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Abstract
Pressure algometry provides an objective, non-invasive, and repeatable tool to measure musculoskeletal pain in horses. Compared to a control group, a series of chiropractic treatments produced a measurable increase in pain pressure thresholds in 10 out of 10 vertebral locations treated; however, only 5 of 10 of these vertebral locations had a statistically significant increase in values.

1. Introduction
Non-specific muscle pain that is not related to a known physical trauma or inflammation is often present in horses. Therefore, veterinary medicine is challenged by the lack of objective measures of back pain in animals. Pain generation can be categorized into mechanical, chemical, or thermal mechanisms of injury. In horses, mechanical forms of musculoskeletal injury are more likely to occur and be observed clinically than chemical or thermal injuries. Pressure algometry is a mechanical form of pain assessment that has been used to quantify the subjective assessment of pain-pressure thresholds or tenderness within musculoskeletal structures [1]. A pressure algometer consists of a pressure gauge attached to a rubber tipped plunger that is pressed against a pre-determined musculoskeletal landmark until a perceived noxious reaction is produced (Fig. 1). In humans, pressure algometry has been used in the clinical management of pain, especially in the diagnosis and treatment of soft tissue or muscle pain (e.g., myofascial pain syndromes) or assessment of periarticular tenderness associated with osteoarthritis [2,3].
Currently, scientific evidence supports the beneficial effects of chiropractic treatment on spinal pain in humans [4-9]. Spinal manipulation is now being applied to horses, but there is no scientific evidence of the potential beneficial effects of chiropractic treatment on spinal pain in horses.
The objectives of the descriptive portion of this project were to evaluate a direct mechanical evaluation of pain using a pressure algometer to measure pain-pressure thresholds objectively and to develop standardized values for assessing spinal pain in horses. The goal of the experimental portion of this project was to objectively assess the effects of a series of chiropractic treatments on pain-pressure thresholds. Pain-pressure thresholds were measured in the experimental group of horses receiving a series of chiropractic treatments and compared with the pain-pressure thresholds of the control group not receiving chiropractic treatments.

2. Materials and Methods
Twenty-six horses that did not have a current history of lameness or acute back problems were selected from the Oxley Equestrian Center at Cornell University to develop standardized pressure algometry values. The Equestrian Center's horses
provide a uniform population of horses that are undergoing active athletic training with constant observation and verbal feedback of athletic capabilities by their riders and trainers. The horses were studied under animal use protocols approved by the Center for Research Animal Resources (CRAR 01 - 38) and the Institutional Animal Care and Use Committee (IACUC) at Cornell University. The subjects were 11 mares and 15 geldings with a median age of 13 yr (range = 4 - 21 yr) and a median body weight of 466 kg (range = 391 - 614 kg). The breeds included 16 Thoroughbreds, 3 Quarter Horses, 2 Mixed breed, 1 Paint, 1 Morgan cross, 1 Connemara-Thoroughbred cross, 1 Palomino, and 1 Dutch Warmblood. All horses were at the beginning of their training season, and 25 horses participated in either collegiate lessons (n = 12), polo (n = 9), or team activities (n = 4). One subject was privately owned (n = 1). Athletic activities of the lesson and team horses involved English riding at a walk, trot, and canter as well as jumping. The median duration of participation in collegiate programs was 3 yr (range = 4 mo - 17 yr). The horses were exposed to a wide variety of riders from inexperienced to advanced. Variable degrees and durations of chronic back problems were reported in some horses with the majority being related to back stiffness. Horses were not assessed for back problems before the pressure algometry measurements to limit any potential bias associated with the clinical assessment of back pain.

Pressure algometry was used to develop standardized values of local pain-pressure thresholds at 52 pre-determined anatomic locations along the axial skeleton. Musculoskeletal locations that were regionally representative of the axial skeleton were chosen based on ease and consistency of identification. The standardized locations included bilateral osseous landmarks (n = 22), apices of dorsal spinous processes (n = 6), and bilateral soft tissue landmarks (n = 24). All musculoskeletal landmarks were consistently assessed beginning cranially and continuing caudally in the following order: (1) osseous landmarks on the left side, (2) dorsal spinous processes, (3) soft tissue landmarks on the left side, (4) osseous landmarks on the right side, and (5) soft tissue landmarks on the right side of the horse. The osseous landmarks included: the caudal aspect of the temporomandibular joint (TMJ), the caudoventral aspect of the wing of the atlas (C1 TP), the dorsolateral aspect of the transverse process of the third cervical vertebra (C3 TP), the dorsolateral aspect of the transverse process of the fifth cervical vertebra (C5 TP), the caudal lateral aspect of the midportion of the scapular spine (SCAP), the lateral aspect of the costochondral junction of the seventh rib (RIB 7), the lateral aspect of the middle of the eleventh rib (RIB 11), the caudal lateral aspect of the eighteenth rib (RIB 18), the dorsal aspect of the tibia (TSAC), the dorsiocaudal aspect of the tuber coxae (TCOX), and the dorsiocaudal aspect of the caudal portion of the greater trochanter of the femur (GR TR). The apices of the dorsal spinous processes evaluated include: the fourth thoracic vertebra (T4 SP), the eleventh thoracic vertebra (T11 SP), the fifteenth thoracic vertebra (T15 SP), the first lumbar vertebra (L1 SP), the fifth lumbar vertebra (L5 SP), and the second sacral vertebra (S2 SP). The soft tissue landmarks include: the dorsal poll musculature overlying the wing of the atlas (C1 M), the middle of the splenius muscle at the level of the third cervical vertebra (C3 M), the dorsal portion of the serratus ventralis cervicis muscle at the level of the fifth cervical vertebra (C5 M), the dorsiocaudal aspect of the rhomboideus cervicis muscle at the level of the third thoracic spinous process (T3 M), the dorsiocaudal aspect of the spinalis thoracis muscle at the level of the ninth thoracic spinous process (T9 M), the middle of the longissimus thoracis muscle at the level of the thirteenth thoracic vertebra (T13 LONG), 2 cm lateral to the dorsal midline and over the longissimus thoracis muscle at the level of the thirteenth thoracic vertebra (T13 MULT), the middle of the longissimus thoracis muscle at the level of the eighteenth thoracic vertebra (T18 LONG), 2 cm lateral to the dorsal midline and over the longissimus thoracis muscle at the level of the eighteenth thoracic vertebra (T18 MULT), the middle of the middle gluteal muscle at the level of the third lumbar vertebra (L3 M), the middle of the middle gluteal muscle at the level of the sixth lumbar vertebra (L6 M), and the middle of the middle gluteal muscle at the level of the second sacral vertebra (S2 M).

The horses were quietly restrained in stocks with crossties and without sedation. A pressure algometer [a] with a range of 0 - 44 lb/cm² and a 1 cm² rubber plunger tip was used to determine pain-pressure thresholds. Pressure was applied perpendicular to the pre-determined anatomical landmarks at a standard rate of application (approximately 1 kg/s) until a local avoidance reaction was noted [10]. Positive reactions to the applied pressure included a localized muscle fasciculation, a cutaneous trunci reflex (i.e., skin twitch), an active vertebral movement (e.g., lordosis), or a stepping away from the applied pressure. The corresponding applied pressure algometry value was recorded: lower values corresponded to low pain-pressure thresholds, whereas higher values corresponded to high pain-pressure thresholds. The process was immediately repeated at the same location for three consecutive measurements at each of the 52 musculoskeletal sites for a total of 156 measurements per horse. Each measurement session required approximately 25 - 30 min to complete. To increase precision, the median value of the three measurements at each location was used to assess the individual pain-pressure thresholds within each horse. The mean (SD) pain-pressure values for all horses were then calculated to determine standardized values of local pain-pressure thresholds. Repeatability of the measurements was assessed by determining the trend (e.g., increasing trend, decreasing trend, or no change or no consistent trend) of the three consecutive measurements at a location. Variability was determined by the range (i.e., maximum - minimum values) of the three consecutive measurements at a location.

For the experimental portion of this project, 24 of 26 horses were randomized (by restricted lottery) into a treatment (n = 12) or control (n = 12) group. Two of 26 horses were excluded from this portion of the study because of refusal to enter or stand quietly in the stocks without sedation. Treatment involved chiropractic manipulation, which is characterized as a high-velocity, low-amplitude (HVLA) manual thrust. During each treatment session, HVLA treatments were applied bilaterally at...
five vertebral levels from the T13 to the L6 thoracolumbar spinal region. The treatment group was treated three times at weekly intervals (i.e., days 0, 7, and 14) to assess the long-term effects of chiropractic treatment on pain-pressure thresholds. The control group had no treatment applied over the 2-wk period. The mean values for day 0 (baseline) and day 14 (post-treatment or control) were used to calculate the percent change (i.e., [(Post - Pre)/Pre] x 100) in pain-pressure thresholds from baseline. Because spinal manipulation is being applied clinically to horses with presumed back problems, one hypothesis of interest was that pain-pressure thresholds within the treatment location (i.e., T13 - L6 vertebrae, 10 treatment sites) would be significantly increased in the treatment group versus the control group. Higher pain-pressure threshold values were interpreted as an indication of increased pain tolerance to applied pressure [3]. Conversely, lower values were interpreted as an indication of decreased pain tolerance. A related hypothesis was that pain-pressure threshold values outside the applied treatment region (i.e., areas other than T13 - L6, 19 control sites) would not be significantly different in the treatment group versus the control group.

The pain-pressure threshold measurements were not normally distributed; therefore, data were analyzed using nonparametric methods. Bilateral osseous and soft tissue landmark comparisons were made using the Wilcoxon signed-rank test (two sided) to evaluate if left and right values could be combined into a single pain-pressure threshold value for that location. Percent change from baseline comparisons between the treatment and control groups were made using the Wilcoxon rank sum test (one-sided). Significance for all tests was set at P = 0.05.

3. Results

Each horse's site-specific left and right pain-pressure threshold values were averaged for all osseous and soft tissue landmarks, because there were no significant left-right differences. The baseline pressure algometry values for the osseous, dorsal spinous process, and soft tissue landmarks are reported in Figure 2. The landmarks are organized from cranial to caudal. A gradual increase in pain-pressure threshold values is noted from the TMJ to the GR TR. The three consecutive measurements at each anatomical location sequentially increased in 26% of the measurements, decreased in 6% of the measurements, and had no change or consistent trend in 68% of the measurements. The average range of the three consecutive measurements at all anatomical locations was 3 lb/cm².

The percent change from baseline pressure algometry values in the treatment and control groups are reported in Figure 3. The average percent increase from baseline is 11 ± 7% in the treatment group and 5 ± 6% in the control group. Within the treatment location (i.e., T13 - L6), the average increase in the treatment baseline versus the control baseline was 11 ± 4%. In comparison, the average increase in the treatment baseline versus the control baseline was 3 ± 8% outside of the treatment location (i.e., areas other than T13 - L6).

The percent change from baseline is increased (by inspection) in the treatment group versus the control group in 21 of 29 musculoskeletal landmarks. Significant differences between the treatment values versus the control values were noted at 7 of 29 locations. Two of seven landmarks (SCAP, GR TR) were outside of the applied treatment area (i.e., areas other than T13 - L6), whereas five of seven landmarks (T18 MULT, T18 LONG, RIB 18, L3 M, L5 SP) were within the applied treatment area (i.e., T13 - L6). Within the treatment area, 10 of 10 landmarks were increased in the treatment group versus the control group. Outside of the treatment area, 11 of 19 treatment values were increased, and 8 of 19 treatment values were decreased (n = 6) or had the same value (n = 2) as the control group.

4. Discussion

Trends noted in the baseline pain-pressure threshold values (Fig. 1) include the lowest value at the temporomandibular joint with a gradual increase within the caudal cervical region (TMJ to C5 M), a relative plateau within the thoracolumbar region (SCAP to RIB 18), and a second increasing trend within the lumbar and pelvic regions (L3 M to GR TR). In humans, a similar pattern of increased pressure algometry values has been reported in upper body regions versus lower body regions.
In this project, spinous processes had higher pain-pressure thresholds than surrounding soft tissue or other osseous sites. The individual pain pressure threshold measurements are very consistent within horses (average range = 3 lb/cm²) but vary largely between horses. The baseline pressure algometry values at the 52 standardized locations provide a standard to which other horses with suspected or known neck or back pain can be compared. Pressure algometry values are consistently less than 10 lb/cm² in other projects that induced acute back pain by placing Steinmann pins into dorsal spinous processes or by injecting hypertonic saline into the epaxial musculature (Haussler KK, unpublished data) [b].

Many horses step away from applied manual pressure because of their training or instincts; therefore, most horses require a slight acclimation period to the pressure algometry measurements. Once the horses become accustomed to the technique, they stand quietly for the applied pressure but still consistently and repeatedly respond locally with a muscle fasciculation or a cutaneous trunci reflex. The majority of horses do not demonstrate accommodation (i.e., increasing values) or sensitization (i.e., decreasing values) to serial pressure algometry measurements, although accommodation and sensitization are confounding variables that need to be recognized and monitored. Other sources of error may result from the practitioner's method. If the practitioner is tentative or does not apply full pressure at the first measurement, increasing values (i.e., accommodation) can be noted. Conversely, if the practitioner is overly forceful and applies too much pressure during the initial measurement, then decreasing values (i.e., sensitization) can be noted.

Variables known to affect the accuracy and reproducibility of pressure algometry include: accurate localization of the anatomical structure to be tested, perpendicular application of pressure, uniform size of the instrument surface in contact with the tissue, application of a consistent rate of pressure, and uniform endpoint (verbal response, grimace, or withdrawal) [10]. The amplitude of pain-pressure thresholds within the treatment location (i.e., T13 - L6) was uniformly increased in the treatment group versus the control group, but not all changes were significant. It seems that the HVLA treatment has mixed effects outside of the treatment area compared with the control group.

The opportunity to evaluate horses that were in active training and under constant observation added to the clinical relevance of this study. To our surprise, we were not able to identify a large number of horses with obvious back pain, despite using horses that were beginning heavy training schedules and/or were being ridden by inexperienced riders.

Pressure algometry provides a non-invasive tool to objectively assess musculoskeletal pain and to assess the therapeutic effectiveness of traditional or non-traditional modalities. Pain-pressure threshold measurements are highly reproducible and easy to use in horses. Chiropractic treatment provided some long-term increases in pain-pressure thresholds, although not all changes were statistically significant.

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Footnotes
[a] Force gage, Model FDK 40; Wagner Instruments Inc., PO Box 1217, Greenwich, CT 06878.

References


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