%)
PVF (N/kg)	9.810	10.240	4	10.100	10.226	1
VI (ns/kg)	1.892	1.892	0	1.896	1.916	1
	RH Baseline	**RH post Bilateral MFT joint block**	**Percent change (%)**	**LH Baseline**	**LH post Bilateral MFT joint block**	**Percent change (%)**
PVF (N/kg)	8.062	8.154	1	8.148	8.304	2
VI (ns/kg)	1.448	1.422	-2	1.456	1.464	1

Semi-quantitative fetlock extension: Five unobstructed video trials were analyzed for each limb (Table 2.3.8.10). There was decreased fetlock extension of the RF and LF. The asymmetry between right and left forelimb suggests a left forelimb lameness. There was increased fetlock extension of the RH and LH compared to baseline. There was still greater fetlock extension of the RH compared to the LH supporting a left hindlimb lameness.

Table 2.3.8.10: Horse 8 angles (degrees; mean and SD) of fetlock extension at a walk, as determined from the dorsum (2-D) post bilateral medial femorotibial (MFT) joint blocks with comparison to baseline.

	RF	LF	RH	LH
Angle post bilateral MFT blocks	142.2 ± 0.72	138.8 ± 2.6	145.7 ± 0.86	147.5 ± 3.12
Baseline angle	135.9	137.9	147.3	150.4
Percent change (%)	-5	-1	1	2

Subjective clinical assessment for 1st block:

The subjective lameness exam concluded that the bilateral diagnostic analgesia of the medial femorotibial joints improved the left hind limb lameness 70% and was deemed a satisfactory improvement in the lameness. Due to the subjective improvement to the medial femorotibial joint blocks, stifle radiographs and ultrasound were chosen to investigate potential osseous and soft tissue abnormalities. After objective analysis was performed, the worsening lameness in the right hindlimb on objective examination and the abnormalities seen on force plate at the walk were concerning. Hindlimb CT was performed to investigate possible abnormalities from the foot to the level of the distal tibia.

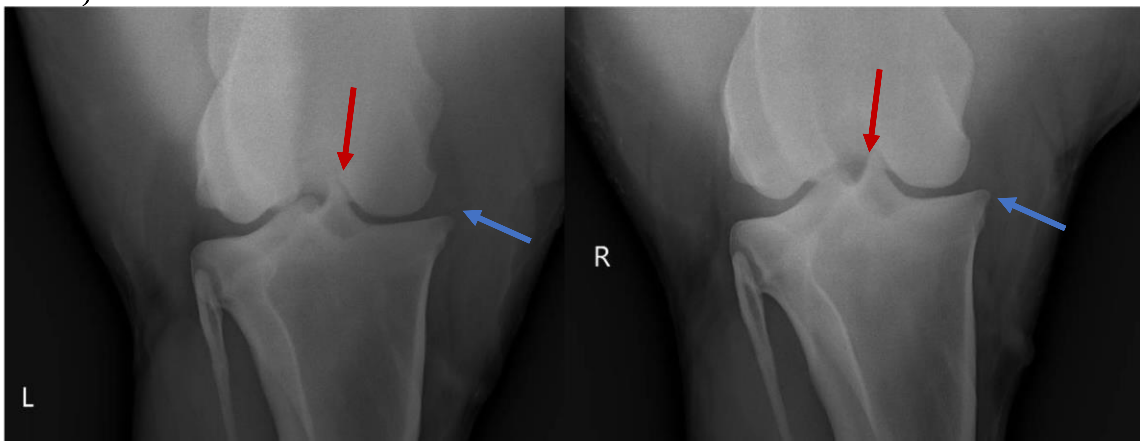
Diagnostic Imaging:

Radiographs: Stifle, bilateral (Figure 2.3.8.7)

Left stifle: There was evidence of intracapsular swelling. There is an osteophyte on the proximal medial tibial plateau, with the left osteophyte larger than the right. There is an osteophyte on the axial aspect of the medial epicondyle next to the intercondylar eminence.

Right stifle: There was evidence of intracapsular swelling. The intercondylar eminence was more prominent on the right hindlimb compared to the left hindlimb. There is an osteophyte on the proximal medial tibial plateau, with the left osteophyte larger than the right. There is an osteophyte on the axial aspect of the medial epicondyle next to the intercondylar eminence.

Figure 2.3.8.7: Caudal cranial radiographs of the L (left image) and R (right image) stifle. Lateral is to the left of each image. The intercondylar eminence was more prominent on the right hindlimb compared to the left hindlimb (red arrows). There is an osteophyte on the proximal medial tibial plateau, with the left osteophyte larger than the right (blue arrows).



Ultrasound: Medial femorotibial (MFT) joint, bilaterally

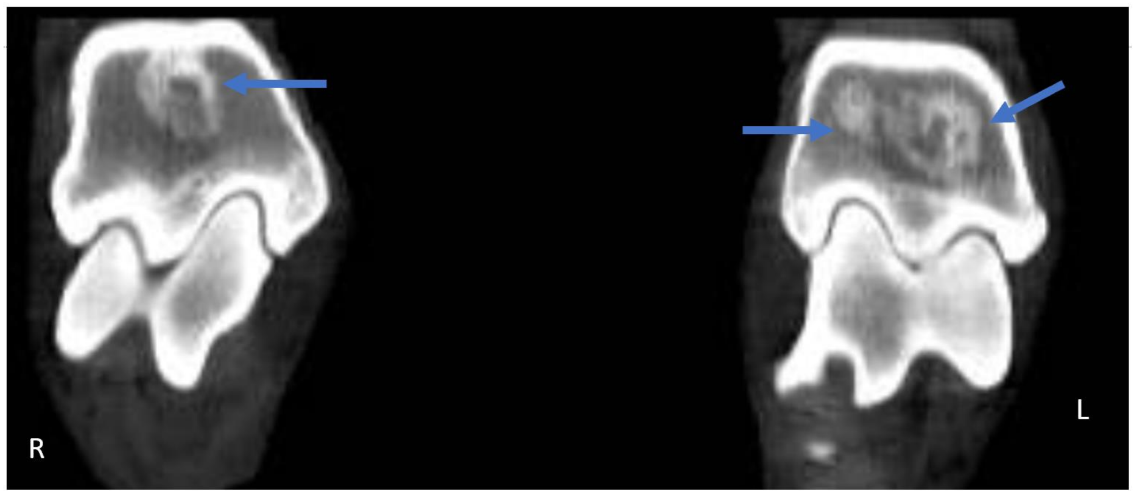
On ultrasound, there was effusion within the MFT and changes to medial meniscus (LH > RH). There was a mild increase in hypoechogenicity of the medial meniscus bilaterally compared to a normal meniscus. The LH had greater hypoechogenicity compared to the

RH. There was increased anechoic fluid in the MFT joint compared to a normal MFT bilaterally.

Hindlimb CT (focus on tarsus): (Figure 2.3.8.8)

There was multifocal to coalescing hyperdensity of the epiphysis of the distal tibia bilaterally.

Figure 2.3.8.8: Frontal plane CT images of the right (left image) and left (right image) hindlimbs at the mid-distal tibia and talus. There was multifocal to coalescing hyperdensity of the epiphysis of the distal tibia bilaterally (blue arrows). Lateral is denoted by the location of the letter and proximal is to the top of the image.



Diagnosis:

Osteoarthritis of the left and right medial femorotibial joints, left greater than right.

Open for sclerosis of the distal tibia (region of the physis), bilateral.

Comparison of subjective and objective lameness exam findings:

The subjective lameness exam concluded that the bilateral diagnostic analgesia of the medial femorotibial joints improved the lameness 70%. The Lameness Locator® findings identified a RF and RH lameness, but the evidence was not sufficient to determine which limb was primary. The RF lameness improved after the medial femorotibial block. The RH lameness worsened after the bilateral medial femorotibial joint block and then was identified as the primary lameness.

Main points for clinical gait analysis from Horse 8:

The subjective exam and fetlock extension both indicated a left hindlimb lameness on baseline while the Lameness Locator® and force plate at the trot both indicated a right hindlimb lameness and that this lameness worsened when bilateral MFT blocks were performed. The changes at the walk on the force plate indicated a bilateral hindlimb lameness that worsened with blocking of the medial femorotibial joints.

For Horse 8, the subjective, objective kinematic and kinetic components highlighted a different aspect of her lameness. Overall, Horse 8 had a mild lameness that was bilateral. Although the subjective assessment concluded an improvement in the lameness, the objective components highlighted that there was still residual lameness that needed to be addressed. She did have ultrasonographic evidence of mild meniscal injury and medial femorotibial effusion and blocking the MFT joints bilaterally did change the subjective and objective data but did not return to soundness on objective assessment. This is highlighted by worsening of RH lameness on the Lameness Locator®, increased asymmetry for the hindlimbs on the force plate supporting RH lameness and abnormal force distribution at the walk on the force plate for both hindlimbs where the heel PVF decreased and the midstance PVF increased. Using the objective data in real time would have resulted in a continuation of blocking compared to using the subjective exams alone.

CHAPTER 3

3.1 Introduction

In the clinical setting, subjective observation has historically been used to assess equine gait and lameness (Baxter 2020). Objective analysis is not frequently performed because of the need for special equipment (Keegan 2020b). However, it would be helpful to apply objective techniques to the clinical setting to aid in the diagnosis of subtle and multi-limb lameness and to overcome the challenges associated with subjectivity of lameness exams for the evaluation of diagnostic analgesia and response to treatment (Keegan 2020b; Donnell 2015; Keegan 2010; Keegan 2012; McCracken 2012). Historically, gait analysis has primarily been used in the research setting to validate or define experimentally created lameness, but select technologies have the potential to be used clinically (Keegan 2020b). The current gap in knowledge in the field in kinetic and kinematic responses to clinical interventions for naturally-occurring lameness is a barrier to the clinical implementation of these technologies.

By combining kinetic and kinematic analysis, correlations could be identified that would not only aid in the evaluation of lameness in the hospital setting, but also potentially in the field setting. It is important to point out that objective gait analysis is not without limitations in its applications in the clinical setting. For many, there is significant time investment needed for the collection and analysis of data, which might be difficult to quickly obtain during a lameness exam. In addition, most technologies such as 3D kinematic analysis or force plate are not mobile and therefore can only be used in a hospital or clinic setting. However, body mounted inertial sensors (BMISS) have the capability to be used by field practitioners because they use wireless sensors that are placed on specific landmarks on the horse.

A few studies have performed objective analysis to investigate the use of perineural analgesia in sound horses (Van de Water 2016), experimentally-induced lameness (Radtke 2020) or naturally-occurring lameness (Bidwell 2004; Leelamankong 2020). Thus, much of the knowledge about objective data must be extrapolated from experimentally-induced lameness to compare to the potential effect of abolishment of naturally-occurring lameness. By examining response to analgesics using multiple objective measures together, it might be possible to identify where the subjective analysis is correct as well as when a particular objective measure might actually be best for a particular clinical evaluation so that horses can be directed to those locations with that technology present. Therefore, this study will attempt to fill in some of this gap in knowledge in this field. The objective of this study was to investigate the kinematic and kinetic effects of diagnostic analgesia in naturally-occurring lameness in 8 horses and compare their responses to determine similarities, or patterns of interest that might develop based on lameness, technique used, or disease.

We hypothesized that the application of diagnostic analgesia would alter kinetic and kinematic values at the walk and trot in naturally-occurring lameness. For kinetics, this would mean increased PVF on the lame limb in response to diagnostic analgesia. For kinematics, this would mean decreased asymmetry in kinematic parameters. Secondly, we hypothesized that the application of diagnostic analgesia will result in the reversal of compensatory changes in the non-lame limbs. Finally, in horses with the same diagnosis, there will be similar patterns in their response to diagnostic analgesia.

3.2 Methods

Subjective and objective gait analysis was performed on the eight Quarter Horse mares as described in Chapter 2. Briefly, a subjective lameness exam was performed for each horse as it would be for a traditional clinical exam. This includes a passive exam of musculoskeletal structures followed by the active exam consisting of straight line, circles, and flexion tests to establish a baseline lameness and identify the most appropriate course of action for diagnostic analgesia. The lameness exam was guided by subjective evaluation as is done in the clinical setting. A primary lame leg was identified using subjective evaluation. Palpation, lunging and flexion tests were used to determine the region of interest for diagnostic analgesia. Then, diagnostic analgesia was performed with bupivacaine to systematically desensitize regions of the limbs to localize the source of pain.

Peri-neural and intraarticular analgesia techniques were performed as described in Equine Joint Injection and Regional Anesthesia (Moyer 2007). Improvement in lameness as a result of diagnostic analgesia was subjectively graded, as it is in the typical clinical scenario, and performed until the horse was determined to have reached a satisfactory level of improvement (usually >60% subjective improvement from baseline). Diagnostic imaging appropriate for the region identified by diagnostic anesthesia was then performed to reach a definitive diagnosis.

During the exam described above, objective data was collected at the walk and trot as described in Chapter 2. Data was collected using each objective method for baseline then after each diagnostic analgesia performed. Objective data was analyzed retrospectively to compare to the assessment and conclusions of the subjective exam. Briefly, at the trot, kinematic data collection was performed using the Lameness Locator® system[d], a commercially available body mounted inertial sensor system. At least 25 strides were collected for one complete trial. Two trials were collected for each baseline, unless the horse's lameness was severe and welfare was compromised by additional forced trotting. Kinetic data was collected at the walk and trot using an in-ground force plate[e] recessed in the lameness runway, which is covered by a non-slip rubber mat. At least five trials were collected per limb for the walk and trot. Symmetry scores were calculated by taking the value of the parameter for the left limb divided by the value of the parameter for the right limb. In a perfectly symmetrical horse, the value would be 1.00. In a left sided asymmetry (left limb is lame), the value would be less than 1.00. In a right sided asymmetry (right limb is lame), the value would be greater than 1.00.

During the walk data collection on the force plate, two-dimensional sagittal plane extension of the fetlock was measured using a single camera (Sony)[a] with a recording speed of 120 frames per second. Skin surface markers were applied using AluSpray®[b] on 3 anatomical landmarks: the medial and lateral midpoint of the proximal third metacarpal bone, the lateral and medial epicondyle of the third metacarpal bone, the lateral and medial midpoint of the coronary band. Midstance of the stride was defined as when the foot was on the ground and the contralateral limb passed it in the swing phase; a still image was acquired at midstance and proximal and distal segments were created using anatomical landmarks. Fetlock angle of extension was measured using a screen protractor (Iconico, Inc.[c]) along the dorsal aspect of the joint so that an angle closer to 90 degrees equates to greater extension (hyperextension) and an angle closer to 180 degrees equates to less extension.

The data from each horse before and after diagnostic analgesia were compared for changes within a horse for response to diagnostic analgesia in each objective method. The response of each analgesic block was compared to either baseline, or the response to the previous block to determine the percent change before and after a specific block. Therefore, each horse served as its own control. Paired t-test of means before and after diagnostic analgesia for selected parameters were performed for each horse and a P-value ≤ 0.05 was considered to be significant.

In order to make comparisons between horses and across technological methods, horses were grouped based on the primary lameness identified. For instance, if the primary lameness was in the forelimb, then horses were grouped based on whether the forelimb lameness was unilateral or bilateral; this was applied to the hindlimb as well when that was determined to be the primary lameness. This grouping was used to analyze changes in response to diagnostic analgesia as well as the revelation of compensation patterns. Finally, horses were grouped by diagnosis or lesion to determine if any consistent change could be observed between horses with pain localized to a similar origin.

3.3 Results and Discussion

3.3.1 Changes in the lame limb in response to diagnostic analgesia

FORELIMB LAMENESS

<u>*Lameness Locator®*</u>

In cases with forelimb lameness (Horses 1-4, Table 3.3.1.1), there was a decreased vector sum after blocking a unilateral forelimb lameness (Horse 1 and 2; Table 3.3.1.1) which indicates an improvement in lameness that was comparable to subjective improvement (80% and 50%, respectively). In bilateral forelimb lameness cases (Horse 3 and 4; Table 3.3.1.1), the vector sum switched to indicate lameness on the contralateral forelimb, which was the same finding as the subjective exam. The only difference was on Horse 3 where the subjective exam called the improvement of the RF to be 75% after the abaxial block.

Table 3.3.1.1: The Lameness Locator® data in a straight line (mean ± SD) indicating head movement asymmetry before and after performing forelimb diagnostic analgesia with the calculated percent change and P value from paired t-test if appropriate. The lame limb is highlighted in the parentheses. LF=left front; RF=right front; PDN=palmar digital nerve

	Pre block vector sum (mm)	**Post block vector sum (mm)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint block	29.9 ± 5 (L)	12.2 (L)	- 59	0.075
Horse 2 RF low 4-point block	23.8 (R)	11.7 (R)	- 51	NA
Horse 3 RF PDN	17.7 ± 1.56 (R)	14.9 (L)	^	NA
Horse 3 LF PDN	14.9 (L)	21.6 (R)	^	NA
Horse 3 RF abaxial	21.6 (R)	14.5 (R)	- 33	NA
Horse 4 LF PDN	25.8 ± 1.27 (L)	11.3 (R)	^	NA
Horse 4 RF PDN	11.3 (R)	21.5 (L)	^	NA

^Lameness switched to contralateral limb.

Force Plate: Trot

Diagnostic analgesia increased the PVF in the lame limb in horses with forelimb lameness (Horses 1-3; Table 3.3.1.2). Horse 4 was not included in this portion because her degree of lameness was marked enough that the collection of force plate data was not feasible. There was a similar increase in VI in response to forelimb diagnostic analgesia in Horses 1 and 3 while Horse 2 showed a decrease in VI (Table 3.3.1.3). Horse 2 had a subjectively worsening lameness after the first two blocks, which were not recorded due to severity of lameness. The PVF and VI observed after the low four-point block in the right forelimb likely represent an improvement compared to the worsening lameness. The PVF increased while the VI decreased. This could occur if the horse has a shorter duration stance phase once the block has been performed. It is important to note that while the percent change was not large for any of the blocks, the difference in PVF and VI was significant for all of the blocks performed. In addition, this data concurs with subjective and Lameness Locator® data.

Table 3.3.1.2: Forelimb peak vertical force (PVF; mean ± SD) for the primary lame limb at the trot before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve

	Pre block PVF (N/kg)	**Post block PVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint block	8.562 ± 0.288	9.334 ± 0.242	+ 9	0.001*
Horse 2 RF low 4-point block	9.387 ± 0.418	9.878 ± 0.252	+ 5	0.048*
Horse 3 RF PDN	8.916 ± 0.200	10.128 ± 0.234	+ 14	<0.001*
Horse 3 LF PDN	9.165 ± 0.200	9.842 ± 0.209	+ 7	<0.001*
Horse 3 RF abaxial	8.262 ± 0.152	9.442 ± 0.093	+ 14	<0.001*

Table 3.3.1.3: Forelimb vertical impulse (VI; mean ± SD) for the primary lame limb at the trot before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint block	1.478 ± 0.049	1.644 ± 0.063	+ 11	0.001*
Horse 2 RF low 4-point block	1.993 ± 0.077	1.882 ± 0.057	- 6	0.026*
Horse 3 RF PDN	1.646 ± 0.066	1.754 ± 0.047	+ 7	0.018*
Horse 3 LF PDN	1.705 ± 0.063	1.860 ± 0.070	+ 9	0.004*
Horse 3 RF abaxial	1.558 ± 0.038	1.710 ± 0.058	+ 10	0.001*

Symmetry scores

Changes in symmetry scores after blocking were variable (Tables 3.3.1.4-3.3.1.5). In Horse 1 and Horse 3 after the right forelimb abaxial nerve block, the symmetry improved after the blocks. This indicated that the horse was still lame on the initial primary limb, however. In Horse 2 and Horse 3 after RF and LF palmar digital nerve block, the symmetry score indicated that the lameness switched to the contralateral limb.

Table 3.3.1.4: Symmetry scores for the mean PVF of the forelimbs at a trot before and after forelimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the left forelimb by the value for the right forelimb so numbers greater than 1 indicate a right sided lameness or asymmetry and values less than 1 indicate a left sided lameness or asymmetry.

	Pre block forelimb PVF symmetry score	**Post block forelimb PVF symmetry score**
Horse 1 LF middle carpal joint block	0.85	0.97
Horse 2 RF low 4-point block	1.07	0.98
Horse 3 RF PDN	1.03	0.90
Horse 3 LF PDN	0.90	1.19
Horse 3 RF abaxial	1.19	0.96

Table 3.3.1.5: Symmetry scores for the mean vertical impulse (VI) of the forelimbs at a trot before and after forelimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the left forelimb by the value for the right forelimb so numbers greater than 1 indicate a right sided lameness or asymmetry and values less than 1 indicate a left sided lameness or asymmetry.

	Pre block forelimb VI symmetry score	**Post block forelimb VI symmetry score**
Horse 1 LF middle carpal joint block	0.89	0.97
Horse 2 RF low 4-point block	1.02	1.04
Horse 3 RF PDN	1.06	0.97
Horse 3 LF PDN	0.97	1.19
Horse 3 RF abaxial	1.19	1.02

Force plate: Walk

There were variable responses to diagnostic analgesia for a primary forelimb lameness in Horses 1-4 (Tables 3.3.1.6-3.3.1.8). For Horse 1 the heel and midstance PVF increased (Table 3.3.1.6-7). In horse 2, there was no change in the heel PVF, but the midstance PVF decreased (Table 3.3.1.6-7). For Horses 3 and 4, heel PVF decreased after palmar digital analgesia despite increases in the trot PVF (Table 3.3.1.6-7). In most cases, increased VI was observed (Table 3.3.1.8). Increases in all parameters were seen in Horse 1 (Tables 3.3.1.6-3.3.1.8). Vertical impulse increase at the walk appears to correlate with increase in PVF at the trot (Table 3.3.1.2), which may indicate that vertical impulse is a useful determinant of lameness as a walk, just as changes in the PVF is a useful indicator of lameness at the trot. Vertical impulse was decreased in Horse 2 at the trot and walk (Table 3.3.1.4 and table 3.3.1.8 respectively).

Table 3.3.1.6: Force plate data at the walk for heel peak vertical force (PVF; mean ± SD) for the primary lame forelimb before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block heel PVF (N/kg)	**Post block heel PVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint	5.014 ± 0.095	5.102 ± 0.056	+ 2	0.112
Horse 2 RF low 4-point	5.248 ± 0.114	5.230 ± 0.161	0	0.823
Horse 3 RF PDN	5.340 ± 0.219	5.224 ± 0.176	- 2	0.383
Horse 3 LF PDN	5.696 ± 0.211	5.620 ± 0.221	- 1	0.593
Horse 3 RF abaxial	4.984 ± 0.323	5.066 ± 0.087	+ 2	0.599
Horse 4 LF PDN	5.574 ± 0.066	5.448 ± 0.083	- 2	0.029*
Horse 4 RF PDN	5.513 ± 0.210	5.478 ± 0.090	- 1	0.715

Table 3.3.1.7: Force plate data at the walk for midstance (Ms) peak vertical force (PVF; mean ± SD) for the primary lame forelimb before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block MsPVF (N/kg)	**Post block MsPVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint	4.772 ± 0.135	5.020 ± 0.100	+ 5	0.011*
Horse 2 RF low 4-point	5.243 ± 0.128	4.940 ± 0.159	- 6	0.003*
Horse 3 RF PDN	5.410 ± 0.207	5.204 ± 0.185	- 4	0.136
Horse 3 LF PDN	5.586 ± 0.158	5.500 ± 0.176	- 2	0.440
Horse 3 RF abaxial	5.120 ± 0.204	5.058 ± 0.085	- 1	0.548
Horse 4 LF PDN	5.606 ± 0.035	5.442 ± 0.084	- 3	0.004*
Horse 4 RF PDN	5.438 ± 0.227	5.414 ± 0.117	0	0.823

Table 3.3.1.8: Force plate data at the walk for vertical impulse (VI; mean ± SD) for the primary lame forelimb before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint	2.562 ± 0.079	2.758 ± 0.063	+ 8	0.003*
Horse 2 RF low 4-point	3.512 ± 0.082	3.306 ± 0.077	- 6	0.001*
Horse 3 RF PDN	2.960 ± 0.111	3.144 ± 0.121	+ 6	0.037*
Horse 3 LF PDN	3.058 ± 0.051	3.040 ± 0.079	- 1	0.680
Horse 3 RF abaxial	2.980 ± 0.024	3.198 ± 0.150	+ 7	0.012*
Horse 4 LF PDN	2.834 ± 0.056	2.920 ± 0.064	+ 3	0.054
Horse 4 RF PDN	2.908 ± 0.092	3.030 ± 0.166	+ 4	0.146

Fetlock extension

Changes in fetlock extension after blocking were variable, but changes were not significant even when present (Table 3.3.1.9). There was no change in horses with unilateral forelimb lameness between baseline and post diagnostic analgesia (Horse 1 and 2, Table 3.3.1.9). This is does not align with the results of the trot and lameness locator that did show change that indicated improvement. There was increased extension in the baseline primary lame limb after the first event of diagnostic analgesia in horses with bilateral forelimb lameness (Horses 3 and 4, table 3.3.1.9). Although it was a minimal improvement and improvement was not statistically significant, it was consistent with improvement in the lameness at the trot observed with lameness locator (for both) and force plate at the trot (Horse 3).

Table 3.3.1.9: Sagittal plane fetlock extension (mean ± SD) at the midstance phase is listed for horses with primary forelimb lameness before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block Fetlock extension (degrees)	**Post block Fetlock extension (degrees)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 LF middle carpal joint LF	139.97 ± 2.78	139.65 ± 1.45	0	0.825
Horse 2 RF low 4-point RF	140.73 ± 1.07	141.12 ± 1.48	0	0.603
Horse 3 RF PDN RF	136.55 ± 4.86	133.38 ± 2.48	-2	0.230
Horse 3 LF PDN LF	137.68 ± 2.59	136.59 ± 1.51	-1	0.494
Horse 3 RF abaxial RF	134.11 ± 2.38	132.62 ± 2.31	-1	0.345
Horse 4 LF PDN LF	142.14 ± 2.90	139.44 ± 2.18	-2	0.135
Horse 4 RF PDN RF	141.32 ± 3.71	145.58 ± 2.86	3	0.066

HINDLIMB LAMENESS

Lameness Locator®

There were no cases with primary unilateral hindlimb lameness in this study. In cases of primary bilateral hindlimb lameness (Horses 5-8; Table 3.3.1.10 and Table 3.3.1.11), there were mixed results. In one case (Horse 6), the impact lameness switched to the other hindlimb, which fit with the subjective analysis. In all cases there was a greater improvement observed in impact lameness than in push-off lameness and the percent improvement subjectively was more in line with the impact lameness (Horse 5 and 7 improved 70% subjectively). In the one case in which stifles were blocked (Horse 8), there was worsening of both the impact and push-off lameness. Interestingly, Horse 8 was called a LH lameness subjectively that improved 70%, which is completely different to the Lameness Locator® data. None of the changes reported were significantly different, however.

Table 3.3.1.10: Impact Lameness Locator® data in a straight line indicated by vertical difference of pelvis at its minimum position (mean ± SD) and percent change for cases of bilateral hindlimb lameness before and after diagnostic analgesia. P values for a paired t-test are provided when applicable. The lame limb is highlighted in parentheses. DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

Impact lameness	Pre block Diff Min Pelvis (mm)	Post block Diff Min Pelvis (mm)	Percent change (%)	T-test (P-value)
Horse 5 bilateral DIT/TMT joint blocks	14.1 ± 6.7 (R)	3.4 ± 4.5 (R)	- 76	0.202
Horse 6 bilateral DIT/TMT joint blocks	1.5 ± 3.4 (R)	1.4 ± 2.3 (L)	^	NA
Horse 7 bilateral DIT/TMT joint blocks	14.0 ± 3.4 (L)	6.9 ± 2.3 (L)	- 51	0.134
Horse 8 bilateral MFT blocks	3.5 ± 3.5 (R)	6.3 ± 2.2 (R)	+ 83	0.439

^Lameness switched to contralateral limb

Table 3.3.1.11: Push-off Lameness Locator® data in a straight line indicated by vertical difference of pelvis at its maximum position (mean ± SD) and percent change for cases of bilateral hindlimb lameness before and after diagnostic analgesia. P values for a paired t-test are provided when applicable. The lame limb is highlighted in the parentheses. DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

Push-off lameness	**Pre block Diff Max pelvis (mm)**	**Post block Diff max pelvis (mm)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT joint blocks	12.3 ± 9.5 (R)	6.1 ± 3.4 (R)	- 50	0.476
Horse 6 bilateral DIT/TMT joint blocks	10.1 ± 3.3 (L)	9.4 ± 2.5 (L)	- 7	0.833
Horse 7 bilateral DIT/TMT joint blocks	12.1 ± 2.2 (L)	7.6 ± 2.2 (L)	- 37	0.178
Horse 8 bilateral MFT blocks	4.6 ± 2.4 (R)	5.7 ± 2.4 (R)	+ 24	0.692

Force Plate Trot

There were no cases with primary unilateral hindlimb lameness in this study. In cases with primary bilateral hindlimb lameness, there was an increase in PVF in response to diagnostic analgesia in all horses (Horse 5, 6, and 8) except for Horse 7 (RH; Table 3.3.1.12). The degree of change was smaller in most cases in comparison to forelimb blocks and with fewer being significantly different. One possible explanation for this is due to the use of bilateral hindlimb blocks in comparison to unilateral forelimb blocks. There was an increased VI in response to diagnostic analgesia in most cases (Table 3.3.1.13). Interestingly, in general, the changes were small with the largest increase in PVF and VI corresponding to the most lame leg. In addition, both PVF and VI demonstrated improvement in Horse 7 after the low 6-pt block that was not accounted for subjectively (no change) or with the Lameness Locator® (LH worse). This improvement also made it look like there was less improvement post bilateral DIT/TMT for Horse 7 since the comparison was made to the post low 6-pt block instead of baseline. If they were compared to baseline, the PVF and VI would have increased post DIT/TMT block for the LH and remained similar for the RH (6% improvement in the LH). For Horse 8 the greatest improvement for both PVF and VI occurred with the LH which fits more with the subjective findings at baseline (LH) versus the Lameness Locator® findings at baseline (RH).

Table 3.3.1.12: Hindlimb peak vertical force (PVF; mean ± SD) for the primary lame limbs at the trot before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LH=left hindlimb; RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block PVF (N/kg)	**Post block PVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	7.346 ± 0.216	7.518 ± 0.257	+ 4	0.285
Horse 5 bilateral DIT/TMT LH	7.567 ± 0.494	7.864 ± 0.269	+ 2	0.285
Horse 6 bilateral DIT/TMT RH	7.964 ± 0.143	8.192 ± 0.018	+ 3	0.008*
Horse 6 bilateral DIT/TMT LH	7.937 ± 0.128	8.093 ± 0.118	+ 2	0.053
Horse 7 low 6-point RH	7.200 ± 0.064	8.160 ± 0.060	+ 13	<0.001*
Horse 7 low 6-point LH	6.390 ± 0.120	6.762 ± 0.204	+ 6	0.008*
Horse 7 bilateral DIT/TMT RH	8.160 ± 0.060	7.220 ± 0.168	- 12	<0.001*
Horse 7 bilateral DIT/TMT LH	6.762 ± 0.204	6.780 ± 0.098	0	0.863
Horse 8 bilateral MFT RH	8.062 ± 0.245	8.154 ± 0.222	+ 1	0.551
Horse 8 bilateral MFT LH	8.148 ± 0.227	8.304 ± 0.243	+ 2	0.325

Table 3.3.1.13: Hindlimb vertical impulse (VI; mean ± SD) for the primary lame limb at the trot before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LH=left hindlimb; RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	1.346 ± 0.051	1.298 ± 0.060	+ 1	0.210
Horse 5 bilateral DIT/TMT LH	1.353 ± 0.115	1.364 ± 0.052	- 4	0.245
Horse 6 bilateral DIT/TMT RH	1.422 ± 0.029	1.492 ± 0.062	+ 5	0.052
Horse 6 bilateral DIT/TMT LH	1.420 ± 0.023	1.462 ± 0.035	+ 3	0.034*
Horse 7 low 6-point RH	1.430 ± 0.035	1.542 ± 0.027	+ 8	0.001*
Horse 7 low 6-point LH	1.244 ± 0.055	1.297 ± 0.036	+ 4	0.109
Horse 7 bilateral DIT/TMT RH	1.542 ± 0.027	1.450 ± 0.041	- 6	0.002*
Horse 7 bilateral DIT/TMT LH	1.297 ± 0.036	1.370 ± 0.040	+ 6	0.016*
Horse 8 bilateral MFT RH	1.448 ± 0.071	1.422 ± 0.047	- 2	0.514
Horse 8 bilateral MFT LH	1.456 ± 0.039	1.464 ± 0.025	+ 1	0.709

Symmetry scores

Interestingly, PVF and VI symmetry scores worsened in 3 of 5 blocks performed (Horse 5, Horse 8 and Horse 7 after the low 6 point block; Table 3.3.1.14 and 3.3.1.15). This could be a result of the application of bilateral hindlimb blocks and the degree of improvement was asymmetrical between the legs, thus masking improvement on the most affected leg. The only horse that showed marked improvement in PVF symmetry was horse 7 after DIT/TMT blocks. Horse 6 remained symmetrical pre and post block.

Table 3.3.1.14: Symmetry scores for the mean PVF of the hindlimbs at a trot before and after hindlimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the left hindlimb by the value for the right hindlimb so numbers greater than 1 indicate a right sided lameness or asymmetry and values less than 1 indicate a left sided lameness or asymmetry.

	Pre block hindlimb PVF symmetry score	**Post block hindlimb PVF symmetry score**
Horse 5 bilateral DIT/TMT	1.03	1.05
Horse 6 bilateral DIT/TMT	1.00	0.99
Horse 7 bilateral low 6-point	0.89	0.83
Horse 7 bilateral DIT/TMT	0.83	0.94
Horse 8 bilateral MFT	1.01	1.02

Table 3.3.1.15: Symmetry scores for the mean vertical impulse (VI) of the hindlimbs at a trot before and after hindlimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the left hindlimb by the value for the right hindlimb so numbers greater than 1 indicate a right sided lameness or asymmetry and values less than 1 indicate a left sided lameness or asymmetry.

	Pre block hindlimb VI symmetry score	**Post block hindlimb VI symmetry score**
Horse 5 bilateral DIT/TMT	1.01	1.05
Horse 6 bilateral DIT/TMT	1.00	0.98
Horse 7 bilateral low 6-point	0.87	0.84
Horse 7 bilateral DIT/TMT	0.84	0.94
Horse 8 bilateral MFT	1.01	1.03

Force Plate Walk

There were no cases with primary unilateral hindlimb lameness in this study. For cases with primary bilateral hindlimb lameness, there was variable change when comparing across horses. The change in heel PVF was variable between horses and between limbs within a horse (Table 3.3.1.16). In all horses except for Horse 8, there was a decrease in midstance PVF when compared to their baseline (Table 3.3.1.17) Similarly, there was a decrease in VI when compared to their baseline in all horses except Horse 8 (Table 3.3.1.18). Together, this suggest that decreasing MsPVF and VI are good indicators of improvement post-analgesia, even with small changes.

Table 3.3.1.16: Force plate data at the walk for heel peak vertical force (PVF; mean ± SD) for the primary lame hindlimb before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LH=left hindlimb; RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block heel PVF (N/kg)	**Post block heel PVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	4.188 ± 0.119	4.260 ± 0.055	+ 2	0.254
Horse 5 bilateral DIT/TMT LH	4.297 ± 0.359	4.226 ± 0.182	- 2	0.704
Horse 6 bilateral DIT/TMT RH	4.120 ± 0.123	4.246 ± 0.322	+ 3	0.396
Horse 6 bilateral DIT/TMT LH	4.228 ± 0.058	4.162 ± 0.180	- 2	0.455
Horse 7 low 6-point RH	3.794 ± 0.234	3.978 ± 0.164	+ 5	0.188
Horse 7 low 6-point LH	3.792 ± 0.140	3.994 ± 0.295	+ 5	0.204
Horse 7 bilateral DIT/TMT RH	3.978 ± 0.164	4.068 ± 0.157	+ 2	0.401
Horse 7 bilateral DIT/TMT LH	3.994 ± 0.295	3.810 ± 0.174	- 5	0.264
Horse 8 bilateral MFT RH	3.944 ± 0.415	3.654 ± 0.131	- 7	0.175
Horse 8 bilateral MFT LH	4.078 ± 0.460	3.686 ± 0.131	- 10	0.104

Table 3.3.1.17: Force plate data at the walk for midstance (Ms) peak vertical force (PVF; mean ± SD) for the primary lame limb before and after diagnostic analgesia with percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block MsPVF (N/kg)	**Post block MsPVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	3.346 ± 0.072	3.230 ± 0.082	- 3	0.045*
Horse 5 bilateral DIT/TMT LH	3.278 ± 0.154	3.230 ± 0.108	- 1	0.584
Horse 6 bilateral DIT/TMT RH	3.215 ± 0.054	3.092 ± 0.048	- 4	0.003*
Horse 6 bilateral DIT/TMT LH	3.072 ± 0.051	3.002 ± 0.078	- 2	0.120
Horse 7 low 6-point RH	3.550 ± 0.123	3.368 ± 0.055	- 5	0.017*
Horse 7 low 6-point LH	3.530 ± 0.183	3.136 ± 0.098	- 11	0.003*
Horse 7 bilateral DIT/TMT RH	3.368 ± 0.055	3.176 ± 0.105	- 6	0.007*
Horse 7 bilateral DIT/TMT LH	3.136 ± 0.098	3.200 ± 0.070	+ 2	0.269
Horse 8 bilateral MFT RH	3.345 ± 0.209	3.510 ± 0.056	+ 5	0.127
Horse 8 bilateral MFT LH	3.088 ± 0.426	3.374 ± 0.077	+ 9	0.178

Table 3.3.1.18: Force plate data at the walk for vertical impulse (VI; mean ± SD) for the primary lame limb(s) before and after diagnostic analgesia with percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	2.380 ± 0.069	2.344 ± 0.054	- 2	0.385
Horse 5 bilateral DIT/TMT LH	2.427 ± 0.123	2.424 ± 0.061	0	0.962
Horse 6 bilateral DIT/TMT RH	2.662 ± 0.098	2.646 ± 0.110	- 1	0.804
Horse 6 bilateral DIT/TMT LH	2.670 ± 0.014	2.650 ± 0.063	- 1	0.508
Horse 7 low 6-point RH	2.550 ± 0.087	2.436 ± 0.092	- 5	0.079
Horse 7 low 6-point LH	2.490 ± 0.129	2.286 ± 0.065	- 8	0.013*
Horse 7 bilateral DIT/TMT RH	2.436 ± 0.092	2.422 ± 0.061	- 1	0.784
Horse 7 bilateral DIT/TMT LH	2.286 ± 0.065	2.336 ± 0.060	+ 2	0.242
Horse 8 bilateral MFT RH	2.366 ± 0.071	2.474 ± 0.036	+ 5	0.016*
Horse 8 bilateral MFT LH	2.310 ± 0.193	2.476 ± 0.091	+ 7	0.120

Fetlock extension

There were small changes in fetlock extension in response to diagnostic analgesia, however a few changes were significant (Table 3.3.1.19). There was significantly increased fetlock extension in Horse 5 in the primary lame limb and in both limbs in Horse 6 after bilateral DIT/TMT block. This is consistent with the increase in PVF at the trot and decrease in asymmetry with the Lameness Locator®. This also corresponds with the change in distribution of forces in the hindlimbs at the walk where the midstance PVF decreased and slight increase in heel PVF in the primary lame limb for both horses. The remaining horses did not show a statistically significant change in fetlock extension.

Table 3.3.1.19: Sagittal plane fetlock extension (mean ± SD) at the midstance phase is listed for horses with primary hindlimb lameness before and after diagnostic analgesia with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). RH=right hindlimb; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block Fetlock extension (degrees)	**Post block Fetlock extension (degrees)**	**Percent change (%)**	**T-test (P-value)**
Horse 5 bilateral DIT/TMT RH	150.28 ± 1.86	145.05 ± 2.53	-3	0.006*
Horse 5 bilateral DIT/TMT LH	148.44 ± 4.45	151.19 ± 3.42	2	0.305
Horse 6 bilateral DIT/TMT RH	147.40 ± 3.07	143.42 ± 2.6	-3	0.048*
Horse 6 bilateral DIT/TMT LH	147.48 ± 1.95	144.20 ± 1.96	-2	0.022*
Horse 7 low 6-point RH	142.63 ± 3.67	141.48 ± 2.36	-1	0.572
Horse 7 low 6-point LH	141.07 ± 1.80	140.74 ± 1.61	0	0.758
Horse 7 bilateral DIT/TMT RH	141.48 ± 2.36	140.17 ± 2.10	-1	0.381
Horse 7 bilateral DIT/TMT LH	140.74 ± 1.61	142.46 ± 1.83	1	0.153
Horse 8 bilateral MFT RH	147.27 ± 3.37	145.67 ± 0.86	-1	0.334
Horse 8 bilateral MFT LH	150.36 ± 2.48	147.54 ± 3.12	-2	0.152

Discussion:

Subjective assessment compared to objective analysis

Among the different lameness types, the unilateral forelimb lameness objective measures and subjective measures had the greatest agreement, followed by bilateral forelimb lameness. There was the greatest discrepancy between objective and subjective evaluation for bilateral hindlimb lameness. This is likely because the hindlimb blocks were performed bilaterally. There have been studies to compare the subjective evaluation of experimentally-induced lameness with objective measures and subjective evaluation (Donnell 2015; Keegan 2012). In one study comparing subjective evaluation to objective measures, body mounted inertial sensor systems and force plate at the trot (Donnell 2015), lameness was experimentally-induced by creating an osteochondral fragment in the middle carpal joint. They compared the outcomes for subjective lameness evaluations (blinded and unblinded), force platforms (kinetic measurements) and an inertial sensor system (kinematic measurements) that were all used to detect lameness at the trot at four time points. Their findings demonstrated that blinded subjective evaluation and inertial sensor systems had higher agreement (50%, mild positive correlation) than subjective evaluation and force plate exams (38%), with mild negative correlations between inertial sensor systems and force plate. The greater correlation between lameness locator and subjective evaluation is logical since they are both based on kinematic evaluation whereas the force plate is a kinetic measurement of force. In this thesis, subjective evaluation consistently over estimated improvement compared to the lameness locator by 10-20%. However, it should be noted that this does not mean the force plate exam was unable to determine lameness as they reported a 3.6% decrease in mean PVF at day 15 in the osteochondral fragment limb of all horses compared to baseline, indicating greater lameness due to less force being placed on the limb (Donnell 2015). This compares to the data we present in this thesis where small changes in the PVF or VI at a walk show statistical and clinical significance. In another study using the force plate to exam the trot after experimentally-induced lameness by injecting Lipopolysaccharide into a single forelimb metacarpophalangeal joint, PVF and VI were significantly decreased in subjectively mild or unobservable lameness (Ishihara 2005). This finding supports that use of objective measures can quantify changes that are unobservable to the human eye.

In this thesis, subjective assessment overestimated improvement in lameness after diagnostic analgesia compared to objective measures. Unilateral forelimb lameness was identified on straight-line baseline with subjective assessment, Lameness Locator® and force plate data. In contrast to the subjective evaluation and Lameness Locator®, there was evidence of bilateral disease on straight-line baseline measurements for force plate measurements at the walk. Subjective assessment requires ancillary evaluation for suggestion of bilateral disease, including circles or lunging and flexion tests. Additionally, differences in walk force plate data with other methods could be attributed to the difference in gait mechanics and speed between the walk and trot. The use of fetlock extension can be a useful component of the lameness exam, but the methodology used in this study was the limiting factor as it may have been over simplified in attempt to make it more useful for everyday clinical use. Changes in fetlock extension with lameness have been documented using 3D kinematics (Serra Bragança 2021). Alternative methods should be considered in order to reflect the utility of evaluating fetlock extension that would be more accurate. Overall, objective measures highlighted subtle changes that subjective assessment could not capture, which will be highlighted below.

Unilateral forelimb lameness

The greatest amount of published data is available for unilateral forelimb lameness compared to other patterns of lameness (Donnell 2015; Ishihara 2005; McCracken 2012; Weishaupt 2006). Two horses in this study had unilateral forelimb lameness. In both, subjective evaluation, Lameness Locator®, and force plate baseline data on a straight line at the trot determined that a unilateral forelimb lameness was present, and its improvement was identified with all after diagnostic analgesia. For the Lameness Locator®, after diagnostic analgesia there was a decrease in the magnitude of the vector sum of the lame limb which is consistent with a previous study that investigated the use of inertial sensor systems to quantify improvement after palmar digital nerve block in a unilateral forelimb lameness (Mayliye 2013). On the force plate, Horse 1 had an increase in PVF (Table 3.3.1.2) and VI (Table 3.3.1.3) at the trot in the primary lame limb in response to diagnostic analgesia. In Horse 2, there was also an increase in PVF while the VI decreased in the primary lame limb in response to diagnostic analgesia. This could occur if the horse has a shorter duration stance phase once the block has been performed. However, in both Horses 1 and 2 PVF symmetry scores were closer to 1, indicating improvement in lameness in the primary forelimb (Table 3.3.1.4). Together, this is supportive of evidence available in the current literature that PVF and VI are reliable indicators of lameness at the trot (Serra Bragança 2021; Weishaupt 2006). It has been shown that the PVF decreases when lameness is induced in a unilateral forelimb (Weishaupt 2006) and conversely PVF increases in horses with unilateral forelimb lameness after diagnostic analgesia (Bidwell 2004). It should be noted that in our study, there was a greater percentage improvement in the Lameness Locator® data for both of these horses when compared to the increase in PVF on the force plate after the block. However, it is important to consider that the PVF is reported in Newtons per kilogram to correct for the horse's weight and facilitate comparison between horses. Thus, for example, a 9% increase in PVF (N/kg) for Horse 1, who weighed 545.45 kg, equates to 421N or 94 pounds of increased force on the limb.

Compared to the trot, there is a relative paucity of force plate data at the walk in the literature (Merkens 1986; Merkens 1988; Serra Bragança 2021), even for unilateral forelimb lameness. Most of these examine the walk data in normal horses only (Merkens 1986; Merkens 1988), with only Serra Bragança et. al. reporting on the response of the walk to experimental lameness (Serra Bragança 2021). Therefore, to the authors' knowledge, this thesis is the first report on lameness at a walk in naturally-occurring unilateral forelimb lameness and its response to diagnostic analgesia. The authors would note that examination of the walk data should include visual analysis of the force curve (as shown in Chapter 1 for the normal case and as shown in Chapter 2 for each horse participant in this study) as well as analysis of the magnitude of the ground reaction forces. Based off of previous pilot data from experimentally-induced lameness reported in Chapter 1, as well as the horses with naturally-occurring lameness reported in this study, variable changes can occur to the heel, midstance, or toe PVF, and as such the VI. Findings in Horse 1are consistent with literature for induced unilateral forelimb lameness using a solar pressure model (Serra Bragança 2021), which resulted in a decrease in VI in the lame limb at a walk. A decrease in VI by 5.1% has been described with the solar pressure induced lameness compared to sound baseline (Serra Bragança 2021). At the walk, Horse 1 had an increase in VI and Horse 2 had a decrease in VI after diagnostic analgesia (Table 3.3.1.8). A slightly greater increase in VI at the walk was observed in Horse 1 in response to diagnostic analgesia than was found in the solar pressure model. The decreases in VI at the walk seen in Horse 2 compared to baseline could be explained by the fact that she became increasingly lame at the trot after the palmar digital nerve block and maintained a worsened lameness after the abaxial sesamoid nerve block. The decreases observed relative to baseline are likely improvements compared to the palmar digital and abaxial sesamoid peri-neural analgesia. Force plate data was not collected at these time points due to welfare concerns. In addition, similar to other parameters, Horse 1 had an increase in heel PVF (Table 3.3.1.6) and midstance PVF (Table 3.3.1.7) in response to diagnostic analgesia, where Horse 2 had a decrease in heel and midstance PVF compared to baseline. Horse 2 had a greater percent decrease in midstance PVF compared to the heel PVF. Although a decrease occurred, this may actually represent a shift toward the force distribution within the stance phase that is seen in a normal horse where the midstance PVF is less than the heel PVF.

With a unilateral forelimb lameness, there were minimal changes in fetlock extension at the walk in the lame limb in response to diagnostic analgesia (Table 3.3.1.9). This is less change than was observed in Serra Bragança's study that measured a 3.3% decrease in fetlock extension at the trot with solar pressure induced lameness using 3D kinematics (Serra Bragança 2021). The decreased difference seen at the walk is likely a function of different method of measurement and different gait. There was inconsistency in the direction of change in response to diagnostic analgesia in unilateral forelimb lameness. Horse 1 fetlock extension was essentially unchanged. Horse 2 had a decreased fetlock extension, which could be consistent with the decrease observed in midstance PVF observed in the force plate walk data.

Bilateral forelimb lameness

Fewer studies are available for comparison of the analysis of bilateral forelimb lameness than unilateral forelimb lameness (Keegan 2012). Horse 3 and 4 had similar lameness patterns in response to diagnostic analgesia. There was switching of forelimb lameness between the primary and contralateral forelimb between different blocks.

Keegan et al reported that the Lameness Locator® was adequate for detection of the forelimb with the greatest lameness in cases of bilateral forelimb lameness when compared with the use of a force plate (Keegan 2012). This means that only one of the forelimbs was identified as lame on baseline. This is supported by the current study data in that the Lameness Locator® indicated a unilateral forelimb lameness based on asymmetry in head movement, and the vector sum switched to the contralateral forelimb after a block of the primary lame limb. However, the force plate data provided evidence at the walk and trot that there was a bilateral forelimb lameness on the straight-line baseline. There was decreased PVF in the forelimbs as well as abnormal distribution of forces at the walk in the forelimbs relative to normal horses (graphically shown in Chapter 1). This is consistent with studies that have shown that PVF is a reliable indicator of forelimb lameness in an experimentally induced lameness (Clayton 2013; Keegan 2020b; Serra Bragança 2021; Weishaupt 2006).

Trot data was only available with Horse 3 as Horse 4 did not have force plate data collected at the trot due to the severity of her lameness. After diagnostic analgesia, Horse 3 had increased PVF and VI in the lame limb (Tables 3.3.1.2-3). This is consistent with a study using the force plate to quantify the response to palmar digital nerve diagnostic analgesia in cases of unilateral navicular disease (Bidwell 2004). They reported that the contralateral forelimb PVF was significantly higher than in the lame forelimb before the palmar digital nerve block. However, after the palmar digital nerve block, there was no significant difference between the PVF in the lame and contralateral forelimbs (Bidwell 2004). In contrast, Horse 3 with bilateral limb lameness had a significant difference in PVF between the original primary lame limb and the contralateral limb after blocking, where the contralateral limb PVF was significantly lower. Thus, blocking the primary lame limb revealed that the contralateral forelimb was also lame, but was masked by the primary limb.

Horse 3 and Horse 4 had similar responses to diagnostic analgesia at the walk. There were decreases in heel PVF (Table 3.3.1.6) and midstance PVF (table 3.3.1.7), but the vertical impulse increased in response to diagnostic analgesia (Table 3.3.1.8). This decrease in heel PVF at the walk after blocks occurred despite an increase in PVF at the trot in the lame limb and switching of lameness at the trot. In these cases, Vertical impulse appeared to be the indicator that the lameness switched between the forelimbs. In the evaluation of a solar pressure induced model of forelimb lameness, investigators found reduction of the first vertical force peak by 1.9% (equivalent to heel PVF in this thesis) and a reduction in the second vertical force peak (equivalent to toe PVF in this thesis) by 6.1% (Serra Bragança 2021), which is in contrast to the results of this thesis. This suggests that there may be differences with the force distribution in the lame limb in naturally occurring and induced lameness models. The increases in VI are consistent with expected response to diagnostic analgesia because it has been shown that induced unilateral forelimb lameness using a solar pressure model there was a decrease in VI in the lame limb (Serra Bragança 2021). Since vertical impulse considers force applied over the duration of the stance, these results indicate the horses are placing force on the limb for a greater period of time due to diagnostic analgesia, but reducing the peak values of force reached.

If any changes were present in fetlock extension, they were small changes at the walk in the lame limb in response to diagnostic analgesia and not significant (Tables 3.3.1.9). This is less change than was observed in Serra Bragança's study that measured a 3.3% decrease in fetlock extension at the trot with solar pressure induced lameness using 3D kinematics (Serra Bragança 2021). The decreased difference seen at the walk is likely a function of different method of measurement and different gait. Horse 3 had increased fetlock extension in the lame limb after each of the three blocks performed. Horse 4 had increased fetlock extension in response to diagnostic analgesia in the primary lame limb from baseline but had decreased fetlock extension in the contralateral limb in response to diagnostic analgesia despite showing improvement in lameness in subjective lameness, in Lameness Locator® asymmetry and in force plate parameters.

<u>Bilateral hindlimb lameness</u>

Unlike the forelimb scenarios, there were no horses in the study with unilateral hindlimb lameness. This is representative of naturally-occurring disease, where bilateral hindlimb lameness is more common than unilateral hindlimb lameness in horses. In addition, in all hindlimb cases the blocks were performed bilaterally at the same time instead of blocking the most lame leg first as done in the forelimbs. This was done due to time required to collect objective data, duration of local anesthetic and the ultimate number of blocks that would be necessary to abolish the lameness was unknown. This plays a significant role in the results of response to analgesia because unlike the forelimbs, the lameness is not just going to switch to the opposite limb. Overall, bilateral hindlimb lameness is difficult to detect subjectively in a straight line, even for the experienced clinician. Baseline lameness can often be subtle and changes in lameness during the exam can occur due to the bilateral nature of the disease. Often, a suspicion of bilateral disease is based on ancillary components of the lameness exam, such as palpation of joint effusion, a positive response to the Churchill test and positive flexion test responses. There are few publications describing bilateral hindlimb lameness as a result of naturally-occurring disease as a clinical case series (Leelamankong 2020; Reed 2020).

There were discrepancies in hindlimb lameness on baseline and in response to diagnostic analgesia between subjective and objective evaluation, which is not unexpected due to the diagnostic challenge presented by bilateral hindlimb lameness. This is consistent with published studies using BMISS to evaluate clinical hindlimb lameness cases compared with subjective evaluation. For instance, there is evidence of slight agreement between highly experienced clinicians and the BMISS for less severe hindlimb lameness, but substantial agreement between highly experienced clinicians and more severe hindlimb lameness (Leelamonkong 2020). Similarly in our study there were important changes gleaned from the objective analysis that could not be captured by subjective assessment. In Horse 7, subjective assessment and Lameness Locator® data showed no change and a worsening of lameness, respectively after the bilateral low six-point block. However, the force plate analysis at both the walk and trot showed an increase in forces placed on both hindlimbs compared to baseline. The improvement was greater in the right hindlimb than the left hindlimb, which may have led to the subjective and kinematic assessment of worsening left sided asymmetry. In Horse 8, the baseline left hindlimb lameness subjectively improved after the bilateral intra-articular analgesia of both medial femorotibial joints. However, there was disagreement between subjective assessment (left hind) and objective analysis on baseline (right hind). After bilateral medial femorotibial joint intra-articular analgesia, Lameness Locator® data indicated a worsening of a right hindlimb lameness, while the force plate data at the walk demonstrated a change in the distribution of forces in the hindlimbs bilaterally. There was increased midstance PVF and decreased heel PVF at the walk in both hindlimbs after bilateral medial femorotibial joint intra-articular analgesia.

Lameness Locator® data for the bilateral hindlimb lameness cases in our study had a variety of manifestations in baseline lameness patterns and response to diagnostic analgesia compared to the consistency seen in the forelimb lameness cases (Tables 3.3.1.10 and 3.3.1.11). This is similar to a study recently published that reported the BMISS baseline lameness data in conjunction with definitive diagnosis of 1,224 naturally-occurring lameness cases. In this study, horses that had a final diagnosis of bilateral hindlimb lameness had BMISS data showing 8 different concurrent forelimb and hindlimb lameness patterns on baseline (Reed 2020). In our study, Horse 5 and 7 had similar responses to intra-articular analgesia of the DIT and TMT joints where there was an improvement in both impact and push-off lameness. Horse 6 had an impact asymmetry that was within the reference interval for normal asymmetry. However, this asymmetry shifted to the contralateral hindlimb after DIT/TMT blocks. Horse 6 had a greater push-off lameness and there was no significant improvement after DIT/TMT block. Horse 8 had a worsening push off and impact lameness after block of the medial femorotibial joints bilaterally, but the impact lameness had a greater degree of change than the push off lameness. This may suggest that Horse 6 and Horse 8 had additional painful structures in the hindlimbs despite subjective improvement in lameness.

The ground reaction force data was able to define more changes of the bilateral hindlimb lameness in response to analgesia because it was able to look at each limb separately. For instance, there was an increase in PVF (Table 3.3.1.12) and VI (Table 3.3.1.13) at the trot in the primary lame limb in response to diagnostic analgesia in all horses, and there was an increase in PVF and VI in the contralateral limb in most horses. Horse 7 had two blocks performed and the cumulative effect was increased PVF and VI compared to baseline. Based on a previous report from a solar pressure model of induced unilateral hindlimb lameness, the vertical impulse and stride duration were decreased in a moderate lameness (Weishaupt 2006), so an increase in the VI in response to diagnostic analgesia would be an appropriate response if the lameness was improving. However, hindlimb PVF and VI symmetry scores at the trot were less symmetrical compared to baseline with bilateral hindlimb diagnostic analgesia in all horses with bilateral hindlimb blocks, except Horse 7 (Table 3.3.1.14 and 3.3.1.15), despite increases in PVF and VI (Table 3.3.1.12-13) in both hindlimbs after blocks. The symmetry scores for Horse 7 improved after bilateral distal intertarsal joint and tarsometatarsal joint (DIT/TMT) blocks. The most likely reason for the lack of improvement in symmetry scores is that the hindlimbs were blocked simultaneously and there was either equal improvement between legs or the "sound" limb improved more than the primary lame limb because disease was also present in the "sound" limb.

At a walk, the midstance PVF and VI appeared to demonstrate the most change after bilateral diagnostic analgesia in bilateral hindlimb lameness. There was a decrease in midstance PVF compared to baseline for Horse 5, 6 and 7 in both limbs (Table 3.3.1.17). However, Horse 8 had an increase in midstance PVF compared to baseline, but instead had . Horse 8 showed a decreased heel PVF after bilateral hindlimb diagnostic analgesia, with. There was a greater degree of change compared to the change seen in other horses. Vertical impulse decreased or had minimal change compared to baseline in Horse 5, 6, and 7, while VI increased in both hindlimbs for Horse 8. Since the VI is a calculation of force applied over time, the decrease or increase in midstance PVF likely contributes the most to this change in VI and the other variables remain relatively similar. It is possible that this increase in midstance PVF is reflective of a loss of dynamic motion of the foot or a more stilted stance phase to remove force from painful regions.

Overall, there were small changes in fetlock extension at the walk in the lame limb in response to diagnostic analgesia (Table 3.3.1.19). However, there was an increase in fetlock extension in all horses in the primary lame limb from baseline in response to diagnostic analgesia except for Horse 7 in response to the DIT/TMT block. This is supportive of increased weight bearing on that limb, and since changes in ground reaction forces are smaller at the walk, it is expected that the degree of change at the walk would be less that the degree of change at the trot. Serra Bragança found on average fetlock extension decreased 3.3% in response to the induction of a grade 3 out of 5 forelimb lameness (Serra Bragança 2021). In light of these findings, the small degree of change in response to blocking in these naturally-occurring lamenesses are not surprising, and in fact, some were significantly different from baseline. Furthermore, the standard deviation for the measurements of fetlock extension from the clinical cases in the current study are similar to the standard deviations reported in other publications (Clayton 2007) where the sagittal flexion extension range of motion of the fetlock joint was on average 31 ± 3 degrees at the walk. It is important to point out that the static image at a single time point was used in order to simplify objective analysis for the clinical setting. Although, evaluation of a static image may have limited value compared to evaluation of dynamic range of motion throughout the stance phase, which could provide substantially greater information about the lameness.

3.3.2 Compensatory changes

Responses to forelimb diagnostic analgesia

Lameness Locator®

With the Lameness Locator® it is not really possible to tell if the contralateral forelimb is compensating for the lame forelimb. Therefore, the data below (Table 3.3.2.1 and 3.3.2.2) focuses on how the hind end would compensate for the lame forelimb(s). For unilateral forelimb lameness (Horse 1 and 2) there was no hindlimb lameness (Diff Min and Max of the pelvis was <3 mm) present prior to blocks and only Horse 2 demonstrated a mild push-off lameness after the forelimb block on the contralateral hindlimb. It is unclear if this represents a compensatory pattern or a mild hindlimb lameness that becomes apparent after the forelimb is blocked out. Interestingly, for both horses with primary bilateral forelimb lameness (Horse 3 and 4) there was evidence of a mild impact lameness but no push-off lameness prior to blocking. For Horse 3, the hindlimb lameness was on the ipsilateral limb, and for horse 4, it was on the contralateral limb. For both cases, the impact lameness decreased after the first block indicating some degree of compensation was present, although Horse 4 appeared to have a real hindlimb lameness since a mild impact lameness persisted after all blocks.

Table 3.3.2.1: For cases of forelimb lameness, impact data from the Lameness Locator® are represented by vertical difference of pelvis (mean ± SD) at its minimum position (Diff Min) and the calculated percent change for the hindlimbs in response to diagnostic analgesia in the forelimbs. The lame hindlimb is highlighted in parentheses. LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block Diff Min Pelvis (mm)	**Post block Diff Min Pelvis (mm)**	**Percent change (%)**
Horse 1 LF middle carpal joint block	1.5 ± 0.3 (R)*	2.5 ± 3.0 (L)*	^*
Horse 2 RF low 4-point block	2.4 (L)*	2.8 (L)*	17*
Horse 3 RF PDN	4.6 (R)	0.9 ± 5.0 (R)*	-80*
Horse 3 LF PDN	0.9 ± 5.0 (R)*	1.8 ± 3.5 (R)*	100*
Horse 3 RF abaxial	1.8 ± 3.5 (R)*	2.5 ± 5.2 (R)*	39*
Horse 4 LF PDN	10.6 ± 0.99 (R)	8.7 ± 3.9 (R)	-18%
Horse 4 RF PDN	8.7 ± 3.9 (R)	7.0 ± 2.2 (R)	-20%

*Asymmetry below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb

Table 3.3.2.2: For cases of forelimb lameness, push-off data from the Lameness Locator® are represented by vertical difference of pelvis (mean ± SD) at its maximum position (Diff Max) and the calculated percent change for hindlimbs in response to diagnostic analgesia in the forelimbs. The lame hindlimb is highlighted in parentheses. LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block Diff Max Pelvis (mm)	**Post block Diff Max Pelvis (mm)**	**Percent change (%)**
Horse 1 LF middle carpal joint block	2.0 ± 0.5 (L)*	1.7 ± 2.6 (L)*	-13*
Horse 2 RF low 4-point block	3.2 (L)	6.8 (L)	113
Horse 3 RF PDN	0.9 (R)*	4.8 ± 3.0 (R)	433*
Horse 3 LF PDN	4.8 ± 3.0 (R)	1.5 ± 2.5 (L)*	^*
Horse 3 RF abaxial	1.5 ± 2.5 (L)*	4.0 ± 5.8 (L)	167*
Horse 4 LF PDN	1.0 ± 0.4 (R)*	2.4 ± 2.9 (L)*	^*
Horse 4 RF PDN	2.4 ± 2.9 (L)*	0.25 ± 2.4 (L)*	-90*

*Asymmetry below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb

Force Plate Trot

Contralateral forelimb

The PVF and VI decreased on the contralateral limb (Table 3.3.2.3 and 3.3.2.4) after blocking for both unilateral forelimb cases (Horse 1 and 2). This indicates that the contralateral forelimb was compensating for the lame limb via increased ground reaction forces. In addition, for the bilateral forelimb case (Horse 3) there was minimal to no change in the PVF and VI after the first block that switch the lameness to the contralateral limb. This makes sense since that limb now becomes the primary lameness. After that, the PVF and VI decrease on the contralateral limb with each successive block indicating that the contralateral forelimb was compensating similar to that described above for a unilateral lameness.

Table 3.3.2.3: For cases of forelimb lameness, mean ± SD peak vertical forces (PVF) of the contralateral forelimb (non-lame) are listed at the trot before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block PVF (N/kg)	**Post block PVF (N/kg)**	**Percent change (%)**
Horse 1 RF (LF middle carpal joint block)	10.032 ± 0.322	9.614 ± 0.152	-4
Horse 2 LF (RF low 4-point block)	10.066 ± 0.381	9.690 ± 0.367	-4
Horse 3 LF (RF PDN)	9.168 ± 0.164	9.165 ± 0.200	0
Horse 3 RF (LF PDN)	10.128 ± 0.234	8.262 ± 0.152	-18
Horse 3 LF (RF abaxial)	9.842 ± 0.209	9.054 ± 0.452	-8

Table 3.3.2.4: For cases of forelimb lameness, mean ± SD vertical impulses (VI) of the contralateral forelimb (non-lame) are listed at the trot before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**
Horse 1 RF (LF middle carpal joint block)	1.668 ± 0.041	1.696 ± 0.030	-2
Horse 2 LF (RF low 4-point block)	2.034 ± 0.036	1.958 ± 0.056	-4
Horse 3 LF (RF PDN)	1.738 ± 0.033	1.705 ± 0.063	-2
Horse 3 RF (LF PDN)	1.754 ± 0.047	1.558 ± 0.038	-11
Horse 3 LF (RF abaxial)	1.860 ± 0.070	1.738 ± 0.054	-7

Hindlimbs

There was a change observed in hindlimb symmetry scores after performing forelimb blocks (Tables 3.3.2.5-3.3.2.8). Compensatory change appeared to only be present in one of the horses with a unilateral forelimb lameness. In Horse 1 the PVF and VI increased in both hindlimbs after the block, with the most change in the contralateral hindlimb, indicating that the primary compensatory hindlimb was the contralateral. For Horse 2, it appeared that a RH lameness might have been present and became more obvious after blocking the RF. Interestingly, for the horse with bilateral forelimb lameness (Horse 3), the PVF and VI had the most change with the first block with less change after the second and third blocks, while the symmetry score for PVF and VI was opposite that such that the hind end was most symmetrical after the third block. The combination of these indicates that the hind end does compensate for a bilateral forelimb lameness since its ground reaction forces changed in response to forelimb analgesia; perhaps the response of the symmetry score is the best indicator of compensation in horses with bilateral forelimb lameness.

Table 3.3.2.5: For cases of forelimb lameness, mean ± SD peak vertical force (PVF) of hindlimbs (non-lame) are listed at the trot before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH=left hind; RH=right hind; PDN=palmar digital nerve.

	Pre block PVF (N/kg)	**Post block PVF (N/kg)**	**Percent change (%)**
Horse 1 RH (LF middle carpal joint block)	7.792 ± 0.313	8.178 ± 0.212	+5
Horse 1 LH (LF middle carpal joint block)	8.037 ± 0.420	8.110 ± 0.246	+1
Horse 2 RH (RF low 4-point block)	8.922 ± 0.121	9.018 ± 0.165	+1
Horse 2 LH (RF low 4-point block)	8.798 ± 0.239	8.768 ± 0.304	0
Horse 3 RH (RF PDN)	7.464 ± 0.267	7.866 ± 0.119	+5
Horse 3 LH (RF PDN)	7.758 ± 0.216	8.067 ± 0.028	+4
Horse 3 RH (LF PDN)	7.866 ± 0.119	7.504 ± 0.198	-5
Horse 3 LH (LF PDN)	8.067 ± 0.028	7.916 ± 0.158	-2
Horse 3 RH (RF abaxial)	7.504 ± 0.198	7.994 ± 0.116	+7
Horse 3 LH (RF abaxial)	7.916 ± 0.158	7.846 ± 0.372	-1

Table 3.3.2.6: Hindlimb symmetry for peak vertical force (PVF) at a trot before and after diagnostic analgesia for forelimb lameness. LF=left front; RF=right front; PDN=palmar digital nerve. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

	Pre block hindlimb PVF symmetry score	**Post block hindlimb PVF symmetry score**
Horse 1 LF middle carpal joint block	1.03	0.99
Horse 2 RF low 4-point block	0.99	0.97
Horse 3 RF PDN	1.04	1.03
Horse 3 LF PDN	1.03	1.05
Horse 3 RF abaxial	1.05	0.98

Table 3.3.2.7: For cases of forelimb lameness, mean ± SD vertical impulse (VI) of hindlimbs (non-lame) are listed at the trot before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH=left hind; RH=right hind; PDN=palmar digital nerve.

	Pre block limb VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**
Horse 1 RH (LF middle carpal joint block)	1.330 ± 0.082	1.450 ± 0.035	9
Horse 1 LH (LF middle carpal joint block)	1.350 ± 0.096	1.394 ± 0.029	3
Horse 2 RH (RF low 4-point block)	1.602 ± 0.029	1.520 ± 0.087	-5
Horse 2 LH (RF low 4-point block)	1.556 ± 0.015	1.548 ± 0.036	-1
Horse 3 RH (RF PDN)	1.388 ± 0.075	1.360 ± 0.037	-2
Horse 3 LH (RF PDN)	1.422 ± 0.060	1.445 ± 0.048	2
Horse 3 RH (LF PDN)	1.360 ± 0.037	1.328 ± 0.030	-2
Horse 3 LH (LF PDN)	1.445 ± 0.048	1.390 ± 0.038	-4
Horse 3 RH (RF abaxial)	1.328 ± 0.030	1.404 ± 0.044	1
Horse 3 LH (RF abaxial)	1.390 ± 0.038	1.392 ± 0.014	0

Table 3.3.2.8: Hindlimb vertical impulse (VI) symmetry scores at a trot before and after blocking for forelimb lameness. LF=left front; RF=right front; DN=palmar digital nerve. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

	Pre block hindlimb VI symmetry score	**Post block hindlimb VI symmetry score**
Horse 1 LF middle carpal joint block	1.02	0.96
Horse 2 RF low 4-point block	0.97	1.02
Horse 3 RF PDN	1.02	1.06
Horse 3 LF PDN	1.06	1.05
Horse 3 RF abaxial	1.05	0.99

Force Plate Walk

There were changes to both hindlimbs in response to blocking forelimb lameness. The heel PVF was increased in the hindlimbs on baseline compared to a normal sound horse (4.149 N/kg ± 0.628) and it was also increased relative to the forelimb heel PVF of a normal horse (5.085 N/kg ± 0.750). In response to diagnostic analgesia in the forelimb, there were common decreases in heel PVF and increases in midstance PVF (Table 3.3.2.9-10; Horses 1, 3 and 4). The combination of these findings indicate that the horses were using the hindlimb heels to compensate for the forelimb lameness. Horse 2 is different because the lameness worsened with initial blocks before improving with the final block.

Table 3.3.2.9: For cases of forelimb lameness, mean ± SD heel peak vertical force (PVF) of hindlimbs (non-lame) are listed at the walk before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; LH=left hind; RH=right hind; PDN=palmar digital nerve.

	Pre block heel PVF (N/kg)	**Post block heel PVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 RH (LF middle carpal joint block)	5.170 ± 0.176	4.828 ± 0.194	- 7	0.020*
Horse 1 LH (LF middle carpal joint block)	5.530 ± 0.517	4.798 ± 0.151	- 13	0.016*
Horse 2 RH (RF low 4-point block)	4.673 ± 0.141	4.849 ± 0.174	+ 4	0.073
Horse 2 LH (RF low 4-point block)	4.325 ± 0.120	4.658 ± 0.129	+ 8	0.003*
Horse 3 RH (RF PDN)	4.740 ± 0.196	4.530 ± 0.117	- 5	0.074
Horse 3 LH (RF PDN)	4.486 ± 0.499	4.238 ± 0.189	- 6	0.329
Horse 3 RH (LF PDN)	4.530 ± 0.117	4.596 ± 0.167	+ 2	0.490
Horse 3 LH (LF PDN)	4.238 ± 0.189	4.140 ± 0.147	- 2	0.387
Horse 3 RH (RF abaxial)	4.596 ± 0.167	4.266 ± 0.258	- 7	0.043*
Horse 3 LH (RF abaxial)	4.140 ± 0.147	4.118 ± 0.095	- 1	0.786
Horse 4 RH (LF PDN)	4.540 ± 0.265	4.160 ± 0.171	- 8	0.015*
Horse 4 LH (LF PDN)	4.588 ± 0.362	4.242 ± 0.259	- 8	0.120
Horse 4 RH (RF PDN)	4.160 ± 0.171	3.958 ± 0.309	- 5	0.192
Horse 4 LH (RF PDN)	4.242 ± 0.259	4.576 ± 0.142	+ 8	0.035*

Table 3.3.2.10: For cases of forelimb lameness, mean ± SD midstance peak vertical force (MsPVF) of hindlimbs (non-lame) are listed at the walk before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; LH=left hind; RH=right hind; PDN=palmar digital nerve.

	Pre block MsPVF (N/kg)	**Post block MsPVF (N/kg)**	**Percent change (%)**	**T-test (P-value)**
Horse 1 RH (LF middle carpal joint block)	2.698 ± 0.167	2.822 ± 0.129	+ 5	0.225
Horse 1 LH (LF middle carpal joint block)	2.500 ± 0.156	2.856 ± 0.169	+ 14	0.009*
Horse 2 RH (RF low 4-point block)	2.987 ± 0.097	2.786 ± 0.108	- 7	0.005*
Horse 2 LH (RF low 4-point block)	3.088 ± 0.083	2.806 ± 0.104	- 9	0.002*
Horse 3 RH (RF PDN)	2.910 ± 0.234	2.870 ± 0.172	- 1	0.766
Horse 3 LH (RF PDN)	3.000 ± 0.315	3.098 ± 0.066	+ 3	0.515
Horse 3 RH (LF PDN)	2.870 ± 0.172	2.898 ± 0.229	+ 1	0.832
Horse 3 LH (LF PDN)	3.098 ± 0.066	3.138 ± 0.075	+ 1	0.305
Horse 3 RH (RF abaxial)	2.898 ± 0.229	3.126 ± 0.202	+ 8	0.134
Horse 3 LH (RF abaxial)	3.138 ± 0.075	3.068 ± 0.070	- 2	0.166
Horse 4 RH (LF PDN)	2.975 ± 0.178	3.127 ± 0.103	+ 5	0.100
Horse 4 LH (LF PDN)	2.976 ± 0.229	3.216 ± 0.194	+ 8	0.112
Horse 4 RH (RF PDN)	3.127 ± 0.103	3.230 ± 0.245	+ 3	0.365
Horse 4 LH (RF PDN)	3.216 ± 0.194	2.930 ± 0.104	- 9	0.020*

Fetlock extension

There is very minimal change, if any, in fetlock extension with blocks and there is a high standard deviation (Table 3.3.2.11 and 3.3.2.12). This is likely a function of the method of measurement as opposed to no change in the fetlock extension. Nonetheless, fetlock extension, as reported in this thesis, does not appear to provide any compensatory information.

Table 3.3.2.11: For cases of forelimb lameness, mean ± SD fetlock extension of the contralateral forelimb (non-lame) are listed at the walk before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; PDN=palmar digital nerve.

	Pre block Fetlock Extension (degrees)	Post block Fetlock Extension (degrees)	Percent change (%)
Horse 1 RF (LF middle carpal joint block)	137.18 ± 1.42	137.80 ± 2.15	1
Horse 2 LF (RF low 4-point block)	140.34 ± 1.28	143.98 ± 2.06	3
Horse 3 LF (RF PDN)	137.11 ± 2.15	137.68 ± 2.59	0
Horse 3 RF (LF PDN)	133.38 ± 2.48	134.11 ± 2.38	1
Horse 3 LF (RF abaxial)	136.59 ± 1.51	138.62 ± 2.31	1
Horse 4 RF (LF PDN)	143.16 ± 2.03	141.32 ± 3.71	-1
Horse 4 LF (RF PDN)	139.44 ± 2.18	143.47 ± 3.61	3

Table 3.3.2.12: For cases of forelimb lameness, mean ± SD fetlock extension of both hindlimbs (non-lame) are listed at the walk before and after the block of the lame forelimb (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH= left hind; RH=right hind; PDN=palmar digital nerve.

	Pre block Fetlock Extension (degrees)	Post block Fetlock Extension (degrees)	Percent change (%)
Horse 1 RH (LF middle carpal joint block)	147.67 ± 2.45	152.31 ± 2.57	3
Horse 1 LH (LF middle carpal joint block)	149.69 ± 2.92	151.36 ± 3.15	1
Horse 2 RH (RF low 4-point block)	147.38 ± 2.05	147.96 ± 1.64	0
Horse 2 LH (RF low 4-point block)	146.90 ± 1.81	149.25 ± 3.12	2
Horse 3 RH (RF PDN)	144.96 ± 2.81	143.28 ± 2.73	-1
Horse 3 LH (RF PDN)	143.72 ± 3.41	143.14 ± 3.36	0
Horse 3 RH (LF PDN)	143.28 ± 2.73	146.80 ± 3.17	2
Horse 3 RH (RF abaxial)	146.80 ± 3.17	141.79 ± 2.62	-3
Horse 3 RH (RF abaxial)	145.38 ± 2.44	143.76 ± 4.36	-1
Horse 4 RH (LF PDN)	145.62 ± 0.94	143.96 ± 2.64	-1
Horse 4 LH (LF PDN)	149.36 ± 3.96	147.53 ± 3.48	-1
Horse 4 RH (RF PDN)	143.96 ± 2.64	145.26 ± 5.33	1
Horse 4 LH (RF PDN)	147.53 ± 3.48	148.85 ± 2.88	1

Reponses to Hindlimb diagnostic analgesia

Lameness Locator®

At the time of the final block for all horses with primary hindlimb lameness (Horse 5-8), the forelimb lameness was decreased or switched in all horses (Table 3.3.2.13). This demonstrates that the forelimbs compensate for the hindlimb when it is lame.

Table 3.3.2.13: For cases of bilateral hindlimb lameness, vector sum data (mean ± SD) from the Lameness Locator® are listed as well as the calculated percent change for the forelimbs in response to diagnostic analgesia in the hindlimbs. The lame forelimb is highlighted in parentheses. DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Baseline Vector Sum (mm)	**Post bilateral hindlimb blocks Vector Sum (mm)**	**Percent change (%)**
Horse 5 bilateral DIT/TMT	15.6 (L)	12.8 (L)	-18
Horse 6 bilateral DIT/TMT	14.3 (L)	12.0 (R)	^
Horse 7 bilateral Low 6	17.1 (L)	17.9 (L)	+5
Horse 7 bilateral DIT/TMT	17.9 (L)	8.2 (L)	-54
Horse 8 bilateral MFT	18.1 (R)	11.4 (R)	- 37

^Lameness switched to contralateral limb

Force plate trot

There was variable change present in the PVF and VI of the forelimbs between horses after bilateral hindlimb blocks (Tables 3.3.2.14 and 3.3.3.2.16). For Horse 6, 7, and 8 after the final bilateral hindlimb block was performed, the PVF and VI increased slightly which is the opposite of what one would expect if the horse were compensating with the front limbs. However, Horse 5 demonstrated slight decreases in VI and PVF after the bilateral hindlimb blocks, indicating that some compensation to the forelimbs had occurred.

Table 3.3.2.14: For cases of bilateral hindlimb lameness, mean ± SD peak vertical forces (PVF) of the forelimbs (non-lame) are listed at the trot before and after bilateral blocks of the hindlimbs (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block PVF (N/kg)	**Post block PVF (N/kg)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	9.486 ± 0.480	9.362 ± 0.445	-1
Horse 5 LF (bilateral DIT/ TMT)	8.903 ± 0.234	8.902 ± 0.112	0
Horse 6 RF (bilateral DIT/ TMT)	9.968 ± 0.117	10.158 ± 0.280	+2
Horse 6 LF (bilateral DIT/ TMT)	9.790 ± 0.096	10.058 ± 0.280	+3
Horse 7 RF (low 6-point)	9.155 ± 0.136	9.130 ± 0.272	0
Horse 7 LF (low 6-point)	9.054 ± 0.166	9.162 ± 0.069	+1
Horse 7 RF (bilateral DIT/ TMT)	9.130 ± 0.272	9.178 ± 0.142	+1
Horse 7 LF (bilateral DIT/ TMT)	9.162 ± 0.069	9.138 ± 0.203	0
Horse 8 RF (bilateral MFT)	9.810 ± 0.252	10.240 ± 0.233	+5
Horse 8 LF (bilateral MFT)	10.100 ± 0.210	10.226 ± 0.086	+1

Table 3.3.2.15: Symmetry scores for forelimb PVF at a trot before and after bilateral hindlimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

	Pre-Block Forelimb PVF Symmetry Score	**Post Block Forelimb PVF Symmetry Score**
Horse 5 bilateral DIT/TMT block	0.94	0.95
Horse 6 bilateral DIT/TMT blocks	0.98	0.99
Horse 7 bilateral Low 6 blocks	0.99	1.00
Horse 7 bilateral DIT/TMT blocks	1.00	1.00
Horse 8 bilateral MFT blocks	1.03	1.00

Table 3.3.2.16: For cases of bilateral hindlimb lameness, mean ± SD vertical impulse (VI) of the forelimbs (non-lame) are listed at the trot before and after bilateral blocks of the hindlimbs (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	1.830 ± 0.049	1.738 ± 0.055	-5
Horse 5 LF (bilateral DIT/ TMT)	1.740 ± 0.032	1.718 ± 0.025	-1
Horse 6 RF (bilateral DIT/ TMT)	1.864 ± 0.029	1.898 ± 0.051	+2
Horse 6 LF (bilateral DIT/ TMT)	1.892 ± 0.049	1.910 ± 0.037	+1
Horse 7 RF (low 6-point)	1.813 ± 0.039	1.800 ± 0.087	-1
Horse 7 LF (low 6-point)	1.850 ± 0.036	1.917 ± 0.056	+4
Horse 7 RF (bilateral DIT/ TMT)	1.800 ± 0.087	1.906 ± 0.049	+6
Horse 7 LF (bilateral DIT/ TMT)	1.917 ± 0.056	1.940 ± 0.062	+1
Horse 8 RF (bilateral MFT)	1.892 ± 0.069	1.916 ± 0.031	+4
Horse 8 LF (bilateral MFT)	1.916 ± 0.031	1.892 ± 0.069	+1

Table 3.3.2.17: Forelimb vertical impulse (VI) symmetry scores at a trot before and after bilateral hindlimb diagnostic analgesia. Symmetry scores were calculated by dividing the value for the parameter for the left limb by the value for the parameter for the right limb. Therefore, symmetry scores less than 1 indicate a left sided asymmetry and symmetry scores greater than 1 indicate a right sided asymmetry.

	Pre-Block Forelimb VI Symmetry Score	**Post Block Forelimb VI Symmetry Score**
Horse 5 bilateral DIT/TMT	0.95	0.99
Horse 6 bilateral DIT/TMT	1.01	1.01
Horse 7 bilateral Low 6	1.02	1.06
Horse 7 bilateral DIT/TMT	1.06	1.02
Horse 8 bilateral MFT	1.00	1.01

Force plate walk

After block of the bilateral DIT and TMT joints, there were changes in the force plate data at the walk in both forelimbs (Tables 3.3.2.18-3.3.2.20). There were decreases in the forelimb heel PVF and midstance PVF after bilateral hindlimb diagnostic analgesia (Tables 3.3.2.18 and 3.3.2.19). This is supportive that the increased heel and midstance PVF for the forelimbs was a measure of compensation for the bilateral hindlimb lameness. For Horse 8, there was a bilateral increase in the vertical impulse in the forelimbs which might suggest that the horse is leaving the foot on the ground longer since the PVF decreased.

Table 3.3.2.18: For cases of hindlimb lameness, mean ± SD heel peak vertical force (PVF) of forelimb (non-lame) are listed at the walk before and after the bilateral hindlimb block (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH=left hind; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block heel PVF (N/kg)	**Post block heel PVF (N/kg)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	5.718 ± 0.270	5.440 ± 0.263	- 5
Horse 5 LF (bilateral DIT/ TMT)	5.732 ± 0.190	5.186 ± 0.709	- 10
Horse 6 RF (bilateral DIT/ TMT)	5.407 ± 0.174	5.222 ± 0.158	- 3
Horse 6 LF (bilateral DIT/ TMT)	5.438 ± 0.142	5.357 ± 0.129	- 2
Horse 7 RF (low 6-point)	5.474 ± 0.099	5.276 ± 0.155	- 4
Horse 7 LF (low 6-point)	5.676 ± 0.118	5.258 ± 0.129	- 7
Horse 7 RF (bilateral DIT/ TMT)	5.276 ± 0.155	5.200 ± 0.096	- 1
Horse 7 LF (bilateral DIT/ TMT)	5.258 ± 0.129	5.308 ± 0.110	+ 1
Horse 8 RF (bilateral MFT)	5.834 ± 0.076	5.526 ± 0.160	- 5
Horse 8 LF (bilateral MFT)	5.858 ± 0.223	5.476 ± 0.109	- 7

Table 3.3.2.19: For cases of hindlimb lameness, mean ± SD midstance peak vertical force (MsPVF) of forelimb (non-lame) are listed at the walk before and after the bilateral hindlimb block (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH=left hind; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block MsPVF (N/kg)	**Post block MsPVF (N/kg)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	5.708 ± 0.168	5.530 ± 0.228	- 3
Horse 5 LF (bilateral DIT/ TMT)	5.790 ± 0.148	5.576 ± 0.203	- 4
Horse 6 RF (bilateral DIT/ TMT)	5.343 ± 0.144	5.176 ± 0.133	- 3
Horse 6 LF (bilateral DIT/ TMT)	5.308 ± 0.090	5.252 ± 0.127	- 1
Horse 7 RF (low 6-point)	5.306 ± 0.169	5.182 ± 0.150	- 2
Horse 7 LF (low 6-point)	5.478 ± 0.169	5.154 ± 0.088	- 6
Horse 7 RF (bilateral DIT/ TMT)	5.182 ± 0.150	5.132 ± 0.096	- 1
Horse 7 LF (bilateral DIT/ TMT)	5.154 ± 0.088	5.170 ± 0.152	0
Horse 8 RF (bilateral MFT)	5.780 ± 0.050	5.372 ± 0.072	- 7
Horse 8 LF (bilateral MFT)	5.806 ± 0.200	5.388 ± 0.104	- 7

Table 3.3.2.20: For cases of hindlimb lameness, mean ± SD vertical impulse (VI) of forelimb (non-lame) are listed at the walk before and after the bilateral hindlimb block (listed in parentheses) along with the calculated percent change. P-value for a paired t-test is provided (statistically significant results are indicated by asterisk). LF=left front; RF=right front; LH=left hind; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block VI (Ns/kg)	**Post block VI (Ns/kg)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	3.248 ± 0.101	3.104 ± 0.086	- 4
Horse 5 LF (bilateral DIT/ TMT)	3.125 ± 0.113	3.220 ± 0.099	+ 3
Horse 6 RF (bilateral DIT/ TMT)	3.610 ± 0.106	3.486 ± 0.123	- 3
Horse 6 LF (bilateral DIT/ TMT)	3.516 ± 0.046	3.570 ± 0.051	+ 2
Horse 7 RF (low 6-point)	3.348 ± 0.102	3.218 ± 0.231	- 4
Horse 7 LF (low 6-point)	3.426 ± 0.193	3.132 ± 0.180	- 9
Horse 7 RF (bilateral DIT/ TMT)	3.218 ± 0.231	3.264 ± 0.046	+ 1
Horse 7 LF (bilateral DIT/ TMT)	3.132 ± 0.180	3.206 ± 0.094	+ 2
Horse 8 RF (bilateral MFT)	3.116 ± 0.093	3.368 ± 0.151	+ 8
Horse 8 LF (bilateral MFT)	3.146 ± 0.269	3.456 ± 0.120	+ 10

Fetlock extension

There is very minimal change, if any, in fetlock extension with blocks and there is a high standard deviation (Table 3.3.2.21). This is likely a function of the method of measurement as opposed to no change in the fetlock extension. Nonetheless, fetlock extension, as reported in this thesis, does not appear to provide any compensatory information.

Table 3.3.2.21: For cases of hindlimb lameness, mean ± SD fetlock extension of both forelimbs (non-lame) are listed at the walk before and after the bilateral hindlimb block (listed in parentheses) along with the calculated percent change. LF=left front; RF=right front; LH=left hind; DIT/TMT=distal intertarsal/ tarsometatarsal; MFT=medial femorotibial.

	Pre block Fetlock Extension (degrees)	**Post block Fetlock Extension (degrees)**	**Percent change (%)**
Horse 5 RF (bilateral DIT/ TMT)	138.90 ± 2.26	140.42 ± 2.80	1
Horse 5 LF (bilateral DIT/ TMT)	138.33 ± 1.97	138.42 ± 1.94	0
Horse 6 RF (bilateral DIT/ TMT)	139.77 ± 2.94	139.84 ± 1.55	0
Horse 6 LF (bilateral DIT/ TMT)	140.27 ± 1.36	141.88 ± 2.66	1
Horse 7 RF (low 6-point)	134.30 ± 2.74	136.13 ± 1.95	1
Horse 7 LF (low 6-point)	128.40 ± 1.28	130.18 ± 1.01	1
Horse 7 RF (bilateral DIT/ TMT)	136.13 ± 1.95	135.78 ± 2.14	0
Horse 7 LF (bilateral DIT/ TMT)	130.18 ± 1.01	130.29 ± 1.98	0
Horse 8 RF (bilateral MFT)	135.87 ± 3.31	142.2 ± 0.72	5
Horse 8 LF (bilateral MFT)	137.86 ± 2.02	138.8 ± 2.57	1

Discussion:

Compensation in unilateral forelimb lameness

Compensatory mechanisms are well described for unilateral forelimb lameness (Keegan 2020a; Weishaupt 2008). Compensatory mechanisms in the trot include a reduction in total vertical impulse in the lame limb, which is accomplished by increasing stride frequency, and decreases in diagonal vertical impulse in the lame diagonal. Ultimately, the force and impulse shifts so that there is increased force placed on the contralateral forelimb and additionally there is an appearance of a diagonal hindlimb lameness. In this thesis, both horses with unilateral forelimb lameness adhered to these principles when diagnostic analgesia was applied to the primary limb. Components of this compensation could be detected using the Lameness Locator®, the force plate at the walk and trot, but not with the fetlock extension. The Lameness Locator® was best to examine the hindlimb compensation (Tables 3.3.2.1 and 3.3.2.2). For instance, Horse 1 had a predominant left forelimb lameness and the pelvic asymmetry shifted from the right hindlimb to the left hindlimb after blocking of the left forelimb while Horse 2 had a worsening contralateral hindlimb push-off lameness, but a similar contralateral impact hindlimb lameness compared to baseline. Since this technology isolates the lameness to the predominant forelimb, it is not really able to detect compensatory patterns in the other forelimb. The force plate was better at telling what happened to all limbs (contralateral fore and hind) at the walk and trot (Tables 3.3.2.3-3.3.2.10). For instance, at a walk, Horse 1 demonstrated a bilateral decrease in heel PVF after blocking the primary forelimb indicating that the hind heels were compensating for the forelimb. At a trot, both horses with unilateral forelimb lameness had decreased peak vertical force and vertical impulse in the contralateral forelimb at the trot after blocking the primary lame forelimb. None of this compensatory change was reflected in the fetlock extension data as changes in fetlock extension were variable between horses and there was considerable standard deviation present which may suggest that methods used were not sufficient to detect subtle changes.

Compensation in bilateral forelimb lameness

Unlike the unilateral forelimb lameness, to the authors' knowledge, there is not a clear description about how a horse would compensate when it has a bilateral forelimb lameness. However, the compensatory mechanisms in the trot should be similar to that described in a unilateral forelimb lameness. In other words, there should be a reduction in total vertical impulse in the lame limb, which is accomplished by increasing stride frequency (Keegan 2020a; Weishaupt 2008). Presumably, this would result in shifting the limb impulse more to the hindlimb in the lame diagonal and less to the contralateral forelimb. Overall, the results of this thesis, support this concept using the Lameness Locator®, and force plate at the walk and trot, but not with the fetlock extension measurements. For instance, with the Lameness Locator®, Horse 3 demonstrated a worsened lameness in the contralateral hindlimb (right hindlimb) after the first block and the forelimb lameness switched from right forelimb to left forelimb (right forelimb palmar digital nerve block). After second block (left forelimb palmar digital nerve block), the lameness switched from LF to RF and the hindlimb asymmetry switched from RH to LH, so the horse maintained a contralateral hindlimb lameness to the primary forelimb lameness. Horse 4 initially had a LF lameness and contralateral hindlimb lameness, after blocking the forelimb lameness and hindlimb asymmetry switched to the opposite limb (a right forelimb lameness and a left hindlimb lameness). After nerve block of the right forelimb, the left hindlimb asymmetry decreased. These findings are consistent with published compensatory patterns for a primary forelimb lameness, where horses demonstrate a compensatory contralateral hindlimb lameness (Keegan 2020a; Weishaupt 2008).

Both horses with bilateral forelimb lameness (Table 3.3.2.2 and 3.3.2.3) had decreased peak vertical force and vertical impulse at the trot in the contralateral forelimb after blocking the primary lame forelimb. At the walk, there was variable change in the midstance PVF in the contralateral forelimb (Table 3.3.2.10). Together, our force plate data suggests some compensatory change in the contralateral forelimb, similar to the mild compensatory changes noted in the contralateral forelimb from Serra Bragança et. al. (Serra Bragança 2021). In addition, each horse had altered hindlimb PVF and VI symmetry scores at the trot after diagnostic analgesia of the forelimb (Table 3.3.2.6 and 3.3.2.8). However, the changes in hindlimb asymmetry were not consistent in the degree of change or direction of change as would be expected in a unilateral forelimb lameness (Keegan 2020a; Weishaupt 2008). This was supported by the walk data as well (Table 3.3.2.9). There was a decrease in hindlimb heel peak vertical force after the forelimb diagnostic analgesia when compared to baseline. This suggests that the horse shifted weight to the hindlimb heels bilaterally to compensate for the forelimb lameness as opposed to shifting solely to the contralateral forelimb. This is similar to the findings by Serra Bragança et. al. where they noted there was an increase in the diagonal hindlimb first peak (equivalent to heel PVF in this investigation) by 4.8 percent (Serra Bragança 2021). In addition, we had an increase in the hind midstance PVF in Horses 3 and 4 bilaterally in response to forelimb diagnostic analgesia (Table 3.3.2.10). The expected result in these cases would be that a compensatory contralateral hindlimb asymmetry would be abolished after blocking the primary lame forelimb. This may suggest that the horses in this study also had hindlimb lameness even though their forelimb lameness had a greater severity. This would not be entirely surprising considering that the hindlimbs taking extra force to compensate for forelimb lameness. However, this would require additional diagnostic analgesia to confirm this thought.

Compensatory change was not reflected in the fetlock extension data as changes in fetlock extension were variable between horses (Table 3.3.2.11 and 3.3.2.12) and there was considerable standard deviation present. There was minimal change in the hindlimb fetlock extension in response to forelimb blocks, and there were minimal changes in the contralateral forelimb fetlock extension even though the forelimb lameness switched to the contralateral limb at the trot after diagnostic analgesia. This may be a result of the difference in mechanics of the walk as opposed to the trot. It may be easier to dissipate forces across all four limbs at the walk because it is a four-beat gait and three limbs are on the ground at the same time, as opposed to the trot, which is a two-beat symmetrical gait where two limbs are on the ground at the same time while the other two limbs are in the swing phase (Clayton 2004).

Overall, compensatory changes were present in all three other limbs after diagnostic analgesia for forelimb lameness as demonstrated by the changes in PVF and switching of Lameness Locator® asymmetry in the forelimbs at the trot as well as in changes in force plate trot symmetry scores and Lameness Locator® asymmetry in the hindlimbs at the trot and force distribution at the walk in the hindlimbs.

Compensation in bilateral hindlimb lameness

To the authors knowledge, no publications are available for comparison for kinematic and kinetic description of compensatory responses of diagnostic analgesia in naturally-occurring bilateral hindlimb lameness. It has been described that with unilateral hindlimb lameness, the impulse shifts to the contralateral hindlimb. Additionally, it has been described that the rate of loading and peak forces are reduced by prolonging the stance duration (Weishaupt 2008). For further extrapolation, a study of responses to induction of unilateral hindlimb lameness using a solar pressure model was used for comparison (Weishaupt 2006). In a solar pressure induced single hindlimb lameness, the compensatory mechanisms identified were a decrease in the diagonal impulse and the vertical impulse shifted to the forelimb during the lame diagonal stance (+6.5%) and the vertical impulse shifted to the sound diagonal stance (+3.2%) (Weishaupt 2006). This phenomenon was not observed in this thesis population, likely because the horses had bilateral and not unilateral hindlimb lameness and the blocking of hindlimbs occurred simultaneously which could have masked compensatory responses.

However, with that said, there was significant change in head movement asymmetry in response to bilateral hindlimb blocking in Horse 7 and 8 and the forelimb lameness in Horse 6 switched between forelimbs (Table 3.3.2.13). This is defined as greater than 25% improvement by the Equinosis manual Lameness Locator® software criteria. This improvement in forelimb lameness was the ipsilateral forelimb to the primary lame hindlimb identified by the Lameness Locator®. However, there was minimal alteration in forelimb symmetry scores for PVF and VI at the trot after diagnostic analgesia in the hindlimbs (Tables 3.3.2.15 and 3.3.2.17), except for in Horse 8. In many cases, symmetry scores were close to 1 between forelimbs on baseline. Since bilateral hindlimb blocks were performed, it is not surprising that symmetry scores remained similar to baseline with minimal initial asymmetry for most horses.

There were additional findings in individual horses that were not conserved between horses in response to diagnostic analgesia that may be meaningful for that particular horse and indicative of another lameness issue, either in another limb or additional structure in that limb. For Horse 5, there was a head movement asymmetry that indicated a left forelimb lameness despite a right pelvic movement asymmetry that persisted after bilateral hindlimb blocking, which may suggest that the left forelimb lameness is a second primary lameness. Additionally, in Horse 5, there was a slightly larger degree of asymmetry that persisted after hindlimb blocks that was contralateral to the hindlimb that was primarily lame. This is suggestive that there is a true primary lameness in the forelimb for Horse 5, as forelimb lameness that is compensatory for a primary hindlimb lameness is typically in the ipsilateral forelimb (Keegan 2020b; Weishaupt 2008).

There was a decrease in heel and midstance peak vertical force at the walk in the forelimbs bilaterally in response to bilateral hindlimb diagnostic analgesia (Tables 3.3.2.18 and 3.3.2.19). This suggests that the horse was using both forelimbs to aid in compensation for bilateral hindlimb lameness. These findings are consistent with the fetlock extension data obtained at the walk. After hindlimb diagnostic analgesia, there was less fetlock extension in most forelimbs, but the degree of change was very small (Table 3.3.2.21). Since there was less extension in the forelimbs, indicating decreased loading, and thus increased loading in the forelimbs to compensate for the bilateral hindlimb lameness. This is an expected reversal to Serra Bragança's findings where there was an increase in fetlock extension in all three other limbs after lameness induction in a single limb to increase loading in the non lame limbs as compensation.

Overall, compensation for bilateral hindlimb blocks was achieved by shifting force to both forelimbs. The contralateral forelimb to the primary lame hind limb took the greater amount of force. At the walk, the heels of the forelimbs appeared to take more of this compensatory role with increases in the midstance phase of the stride to a lesser degree.

3.3.3 Changes associated with a diagnosis

Bilateral navicular syndrome

Two horses had a diagnosis of bilateral navicular syndrome. There were no patterns in the Lameness Locator®, force plate at trot, and fetlock extension data at baseline or after the blocks to make one think these horses had navicular syndrome. However, intuitively, the walk data with force plate should provide the most information because it also shows dynamics between the heel and toe. Interestingly, the heel PVF value for both horses was comparable to control horses bilaterally. The most significant difference noted in these horses compared to other horses with forelimb lameness is that there was a decrease in heel PVF after the blocks (Table 3.3.1.6). This is counterintuitive to the expected result because it would be reasonable to expect that heel PVF would increase in horses with this lesion in response to desensitization of structures in the palmar foot region. It is possible that therapeutic shoeing could have contributed to this finding. As noted in their individual case descriptions, Horse 4 was shod with a wedge shoe, but Horse 3 had a plain steel shoe with a snow pad. The presence of wedge shoes could change the forces placed on the limb and it is possible that the snow pad created a wedge effect to a lesser extent. It has been described that wedge shoes can decrease the amount of force exerted on the navicular bone by the deep digital flexor tendon (Willemen 1999). Additionally, the decrease in heel PVF at the walk after diagnostic analgesia occurred despite an increase in PVF at the trot (Table 3.3.1.2) in the limb where the predominant lameness switched to the contralateral forelimb

Distal intertarsal joint and tarsometatarsal joint osteoarthritis

Three horses were diagnosed with osteoarthritis of the distal intertarsal and tarsometatarsal joints with radiographs and/or computed tomography after successful blocking via intra-articular diagnostic analgesia of the distal intertarsal and tarsometatarsal joints. These horses all showed consistent change in their Lameness Locator® data (Table 3.3.3.1 and Table 3.3.3.2) by demonstrating a decrease in the impact lameness and the push off lameness in response to distal intertarsal and tarsometatarsal intra-articular analgesia. There was a greater improvement in the impact lameness (greater decrease in asymmetry) or minimum difference of pelvis displacement in response to diagnostic analgesia of the distal tarsal joints compared to the push-off lameness (Tables 3.3.3.1 and 3.3.3.2). However. it is important to note that the change in asymmetry for Horse 6 was not significant in response to blocks. This may mean that distal hock associated lameness could cause slightly more pain on impact than on push-off.

Table 3.3.3.1: Lameness Locator® impact lameness data for the mean minimum difference of the pelvis ("Diff Min Pelvis") between left and right sides before and after bilateral distal intertarsal and tarsometatarsal (DIT/TMT) joint blocks. The percent change before and after joint blocks was calculated. The lame limb is listed in parentheses.

Impact lameness	**Diff Min Pelvis Pre block of bilateral DIT/TMT**	**Diff Min Pelvis Post block of bilateral DIT/TMT**	**Percent change (%)**
Horse 5	14.1 (R)	3.4 (R)	- 76
Horse 6	1.5 (R)*	1.4 (L)*	^*
Horse 7	14.0 (L)	6.9 (L)	- 51

*Asymmetry was below the 3mm threshold for hindlimb lameness
^Lameness switched to contralateral limb

Table 3.3.3.2: Lameness Locator® push-off lameness data for the mean maximum difference of the pelvis ("Diff Max Pelvis") between left and right sides before and after bilateral distal intertarsal and tarsometatarsal (DIT/TMT) joint blocks. The percent change before and after joint blocks was calculated. The lame limb is listed in parentheses.

Push-off lameness	**Diff Max Pelvis Pre block of bilateral DIT/TMT**	**Diff Max Pelvis Post block of bilateral DIT/TMT**	**Percent change (%)**
Horse 5	12.39 (R)	6.1 (R)	- 50
Horse 6	10.1 (L)	9.4 (L)	- 7
Horse 7	12.1 (L)	7.6 (L)	- 37

In Horse 5 and 6, there was increased PVF at the trot in both hindlimbs in response to diagnostic analgesia (Table 3.3.1.12). This is consistent with a study performed that compared the hindlimb pelvic asymmetry to force plate findings which found that differences in the minimum difference of the pelvis were moderately positively correlated with differences in PVF in the hindlimbs (Bell 2016). In all three horses, there was a decrease in hindlimb midstance peak vertical force (Table 3.3.1.12). In Horses 5 and 6, there was an increase in heel peak vertical force (Table 3.3.1.16) in the primary lame limb after diagnostic analgesia compared to baseline. There was an increase in heel PVF in both limbs compared to baseline after bilateral DIT/TMT blocks. This supports that there is a redistribution of normal forces in response to diagnostic analgesia to the TMT/DIT joints at the walk that accompanies the increase in PVF at the trot. Although there is a small sample size, this is an interesting trend to consider in light of the contrast observed in Horse 8 after blocking of the medial femorotibial joint. In Horse 8, the changes in heel peak vertical force and midstance peak vertical force were opposite of these three DIT/TMT horses. To the author's knowledge, there is no publication addressing the kinetic and kinematic responses at the walk to intra-articular analgesia of the DIT/TMT joints in naturally-occurring osteoarthritis for comparison.

Medial Femorotibial Joint Osteoarthritis

The most striking change associated with this horse was the force plate data at the walk demonstrated a decrease in heel peak vertical force and an increase in midstance peak vertical force in response to diagnostic analgesia (Tables 3.3.1.16 and 3.3.1.17). There was also a worsening right hindlimb impact and push-off lameness on the Lameness Locator® data (Table 3.3.1.10-11). This is significant due to the contrasting response to diagnostic analgesia when compared to the horses with DIT/TMT analgesia, along with the fact of worsening asymmetry of hindlimbs at the trot accompanied an abnormal distribution of forces between the heel and midstance phases on the force plate at the walk. However, it should be considered that this horse had additional sclerotic intra-medullary lesions in the distal tibia and proximal third metatarsal bone that complicate this analysis as the diagnosis is unknown as well as whether they cause any lameness.

<u>The unknown lameness</u>

At this time, objective measures of lameness are primarily used in the research setting where it is used to validate lameness associated with experimentally-induced lameness where lesions are known. It would be ideal to apply this technology to the clinical setting in which the lameness is unknown. When working to identify and define an unknown lameness, each technology can bring different pieces of information to a case work-up. Most lameness evaluations rely on the trot to define the lameness. This is important for identifying the predominant lameness. The Lameness Locator® and force plate at the trot are helpful for this step. The Lameness Locator® provides the assessment of kinematic vertical displacement asymmetry in the head and pelvis and this is the most similar in method to the traditional subjective lameness exam. One difference is that the Lameness Locator® measures the vertical displacement of the highest point of the pelvis at its maximum and minimum, where the traditional subjective lameness exam focuses on the difference in rotational displacement of the tuber coxae (Keegan 2020a; Keegan 2020b). For the hindlimb lameness, it can provide both impact and push off lameness scores. This can add information to the clinician's observations of the lameness on the straight line. The advantages of the Lameness Locator® are that it is a mobile technology that provides rapid results with interpretation of the data. Additionally, a greater number of strides are assessed than using a force plate but based on our data there is greater variability than the force plate. The likely reason for this is that for the force plate the inclusion criteria is relatively small leading to low trial to trial variability that increases likelihood of identifying small changes in forces (Clayton 2013; Keegan 2020b).

In a traditional lameness exam, less importance is placed on evaluation of the horse at the walk in a case where the horse has a subtle lameness. However, evaluation of the walk can be beneficial to highlight a multi limb component to the lameness. A primary advantage of the force plate is that there is direct measurement of force on each limb that can be used to evaluate each limb individually and provide comparisons of forces between limbs (Merkens 1986). Therefore, the advantage of adding analysis of the walk to the trot analysis is that it provides force distribution within a limb over time during the stance phase. This means that there are discrete values (heel, midstance and toe regions) that can be measured, as well as the slope of the changes in force throughout the stance phase. Additionally, the order and transfer of weight differs between the walk as a result of gait mechanics. The walk is a four-beat gait and the trot is a two-beat gait where contralateral fore and hindlimbs hit the ground simultaneously. The biomechanics of each limb at the walk function as a pendulum, whereas the limbs function as a mass and spring model at the trot (Biewener 2006). Analysis at the walk was helpful in bilateral hindlimb cases especially in the cases analyzed in this thesis. This can provide a suggestion of bilateral fore or hindlimb lameness on baseline in a straight line. There is also use of comparison to other limbs to identify compensatory mechanisms based on ratios of PVF or vertical impulse between the forelimbs and hindlimbs.

Limitations of objective technology for an unknown lameness however, are that interpretations can be difficult with multiple patterns of lameness and compensation (Phutthachalee 2021; Reed 2020). The Lameness Locator® is helpful for the assessment of change in lameness in response to diagnostic analgesia in bilateral forelimb lameness as is the force plate at a trot, but it does not give an indication of bilateral lameness on baseline (Keegan 2012). The Lameness Locator® was most helpful in identification of unilateral forelimb lameness and the predominantly lame limb in bilateral lameness cases in this thesis, as well as determining response to blocks in bilateral forelimb lameness cases. The limitations of force plate analysis are that it only measures one stride at a time and there is significant time invested in the collection of data and data processing (Clayton 2004; Merkens 1986). Additionally, the outcomes have not been well defined for naturally-occurring lameness, which this thesis aims to address. However, the comparison of forces distributed between different time points of the stance phase, along with comparison of forces applied to each limb with the other three limbs can provide useful information for determining the primary lame limb as well as demonstrating compensatory effects using the rule of thumb that 60 percent of the weight is taken by the forelimbs and 40 percent of the weight is distributed to the hindlimb (Clayton 2004).

The advantage of measuring fetlock extension is the possibility of use in the field. In this thesis, the use of a static image of the fetlock at the midstance phase was used to approximate dynamic range of motion in comparison with other studies (Clayton 2007; Hodson 2001). The small degree of changes observed in combination with high variability in measurement made this method of static image angle measurement of limited use in this study. The use of dynamic range of motion would be ideal as it provides more information about the lameness, especially in light of the results of the force plate data at the walk where the force distribution changes within a horse with naturally-occurring lameness compared to post diagnostic analgesia.

Limitations

A major limitation in this study is that there is a small sample size of horses. Furthermore, the population in this study was a population of convenience as they are members of the teaching herd.

The purpose of this thesis was to characterize naturally-occurring lameness with the aim to facilitate the use of gait analysis in the clinical setting for clinical cases. Without the attempt to describe naturally-occurring lameness using kinetic and kinematic objective measures, the technology will remain esoteric. However, the limitations of investigating naturally-occurring lameness must be acknowledged. There was variation in severity of lameness and in disease process or specific structures that were causing lameness. Variation affects objective analysis because it makes it more difficult to identify changes that are truly significant. In this thesis, there were changes observed in the horses that were biologically significant because their pain was clinically improved, but these changes were not statistically significant. Additionally, horses may have developed other musculoskeletal pain as a result of compensation for a primary lameness over time that affected their lameness in response to perineural or intra-articular diagnostic analgesia.

The application of bilateral hindlimb blocks most likely affected the degree of changes observed in all technologies. Bilateral hindlimb blocks were performed because there was evidence of bilateral disease process on the passive exam and in flexion test responses. Bilateral hindlimb blocks were also performed because of the cumulative time required for block to take effect for intra-articular analgesia and the time required to perform objective method data collection. Bupivacaine was chosen as the local anesthetic for intra-articular and perineural analgesia for its longer duration of action. One potential future direction for this study would be to repeat diagnostic analgesia on the cases of hindlimb lameness. Four of the eight horses had simultaneous bilateral hindlimb diagnostic analgesia performed. It would be interesting to perform the diagnostic analgesia unilaterally to determine if any differences would be observed, such as the lameness switching to the contralateral limb after blocking the primary limb. Additionally, several of these horses had suggestion of additional primary lameness after considering the objective data results. Ideally, this additional lameness would be investigated further with diagnostic analgesia and imaging.

In many cases it was subjectively noted that lameness changed during the force plate exam, which was always performed after the subjective and Lameness Locator®. There are multiple possible explanations for this observation. The first is that diffusion of the local anesthetic occurs with time and thus the desensitization of additional structures altered the lameness. Another possibility is that it took a longer time for the blocks to reach full efficacy than was initially given. This could be addressed in future studies by performing the force plate exam first to counter the effects of diffusion, or more time could be given for joint blocks to take effect before collecting objective data. Additionally, BMISS data could be collected before and after force plate data collection to investigate subtle changes and the effect of time on the response to diagnostic analgesia.

Another limitation of this investigation was the use of a static image of the fetlock to measure angle of hyperextension. It would be ideal to evaluate the dynamic range of motion of the fetlock throughout the stance phase to assess lameness as opposed to a single time point. However, the software to accomplish this is costly.

Future Directions

In the future, it would be beneficial to expand the number of naturally-occurring lameness cases assessed with objective gait analysis in conjunction with the traditional exam. As the Lameness Locator® data for bilateral hindlimb lameness had the smallest difference with the greatest standard deviation, this data was used for power calculations. The number of horses required to show a difference, if one truly exists, with diagnostic analgesia would be 20 horses. There were trends observed with the small sample size available for this study that could be further investigated. This includes the changes observed at the walk in response to bilateral hindlimb analgesia.

Another potential continuation of this study would be the effects of treatment of joint disease. The time to peak effect of treatment and duration of therapeutic effects could be quantified over time.

Footnotes

a. Handycam 4K FDR-AX53, Sony, Tokyo, Japan Sony Electronics, Tokyo, Japan
b. Aluspray, Neogen, Lansing, Michigan
c. Screen Protractor, Iconico, Inc., New York, New York
d. Lameness Locator®, Equinosis, LLC, Colombia, MO, USA
e. In-ground strain gauge force plate (1200 mm x 1200 mm) Advanced Medical Technology, Inc, Watertown, MA, USA
f. Acquire, Sharon Software, Inc., Lansing, MI, USA.

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