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Effect of a Core Conditioning Program on Lumbar Paraspinal Area, Asymmetry and Pain Score in Military Working Dogs with Lumbosacral Pain

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To the Graduate Council:

I am submitting herewith a thesis written by Andrea Leigh Henderson entitled "Effect of a Core Conditioning Program on Lumbar Paraspinal Area, Asymmetry and Pain Score in Military Working Dogs with Lumbosacral Pain." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Comparative and Experimental Medicine.

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Effect of a Core Conditioning Program on Lumbar Paraspinal Area, Asymmetry and Pain Score

in Military Working Dogs with Lumbosacral Pain

A Thesis Presented for the

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Abstract

Introduction: Lumbosacral pain and stenosis are common causes of retirement from duty for Military Working Dogs (MWDs). Working dogs that receive surgical management for this condition often have a poor prognosis for return to duty after recovery. Humans with chronic low back pain demonstrate paraspinal muscle asymmetry, pain and dysfunction that often improve in response to an exercise program. This study investigated whether dogs with mild lumbosacral pain have decreased lumbar paraspinal muscle area, symmetry, and density, as well as increased pain and dysfunction compared to control dogs. Additionally, response of pain and dysfunction to an exercise program was assessed.

Materials and Methods: Visual Analog Scale (VAS) scores for lumbosacral pain, functional questionnaire scores for search and detection tasks, and computed tomography images were evaluated for eight MWDs with lumbosacral pain along with eight control dogs. Mean cross-sectional muscle area (CSA)-to-vertebral ratio, asymmetry and density were determined for five lumbar paraspinal muscles bilaterally at the L5, L6 and L7 caudal endplates. Four dogs with lumbosacral pain rested and four dogs completed an eight-week core stabilizing exercise program. Repeated assessments of lumbosacral pain, dysfunction and muscle parameters for dogs with lumbosacral pain were made at the conclusion of the exercise program.

Results: The multifidus lumborum and longissimus lumborum muscles demonstrated significantly reduced CSA (p= 0.020, p = 0.021, respectively) in dogs with lumbosacral pain. Muscle density was decreased in dogs with lumbosacral pain for multifidus lumborum (p = 0.030) and quadratus lumborum (p = 0.011). Multifidus lumborum muscle CSA (p = 0.019), symmetry (p = 0.002) and density (p = 0.024) were significantly higher than at baseline for dogs with LS pain after completion of the exercise program. Functional questionnaire scores improved significantly for exercised dogs (p = 0.031) but did not improve for rested dogs (p = 0.828).

Discussion: Military Working Dogs with mild lumbosacral pain and dysfunction had significantly smaller CSA, symmetry and density for both multifidus lumborum and longissimus lumborum muscle groups. An 8-week core strengthening program was associated with significantly improved performance in evaluated tasks for dogs with lumbosacral pain.

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Chapter 1: Introduction

Degenerative lumbosacral stenosis (DLSS) is the most common pathologic condition of the lumbar spine in large-breed dogs. It is one of several possible etiologies of cauda equina syndrome, a degenerative condition that results in compression of the nerve roots composing the lumbosacral trunk. Intervertebral disc degeneration at L7-S1 plays a large role in the pathogenesis of DLSS. Congenital or activity-related hypermobility at this joint may facilitate L7-S1 disc degeneration, contributing to instability. Surrounding soft tissues proliferate in an attempt to stabilize the region, worsening spinal canal stenosis, neuropathic pain, and further alterations in biomechanics. A continuous cycle of pain and neurologic dysfunction occurs due to compression and compromised blood supply to the nerve roots (Meij & Bergknut 2010).

German Shepherd Dogs and structurally related breeds, such as the Belgian Malinois, appear to be particularly susceptible to DLSS; Shepherds represent an estimated 25–57% of all breeds evaluated for DLSS (Daniellson & Sjostrum 1999, De Risio *et al.* 2001, Suwankong *et al.* 2008). The reason for this breed predisposition is not well-understood, but in one study, German Shepherd Dogs demonstrated reduced spinal mobility at L7-S1, which was attributed to reduced angulation of articular facets (Benninger *et al.* 2006). Such structural alterations may contribute to disc degeneration in this breed. Males are over-represented among dogs with DLSS, with odds ratios from 1.3:1 to 5:1 reported. Clinical signs of DLSS most often develop in middle-aged or older dogs, with an average presenting age of 7 years. Clinical history may include pelvic limb lameness and pain or difficulty on rising from recumbency, climbing stairs, or jumping; tail hypotonia or urinary or fecal incontinence (Meij & Bergknut 2010).

Spinal pain has been suggested to be the third most common reason for working dog retirement (Moore *et al.* 2001). Specifically, DLSS and lumbosacral pain are common in the Department of Defense (DoD) military working dog population and are a frequent cause of retirement of dogs from active duty. A number of surgical procedures have been performed on military working dogs to correct lumbosacral instability and/or disc extrusion that may be the source of pain in this area. However, Linn *et al.* (2003) found that only 41% of 29 American military working dogs with DLSS successfully returned to regular duty after surgical management. The prognosis for return to duty was negatively correlated with age and severity of signs. In many cases, dogs are not surgical candidates due to age, severity of the condition, logistics and expected poor continued working life without surgery.

Degenerative lumbosacral stenosis (DLSS) in dogs has similar manifestations of pain and neurologic dysfunction to those attributed to chronic low back pain (CLBP) in humans. Despite obvious differences in posture between bipeds and quadrupeds, humans and dogs share several spinal biomechanical characteristics, including similarities in axial compressive loads (Smit 2002, Zimmerman *et al.* 1992) and in the pathogenesis of disc degeneration in non-chondrodystrophic breeds (Benninger *et al.* 2006). CLBP is one of the leading causes of disability in working people, and is associated with muscle atrophy and asymmetry, pain, and dysfunction (Gibbons *et al.* 1997, Kamaz *et al.* 2007, Parkkola *et al.*1992, Danneels *et al.* 2000, Kader *et al.* 2000, Hides *et al.* 2008, Marshall *et al.* 2011, van Dieen *et al.* 2003). Frequently clinical signs of CLBP are not well-correlated with specific abnormalities, such as lumbar disc degeneration, on advanced imaging (Beattie *et al.* 2000, Takatalo *et al.* 2011), and are treated non-surgically. Several studies have shown that symptoms of chronic low back pain in people

frequently respond to paraspinal muscle strengthening programs (Hides *et al.* 2008, Marshall *et al.* 2006), though the treatment response may vary depending on the mechanism of the pain. Danneels *et al.* (2000) postulated that pain-guarding behavior, reflex inhibition, or inflammation may result in reduced activation of paraspinal muscles, leading to disuse atrophy. Renkawitz (2006) identified altered paraspinal neuromuscular activation patterns in athletes with low back pain.

Several muscle groups are associated with the lumbar spine and are thought to contribute to spinal stability. These are generally categorized as either deep (local) or superficial (global) muscles, based on their anatomic location relative to the vertebral axis. Deep muscles such as the lumbar multifidus contribute to spinal stabilization and may be dysfunctional in human patients with CLBP. However, global muscles are thought to provide compensatory stabilization in the face of dysfunctional deep muscle groups, leading to abnormal activation patterns (Barr *et al.* 2005).

Several studies have identified selective, significant atrophy of the lumbar multifidus muscle in human CLBP patients (Danneels *et al.* 2000, Kamaz *et al.* 2007), even in elite athletes (Hides *et al.* 2008). The lumbar multifidus is thought to be the most important muscle for lumbar segmental stability in humans because it is the largest paraspinal muscle in the region with the most medial location, flanking the dorsal spinous processes. The multifidus contributes the most of all the muscle groups to stability and control of neutral zone movement in the spine, and in one study, magnetic resonance imaging (MRI) showed that lumbar multifidus muscle mass was atrophied in 80% of patients with disc degeneration and nerve compression (Kader *et al.*

2000). Kamaz *et al.* (2007) found that cross-sectional area (CSA) of the multifidus, psoas, and quadratus lumborum was significantly lower in patients with CLBP than in controls. Atrophy was most prominent in the lumbar multifidus, which agrees with other findings (Bouche *et al.* 2011, Danneels *et al.* 2000). Another small study (Gibbons *et al.* 1997) found no significant difference in muscle CSA between CLBP patients and healthy controls, but found degenerative changes within the muscles. Atrophy of the psoas major muscle has been demonstrated as well, but has not always coincided with the symptomatic side of the body in the case of lateralized signs. Nonetheless, shifting, bilateral pain frequently occurs in association with CLBP in humans (Kamaz *et al.* 2007).

The quadratus lumborum muscle acts synergistically on lumbar vertebrae with the psoas and deep erector spinae muscles, facilitating lumbar and pelvic stability in all major planes of motion. The psoas major keeps the human body erect in all three planes, and the gluteus maximus contributes to spinal stability through the thoracolumbar fascia (Kamaz *et al.* 2007). In dogs, it has been suggested that the quadratus lumborum is responsible for stabilization of the lumbar portion of the vertebral column by restricting lateral spinal flexion (Hermanson & Evans 1993).

Lumbar stabilization programs for treatment of CLBP must be multifaceted to address the associated muscle groups and dysfunctions. Deeper, local muscle groups are often the target for therapeutic interventions for CLBP, but likely global muscle stabilization is necessary as well. Appropriate lumbar muscular function has been shown to overcome structural abnormalities in the spinal column (Hides *et al.* 2008, Panjabi 1992, Barr *et al.* 2005). Additionally, lumbar

pelvic stabilization is closely related to global body awareness, proprioception and balance (Hodges *et al.* 2004), and patients with CLBP have been shown to have reduced performance on balance tests (Ebenbichler *et al.* 2001). Therefore, improving these components should be among the goals of a conditioning program to address CLBP. Development of consistently appropriate interventions requires a thorough understanding of the roles of the paraspinal trunk muscles in normal motion and in the pathogenesis of CLBP.

Similarly, characterization of canine DLSS-affected muscle groups may be useful for determining ways to redistribute axial and shear loads imposed upon the lumbar spine and improve pain and function. Therefore, dogs that are mildly affected by DLSS may benefit from paraspinal muscle strengthening if asymmetry and reduced muscle CSA reflect abnormal activation patterns that contribute to the clinical manifestations of pain and dysfunction.

Core stabilizing and strengthening exercise programs have been shown to increase lumbar paraspinal muscle mass/symmetry, as well as improve pain and return to function in people with CLBP (Kim *et al.* 2011, Marshall *et al.* 2006, Niemisto *et al.* 2003, O'Sullivan *et al.* 1998). Such activities are designed not to treat the underlying source of the pain, but to promote spinal stability, muscular control, and reverse pathological paraspinal muscle activation patterns that contribute to prolonged pain and reduced function. Both anticipatory and responsive muscle activation patterns are targeted in traditional programs (Carneiro *et al.* 2010). Such exercises include combinations of dynamic and sustained contractions of deep abdominal and local and global lumbar paraspinal muscles. These contractions can be achieved through postures and exercises for which balance is required in the face of instability. Additional exercises are

designed to promote extension, lateral flexion and ventroflexion of the spine. Core stabilization activities for dogs may include balancing on such surfaces as physioballs, balance boards and inflated disks, walking up and down stairs or ramps, circling, weaving or performing spinal movements to follow a reward while standing on an unstable surface.

There are currently no published studies on the effects of core stabilization exercises on epaxial musculature and spinal pain in dogs. A small pilot study has demonstrated increase in lumbar multifidus muscle CSA of three healthy dogs after an 8-week program of stabilization exercises on a physioball. The muscle CSA was estimated using ultrasound, and there was an insufficient number of cases to achieve significance (Teeling and Van den Berg 2012). One equine study found that dynamic spinal mobilization exercises in eight horses without neck or back pain increased the thoracolumbar multifidus paraspinal muscle cross-sectional area and symmetry, though no control group was used (Stubbs *et al.* 2011).

The objective of the study reported here was to determine whether lumbar paraspinal muscle cross-sectional area (CSA), symmetry and density are decreased in military working dogs with lumbosacral pain as compared with normal dogs. Additionally, the study evaluated effects of an eight-week core conditioning program on muscle mass, symmetry, pain and function in dogs with DLSS.

Chapter 2: Materials and Methods

Subject Assessment

Records of 114 military working dogs with no history of orthopedic or neurologic disease were evaluated from within the resident population of canine training aids available at the Department of Defense (DoD) Military Working Dog Veterinary Services. Participants in the study were required to be one of the following three breeds: German Shepherd Dog, Belgian Malinois or Dutch Shepherd Dog. Additional inclusion criteria for selected dogs were a normal orthopedic and neurologic examination, age between 5 and 11 years, single-purpose training in explosives detection, a temperament that would allow handling during the exercise program, and absence of administration of any analgesic or anti-inflammatory medications for eight weeks prior to the beginning of the study.

A complete physical, orthopedic and neurologic examination was performed for each dog by a single veterinarian (A.H.). The evaluation included subjective gait analysis and assessment of lumbosacral pain based on digital pressure, tail hyperextension and lumbar hyperextension. Additionally, objective data collected on examined dogs included goniometric tail elevation angle and discomfort generated by dorso-ventral pressure over L7-S1 using an algometer (Pain Diagnostics and Thermography, Great Neck, New York, USA). For the goniometric tail elevation angle, zero degrees was represented by a line drawn from the tuber sacrale to the tuber ischium, with the axis of rotation positioned at the midline of the tail base (Figure 1). Dogs were excluded from the study if any of the following abnormalities were found: visible lameness

associated with any physical exam findings not consistent with LS pain, paresis or ataxia, discomfort, abnormal range of motion or abnormal palpation findings on the orthopedic exam (Appendix A). Additionally, dogs were eliminated if they demonstrated any of the following upon neurological exam (Appendix A): proprioceptive deficits, abnormal myotatic, flexor or perineal reflexes, or abnormal postural reactions.
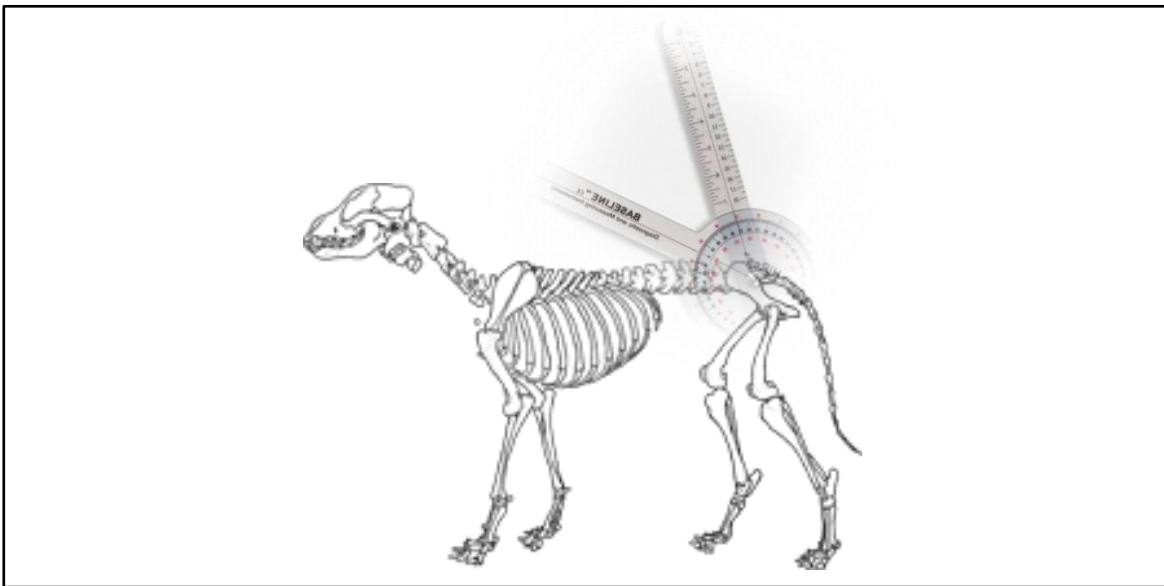
Figure 1: *Illustration showing goniometer position with fixed arm bisecting the wing of the ilium and axis of rotation at the base of the tail. A smaller angle (degrees) represents more tail hyperextension.*

After the initial screening orthopedic and neurologic evaluation for selection of cases, dogs returned to their normal daily activities for 10 weeks before performing the baseline CT scans and pain and function assessments. Dogs were removed from the study if they underwent any change in activity, analgesic, anti-inflammatory or chondroprotective agent administration during the study. Dogs were also removed from the study if they demonstrated illness, obvious discomfort or other adverse effects deemed sufficient by the attending veterinarian to warrant rescue analgesia, rest or surgical intervention. This study received approval by the DoD Military

Working Dog Veterinary Services Institutional Animal Care and Use Committee prior to initiating the experimental design.

Outcome Measures

A single blinded observer (S.M.) completed a baseline functional assessment and visual analog scale (VAS) assessment for lumbosacral pain in all dogs after the ten-week period of baseline activity, followed by radiographic and CT imaging. The following VAS scoring guidelines were provided to the assessor:

1. The VAS was defined using the number of millimeters past zero on a continuous 100mm line with "no pain" marked at zero and "maximum possible pain" marked at 100.

2. VAS score was based on subjective evaluation of physical exam findings, including:

    a. pain on lordosis test (hyperextension) of the lumbar spine with hips in flexion

    b. pain upon mildly or moderately applied ventral digital pressure over the L7-S1 disc space or articular facets

    c. subjective lameness identified in one or both pelvic limbs that cannot be attributed to any orthopedic findings on physical exam at a walk or trot on a flat horizontal surface or during circling in clockwise and counterclockwise directions at a walk and trot. Circles had a diameter of approximately 6-8 feet around the handler

    d. pain on dorsal tail base elevation

Following each VAS scoring assessment, the same evaluator observed each dog performing normal tasks required for search and detection training or operations. Assessment was captured

quantitatively using a 10-item functional assessment questionnaire designed specifically for this study to evaluate military working dogs during tasks required for detection (Appendix B, MWD Functional Questionnaire). Activities assessed included jumping into a position in which forelimbs were elevated with feet at the height of the withers, jumping onto and off of an obstacle at the approximate height of a vehicle interior, sit-to-stand and sit-to-down, and navigation of obstacles including a 2-foot jump, a double stairway (8 x 23 feet) and a narrow dog-walk 18 feet in length. Each dog was encouraged to perform five trials of each activity. If the assessor observed significant discomfort or inability for the dog to perform the task, the task ended without completion of five trials and the assessor completed the question based on the number of trials that had been attempted up to that point. All military working dogs had past experience with the obstacle course because the obstacles are included in their normal training protocols. Both outcome measures (VAS scores and functional questionnaires) were used to assign dogs to each study group (LS pain positive or LS pain negative), as well as to evaluate progress in dogs with LS pain after the 8-week exercise program. Dogs with a VAS score of less than or equal to 10% and a functional questionnaire score of less than or equal to four were placed in the control study group; dogs with values greater than these were considered "LS pain positive."

Radiographic and Computed Tomography (CT) Imaging

All dogs receiving imaging were sedated with dexmedetomidine HCl (DexDomitor®, Zoetis, NJ, USA) and butorphanol at 0.003-0.007 mg/kg and 0.3mg/kg, respectively. Dogs were

administered atipamezole (Antisedan®, Zoetis, NJ, USA) at a volume equal to that of the dexmedetomidine following completion of the imaging studies.

Lateral and ventrodorsal pelvic limb radiographs were made under sedation prior to each CT scan. Dogs were excluded from the study if pelvic films demonstrated radiographic evidence of hip osteoarthritis beyond subtle osteophytes, transitional vertebrae or other musculoskeletal abnormalities expected to overlap with the clinical signs of degenerative lumbosacral stenosis.
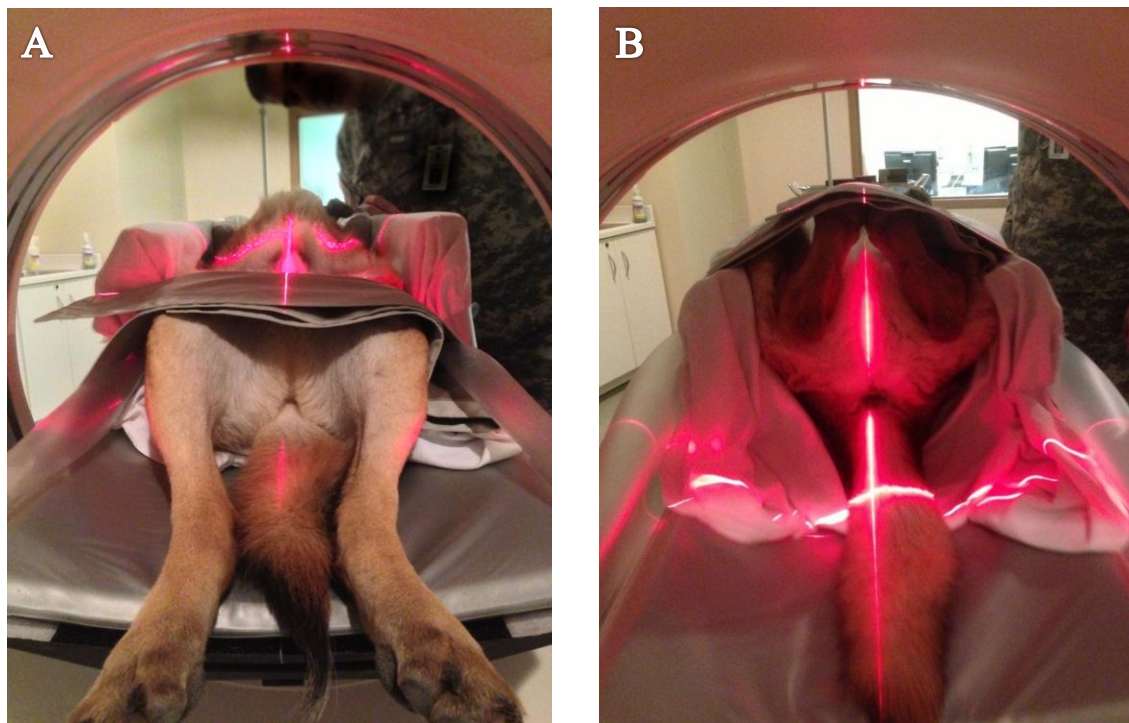
Figure 2: Positioning of military working dogs for CT of the lumbar spine in A, flexion of the hips at 50 +/- 3 degrees and B, extension of the hips to 145 +/- 3 degrees

All dogs were placed in dorsal recumbency for the CT scans (Figure 2). CT scans were performed using a 64-slice volume CT scanner (GE Light-Speed VCT-XT; GE Healthcare, U.K.) at 120 kV and 50 mA with 1.25 mm slice thickness, immediately following pelvic limb radiographs for all dogs selected to remain in the study. Two separate lumbar CT scans were acquired from L1-L2 to the level of the pelvic ischium, the first with the pelvic limbs at 145 degrees (+/- 3 degrees) of hip extension and the second with the pelvic limbs at 50 degrees (+/- 3 degrees) of hip flexion. All CT scans were collected by a board-certified veterinary radiologist (P.G.). A density calibration phantom (Image Analysis QCT-Bone Mineral™ Phantom; Image Analysis, KY, USA) was included in the field of view for each scan as part of routine research CT scan protocols at the DoD Military Working Dog Center.
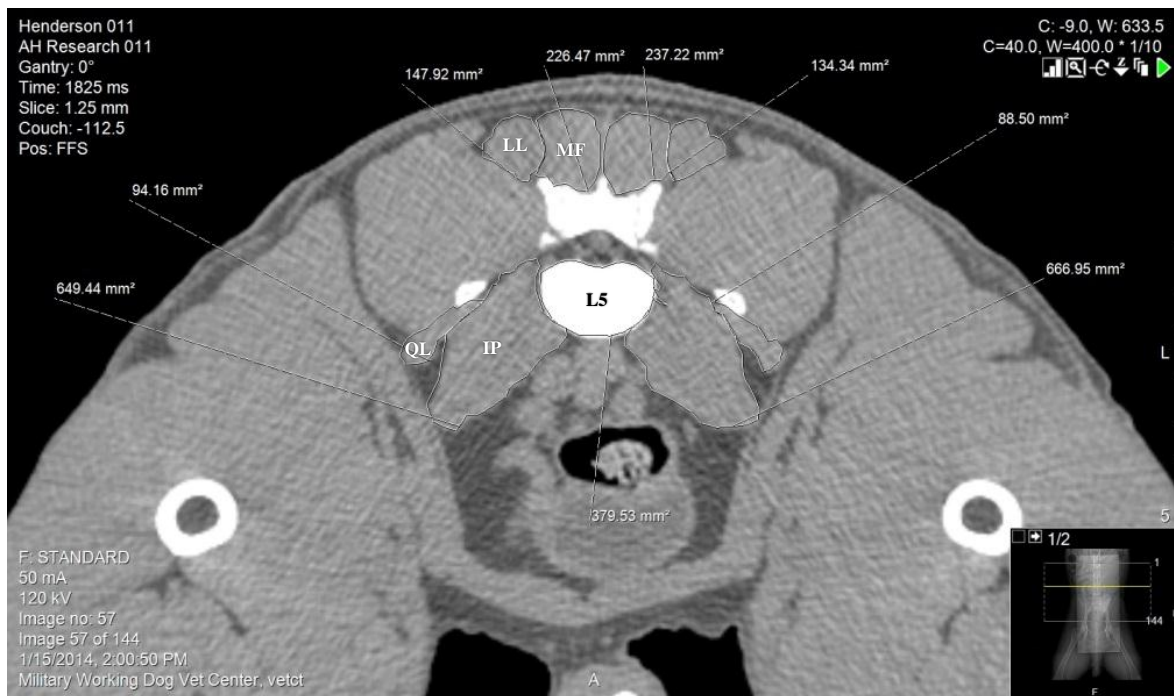
Figure 3: Sample CT image slice at the caudal endplate of L5. Cross-sectional areas of the vertebral body (L5) and left and right multifidus lumborum (MF), longissimus lumborum (LL), quadratus lumborum (QL) and iliopsoas (IP) were measured.

A commercial picture archival and communication system (SECTRA PACS IDS7; Sectra Medical Systems AB, Sweden) was used for image viewing and measurements. CT information was evaluated and measured by two individuals who were blinded to the treatment group assignment of each dog (S.H. and A.H). Cross-sectional area (mm^2) and density in Hounsfield Units (HU) were measured from transverse sections of the left and right multifidus lumborum, longissimus lumborum, quadratus lumborum, gluteus medius and iliopsoas muscles as well as the vertebral body at the level of the caudal endplates of L5, L6 and L7 (Figure 2). Measurements were performed at the caudal endplates of L5, L6, and L7 to allow inclusion of more muscles in the analyses and to account for variable conspicuity and anatomic variation in size of muscles at various levels. For example, the quadratus lumborum muscle was best visualized in the cranial images, and the gluteus medius muscle predominated at the L7 caudal endplate. Muscle measurements were performed using a soft tissue window (window center (C) = 40 Hounsfield units (HU); window width (W) = 400 HU) and bone measurements were performed using a bone window (C = 400 HU; W = 1700 HU). Each measurement was made twice by both observers, and the mean value for each was used for further calculations. Mean CSA was determined between the left and right side for each muscle group, and was calculated as a ratio to the CSA of the vertebral endplate within the same image slice. Asymmetry indices (ASI) were calculated for each muscle group according to the following equations, employing the method of Reeves *et al.* (2006):

$$Ratio = \frac{right\ multifidus\ CSA}{left\ multifidus\ CSA}$$

$$If\ ratio \geq 1, Symmetry\ \% = (ratio - 1) \times 100$$

$$If\ ratio < 1, Symmetry\ \% = -\left(\left(\frac{1}{ratio}\right) - 1\right) \times 100$$

With this calculation, an asymmetry index value of zero would indicate perfect symmetry and a value of 100 would indicate a two-fold difference in CSA between paraspinal muscles on each side. Density in HU was also measured for a central region of interest within each muscle.

Exercise Protocol

Following VAS scoring, functional evaluation and CT scans, four dogs within the lumbosacral pain group were enrolled in an 8-week core conditioning exercise program. The dogs were selected as a convenience sampling, based on the projected training schedules. Dogs were exercised for approximately 45 minutes per session, three times per week, consisting of four progressive stages outlined in the exercise protocol (Appendix C). These progressive stages were based on recommendations from the human literature for core strengthening exercises in people with chronic low back pain (Danneels *et al.* 2000, Kim *et al.* 2011, Macedo *et al.* 2009, O'Sullivan *et al.* 1997, Stuge *et al.* 2004) and knowledge of canine rehabilitation:

- Weeks 1 and 2: Focus on isometric and light conditioning
- Weeks 3 and 4: Increase strength/endurance at the level used in weeks 1-2
- Weeks 5 and 6: Focus on controlled concentric and eccentric exercises, dynamic mobilization and moderate conditioning
- Weeks 7 and 8: Increase strength/endurance at the level used in weeks 5-6

The remaining four dogs classified as having lumbosacral pain did not participate in the exercise program and served as controls for pain and function assessments. Activities for all dogs outside

of the exercise program were limited to brief slow, controlled leash walks, as regulated for all locally housed military working dogs.

Within one week of completing the 8-week period of exercise, all dogs with lumbosacral pain received repeated assessment including VAS score for lumbosacral pain, military working dog functional assessment questionnaire, and computed tomography using the same technique as previously described. The same individual that performed pain and functional assessment (S.M.) or CT scans (P.G.) prior to the exercise intervention also performed the 8-week assessments to eliminate inter-rater variability. The observers were unaware of treatment groups at the time of the second observation. However, evaluators of the computed tomography images were not blinded for the second CT scan assessment because only the exercised dogs received repeated CT scans at the end of the 8-week program due to time and personnel constraints at the facility.

Data Analysis

An independent-samples t-test was used to compare age between the study populations, and Pearson's chi-squared analysis was used to compare breeds. Gender was not analyzed statistically because an equal number of males and females were present in each group. Mean goniometric tail extension angle (degrees) and lumbosacral dorso-ventral pressure (PSI) collected at initial screening exams were compared between dogs with and without subjective findings suggestive of lumbosacral pain. Independent-samples t-tests were performed to compare objective measurements between pain and control populations in each case.

Mean values among the three slices for muscle asymmetry index, density and cross-sectional area relative to the vertebra were compared between treatment groups for the five evaluated muscle groups using independent-samples t tests.

Independent samples t-tests were used to compare mean muscle:vertebral CSA, asymmetry indices and densities between the control population of dogs and those with lumbosacral pain. For dogs that underwent the 8-week exercise protocol, paired samples t-tests were used to compare mean pre- and post-exercise paraspinal muscle CSA, asymmetry and density values. Equality of variance was evaluated using Levene's Test for Equality of Variance. Statistical analyses were performed using IBM SPSS® Statistics (IBM®, Version 22, 2013, NY, USA).

Agreement between the two repeated measurements within observer (intra-observer reliability) and between observers (inter-observer reliability) was assessed by evaluating the coefficient of accuracy (Lin 1989) for mean muscle-to-L7 ratio, asymmetry index and density measurements.

Upon completion of all measurements, a board-certified radiologist (S.H.) evaluated the entire image series of each patient to determine presence or absence of imaging evidence of degenerative lumbosacral stenosis. Specific criteria evaluated were foraminal stenosis, dorso-ventral narrowing of the spinal canal at the lumbosacral junction, loss of epidural fat, and spondylosis deformans.

Chapter 3: Results

Case Selection

Forty-one military working dogs that met the inclusion criteria underwent initial orthopedic and neurologic evaluations by the principal investigator. Twenty-four dogs with no orthopedic or neurological findings (excluding obvious lumbosacral pain) were selected to proceed with 1) pain and functional assessment by the assigned evaluator (S.M.) and 2) radiographic and CT imaging. Two dogs were removed from the study between the initial screening and the imaging procedures due to development of a clinical condition unrelated to the study. Additionally, three dogs were eliminated based on pelvic radiographs; two due to evidence of hip osteoarthritis and one due to presence of a transitional lumbosacral vertebra. Finally, three dogs were not included in the data analysis because their VAS and/or functional questionnaire scores were equivocal, preventing clear placement in either the control or lumbosacral pain study groups. A total of 16 military working dogs were therefore included in the study population; 8 dogs with and 8 dogs without evidence of lumbosacral pain.

Study Populations and Initial LS Pain Assessment

The mean age of the control group was 6.6 years; that of the group with lumbosacral pain was 6.0 years. This difference was not significant ($p = 0.437$). There was no association between breed and study group ($p = 0.320$). There were four males and four females in each group, indicating no gender difference between groups overall. However, an unbalanced distribution of

neutered vs. intact males and females was present in that the control group contained the only intact female and all control males were intact. All males in the LS pain group were castrated.

Goniometric tail angle and LS pressure data at initial screening were significantly different between dogs found to have subjective evidence of lumbosacral pain (n = 11) and those that did not (n = 13) at the initial screening (A.H.. Figure 4). Angle of dorsal tail extension was significantly different between groups (p = 0.0002) at the initial screening, with the lumbosacral pain group having reduced dorsal deviation. Mean goniometric angle of dogs with LS pain was 109.0° +/- 14.9°; that of dogs without pain was 85.1° +/- 6.3°. Pressure algometer readings were also lower (p = 0.0035) for the group with LS pain. Mean tolerated LS pressure was 13.01 PSI +/- 4.73 PSI for dogs with LS pain, and 18.65 PSI +/- 3.09 PSI for dogs without pain.
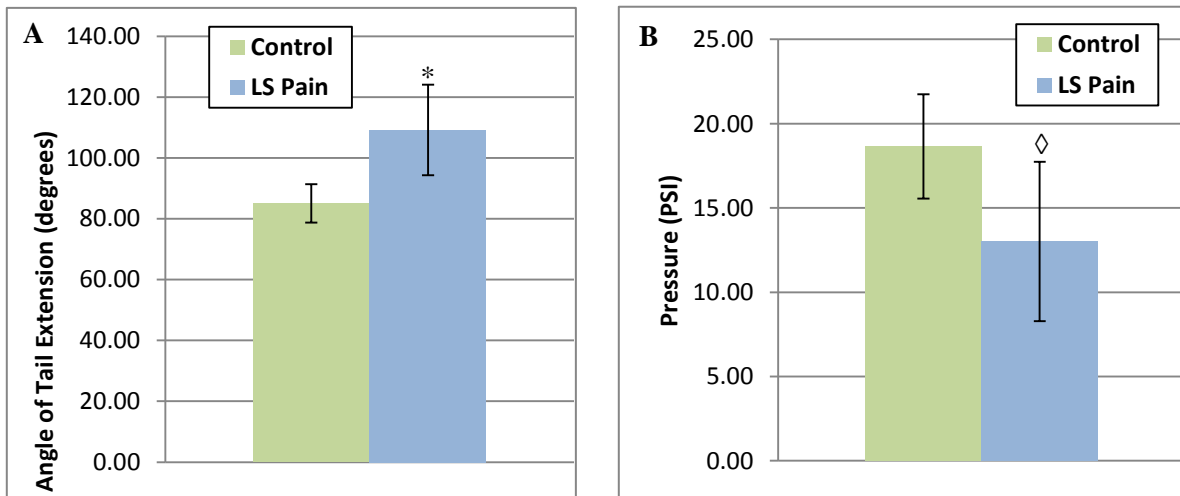
Figure 4: Differences between dogs with LS pain and control dogs regarding A, goniometric angle of tail extension and B, dorso-ventral pressure over the L7-S1 disc space. *p<0.001, ◊p <0.01

All data for comparison of outcome measures were found to have equal variance by Levene's Test for Inequality of Variance. Mean VAS scores (maximum possible pain = 100%) were 34% for dogs with lumbosacral pain and 1% for control dogs. Mean functional questionnaire scores (maximum dysfunction = 32) were 15.88 for dogs with lumbosacral pain and 0.63 for dogs in the control group. The differences between groups were statistically significant ($p < 0.001$) for both VAS and functional questionnaire scores. Furthermore, there was a moderate to strong positive linear association between VAS pain level and functional disability as determined by the functional questionnaire ($r^2 = 0.670$, Figure 5). There was no significant difference between exercised and non-exercised dogs within the LS pain group for VAS or functional questionnaire score at the baseline evaluation ($p = 0.093$ and $p=0.412$, respectively).
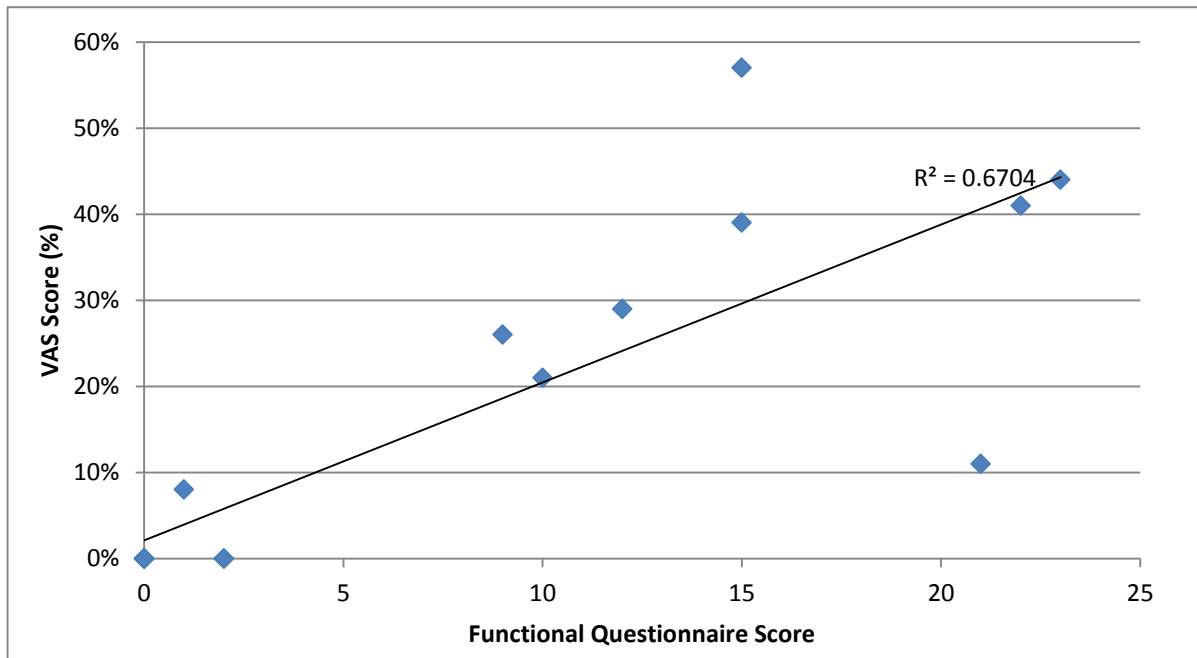
Figure 5: *Correlation between VAS (out of 100%) and functional questionnaire score (out of 32 possible points) at the baseline pain and function evaluation*

Lumbar Paraspinal Muscle CSA, Asymmetry Index and Density Pre-Exercise

All data for comparison of muscle parameters were found to have equal variance by Levene's Test for Inequality of Variance. Mean muscle-to-vertebral CSA ratios (Figure 6) for the multifidus lumborum and longissimus lumborum were significantly smaller in dogs with LS pain than in control dogs (p = 0.020 and p = 0.021, respectively). The mean muscle-to-vertebral CSA ratio for the epaxial muscles combined (multifidus lumborum and longissimus lumborum) was also significantly smaller in dogs with LS pain than in control dogs (p = 0.0095). The mean muscle-to-vertebral CSA ratio for gluteus medius was significantly larger in dogs with LS pain than in those without (p = 0.043). There were no significant differences between the study populations for muscle:vertebral CSA ratio for any other muscle group. Left and right multifidus lumborum ASI (Figure 7) was significantly higher in dogs with LS pain than in those without at the baseline evaluation (p = 0.0005). Control dogs demonstrated a higher ASI for the gluteus medius muscle than dogs with LS pain (p = 0.011). There were no other significant differences in muscle ASI between LS pain and control groups. Mean muscle density values were higher in control dogs than in dogs with LS pain only for the multifidus lumborum (p = 0.03) and quadratus lumborum (p = 0.011) muscle groups (Figure 8).
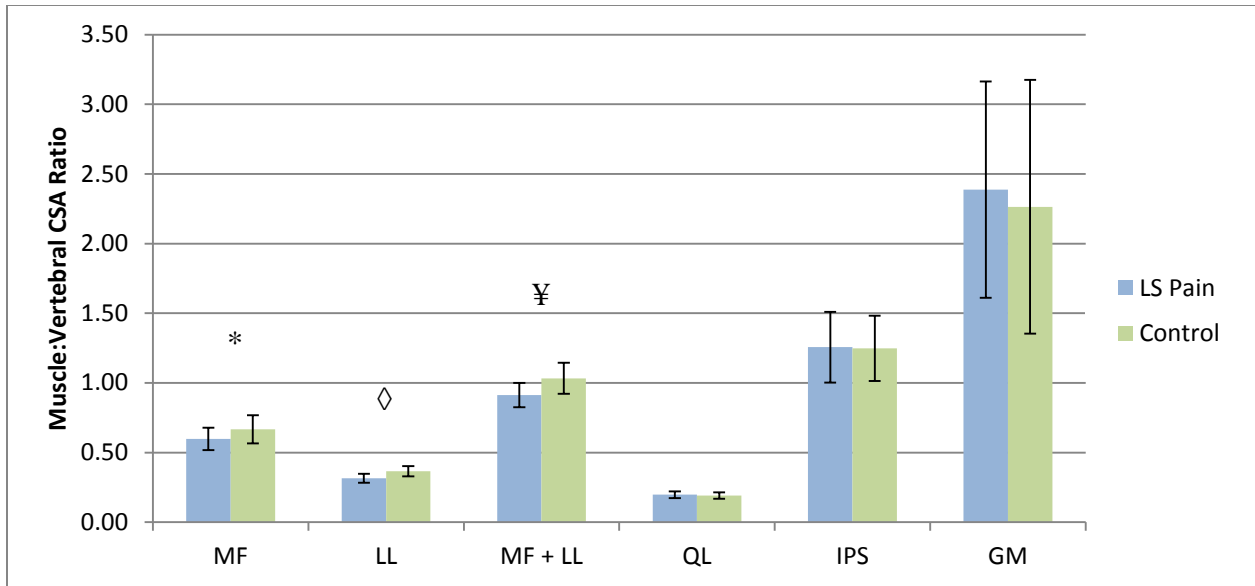
Figure 6: *Baseline muscle:vertebral CSA ratios for dogs with LS pain and control dogs* *,◊ p<0.05, ¥ p <0.01. MF = Multifidus lumborum, LL = longissimus lumborum, QL = Quadratus lumborum, IPS = Iliopsoas, GM = Gluteus medius. Error bars represent one standard deviation above and below the mean.*
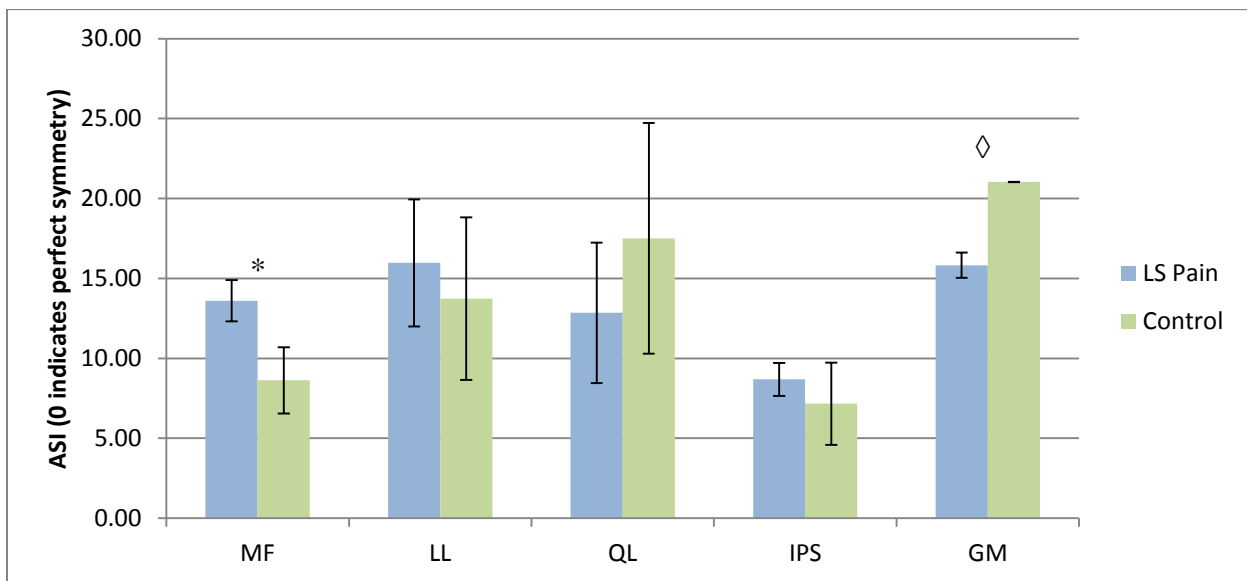
Figure 7: *Baseline muscle ASI for dogs with LS pain and control dogs. An ASI value of zero indicates perfect symmetry; 100 would indicate that muscle on one side would have twice the CSA of the muscle on the opposite side. *,◊ p<0.05. Error bars represent one standard deviation above and below the mean.*

Exercise Protocol

The four dogs with lumbosacral pain that received core conditioning were able to perform all exercises and complete the 8-week program. Based on detailed subjective observations made by the individual administering the exercises, dogs demonstrated a tendency to have mild to moderate difficulty with some exercises at the beginning of each new stage in the bimonthly progression, with improvement by the end of the two weeks. No dog in either the exercised or rested group required rescue analgesia nor received a change in activity throughout the study.
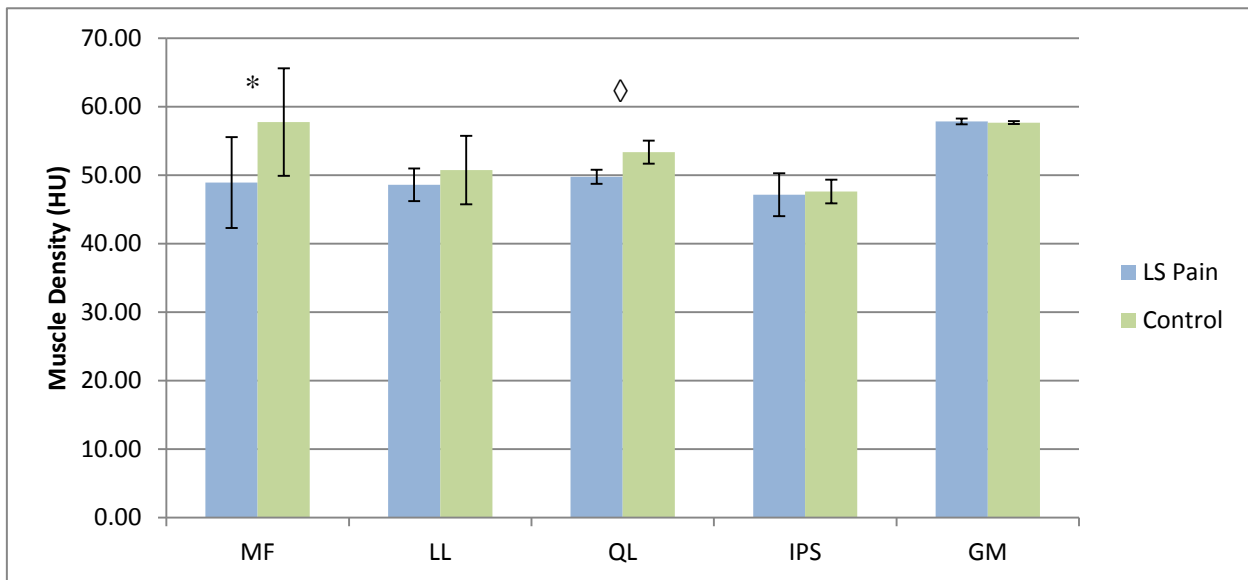
Figure 8: *Baseline muscle density (HU) for dogs with LS pain and control dogs*
, ◊ p<0.05. Error bars represent one standard deviation above and below the mean.

Pain and Functional Assessments: Post-Exercise

The mean percent change in VAS score after the 8-week exercise protocol was -9% for dogs that exercised and was -31% for dogs that did not undergo exercise. However, the change in VAS scores after the 8-week study protocol was not significant in either the exercised or rested dogs (p=0.379 and p=0.066, respectively, Figure 9). The mean percent change in functional questionnaire score was -57% in dogs that performed the exercises and was -6% in dogs that did not exercise. Functional questionnaire scores improved significantly in dogs that were exercised (p=0.031), but not in those that were rested (p=0.828), between the evaluation time points. There was no association between VAS pain level and functional disability score ($r^2 = 0.008$) at the post-exercise evaluation of dogs in either group.
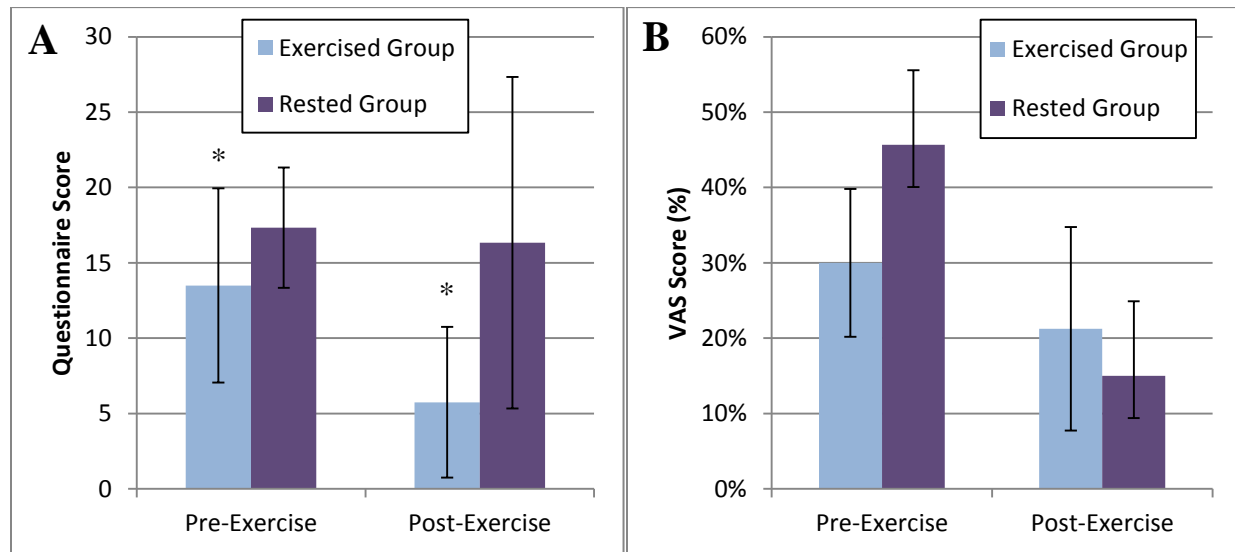
Figure 9: *Functional questionnaire (A) and VAS (B) scores for military working dogs with mild lumbosacral pain before and after exercise. * p<0.05*

Lumbar Paraspinal Muscle CSA, Asymmetry Index and Density Post-Exercise

Dogs with lumbosacral pain that received exercise had a significantly increased muscle:vertebral CSA ratio for the multifidus lumborum muscle ($p = 0.019$), but ratios were not significantly different after exercise for any other muscle group assessed (Figure 10). Additionally, exercised dogs demonstrated a significant decrease in asymmetry index ($p = 0.002$) and a significant increase in density ($p = 0.024$) for the multifidus lumborum muscles upon evaluation of CT scans after the 8-week exercise protocol. ASI and density did not significantly change after exercise for any other muscle group assessed.
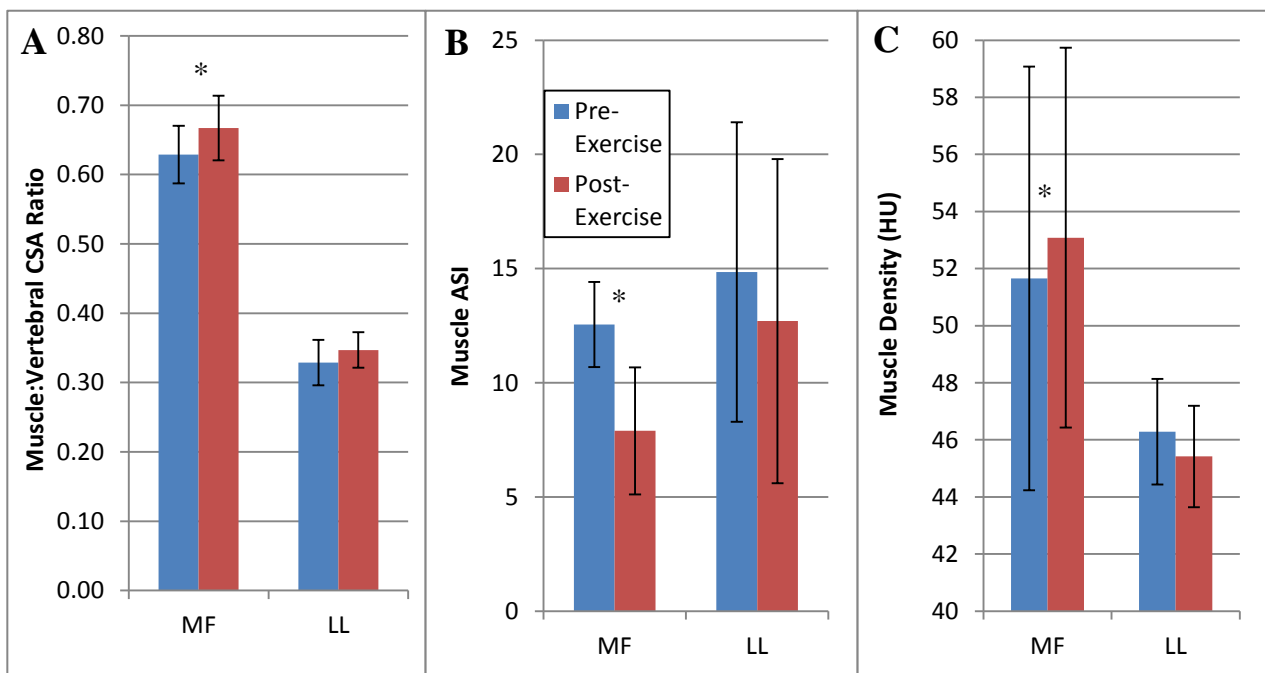
Figure 10: Pre- and post-exercise multifidus lumborum and longissimus lumborum muscle:vertebral CSA ratio (A), ASI (B) and density (C) for dogs with LS pain that underwent the 8-week exercise program. * p < 0.05. Error bars represent one standard deviation above and below the mean.

Intra- and Inter-Observer Agreement

Random sampling of ten measurements to assess agreement between the two observers for muscle CSA measurements demonstrated a concordance correlation coefficient of 0.9868, demonstrating excellent agreement. Moderate agreement (CCC = 0.7988) was seen for muscle density measurements. No agreement (CCC = 0.1491) was noted for ASI measurements.

Concordance correlation coefficient for intra-rater repeatability between two measurements demonstrated substantial agreement for muscle CSA (CCC = 0.9965) and density (CCC = 0.988) for the observer A.H. For the observer S.H., substantial agreement was present with respect to cross sectional area (CCC = 0.9981), with moderate agreement regarding measurements of muscle density (CCC = 0.8814).

Imaging and Clinical Agreement

There was no association between clinical findings of lumbosacral pain and CT-based structural findings indicative of degenerative lumbosacral stenosis. Only two of the sixteen dogs had no evidence of DLSS on CT imaging evaluation. One dog had been categorized as a control and one had been categorized as having lumbosacral pain. Five dogs had equivocal evidence of DLSS on CT imaging, characterized as foraminal stenosis or spondylosis deformans at L7-S1 without other accompanying structural changes or obvious nerve root compression. Three of these dogs had been categorized as having lumbosacral pain; two had been categorized as controls based on clinical and functional assessment. The remaining nine dogs were diagnosed

as having DLSS based on imaging. Four of these were dogs with lumbosacral pain and five had

been clinically and functionally determined to be controls.

Chapter 4: Discussion

Both Belgian Malinois and German Shepherd Dogs are the two most common breeds in the U.S. Military Working Dog program. German Shepherd Dogs have demonstrated a substantial predisposition for lumbosacral stenosis (Daniellson & Sjostrum 1999, De Risio *et al.* 2001, Suwankong *et al.* 2008). Although this study investigated a small number of dogs, distribution of breeds between study groups was suggestive that German Shepherd Dogs and Belgian Malinois may be similarly predisposed to lumbosacral stenosis. This is supported by identification of radiographic/computed tomographic indicators of lumbosacral disease even in several clinically normal military working dogs of both breeds. These findings warrant further study and emphasize a need to investigate improved diagnostic and management strategies for DLSS in military working dogs.

Lack of agreement between CT characteristics of DLSS and lumbosacral pain supported findings by Jones *et al.* (2000) for working dogs with DLSS treated surgically, in which clinical findings were more important predictors of post-operative outcome than imaging evidence. Additionally, symptoms in human patients with CLBP have a poor association with diagnostic imaging findings (Beattie *et al.* 2000, Takatalo *et al.* 2011). These findings indicate a need for more objective pain or functional assessment tools for dogs with lumbosacral pain. The screening evaluation in this study provided preliminary evidence (Appendix) in support of two objective assessment tools: goniometric tail angle and dorso-ventral pressure with an algometer over L7-S1. Outcomes from these objective measures were significantly different between the group of dogs that had pain and those that did not by subjective evaluation at the same time. However,

subjective evaluation and objective data collection for goniometry and tail elevation angle were performed by the same individual, prohibiting blinding.

Three dogs that did not demonstrate subjective signs of LS pain at initial screening were determined to have lumbosacral pain at the follow-up evaluation based on VAS scores and functional questionnaire assessment. One dog identified as having LS pain and one dog with questionable pain at initial screening exam were re-classified as controls at the follow-up evaluation based on VAS and functional assessment tests. This difference in findings may be due to the variable nature of pain, or to differences in criteria of assessment used by two separate individuals. Having two distinct observers at two different time-points was a logistical necessity that posed a limitation to the study design. Comparison of goniometric angle of tail elevation and objective dorso-ventral pressure at L7-S1 to other means of assessment by a single individual may provide more definitive information about their usefulness as outcome measures for DLSS.

Human literature has demonstrated statistically significant findings for reduction of low back pain with exercise with as few as seven subjects. Hides *et al.* (2008) found that specific core stabilization exercises for seven cricket athletes with low back pain reduced their pain by 50% when compared to pain before exercise. Based on this difference, a power analysis was performed on the current study population and demonstrated that a difference of 50% could be detected if 10 dogs were exercised. However, only four dogs could logistically be included in the exercise program in this study due to availability of personnel and availability of dogs to complete the 8-week exercise protocol. Baseline VAS scores in the LS pain dogs did not differ

significantly between the group that underwent exercise and that which did not. VAS scores improved for all subjects by the end of the study period. Although the change was not significant for either group, there was a trend toward greater change favoring reduction in pain in the group that did not undergo the exercise program. Functional scores significantly improved in the exercise group, while control group functional scores did not improve. Furthermore, VAS scores and function scores correlated poorly at the second evaluation. This lack of objective evidence of improved pain in the face of increased function may be due to the low number of subjects used, or may be influenced by limitations inherent in the VAS scoring system. Additionally, these results may suggest that while rest may improve pain, function does not improve. Exercise, however, may improve function and pain (or prevent worsening of pain) in dogs with DLSS. Because of the activities military working dogs must perform, our results suggest that core strengthening exercises may significantly improve function without worsening pain.

Recommendations from the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (IMMPACT) consensus meeting in 2008 (Dworkin *et al.*) regarding application of outcome measures to human patients with CLBP included using at least two outcome measures and understanding that baseline pain would affect interpretation of a change in VAS score, as all changes of the same magnitude on the scale may not be clinically equivalent. The dogs that did not undergo exercise in this study had higher baseline VAS scores than those that exercised, an unexpected finding as groups were selected based on class training schedules. Although this difference was not statistically significant it may have an impact on interpretation of the change in scores after the 8-week study period. Hielm-Björkman *et al.* (2011) demonstrated poor face

validity with owners and VAS scores for osteoarthritis (OA) pain until the pain was alleviated and subsequently reoccurred. It was postulated that a lack of owner experience in recognizing specific signs of pain was the source. VAS for lameness was found to correlate poorly with force plate gait analysis for dogs that were sound, mildly or moderately lame, and only showed good correlation with vertical impulse for each observer if very lame dogs were included (Quinn *et al.* 2007). The present study attempted to improve the accuracy of the VAS scoring system by providing four criteria to consider in the assessment; however individual VAS scores for each criterion may have demonstrated better reliability. Hudson *et al.* (2004) evaluated the repeatability of owner-assessed VAS questionnaires in dogs with pain and lameness, using force plate gait analysis as the gold standard for comparison. The 2004 study generated a 39-point questionnaire addressing various signs of pain and dysfunction with a VAS score assigned to each question. Forty-nine percent of the questions were found to have good repeatability with Spearman rank correlation coefficient of 0.68-0.90. In the present study, the evaluator may have ranked the criteria equally for the VAS score (i.e. dorsal tail elevation and hyperextension of the spine) when there may be unequal distribution among such clinical signs within a population of dogs with lumbosacral pain. Suwankong *et al.* (2008) found via retrospective evaluation that only 5/156 pet dogs (3.2%) with DLSS demonstrated pain on tail extension, whereas pain on hyperextension of the lumbar spine was observed in 107/156 (68%). Another retrospective study found that 97.7% of 131 client-owned dogs diagnosed with DLSS had pain on hyperextension of the lumbar spine and/or tail combined (Danielsson *et al.* 1999). The use of a single VAS scoring system may be an insufficient tool to characterize lumbosacral pain, unless a questionnaire could be developed similar to that used by Hudson *et al.* involving multiple specific criteria with a separate VAS scoring system for each.

The functional assessment questionnaire used in this study was developed specifically to evaluate the performance of military working dogs during familiar tasks used in search and detection that are often sources of handler complaints when dogs begin to show signs that lead to a subsequent diagnosis of DLSS. Therefore, there is no validation history for this questionnaire as an objective assessment tool for evaluating dysfunction associated with lumbosacral pain. At the baseline evaluation, function had a moderate to strong association with VAS score in dogs with lumbosacral pain. This association was not apparent at the follow-up evaluation after the exercise period, suggesting that mild pain may not significantly hinder function if appropriate exercise protocols are instituted. While further studies need to be performed to assess internal and external validity of the functional questionnaire, it appears to have promise as a tool for evaluating military working dogs with lumbosacral pain trained in specific activities.

Multifidus lumborum and longissimus lumborum CSA ratios were significantly smaller in military working dogs with lumbosacral pain than in control dogs. Additionally, multifidus lumborum muscles had decreased density and increased asymmetry between the left and right sides in dogs with lumbosacral pain. The other muscles evaluated had inconsistent or insignificant differences in response to lumbosacral pain and exercise, and their role in stabilization of the lumbosacral region in dogs remains unclear. This study corroborates the human literature in which paraspinal atrophy occurs in people with CLBP and is often most pronounced in the multifidus lumborum muscles (Danneels *et al.* 2000, Hides *et al.* 2008, Kamaz *et al.* 2007). This study also supports the findings of an earlier pilot study performed retrospectively by the principle investigator (Henderson *et al.* 2014). In this study, transverse

magnetic resonance (MR) images through the L7 caudal endplate were evaluated in nine dogs with a diagnosis of LS stenosis or cauda equina syndrome and nine control dogs. Mean cross-sectional area and symmetry of lumbar multifidus and longissimus lumborum muscles were compared between the two groups. There were significant differences between dogs with DLSS and control dogs in muscle CSA to L7 vertebral endplate CSA ratio means for both muscles (p = 0.027 for multifidus lumborum, p = 0.011 for longissimus lumborum). Mean muscle asymmetry indices were higher in dogs with DLSS, but the differences were not statistically significant. In accordance with these pilot study findings, power analysis (α set at 0.05, β set at 0.80) suggested that ten dogs identified as having lumbosacral pain according to the parameters above were needed to detect a significant difference between groups for paraspinal muscle cross-sectional area. Only eight dogs per group met all inclusion criteria for the present study, yet statistical significance was achieved. One difference between the pilot MRI study and the present study was that breed was not controlled in the former, resulting in an over-representation of German Shepherd Dogs in the group with lumbosacral stenosis. Although vertebral cross-sectional area of German Shepherd Dogs was similar to that of other breeds, the role of breed-related conformation in the muscle:vertebral area ratio could not be eliminated. The present study demonstrated, however, that multifidus lumborum and longissimus lumborum atrophy were present in dogs with lumbosacral pain in comparison to structurally similar dogs without pain. This suggests that differences in muscle atrophy and asymmetry are associated with pain and not with conformational characteristics of the dogs.

Another characteristic unique to the present study was the inclusion of paraspinal muscle density measurements. In humans, sarcopenia (age-related muscle loss in the absence of diagnosed

disease) results in approximately 30% loss of muscle mass from 20 to 80 years of age (Freeman 2012). Similar investigations in veterinary patients are limited, but initial studies have demonstrated significant loss of muscle mass with age in healthy dogs (Freeman 2012, Lawler *et al.* 2009). Age was not different between control and LS pain groups in the present study. Increased paraspinal muscle fat content has also been observed in people with CLBP when compared to asymptomatic individuals (Bouche *et al.* 2011, Parkkola *et al.* 1993). Fat has a lower density (HU) than muscle when evaluated by computed tomography. Increased intramuscular fat may have accounted for the decreased density of the multifidus lumborum in dogs with lumbosacral pain in this study, and muscle hypertrophy may have explained the increased density seen in the same muscle group in response to exercise. Additional studies involving precise algorithms for normalizing fat content are warranted to further investigate the potential effect of lumbosacral pain and exercise on intramuscular fat content in dogs.

For people with CLBP, paraspinal musculature, pain and functional response to exercise programs are variable in the literature. Several mechanisms for CLBP have been proposed for people, calling for a classification system that may further guide diagnosis and therapeutic intervention (Gudavalli *et al.* 2006, Maluf *et al.* 2000, O'Sullivan 2005). O'Sullivan has postulated that there is a large subcategory of individuals with chronic low back pain that have ongoing symptoms secondary to compensation for a mechanical deficit or excess of stability. He argues that these patients may be more responsive to management with therapeutic exercise regimens designed to alter paraspinal muscle activation patterns. This could be a common mechanism for the pain associated with DLSS in dogs as well. Therefore, dogs with structural abnormalities at the lumbosacral junction may be able to respond favorably to a similar exercise

regimen. Various exercise protocols recommended to improve pain, function and increase paraspinal muscle area in humans include beginning with sustained low-load contractions, then gradually adding in limb movements mimicking functional tasks, progressively increasing in difficulty (O'Sullivan *et al.* 1997). Additionally, studies with humans and CLBP have found that a combination of stabilization and resistance exercises is necessary to elicit significant increases in paraspinal cross-sectional area (Kim *et al.* 2011, Danneels *et al.* 2000). We found no published canine study that identified significant changes in paraspinal muscles in response to exercise. However, a study by Stubbs *et al.* (2011) compared pre- and post- dynamic mobilization exercise effects on thoracolumbar multifidus muscle cross-sectional area in eight healthy horses. All subjects demonstrated a statistically significant increase in muscle mass after exercise ($p < 0.05$). However, the study did not examine the effect of exercises on lumbar/lumbosacral pain level in an affected population. The present study demonstrated a significant ($p < 0.05$) increase in multifidus lumborum cross-sectional area, symmetry and density in military working dogs with lumbosacral pain in response to core-strengthening. These findings would ideally have been compared to repeated CT scans of dogs with pain that were rested. However, there were insufficient resources to repeat CT scans, which imposed a limitation on the experimental design.

Results of this study indicate that functional improvement for tasks required during detection duties and an increase in size of the lumbar multifidus muscles can be achieved with a core conditioning program in dogs with mild to moderate lumbosacral pain without neurological deficits. Additional research to assess for a consistent and sustained response may involve modeling the exercise program more closely after those found most successful in the human

CLBP patient population. Future investigation of effects of lumbosacral pain and core strengthening on paraspinal muscles would ideally include electromyography to compare muscle activation patterns between control groups and treated groups undergoing exercise and training. To determine whether increase in muscle size in response to exercise may be more profound and include additional muscle groups, application of a 10-12 week exercise program with additional resistance exercises should be evaluated. Further work in dogs with more severe pain could result in greater differences in pain, function, paraspinal muscle area and muscle density in response to exercise. However, the case population used in this study was intended to represent that which would be most likely to return to duty with a conservative physical rehabilitation program as the initial treatment intervention.

In this study, Military Working Dogs with clinically significant lumbosacral pain had increased cross-sectional area, density and symmetry in multifidus lumborum as well as improved function in response to an 8-week core strengthening program. This is the first study to evaluate muscular, functional and pain response of dogs with lumbosacral pain to any exercise regimen. A conservative, evidence-based physical rehabilitation program to address lumbosacral pain would be highly worthwhile to the DoD Military Working Dog Program since the cost of training new military working dogs to replace those no longer able to perform exceeds $30,000 per animal. Long-term possible benefits may include the development of a paraspinal muscle conditioning program that could be provided to military working dogs as an aid to prevent lumbosacral pain in otherwise predisposed dogs.

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Appendices

Appendix A: Orthopedic and Neurologic Examination

Neurological Examination:

OBSERVATIONS						
Behavior	Normal	Aggressive	Excited	Anxious	Apathetic	
Gait	Ataxia	Circling	Hypometria	Hypermetria	Lameness	Affected Limbs:
Voluntary Movement	Normal	Monoparesis /plegia	Paraparesis /plegia	Tetraparesis /plegia	Tremors	LF RF LH RH

POSTURAL REACTIONS	LIMB AND	DEGREE			KEY
Hopping	LF	RF	LH	RH	*0 = absent*
Hemiwalking	LF	RF	LH	RH	*+1 = decreased*
Proprioceptive Positioning (Knuckling)	LF	RF	LH	RH	*+2 = normal*
Extensor Postural Thrust	LF	RF	LH	RH	*+3 = exaggerated*
Placing: Tactle	LF	RF	LH	RH	
Placing: Visual	LF	RF	LH	RH	

REFLEXES	LIMB AND DEGREE						KEY
MYOTATIC	Pelvic			Thoracic			*0 = absent*
Left	Patellar	Gastroc	Cranial Tibialis	Triceps	Biceps	ECR	*+1 = decreased*
Right	Patellar	Gastroc	Cranial Tibialis	Triceps	Biceps	ECR	*+2 = normal*
Flexion	LF	RF	LH	RH	**Perineal**	**Cutaneous Trunci**	*+3 = exaggerated*
Crossed Extensor	LF	RF	LH	RH			*+4 = clonus*

ADDITIONAL INFORMATION			
Hyperesthesia	Cervical? Y/N	Thoracolumbar Y/N	Location/Comments:
Bladder Control	Normal	Abnormal	Comments:
Bowel Control	Normal	Abnormal	Comments:

Orthopedic Examination:

GAIT EVALUATION	LEFT THORACIC	RIGHT THORACIC	LEFT PELVIC	RIGHT PELVIC
Lameness at a Stance	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Lameness at a Walk	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5
Lameness at a Trot	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5

Zero is no lameness, 4 (at a stance) and 5 (at a walk/trot) represent continuous non-weight-bearing lameness

ADDITIONAL INFORMATION	PALPATION	JOINT RANGE OF MOTION	ATROPHY	
Right Thoracic	Pain? Y / N Asymmetry: Y / N	Restricted? Y / N Painful? Y / N	None Mild Mod Severe	Comments/Location(s):
Left Thoracic	Pain? Y / N Asymmetry: Y / N	Restricted? Y / N Painful? Y / N	None Mild Mod Severe	Comments/Location(s):
Right Pelvic	Pain? Y / N Asymmetry: Y / N	Restricted? Y / N Painful? Y / N	None Mild Mod Severe	Comments/Location(s):
Left Pelvic	Pain? Y / N Asymmetry: Y / N	Restricted? Y / N Painful? Y / N	None Mild Mod Severe	Comments/Location(s):

ADDITIONAL FINDINGS/COMMENTS:

_____
_____
_____
_____
_____

TEST	PAIN		TEST	RESULTS
Lumbar Hyperextension with Hips in Flexion	Present	Absent	**Algometer at L7-S1** *(always after digital test)*	Pressure (PSI):
Dorsal Tail-Base Elevation	Present	Absent	**Goniometric Angle of Max Tail Elevation** *(0 degrees is parallel to the ground surface)*	Angle (Degrees):
Digital Pressure over L7-S1	Present	Absent		

Dog Meets Inclusion Criteria | Dog Does Not Meet Inclusion Criteria

LS Pain Present   or   LS Pain Absent

_____

Signature of Examiner

Appendix B: Functional Assessment Questionnaire

Handler: **First Name**_____   **Last Name**_____

                 Branch of Service (circle one):   Army   Air Force   Navy   Marines

Dog: **Name**_____   **Sex (Circle One):**   Male   Female

                 Spayed/Neutered? (Circle One):   Yes   No

                 Age (round to the nearest year)_____

                 Breed: German Shepherd   Belgian Malinois

Functional Assessment

The following questions are about your evaluation of your military working dog's performance during a training session. Please read the following questions and answer each one to the best of your ability. *Provide only one answer for each question.*

1. **How long does the dog stay in the "hup" position during the evaluation routine?**
   a. 0 seconds, the dog refuses to "hup" when I ask
   b. 1-2 seconds
   c. 3-4 seconds
   d. 5-6 seconds
   e. 7 or more seconds

2. **Does the dog show any difficulty "hupping" each time you ask, to a distance of at least three feet off the ground at the dog's shoulder level?** *Difficulty may be defined as hesitation in going into the hup, repeatedly unsuccessful attempts at rising into the "hup," refusal to "hup" or crying out when performing the activity.*

    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

3. **Does the dog show any difficulty in jumping INTO a vehicle?** *Difficulty may be defined as hesitation, inability to complete the jump the first time, crying out when performing the activity, or slipping or falling during or after the jump.*

    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

4. **Does the dog show any difficulty in jumping OUT OF a vehicle?** *Difficulty may be defined as hesitation, crying out when performing the activity, or slipping or falling during or after the jump.*

    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

5. **Does the dog show any difficulty in climbing the staircase on an obstacle course?** *Difficulty may be defined as hesitation, repeatedly attempting to get down, refusal to climb, crying out when performing the activity, or slipping or falling during the climb.*
   a. Never
   b. Rarely
   c. Sometimes
   d. Frequently
   e. Always

6. **Does the dog show any difficulty in climbing up or down the A-frame on an obstacle course?** *Difficulty may be defined as hesitation, repeatedly attempting to get down, refusal to climb, crying out when performing the activity, or slipping or falling during the climb.*
   a. Never
   b. Rarely
   c. Sometimes
   d. Frequently
   e. Always

7. **Does the dog show any difficulty performing 1-meter jumps on an obstacle course?** *Difficulty may be defined as hesitation, refusal to jump, crying out when performing the activity, not clearing the jump, or slipping or falling upon landing.*
   a. Never
   b. Rarely
   c. Sometimes
   d. Frequently
   e. Always

8. **Does the dog show any difficulty sitting from a standing position and/or standing from a sitting position when performing this exercise 5 times in a row rapidly?** *Difficulty may be defined as hesitation or reluctance to down/stand, refusal to down or stand, or delayed or awkward changes in position when going into a down or rising into a stand.*
    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

9. **Does the dog show any difficulty rising from a down position and/or going into down from a standing position when performing this exercise 5 times in a row rapidly?** *Difficulty may be defined as hesitation or reluctance to sit/stand, refusal to sit or stand, or delayed or awkward changes in position when sitting or rising into a stand.*
    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

10. **Does the dog show any difficulty performing a 2-meter tunnel crawl on an obstacle course?** *Difficulty may be defined as hesitation in going into or coming out of the tunnel, repeatedly unsuccessful attempts at getting down or rising, refusal to enter the tunnel or get up from the crawl position, or crying out when performing the activity.*
    a. Never
    b. Rarely
    c. Sometimes
    d. Frequently
    e. Always

Questionnaire Scoring and Score Categorization

- A score value of 0 to 4 will be assigned to each answer choice for Question 1 in the following manner:
    - Answers of "0 seconds" will receive a score of 4
    - Answers of "1-2 seconds" will receive a score of 3
    - Answers of "3-4 seconds" will receive a score of 2
    - Answers of "5-6 seconds" will receive a score of 1
    - Answers of "7 or more seconds" will receive a score of 0

  A score value of 0 to 4 will be assigned to each answer choice for Questions 2-10 in the following manner:
    - "Never" receives a score of 0
    - "Rarely" receives a score of 1
    - "Sometimes" receives a score of 2
    - "Frequently" receives a score of 3
    - "Always" receives a score of 4

- Scores from all questions from which a score from 0 to 4 was obtained will be totaled.

- The total questionnaire score for each Military Working Dog will be categorized as follows:
    - A total score less than or equal to 4 will be classified as "absence of functional evidence for back pain."
    - A total score greater than or equal to 8 will be categorized as "presence of functional evidence for back pain."
    - A total score of 5 to 7 will be considered as "borderline for presence of functional evidence for back pain" and will not be considered sufficient for dogs to be categorized in the LS pain group.

Appendix C: Exercise Protocol

The following describes the 8-week exercise protocol for the treatment group (LS Pain present with exercise):

Exercises are to be performed twice per week on non-consecutive days. One exercise session will precede each 8-week intervention program for all dogs consisting of brief (30-second to 1-minute) trials with the various exercises for familiarization with the equipment, and determination of the dog's functionality for program individualization if necessary. These exercises will be in addition to the dog's normal walking routine as part of normal training aid husbandry. Exercises should be performed continuously for each session. Each session is expected to take approximately 35-45 personnel minutes total.

Weeks 1 and 2 Goals: Isometric Focus and Light Conditioning (Level I)

Exercise Routine:

a. Walk-trot intervals (one min each) on a land treadmill at zero incline for 15 minutes. Warm up for first three minutes and cool down for last 2 minutes.
b. Walking at a moderate pace through weave poles (5-6 poles) spaced at the same length as the dog's body, 10 times in each direction.
c. Stand/Sit/Down/Roll for 5 reps each on a mildly unstable surface, ie mattress. Use a reward.
d. Standing on a large (85cm diameter) physioroll peanut for 5 minutes with personnel stabilization at one end of the roll, providing very small movements of the ball in a bouncing motion towards the floor, and rocking from side to side.
e. Step up and down exercises (have the dog step one forelimb at a time onto a stairstep, then back down one limb at a time. Repeat up to 10 times as tolerated.
f. Standing on a flat surface with one forelimb and the opposite hindlimb raised while maintaining the dog in a square position, preventing weight-shifting to accommodate for the lifted limbs. Perform this exercise for 30 seconds at a time with 30 second breaks between, for 10 repetitions. Easier variation: raise one forelimb or hindlimb alone.
g. Standing on a flat surface and leaning in the following directions for a cookie, 10 repetitions:
    i. Head to between front feet
    ii. Head to left hind foot
    iii. Head to right hind foot
        a. Head straight up at 90 degrees from the dog's longitudinal axis

Weeks 3 and 4 Goals: Increasing Strength and Endurance Level I

Exercise Routine:

a. Walk-trot intervals (2 minutes each) on a land treadmill at zero incline for 15 minutes. Warm up for first three minutes and cool down for last 2 minutes.
b. Trotting through weave poles (6-8 poles) spaced at the length of the dog's body, 10 times in each direction.
c. Stand/Sit/Down/Roll for 10 reps in each direction on a mildly unstable surface, ie mattress pad. Use a reward.
d. Standing on a large (85cm diameter) physioroll peanut for 2 sets of 5 minutes each with personnel stabilization at one end of the roll, providing very small movements of the ball in a bouncing motion towards the floor, and rocking from side to side.
e. "Hup" exercises: With dog's forelimbs elevated on a steady surface at approximately 4 feet to dog's shoulder in height, have the dog follow a treat while leaning right, left, forward and back without changing position of the hindlimbs. Hold the treat for 3-5 seconds in each direction with intermittent rewarding. Do this for 5 repetitions (allowing the dog to resume normal standing position off the hup between reps) in each of the 4 directions.
f. Planks with forelimbs resting on a medium-sized peanut-shaped physioroll (approximately 70cm diameter at widest point of the peanut). Hold for 30 seconds, with 30-second to 1-minute breaks between, for 10 repetitions.
g. Step up and down exercises (have the dog step one forelimb at a time onto a stairstep, hold for 10 seconds, then back down one limb at a time. Repeat up to 10 times as tolerated.
h. "Superman" standing on a flat stable surface with contralateral forelimb and hindlimb raised and gentle displacement forces in sagittal plane (cranial-caudal) and frontal plane (axial-abaxial) applied. 30 seconds at a time with 30 second breaks between, for 10 repetitions.

Weeks 5 and 6 Goals: Controlled concentric/eccentric, Dynamic Exercises and Moderate Conditioning (Level II)

Exercise Routine:

a. Walk-trot intervals (1 minute each) on a land treadmill at a mild incline (5 degrees) for 15 minutes. Warm up for first three minutes and cool down for last 2 minutes.
b. Trotting on leash through weave poles (6-8 poles) spaced at 2/3 of the length of the dog's body, 15 times in each direction.
c. Stand/sit/beg/down/roll for 2 sets of 5 reps (one set in each direction) on a mattress. With each sit, have the dog go slowly into a hup/beg position and hold for about 1 second before lowering back into the sit and standing again for the next rep.
d. "Hup" exercises: With dog's forelimbs elevated on a steady surface at approximately 4 feet to dog's shoulder in height, have the dog follow a treat while leaning right, left, forward and back without changing position of the hindlimbs. Hold the treat for 3-5 seconds in each direction with intermittent rewarding. Do this for 10 repetitions (allowing the dog to resume normal standing position off the hup between reps) in each of the 4 directions.
e. Standing on a large (85cm diameter) physioroll peanut for 5 minutes with personnel stabilization at one end of the roll, providing small movements of the ball in a bouncing motion towards the floor, and rocking from side to side.
f. Three-legged standing on the large physioroll peanut for 5 minutes, with one forelimb raised for 2.5 minutes and one hindlimb raised for the remaining 2.5 minutes. This exercise will require 2 people.
g. Forelimbs on stable surface level with a Fit Pawz donut, hind limbs on donut, balance for 5 minutes
h. Plank-to-push up exercises with 85cm diameter physioroll peanut: With the dog's hindlimbs planted on a mattress, have the dog's forelimbs up on the physioroll. Gently roll the physioroll cranially and caudally so the dog's antebrachii alternatively rest on the roll when in a more forward position, and paws rest on the roll when in a more backward position. The ball movement should be small so the hindlimbs stay in position. Perform this exercise for 2 sets of 5 reps in each direction.

Exercise Routine:

a. Walk-trot intervals (2 minutes each) on a land treadmill at a mild incline (10 degrees) for 15 minutes. Warm up for first three minutes and cool down for last 2 minutes.
b. Trotting on leash through weave poles (6-8 poles) spaced at the 2/3 of the length of the dog's body, 15 times in each direction.
c. Stand/sit/down/roll for 2 sets of 5 reps each on a mattress, ensuring every other set is in the opposite direction. With each sit, have the dog go slowly into a beg position and hold for about 2 seconds before lowering back into the sit and standing again for the next rep.
d. Standing on a large (85cm diameter) physioroll peanut for 5 minutes with personnel stabilization at one end of the roll, providing small movements of the ball in a bouncing motion towards the floor, and rocking from side to side.
e. Three-legged standing on the large physioroll peanut for 5 minutes, with one forelimb raised for 2.5 minutes and one hindlimb raised for the remaining 2.5 minutes. This exercise will require 2 people.
f. With hindlimbs on a donut and forelimbs on a stable surface at the same height as the donut, balance for 5 minutes
g. Sitting/standing for 2 sets of 5 reps each with the dog entirely on a physioroll peanut. Use a reward.
h. Plank-to-push up exercises with 85cm diameter physioroll peanut: With the dog's hindlimbs planted on a mattress, have the dog's forelimbs up on the physioroll. Gently roll the physioroll cranially and caudally so the dog's antebrachii alternatively rest on the roll when in a more forward position, and paws rest on the roll when in a more backward position. The ball movement should be small so the hindlimbs stay in position. Perform this exercise for 2 sets of 10 reps in each direction.
i. Step up and down exercises (have the dog step one forelimb at a time onto a first and second stairstep, hold for 5 seconds, then back down one limb at a time. Repeat 10 times as tolerated.

Vita

Dr. Andrea Henderson was born in Roanoke, VA and attended the Roanoke Valley Governor's School for Math and Science and Lord Botetourt High School, graduating in 1996. She graduated with distinction with a Bachelor of Arts in Biology at the University of Virginia in 2000. Dr. Henderson was accepted into veterinary school and received her Doctorate of Veterinary Medicine from the Virginia-Maryland Regional College of Veterinary Medicine in 2005. She participated in a Summer Fellowship Program in 2002 in which she conducted a research project involving working dog and handler interactions. Her passion for working dogs led her to join the U.S. Army Veterinary Corps in 2003, swearing in to active duty in May 2005. She has been an active duty officer for nine years and currently holds the rank of Major. Her first assignment was an internship at the Department of Defense Military Working Dog Veterinary Services in San Antonio, Texas. She has since held leadership positions overseeing the Mine Detector Dog program at Fort Leonard Wood, Missouri and the Kaiserslautern Branch Veterinary Services in Germany. In July 2011, Dr. Henderson began a residency in canine sports medicine and rehabilitation at the University of Tennessee in Knoxville, and has completed all requirements of her residency in good standing. She is concurrently pursuing a Master of Science with a focus in Kinesiology with plans to graduate in December 2014. In fall 2014 she returns to the DoD Military Working Dog Center in San Antonio to oversee and expand the sports medicine and conditioning programs for the military working dogs. Dr. Henderson has specific interests in therapeutic laser applications in healing and nerve regeneration, perioperative multimodal analgesia, and conservative management of degenerative lumbosacral stenosis in Military Working Dogs.