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

in Military Working Dogs with Lumbosacral Pain

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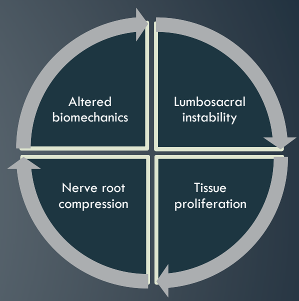
Introduction

Degenerative Lumbosacral Stenosis (DLSS)

- Degenerative cause of cauda equina nerve root compression
  - IVDD, tissue proliferation and stenosis, instability at L7-S1



- Risk Factors for Dogs:
  - *Male > female*
  - *Middle-aged to older adults (mean = 7 yr)*
  - *Large breed; GSDs*
    - *Reduced mobility at L7-S1, decreased articular facet angulation (Benninger et al. 2006)*
  - *Working dogs*

DLSS: Anatomy

- Cranial origin of cauda equina varies with dog size
- Nerve roots bordered by:
  - *Dorsal – laminae and ligamentum flavum (interarcuate ligament)*
  - *Dorsolateral – articular processes and joint capsules*
  - *Lateral – pedicles*
  - *Ventral – L7 and S1 vertebral bodies, dorsal longitudinal ligament and L7-S1 dorsal annulus fibrosus*
- Proliferation, swelling or neoplasia of a number of these structures may lead to compression of the nerve root

DLSS: Pathophysiology

- Degenerative conditions:
- Vicious cycle?

DLSS: Clinical Signs

- Pain
  - Many manifestations
  - Pain with examination: pressure on L7-S1 percutaneously or per rectum; dorsal hyperextension of the tail base; lordosis with hips in flexion
  - Pelvic limb nerve root signature/lameness
- Loss of function
  - Atrophy of pelvic limb +/- paraspinal musculature
  - Difficulty with sit/down or rising from these positions
  - Neurologic deficits – absent to severe
  - Urinary/fecal incontinence
- Military working dogs:
  - Failure to "hup" during search
  - Reluctance to jump into or out of vehicles
  - Hesitation on jumps, A-frame and other obstacles

DLSS: Diagnosis

- Physical examination and evaluation for pain, lameness, loss of function
  - Adequate objective outcome measures for LS pain?
- Diagnostic Imaging
  - CT, MRI – does not always correlate with clinical signs or outcome
    - *Jones & Inzana 2000, Jones et al. 2000*
    - Humans with chronic low back pain
      - Beattie *et al.* 2000
      - Takatalo *et al.* 2011

DLSS: Treatment

- Medical management
  - Recommended for first-time incidence, mild pain without neurologic deficits and dogs that are not highly active
  - Historically consists of rest and analgesic/anti-inflammatory Rx
- Surgical management
  - Decompression – most often dorsal laminectomy/discectomy
  - Distraction and fusion may be elected to break the cycle of instability, tissue proliferation and compression
  - Controversial as to whether to distract/fuse
- To cut or not to cut?

DLSS: Outcomes after Medical Treatment

- Medical treatment previously defined as 2-4 weeks of cage rest and oral medications such as analgesics, anti-inflammatories
- Often recommended for dogs at first episode, or non-working dogs with intermittent episodes of LS pain only (Worth *et al.* 2009)
- Historically, approximately 50% of dogs reported to have improvement or resolution of clinical signs with medical management (Ness *et al.* 1994)
- Reoccurrence is common
- Moderate-severe LS pain and/or neurological deficits considered indicators of surgery

DLSS: Post-Operative Outcomes

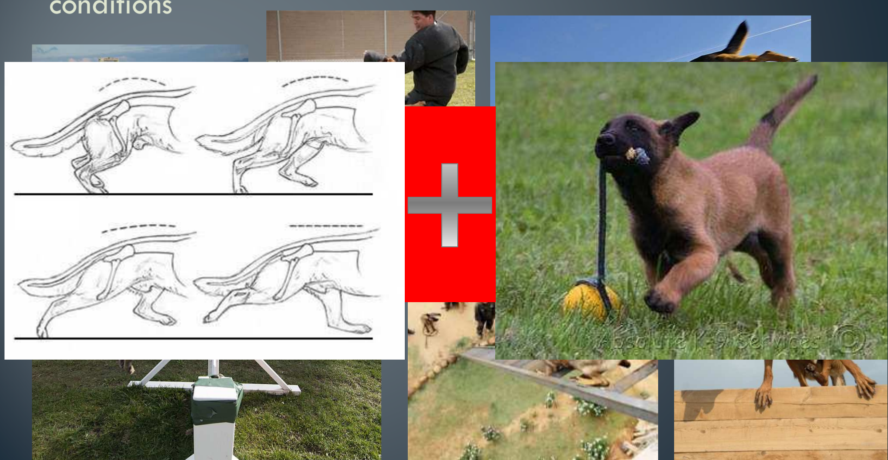
- More favorable in pets than in MWDs
- Chambers et al, 1988 – 77% dogs had good to excellent results at 14 months post op DL and discectomy
- Oliver et al, 1978 – 73% dogs had good to excellent results at 21 months post op DL and discectomy
- Danielsson et al 1999 – 79% return to normal function, 93% improvement (median follow-up 26 months), reoccurrence in 18%
- Suwankong et al 2008 – 79% showed clinical improvement and 76% of those available for follow-up continued to show improvement at 5 years post-op

DLSS in Military Working Dogs

- Signalment
- Nature of activity:
  - Patrol work
  - Detection work
- Surgical treatment has historically been the mainstay with intent of return to duty

MWD Duties and Spinal Biomechanics

- Requires spinal flexion under repetitive and high-impact conditions



DLSS in Military Working Dogs

- Variable prognosis for military working dog return to duty after lumbosacral surgery of any type (41% returned to normal function – Linn et al 2004)
- Prognosis for return to normal function worsened with age and disease severity
- Canine lumbosacral disease physical exam findings do not always correlate with advanced imaging (severity)
- Is surgery always indicated?

Lumbosacral Pain, Epaxial Musculature and Conditioning

- Humans with chronic low back pain (CLBP) have been assessed to have:
  - spinal instability (postulated association with intervertebral disc degeneration)
  - reduced paraspinal muscular CSA, strength and control
    - Lumbar multifidus has been the most consistently affected
    - Muscles with reduced CSA in CLBP - per CT evaluation: lumbar multifidus, longissimus group, psoas major and quadratus lumborum
  - pathological paraspinal muscle activation

  (Gibbons *et al.* 1997, Kamaz *et al.* 2007, Parkkola *et al.*1992, Danneels *et al.* 2000, Kader *et al.* 2000, and many others)
- Clinical Signs often not correlated with specific advanced imaging abnormalities, → non-surgical treatment approaches

  (Beattie *et al.* 2000, Takatalo *et al.* 2011)

Lumbosacral Pain, Epaxial Musculature and Conditioning

- Dogs with lumbosacral pain may also demonstrate atrophy of similar paraspinal muscle groups – results of two pilot studies:
  - Paraspinal muscle cross-sectional area (CSA):vertebral ratio and density (for region of interest) measured via Computed Tomography
  - Dogs with clinical signs of LS pain vs. dogs without
  - Francis *et al.* 2012 (Published Abstract) – Labrador Retrievers
    - Lower CSA in multifidus lumborum, quadratus lumborum and iliopsoas in dogs with LS pain (but not longissimus)
    - CT densities – varied
  - Cain *et al.* 2013 (Published Abstract) – Belgian Malinois
    - Lower CSA in multifidus lumborum, longissimus lumborum, iliopsoas and sacrocaudalis dorsalis (but not quadratus) in working Malinois with LS pain

Lumbosacral Pain, Epaxial Musculature and Conditioning

- Conservative management (e.g., core stabilization exercise) → evidence of improved pain and function in people, including athletes, with CLBP (Hides *et al.* 2008, Marshall *et al.* 2006)
- Biomechanical differences, but possibly similar results in dogs with lumbosacral pain?

Epaxial Musculature in Dogs and Horses

- Canine Pilot Study (Teeling et al, 2012):
  - Three healthy Labrador Retrievers exercised three times per week for 8 weeks by standing on a peanut physioroll.
  - Lumbar epaxial cross-sectional area measured before and after the exercise program using diagnostic ultrasound
  - Lumbar epaxial CSA increased for all three dogs, n too small for statistical significance and no controls used
- Stubbs et al, 2011:
  - Healthy Horses (n=8) exhibited statistically significant multifidus muscle CSA increase from baseline (T10-L5) after a 12-week dynamic mobilization program using cervical flexion series
  - Exercises: 5 reps of each, 5 days per week
  - Muscle CSA was measured using diagnostic ultrasound

Objectives

1. To determine whether evidence exists of lumbar paraspinal muscle atrophy in dogs with lumbosacral pain

2. To determine whether an 8-week core conditioning program will, in dogs with LS pain:
   a. Increase muscle CSA, symmetry and density
   b. Improve pain and function

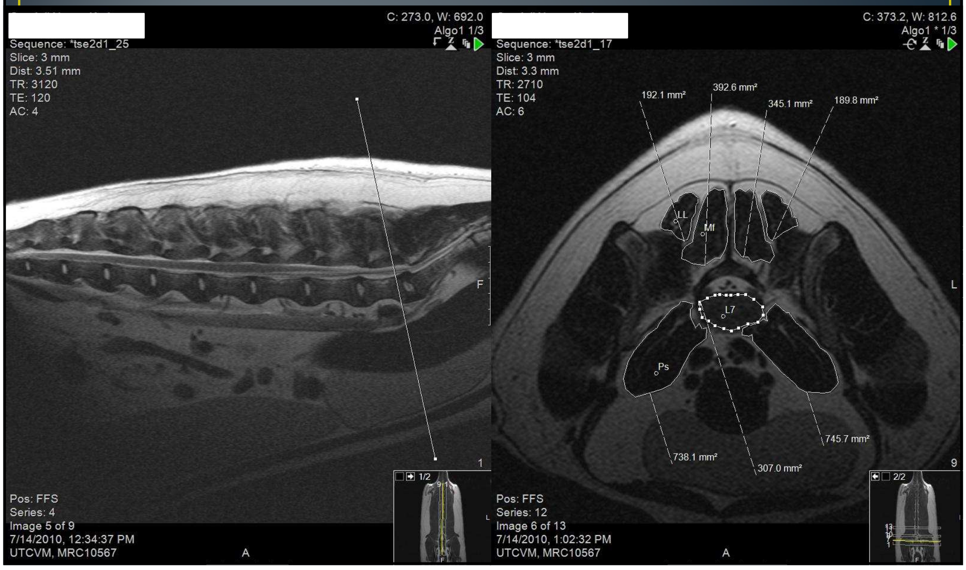
Hypothesis: Dogs with lumbosacral pain will have reduced muscle cross-sectional area, asymmetry and density when compared to control dogs without pain. A core conditioning program for dogs with lumbosacral pain will yield improved epaxial muscle CSA, symmetry and density, as well as reduced pain and increased function

Materials & Methods

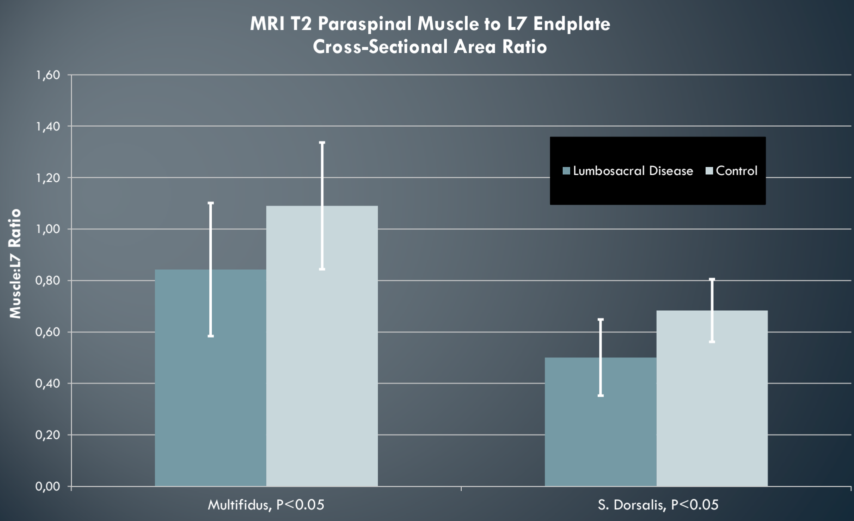
MRI Pilot Study

- 9 Dogs diagnosed with DLSS
- 9 Control Dogs
  - LS MRI added for patients receiving MRI for reasons unexpected to cause lumbar paraspinal atrophy
- MRI T2 sequence transverse images at L7 endplate
- Measured cross-sectional area of sacrocaudalis dorsalis, multifidus, iliopsoas and L7 body
- IPS not used – variability perceived due to positioning
- Determined mean cross-sectional area (left and right) and an asymmetry index for each muscle pair

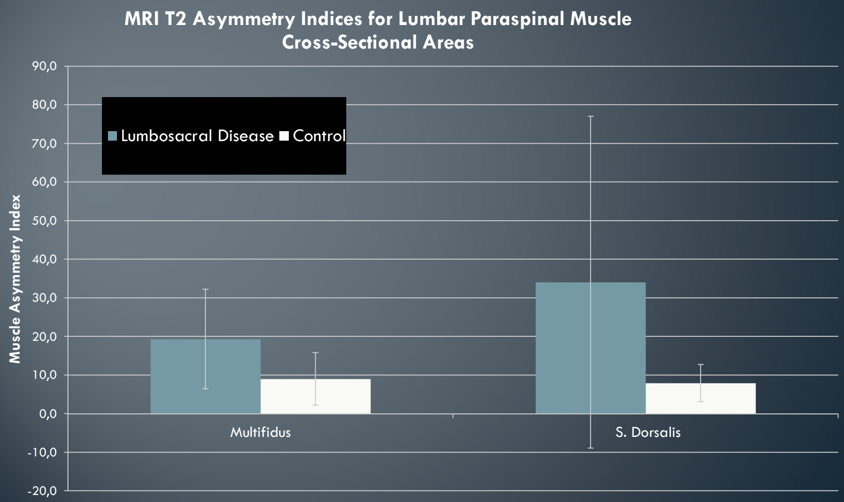
MRI Pilot Study



MRI Pilot Study



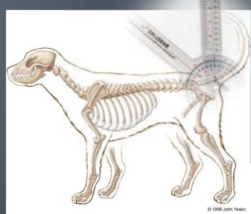
MRI Pilot Study



Military Working Dog Study

- Records of all MWDs used as search/detection training aids

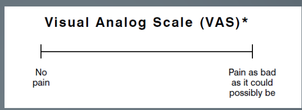
- Inclusion Criteria:
  - Age: 5-11 years
  - Breed: German Shepherd Dog, Belgian Malinois, Dutch shepherd
  - Normal orthopedic and neurological exam (excl. LS pain in cases)
  - Suitable temperament
  - No anti-inflammatory/analgesic medications, supplements or diets for previous 8 weeks.
  - 13 control dogs
  - 11 dogs with LS pain



Pressure Algometer over L7-S1
Goniometry of Tail Elevation Angle

Pain and Function Assessments

- Pain: VAS Assessment



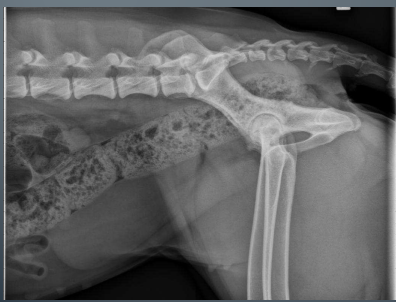
- Function: Search and Detection Task Proficiency
  - 10-item questionnaire
  - 8 items utilized
  - 5 trials per item (based on ability)
  - Max score 32 (4 per question)
  - Ideal performance = score of zero

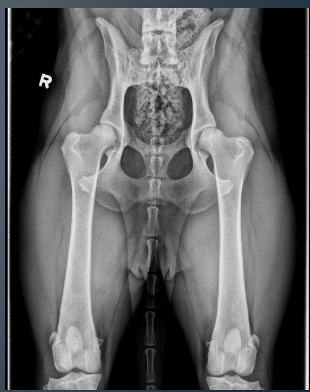
Functional Assessment Questionnaire

- Jumping up, down at vehicle seat height
- Jumping over 2-foot hurdle
- Double Stairway
- Dog Walk
- Sit-to-Stand
- “Hup”

Pelvic Radiographs

- Exclusion Criteria:
  - Lumbosacral Transitional Vertebrae
  - Hip DJD beyond minimal osteophytes
  - Anything that could have overlapping signs with DLSS





CT Acquisition Protocol

- 64-Slice Volume Scanner
- 120 kV, 50mA
- 1.25mm slices
- Twice, varied position:
  - 145° Hip Extension
  - 50° Hip Flexion
  - Margin of Error +/- 2.5°
- Density calibration phantom included

Muscle Measurements

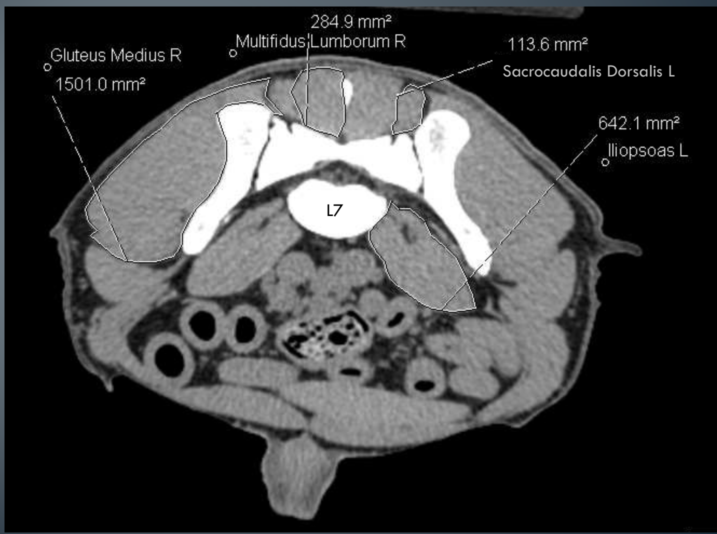
- Muscles:
  - Multifidus lumborum
  - Sacrocaudalis dorsalis (longissimus group)
  - Quadratus lumborum
  - Iliopsoas
  - Gluteus medius
- Muscle:Vertebral CSA Ratio
  - L5, L6 or L7 depending on slice
- Muscle Asymmetry Index

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

- Muscle Density (Hounsfield Units)

Muscle CSA Measurements Example – L5 Caudal Endplate

Muscle CSA Measurements Example – L7 Caudal Endplate



Agreement Tests

- Intra-observer and inter-observer agreement
  - Board-certified radiologist and resident measuring from CT images
  - Compared for agreement of continuous measurements using Concordance Correlation Coefficient (Lin, 1989)
  - Randomly sampled 10 measurements for all comparisons
- Clinical and Imaging Agreement
  - Comparison of dogs categorized as LS or control by objective clinical findings to CT imaging-based diagnosis of DLSS by blinded radiologist

Exercise Protocol

- Four dogs in the LS pain group completed
- 8 weeks, three sessions per week, 45-50 min/session
- Modeled after frequency and duration from Kim *et al.* 2011

Exercise Protocol

- Weeks 1 and 2: Isometric and light conditioning
- Weeks 3 and 4: Increase strength/endurance at the above level
- Weeks 5 and 6: Controlled concentric and eccentric exercises, dynamic mobilization and moderate conditioning
- Weeks 7 and 8: Increase strength/endurance at the level utilized in weeks 5-6

Exercise Protocol Record

WEEKS ONE AND TWO

MWD Name________________________ Tattoo Number________________ Date___________

board on 22 inch blue Fit Paws disc, 3 minutes, 2 sets (2 minutes between sets)			
Front legs "hupped" on PT table set at 2 feet high, moving head and forelimbs 2 feet to left and right, 10 reps each direction, 2 sets (2 minutes between sets)			
Front legs stepping up and down one Reebok aerobics step (6-inch steps) – 10 times, 2 sets (2 min betw sets)			*step forwards up with each leg, then step backwards off for each leg*

Exercise Protocol Record

WEEKS SEVEN AND EIGHT

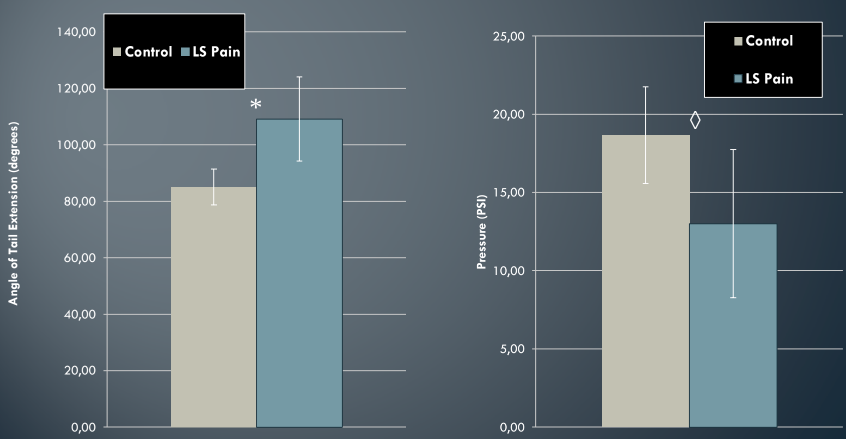
MWD Name________________________ Tattoo Number________________ Date___________

Standing on balance board (three legs down, one leg up) with board on 13 inch green Dynadisc, , 1 minute, 4 sets (30 seconds between sets) with each of the four legs lifted up for one minute per leg			
Front legs "hupped" on PT table set at 3 feet high, moving front legs/head left to right with hind legs on 13" green Dyna disc, 10 reps each direction, 2 sets (2 minutes between sets)			
Walking forward with front legs on the blue egg and back legs on the ground, pushing the blue egg forward for five steps and backwards for five steps (5 times each direction, 2 sets)			*step forwards up with each leg, then step backwards off for each leg*

Results

Tail Elevation Angle and L7-S1 Pressure

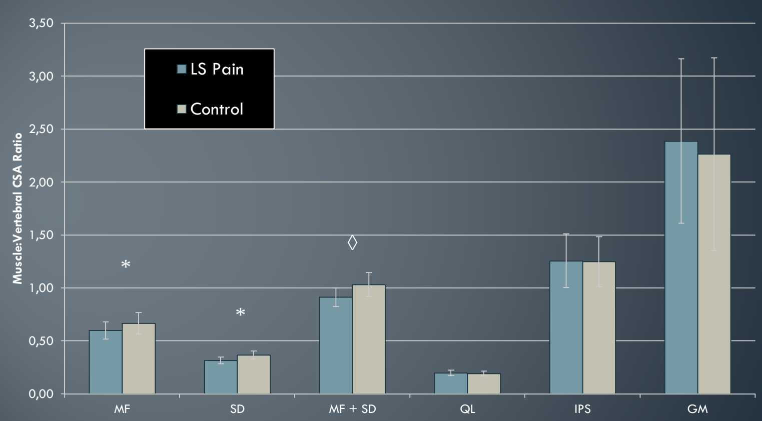
*Differences between dogs with LS pain and control dogs regarding goniometric angle of tail extension (left) and dorso-ventral pressure over the L7-S1 disc space (right). *P<0.001, ◊P <0.01*



Pain and Functional Assessments: Pre-Exercises

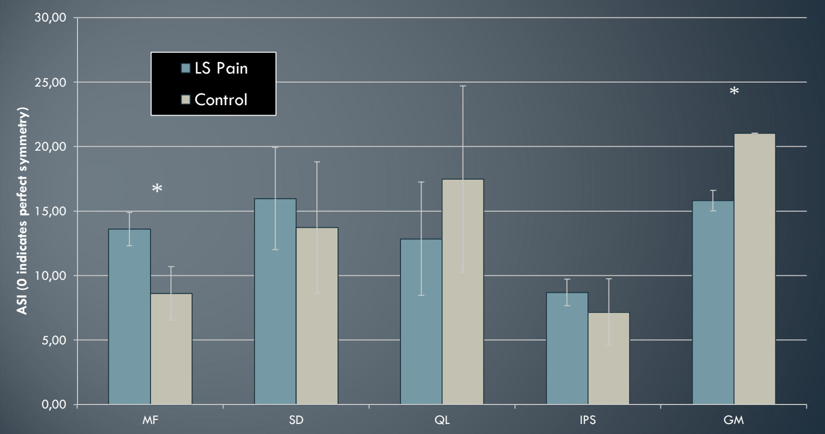
- VAS Scores (0-100%)
  - Control group mean = 1%
  - LS Pain group mean = 34%
  - Significant difference between groups ($P < 0.001$)
- Functional Questionnaire (0-32)
  - Control group mean = 0.63
  - LS Pain group mean = 15.88
  - Significant difference between groups ($P < 0.001$)
- Moderate to strong positive linear association ($R^2 = 0.67$) between VAS and functional questionnaire scores

CT Muscles Pre-Exercise: CSA



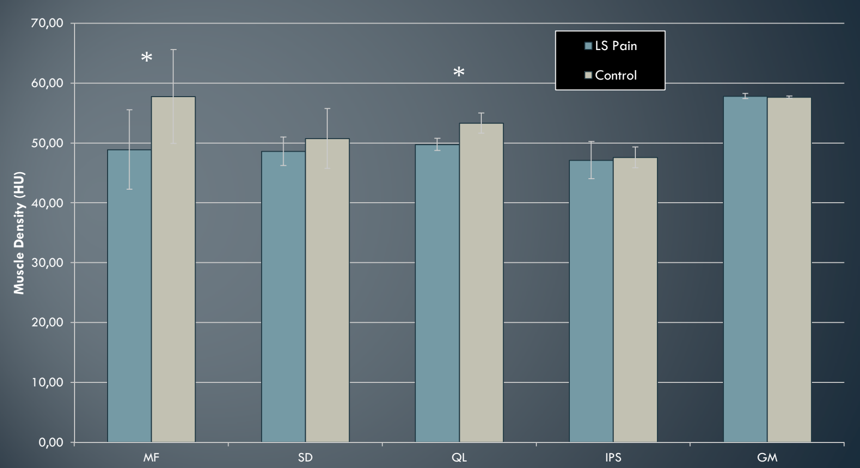
Baseline muscle:vertebral CSA ratio for dogs with LS pain and control dogs
** P<0.05, ◊ P <0.01.*
Error bars represent one standard deviation above and below the mean.

CT Muscles Pre-Exercise: ASI



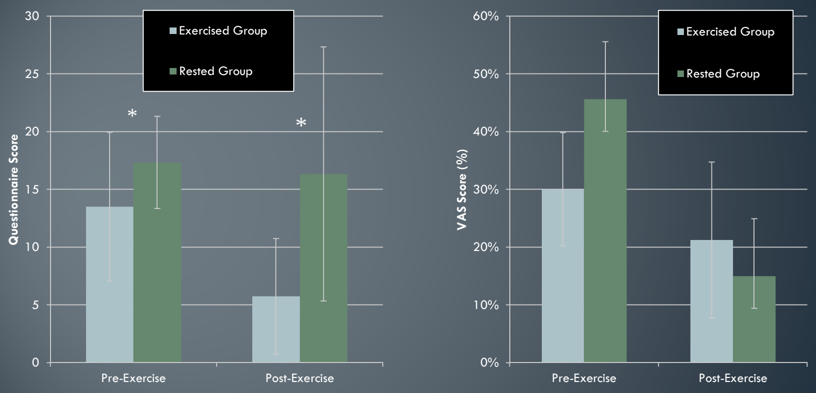
*Baseline muscle ASI for dogs with LS pain and control dogs. An ASI value of zero indicates perfect symmetry; 100 would indicate that muscle on one side would have twice the CSA of the muscle on the opposite side. * P<0.05. Error bars represent one standard deviation above and below the mean.*

CT Muscles Pre-Exercise: Density



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.*

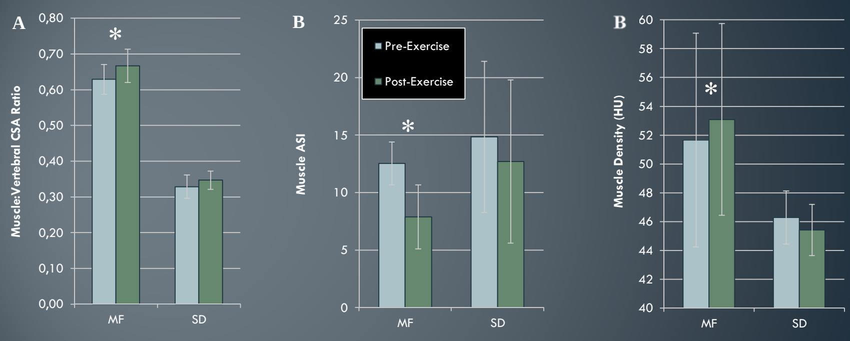
Pain and Functional Assessments: Post-Exercise



*Functional Questionnaire (A) and VAS (B) scores for Military Working Dogs with Mild Lumbosacral Pain Before and After Exercise. * P<0.05*

- No association between VAS pain level and functional disability score ($R^2 = 0.008$) between exercised and rested groups

CT Muscles Post-Exercise



*Pre- and post-exercise multifidus lumborum and sacrocaudalis dorsalis 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*

Intra- and Inter-Observer Agreement

- Intra-observer agreement: strong for muscle CSA and density:
  - CSA: CCC = 0.987-0.997
  - Density: CCC = 0.881-0.988
- Inter-observer agreement: strong for muscle CSA and density:
  - CSA: CCC = 0.987
  - Density: CCC = 0.799
- Agreement was poor for ASI for both intra- and inter-observer agreement
  - CCC < 0.200

Clinical Signs vs. CT

CT evaluation for DLSS by a radiologist of the 16 participating working dogs:

- No DLSS evidence: 2 dogs
- Some evidence suggestive of DLSS (foraminal stenosis, spondylosis): 5 dogs
- DLSS evidence definitively present: 9 dogs

- No association between clinical signs of LS pain and CT findings suggestive or definitive for DLSS

Discussion

Discussion

- Study demonstrated:
  - Moderately strong correlation between signs of pain (VAS score) and dysfunction (Functional Assessment Questionnaire) in dogs with LS pain
  - Statistically significant improvement in function in LS pain dogs with core exercises; rested dogs did not improve
  - Trend towards (but not significant) improvement in LS pain in both rested and exercised dogs
  - Significantly reduced multifidus cross-sectional area, density and asymmetry index in dogs with LS pain vs. control dogs
  - Significant increase in multifidus muscle cross-sectional area and density in response to an 8-week core conditioning program

Discussion

Clinical Findings of LS Pain vs. CT Image Assessment

- This study supports the historically poor correlation
- Additional factors:
  - Breeds in this study – structural characteristics?
  - CT vs. MRI for complete analysis of the lumbosacral region
  - These areas warrant further investigation but it may be that LS pain could be a more reliable evaluation tool for comparing to function and determining response to interventions
  - However, poor correlation between VAS score and function assessment at the post-exercise period
- Findings highlight the need for more reliable objective outcome measures
  - Validation of the functional questionnaire
  - Further assessment of goniometric tail angle and pressure algometry

Muscle CSA and ASI Measurements

- Consistently, multifidus lumborum appears to be the most often affected muscle group for
  - reduced muscle size and symmetry (Danneels *et al.*, 2000, Hides *et al.*, 2008, Kamaz *et al.*, 2007)
  - response to exercise in people with CLBP (Hides, 2008)
  - Both findings also present in dogs in this study

Muscle CSA and ASI Measurements

- Human response of paraspinal muscles to exercise programs designed to strengthen them – variable.
- Subcategorization of CLBP may help guide management
  - Characteristics of CLBP most likely to respond to exercise regimen: mechanically-induced pain and adaptive movement impairments (O'Sullivan, 2005)
    - Other subcategories: pathological source (IVDD) or psychologically/socially driven abnormal movements
  - DLSS: Better identification of mechanisms behind pain and functional deficits may help guide therapeutic intervention
- Other significant changes (increased ASI in control dogs' gluteus medius without corresponding CSA differences)
- ASI reliability questionable given large variation and lack of investigation of disease lateralization– results should be interpreted with caution

Muscle Density Measurements

- Density in Hounsfield Units (HU) can provide indications of tissue type with CT evaluation
- Muscle has more density (higher number in HU) than fat
- Muscle loss with aging (sarcopenia)
  - Loss mainly Type II fibers – replacement with fat and connective tissue
  - Slow neurogenic process
- Human psoas major evaluated via CT at various ages (Imamura *et al.* 1983)
  - Men and Women from ages 10-39: approx 60-65 HU
  - Men and Women from ages 40+: approx 45-50 HU
- Atrophy associated with CLBP and DLSS?
- If so, results suggest this can be improved for multifidus lumborum with core strengthening exercises.

Limitations:

- Small study population
- Logistics – limitations on personnel available to handle and work with the dogs, handler requirement
- Delay between pre-screening and VAS/Functional assessments
- Dogs evaluated were all in lean body condition, impeding good visualization of muscle borders
- MRI more appropriate for soft tissue analysis for DLSS diagnosis and for muscle border identification

Conclusions

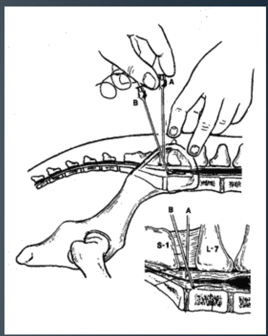
- Results of this ~~study~~ indicate that, like people with CLBP, dogs with LS pain demonstrate evidence of atrophy of the lumbar multifidus and longissimus group (sacrocaudalis dorsalis) epaxial muscles.
- Dogs with LS pain can achieve functional improvement for tasks required during detection duties and an increase in area and density of the lumbar multifidus muscles can be achieved with a core conditioning program in dogs with mild to moderate lumbosacral pain without neurological deficits.

Where do we go from here?

- Prospective, blinded investigation of objective outcome measures for lumbosacral pain:
  - Goniometric tail hyperextension angle
  - Pressure algometry
  - Functional Assessment Questionnaire
- Structural analysis of breeds
  - CT characteristics at L7-S1
- Electromyography
  - muscle activation patterns
- Variations of exercise program
  - added resistance to optimize effects on LS pain and muscle area
  - Multi-modal non-surgical treatment?
  - Prevention strategy with core conditioning?

DLSS: Additional Potential Conservative Treatments

- Epidural corticosteroid injections:
  - Janssens et al, 2009: Retrospective
  - 1mg/kg methylprednisolone acetate epidurally at L7-S1
  - Injections at t=0, 2 weeks and 6 weeks
  - Dogs were without proprioceptive deficits or HL orthopedic disease (n = 38)
  - Owner follow-up (range, 5-66 months) indicated 79% were improved and 53% were resolved
- Extracorporeal Shock Wave Therapy
  - No evidence basis in the literature at this time for use with DLSS
  - Anecdotally, may be a component of multimodal pain management
- LASER?
  - Enclosed SC versus post-hemilaminectomy
  - Dog size vs. rat models in nerve regeneration studies



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- Should this be "and"?
- Identical with reference 14
- In reference 15 (Miller) the editor is listed at the end, here he is listed in the middle. Should probably be consistent.

Questions?