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Individuals with Recurrent Low Back Pain Exhibit Significant Changes of Paraspinal Muscle Performance after Lumbar Multifidus Intramuscular Fine Wire Electrode Insertion

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INDIVIDUALS WITH RECURRENT LOW BACK PAIN EXHIBIT SIGNIFICANT CHANGES OF PARASPINAL MUSCLE PERFORMANCE AFTER LUMBAR MULTIFIDUS INTRAMUSCULAR FINE WIRE ELECTRODE INSERTION

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ABSTRACT

STUDY DESIGN: Case control study.

BACKGROUND: Recurrent low back pain (RLBP) is associated with paraspinal muscle dysfunction. Intramuscular electromyography (EMG) is a common tool for studying activation of the deep lumbar paraspinal muscles such as multifidi muscles, but it is currently currently unclear how muscle performance and activation are affected by the pain and micro-injury associated with intramuscular fine-wire electrode (IFWE) insertion and how it interacts with the presence of RLBP.

OBJECTIVES: The purpose of this study was to examine how IFWE insertion into the lumbar multifidus affects paraspinal muscle strength and endurance in subjects with and without RLBP.

METHODS: Forty subjects aged 18 - 40 were recruited; 20 subjects with a history of RLBP were compared with a group of 20 age-matched controls with no RLBP. Paraspinal extensor strength and endurance were measured under three conditions over three testing days. On Day 1, the baseline condition (BL), we obtained preliminary measures of discomfort, force production, endurance, and muscle activation. On Days 2 and 3, the participants randomly alternated between the two experimental conditions: (i) a wire-in condition (WI) in which the IFWE was inserted and remained within the muscle and (ii) a wire-out condition (WO) in which the IFWE was inserted and immediately removed. Participants were blinded to the order of the fine-wire conditions. Subjective pain levels were recorded via the Visual Analog Scale at specific time points throughout the testing protocol.

RESULTS: Individuals with RLBP showed a significant decrease in strength in both conditions that involved IFWE insertion. Controls showed no significant difference in strength across conditions. Both groups exhibited similar performance in the endurance test.

CONCLUSION: Our findings indicate IFWE insertion into lumbar multifidus may lead to reduced peak spinal extensor muscle force production in individuals with a history of RLBP compared to healthy controls.

LEVEL OF EVIDENCE: 2

KEY WORDS: electromyography, low back pain, multifidus

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INTRODUCTION

Low back pain affects 84% of the world's population at some point during the lifespan[1]. Many individuals experience recurrent low back pain (RLBP) and persistent impairments and disabilities such as increased back muscle fatigability[2], decreased strength and endurance[3], and reduced ability to participate in work and leisure compared to those without RLBP. RLPB is often attributed to weakness of local, deep muscles supporting the spine, particularly the lumbar multifidi[4]. The morphology of the multifidi -- a series of small, short fibers that originate at the transverse processes of each vertebrae and attach to the spinous processes 1-2 levels above -- makes them an important intersegmental stabilizer of the spine[4]. In addition to facilitating spinal motions, the multifidi provide dynamic stability to the intervertebral joints during limb and trunk movements. Researchers have studied the effects of their atrophy[4], changes in cross-sectional area[5], neuromuscular control[6], and activation[7] in relation to the occurrence and severity of RLBP.

A common method used to study muscle activation is electromyography (EMG), which records action potential propagation during muscle contraction. Surface EMG (SEMG) electrodes, when used to assess paraspinal muscle activation, collect from a large area and therefore may be subject to "cross talk" from superficial and adjacent muscles. Stokes et al. found that SEMG is susceptible to crosstalk signals from surrounding, superficial musculature during voluntary contraction of the multifidus[8]. The more superficial paraspinal muscles, e.g. erector spinae, act to produce larger movements such as gross spinal extension due to their longer lever arms, while the deeper, intersegmental multifidi have a greater role in spinal stability[9]. The two muscle groups serve different mechanical functions, yet both are recruited and active during lumbar extension[10]. Therefore, SEMG is not ideal for measuring activation of the deeper multifidi muscles. Researchers of RLBP often use intramuscular fine-wire EMG electrodes (IFWE) to specific assess activation of mutifidi.

While SEMG has been shown to be inconsistent in measuring activation of deep spinal muscles such as multifidus when compared to IFWE[8], the use of IFWE may produce unintended side effects due

to the pain and tissue damage caused by insertion of the needle used to guide the IFWE into the target muscle, or the discomfort due to the presence of IFWE during muscle contraction. These factors may alter muscle performance, especially during high levels of exertion. This is especially significant for patients with RLBP who may exhibit altered sensitivity to nociceptive stimuli[11,12]. To validate the use of IFWE insertion for studying multifidus activation during activities that require high level of paraspinal muscle activation, this potentially confounding factor must be investigated.

In addition to altered sensation, it is possible that individuals with RLBP may develop unfavorable beliefs for pain perceptions localized to the lower back region. Waddell et al. discuss the misconception common among individuals with RLBP that pain is readily associated with tissue damage[13]. Nociception, defined as afferent neural activity transmitting sensory information about noxious stimuli, is distinct from pain, which is an interpreted conscious perception that can exist with or without nociception[14]. Pain experienced in individuals with RLBP may not be related to a physical impairment, but rather a psychological or cognitive-behavioral impairment. Fear of reproducing pain and causing further injury can lead people experiencing RLBP to avoid strong paraspinal muscle recruitment.

There is currently no research investigating how the insertion and presence of the IFWE affect muscle performance in individuals with RLBP during high exertion muscle contractions. Therefore, the purpose of this study was to determine how the insertion and presence of IFWE affect paraspinal muscle strength, endurance and muscle activation in this population. This study would improve our understanding of the relationship between focal tissue damage (e.g., IFWE), perceived pain level, and muscle performance in people with RLBP. It is important to investigate these factors since they can confound research findings obtained with the IFWE methods. We hypothesized that IFWE insertion would lead to a greater reduction in lumbar extensor strength in individuals with RLBP. Secondly, we hypothesized that IFWE insertion would also lead to reduced lumbar extensor endurance in individuals with RLBP. Finally, we hypothesized that the percent muscle activation of the lumbar extensors during the first and last 30 seconds of the Sorensen's Test (ST) would not differ between groups.

METHODS

Subjects

Forty subjects participated in the study (22 male, 18 female). The required number of subjects (20) for each group (control and RLBP) was calculated ($\alpha = 0.05$ and $\beta = 0.95$) with G*Power software based on effect size estimated from da Silva et al.[2,15] regarding paraspinal muscle performance in individuals with and without RLBP. Subjects were recruited as a sample of convenience and provided written consent prior to participating. Subjects were included in the RLBP group if they were between the ages of 18 and 40, had a history of recurrent episodes of LBP defined as at least two functionally limiting episodes in the last 6 months, and a current report of visual analog scale (VAS) pain score of 0.5/10 cm or less[16]. The pain level at the time of testing is important to ensure pain did not inhibit muscle activation. Subjects were included in the control group if they were in the same age group and had no history of LBP in the last 6 months that required activity modification or medical care. Exclusion criteria are detailed in Table 4. Subjects were informed of their right to withdraw from the study at any time. The study protocol was approved by the Institutional Review Board of University of Nevada, Las Vegas for Biomedical Research.

Prior to performing the muscle tests, subjects in the RLBP group completed the Fear-Avoidance Beliefs Questionnaire (FABQ) and the Oswestry Disability Index (ODI) to obtain a subjective level of disability during everyday life activities[13,17]. Pain level and laterality of prior LBP episodes were recorded. Each subject's pain level was assessed at different time points during the experiment using the VAS as shown in Table 1.

Instrumentation

The Humac Norm™ Isokinetic Extremity System (Humac Norm Isokinetic Extremity System; Computer Sports Medicine, Inc., Stoughton, Massachusetts) was used to measure spinal extensor

strength**.** A Delysis Trigno™ Wireless system (Delsys Trigno Wireless System; Delsys, Inc., Natick, Massachusetts) was used to collect SEMG data. Each sensor had four silver contact electrodes with an inter-electrode distance of 10 mm. EMG signals were collected at a sampling rate of 2000 Hz using a data acquisition software (Vicon Nexus 2, Vicon Motion Systems, Ltd. Oxford, UK). To insert the intramuscular fine wire electrodes (paired hook-wire, insulated nickel alloy wires; Natus Neurology), a 27 gauge, 30 mm hypodermic guide needle was used (Natus Neurology).

Procedure

Participants attended three separate days of testing. Each testing day was scheduled 7 to 14 days apart to allow muscle soreness, tissue damage, and effects from the previous session to resolve. Subjects were rescheduled if they reported more than 0.5/10 of pain or soreness on the VAS scale.

On Day 1, the baseline condition (BL), we obtained preliminary measures of discomfort, force production, endurance, and muscle activation. On Days 2 and 3, the participants randomly alternated between the two experimental conditions: (i) a wire-in condition (WI) in which the IFWE was inserted and remained within the muscle and (ii) a wire-out condition (WO) in which the IFWE was inserted and immediately removed (Table 2).

EMG Placement

The participants were asked to lay prone on the treatment table with the low back region exposed. Skin over the paraspinal muscles was abraded and disinfected with an alcohol wipe, and the SEMG was placed over the muscles at the level of the L4 vertebrae. On Day 2 and 3, a diagnostic ultrasound imaging unit was used to identify the lumbar multifidus muscle and to insert the IFWE housed within a guide needle into the deep fibers of multifidus (L4 level). The use of real-time sonographic video allowed precise placement of the IFWE at proper depth of the multifidus muscle (Figure 1). One investigator performed all insertions. Following placement of the IFWE, the participant was asked to perform low level active lumbar extension to set the electrodes in the muscle. The SEMG was placed to the right of the

spinous process, and the IFWE was inserted on the left side of all subjects. The subjects were informed they may or may not feel the placement of the IFWE. For both WI and WO, all subjects were instructed to avoid lumbar flexion when transferring between tasks to avoid IFWE egression.

Back Extension Strength Assessment

Performance testing began with the back extension strength assessment. The participant laid prone on the table with ankles and lower thighs secured to the table with straps (Figure 2). One researcher held the participant's ankles to provide additional support during testing. The axis of the dynamometer was aligned with the L4 vertebral body[18] (Figure 2). The participant was instructed to place their hands behind their head to allow placement of the dynamometer lever just inferior to the spine of the scapula. The participant performed a submaximal practice trial followed by three, 5-second trials of MVIC into back extension. Each MVIC trial was separated by a 1-minute rest period. After strength testing, the participant rested for a period of at least 5 minutes before the endurance test.

Sorensen's Test for Back Extension Endurance

The participant performed ST in a prone position on a platform table with the upper body (trunk above the level of anterior superior iliac spine) unsupported off one end of the table (Figure 3). The participant's legs were supported and secured to the table. A ball attachment was placed around the participant's neck with length of the string adjusted so the spine neutral position coincided with the ball lifted just off a bench below (Figure 3). This was done to provide a visual reference point to both the participant and testers. The start of the test was defined as when the participant assumed a back extension posture position raising the ball off the bench surface. The participant maintained the back extension posture throughout the test. Termination of the test was defined as when the participant volitionally stopped the test or when the ball made contact with the bench surface. Endurance performance was measured as time elapsed using a stopwatch.

Percent Activation Assessment

Lumbar extensor muscle activation was recorded via SEMG placed over the paraspinal muscles at the level of the L4 vertebra. Activation was recorded during all strength and endurance trials for each condition.

Data Analysis

During strength testing, maximum voluntary isometric torque, measured in Newton-meters via the dynamometer, was recorded for all three trials of each condition (BL, WI, and WO). The mean of the subject's peak torque values from 3 trials within each condition was recorded as their average peak torque. The EMG data were analyzed using a customized Matlab program (Mathworks, Inc., Natick, Massachusetts). The EMG data was band-pass filtered using a digital Butterworth filter (4^{th} order, 10-350 Hz), then full-wave rectified. Because ST time varied among all subjects, muscle activation of only the first and last 30 seconds of the test was analyzed. Within each condition, percent activation was calculated assuming that the highest activation level obtained from the strength trials was 100% muscle activation.

Statistical analysis

The characteristics of the two groups were compared using independent t-tests. Two-way (2 by 3) repeated-measures ANOVAs were used to examine the main effects and interaction of group (control vs. RLBP; 2 levels) and condition (BL vs. WI vs. WO; 3 levels) on peak torque, ST time, and percent activation during ST. When significant main effects or interaction were detected, post-hoc comparisons were performed using a pairwise comparison (Bonferroni adjusted) or one-way repeated measures ANOVA to examine the subgroup differences. All statistical analyses were performed using SPSS software version 23.0 with significance levels set at $p < 0.05$.

RESULTS

There were no significant differences in the age ($p = 0.209$), height ($p = 0.944$), weight ($p = 0.981$), and BMI ($p = 0.995$) between the control and RLBP groups (Table 3). Number of episodes of back pain, ODI, FABQ scores for work (FABQW) and physical activity (FABQPA) of the RLBP group are shown in Table 3.

Average Peak Torque

The two-way ANOVA revealed no significant group main effect on average peak torque ($p = 0.788$). However, there was a significant main effect of condition ($p = 0.027$). Further, a significant group-by-condition interaction was observed ($p = 0.001$; Figure 4). Post-hoc analyses showed that within the RLBP group, there was a significant difference across conditions ($p < 0.001$) and that peak torque at BL was significantly greater than both WI and WO (BL: 133.81 ± 47.94 vs WI: 115.63 ± 48.42, $p < 0.001$; BL: 133.81 ± 47.94 vs WO: 116.215 ± 43.49, $p = 0.001$).

Sorensen's Test

The two-way ANOVA on ST time revealed no significant main effects for group ($p = 0.396$). However, a significant main effect was observed among the three conditions ($p = 0.001$). There was no interaction between group and condition ($p = 0.303$). A Bonferroni corrected post-hoc comparison revealed that in both the control and RLBP groups, the ST time at BL was significantly shorter than in WI and WO conditions ($p < 0.05$; Figure 5).

Percent Activation

There was no significant group and condition main effects in muscle activation level during the first 30 seconds of the ST ($p = 0.821$ and $p = 0.141$, respectively) and no significant interaction ($p = 0.413$; Figure 6). Two-way ANOVA analysis on the last 30 seconds also revealed no significant group and condition main effects ($p = 0.522$ and $p = 0.129$, respectively) and no significant interaction ($p = 0.275$; Figure 7). Average percent activation levels during the first and last 30 seconds of ST for all subjects were 48.39% and 55.89%, respectively.

DISCUSSION

This study is the first to specifically investigate the effects of IFWE insertion into the lumbar multifidi on the performance (strength, endurance, and percent activation) of spinal extensors in individuals with and without RLBP. This study provides insight into the validity of IFWE usage in this population and supports a growing body of evidence of altered pain perception in those with recurrent pain. The results support our first hypothesis; IFWE insertion reduced lumbar extensor strength in individuals with RLBP, regardless of whether the IFWE remained within multifidi during the strength test. However, the results do not support our second hypothesis, in that IFWE insertion did not reduce lumbar extensor endurance in individuals with RLBP. Further, our findings suggested that during muscle endurance testing, there was no significant difference in percent activation of the lumbar extensors between the RLBP and control groups, and among the three conditions.

Peak Torque

Smith et al. demonstrated that at low levels of paraspinal activation during gait, individuals with RLBP did not exhibit significant changes in motor behavior following IFWE insertion into the lumbar multifidus when compared to those without back pain[16]. Our findings suggest that at near maximal levels of paraspinal activation, however, IFWE insertion negatively impacts back extensor torque in individuals with RLBP while having no effect on controls. Interestingly, whether the IFWE remained within the lumbar multifidus muscle made no significant difference -- the process of IFWE insertion alone was enough to cause diminished torque in those with RLBP, perhaps due to pain associated with the insertion of guide needle. Indeed, experimentally induced pain has been shown to reduce maximal force in various muscle groups[19–21]. Puta et al. found that when compared to healthy individuals, people with LBP exhibited enhanced sensitivity and hyperalgesia to punctate mechanical pinprick stimuli, a sensation similar to needle insertion[22]. Their study also demonstrated that lower pain thresholds extend far beyond the lumbar region, suggesting supraspinal plasticity or reduced descending control alters pain perception in this population[22]. A number of studies have shown similar results, in which people with LBP exhibit

lower mechanical pain thresholds at sites distant from the lumbar spine[11,23,24], and these changes are again attributed to altered cortical mechanisms[25] such as central sensitization[22]. It appears that over time, the recurrence of back pain episodes may disrupt nociceptive regulation at the spinal level or above, making this population more susceptible to the nociceptive sensation from IFWE insertion.

Although expectations of pain have been correlated with a reduction in physical capacity in people with LBP[13], our subjects had relatively low fear avoidance. The FABQ and ODI, however, relate to activities of daily living, tasks that do not require the near-maximal levels of muscle activation that are required during strength testing. Therefore, psychological factors related to pain perception and avoidance cannot be discounted. FABQ subscale scores have been shown to have little to no correlation with anticipated pain in individuals with LBP[26], and several studies have observed an association between anticipated pain and reduced performance for both submaximal activities[27] and strength testing[26] in this population. Further, Crombez et al. showed anticipated pain-related fear as the best predictor of performance for a trunk extension-flexion task[28]. Therefore, although the RLBP group presented with low FABQ scores, low ODI percentages, and comparable pain ratings to the control group, anticipation of pain and potential resurfacing of fear avoidance may still have contributed to their reduced strength performance.

Sorensen's Test Performance

Regardless of condition, our findings showed that the RLBP and control groups were able to produce statistically comparable Sorensen's test times. This conflicts with findings of a similar study by Beneck et al., in which individuals with RLBP had significantly lower endurance than those without[29]. Both Beneck et al. and the current study inserted IFWE in the lumbar multifidi and used the ST to measure endurance. However, subjects with LBP in Beneck et al. were about 10 years older (34.0 ± 5.4) than those in the current study (24.4 ± 2.9). (Beneck: control 144.4 ± 41.4s, RLBP 87.5 ± 25.5s; current study: control 155.95 ± 58.50s, RLBP 144.25 ± 54.03s.) Endurance as measured by ST has been shown to decline with age[30,31]. The relatively young age of both our groups may explain the small difference

between their Sorensen's test performances.

In the current study, although focal pain incited a reduction in maximal torque in individuals with RLBP, during endurance testing, the paraspinal muscles are only submaximally activated[32], requiring only 40-52% paraspinal muscle activation[21] compared to the near 100% activation required during strength testing. Tucker et al. found that in healthy subjects, submaximal strength was not affected by experimentally induced pain[33]. They suggest the nervous system employs an altered motor unit recruitment strategy to maintain force despite acute, experimentally induced pain[33]. The RLBP group in the current study may have utilized a similar strategy, resulting in little difference between the fatigability of the two groups.

Further, the pre-test instructions for ST may not have amplified anticipated pain to the same extent as the instructions preceding MVIC trials. Prior to strength testing, subjects were instructed to push as hard as they could, while prior to endurance testing, they were told to hold the position for as long as possible. This also provides an explanation for the improved performance seen in ST across the three conditions relative to the reduced performance seen during the back extensor strength test following BL.

Percent Activation

Activation of paraspinal muscles as a percentage of MVIC during the first and last 30 seconds of ST did not significantly differ between groups. Further, the results indicate IFWE insertion does not affect percent activation during these time intervals. This result supports the altered motor unit recruitment strategy described by Tucker et al[33]. Studies have also demonstrated similar results in the absence of experimentally induced pain, attributing the maintenance of performance to flexibility in motor control and motor unit recruitment when muscles begin to fatigue[34]. Regardless, because EMG in the current study was not intended to measure recruitment of individual motor units, it is not possible to distinguish the recruitment patterns between groups. Future research should employ multiple IFWEs into different motor units to investigate differences in recruitment strategies between individuals with and without a history of RBLP.

Limitations

The degree of physical activity present within our subject population was not investigated. Numerous studies examining individuals with LBP control for inconsistencies in the physical fitness of subjects via exclusion criteria, questionnaires, or selective sampling[16,29,35]. Because the experimental tasks used in the study demanded high levels of physical exertion, a subject's physical fitness may have influenced performance and results. Further, the average age of subjects in the current study was lower (24.4 ± 2.95) than the age group that experiences the highest prevalence of RLBP (45-64)[1]. It may have been beneficial to further assess psychological factors associated with LBP. Subjects' fear avoidance behavior was not reassessed following baseline measurements, leaving the potential for re-emerging fear to affect performance under maximal exertion. Similarly, although the subjects' current pain levels were measured, their anticipation of pain was not.

CONCLUSION

Research investigating the effects of IFWE on multifidus in people with RLBP has been limited to evaluating activation during low exertion activities such as endurance testing or walking. In this study, we examined the validity of using IFWE in this population when assessing muscle performance during high-exertion activation. Our findings showed the invasive procedure of IFWE insertion can cause a reduction in strength of spinal extensors during maximal activation. However, IFWE use measuring activation in this population during submaximal contractions, such as with endurance tasks, appears viable. Researchers need to take these factors into consideration when using IFWE in individuals with RLBP.

APPENDIX

TABLE 1. Points of VAS pain score assessment

	Points of Subjective Reports
1.	Upon arrival at the lab
2.	After insertion in both WI and WO conditions
3.	After strength trials 1, 2 and 3
4.	1 minute following the 3rd strength trial
5.	Approximately 1 minute into ST
6.	Following ST completion

Abbreviations: WI, Wire-in; WO, Wire-out; ST, Sorensen's Test

TABLE 2. Testing conditions and order of testing procedure

Day 1: Baseline	**Day 2 or 3: Wire-In**	**Day 2 or 3: Wire-Out**
No insertion	Insertion of IFWE	Insertion and immediate removal of IFWE

Abbreviations: IFWE, Intramuscular fine-wire electrode

TABLE 3. Mean anthropometric characteristics of the two groups.

•	RLBP (n=20)	Control (n=20)	p-value
Age (years)	24.4 ± 2.95	26.7 ± 3.47	0.209
BMI (kg/m^2)	24.77 ± 3.14	24.78 ± 5.03	0.995
Height (m)	1.73 ± 0.09	1.73 ± 0.09	0.825
Weight (kg)	74.15 ± 12.89	74.26 ± 14.33	0.981
Episodes of back pain (within past 6 months)	3.45 ± 2.84	N/A	
FABQW	5.7 ± 6.81	N/A	
FABQPA	8.0 ± 5.51	N/A	
Oswestry disability index (%)	4.2 ± 4.15	N/A	

Abbreviations: RLBP, Recurrent low back pain; FABQW, Fear Avoidance Belief Questionnaire Work subscale; FABQPA, Fear Avoidance Belief Questionnaire Physical Activity subscale

TABLE 4. Exclusion Criteria

1.	Diabetes mellitus
2.	Rheumatic joint disease
3.	Clotting disorder or other bleeding problem
4.	Polyneuropathy
5.	Lower back surgery
6.	Bilateral leg pain
7.	Radiological/clinical diagnosis of spinal stenosis
8.	Radiological/clinical diagnosis of structural scoliosis
9.	Spinal malignancy
10.	Spinal infection
11.	Lumbar radiculopathy
12.	Pregnancy
13.	Fear of needles
14.	Diagnosed immunodeficiency or history of recurrent unexplained infections

FIGURE 1. Axial ultrasound image and schematic demonstrating insertion of the IFWE (and guide needle)

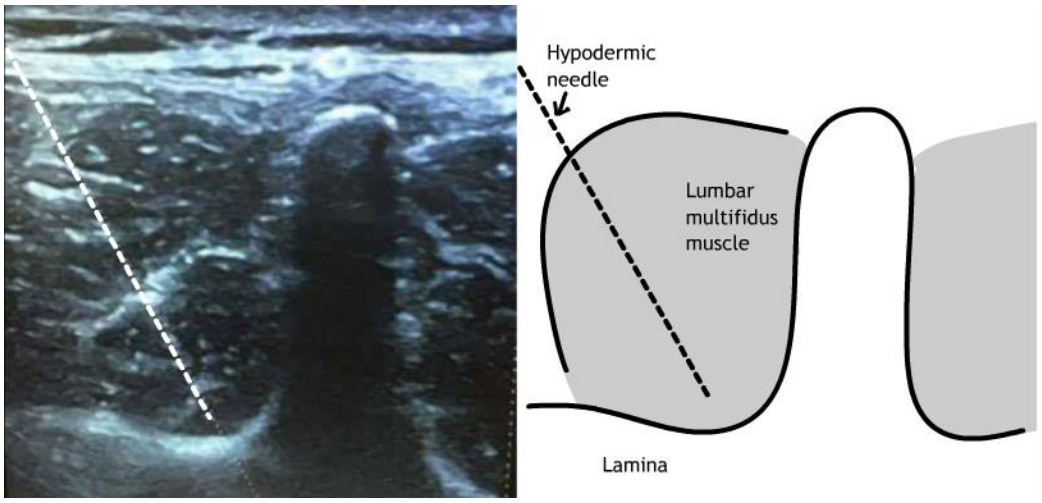


FIGURE 2. Back extension torque test

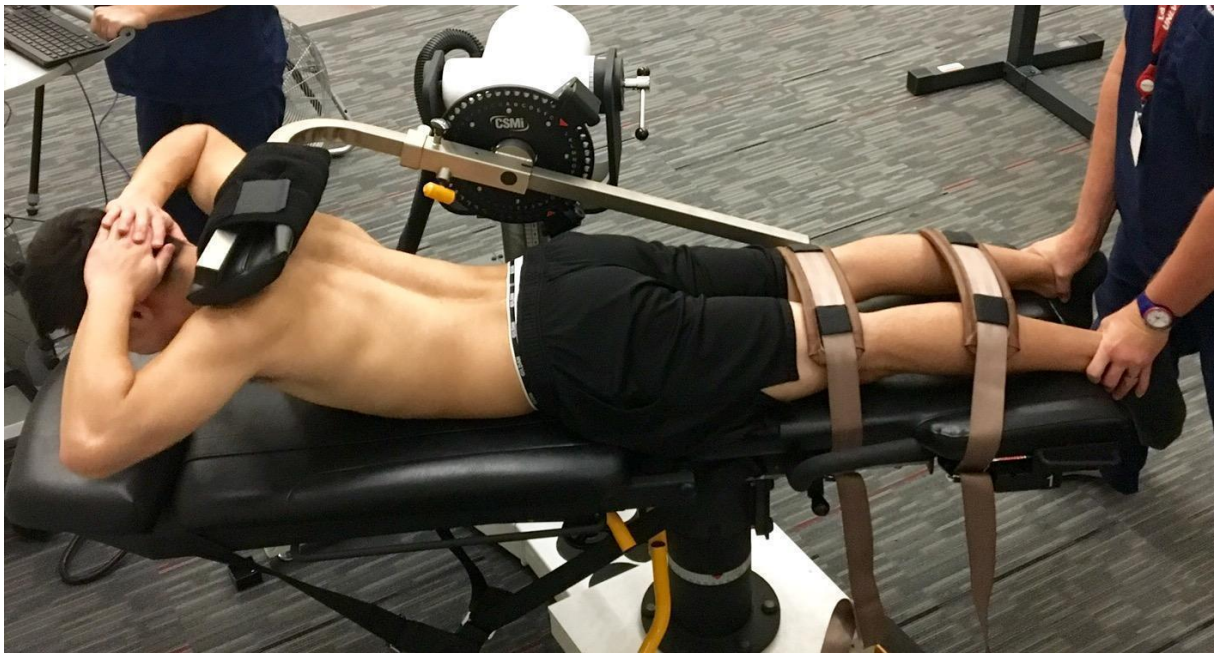


FIGURE 3. Sorensen's Test.

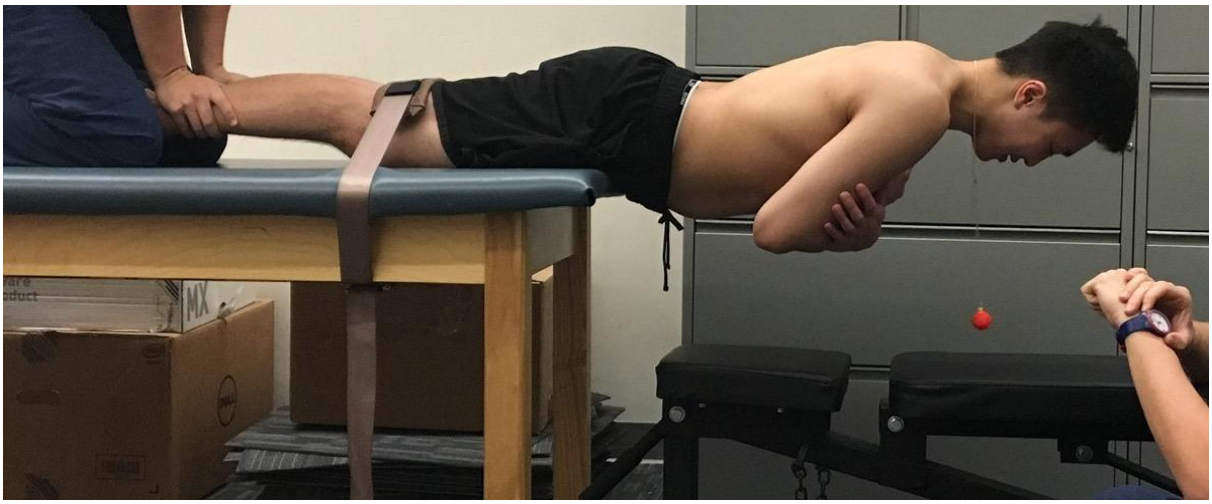


FIGURE 4**.** Mean average peak torque (Nm) of two groups across three conditions

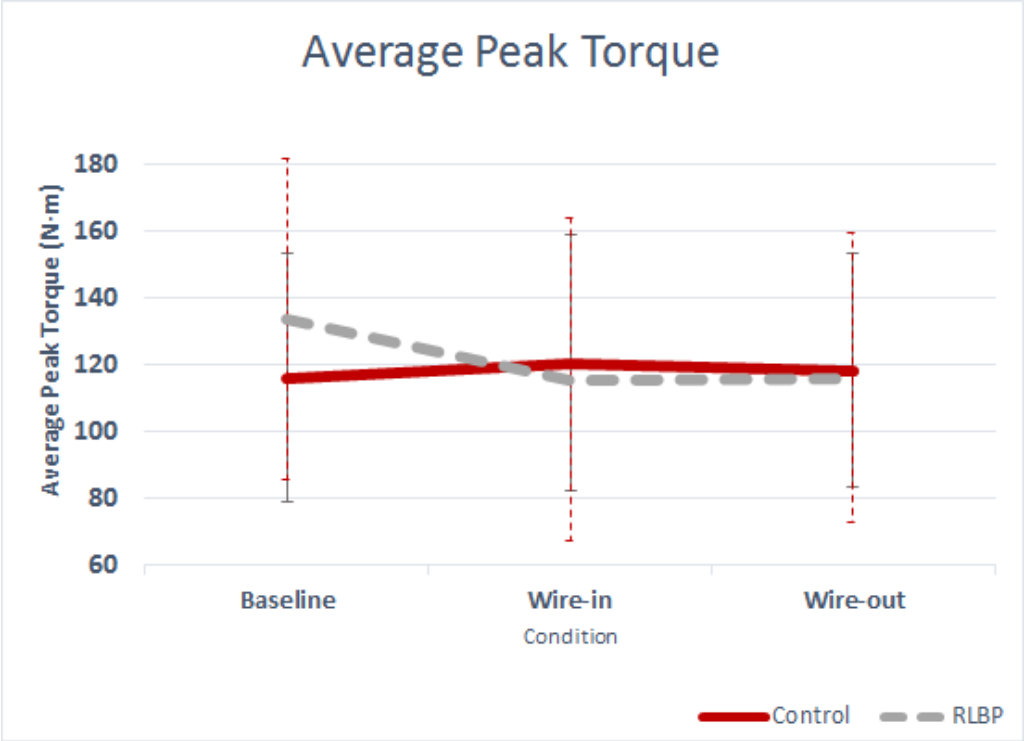


FIGURE 5. Mean ST Time (s) of two groups across three conditions

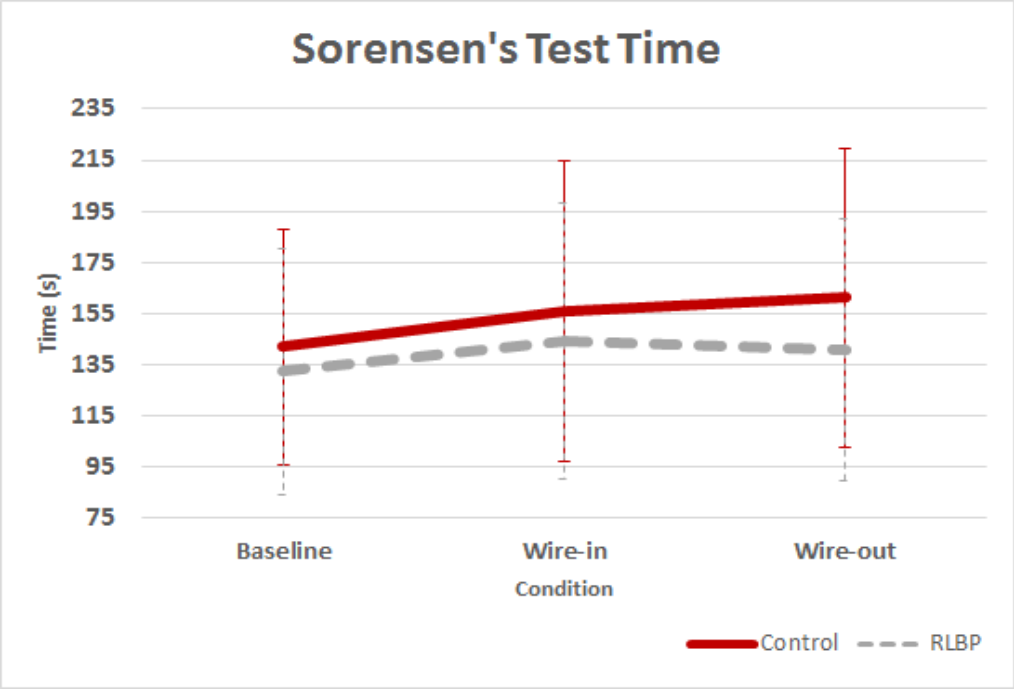


FIGURE 6. Percentage activation of paraspinal muscles as measured by SEMG of two groups across three conditions (during first 30 seconds of ST)

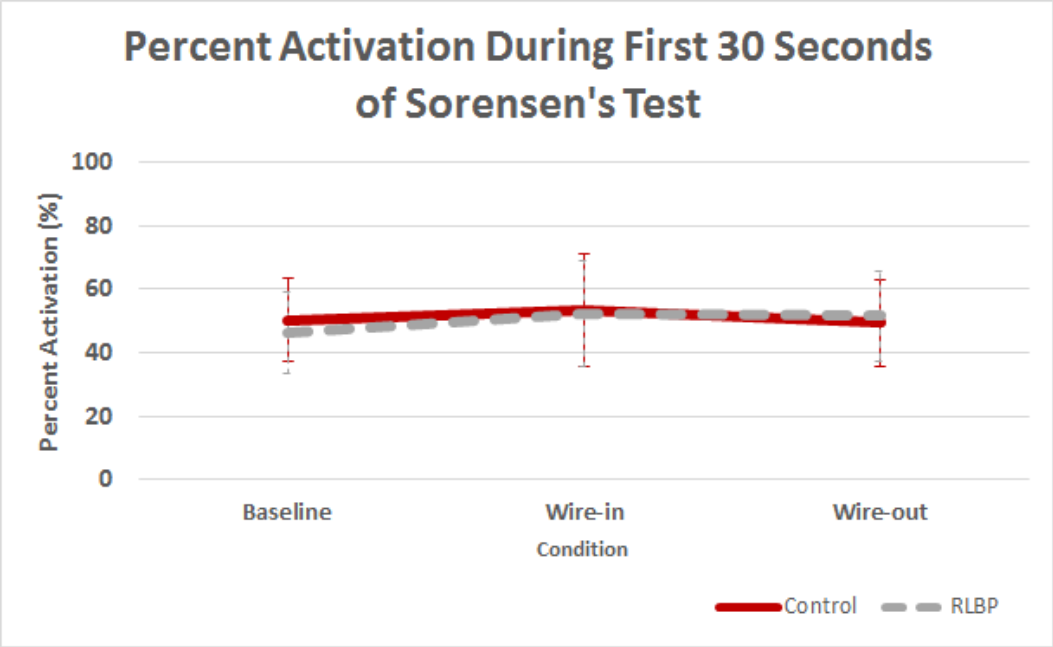
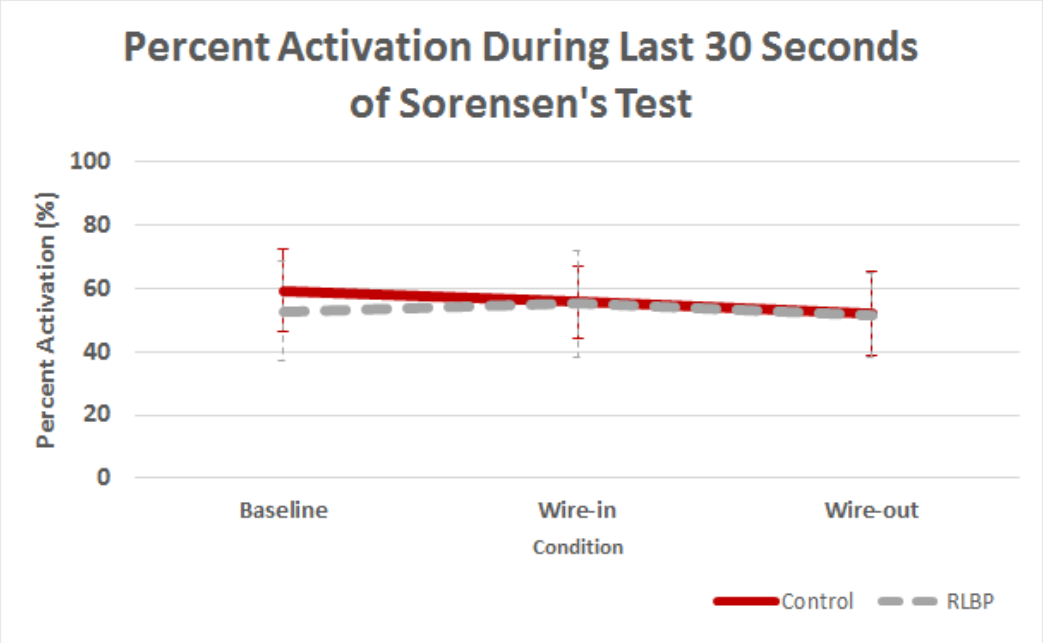


FIGURE 7. Percentage activation of paraspinal muscles as measured by SEMG of two groups across three conditions (during last 30 seconds of ST)



REFERENCES

1. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. *Lancet*. 2012;379(9814):482-491. doi:10.1016/S0140-6736(11)60610-7.
2. da Silva RA, Vieira ER, Cabrera M, et al. Back muscle fatigue of younger and older adults with and without chronic low back pain using two protocols: A case-control study. *J Electromyogr Kinesiol*. 2015;25(6):928-936. doi:10.1016/j.jelekin.2015.10.003.
3. Davarian S, Maroufi N, Ebrahimi I, Farahmand F, Parnianpour M. Trunk muscles strength and endurance in chronic low back pain patients with and without clinical instability. *J Back Musculoskelet Rehabil*. 2012;25(2):123-129. doi:10.3233/BMR-2012-0320.
4. Freeman MD, Woodham MA, Woodham AW. The Role of the Lumbar Multifidus in Chronic Low Back Pain: A Review. *PM&R*. 2010;2(2):142-146. doi:10.1016/j.pmrj.2009.11.006.
5. Hosseinifar M, Akbari M, Behtash H, Amiri M, Sarrafzadeh J. The Effects of Stabilization and Mckenzie Exercises on Transverse Abdominis and Multifidus Muscle Thickness, Pain, and Disability: A Randomized Controlled Trial in NonSpecific Chronic Low Back Pain. *J Phys Ther Sci*. 2013;25(12):1541-1545. doi:10.1589/jpts.25.1541.
6. Lamoth CJC, Meijer OG, Daffertshofer A, Wuisman PIJM, Beek PJ. Effects of chronic low back pain on trunk coordination and back muscle activity during walking: changes in motor control. *Eur Spine J*. 2006;15(1):23-40. doi:10.1007/s00586-004-0825-y.
7. Danneels LA, Coorevits PL, Cools AM, et al. Differences in electromyographic activity in the multifidus muscle and the iliocostalis lumborum between healthy subjects and patients with sub-acute and chronic low back pain. *Eur Spine J*. 2002;11(1):13-19. http://www.ncbi.nlm.nih.gov/pubmed/11931058. Accessed February 12, 2017.
8. Stokes IAF, Henry SM, Single RM. Surface EMG electrodes do not accurately record from lumbar multifidus muscles. *Clin Biomech (Bristol, Avon)*. 2003;18(1):9-13. http://www.ncbi.nlm.nih.gov/pubmed/12527241. Accessed February 12, 2017.

9. Panjabi M, Abumi K, Duranceau J, Oxland T. Spinal stability and intersegmental muscle forces. A biomechanical model. *Spine (Phila Pa 1976)*. 1989;14(2):194-200. http://www.ncbi.nlm.nih.gov/pubmed/2922640. Accessed February 12, 2017.

10. Ng J, Richardson C. EMG study of erector spinae and multifidus in two isometric back extension exercises. *Aust J Physiother*. 1994;40(2):115-121. doi:10.1016/S0004-9514(14)60458-X.

11. Giesbrecht RJ, Battié MC. A comparison of pressure pain detection thresholds in people with chronic low back pain and volunteers without pain. *Phys Ther*. 2005;85(10):1085-1092. http://www.ncbi.nlm.nih.gov/pubmed/16180957. Accessed February 12, 2017.

12. Corrêa JB, Costa LOP, de Oliveira NTB, Sluka KA, Liebano RE. Central sensitization and changes in conditioned pain modulation in people with chronic nonspecific low back pain: a case–control study. *Exp Brain Res*. 2015;233(8):2391-2399. doi:10.1007/s00221-015-4309-6.

13. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain*. 1993;52(2):157-168. http://www.ncbi.nlm.nih.gov/pubmed/8455963. Accessed February 12, 2017.

14. Kandel ER. *Principles of Neural Science*. McGraw-Hill; 2012.

15. Faul F, Erdfelder E, Lang A-G, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191. http://www.ncbi.nlm.nih.gov/pubmed/17695343. Accessed February 12, 2017.

16. Armour Smith J, Kulig K. Does insertion of intramuscular electromyographic electrodes alter motor behavior during locomotion? *J Electromyogr Kinesiol*. 2015;25(3):431-437. doi:10.1016/j.jelekin.2015.01.003.

17. Fairbank JC, Pynsent PB. The Oswestry Disability Index. *Spine (Phila Pa 1976)*. 2000;25(22):2940-52; discussion 2952. http://www.ncbi.nlm.nih.gov/pubmed/11074683. Accessed February 12, 2017.

18. Yoshioka T, Tsuji H, Hirano N, Sainoh S. Motion characteristic of the normal lumbar spine in young adults: instantaneous axis of rotation and vertebral center motion analyses. *J Spinal Disord*. 1990;3(2):103-113. http://www.ncbi.nlm.nih.gov/pubmed/2134418. Accessed February 12, 2017.

19. Graven-Nielsen T, Lund H, Arendt-Nielsen L, Danneskiold-Samsøe B, Bliddal H. Inhibition of maximal voluntary contraction force by experimental muscle pain: A centrally mediated mechanism. *Muscle Nerve*. 2002;26(5):708-712. doi:10.1002/mus.10225.

20. Henriksen M, Rosager S, Aaboe J, Graven-Nielsen T, Bliddal H. Experimental Knee Pain Reduces Muscle Strength. *J Pain*. 2011;12(4):460-467. doi:10.1016/j.jpain.2010.10.004.

21. Salomoni S, Tucker K, Hug F, McPhee M, Hodges P. Reduced Maximal Force during Acute Anterior Knee Pain Is Associated with Deficits in Voluntary Muscle Activation. Ivanenko YP, ed. *PLoS One*. 2016;11(8):e0161487. doi:10.1371/journal.pone.0161487.

22. Puta C, Schulz B, Schoeler S, et al. Enhanced sensitivity to punctate painful stimuli in female patients with chronic low back pain. *BMC Neurol*. 2012;12(1):98. doi:10.1186/1471-2377-12-98.

23. Kobayashi Y, Kurata J, Sekiguchi M, et al. Augmented Cerebral Activation by Lumbar Mechanical Stimulus in Chronic Low Back Pain Patients. *Spine (Phila Pa 1976)*. 2009;34(22):2431-2436. doi:10.1097/BRS.0b013e3181b1fb76.

24. Giesecke T, Gracely RH, Grant MAB, et al. Evidence of augmented central pain processing in idiopathic chronic low back pain. *Arthritis Rheum*. 2004;50(2):613-623. doi:10.1002/art.20063.

25. Wand BM, Parkitny L, O'Connell NE, et al. Cortical changes in chronic low back pain: Current state of the art and implications for clinical practice. *Man Ther*. 2011;16(1):15-20. doi:10.1016/j.math.2010.06.008.

26. Al-Obaidi SM, Beattie P, Al-Zoabi B, Al-Wekeel S. The relationship of anticipated pain and fear avoidance beliefs to outcome in patients with chronic low back pain who are not receiving workers' compensation. *Spine (Phila Pa 1976)*. 2005;30(9):1051-1057. http://www.ncbi.nlm.nih.gov/pubmed/15864158. Accessed February 12, 2017.

27. Council JR, Ahern DK, Follick MJ, Kline CL. Expectancies and functional impairment in chronic low back pain. *Pain*. 1988;33(3):323-331. doi:10.1016/0304-3959(88)90291-6.

28. Crombez G, Vlaeyen JW, Heuts PH, Lysens R. Pain-related fear is more disabling than pain itself: evidence on the role of pain-related fear in chronic back pain disability. *Pain*. 1999;80(1-2):329-339. http://www.ncbi.nlm.nih.gov/pubmed/10204746. Accessed August 27, 2017.

29. Beneck GJ, Baker LL, Kulig K. Spectral analysis of EMG using intramuscular electrodes reveals non-linear fatigability characteristics in persons with chronic low back pain. *J Electromyogr Kinesiol*. 2013;23(1):70-77. doi:10.1016/j.jelekin.2012.07.001.

30. Kankaanpää M, Laaksonen D, Taimela S, Kokko SM, Airaksinen O, Hänninen O. Age, sex, and body mass index as determinants of back and hip extensor fatigue in the isometric Sørensen back endurance test. *Arch Phys Med Rehabil*. 1998;79(9):1069-1075. http://www.ncbi.nlm.nih.gov/pubmed/9749686. Accessed February 12, 2017.

31. Alaranta H, Hurri H, Heliövaara M, Soukka A, Harju R. Non-dynamometric trunk performance tests: reliability and normative data. *Scand J Rehabil Med*. 1994;26(4):211-215. http://www.ncbi.nlm.nih.gov/pubmed/7878396. Accessed February 12, 2017.

32. Demoulin C, Vanderthommen M, Duysens C, Crielaard J-M. Spinal muscle evaluation using the Sorensen test: a critical appraisal of the literature. *Jt Bone Spine*. 2006;73(1):43-50. doi:10.1016/j.jbspin.2004.08.002.

33. Tucker K, Butler J, Graven-Nielsen T, Riek S, Hodges P. Motor Unit Recruitment Strategies Are Altered during Deep-Tissue Pain. *J Neurosci*. 2009;29(35):10820-10826. doi:10.1523/JNEUROSCI.5211-08.2009.

34. Abboud J, Nougarou F, Pagé I, Cantin V, Massicotte D, Descarreaux M. Trunk motor variability in patients with non-specific chronic low back pain. *Eur J Appl Physiol*. 2014;114(12):2645-2654. doi:10.1007/s00421-014-2985-8.

35. Klein AB, Snyder-Mackler L, Roy SH, DeLuca CJ. Comparison of spinal mobility and isometric

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