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by

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Bachelor of Science
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A doctoral dissertation submitted in partial fulfillment of
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ABSTRACT

Ultrasound Imaging of the Lumbar Multifidus Immediately Following Three Physical Therapy Techniques in Asymptomatic Individuals

by

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Study Design

Randomized, blinded, cohort, within subjects design.

Background and Objective

The effects of different manual therapy (MT) techniques on lumbar multifidus (LM) thickness have been investigated in subjects with low back pain (LBP) but have not been investigated in asymptomatic subjects. The objective of this study was to examine the immediate effects of mobilization and manipulation on contraction thickness of LM in healthy individuals.

Methods and Measures

Forty-two healthy individuals participated in the study. Ultrasound imaging techniques were used to record LM thickness (L4-5 level) at rest, during an abdominal drawing in maneuver (ADIM), and during a prone upper extremity (PUEL) lifting task.

Images were taken before and immediately following one of three randomly assigned MT techniques. Participants returned on two subsequent days to receive the remaining techniques, and data was compared to assess the effects of each technique.

Results

A statistically significant interaction was found between treatment, contraction state and time for the PUEL task ($p=0.019$). Post hoc analysis revealed a statistically significant increase in resting muscle thickness following the supine anterior posterior thrust technique ($p=0.005$). No significant differences in muscle thickness were found with the other two techniques at rest or during the PUEL task ($ps \geq 0.887$). This suggests that the supine AP thrust technique causes an increase in resting muscle thickness that does not occur with other MT techniques. For the ADIM data, no interaction among the three variables was found ($p= 0.233$). This suggests that no MT technique changed resting or contracted muscle thickness when the participants performed the ADIM.

Conclusion

Taken together, the findings from this study demonstrate that manual therapy had no effect on resting or contracted thickness in asymptomatic individuals. It may be that the changes in muscle thickness reported in the current body of literature are only observed in patients with LBP and may not occur in healthy individuals.
Key Words: multifidus, manual therapy, manipulation, ultrasound imaging, lumbar spine

Introduction

The role of the lumbar multifidus (LM) in segmental spinal stabilization is well established in current literature and is often a target of physical therapy interventions to address low back pain (LBP). Evidence supports the view that the LM, composed of superficial (SM) and deep fibers (DM), has differing roles in spinal stabilization.[1] Biomechanical analysis of each fiber type suggests that the SM is responsible for controlling segmental rotation and compression of the intervertebral segments whereas the DM is responsible for intervertebral compression but does not change in length with rotation of the spine.[1] This implicates the DM as a primary stabilizer of the spine. It is theorized that the transversus abdominis (TrA) and DM work together via the thoracolumbar fascia to form a corset action around the spine in order to provide lumbar stability.[1-2] Although co-contraction of the TrA and the DM is not considered to be an obligatory action,[1] it has been found to occur involuntarily during general limb movements.[1-7] It has also been theorized that voluntary activation of LM occurs during the abdominal drawing in maneuver (ADIM) in order to stabilize the spine.[1]

Fine wire electromyography (EMG) has been used in healthy subjects and subjects with LBP to quantify the role of LM in spinal stabilization.[1,2,5-9] The differences between the DM and the SM were evaluated by Moseley *et al*, who found that in healthy subjects, DM activation occurred prior to initiation of upper extremity (UE) movements and occurred independently of direction of UE motion; in contrast, SM firing occurred concurrently with UE movement and was directionally dependent.[2] Similar results have been found with EMG studies performed on TrA, indicating that both the DM and TrA may work together via a feed forward mechanism to provide spinal stability in

anticipation of movement.[1,2,5,8-13] In subjects with LBP, EMG activity of the DM has been found to be delayed and of lesser amplitude than asymptomatic individuals.[6-7]

In addition to EMG, ultrasound imaging (USI) has been used to measure LM thickness as an indirect indicator of muscle activity.[3,14] Researchers have found a strong relationship between EMG activity and LM thickness as measured by USI.[3] Previous studies have used USI to determine differences in muscle thickness between subjects with and without LBP.[4,15-16] Hides *et al* found that subjects with LBP had a decrease in cross sectional area (CSA) of LM that corresponded to the painful side.[16] Kiesel *et al* found that subjects with LBP had a smaller change in muscle thickness from resting to contracted states than subjects without LBP.[4]

Recent studies have investigated changes in LM and TrA muscle activation and muscle thickness associated with different manual therapy techniques. EMG and USI studies have demonstrated that both spinal manipulation and mobilization affect trunk muscle activity and muscle thickness in subjects with LBP.[17-20] In a case study on a subject with acute LBP, resting EMG activity of the DM was found to decrease following a side-lying rotational manipulation.[17] A case study by Brenner *et al* found an immediate increase in contracted thickness of the LM at both the L4-L5 and at the L5-S1 levels following an Anterior Posterior (AP) sacroiliac (SI) thrust manipulation in a subject with chronic LBP. This change was maintained past 24 hours.[18] In a case series, Raney et al found that some subjects with LBP had a decrease in resting thickness and an increase in contracted muscle thickness of the TrA following a supine lumbopelvic manipulation.[19] The effects of mobilization and manipulation on TrA muscle thickness have also been investigated in individuals without LBP. A randomized controlled trial by Puentedura *et*

al found no change in TrA muscle thickness following spinal mobilization or side-lying lumbar thrust manipulation in healthy individuals.[21]

To date, the published research on manipulation and its effects on LM muscle thickness have been limited to a case study and a case series involving subjects with LBP. There are no published data reflecting a randomized control trial on the effects of manipulation or mobilization on LM muscle thickness in healthy individuals. Furthermore, none of the published literature has demonstrated the impact of different manual therapy techniques on changing LM thickness in asymptomatic individuals. Therefore, the purpose of our study was to determine if there was a difference between manual therapy techniques on LM thickness during voluntary and involuntary contractions in individuals without LBP. Additionally, we hoped to determine which MT technique would produce the greatest amount of change in muscle thickness. We hypothesized that following both mobilization and manipulation there would be a change in LM thickness during both voluntary and involuntary contractions.

Methods

Subjects

A sample of convenience of forty-two healthy, asymptomatic individuals (male= 23, female=19) (mean age=27.8, SD=7.2, range=21-55) participated in this study. Participants were excluded from the study based on the following criteria: LBP in the last 6 months for which the subject had sought medical care; pregnancy or those who could be pregnant; past abdominal or spinal surgery; presence of a medical condition that is a contraindication for lumbar joint manipulation including scoliosis, rheumatoid arthritis,

osteoporosis, osteopenia and active ankylosing spondylitis. The UNLV Biomedical Institutional Review Board approved this study. All participants signed an informed consent before participation.

ADIM training

At the beginning of each session, participants were instructed on the volitional contraction of LM using the ADIM with emphasis on swelling the multifidus. Participants were trained to perform the ADIM with the multifidus swell in three different positions: quadruped, supine hook lying and prone using both visual and tactile cuing. Participants were first placed in quadruped and assisted with finding a neutral spine position. This position is considered an ideal position for individuals to learn the ADIM because of the gravitational pull on the abdominal contents.[22] Participants were instructed to lift their umbilicus towards their spine after exhaling normally and without moving their spine. At the end of the contraction, they were told to “swell their LM”. They were instructed to perform the remaining contractions at 25% of their perceived maximum voluntary contraction (MVC). A 25% ADIM contraction was chosen because researchers have demonstrated good correlation between EMG activity and muscle thickness change in TrA.[23] Although no research has specifically linked EMG activity and the muscle thickness of the LM, the 25% contraction was also selected with the idea to attempt to isolate the LM from the more superficial back muscles and to help mitigate fatigue in the participants during data collection. Participants were instructed to hold each contraction for 10 seconds, and the ADIM was repeated 9 more times for a total of 10 repetitions. Participants were then positioned in supine hook-lying and instructed to perform the ADIM utilizing the same instructions. Finally, the participants practiced the

ADIM in prone, using one or two pillows under the abdomen to assist in achieving a neutral spine. In this position, the participants were given visual biofeedback of the LM using USI. Finally, a 2-minute rest was given to reduce the effects of fatigue after the training session prior to data collection using USI.

Ultrasound Imaging

Ultrasound images of the LM muscle were generated using a Biosound Esaote MyLab25 Gold unit[*] using a variable 2.5-6.6 MHz, 60-mm curvilinear array in b-mode. Images were obtained for both pre and post treatment with the participant in the prone position. Researchers palpated the posterior superior iliac spine and fourth and fifth levels of the lumbar spinous processes. A mark was made at the L4 and L5 spinal levels on the contralateral, unmeasured side to ensure consistent transducer placement. The transducer was placed parallel to the spine with the focal point over the L4 spinous process. It was then moved laterally to obtain the best image possible. Previous researchers have shown that measurements taken from images of this area have high intra and interrater reliability by both novice and expert raters.[24-25] Interrater reliability has been reported as 0.97 and intrarater reliability has been reported to be between 0.88-0.98.[24,26-27]

Images were captured for 6 consecutive relaxed and contracted cycles. The ADIM, with LM swell, was performed for the first 3 contractions (voluntary) and a prone upper extremity lifting (PUEL) task was performed for the second 3 contractions (involuntary). For the PUEL, participants were instructed to lift their contralateral arm 2 inches off the

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[*] Biosound Inc, Indianapolis, IN Biosound Esaote, Inc 8000 Castleway Drive Indianapolis, IN 46250 Phone: (317)813-6000/(800)428-4374 info@biosound.com

treatment table while lying prone. This was performed with approximately 120 degrees of shoulder abduction and the elbow fully extended. Researchers have shown that a method similar to this is effective in achieving 19% MVC in the LM.[3] Participants were not allowed to view the ultrasound screen during the collection of all images. The researchers who were collecting the USI images then left the room and the researcher performing the manual therapy techniques entered the room and administered one of the 3 techniques in a random order: 1. posterior-anterior (PA) grade IV non-thrust mobilization with subject in prone (PA mobilization) 2. high-velocity low amplitude rotational lumbar thrust manipulation with subject in side-lying (Side-lying thrust manipulation) 3. high-velocity anterior-posterior (AP) lumbopelvic thrust manipulation with subject in supine (Supine AP thrust manipulation**)**. In order to maintain blinding, the participants were told not to discuss the type of technique received with the researchers acquiring the ultrasound images. Following the technique, images were then taken for 6 relaxed and contraction cycles as performed prior to treatment.

A total of 24 images were acquired for each session: 3 pre-MT technique relaxed, 3 pre-MT technique contracted (ADIM), 3 pre-MT technique relaxed, 3 pre-MT technique contracted (PUEL task), 3 post-MT technique relaxed, 3 post-MT technique contracted (ADIM), 3 post-MT technique relaxed, 3 post-MT technique contracted (PUEL task). Participants returned two days later to receive the second technique and another set of 24 images were obtained. A third session was performed 2 days later and the final set of 24 images was obtained. For each subject, a total of 72 images were obtained (See figure 1 for study flow chart).

Manual Therapy Techniques

Participants received all three MT techniques on three separate sessions with at least 48 hours between sessions. To control for carry over effects and researcher bias, participants were randomly assigned to different groups and received techniques in a predetermined order depending on the group they were assigned. The PA mobilization was performed with the subject prone and the researcher performing Maitland Posterior to Anterior (PA) Grade IV oscillations using pisiform contact (Figure 2). The PA mobilizations were performed for 30 second repetitions over the L5, L4 and L3 spinous processes. The side-lying thrust manipulation was performed as described by Cleland *et al*[28] (Figure 3). The supine AP thrust manipulation was performed as previously described by Flynn *et al*[29] (Figure 4). For each manipulation, participants were placed in positioning for manipulation of the right side. Following thrust, if cavitation was not heard, participants were positioned on the opposite side and the thrust was repeated. If no cavitation was heard, participants were then repositioned on the right side and thrust manipulation was performed for a third time. If no cavitation was heard, participants were repositioned on the left side and a final thrust was performed. A maximum of two attempts per side were made to achieve cavitation.

Data Management and Analysis

USI images were stored on the ultrasound unit's hard drive. The USI unit's built-in caliper was used to determine LM muscle thickness to an accuracy of 0.1mm. Measurements were taken from the highest point of the L4-L5 zygapophyseal joint to the first distinguishable fascial layer (Figure 5). An average of the three resting

measurements was calculated. It has been shown that averaging 3 measurements of LM reduces standard error of measurement (SEM) by 50%.[26]

Statistical analysis was done using SPSS version 17.[†] Intraclass correlation coefficients (ICC) were calculated to establish inter- and intra-rater reliability on the first 7 participants. Pre intervention measurements were taken from images of resting, ADIM, and PUEL conditions on different days to determine interrater and intrarater reliability. This method of determining reliability is comparable to another study utilizing USI images of the LM.[25] We found both high intrarater reliability ($ICC_{3,3}$= 0.962 to 0.973; 95% CI: 0.857 to 0.995) and interrater reliability ($ICC_{3,3}$= 0.982; 95% CI: 0.962 to 0.992). Because we found both interrater and intrarater reliabilities to be high, we determined that different raters could reliably take measurements of the images.

To assess measurement precision, standard error of measurement (SEM) was calculated using the formula suggested by Portney and Watkins: *SEM = Standard Deviation (SD)* $\sqrt{1-ICC}$.[30] Following analysis of our raw data, we observed that many of our participants had only slight changes in contraction thickness during the ADIM task; therefore, we calculated the minimal detectable change (MDC). We intended to compare the MDC value to the change in muscle thickness values to determine if our participants were able to voluntarily contract LM with the ADIM beyond that of measurement error. MDC was calculated using $MDC = SEMx1.96x\sqrt{3}$ (three measurements were taken).[30] The MDC represents the minimal change in thickness that

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[†] SPSS Inc., 233 S. Wacker Drive, 11th floor Chicago, IL 60606 Phone: (312)651-3000 http://www.spss.com

must occur in order to be 95% confident that a true change occurred. We found MDC to be 0.208.

In order to compare the effects of the three interventions on LM muscle thickness, two separate 3 (MT technique: PA mobilization, side-lying thrust manipulation, and supine AP thrust manipulation) X 2 (muscle contraction state: rest, contract) X 2 (time: pre and post) within subjects factorial Analysis of Variance (ANOVA) were performed for the ADIM data and the PUEL data with appropriate post hoc analyses.

Results

ADIM

No interaction among the three variables was found for the ADIM data, $F(2, 82)= 1.482$, $p= 0.233$. There was also no significant interaction between MT technique and time, $F(2,82)=0.121$, $p=0.858$, MT technique and contraction state, $F(2,82)=1.416$, $p=0.249$ (Greenhouse-Geisser corrected secondary to a violation of sphericity, $p<.05$), time and contraction state, $F(1,41)=1.257$, $p=0.269$ (Greenhouse-Geisser corrected secondary to a violation of sphericity, $p<.05$) (Table 1 for means and standard deviations). Because no interactions were observed, main effects were analyzed. We found a statistically significant main effect for contraction state (Rest mean= 3.428 SE=0.082; contracted mean=3.494 SE=0.082), $F (1,41)=38.351$, $p \leq 0.0005$ (Figure 6). There was no main effect for time ($p=0.066$) or treatment ($p=0.413$) (Figure 7-9).

PUEL

A statistically significant interaction was found among MT technique, contraction state and time, $F(2,82)=4.574$, $p=0.019$ (Greenhouse-Geisser corrected secondary to a

violation of sphericity $p<0.05$) (Table 2 for means and standard deviations and Figure 9). In order to break down the interaction, a 2(time) x 2(contracted state) within subjects ANOVA was performed for each of the three MT techniques. A Bonferroni corrected alpha of 0.0167 (3 ANOVA's: one for each technique) was used. A statistically significant interaction was found with the supine AP thrust manipulation, $F(1,41)=18.396$, $p\leq0.0005$. Post hoc analysis of this ANOVA using 4 paired samples t-tests revealed a statistically significant increase in resting muscle thickness following the supine AP thrust manipulation ($p=0.005$). However, no significant difference was found in contracted muscle thickness after the same technique ($p=0.326$). We also found a statistically significant difference between resting and contracted muscle thickness before the supine AP thrust technique ($p\leq0.0005$) as well as a difference between resting and contracted muscle thickness after the technique ($p\leq0.0005$). This suggests that we were able to detect a difference between resting and contracted muscle states both before and after the MT technique was administered (Figures 11-13).

No significant interactions were found in post hoc analysis for the prone PA mobilization technique, $F(1,41)=0.02$, $p=0.887$ or the side-lying lumbar thrust manipulation, $F(1,41)=2.716$, $p=0.107$.

Discussion

Several inferences can be made from our results. We found an increase in LM resting thickness following the supine AP thrust manipulation that was not observed with any of the other manual therapy techniques. This increase, however, was only observed when participants performed the PUEL task and was not found when participants performed the

ADIM task. We also found that regardless of the intervention, there was a change in muscle thickness from resting to contracted state for both the PUEL and ADIM tasks which suggests that both methods are appropriate ways to activate LM.

Our results contrast findings from previously published literature which have shown decreases in resting thickness and increases in contracted thickness of LM and TrA following manual therapy techniques.[17-20] In a case study, Brenner *et al* found a decrease in resting LM thickness and increase in contracted LM thickness following the supine AP thrust manipulation.[18] Raney *et al* found decreased resting TrA thickness in 5 out of 9 participants and increased contracted TrA thickness in 6 out of 9 participants following the same manipulation.[19] Additionally, EMG studies have found decreased muscle activity following both thrust and non-thrust manual therapy interventions.[20] Brenner *et al* suggest that spinal manipulation influences muscle thickness via a reflexogenic effect on the muscle spindle which in turn alters central or peripheral nervous system pathways.[18] When these pathways are altered it may have an excitatory or inhibitory effect on the muscle.[17,31] The authors concluded that an inhibitory effect may have been responsible for the decrease in thickness seen in their case study.[17] It should be noted that the participants included in both the Brenner *et al* and Raney *et al* studies had a history of LBP and/or a presence of hypomobility.[18-19] Since our subjects were asymptomatic, it may be that the supine AP thrust manipulation caused an excitatory reflexogenic response[31] rather than the inhibitory response seen in symptomatic individuals,[18-19] thus leading to an increase in resting muscle thickness. This theory is supported by EMG research by Herzog *et al* who found an increase in paraspinal muscle activity following side-lying thrust manipulations in asymptomatic participants.[32] However, deeper spinal

stabilizers such as the LM were not evaluated in the Herzog *et al s*tudy, therefore, the results may not be generalizable to other postural muscles.

Although we found an increase in resting muscle thickness of LM with the supine AP thrust manipulation, we did not see an increase in contracted muscle thickness following this technique. There are several plausible explanations for our findings. First, it is possible that the increase in resting muscle thickness seen following the supine AP thrust was a result of increased neuromotor tone, and the maximal recruitment of motor units that were required to achieve a contraction may have negated any further increases in neuromotor tone following the manipulation. However, if this were the case, we would have expected to also find an increase in resting muscle thickness prior to the ADIM contractions which preceded the PUEL contractions. It is possible that the performance of the ADIM contractions influenced the resting images taken before the PUEL, thereby increasing resting neuromotor tone for these later images. It is also possible that participants were unable to fully relax LM prior to the start of image collection for the PUEL task.

In addition to changes in resting muscle thickness following the supine AP manipulation, we found a difference between resting and contracted measurements before and after each intervention. This is in agreement with others studies that suggest the PUEL is an effective way to achieve involuntary LM contraction.[4, 18, 33]

We found no difference between manual therapy techniques (PA mobilization, side-lying thrust manipulation, and supine AP thrust manipulation) on the resting or contracted LM thickness during the ADIM series. This refutes our original hypothesis and suggests that these manual therapy techniques may not affect LM thickness in

individuals without LBP. The results from this study are similar to those found by Puentedura *et al* who found no difference between sham (mobilization) and supine lumbo-pelvic thrust in TrA muscle thickness in asymptomatic individuals.[21] Puentedura argues that although descending pain inhibitory influences may account for decreases in resting muscle thickness in subjects with LBP, the same influences may have little effect in asymptomatic individuals.[21] Although we did not evaluate TrA muscle thickness in our study, this may be an explanation as to why the LM muscle activity was not significantly affected by any of the interventions during the ADIM.

We did find a statistical difference between the resting and contracted thicknesses of the LM during ADIM regardless of the manual therapy technique, suggesting that subjects were able to contract the LM with the ADIM. Although statically significant results were obtained, only 7% of the ADIM contractions met the MDC, indicating that most participants were not actually able to perform a contraction that exceeded measurement error. Many of our participants expressed difficulty achieving LM contraction and further differentiating a 25% maximal voluntary contraction. Participants were instructed to "swell" the LM but due to the difficult nature of the contraction, many participants expressed and/or demonstrated difficulty doing so even with visual biofeedback. It is evident that the 25% MVC utilized during the ADIM was not effective for voluntary activation of the LM muscle sufficient for detection using USI. The subjectivity of performing an ADIM at 25% MVC and "swelling" the LM is substantial and this likely contributed to variability within the data. It is also recognized that volitionally contracting the deep muscle system varies substantially in asymptomatic individuals,[18] and this variation may have affected our data.

Limitations

Our study was not without limitations. Our sample population was one of convenience with the majority of our participants being young and active students, thereby limiting the generalizability of our results. A second limitation was the use of the ADIM to activate the LM. At this time, no research has been conducted to validate the use of the ADIM for voluntary contraction of the LM. Additionally, the quality of the USI images made it difficult to distinguish between the SM, DM, and paraspinal musculature. In subjects where the fascial lines were indistinct, it is possible that we measured both the LM and the erector spinae. Finally, our study design did not include a true control technique in which subjects received no treatment. As a result, we compared only three manual therapy techniques without comparing them to a “no treatment" condition. By including a true control in the study design, we may have been able to determine if the changes seen following manual therapy interventions exceeded normal changes in muscle tone that may be present following ADIM and PUEL training without an intervention.

Further research should investigate the effects of various MT techniques in subjects with LBP using USI. Researchers should include mobilization, manipulation and control in their study design to determine the influence of each on muscle thickness. Researchers should also investigate the effectiveness of the ADIM in activating the LM to determine if voluntary co-contraction of the TrA and LM occurs as hypothesized. If this co-contraction does indeed occur, researchers should consider what percentage of MVC during ADIM facilitates optimal activation of LM.

Conclusion

Based on the results of this study, we conclude that manual therapy has no effect on resting or contracted LM thickness in asymptomatic individuals. We did find an increase in resting muscle thickness following the supine AP thrust technique. However, because resting muscle thickness increased only after the performance of several ADIM contractions we do not believe that this phenomenon was solely a result of the thrust technique. It may be that the LM muscle activation and thickness changes seen in other literature are exclusive to subjects with LBP, and that these changes do not occur in healthy subjects. Further research should investigate the effects of different manual therapy techniques on individuals with LBP to determine their influence on muscle thickness.

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Table 1. Means and standard deviations for ADIM data

	Mean	Standard Deviation	N
Prone lumbar non thrust mobilization			
Pre treatment resting thickness	3.436	0.523	42
Pre treatment contracted thickness	3.504	0.518	42
Post treatment resting thickness	3.465	0.557	42
Post treatment contracted thickness	3.538	0.538	42
Side-lying lumbar thrust manipulation			
Pre treatment resting thickness	3.397	0.575	42
Pre treatment contracted thickness	3.456	0.592	42
Post treatment resting thickness	3.423	0.548	42
Post treatment contracted thickness	3.511	0.548	42
Supine Lumbopelvic thrust manipulation			
Pre treatment resting thickness	3.414	0.515	42
Pre treatment contracted thickness	3.469	0.520	42
Post treatment resting thickness	3.434	0.595	42
Post treatment contracted thickness	3.489	0.584	42

Table 2. Means and standard deviations for PUEL data

	Mean	Standard Deviation	N
Prone lumbar non thrust mobilization			
Pre treatment resting thickness	3.483	0.561	42
Pre treatment contracted thickness	3.848	0.625	42
Post treatment resting thickness	3.487	0.558	42
Post treatment contracted thickness	3.847	0.605	42
Side-lying lumbar thrust manipulation			
Pre treatment resting thickness	3.441	0.574	42
Pre treatment contracted thickness	3.791	0.609	42
Post treatment resting thickness	3.455	0.540	42
Post treatment contracted thickness	3.843	0.598	42
Supine lumbopelvic thrust manipulation			
Pre treatment resting thickness	3.451	0.503	42
Pre treatment contracted thickness	3.796	0.579	42
Post treatment resting thickness	3.574	0.606	42
Post treatment contracted thickness	3.835	0.666	42

Figure 1. Study flow chart

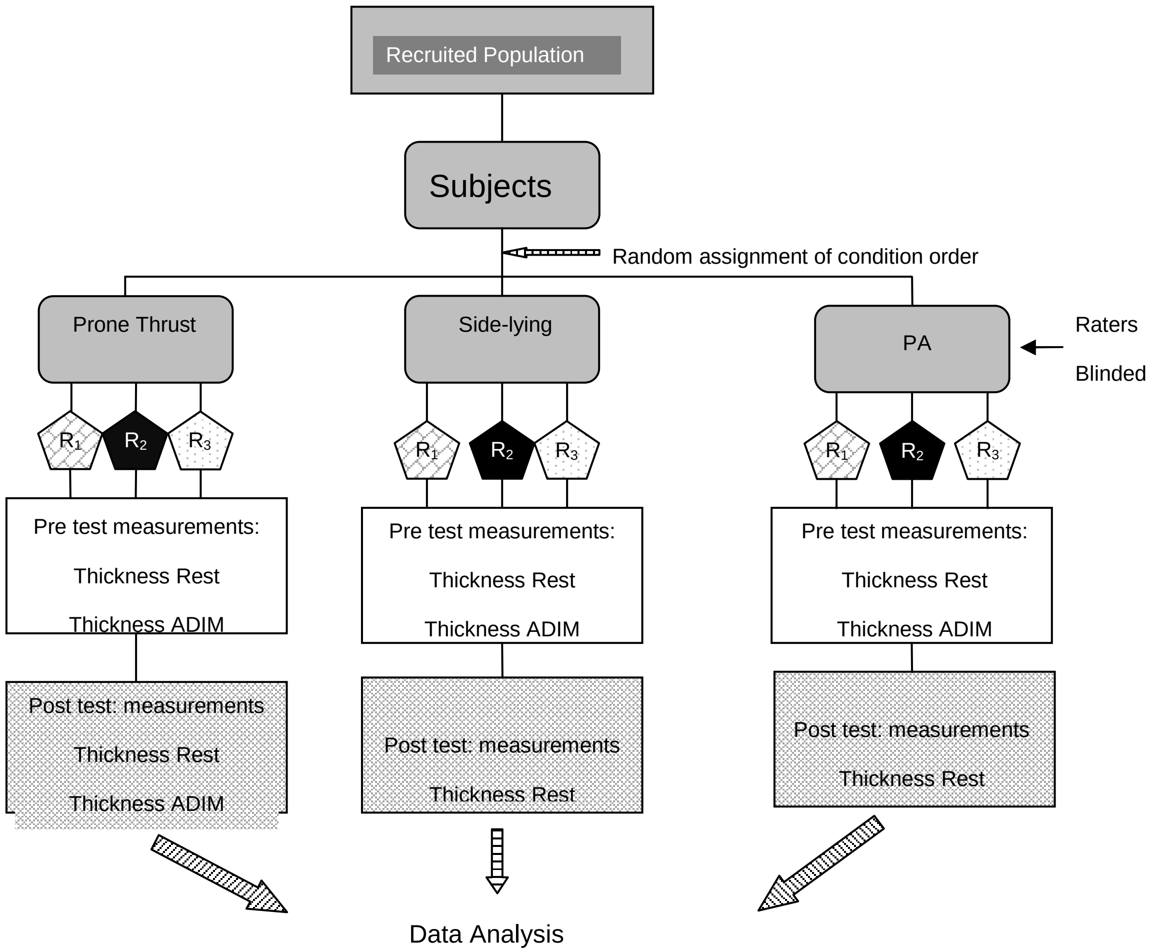


Figure 2. Prone Maitland grade IV oscillations with pisiform grip

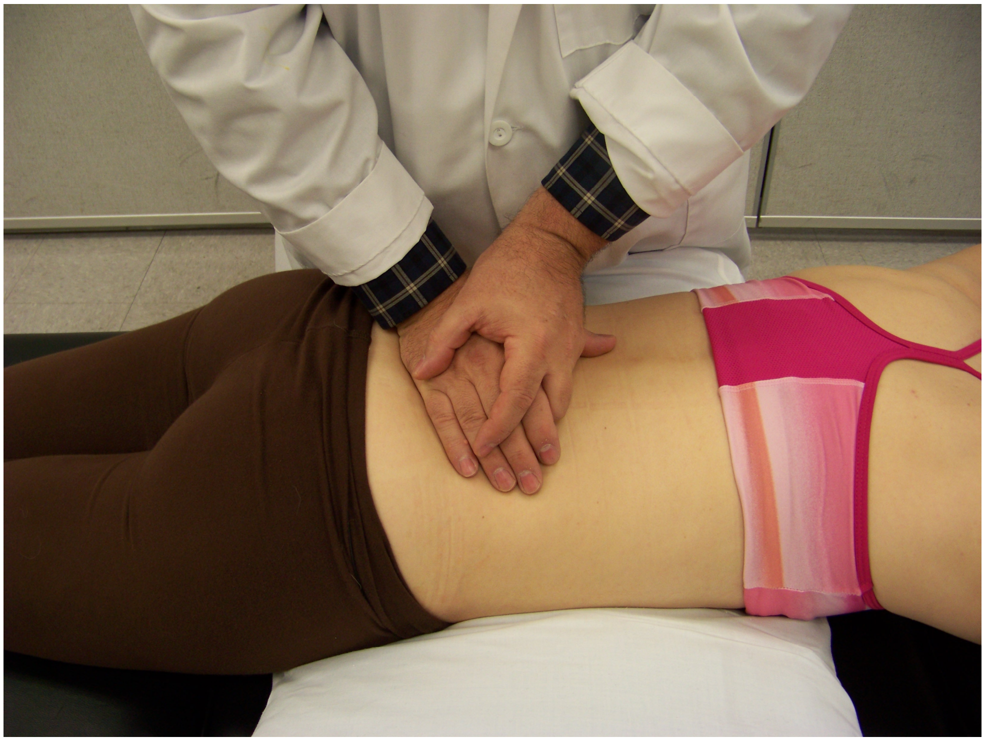


Figure 3. Side-lying thrust manipulation

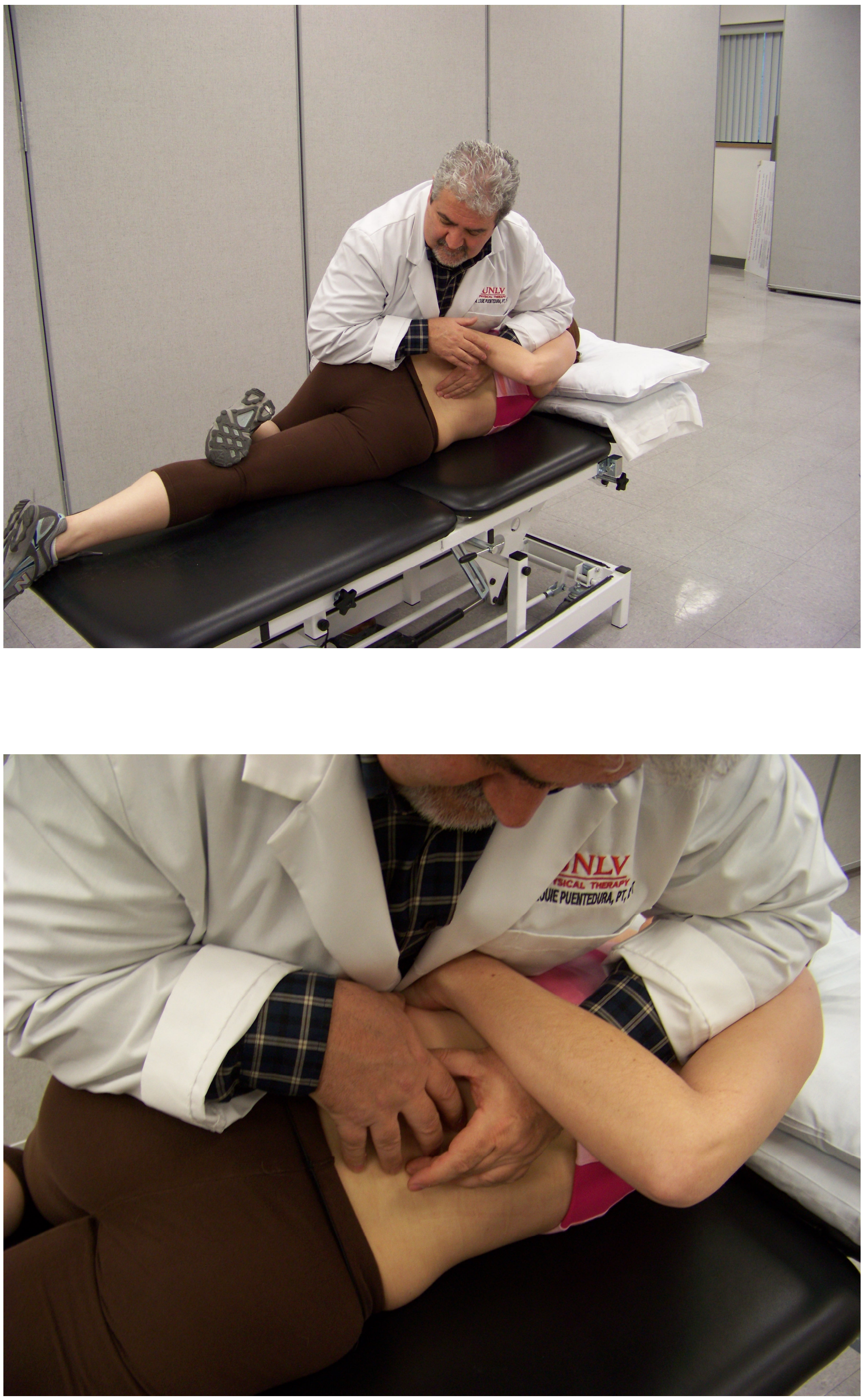


Figure 4. Supine lumbo-pelvic thrust manipulation

Figure 5. Measurement of lumbar multifidus USI image

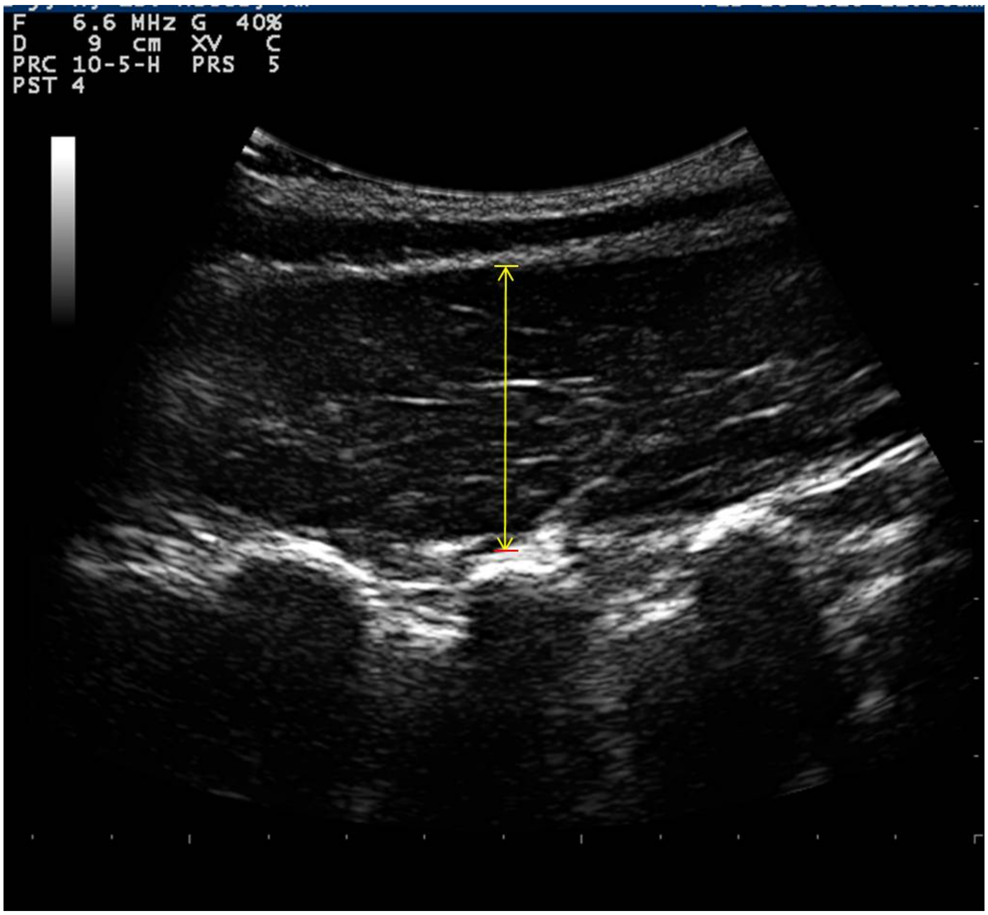


Figure 6. ADIM Main effects for contraction state with standard error (SE)

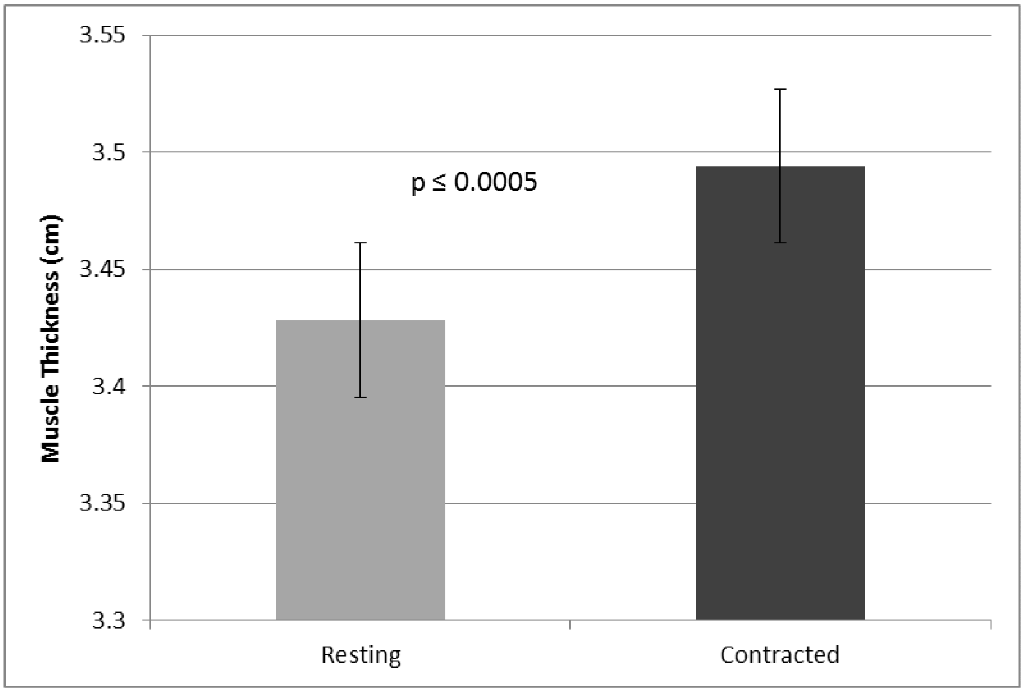


Figure 7. ADIM main effects for time with SE

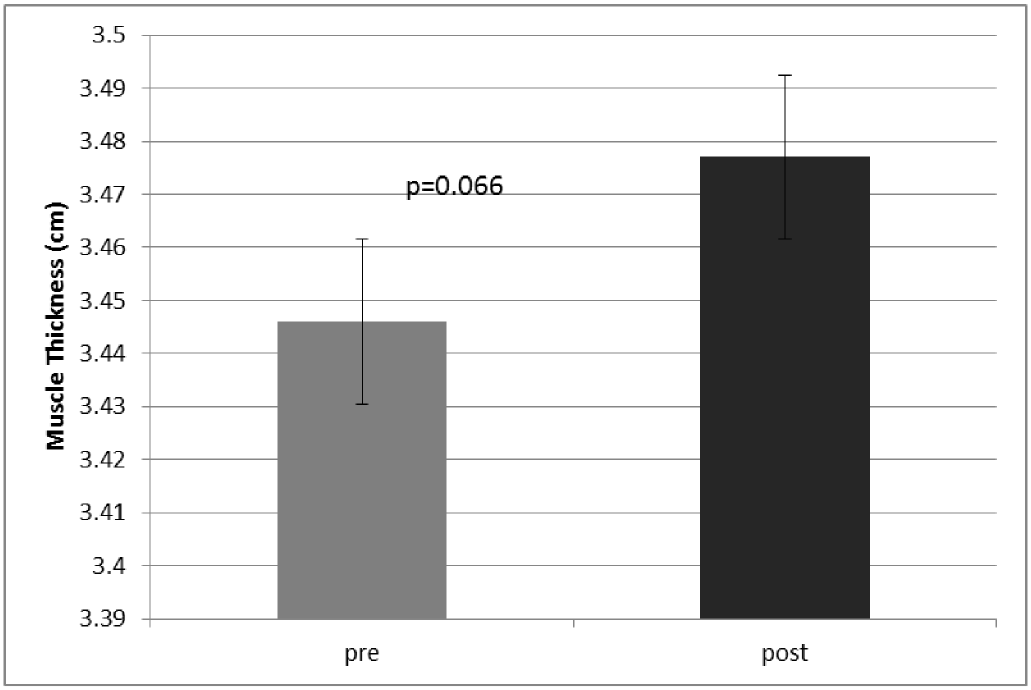


Figure 8. ADIM main effect for MT technique with SE

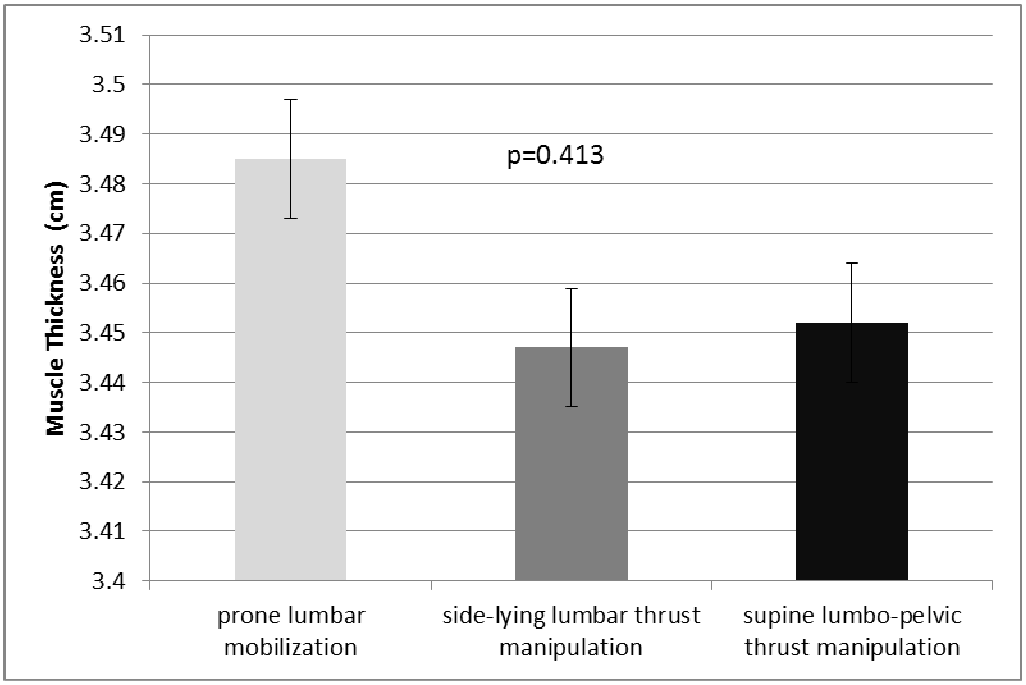


Figure 9. ADIM main effect for MT technique and contraction state with SE

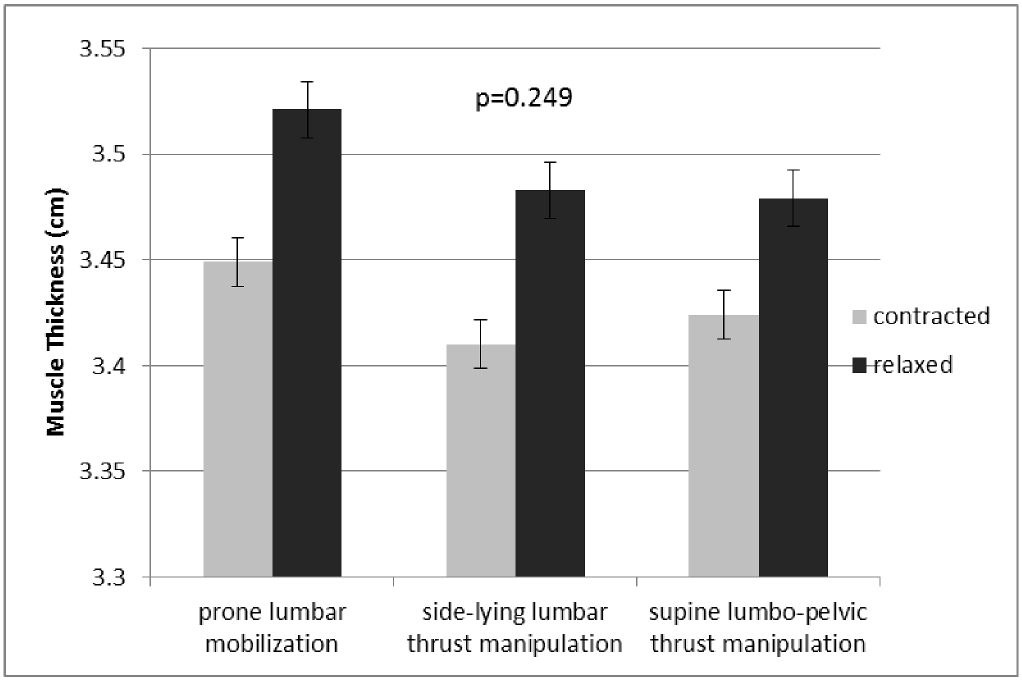


Figure 10. ADIM main effects for MT technique x time

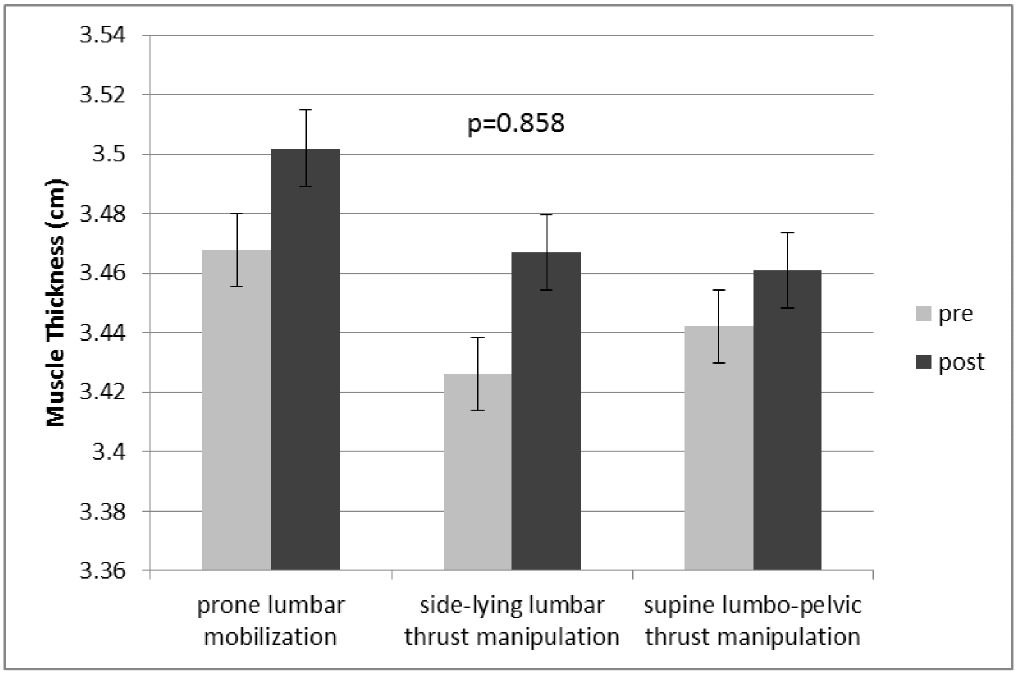


Figure 11. PUEL prone lumbar PA mobilization post hoc ANOVA (time x contraction state) with SE

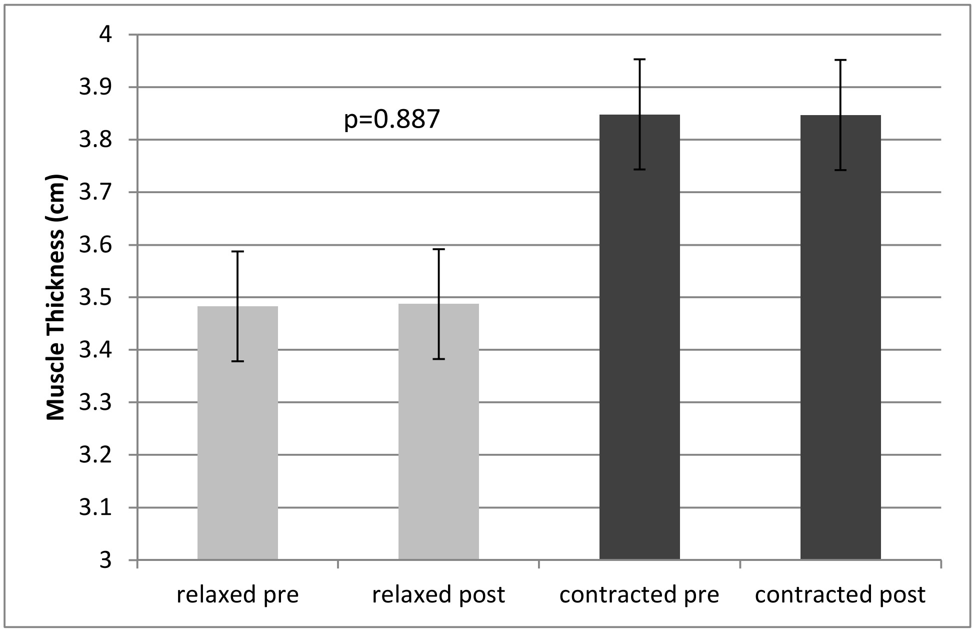


Figure 12. PUEL side-lying thrust manipulation post hoc ANOVA (time x contraction state) with SE

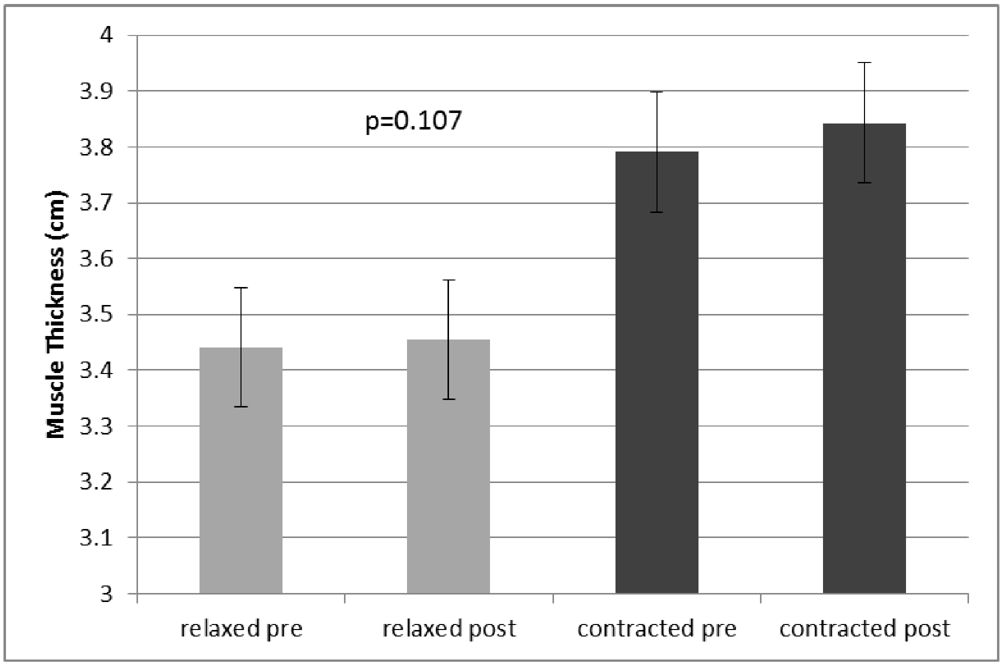
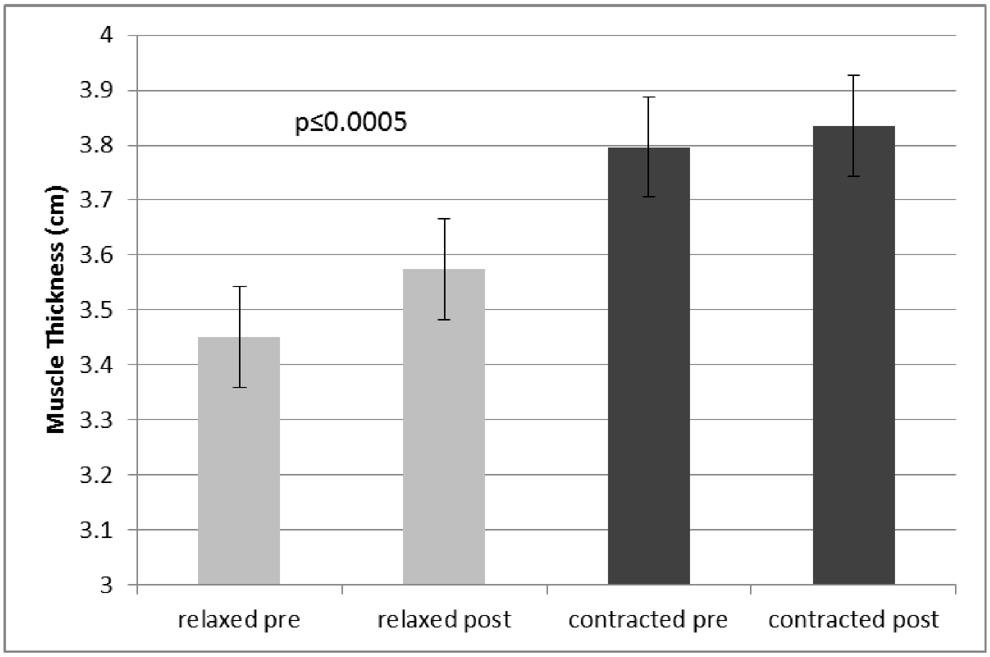


Figure 13. Supine lumbo-pelvic thrust manipulation post hoc ANOVA (time x contraction state) with SE



APPENDIX

Biomedical IRB – Full Board Review
Approval Notice

NOTICE TO ALL RESEARCHERS:

Please be aware that a protocol violation (e.g., failure to submit a modification for any change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation suspension of any research protocol at issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol at issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE: May 19, 2009

TO: **Dr. Louie Puentedura**, Physical Therapy

FROM: Office for the Protection of Research Subjects

RE: Notification of IRB Action
Protocol Title: **A Real Time Ultrasound Examination of the Lumbar Multifidus Immediately Following 3 Physical Therapy Interventions in Asymptomatic Subjects**
Protocol #: 0903-3066

This memorandum is notification that the project referenced above has been reviewed by the UNLV Biomedical Institutional Review Board (IRB) as indicated in Federal regulatory statutes 45CFR46. The protocol has been reviewed and approved.

The protocol is approved for a period of one year from the date of IRB approval. The expiration date of this protocol is April 20, 2010. Work on the project may begin as soon as you receive written notification from the Office for the Protection of Research Subjects (OPRS).

PLEASE NOTE:
Attached to this approval notice is the **official Informed Consent/Assent (IC/IA) Form** for this study. The IC/IA contains an official approval stamp. Only copies of this official IC/IA form may be used when obtaining consent. Please keep the original for your records.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through OPRS. No changes may be made to the existing protocol until modifications have been approved by the IRB.

Should the use of human subjects described in this protocol continue beyond April 20, 2010, it would be necessary to submit a **Continuing Review Request Form** *60 days* before the expiration date.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@unlv.edu or call 895-2794

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Dissertation Title: Ultrasound Imaging of the Lumbar Multifidus Immediately Following Three Physical Therapy Techniques in Asymptomatic Individuals

Dissertation Committee:
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Dr. Merrill Landers, DPT, OCS