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TITLE: Lumbar Spine Musculoskeletal Physiology and Biomechanics During Simulated Military Operations

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14. ABSTRACT This study evaluated the relationship between 3D geometry of the lumbar spine, under different positions, and the pathophysiology of the intervertebral disc and lumbar trunk muscles. 43 Marines were scanned using upright MRI in operationally relevant loading conditions with minimum operational load, 39 of these Marines were also scanned in a high-resolution MRI to assess muscle and disc physiology. Local changes in posture were found in sitting and prone on elbows positions. A caudal increase in fat fraction of the multifidus was observed. No significant correlations were found between disc injury, low back pain, and muscle pathophysiology. Erector spinae fractional anisotropy was found to be a significant predictor of lumbar posture; increased fractional anisotropy predicts straighter, forward leaning posture.					
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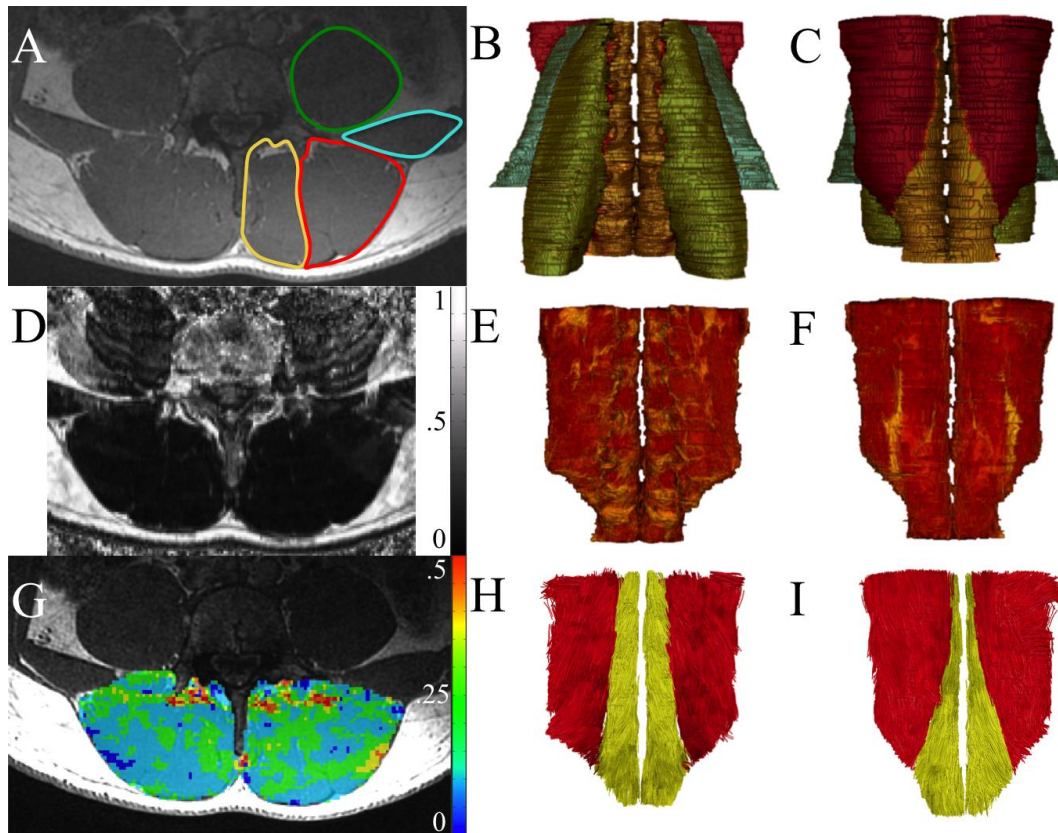
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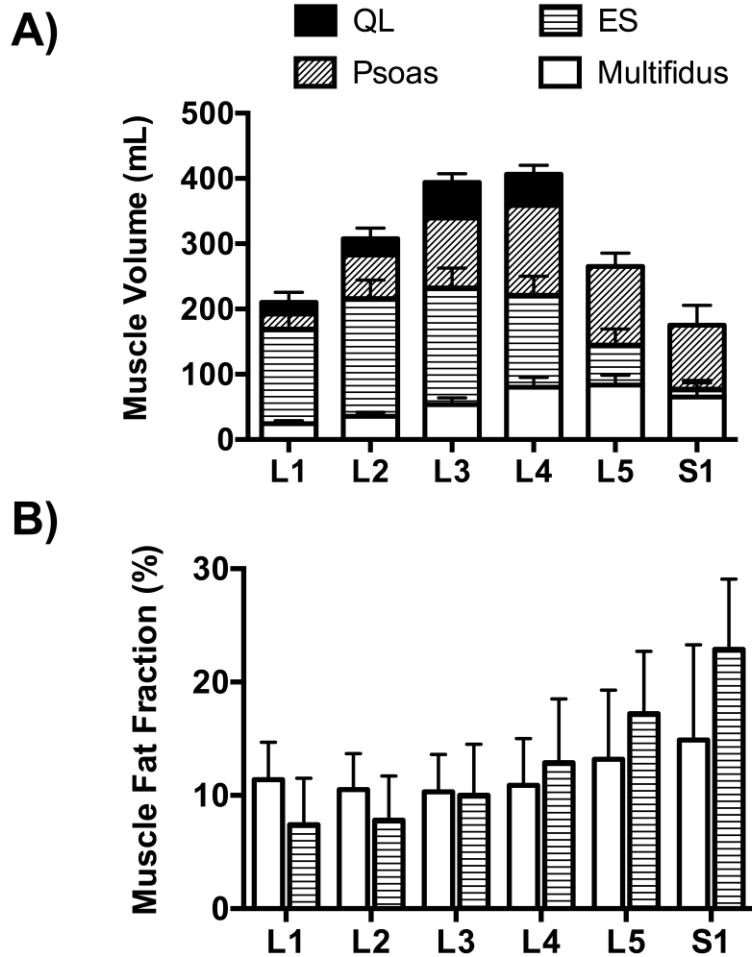
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1. **INTRODUCTION:** The weights of loads carried into battle pose an injury and performance problem for the US Marines. Marine Corps assault loads range from 44kg for the rifleman to 61kg for the squad leader. These are well in excess of the recommended assault load of 22.7kg; 30% of body weight. Two things are clear: (1) Marines routinely carry more weight than the recommended limit, and (2) the Veterans Administration shows an increasing trend in disabilities related to lower back injury as a result of carrying excessive loads in operational environments. We have implemented new MRI technologies enabling quantification of lumbar spine kinematics under simulated march conditions. From these investigations, we have observed a large number (37.5%) of Marines with some evidence of disc pathology. However, it is unclear if these disc changes, or the expected concomitant muscle changes, are related to kinematic changes in the lumbar spine. Further, it is not known whether pre-existing disc pathology predicts future injury and service life in U.S. Marines. Our central hypothesis is that lumbar disc and muscle degeneration alters the kinematic response of the lumbar spine to functional positions and loads, predisposing individuals to injury.
2. **KEYWORDS:** Spine, Lumbar, Kinematics, Muscle Architecture, Low Back Pain, Position
3. **ACCOMPLISHMENTS:**
 - **What were the major goals of the project?**
 - Major Goal 1: To compare lumbar spine kinematics in simulated operational conditions in Marines with measurable lumbar disc pathology
 - Task 1-Approved IRB Protocols
 - Local IRB Approvals
 - Complete: 01 August 2013
 - HRPO Approvals
 - Complete: 01 August 2013
 - Task 2-Subject battalions identified and coordinated
 - Complete: 01 July 2015
 - 55 Subjects recruited
 - Task 3-Data Collection/Analysis
 - Vertical data acquisition
 - Complete: 14 July 2015
 - 55 Subjects scanned
 - Vertical data analysis
 - Complete: 16 July 2015
 - Major Goal 2: To quantify changes in lumbar spine muscle architecture in Marines with measurable lumbar disc pathology.
 - Task 1-Approved IRB Protocols
 - Local IRB Approvals

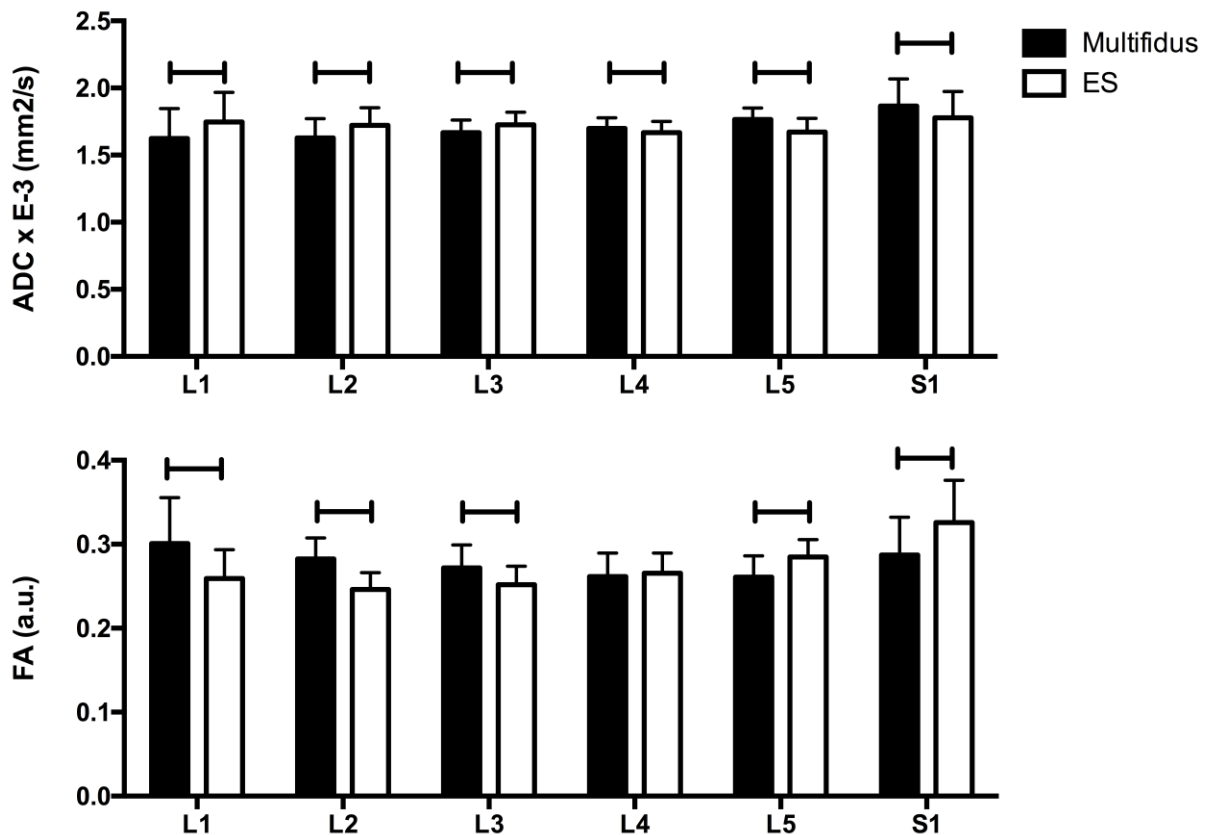
- Complete: 01 August 2013
 - HRPO Approvals
 - Complete: 01 August 2013
 - Task 2-Subject battalions identified and coordinated
 - Complete: 01 July 2015
 - 43 Subjects recruited
 - Task 3-Data Collection/Analysis
 - Vertical data acquisition
 - Complete: 14 July 2015
 - 39 Subjects scanned
 - Supine data analysis
 - Complete: 15 June 2016
- **What was accomplished under these goals?**
- Study 1: NONINVASIVE ASSESSMENT OF PARASPINAL MUSCLE COMPOSITION IN ACTIVE-DUTY MARINES
 - 43 Marines (mean age = 26.8 ± 6.4 years, height = 1.78 ± 0.07 meters, weight = 82.04 ± 9.85 kg., BMI = 25.90 ± 2.86 kg/m²) volunteered to participate for this study. Magnetic resonance images of the lumbar spine (L1-S1) of this group of Marines were acquired using an upright 3T MRI scanner (GE MR350 Discovery, GE Healthcare) and spine array coil. The imaging protocol consisted of 1) an anatomical, 2) fat and water separation scan, 3) diffusion tensor imaging of the LS and 4) T2 mapping of each lumbar intervertebral disc. Anatomic images were imported into Osirix for semi-automatic segmentation. The contours of the multifidus, erector spinae group, psoas and quadratus lumborum muscles were manually traced from L1 to S1. The resulting segmentations were used to generate masks to quantify muscles volume, fat content and diffusion properties. Two subjects dropped out of this study due to claustrophobia in the MRI scanner. Respiratory artifacts were found in 6 masks of the psoas and these data were excluded from analysis. Additionally, breathing artifact was found in the DTI scans of 10 subjects and the data was excluded from analysis.



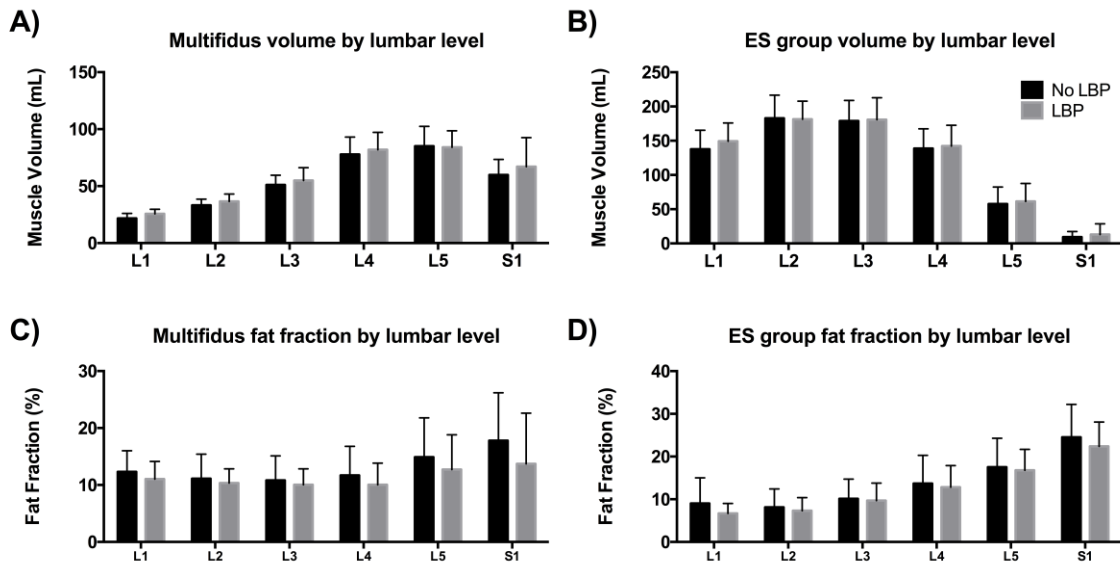
Study 1 Figure 1. **A)** Example of anatomical MR images used for segmentation of multifidus (yellow), erector spinae group (ES, red), psoas (green) and quadratus lumborum (QL, cyan). These segmentations were traced throughout the lumbar spine (L1-S1). **B)** Anterior and **C)** posterior (right) three-dimensional representation of these muscles. **D)** Fat fraction map of the paraspinal muscles. **E)** Anterior and **F)** posterior reconstruction showing fat distribution in multifidus and ES group throughout the lumbar spine. **G)** Fractional anisotropy (FA) map of the multifidus and ES groups overlay on anatomical image. **H)** Anterior and **I)** posterior views of tractography of the erector spinae (red) and multifidus (yellow).



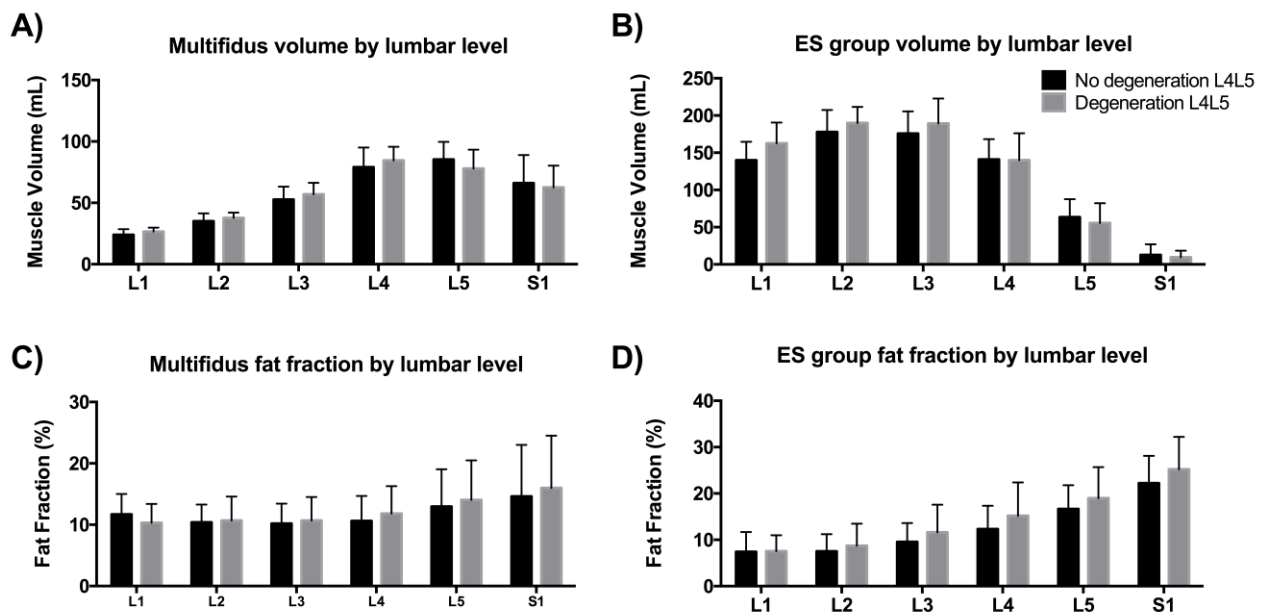
Study 1 Figure 2. A) Muscle volume of the multifidus (white), erector spinae group (ES, horizontal lines), psoas (inclined lines), and quadratus lumborum (QL, black), and **B)** multifidus and ES group fat content by lumbar level (L1-S1). The volume of the ES group was found to be significantly largest ($p < 0.05$) at L2 and L3 (no differences between these two levels), psoas at L4, QL at L3 and L4, and multifidus at L4 and L5 (Fig. 2A). In the superior LS (L1-L4) the largest volume was occupied by the ES group followed by psoas ($P < 0.05$), and finally by multifidus and QL. Contrastingly to superior lumbar levels, at L5 and S1 the ES group was found to be the smallest muscle; while the largest was psoas, which was also significantly ($p < 0.05$) larger than multifidus. Fat fraction of the multifidus was significantly increased at L5 and S1 lumbar levels with respect to the rest of the LS. In the ES, however, the fat fraction significantly increased caudally. The amount of fat fraction present at inferior lumbar levels (L4-S1) was found to be larger ($p < 0.05$) in the ES group, than in the multifidus.



Study 1 Figure 3. Diffusion tensor imaging (DTI) estimates: apparent diffusion coefficient (MD, top) and fractional anisotropy (FA, bottom) for multifidus (black bars) and erector spinae (ES) group (white bars) by lumbar levels. Horizontal lines reflect significant differences between ES muscle group and multifidus muscle. A significant ($p < 0.05$) interaction between muscles (multifidus and ES) and lumbar level were found for MD. The MD of the ES group at L4 and L5 was significantly lower than that of the rest of the spine, while the opposite was found in the multifidus muscle at L5 and S1 levels. Additionally, also in the multifidus, MD was significantly higher at S1 than at L5. Overall, at superior lumbar levels (L1-L3) the MD of the multifidus was smaller ($p < 0.05$) than that of the ES group. Contrastingly, at inferior lumbar level (L4-S1) the MD was significantly smaller in the ES group. A significant interaction between muscle group and lumbar level ($p < 0.05$) were found for FA. In the ES group, FA remained unchanged ($p > 0.05$) from L1 to L4 levels, however at L5 and S1 levels it was significantly higher than the rest of the lumbar levels. Fractional anisotropy was also higher at S1 than at L5. Contrary to these results, FA in the multifidus was found to be significantly lower at L4 and L5 compared to the rest of the lumbar levels. Additionally, FA was different between ES group and multifidus muscle at all levels except L4. In general, FA of the multifidus was higher than that of the ES group from L1 to L4, but lower at L5 and S1.



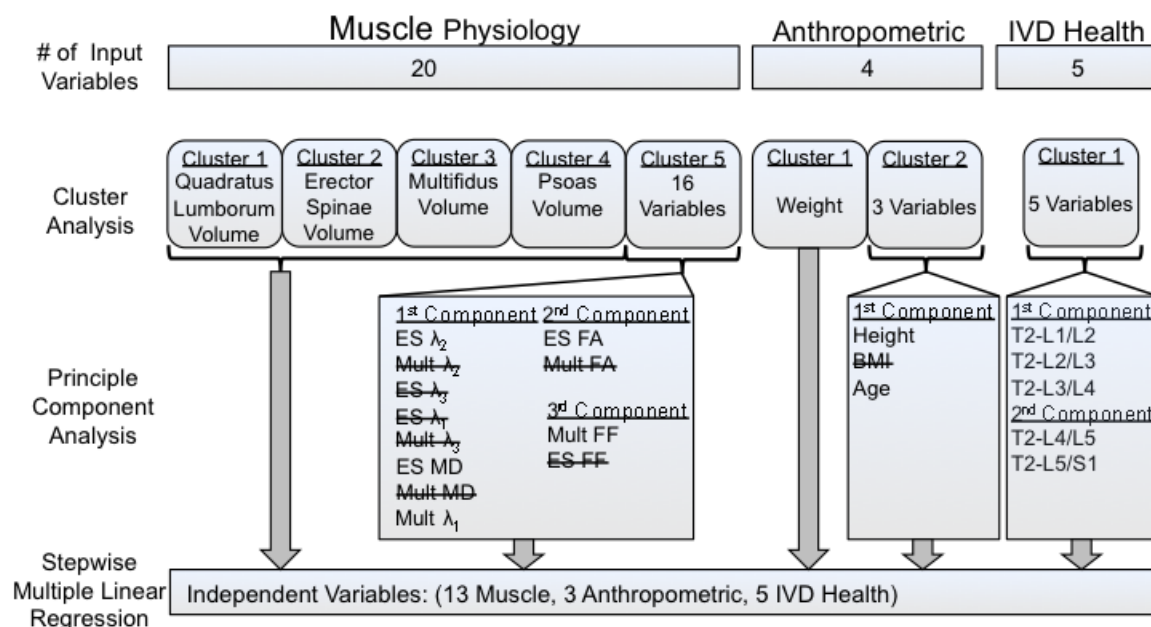
Study 1 Figure 4. Muscle volume and fat fraction of the multifidus (A and C) and ES group (B and D) at lumbar level (L1-S1) by LBP group. No difference in volume or fat fraction of the multifidus or ES when Marines were grouped by low back pain.



Study 1 Figure 5. Muscle volume and fat fraction of the multifidus (A and C) and ES group (B and D) at lumbar level (L1-S1) by L4-L5 degeneration group. No difference in volume or fat fraction of the multifidus or ES when Marines were grouped by L4-L5 intervertebral disc degeneration.

- Study 2: LUMBAR MUSCLE STRUCTURE PREDICTS OPERATIONAL POSTURES IN ACTIVE-DUTY MARINES

- 43 Marines (mean age = 26.8 ± 6.4 years, height = 1.78 ± 0.07 meters, weight = 82.04 ± 9.85 kg., BMI = 25.90 ± 2.86 kg/m²) volunteered to participate for this study. The supine MRI data from STUDY 1 and upright postural MRI data from Berry et al. "Lumbar spine postures in Marines during simulated operational positions" *JOR*, 2017 was used in this study. The purpose of this study is to investigate the predictive capacity of muscle structure, IVD health and anthropometric measures on lumbar spine posture in active-duty Marines.



Study 2 Figure 1. Dependent variables were global postural measurements (angle with respect to the horizontal, sagittal Cobb angle, and sacral angle) for all positions (standing unloaded, standing with load, sitting with load, prone on elbows with load) and the change in load and flexion-extension positions (Δ load, Δ position). An *a priori* approach was used to minimize the number of independent variables input into each model. First, independent variables were empirically grouped into 3 separate domains; muscle structure (volume, FF, FA, MD, λ_{1-3}), IVD health (T2-relaxation of each disc), and anthropometric (age, weight, height, BMI) measures. Hierarchical cluster analysis was used to verify domain groupings. Variables that did not cluster were then sorted into like variables (eigenvectors) using principle components analysis (PCA). Within each eigenvector, Pearson's correlation was used to remove collinear variables ($r > 0.8$). For collinear variables, the variable with the smallest eigenvector value was removed in order to remove redundancy of variance across variables. Remaining variables were entered into a stepwise multiple linear regression model for each dependent variable separately, to identify physiologic measures that are predictive of lumbar spine posture. Collinearity was also verified at this point by variance inflation factor. If a variable had a variance inflation factor > 10 it was removed from the model. After initial grouping of independent variables, collinearity resulted in removal of eight of the twenty-nine independent variables from the

model. Collinear variables that were removed included diffusion measurements from either multifidus or erector spinae, erector spinae fat fraction and BMI.

Study 2 Table 1. Results from stepwise multiple linear regression.

Dependent Variables	Significant Independent Variable(s)	Standardized Beta Coefficient	R ²	p
Cobb Angle: Standing Unloaded	none	-	-	-
Cobb Angle: Standing Loaded	Erector Spinae Fractional Anisotropy	0.453	0.205	0.020
Cobb Angle: Sitting Loaded	none	-	-	-
Cobb Angle: Prone on Elbows Loaded	Weight	0.468	0.219	0.016
Cobb Angle: Δ Load	none	-	-	-
Cobb Angle: Δ Position	none	-	-	-
Angle w.r.t. Horizontal: Standing Unloaded	T2-L4/L5	-0.439	0.192	0.025
Angle w.r.t. Horizontal: Standing Loaded	Erector Spinae Fractional Anisotropy	0.514	0.264	0.007
Angle w.r.t. Horizontal: Sitting Loaded	none	-	-	-
Angle w.r.t. Horizontal: Prone on Elbows Loaded	Erector Spinae Fractional Anisotropy	-0.480	0.230	0.013
Angle w.r.t. Horizontal: Δ Load	none	-	-	-
Angle w.r.t. Horizontal: Δ Position	Erector Spinae Fractional Anisotropy	0.455	0.207	0.020
Sacral Angle: Standing Unloaded	Erector Spinae Fractional Anisotropy	0.442	0.195	0.024
Sacral Angle: Standing Loaded	Erector Spinae Fractional Anisotropy	0.587	0.345	0.002
Sacral Angle: Sitting Loaded	none	-	-	-
Sacral Angle: Prone on Elbows Loaded	Erector Spinae Fractional Anisotropy	0.562	0.316	0.003
Sacral Angle: Δ Load	none	-	-	-
Sacral Angle: Δ Position	none	-	-	-

Δ Load: Standing Unloaded-Standing Loaded. Δ Position: Sitting Loaded-Prone on Elbows Loaded
 Results of the multiple regression demonstrated that FA of the erector spinae was a significant predictor of lumbar posture for 7/18 dependent variables measured and explained 20%-35% of the variance for each outcome. In general, increased FA in erector spinae was predictive of increased lumbar lordosis, increased lumbosacral flexion, and increased pelvic tilt. Additionally, decreased T2 relaxation of the L4-L5 IVD was a significant predictor of increased lumbosacral extension when standing unloaded ($p=.025$, $R^2=.192$). When prone on elbows, increasing subject weight was a significant predictor of increased lumbar lordosis ($p=.016$, $R^2=.219$). No muscle volume, muscle microstructure, IVD health or anthropometric measures were significant predictors of posture when subjects were sitting loaded. In this study, we evaluated the relationship between lumbar spine posture and muscle structure, IVD health and anthropometric measures in 31 active duty male Marines in simulated, relevant operational positions and loading conditions. FA of the erector spinae was a significant predictor of 7/18 measures of lumbar spine posture across several different positions. For the standing loaded condition, FA of the erector spinae

was a significant predictor of all three measures of lumbar posture; Marines with increased FA of the erector spinae, had a more lordotic, extended lumbar posture with greater sacral tilt. Muscle volume was not a significant predictor of any postural measurements, despite being a commonly used proxy for muscle strength. Together, the ability of FA to predict postural behavior in several positions along with the absence of association between muscle volume and lumbar spine posture suggests that muscle quality, but not quantity is an important predictor of lumbar spine posture.

- **What opportunities for training and professional development has the project provided?**
 - The grant supported the graduate student researcher stipend for PhD candidate David Berry.
- **How were the results disseminated to communities of interest?**
 - Nothing to report
- **What do you plan to do during the next reporting period to accomplish the goals?**
 - During the next reporting period, we intend on submitting manuscripts for STUDY 1 and STUDY 2 to SPINE and The Journal of Orthopaedic and Sports Physical Therapy respectively.
 - During the next reporting period, we intend on completing data analysis and preparing manuscripts on the following topic: Intervertebral disc kinematics in Active-Duty Marines with and without lumbar spine pathology.

4. **IMPACT:**

- **What was the impact on the development of the principal discipline(s) of the project?**
 - The results of this study may inform a set of load carriage guidelines to be put in place, through changes in training practices, gear design and/or implementation of exercises to strengthen the musculature of the spine. Additionally, the results of this study will allow researchers to better relate the complex 3D geometry of the lumbar spine in subjects with different levels of lumbar disc and degeneration and muscle health. The role of idiopathic lumbar back pain on lumbar spine kinematics will also allow us to investigate differences in the shape of the lumbar spine between a wide range of positions. Finally, the predicative capacity of a noninvasive measure of muscle quality on maladaptive posture in operational conditions may allow clinicians to tailor rehabilitation protocols to prevent injury, and could potentially be used to predict individuals at risk for lumbar spine injury.
- **What was the impact on other disciplines?**
 - Nothing to report
- **What was the impact on technology transfer?**
 - Nothing to report
- **What was the impact on society beyond science and technology?**
 - The broad impact is that the load recommendations determined from this study can be applied to anyone who works with their spine under awkward or loaded positions.

5. **CHANGES/PROBLEMS:**

- **Changes in approach and reasons for change**
 - Nothing to report

- **Actual or anticipated problems or delays and actions or plans to resolve them**
 - Nothing to report
- **Changes that had a significant impact on expenditures**
 - Nothing to report
- **Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**
 - Nothing to report
- **Significant changes in use or care of human subjects**
 - Nothing to report
- **Significant changes in use or care of vertebrate animals.**
 - Nothing to report
- **Significant changes in use of biohazards and/or select agents**
 - Nothing to report

6. PRODUCTS:

- **Publications, conference papers, and presentations**
 - Poster Presentation-Stambaugh JR, Rodriguez-Soto AE, Berry DB, Parra C, Gombatto SP, Palombo L, Kelly KR, Ward SR. Structural adaptations of paraspinal musculature in active-duty Marines with intervertebral disc degeneration. Military Orthopedic Surgeon Society, Olympic Valley, December 2016.
 - Podium Presentation-Berry DB, Rodriguez-Soto AE, Gombatto SG, Shahidi B, Chung C, Ward SR. "Lumbar spine postures in Marines during simulated operational positions." Orthopaedic Research Society, San Diego, March 2017.
 - Poster Presentation- Berry DB, Rodriguez-Soto AE, Parra C, Stambaugh J, Valaik E, Chung C, Ward SR. "Noninvasive assessment of lumbar muscle architecture in active-duty Marines." Orthopaedic Research Society, San Diego, March 2017.
- **Journal publications.**
 - Rodriguez-Soto AE, Berry DB, Palombo L, Kelly KR, Ward SR. "The effect of load magnitude and distribution on lumbar spine posture in active-duty Marines. *Spine*, 2016; 42(5).
 - Rodriguez-Soto AE, Berry DB, Jaworski R, Jensen A, Chung CB, Niederberger B, Qadir A, Kelly KR, Ward SR. "The effect of training on lumbar spine posture and intervertebral disc degeneration in active-duty Marines" *Ergonomics*, 2016.
 - Berry DB, Rodriguez-Soto AE, Su J, Gombatto SP, Shahidi B, Palombo L, Chung C, Jensen A, Kelly KR, Ward SR. "Lumbar spine postures in Marines during simulated operational positions" *Journal of Orthopaedic Surgery*, 2017.
- **Books or other non-periodical, one-time publications.**
 - Nothing to report
- **Other publications, conference papers, and presentations.**

- Nothing to report
- **Website(s) or other Internet site(s)**
 - Nothing to report
- **Technologies or techniques**
 - Nothing to report
- **Inventions, patent applications, and/or licenses**
 - Nothing to report
- **Other Products**
 - Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

- **What individuals have worked on the project?**

Name:	David Berry
Project Role:	Graduate Student
Researcher Identifier (e.g. ORCID ID):	0000-0001-8275-8322
Nearest person month worked:	12
Contribution to Project:	<i>Mr. Berry has participated in upright MRI data collection, data analysis and interpretation of results</i>
Funding Support:	
Name:	Ana Rodriguez-Soto
Project Role:	Graduate Student
Researcher Identifier (e.g. ORCID ID):	0000-0002-9544-547X
Nearest person month worked:	12
Contribution to Project:	<i>Ms. Rodriguez-Soto has participated in supine data collection, data analysis and interpretation of results</i>
Funding Support:	UC MEXUS-CONACYT Doctoral Fellowship Cohort2010

Name:	Dr. Karen Kelly PT, PhD
Project Role:	Primary Investigator
Researcher Identifier (e.g. ORCID ID):	0000-0001-8003-6123
Nearest person month worked:	6
Contribution to Project:	<i>Dr. Kelly has assisted with subject recruitment, subject scheduling, subject consent, and interpretation of results</i>
Funding Support:	<p>Award #new award 03/01/2015-09/30/2016 2.4 calendar Office of Navy Research Program Evaluation of SEAL Delivery Vehicles Unit Level Training The primary aim of this project is to describe the physiological, physical, cognitive and sleep changes that occur during unit level training in a specialized military operational specialty.</p> <p>Award #N1421 10/01/2014-09/30/2015 2.4 calendar Army Special Operation Command Validating Gender-Neutral Standards for Army Special Forces (SFAS) and Ranger (RASP) Selection The primary aims of this project are (1) To determine whether the selection criteria for entry into SFAS/RASP training are accurate predictors of success during SFAS/RASP training; and (2) To establish task-dependent selection and training criteria, which could then be viewed as “gender neutral,” thus meeting the directive of the Secretary of Defense.</p> <p>Award #N1336 09/01/2013-06/30/2015 9.0 calendar Naval Special Warfare-WARCOM 265,000.00 Validating Gender-Neutral Standards for SEAL and SWCC Selection The primary aims of this project are (1) To determine whether the selection criteria for entry into SEAL/SWCC training are accurate predictors of success during SEAL/SWCC training; and (2) To establish task-dependent selection and training criteria, which could then be viewed as “gender neutral,” thus meeting the directive of the Secretary of Defense.</p>

	<p>Award #N1324 03/01/2013-09/30/2016 0.6 calendar Office of Navy Research Independent Evaluation of the ETOWL software program The Office of Navy Research funded Iowa University to develop a virtual Marine that will predict the effect of load on physiological and biomechanical parameters. This project aims to independently test the developed software using “live” active duty military personnel to determine the accuracy of the software program.</p> <p>Award #N1310 03/01/2013-09/30/2016 2.4 calendar Program Manager-Infantry Combat Equipment Personal Protection Equipment Development The purpose of this project is to test a prototype of a novel plate carrier system against the existing plate carrier system in a variety of different load conditions as well as in various environments.</p> <p>Award #N1305 02/01/2012-09/30/2015 1.0 calendar Congressionally Directed Medical Research Programs Lumbar Spine Musculoskeletal Physiology and Biomechanics During Simulated Military Operations The purpose of this project is to determine if lumbar disc and muscle degeneration alters the kinematics response of the lumbar spine to functional positions and loads, predisposing individuals to injury.</p> <p>Award # N1301 10/01/2012-09/30/2015 0.6 calendar Naval Special Warfare-Center Evaluation of VASPER The purpose of this project is to evaluate whether the VASPER system can be used as an adjunctive mode of training in U.S. Navy SEALs.</p> <p>Award # 21A839 03/01/2012-12/30/2015 1.0 calendar Naval Special Warfare-Group 1 Androgen Deficiency in Navy SEALs The purpose of this project is to identify risk factors associated with hormonal imbalance in our elite forces. The study address caloric intake, expenditure, sleep hygiene, alcohol consumption as well as lifestyle choices that may</p>
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	<p>influence hormone production in Navy SEALs.</p> <p>Award # 21A843 09/30/2012-9/30/2015 0.4 calendar Naval Special Warfare-Group 1 Warrior Development The purpose of this project is to identify risk factors associated with decrements in performance and to evaluate means by which to improve the Special Warfighter.</p> <p>Award # N1263 09/30/2012-09/30/2016 0.6 calendar Space and Naval Warfare Systems Command Bureau of Medicine and Surgery Prescriptive Exercise Therapy Program to Reduce Hyper-arousal in Residential Treatment for Active Duty Service Members Diagnosed with Post-Traumatic Stress Disorder To improve the quality of exercise/physical training the service members are receiving while at OASIS, as well as to develop a new exercise program and assist in training the staff at OASIS to maintain the quality of physical training after the project is complete. It is hypothesized that with better exercise and physical training there will be improvements in symptoms of PTSD, better compliance with exercise, increased mood and thus functionality of the persons obtaining treatment at OASIS.</p>
Name:	Dr. Sara Gombatto PT, PhD
Project Role:	Project Advisor
Researcher Identifier (e.g. ORCID ID):	0000-0002-8284-4789
Nearest person month worked:	3
Contribution to Project:	<i>Dr. Gombatto has assisted with upright MRI data collection and interpretation of results</i>
Funding Support:	University Grants Program, San Diego State

Name:	Dr. Samuel Ward PT, PhD
Project Role:	Primary Investigator
Researcher Identifier (e.g. ORCID ID):	0000-0002-4470-155X
Nearest person month worked:	6
Contribution to Project:	Dr. Ward has assisted with project oversight and interpretation of results
Funding Support:	<p><u>Ongoing Research Support</u></p> <p>R01 HD073180-01A1 (PI: Ward) 04/01/2013 – 03/31/2018 NIH/NICHD</p> <p>The Physiological Basis of Rotator Cuff Muscle Rehabilitation</p> <p>The goal of this project is to elucidate the structural, mechanical, and physiological consequences of tendinopathy-related muscle atrophy and degeneration after rotator cuff tears in humans. Architectural, passive mechanical, and gene expression profiles will be measured and compared amongst patients with different rotator cuff tear severities.</p> <p>2012-5219 PR120576 (PI: Ward) 09/30/2013 – 09/29/2016 DoD (PRMRP/CDMRP)</p> <p>Lumbar Spine Musculoskeletal Physiology and Biomechanics During Simulated Military Operations</p> <p>The goals of this project are to; 1) understand lumbar spine and lumbar disc kinematics during simulated operational conditions, 2) understand the effect of load and body position on spine and disc kinematics when pathology is present, and 3) understand the influence of muscle structure and physiology on lumbar spine kinematics.</p> <p>2R01HD031476-11A1 (PI: Kaufman [Mayo], Sub CO-PI: Ward) 07/01/2011 - 06/30/2016 NIH/NICHD</p> <p>Microsensor for Intramuscular Pressure Measurement</p> <p>The purpose of this grant is to develop a miniature pressure transducer to measure tissue fluid pressure in skeletal muscle and then to determine the effects of muscle architecture, fascia, limb orientation and type of activation on pressure. The study employs the rabbit tibialis anterior muscle model and consists primarily of in situ muscle physiological experimentation combined</p>

	<p>with continuum mechanics modeling.</p> <p>A6239R (PI: Lieber, CO-I: Ward) 10/01/2012-09/30/2016 Veterans Medical Research Foundation Mechanical Basis for Tensioning Tendon Transfers The purpose of this proposal is to measure the <i>in vivo</i> properties of muscles commonly used in tendon transfer surgery. We propose to develop a new instrument for measuring sarcomere lengths intraoperatively and to assess post-operative function in these patients.</p> <p>1P30AR061303 (PI: Lieber, Core-Director: Ward) 09/01/2011-08/31/2016 NIH (NIAMS) San Diego Skeletal Muscle Research Center The purpose of this Center is to establish a consortium of skeletal muscle scientists between UC San Diego, Sanford-Burham, the Scripps Research Institute, and San Diego State University. The Center provides education, pilot funding, and direct scientific support.</p> <p>R01 AR057836 (PI: Thomopolus/Galatz Wash U, Sub PI: Ward) 09/15/2010 – 06/30/2015 NIH/NIAMS Rotator Cuff Degeneration and Repair. The purpose of this study is to measure the passive mechanical and related protein changes in rat skeletal muscle after rotator cuff tears.</p> <p>2 R24 HD050837 (Co-PI: Lieber, Ward) 09/15/2005 - 07/31/2015 NIH/NICHD “National Center for Muscle Rehabilitation Research.” The purpose of this grant is to provide a resource to the rehabilitation professionals to perform state-of-the-art muscle experiments. Disciplines include physiology, microscopic imaging, MR imaging and clinical measurements. In addition, the Center provides sabbatical opportunities and pilot project support to rehabilitation professionals interested in skeletal muscle research.</p> <p>5 R01 AR057393 (Co-PI: Lieber, Ward) 7/01/2010 – 6/30/2015</p>
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	<p>NIH/NIAMS</p> <p>“Muscle Biological and Biomechanical Response in Cerebral Palsy.”</p> <p>The purpose of this proposal is to understand the changes that occur in muscles after contracture formation and to test conservative treatment options. This is due to the large number of children with CP seen in the rehabilitation setting and the number who undergo surgical correction for contracture (making their muscle tissue available)</p> <p>R01 AR057013-01A1 (PI: Ward, Samuel) 07/01/2009 – 06/30/2014</p> <p>NIH/NIMAS</p> <p>Muscle Structure, Toxin Dose, and Exercise Affect Botulinum Toxin Efficiency.</p> <p>The purpose of this grant is to understand the acute and chronic effects of botulinum toxin type A on skeletal muscle structure and function.</p> <p>Experiments include muscle physiology, histology, cellular biology, MRI and bioluminescence measurements.</p>
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- **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

- Nothing to report

- **What other organizations were involved as partners?**

- **Organization Name:** San Diego State University

- **Location of Organization:** San Diego, CA

- **Partner's contribution to the project**

- **Collaboration:** Sara Gombatto PT, PhD. Provided assistance during data collection and data interpretation

8. **SPECIAL REPORTING REQUIREMENTS**

- **COLLABORATIVE AWARDS:** None

- **QUAD CHARTS:** See attached FY1617_QuadChart_W81XWH-13-2-0043

9. **APPENDICES:**

- Quad Chart: FY1617_QuadChart_W18XWH-13-2-0043.pptx



PI: Samuel Ward, Karen Kelly

Org: UC San Diego, NHRC

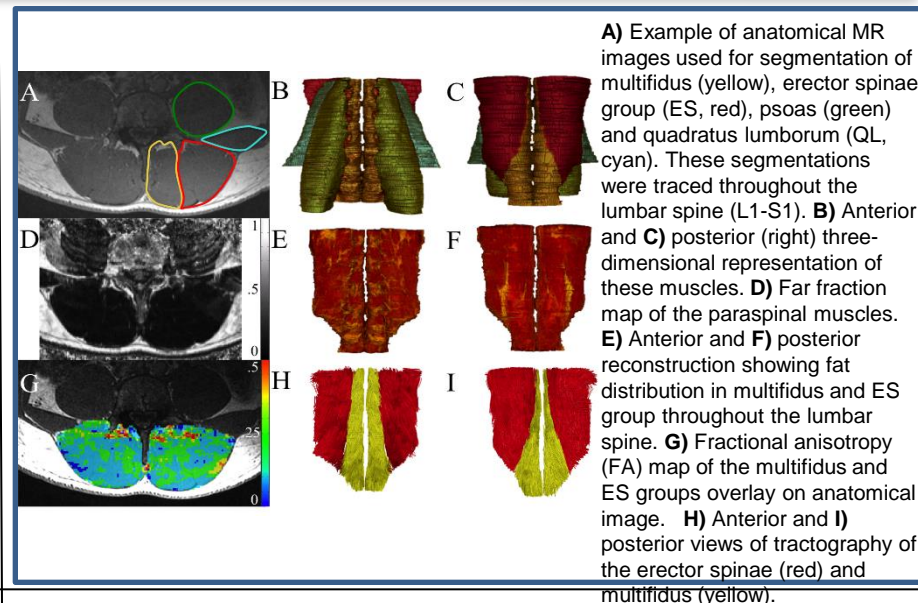
Award Amount: \$1,250,000.00

Study/Product Aim(s)

- To compare lumbar spine kinematics in simulated operational conditions in Marines with measureable disc pathology
- To quantify changes in lumbar spine muscle architecture in Marines with measureable lumbar disc pathology

Approach

Each Marine undergoes high-resolution structural and physiological imaging of the lumbar vertebrae and discs in a high strength (3T) supine MRI. Marines then undergo a 3D imaging protocol in an upright, low strength (0.6T) MRI in standing unloaded, standing loaded (25lb body armor), sitting loaded and prone on elbows positions. To investigate the effect of load magnitude and distribution, some Marines were scanned in standing unloaded and standing loaded conditions (6 conditions: 22kg, 33kg, 45kg x 50/50, 20/80 anterior/posterior). Back pain history is recorded for each subject at time of data collection.



Timeline and Cost

Activities	CY	13	14	15	16	17
Subject Battalion Identification and Coordination		█				
Supine and Vertical MRI Data collection		█				
Data Analysis		█				█
Dissemination of Findings			█			█
Estimated Budget (\$K)		\$168	\$191	\$229	\$80	\$51

Goals/Milestones

CY13 Goal – Initiate subject recruitment/scanning

- Begin acquiring data on minimum 8 subjects

CY14 Goals – Develop measurement tools

- Validate tool for measuring kinematics
- Scan >40 subjects

CY15 Goal – Data Analysis

- Scan remaining subjects
- Analyze data from 80% of the subjects

CY16 Goal – Data Analysis/Disseminate findings

- Correlate kinematic physiologic data
- Disseminate Findings

CY17 Goal – Disseminate findings

- Disseminate Findings

Comments/Challenges/Issues/Concerns

Nothing to Report

Budget Expenditure to Date

Projected Expenditure: \$719,948 total cost (fully expend award through NCE)

Actual Expenditure: \$653,488.07 total cost