Effect of Grade III Lumbar Mobilization on Back Muscles in Chronic Low Back Pain

A Randomized Controlled Trial

Fahed Mehyar, PT, PhD[1,2]
Marcio Santos, PT, PhD[2,3]
Sara E. Wilson, PhD[4]
Vincent S. Staggs, PhD[5,6]
Neena K. Sharma, PT, PhD[2]

BACKGROUND: Lumbar mobilization is a standard intervention for lower back pain (LBP). However, its effect on the activity of back muscles is not well known. **OBJECTIVES:** To investigate the effects of lumbar mobilization on the activity/contraction of erector spinae (ES) and lumbar multifidus (LM) muscles in people with LBP. **DESIGN:** Randomized controlled study. **METHODS:** 21 subjects with LBP received either grade III central lumbar mobilization or placebo (light touch) intervention on lumbar segment level 4 (L4). Surface electromyography (EMG) signals of ES and ultrasound (US) images of LM were captured before and after the intervention. The contraction of LM was calculated from US images at L4 level. The normalized amplitude of EMG signals (nEMG) and activity onset of ES were calculated from the EMG signals at both L1 and L4 levels. **RESULTS:** Significant differences were found between the mobilization and placebo groups in LM contraction (p=0.03), nEMG of ES at L1 (p=0.01) and L4 (p=0.05), and activity onset of ES at L1 (p=0.02). **CONCLUSION:** Lumbar mobilization decreased both the activity amplitude and the activity onset of ES in people with LBP. However, the significant difference in LM contraction was small and may not have clinical significance.
J Allied Health 2020; 49(1):20–28.

LOW BACK PAIN (LBP) is the second most common cause of disability in the United States.[1] LBP is associated with increased activity of superficial back muscle erector spinae (ES) and decreased activity of deep back muscle lumbar multifidus (LM).[2–5] This abnormal activity of superficial and deep muscles in LBP may lead to further pain and limitations in function.[6]

Lumbar mobilization and thrust manipulation are manual therapy interventions that are recommended in the clinical guidelines for managing LBP.[7] There are few differences between lumbar mobilization and thrust manipulation. During mobilization, clinicians target a single lumbar spine vertebra using their hands to apply oscillatory movements within the available range of movement, and with a predetermined grade (grade I, II, III, or IV).[8] Whereas with thrust manipulation, the clinicians apply high speed, low amplitude movements within or at end range of motion.[9] Further, in contrast to mobilization, during thrust manipulation the patient is unable to control or prevent the movement. Both interventions are commonly used for LBP.[10] However, therapists most often select lumbar mobilization over thrust manipulation when the thrust manipulation is contraindicated or when the patient's condition is too irritable.[11]

Manual therapy interventions may reduce pain, lead to hypoalgesia, and change muscle activity.[12] Studies have reported decreased activity of erector spinae (ES) and increased activity of lumbar multifidus (LM) following thrust manipulation in people with LBP,[13,14] and previous mobilization studies found that grade III cervical mobilization decreased the activity of superficial neck muscles and increased the activity of deep neck muscles in people with neck pain.[15,16] Yet, the effect of lumbar mobilization on the activity of back muscles in people with LBP is not known.

The main objective of this study was to determine the effects of grade III posterior-to-anterior lumbar mobilization applied on lumbar segment level 4 (L4) on the activity/contraction of ES at L1 and L4 levels, and LM muscles at L4 level in people with LBP. A secondary objective of this study was to investigate the relationship between pressure pain threshold and the activity/contraction of ES and LM. To our knowledge, this is the first study to investigate the immediate effects of

From the [1]Dep. of Physical Therapy, Eastern Washington University, Cheney, WA; [2]Dep. of Physical Therapy and Rehabilitation Science, University of Kansas Medical Center, Kansas City, KS; [3]College of Rehabilitative Sciences, University of St. Augustine for Health Sciences, Coral Gables, FL; [4]Dep. of Mechanical Engineering, University of Kansas, Lawrence, KS; [5]Health Services and Outcomes Research, Children's Mercy, Kansas City, MO; and [6]School of Medicine, University of Missouri-Kansas City, Kansas City, MO.

Supported in part by a KL2 Award from Frontiers: Heartland Institute for Clinical & Translational Research (CTSA, TR000119) to N.K.S.

RA2024—Received June 9, 2018; accepted July 13, 2019.

Address correspondence to: Dr. Neena K. Sharma, Physical Therapy and Rehab Science, University of Kansas Medical Center, Mailstop 2002, 3901 Rainbow Blvd., Kansas City, KS 66160, USA. Tel 913 588 4566. nsharma@kumc.edu.

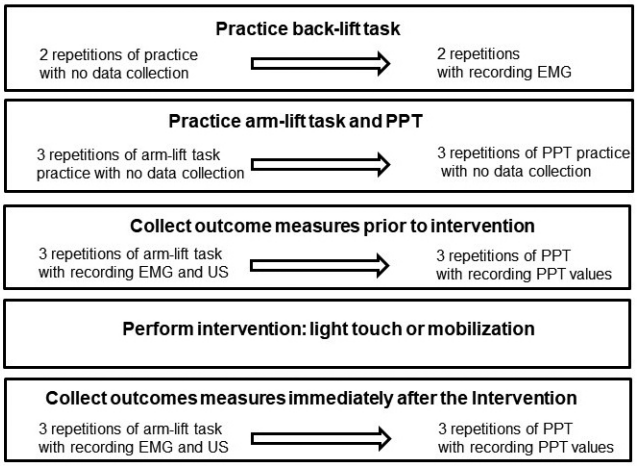

FIGURE 1. Steps of testing procedure in each session. PPT, pressure pain threshold; EMG, electromyography; US, ultrasound.

lumbar mobilization on both deep (LM) and superficial (ES) back muscles in people with LBP. Investigating this effect may lead to a better understanding of lumbar mobilization and its appropriate application for management of LBP, and may also lead to use of lumbar mobilization to correct muscle dysfunction in LBP.

Methods

Subjects between the ages of 18 and 55 years with chronic LBP, defined as pain for more than half the days in the past 6 months,[17] were recruited between August 2015 and June 2016. Subjects were included if they had: 1) pain localized between the 12th rib and the inferior gluteal folds, 2) pain > 3 out of 10 on a 0–10 numerical rating pain scale where 0=no pain and 10=worst pain imagined, and 3) left side or bilateral LBP (since ultrasound measurement was conducted on the left side only). Subjects were excluded if they had symptoms radiating below the knee, body mass index (BMI) > 30 kg/m^2, presence of neuromuscular diseases such as stroke, lumbosacral conditions/pathology such as severe osteoporosis, pregnancy, night pain, progressive neurological deficit, unexplained weight loss, inability to perform the arm-lifting or back-lifting tasks of the study, and inability to tolerate prone position for 1 hour, or if they were involved in an LBP intervention program or spinal mobilization/thrust manipulation within the month prior to the start of the study.

The Human Subjects Committee at University of Kansas Medical Center (#00002870) approved the study before subjects were recruited. All subjects consented prior to the testing. The study followed the US Federal Policy for the Protection of Human Subjects.

Pain intensity was assessed using a 0–10 numeric pain rating scale; the subjects' activity level was assessed using the long form of the International Physical Activity Questionnaire (IPAQ); disability level was measured with the modified Oswestry Back Pain Disability Questionnaire (MOSQ); severity of depression was tested using the Beck Depression Inventory (BDI-II); and pain avoidance behavior was tested using the Fear-Avoidance Beliefs Questionnaire (FABQ). These questionnaires are standard, valid, and reliable.[18–21] These questionnaires were used to address the multidimensional (psychological and physical) aspects of chronic LBP.

A randomized controlled design was used with a convenience sample of 21 subjects with LBP. Due to the nature of the intervention, neither the researcher nor the subjects were blinded to the treatment. Subjects were randomized either to mobilization (10 subjects) or to placebo group (11 subjects) using a randomized block design to ensure approximately equal percentages of males and females in each group. The researcher completed the randomization allocation online using Quickcalcs calculator for each gender separately.[22]

Each subject attended two sessions 2–4 days apart. The testing steps in each session are summarized in Figure 1. A normalization back-lift and an arm-lift task were performed, and a Pressure Pain Threshold (PPT), ultrasound (US) imaging, and electromyographic (EMG) measures were obtained.

Testing Procedures

Back-Lift and Arm-Lift Tasks

Normalization back-lift task: At the beginning of each session, subjects practiced and performed a back-lift normalization task by raising their back from prone position until the spine of their scapula touched a horizontal piece of the stadiometer (approximately 5 cm up). Subjects held this position for 3 seconds to induce submaximal isometric contraction of ES.[23] The back-lift task was used to normalize the EMG signals of the arm-lift task. The subjects' EMG data were captured during two repetitions of the back-lift task only at the beginning of each session.

After the back lift task, the subjects practiced and performed an arm-lift task and Pressure Pain Threshold (PPT) test (described below).

Arm-lift task: The arm-lift task was also performed in the prone position.[24] The researcher used an inclinometer to measure the lumbar curve and placed 1–2 pillows under the subject's abdomen, if necessary, to ensure the curve was <10°.[24] The subject's right arm was placed at approximately 90° of elbow flexion and 120° of shoulder abduction using a goniometer. The subject lifted a weight of 1.5 to 2 lbs in the right hand to achieve 30% of maximal voluntary contraction of LM.[24] The subject stopped the lifting motion when the elbow reached a 5-cm-high horizontal piece of the stadiometer and held the weight for 3 seconds. EMG sig-

nals and US images were captured during three repetitions of the task, and then PPT testing was performed.

Intervention

Next, the researcher applied the intervention of placebo or mobilization. The intervention was applied for 5 minutes as either placebo (light touch) or pain-free grade III posterior-to-anterior mobilization. Light touch was applied with the hand at the L4 vertebra and grade III mobilization at the spinous process of L4 using the pisiform grip for four bouts of 60 seconds each with rest time of 20 seconds between bouts.

Grade III mobilization is described as large amplitude oscillatory movements that move into tissue resistance (8). Therefore, we applied the mobilization forces with large amplitude and with adequate maximum force to exceed the point of tissue resistance. To provide live visual feedback to the therapist about the applied mobilization forces, a force plate (Bertec Force Plate, Columbus, OH) was used with a sampling frequency of 100 Hz. The force plate has been validated and used in previous studies to measure mobilization forces.[23,25–28] In these studies, mobilization forces were estimated indirectly by calculating the difference between the vertical ground-reaction force and the therapist's body mass. The therapist stood on a force plate and tested the maximum force beyond the point of tissue resistance that the subject could tolerate without having pain. Then the mobilization was applied with oscillating forces from 50% to 100% of the maximum force tolerated by each subject. Therefore, the mobilization forces were tailored for each subject to avoid pain. A metronome was used to apply mobilization at the frequency of 1 Hz. The collection, display, and storage of the force plate data were implemented by a LabVIEW program (LabVIEW 2012; NI, Austin, TX).

Mobilization had been shown to have a placebo effect,[29] and therefore we included a placebo intervention in the form of light touch as in previous mobilization studies.[30–32] To our knowledge, no previous study has investigated the effect of touch/light pressure on muscle activity. However, Kinesio tape, another type of light contact pressure, was found to have no effect on muscle strength/activity.[33]

Immediately after the intervention, subjects repeated the arm-lift task and PPT testing three times. PPT was always tested after the arm lift. The researcher captured ES surface EMG signals and US LM images during the arm-lift task and used these measures as outcomes (described below). PPT was tested to understand the relationship between pain reduction (as measured by percent changes in PPT) and the outcome measures.

Ultrasound Imaging

EMG is considered the standard method to measure muscle activity. However, due to the deep location of LM, indwelling needle EMG electrodes[34] or noninvasive US[24] methods are considered valid to measure the contraction of LM muscle. The muscle contraction of LM measured by US during the arm-lift task was found to be highly correlated with the needle EMG activity of LM.[24] The US images in this study were captured with a Logiq P5 ultrasound (GE Healthcare, Milwaukee, WI) with 60-mm curvilinear array transducer at 5-MHz frequency. The US transducer was placed left of the L4 spinous process, angling it medially until the sacrum and left L4–L5 facet joint were visible.[35] The L4 level was selected because the intervention was applied at L4 level. The US images were captured both at rest and during the activity of 3-second isometric arm contraction.

EMG

EMG signals were collected at 1000 Hz using the Bagnoli™ Desktop EMG System (Delsys Inc., Natick, MA) which has an internal band-pass filter bandwidth of 20-450 Hz; electrodes had contact spacing and detection area of 10 and 100 mm^2, respectively. Skin was cleaned and the electrodes were placed at L1 and L4 levels. Although the mobilization was applied at L4 level, the L1 level was added because it is the standard level to be used to measure the EMG activity of ES.[36] To determine L1 and L4 levels, two methods were used: US imaging of facet joints and sacrum, and palpation of spinous processes of lumbar spine. The US imaging method was used to increase the accuracy of identifying the specific levels.[37] The examiner started US imaging by using the sacrum as a landmark in the US image and then moved the US transducer cephalically to clearly visualize the facet joint at the middle of the US image. Palpation of lumbar spine was completed using landmarks of the iliac crest for L4 level and 12th rib for L1 level.[38,39]

We placed three electrodes 3.5 cm lateral to the lumbar spine spinous processes at L1 level (one electrode on each side, L1_Left and L1_Right)[27] and only one electrode at the right side of L4 level (L4_Right) because the left side is used for US. Furthermore, one electrode was placed over the posterior deltoid muscle of the right arm, and the reference electrode was placed over the sacrum.[40] Data acquisition box (USB-6218 BNC, NI, Austin, TX) and LabVIEW program (2012®; NI, Austin, TX) were used for EMG data acquisition. The EMG signals of the back-lift and arm-lift tasks were recorded from rest until the end of the contraction.

Pressure Pain Threshold (PPT)

Algometer PPT is a valid and reliable way to quantify pain.[41] Since an EMG electrode was placed at L4 level, it was not feasible to test the PPT at the same level. Thus, we considered L2–L3 level as acceptable location to test PPT, because in a previous study mobilization forces were

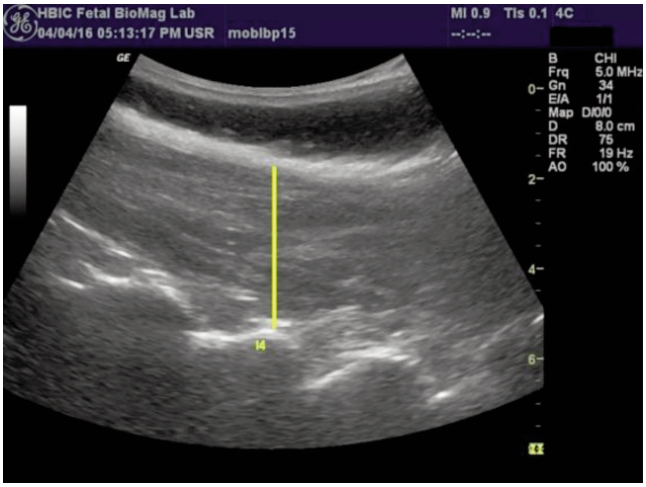

FIGURE 2. Measurement of LM muscle thickness from US images.

found to lead movements at several levels above and below the mobilized segment.[42] Therefore, the mobilization forces applied at L4 level was expected to induce movements and physiological effects at L2–L3 levels. Furthermore, the effect of mobilization on PPT has been observed locally as well as at remote sites in a previous study[43] suggesting central mechanism of pain reduction.

An algometer with a 1-cm square tip was applied at L2–L3 level between the EMG electrodes on the right side (3.5 cm lateral from the lumbar spinous processes). The testing point (L2–L3) was marked with a marker to ensure reliable and rapid location during the experimental procedure. The pressure from the algometer tip was applied at the rate of 1 kg/s using visual feedback on a computer screen provided by the LabVIEW program. Subjects were provided with a computer mouse and instructed to click the mouse button once they began to feel a change in the sensation from pressure to mild pain. The readings of the algometer were captured when the subject clicked the mouse button. The PPT testing was repeated three times with 10 seconds rest between each repetition[44] immediately after the arm-lift task, before and after the intervention.

Data Analysis

IPAQ and Beck depression scores were transformed to categorical variables according to their corresponding guidelines. Furthermore, pain scores less than 5 (i.e., 3 or 4) were categorized as moderate pain, whereas pain scores of 5 or more were categorized as severe pain.[45]

LM muscle thickness from the US images was measured with Image J software (National Institutes of Health, Bethesda, MD).[46] The thickness at both rest and activity was measured as the distance between the posterior part of the facet joint and the fascial plane (Figure 2). The contraction of LM was calculated using the following equation:[47]

$$LMcontraction = \frac{LMthickness_{activity} - LMthickness_{rest}}{LMthickness_{rest}} \quad \text{Eq. 1}$$

To analyze the EMG signals from the back-lift and arm-lift tasks, the MATLAB program was used (MathWorks, Natick, MA). First, the EMG signals were filtered twice, with a second-order Butterworth band pass filter (30-400 Hz) and with a Butterworth notch filters (60, 120, and 180 Hz). These filters were performed both forward and reverse to eliminate temporal effects of the filter. The notch filters were used to remove electrical noise. Second, the signals were rectified and integrated using root-mean-square (RMS, 20-ms window size). Third, the activity onset was determined for the posterior deltoid muscle and defined as the time point when the signal exceeded a threshold of the mean plus 2 SD away from its baseline for more than 25 consecutive samples.[48] Fourth, the RMS values during the middle second of the contraction (second two after the onset) were selected for the three ES electrodes locations (L1_Left, L1_Right, and L4_Right). Finally, the normalized amplitudes of EMG (nEMG) were calculated by dividing the RMS values from the arm-lift task by the RMS values from the back-lift task; the nEMG values were used for statistical analysis.

The activity onsets from the three ES electrodes were calculated the same way as the activity onset of the posterior deltoid muscle. Then, the relative activity onsets from the three ES electrodes were calculated by subtracting the deltoid activity onset.

The contraction of LM, nEMG of ES, and the activity onsets of ES were averaged across the three trials of the arm-lift task in each session. The averaged nEMG at L1 on both sides (L1_Right and L1_Left) were summed. The change in each outcome (the outcome at the end of the session minus the outcome at the beginning of the session) was modeled as the outcome variable in the final analysis. As a result, there were six such outcomes: the change in contraction of LM, the change in nEMG L1, the change in nEMG L4, and the change in ES activity onsets at the three electrodes locations (activity onsets at L1_Left, L1_Right, and L4_Right).

For PPT, the three values were averaged at each time point (before and after the intervention), and the percent (%) change of PPT was calculated using the following equation:

$$\%change\ of\ PPT = \frac{PPT_{afterintervention} - PPT_{baseline}}{PPT_{baseline}} \quad \text{Eq. 2}$$

Statistical Analysis

SAS statistical software (SAS 9.4, SAS Institute Inc., Cary, NC) was used for statistical analysis. For each of the six outcomes, we fitted four mixed models using the SAS MIXED Procedure and chose the best model

TABLE 1. Characteristics of Mobilization and Control Groups

	Placebo (n=11)	Mobilization (n=10)	p-Value*
Gender (no. of males)	5	4	0.58
Age (yrs)	25 (24–42)	24.5 (20–37)	0.25
BMI	22.5 (19.8–25.5)	25.4 (21.0–26.9)	0.19
IPAQ physical activity category (n)Mild Moderate High	227	045	0.45
Pain intensity (0–10)	3 (3–4)	5 (4–5)	0.02†
MOSQ	14 (10–26)	24 (13–29)	0.20
FABQ physical subscale	11 (6–12)	16 (12.5–17.5)	0.01†
FABQ work subscale	9 (6–14)	11 (5–14)	0.65
BDI-II (n)			0.36
Normal	10	6	
Mild mood disturbance	1	2	
Borderline depression	0	1	

Values are in median (25th–75th percentiles) format unless otherwise indicated. BMI, body mass index; IPAQ, International Physical Activity Questionnaire; MOSQ, modified Oswestry Back Pain Disability Questionnaire; FABQ, Fear-Avoidance Beliefs Questionnaire; BDI-II, Beck Depression Inventory.
*Fisher's exact test was used to compare the categorical variables, and Mann-Whitney U test to compare the continuous variables between the two groups.
†Significant difference between the two groups (p<0.05).

according to the corrected Akaike Information Criterion (AICc). Each model included a random subject intercept to adjust for within-subject correlation. The base model included only group (placebo or mobilization) and pain category (moderate or severe) as predictors. A second model included group, pain category, and session; a third model included group, pain category, and group × pain category interaction. The full model included session, group, pain category, and group × pain category interaction. After model selection, we re-fitted the final model for each outcome using "sandwich" variance estimators for robustness against non-normality. In addition, Spearman correlations were computed to investigate the relationship between % change of PPT and any significant changes in the outcomes.

Results

Table 1 describes subject characteristics and clinical outcomes at base line. Two subjects in the placebo group withdrew after the first session due to testing time conflict, and one subject in the mobilization group did not complete the IPAQ, MOSQ, BDI-II, and FABQ questionnaires. The available data from the 21 subjects were analyzed. Most subjects had moderate or high physical activity level (6 moderate, 12 high, and 2 low) and experienced moderate pain intensity (13 moderate, 8 high). Most subjects had minimum to moderate disability (12 minimal disability, 8 moderate disability) and did not report depression (16 had normal score on BDI-II, 3 had mild mood disturbance, and 1 had borderline depression). The mean and SD for the maximum mobilization force that was applied in the mobilization group was 108±35 N.

For three outcomes (changes in LM contraction, nEMG L1, and nEMG L4) the statistical model including group, pain category, and group × pain category interaction was selected as best-fitting. The interaction was statistically significant for all three outcomes (p=0.01, 0.03, and 0.03, respectively). We carried out post hoc tests of group effect by pain category. For the changes in LM contraction, the group effect was significant only for subjects with moderate pain (p=0.03), suggesting mobilization led to more LM contraction compared to the placebo group in subjects with moderate pain. For the changes in nEMG L1 and the changes in nEMG L4, the group effect was significant only for subjects with severe pain (p=0.01 and 0.05, respectively), suggesting that mobilization led to less EMG activity compared to the placebo group in subjects with severe pain. All three of these effects were large, corresponding to an estimated between-group difference exceeding 1 SD (Table 2).

For all three activity onset of ES outcomes, the best-fitting model was the base model (with only group and pain category as predictors). There were statistically significant effects of group in the onset of ES at L1_Left and L1_Right locations. Under placebo the average onset time increased after intervention, whereas the applied mobilization force led to a decrease in the average onset time. The estimated between-group differences for L1 Left and Right, respectively, were 49 ms (p=0.02) and 86 ms (p=0.05), equivalent to differences of 0.63 and 0.72 SD.

There were no statistically significant effects for the activity onset of ES at L4 location, although the effect for group was in the same direction as for the L1 locations (estimated between-group difference = 79 ms, equivalent to 0.61 SD, p=0.08).

For the relationship between the significant changes in the outcomes and the % change in PPT, there were weak to moderate but insignificant correlations (Table 3).

Discussion

The purpose of the study was to investigate the effect of grade III lumbar mobilization on back muscle activity in people with chronic LBP. US imaging of LM muscle

TABLE 2. Changes in LM Contraction and nEMG of ES

Pain Category	Outcomes	Placebo Group Mean (SD)	Mobilization Group Mean (SD)	Estimated Difference Between Groups (SD)	*p*-Value
Moderate pain	nEMGL1	–0.04 (0.16)	0.02 (0.24)	0.39	0.53
	nEMG L4	–0.02 (0.06)	0.01 (0.09)	0.49	0.26
	LM contraction	–0.01 (0.04)	0.03 (0.03)	1.04	0.03†
Severe pain	nEMG L1	0.20 (0.16)	–0.04 (0.08)	–1.39	<0.01†
	nEMG L4	0.08 (0.10)	–0.04 (0.05)	–1.76	0.05†
	LM contraction	0.02 (0.02)	<0.01 (0.03)	–0.53	0.20

*A positive mean value indicates increased activity/contraction after the intervention, while negative values indicate decreased activity/contraction. LM, lumbar multifidus muscle; nEMG, normalized EMG amplitude; ES, erector spinae muscle; L, erector spinae muscle at the specified level (L1 or L4).
†Significant difference between the two groups ($p<0.05$).

and EMG of ES muscles were used to investigate this effect. A significant difference was found in the changes of LM contraction, nEMG of ES, and activity onset of ES between the placebo and the mobilization groups. These results suggest that grade III mobilization can influence muscle activity of deep and superficial back muscles, which is reported to be altered in chronic LBP and may be beneficial for normalizing muscle activation in managing chronic LBP.

There was a significant difference in changes of EMG amplitude, nEMG, between the mobilization and placebo group. Our findings line with the findings from previous studies in people with neck pain where grade III cervical mobilization immediately decreased the activity of superficial muscles and increased the activity of deep muscles.[15,16] In the absence of similar mobilization studies in people with LBP, our results can be compared with the results from thrust manipulation studies, as both thrust manipulation and high grades of mobilization (grades III and IV) apply mechanical force that stretches the joint capsule and the surrounding muscles. In addition, both mobilization and thrust manipulation have shown to change the cervical and thoracic spine muscle activity.[15,16,49,50] Previous thrust manipulation studies had shown contrary findings regarding the direction of change in EMG activity of ES after thrust manipulation in people with LBP.[13,51] Bicalho et al.[13] found that thrust manipulation immediately decreased the EMG activity of ES during dynamic extension in people with chronic LBP, whereas Keller et al.[51] found that thrust manipulation immediately increased the maximum voluntary contraction of ES. The contrast between these studies might be due to the different level of ES contraction tested. Both our study and the study by Bicalho et al.[13] used a task that required low contraction of ES. However, the study by Keller et al.[51] used a task that requires maximum contraction of ES. The decreased activity of EMG in our study reflects positive effect of mobilization toward rectifying the muscle activity since people with LBP have high EMG activity of ES at low level isometric contractions like standing.[52–54]

The significant difference in nEMG of ES in our study was only in people with severe pain. No statistically significant changes were found in people with moderate pain. This may be because back muscle dysfunction in people with LBP is associated with pain severity.[55,56] People with moderate back pain in our study may have had too little impairment in muscle activity to be rectified by the mobilization.

There was a significant difference in the ES activity onset between groups. Mobilization decreased the time of ES activity onset. These results line with the findings of a previous study by Ferreira et al.[57] in which the activity onset of the oblique internus muscle during rapid arm-lift task decreased after grade IV unilateral mobilization. Both ES and oblique internus muscles contract to stabilize the trunk during arm movement. However, the activity of the oblique internus muscle was found to occur before the activity of the deltoid muscle, while in our study the activity of ES was found to occur after the deltoid activity. The different timing of activity is probably due to differences in the task between the two studies. The arm-lift task was performed in standing position in Ferrera et al. study, which perturbed balance in antero-posterior direction[58]; therefore, the central nervous system used anticipatory postural adjustments to counteract the forthcoming postural perturbation,[59] by causing muscle contraction of oblique internal prior to the deltoid muscle with arm-lift task.[58,60–62] In our study, the arm-lift task was performed in prone position where balance was not threatened; hence, there was no need for using anticipatory postural adjustments. The ES muscle activity following the deltoid activity in our study was probably a consequence of contractions in a group of muscles (muscle chain) that synergistically work to generate a proper functional movement[63] of arm lift. The change in ES activity onset found in our study might represent better synergic activity of the muscle chain involving the ES and posterior deltoid as a result of mobilization. The change in ES activity onset found in our study might have clinical significance as a previous study has shown that people with LBP have delayed onset of ES activity.[64]

There was small but statistically significant difference in LM contraction between the two groups. Our findings line up with the results of Koppenhaver et al.[14] in which thrust manipulation was shown to increase 2% muscle thickness of LM during the arm-lift task in people with LBP. In our study, the changes in LM contraction were found only in people with moderate pain but not with severe pain. That may be due to the individualization of mobilization force according to subjects' tolerance. Subjects with severe back pain may have had increased stiffness and thus were not able to tolerance sufficient mobilization forces to stretch the deep LM muscle and the facet joint capsule, therefore causing no detectable change in LM in people with severe pain.

The correlations were insignificant between the % changes in PPT and the changes in normalized EMG, ES activity onset and LM contraction. Although there was insufficient evidence to conclude that observed changes in muscle activity are associated with change in pain threshold level, the PPT was tested after the arm-lift task, and some studies reported increased pressure threshold (pain reduction) after isometric contraction.[65–67] Therefore, it might be that the isometric contraction of the arm-lift task affected the observed PPT values, and we could not find a significant correlation between the calculated % changes in PPT and the outcome measures.

The changes in the back muscles activity/contraction found in this study might result from potential neurophysiological and mechanical effects of mobilization. Joint mobilization has been proposed to stimulate mechanoreceptors in the joints and muscles, which may alter the muscle activity through stimulating—motor neurons at the spinal level[68] and the periaqueductal gray area in the midbrain.[12]

The neurophysiological effects of mobilization are being increasingly recognized in the literature. A recent systematic review supported the neurophysiological effects of mobilization and did not support the hypothesized mechanical effects of inducing intervertebral motion.[69] In addition to the changes in muscle activity increased activity of sympathetic nervous system, both local and extra segmental hypolgesic effects, and decreased neural mechanosensitivity (the sensitivity of peripheral nerves to limb movement) were reported suggesting a potential mechanism of mobilization via modulation of the central nervous system.[69] In our study we only investigated the muscle activity and the local hypolgesic (PPT) effects of mobilization. Therefore, we cannot identify the exact mechanisms that led to the observed changes in back muscle activity/contraction.

The mobilization forces applied in our study are close to previously reported forces of grade III lumbar mobilization in people with low back pain. The mean and standard deviation (mean ± SD) for the maximum mobilization force that was applied in the mobilization group were 108±35 N. Chiradejnant et al. reported 121.4±45.7 N for the maximum force of grade III mobilization in people with LBP.[70]

TABLE 3. Correlation Between % Changes in PPT and Outcomes

	nEMGLI	nEMG L4	LM Contraction	Activity Onset of ES LI_Left	Activity Onset of ES LI_Right
Correlation coefficient	0.42	0.28	0.10	0.21	0.35
p-Value	0.06	0.24	0.68	0.39	0.13

This study has some limitations. First, the minimum detectable change for contraction of LM muscles measured by US imaging has been reported to be 11–13%.[71,72] Therefore, the small change (approximately 3%) in LM contraction found in this study may not have clinical significance. A more sensitive measure, such as needle EMG, is needed in future studies to further investigate the effect of mobilization on deep back muscle activity. Second, we did not perform a clinical examination and posterior-anterior assessment test to examine individual lumbar segmental mobility. The mobilization technique was applied at the lumbar segment L4 on all subjects, which may not represent the clinical application of mobilization treatment. L4 is unlikely to be the most symptomatic lumbar segment in all individuals. Thus, more changes in outcomes might have been induced if mobilization was applied at the most symptomatic segment of the lumbar spine or multiple segments. Furthermore, our study is not considered as a blinded study. Due to the nature of the intervention and placebo, the subjects recognized the intervention. It should also be noted that because the sample size provided limited statistical power, we did not adjust for multiple testing, so the overall false-positive rate may exceed 0.05. Study findings should be independently validated in future research.

Conclusion

This study concludes that lumbar mobilization may decrease both the EMG activity amplitude and onset of ES while increasing the contraction of LM in people with LBP. The findings contribute to the growing knowledge about underlying physiologic mechanisms of mobilization. Future studies with larger sample size and more sensitive methods than US imaging to measure the activity/contraction of deep back muscles are needed to confirm these findings.

References

1. Prevalence of disabilities and associated health conditions among adults–United States, 1999. *MMWR*. 2001;50(7):120–5.

2. Dickx N, Cagnie B, Achten E, et al. Changes in lumbar muscle activity because of induced muscle pain evaluated by muscle functional magnetic resonance imaging. *Spine (Phila Pa 1976).* 2008;33(26):E983–9.
3. Geisser ME. A meta-analytic review of surface electromyography among persons with low back pain and normal, healthy controls. *J Pain.* 2005;6(11):711–26.
4. Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine (Phila Pa 1976).* 1996;21(23):2763–9.
5. Wallwork TL, Stanton WR, Freke M, Hides JA. The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. *Man Ther.* 2009;14(5):496–500.
6. van Dieen JH, Cholewicki J, Radebold A. Trunk muscle recruitment patterns in patients with low back pain enhance the stability of the lumbar spine. *Spine (Phila Pa 1976).* 2003;28(8):834–41.
7. Wong J, Côté P, Sutton D, et al. Clinical practice guidelines for the noninvasive management of low back pain: a systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. *Eur J Pain.* 2016;21(2):201–216.
8. Maitland G, Hengeveld E, Banks K, English K. *Maitland's Vertebral Manipulation.* Edinburgh, Churchill Livingston, 2005.
9. Manipulation Education Committee. *Manipulation Education Manual for Physical Therapist Professional Degree Programs.* Alexandria, VA: APTA; 2004.
10. Coulter ID, Crawford C, Hurwitz EL, et al. Manipulation and mobilization for treating chronic low back pain: a systematic review and meta-analysis. *Spine J.* 2018;18(5):866–79.
11. Carlesso LC, Macdermid JC, Santaguida PL, et al. Beliefs and practice patterns in spinal manipulation and spinal motion palpation reported by canadian manipulative physiotherapists. *Physiother Can.* 2013;65(2):167–75.
12. Bialosky JE, Bishop MD, Price DD, et al. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Man Ther.* 2009;14(5):531–8.
13. Bicalho E, Setti JA, Macagnan J, et al. Immediate effects of a high-velocity spine manipulation in paraspinal muscles activity of nonspecific chronic low-back pain subjects. *Man Ther.* 2010; 15(5):469–75.
14. Koppenhaver SL. Association between changes in abdominal and lumbar multifidus muscle thickness and clinical improvement after spinal manipulation. *J Orthop Sports Phys Ther.* 2011; 41(6):389–99.
15. Dunning JR, Cleland JA, Waldrop MA, et al. Upper cervical and upper thoracic thrust manipulation versus nonthrust mobilization in patients with mechanical neck pain: a multicenter randomized clinical trial. *J Orthop Sports Phys Ther.* 2012;42(1):5–18.
16. Jesus-Moraleida FR, Ferreira PH, Pereira LS, et al. Ultrasonographic analysis of the neck flexor muscles in patients with chronic neck pain and changes after cervical spine mobilization. *J Manip Physiol Ther.* 2011;34(8):514–24.
17. Deyo RA, Dworkin SF, Amtmann D, et al. Report of the NIH Task Force on research standards for chronic low back pain. *Pain Med.* 2014;15(8):1249–67.
18. Booth ML, Ainsworth BE, Pratt M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2003;195(9131/03):3508–1381.
19. Intensity P. Modified Oswestry Low back pain disability questionnaire. *Physiotherapy.* 1980;66:271–3.
20. Wesley AL. Toward more accurate use of the Beck Depression Inventory with chronic back pain patients. *Clin J Pain.* 1999;15(2):117–21.
21. Waddell G, Newton M, Henderson I, et al. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain.* 1993; 52(2):157–68.
22. Graphpad. Randomly assign subjects to treatment groups using QuickCalcs La Jolla California USA. Available from: http://www.graphpad.com/quickcalcs/randomize1.cfm. [cited 2016].
23. Mehyar F, Santos M, Wilson SE, et al. Immediate effect of lumbar mobilization on activity of erector spinae and lumbar multifidus muscles. *J Chiropract Med.* 2017;16(4):271–8.
24. Kiesel KB, Uhl TL, Underwood FB, et al. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Man Ther.* 2007;12(2):161–6.
25. Petty NJ, Bach TM, Cheek L. Accuracy of feedback during training of passive accessory intervertebral movements. *J Man Manip Ther.* 2001;9(2):99–108.
26. Petty NJ, Messenger N. Can the force platform be used to measure the forces applied during a PA mobilisation of the lumbar spine? *J Man Manip Ther.* 1996;4(2):70–6.
27. Krekoukias G. Comparison of surface electromyographic activity of erector spinae before and after the application of central posteroanterior mobilisation on the lumbar spine. *J Electromyogr Kinesiol.* 2009;19(1):39–45
28. Cook C, Turney L, Ramirez L, et al. Predictive factors in poor inter-rater reliability among physical therapists. *J Man Manip Ther.* 2002;10(4):200–5.
29. Bialosky JE, Bishop MD, George SZ, Robinson ME. Placebo response to manual therapy: something out of nothing? *J Man Manip Ther.* 2011;19(1):11–19.
30. Yung E, Wong M, Williams H, Mache K. Blood pressure and heart rate response to posteriorly directed pressure applied to the cervical spine in young, pain-free individuals: a randomized, repeated-measures, double-blind, placebo-controlled study. *J Orthop Sports Phys Ther.* 2014;44(8):622–6.
31. Sipko T, Paluszak A, Siudy A. Effect of sacroiliac joint mobilization on the level of soft tissue pain threshold in asymptomatic women. *J Manip Physiol Ther.* 2018;41(3):258–64.
32. Moutzouri M, Perry J, Billis E. Investigation of the effects of a centrally applied lumbar sustained natural apophyseal glide mobilization on lower limb sympathetic nervous system activity in asymptomatic subjects. *J Manip Physiol Ther.* 2012;35(4):286–94.
33. Csapo R, Alegre LM. Effects of Kinesio® taping on skeletal muscle strength: meta-analysis of current evidence. *J Sci Med Sport.* 2015;18(4):450–6.
34. Stokes IA, Henry SM, Single RM. Surface EMG electrodes do not accurately record from lumbar multifidus muscles. *Clin Biomechan.* 2003;18(1):9–13.
35. Richardson C, Jull G, Hodges P, Hides J. *Therapeutic Exercise For Spinal Segmental Stabilization In Low Back Pain: Scientific Basis And Clinical Approach.* Churchill Livingstone; 1999.
36. Hermens H, Freriks B, Merletti R, et al. SENIAM: European recommendations for surface electromyography; Enschede, Roessingh Research and Development, 1999.
37. Mieritz RM, Kawchuk GN. The accuracy of locating lumbar vertebrae when using palpation versus ultrasonography. *J Manip Physiol Ther.* 2016;39(6):387–92.
38. Reichert B, Stelzenmueller W. *Palpation Techniques: Surface Anatomy for Physical Therapists.* Thieme, 2011.
39. Snider KT, Snider EJ, Degenhardt BF, et al. Palpatory accuracy of lumbar spinous processes using multiple bony landmarks. *J Manip Physiol Ther.* 2011;34(5):306–13.
40. Shirley D, Lee M, Ellis E. The relationship between submaximal activity of the lumbar extensor muscles and lumbar posteroanterior stiffness. *Phys Ther.* 1999;79(3):278–85.
41. Potter L, McCarthy C, Oldham J. Algometer reliability in measuring pain pressure threshold over normal spinal muscles to allow quantification of anti-nociceptive treatment effects. *Int J Osteopath Med.* 2006;9(4):113–9.
42. Lee M, Steven GP, Crosbie J, Higgs RJ. Towards a theory of lumbar mobilisation: the relationship between applied manual force and movements of the spine. *Man Ther.* 1996;1(2):67–75.

43. Vicenzino B, Collins D, Benson H, Wright A. An investigation of the interrelationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. *J Manip Physiol Ther.* 1998; 21(7):448–53.
44. Farasyn A, Meeusen R. Pressure pain thresholds in healthy subjects: influence of physical activity, history of lower back pain factors and the use of endermology as a placebo-like treatment. *J Bodyw Move Ther.* 2003;7(1):53–61.
45. Collins SL, Moore RA, McQuay HJ. The visual analogue pain intensity scale: what is moderate pain in millimetres? *Pain.* 1997; 72(1):95–7.
46. ImageJ. National Institutes of Health, 1997–2014. Available from: http://imagej.nih.gov/ij/.
47. Kiesel KB, Uhl TL, Underwood FB, et al. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Man Ther.* 2007;12(2):161–6.
48. Santos MJ, Kanekar N, Aruin AS. The role of anticipatory postural adjustments in compensatory control of posture: 1. Electromyographic analysis. *J Electromyogr Kinesiol.* 2010;20(3):388–97.
49. Cleland J, Selleck B, Stowell T, et al. Short-term effects of thoracic manipulation on lower trapezius muscle strength. *J Man Manip Ther.* 2004;12(2):82–90.
50. Liebler EJ, Tufano-Coors L, Douris P, et al. The effect of thoracic spine mobilization on lower trapezius strength testing. *J Man Manip Ther.* 2001;9(4):207–12.
51. Keller TS, Colloca CJ. Mechanical force spinal manipulation increases trunk muscle strength assessed by electromyography: a comparative clinical trial. *J Manip Physiol Ther.* 2000;23(9):585–95.
52. Ambroz C, Scott A, Ambroz A, Talbott EO. Chronic low back pain assessment using surface electromyography. *J Occup Environ Med.* 2000;42(6):660–9.
53. Sihvonen T, Partanen J, Hanninen O, Soimakallio S. Electric behavior of low back muscles during lumbar pelvic rhythm in low back pain patients and healthy controls. *Arch Phys Med Rehabil.* 1991;72(13):1080–7.
54. Lofland KR, Cassisi JE, Levin JB, et al. The incremental validity of lumbar surface EMG, behavioral observation, and a symptom checklist in the assessment of patients with chronic low-back pain. *Appl Psychophysiol Biofeedback.* 2000;25(2):67–78.
55. Arendt-Nielsen L, Graven-Nielsen T, et al. The influence of low back pain on muscle activity and coordination during gait: a clinical and experimental study. *Pain.* 1996;64(2):231–40.
56. Sihvonen T, Huttunen M, Makkonen M, Airaksinen O. Functional changes in back muscle activity correlate with pain intensity and prediction of low back pain during pregnancy. *Arch Phys Med Rehabil.* 1998;79(10):1210–2.
57. Ferreira ML, Ferreira PH, Hodges PW. Changes in postural activity of the trunk muscles following spinal manipulative therapy. *Man Ther.* 2007;12(3):240–8.
58. Bleuse S, Cassim F, Blatt JL, et al. Vertical torque allows recording of anticipatory postural adjustments associated with slow, arm-raising movements. *Clin Biomech (Bristol, Avon).* 2005; 20(7):693–9.
59. Santos MJ, Aruin AS. Role of lateral muscles and body orientation in feedforward postural control. *Exp Brain Res.* 2008; 184(4):547–59.
60. Aruin AS, Latash ML. Directional specificity of postural muscles in feed-forward postural reactions during fast voluntary arm movements. *Exp Brain Res.* 1995;103(2):323–32.
61. Friedli WG, Hallett M, Simon SR. Postural adjustments associated with rapid voluntary arm movements 1. Electromyographic data. *J Neurol Neurosurg Psychiatry.* 1984;47(6):611–22.
62. Kanekar N, Santos MJ, Aruin AS. Anticipatory postural control following fatigue of postural and focal muscles. *Clin Neurophysiol.* 2008;119(10):2304–13.
63. Latash ML, Scholz JP, Schoner G. Toward a new theory of motor synergies. *Motor Control.* 2007;11(3):276–308.
64. Boudreau S, Farina D, Kongstad L, et al. The relative timing of trunk muscle activation is retained in response to unanticipated postural-perturbations during acute low back pain. *Exp Brain Res.* 2011;210(2):259–67.
65. Koltyn KF, Umeda M. Contralateral attenuation of pain after short-duration submaximal isometric exercise. *J Pain.* 2007; 8(11):887–92.
66. Gajsar H, Titze C, Hasenbring MI, Vaegter HB. Isometric back exercise has different effect on pressure pain thresholds in healthy men and women. *Pain Med (Malden, Mass).* 2016; 18(5):917–923.
67. Kosek E, Ekholm J. Modulation of pressure pain thresholds during and following isometric contraction. *Pain.* 1995; 61(3):481–6.
68. Sterling M. Cervical mobilisation: concurrent effects on pain, sympathetic nervous system activity and motor activity. *Man Ther.* 2001;6(2):72–81.
69. Lascurain-Aguirrebeña I, Newham D, Critchley DJ. Mechanism of action of spinal mobilizations: a systematic review. *Spine.* 2016;41(2):159–72.
70. Chiradejnant A, Latimer J, Maher CG. Forces applied during manual therapy to patients with low back pain. *J Manip Physiol Ther.* 2002;25(6):362–9.
71. Koppenhaver SL, Hebert JJ, Fritz JM, et al. Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. *Arch Phys Med Rehabil.* 2009;90(1):87–94.
72. Wong AY, Parent E, Kawchuk G. Reliability of 2 ultrasonic imaging analysis methods in quantifying lumbar multifidus thickness. *J Orthop Sports Phys Ther.* 2013;43(4):251–62.