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A Comparison of Select Trunk Muscle Thickness Change Between Subjects With Low Back Pain Classified in the Treatment-Based Classification System and Asymptomatic Controls

The importance of identifying subgroups of patients with low back pain (LBP) to guide clinical intervention and research has been highlighted as a research priority since 1996.[3,4] Because of the difficulties of grouping patients with LBP into relevant pathoanatomical categories, classification schemes derived from clinical examination findings and historical factors have evolved. The Treatment-Based Classification (TBC) system, initially proposed by Delitto et al[14] in 1995, suggests that identifiable subcategories of patients with LBP exist. A clinical commentary of the evolution and current status of the TBC system[21] reviews the current evidence and implications of classifying patients with LBP for clinical research and practice. Research published since 2002 has demonstrated that subgroups of patients with LBP exist and respond differently to treatment.[5,10,19,26,29,42] This line of inquiry has helped challenge the assertion that the majority of LBP is "nonspecific," suggesting that the classification-driven intervention approach is superior to the watchful-waiting treatment approach for patients with LBP.[1,12,22]

• **STUDY DESIGN:** Cross-sectional descriptive.

• **OBJECTIVES:** To investigate if muscle thickness change, as measured with rehabilitative ultrasound imaging (RUSI), is different across subgroups of patients with low back pain (LBP), classified in the Treatment-Based Classification (TBC) system, when compared to controls.

• **BACKGROUND:** Researchers have demonstrated that subgroups of patients with LBP exist and respond differently to treatment, challenging the assertion that LBP is "nonspecific." The TBC system uses 4 categories (stabilization, mobilization, direction specific exercise, or traction) to subgroup patients. Recently, researchers have demonstrated impairments of the transverse abdominis (TrA) and lumbar multifidus (LM) in those with LBP, regardless of classification. Although distinct differences in impairments have been identified between subgroups, TrA and LM impairments have not been studied and may be present across categories of the TBC system.

• **METHODS AND MEASURES:** RUSI was utilized to measure percent thickness change from rest to contracted state during a voluntary task of the TrA and during an upper extremity task known to activate the LM in 56 subjects classified in the TBC system and 20 controls.

• **RESULTS:** During the prone upper extremity lifting task with a hand weight, there was a significant group difference for the LM at L4-L5 (P = .03) and at L5-S1 (P = .04), and during volitional activation for the TrA ($P<.01$). Post hoc testing revealed the differences were between controls and both the direction specific and stabilization categories at the L4-L5 level, between control and direction specific category for the L5-S1 level, and between controls and all 3 categories for the TrA.

• **CONCLUSION:** Deficits in the ability to generate muscle thickness changes in the TrA and LM occurred across categories of the TBC system. Intervention studies should be performed to determine if intervention can correct these deficits and if deficit corrections are related to outcomes.
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• **KEY WORDS:** *multifidus, sonography, spine stabilization, therapeutic exercise, transverse abdominis*

The TBC system utilizes relevant historic factors, current disability and pain levels, and key clinical exam findings to classify patients into 1 of the 4 categories: direction-specific exercise (flexion or extension), mobilization (manipulation), stabilization (core stabilization program), or traction. Studies utilizing the entire TBC system have included subjects with self-reported duration of symptoms of less than 90 days.

Reliability of clinicians classifying subjects into each of the categories of the TBC system was originally reported in 2000 by Fritz et al[23] (κ = 0.56, 65% agreement) and again in 2006 by Fritz

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et al,[20] where an updated algorithm was applied (κ = 0.60, 76% agreement). The reliability of individual clinical examination items used in the TBC system clinical exam has been reported by Hicks et al.[29] In addition, which factors are the most useful to discriminate between categories has been established.[25] Researchers have demonstrated that clinical outcomes are superior when subjects receive an intervention that is matched to their category, as compared to those when subjects receive an unmatched intervention.[5,10,29] Additionally, the results of a randomized trial have provided preliminary evidence demonstrating that interventions based on the TBC system produce superior outcomes when compared to outcomes of LBP interventions based on current medical treatment guidelines.[22]

While the TBC approach to LBP intervention has provided a model for classification and has a growing body of evidence, research supporting the impairment-based approach to LBP intervention has also continued to develop. With an improved ability to measure muscle impairments in subjects with LBP, such as using indwelling electromyography (EMG) to assess muscle activation and timing, there is a growing body of neurophysiologic, as well as clinical, evidence suggesting that the deep musculature of the spine is impaired in those with LBP.[17,43,46] This line of research has been developed independent of the TBC system and has led to the motor control model of spinal stabilization training. The motor control model of spinal stabilization focuses on the function of deep spinal muscles because these structures are thought to have the ability to control motion between vertebral segments. Researchers have demonstrated that impairments in these deep muscles, including atrophy,[2,30,32,38,41,56] delayed activation[16,36,37] and a lack of volitional control,[11,28] are present in subjects with LBP and in those with previous LBP episodes pain-free at the time of testing. The motor control approach emphasizes that subjects learn to preferentially activate the deep trunk muscles,[47] primarily the transverse abdominis (TrA) and lumbar multifidus (LM). For the interested reader, a recent systematic review summarizes the clinical evidence to date supporting the motor control model of intervention.[17]

Clinical assessment of deep muscle performance to help guide clinical intervention is difficult. Indwelling EMG has traditionally been used to assess the magnitude and timing of the TrA and LM. Unfortunately, the invasiveness of these procedures limits their routine clinical use.[53] There is emerging research evidence supporting the use of ultrasound imaging as a noninvasive tool to assess deep muscle function.[34] The application of ultrasound imaging for the purposes of biofeedback and muscle performance measurement by rehabilitation professionals has been named rehabilitative ultrasound imaging (RUSI).[52] The most common parameter measurable with RUSI that relates to muscle activation is a change in muscle thickness. Several researchers have utilized thickness change as an indicator of muscle activation for the TrA[8,7,16,28,49,53] and LM.[31,54] The validity of utilizing muscle thickness change as a measurement of lower level muscle activation has been demonstrated in the TrA[35,44] and LM[40] in an asymptomatic population and for the TrA in subjects with LBP.[16]

Motor control deficits may, in part, be caused by pain, irrespective of the source,[36] which supports the concept that motor control deficits may be present across all LBP classifications. Although a recent study[5] utilizing the TBC system included a general stabilization program for all subjects, specific muscle impairments were not assessed. If differences exist in the performance of deep stabilizing muscles between subjects with LBP in any TBC category and asymptomatic control subjects, basic motor control training, such as TrA and LM volitional activation exercises, may be appropriate across the different categories of the TBC system. The purpose of this study was to investigate the percent of muscle thickness change (as measured by RUSI) from rest to contracted state during a voluntary task of the TrA and during an upper extremity task known to activate the LM across subgroups of patients with LBP classified in the TBC system. A secondary aim of this study was to determine if percent muscle thickness change differs between subjects with LBP based on their current duration of symptoms. Thirdly, the reliability of classifying subjects into the TBC system and of measuring percent muscle thickness change with RUSI was examined.

METHODS

Subjects

Subjects 18 to 60 years of age, with a modified Oswestry score of 25% or greater, who were referred to 1 of 5 physical therapy clinics for treatment of LBP, were recruited for this study. The traction category of the TBC includes patients who have lower extremity symptoms that do not centralize with either repeated flexion or extension movements. This category represents the smallest portion of patients in the TBC system (8%)[25] and unlike the other categories of the TBC system, the traction category has not been validated in an individual study. Therefore, subjects classified in the traction category were excluded from this study. Previous studies utilizing the TBC system have excluded subjects with self-reported duration of symptoms greater than 90 days. In this study, duration of current episode of LBP was not utilized as an exclusion criteria in an effort to broaden the sample to reflect the typical patient referred to physical therapy for LBP. Additional exclusion criteria included prior lumbar surgical intervention, overt neurological compromise including lower limb deep tendon reflex loss or gross myotomal strength loss, fracture, infection, tumor, pregnancy, or recent ingestion of a contrast medium (which is a contraindication to RUSI).

Consecutive subjects were screened for inclusion from March to December 2006.

TABLE 1 Descriptive Statistics*

	Control (n = 20)	Direction-Specific Exercise (n = 16)	Mobilization (n = 22)	Stabilization (n = 18)	*P* Value
Age (y)	41.2 ± 8.6	41.6 ± 11.7	44.1 ± 9.8	42.9 ± 12.0	.82
Height (cm)	170.6 ± 11.2	169.7 ± 8.0	170.0 ± 9.6	166.4 ± 9.1	.68
Body mass (kg)	79.1 ± 15.0	86.8 ± 22.3	80.8 ± 18.6	77.7 ± 25.2	.66
Baecke activity score†	38.1 ± 3.8	40.0 ± 6.8	42.5 ± 6.54	36.2 ± 8.9	.07
Oswestry score‡		42.6 ± 11.6	37.7 ± 15.5	34.8 ± 11.2	.24
Pain rating§		6.1 ± 1.8	5.1 ± 1.7	5.3 ± 1.9	.28
Duration of symptoms (w)		10.8 ± 15.6	11.6 ± 16.4	12.8 ± 14.4	.94
Fear-Avoidance Beliefs Questionnaire (Work)–		14.7 ± 12.2	16.4 ± 11.7	15.2 ± 9.8	.91
Fear-Avoidance Beliefs Questionnaire (Activity)¶		16.1 ± 7.2	16.6 ± 4.3	16.1 ± 6.4	.96

** Values represent mean ± SD.*
† Baecke Activity Questionnaire range of scores is from 0 to 75, with higher scores indicating higher levels of activity.
‡ Oswestry range of scores is from 0 to 100, with higher scores indicating higher levels of disability.
§ Pain rating scale is from 0 to 10 with higher scores indicating higher levels of pain.
– Fear-Avoidance Beliefs Questionnaire (work subscale) range of scores is from 0 to 42 with higher scores indicating higher levels of fear avoidance.
¶ Fear-Avoidance Beliefs Questionnaire (physical activity) range of scores is from 0 to 24 with higher scores indicating higher levels of fear avoidance.

A convenience sample of 20 control subjects, with similar demographic data and activity level, as measured by the Baecke Activity Questionnaire, was recruited. The Baecke Activity Questionnaire is a 17-question survey that measures the physical activity level of the subject. It has 3 activity domains, including activity related to the subject's work, sporting activity, and leisure activity. Its reliability has been reported in a sample of subjects with hip arthritis[45] (ICC = 0.87) and in a sample of asymptomatic adult males[18] (ICC = 0.77). The total score was utilized for analysis and higher scores represent higher levels of activity. Control subjects self-reported that they did not have a history of LBP, demonstrated pain-free trunk range of motion, and were pain-free at the time of testing (**TABLE 1**).

Power calculations performed on data demonstrating that experimentally induced pain reduces thickness change of the TrA and LM[39] indicated that a sample size of 14 per group would be needed to detect a meaningful difference in muscle thickness change with 80% power at the alpha level of .05. To account for attrition, we attempted to recruit approximately 20 subjects per group.

The protocol for this study was approved by the Institutional Review Boards at the University of Kentucky and the University of Evansville. All subjects provided informed consent and their rights were protected at all times.

Procedures

Eight physical therapists who routinely use the TBC system in their daily practice participated in this study. All therapists completed a training session conducted by the principal investigator, which covered the algorithm used to classify subjects into the TBC system and all details of the study protocol. Each therapist received written documentation of the study protocol, which they were able to refer to when needed. Once a subject was enrolled, the treating therapist classified the subject into the appropriate category based on the algorithm described by Fritz et al.[20] The algorithm (**APPENDIX**) was modified to account for subjects with greater than 16 days of symptoms who still fit best into the mobilization category. All the variables of the clinical predictive rule for manipulation are included as part of the clinical examination and clinicians were trained to determine if the subject met this rule. Because a large portion of patients with LBP referred to our clinics are beyond 16 days of onset, it was decided to retain the mobilization criteria described in previous studies of the TBC system.

The subjects received initial treatment based on their category and were scheduled for their RUSI exam as soon as possible after the subject was enrolled. The mean (SD) number of days between initially being enrolled in the study and RUSI exam was 4.0 (2.9). Twelve subjects received 1 additional physical therapy treatment prior to their RUSI exam and the remaining subjects completed the RUSI exam before their next scheduled physical therapy appointment.

To determine the reliability of classifying subjects into the categories of the TBC between the participating clinicians and the principal investigator, all subjects who did not change more than the minimally clinically important difference (MCID) on the Oswestry (6 points)[24,20] were also classified by the principal investigator after completion of the RUSI exam. A total of 30 subjects met this criterion and were included in the TBC reliability analysis.

Ultrasound Exam

RUSI measurements were obtained using the Sonosite 180 Plus (Sonosite, Inc, Bothell, WA) computerized sonography unit with a 2- to 5-MHz curvilinear transducer

TABLE 2 Percent Thickness Change Between Groups Defined Using a Treatment-Based Classification System*

Muscle/Group	Mean ± SD	95% CI	*P* Value
TrA (ADIM)			
Control	99.1 ± 14.8	92.1-105.9	
Direction specific†	66.8 ± 28.6	50.3-83.4	.01
Mobilization†	65.3 ± 26.5	53.5-77.0	<.01
Stabilization†	51.5 ± 21.8	40.6-62.4	<.01
LM at L4-L5 level			
Arm elevation no load			
Control	18.3 ± 5.6	15.7-20.9	
Direction specific	12.5 ± 8.2	7.9-17.1	.11
Mobilization	13.7 ± 9.9	9.4-18.1	.26
Stabilization	14.2 ± 6.1	11.2-17.3	.16
Arm elevation with load			
Control	24.4 ± 7.0	21.1-27.7	
Direction specific†	15.9 ± 9.8	10.5-21.3	.04
Mobilization	17.9 ± 11.7	12.4-23.4	.12
Stabilization†	16.6 ± 7.7	12.8-20.5	.01
LM at L5-S1 level			
Arm elevation no load			
Control	12.5 ± 4.3	10.3-14.8	
Direction specific	8.4 ± 5.2	4.9-11.9	.17
Mobilization	9.1 ± 6.9	5.5-12.7	.89
Stabilization	13.7 ± 8.2	8.7-18.6	.97
Arm elevation with load			
Control	17.4 ± 6.3	14.1-20.7	
Direction specific†	11.1 ± 5.5	7.4-14.8	.04
Mobilization	11.6 ± 7.4	7.7-15.6	.08
Stabilization	12.9 ± 6.0	9.2-16.5	.22

** Values are mean ± SD (95% confidence interval). P values indicate the level of statistical significance compared to the control group. There was no statistical difference among the 3 groups of subjects with low back pain for any of the variables (P>.05).*
† Indicates value is significantly different from control (P<.05).

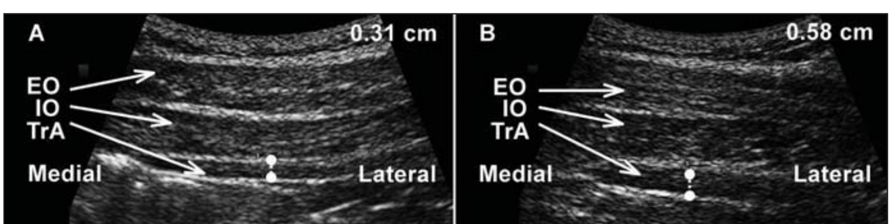

FIGURE 1. Sonogram of the lateral abdominal wall demonstrating an 87% thickness change of the TrA between rest (0.31 cm, left panel) and volitional abdominal drawing-in maneuver (0.58 cm, right panel). Abbreviations: EO, external oblique; IO, internal oblique; TrA, transverse abdominis.

set at 5 MHz. The TrA measurement was performed with the subject in the supine hook-lying position with the transducer placed along the lateral abdominal wall, just superior to the iliac crest, along the midaxillary line[48] and adjusted so the medial portion of the muscle was on the left side of the screen, as described by Henry et al[28] (**FIGURE 1**). Three rest measures were recorded at the end of normal inspiration. The end of inspiration was estimated by the examiner and used as the point to capture the rest images. It has been the experience of the principal investigator that it is more consistent to estimate end inspiration than expiration, but the TrA is slightly thinner near the end of inspiration so this methodological difference may inflate the TrA thickness change values with muscle activation when compared to other studies. Next, the TrA activation measurements were recorded while the subject performed the abdominal drawing-in maneuver (ADIM) (**FIGURE 1**). Subjects were instructed to "exhale and gently draw your lower stomach in toward your spine." This was taught to the subjects by the primary investigator and common errors, including breath holding (monitored visually), excessive external oblique activity (monitored by palpation), and posterior pelvic tilt (monitored by palpation) were corrected. Once the primary investigator determined that the subject was performing the ADIM correctly, 5 practice trials were performed before the start of data collection.

To activate the LM, a prone upper extremity lifting model, modified from a previous study,[40] was utilized. The measurement was performed with the subject in the prone position, with the upper extremity abducted to approximately 120°, the elbow flexed to 90°,[6] and pillow(s) placed under the abdomen to flatten the lumbar spine so that the lumbosacral junction angle was less than or equal to 10° (confirmed by inclinometer measurement). The transducer was placed longitudinally along the midline of the spine, first over the L4 level, then moved laterally and tilted slightly medially until the L4-L5 facet joint was visualized. A measurement from the hyperechogenic facet joint to the plane between the subcutaneous tissue and the multifidus muscle is considered LM thickness (**FIGURE 2**). This parasagittal view of the LM has been described by both Richardson et al[47] and Stokes et al,[51] and the percent thickness change from rest to activation (during contralateral upper extremity lifting) has been shown to be correlated (r = 0.79, P<.001) with EMG activity in asymptomatic subjects.[40] Measurements were taken at the L4-L5 and L5-S1 levels bilaterally, with no load (upper extremity abducted to 120° with the elbow flexed to 90°, no load) and with a hand-held load (same position using either a 0.68-, 0.90-, or 1.36-kg load, which was selected based on the subject's body mass). Previous work has demonstrated that EMG activity during these activation tasks (arm lift with and without a hand-held load) were significantly different from each other in asymptomatic subjects.[40]

Same-day intratester reliability of the RUSI measurements were calculated using data obtained from 15 subjects in the study. The RUSI exam was performed as described, then the subjects were repositioned and the exam was repeated. The tester was blinded to the results of the first examination.

Statistical Analysis

To determine if the control group was similar to the subjects in the separate categories of LBP, 1-way analyses of variance (ANOVAs) were performed on all continuous demographic variables. Muscle thickness data were collected on the left and right sides on all subjects, with the tester blinded to the subjects' TBC system category and painful side. The tester was not blinded to the control subjects. The dependent variables included the percent thickness change of the TrA measured with the subjects in a resting position during the ADIM, and percent thickness change of the LM measured at both the L4-L5 and L5-S1 levels during the prone arm lifting, as described above. All measurements were obtained via the on-screen calipers. The mean of 3 measures, which has been shown to reduce the standard error of the measurement by approximately 50%,[50] was used for all RUSI measurements. There were no significant differences (P values ranging from 0.47 to 0.91) in percent muscle thickness change between the painful and nonpainful sides for any of the 5 measurements obtained. Therefore, the values from the right and left sides for each ultrasound measurement were averaged, and the average percent thickness change values between right and left for the TrA and LM at the L4-L5 and at L5-S1 levels were used in the analysis. Additionally, the 95% confidence intervals were calculated.

To determine if a difference existed in percent thickness change of the LM at each vertebral segment and the TrA between subjects with LBP classified in each of the 3 TBC system categories and controls, separate 1-way ANOVAs for each dependent variable were conducted using TBC system group assignment as the independent variable with 4 levels. The Games-Howell post hoc test was used because the assumption of equal variance was not met for 3 of the 5 dependent variables and the sample sizes were different. The level of significance was set at .05.

To determine if differences in percent muscle thickness change existed between subjects, based only on duration of symptoms, subjects were also grouped based on current duration of symptoms with acute LBP (defined as equal to or less than 4 weeks duration), subacute LBP (defined as current symptom duration of 4 to 12 weeks), and chronic LBP (defined as current symptoms duration greater than 12 weeks). To determine if a difference existed in muscle thickness change between subjects with LBP grouped by duration of symptoms, separate 1-way ANOVAs for each dependent variable were conducted using group assignment (acute, subacute, or chronic) as the independent variable. Again the Games-Howell post hoc test was used because the assumption of equal variance was not met and the sample sizes were different. The level of significance was set at .05.

To determine the interrater reliability of classifying subjects into the TBC system, kappa coefficients and the corresponding percent agreement were calculated between the classification decision of the treating therapist and the classification decision of the principal investigator.

Intratester reliability of the RUSI measurement was examined by calculating the intraclass correlation coefficient using model 3 and the average of the 3 measures ($ICC_{3,3}$). The standard error of the measurement ($SEM = SD \times \sqrt{1 - ICC}$) and the minimal detectable change ($MDC_{95} = SEM \times \sqrt{2} \times 1.96$) were calculated for each ultrasound measurement taken. SPSS Version 14.0 (SPSS, Inc, Chicago, IL) was used for all analyses.

RESULTS

A total of 60 subjects were enrolled in the study. One subject found out she was pregnant after consenting to the study but before the RUSI exam, 1 became ill before the RUSI exam was performed and did not return, and 2 subjects did not show for their scheduled RUSI exam and could not be contacted. Therefore, a total of 56 subjects were included in the analysis. The mean (±SD) age was 43.1 (±10.9) years, height 149.9 (±9.4) cm, and body mass 83.8 (±20.8) kg, and 63% of the subjects were female. There were no significant differences for demographic variables between the control and treatment groups (**TABLE 1**).

Muscle Thickness Change: TBC Categories

The one-way ANOVA revealed a significant group difference in muscle thickness change for the LM arm lift with load at L4-L5 (F = 3.24, P = .03) and L5-S1 (F = 3.01, P = .04). Post hoc testing revealed that, for the LM arm lift with load, the differences were between controls and subjects with LBP in the direction-specific (P = .04) and stabilization (P = .01) categories for L4-L5, and between controls and subjects in the direction-specific category (P = .04) for L5-S1. No differences were identified among TBC system categories (**TABLE 2; FIGURES 3** and **4**). There were no differences among the control group and any of the groups based on the TBC sys-

TABLE 3 Percent Thickness Change Between Groups Based on Duration of Symptoms*

Muscle/Group	Mean ± SD	95% CI	*P* Value
TrA (ADIM)			
Control	99.1 ± 14.8	92.1-105.9	
Acute†	64.4 ± 23.6	54.5-74.1	<.01
Subacute†‡	74.4 ± 27.2	61.4-89.6	.02
Chronic†‡	46.4 ± 26.0	32.9-59.7	<.01
LM at L4-L5 level			
Arm elevation no load			
Control	18.3 ± 5.6	15.7-20.9	
Acute	14.1 ± 6.9	11.2-16.8	.11
Subacute	14.3 ± 9.5	8.2-20.3	.55
Chronic	12.3 ± 9.5	7.4-17.2	.13
Arm elevation with load			
Control	24.4 ± 7.0	21.1-27.7	
Acute†	17.6 ± 8.6	14.2-21.1	.03
Subacute	17.4 ± 9.5	11.4-26.2	.46
Chronic†	15.4 ± 11.2	9.4-21.4	.04
LM at L5-S1 level			
Arm elevation no load			
Control	12.5 ± 4.3	10.3-14.8	
Acute	9.1 ± 5.3	6.4-11.7	.18
Subacute	11.7 ± 7.3	6.2-17.2	.99
Chronic	11.1 ± 9.3	5.8-16.5	.95
Arm elevation with load			
Control	17.4 ± 6.3	14.1-20.7	
Acute†	10.9 ± 5.8	8.1-13.7	.02
Subacute	12.4 ± 5.8	8.3-18.0	.39
Chronic	12.3 ± 7.5	7.9-16.6	.21

** Values are mean ± SD (95% confidence interval). P values indicate the level of statistical significance compared to the control group.*
† Indicates value is significantly different from control (P<.05).
‡ Indicates value is significantly different between groups of subjects with low back pain (P<.05).

tem for the LM arm lift, with no load at either the L4-L5 level (F = 2.00, *P* = .12) or the L5-S1 level (F = 1.17, *P* = .33).

There was a significant difference in TrA percent muscle thickness change during the ADIM (F = 14.53, *P*<.01). Post hoc testing revealed the differences were between controls and subjects classified in each of the TBC categories (*P*<.01) (**TABLE 2; FIGURE 5**).

Muscle Thickness Change: Chronicity Categories

When grouped by duration of symptoms, 48% (27) of our subjects were considered to have acute LBP (duration of less than 4 weeks), 21% (12) subacute LBP (duration of 4 to 12 weeks), and 31% (17) chronic LBP (duration of greater than 12 weeks). When duration of symptoms was used as the between-subjects factor, there was again a statistical difference (**TABLE 3**) for the LM arm lift with load at the L4-L5 level (*P* = .03), L5-S1 level (*P* = .03), and TrA (*P*<.01). Post hoc testing revealed the differences were between the control and the acute and chronic groups at the L4-L5 level and between the control and acute group for the L5-S1 level. For the TrA, all groups were different than controls and the chronic group demonstrated significantly less thickness change than the subacute group. There were no differences identified for the LM arm lift with no load at either the L4-L5 level (F = 2.08, *P* = .11) or the L5-S1 level (F = 0.84, *P* = .83).

Reliability

The intratester reliability, SEM, and $MJDC_{95}$ for each of the measurements assessed were calculated and are reported in **TABLES 4** (LM) and **5** (TrA). The results for percent change in muscle thickness from rest to activation during the test with a load for the LM at L4-L5 was $ICC_{3,3}$ = 0.93 and SEM = 2.49%. For the loaded LM at the L5-S1 the results were $ICC_{3,3}$ = 0.93 and SEM = 2.02%. For the TrA the reliability was $ICC_{3,3}$ = 0.96 and SEM 6.26%.

The reliability of the classification of subjects into the categories of the TBC between the clinicians and the principal investigator was a kappa of 0.65 (agreement, 77%) with a 95% confidence interval of 0.42 to 0.87.

DISCUSSION

The results of this study support the hypothesis that muscle thickness change of the LM and TrA, as measured by RUSI during an arm-lifting task and the ADIM, is different between subjects with LBP and asymptomatic controls, but not different between subjects in the different TBC system categories. A small load added to the subject's hand when lifting the extremity during the LM test was required to expose the difference in muscle thickness change of the LM between subjects with LBP and control subjects. Additionally, the relatively large confidence intervals demonstrate that there was substantial variation in muscle thickness change of the LM between subjects, levels, and sides.

We had subjects self-report their more painful side and tested the hypothesis that the more painful side would demonstrate a greater thickness change impairment. Researchers have previously identified a consistent pattern of LM atrophy on the symptomatic side in subjects with acute[31]

TABLE 4 Same-Day Intratester Reliability for the Lumbar Multifidus*

Level/Condition	ICC (CI_{95})	SEM	MDC_{95}
L4-L5			
Rest	0.99 (0.97-0.99)	0.07 cm	0.19 cm
Arm lift	0.98 (0.92-0.99)	0.09 cm	0.25 cm
Percent change lift	0.98 (0.96-0.99)	2.96%	8.19%
Load lift	0.86 (0.60-0.95)	0.09 cm	0.25 cm
Percent change load	0.93 (0.80-0.97)	2.49%	6.89%
L5-S1			
Rest	0.99 (0.97-0.99)	0.07 cm	0.19 cm
Arm lift	0.99 (0.96-0.99)	0.07 cm	0.19 cm
Percent change lift	0.99 (0.96-0.99)	1.20%	3.32%
Load lift	0.97 (0.92-0.99)	0.07 cm	0.19 cm
Percent change load	0.93 (0.91-0.97)	2.02%	5.59%

Abbreviations: arm lift, lumbar multifidus thickness change when the upper extremity was lifted with no additional weight; CI_{95}, 95% confidence interval; ICC, intraclass correlation coefficient; load lift, lumbar multifidus thickness change when upper extremity was lifted with a weight placed in hand; percent change lift, percent thickness change from rest to activation during arm lifting; percent change load, percent thickness change from rest to activation during loaded arm lifting; SEM, standard error of measurement.
* $ICC_{3,3}$ (n = 15).

TABLE 5 Same-Day Intratester Reliability for the Transverse Abdominis*

Condition	ICC (CI_{95})	SEM	MDC_{95}
Rest	0.98 (0.91-0.99)	0.01 cm	0.03 cm
Abdominal draw-in	0.97 (0.91-0.98)	0.02 cm	0.06 cm
Percent change	0.96 (0.91-0.99)	6.26%	17.34%

Abbreviations: CI_{95}, 95% confidence interval; ICC, intraclass correlation coefficient; percent change, percent thickness change from rest to activation during the abdominal drawing-in maneuver; SEM, standard error of measurement.
* $ICC_{3,3}$ (n = 15).

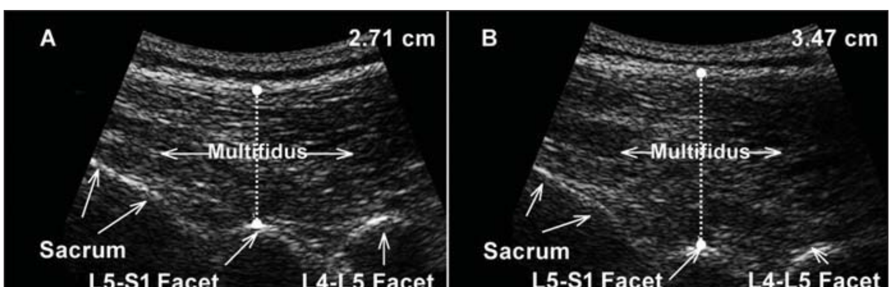

FIGURE 2. Sonogram of a parasagittal view of lumbar spine with the L5-S1 facet joint in the center. Measurement demonstrating a 28% thickness change of the lumbar multifidus between rest (2.71 cm, left panel) and automatic recruitment (3.47 cm, right panel) via contralateral arm lifting with load.

and chronic[30] LBP. Our data were not in agreement with these earlier reports as we did not identify significant statistical differences when we considered painful side or magnitude of side-to-side asymmetry. Some subjects with LBP demonstrated a deficit on their self-reported painful side, while others had a deficit on the opposite side. Similarly, there was no significant side-to-side difference seen in the control subjects. For example, the range of side-to-side differences for percent thickness change at the L4-L5 level on the test of the LM with a load varied from 1% to 26% for subjects with LBP and from 1% to 12% for the asymptomatic subjects.

A key finding of this study was that thickness change of the LM between levels and sides during the arm-lifting task was highly variable in subjects with LBP. While our sample size was large enough to find a statistical difference between controls and subjects with LBP on the LM arm lift with load test, post hoc testing revealed differences between 2 of the 3 groups at L4-L5 and 1 of 3 groups at L5-S1. The 95% confidence intervals for LM thickness change overlap for all categories, indicating variability in this measure. The reader should interpret this finding with caution. It may suggest that individual testing is required to identify if a muscle thickness change deficit is present in any 1 given patient with LBP.

A consistent finding, whether subjects were grouped by TBC category or duration of symptoms, was that it took a small load during testing to expose a deficit in LM muscle. Further research is required to understand this finding, but it appears that the LM responds differently in most subjects with LBP when the load is applied. This may suggest that rehabilitation programs should include activities with small extremity loads to improve this muscle response, as well as using some form of a loaded test when LM impairment measures are taken in future studies.

Recent clinical trials have demonstrated no difference in clinical outcomes when motor control training is compared to conventional exercise[9] for subjects with recurrent LBP or when compared to conventional exercise and manual therapy in patients with chronic nonspecific LBP.[15] Because motor control deficits are highly variable, it is not surprising that nonsignificant findings are reported from studies that randomize subjects who likely have somewhat

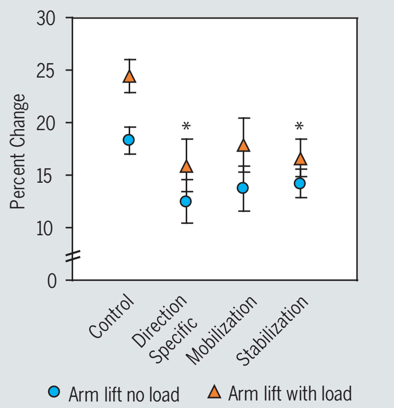

FIGURE 3. Percent thickness change of the lumbar multifidus at the L4-L5 level from rest to activation during the prone arm lift and prone arm lift with load between the control group and subjects classified into the different categories of the Treatment-Based Classification System. Error bars represent standard error of measurement. *Indicates significantly different from control at the .05 level for arm lift with load.

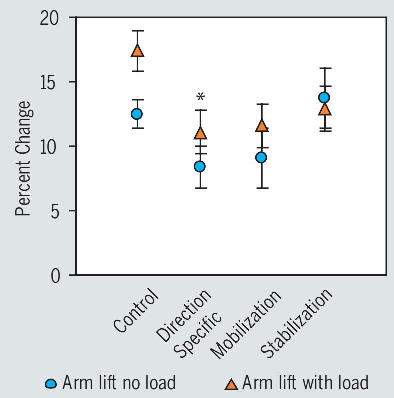

FIGURE 4. Percent thickness change of the lumbar multifidus at the L5-S1 level from rest to activation during the prone arm lift and prone arm lift with load between the control group and subjects classified into the different categories of the Treatment-Based Classification System. Error bars represent standard error of measurement. *Indicates significantly different from control at the .05 level for arm lift with load.

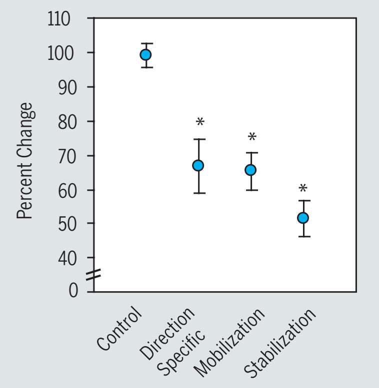

FIGURE 5. Percent thickness change of the transverse abdominis from rest to activation during the abdominal drawing-in maneuver between the control group and subjects classified into the different categories of the Treatment-Based Classification System. Error bars represent standard error of measurement. *Indicates significantly different from control at the .05 level.

heterogeneous clinical presentation (recurrent or chronic nonspecific) into different treatment groups. Some subjects in the general exercise or manual therapy groups may need a program emphasizing motor control training, while some subjects in the motor control group may need an emphasis on general exercise or manual therapy. Future research should be conducted to determine what clinical findings are present in subjects who succeed with motor control training, similar to that of Hicks et al,[29] who developed a preliminary clinical prediction rule to identify patients who would respond favorably to a stabilization program. The exercise program in the Hicks et al study[29] included both motor control training for the TrA and general trunk-strengthening activities that incorporated more global trunk musculature, making it difficult to interpret in the context of motor control training. Current research continues to support the concept described by Delitto that there is no "magic bullet" for LBP.[13]

Reliability

The same-day reliability of the RUSI measurements were good to excellent and considered clinically meaningful according to standards suggested by Portney and Watkins.[55] When considering the clinical accuracy of a measurement tool, it is important to consider the SEM as well. For the TrA, our results for rest and activation were 0.01 and 0.02 cm, which are similar to errors reported by Teyhen et al[50] for similar RUSI measurement utilizing the mean of 3 measures. For the overall measure of percent thickness change of the TrA the SEM was 6.26%. The mean (SD) percent thickness change for subjects with LBP was 61.2% (25.6%), indicating that RUSI has the ability to assess TrA thickness change beyond measurement error. Findings were similar for LM, where the mean percent thickness change for subjects with LBP during the LM arm lift with load was 16.8% (SD, 9.7) at the L4-L5 level and 11.8% (SD, 6.3) for the L5-S1 level. The SEM was 2.49% and 2.02%, respectively, indicating that RUSI can detect percent thickness change of the LM beyond measurement error. The SEM values, as reported, carry with them only 68% certainty. By multiplying the SEM by 1.96, 95% confidence is achieved. Therefore, to be 95% confident that a true difference exists beyond measurement error, the difference would have to exceed the SEM_{95} (L4-L5, 4.8%; L5-S1, 4.0%). Applying this to our nonsignificant findings for the L4-L5 level LM test with load, which were in the mobilization (manipulation) category, the difference between the control group and mobilization (manipulation) group was 7.1%, indicating the measurement was able to detect a difference with 95% certainty if a difference existed. In this case, the mobility (manipulation) category data had more variability than the other 2 groups (SD, 11.7 compared to 9.8 and 7.7), which contributed to the nonsignificant finding.

Our findings for reliability of LM percent thickness change were consistent with the data from Van et al,[54] who reported an ICC of 0.98 and an SEM of 0.31 cm, utilizing the same measurement technique in asymptomatic subjects at the L4-L5 level. Our SEM values were lower (0.07 cm), likely because we used the mean of 3 measures. These results are for the same rater on the same day only. Further research is required to establish reliability between raters and on subjects between days.

The reliability of classifying subjects into the different categories of the TBC system had a kappa of 0.65 (77% agreement). According to Portney and Watkins,[55] this is on the lower range of what is considered to represent substantial agreement (0.61-0.80), while the lower bound estimate of the 95% CI (0.42) falls in the moderate agreement range. Our findings are consistent with other reliability studies of the TBC system. Fritz and George[23] reported a kappa value of 0.56 in an intertester reliability study of 120 subjects with LBP. Fritz et al[20] reported an overall kappa of 0.60 when utilizing a newly developed algorithm for classification that was modified slightly for use in the current study. The greatest source of error in classifying subjects was a discrepancy when categorizing subjects into either the mobilization (manipulation) or stabilization category. In 4 cases, the clinician placed subjects into the stabilization category when the principal investigator had placed them into the mobilization (manipulation) category. The presence of aberrant movement patterns is an individual exam item that has been previously shown to have only fair reliability and may be variable day to day, even in an otherwise stable subject.[20] This important variable to distinguish between the stabilization or mobilization category may have contributed to our lack of agreement; or, even though we included only those subjects who were stable (less than or equal to a 6-point change on the Oswestry), the assessed impairments of patients may have simply changed in the time (mean of 4 days) between exams.

Limitations to this study include maturation, which is a threat to internal validity, as there was an average of 4 days between initial classification and the initial RUSI exam. This may have affected the muscle activation tests, as most subjects received treatment on the initial visit and had been performing their initial home exercises for at least a short period prior to the RUSI exam. Nearly half (26/56) of the subjects' Oswestry scores changed greater than the MCID of 6 points between initial classification into the TBC system and the RUSI exam. Six of the 26 had increased Oswestry scores, while the remaining improved. Completion of all of the RUSI exams on the day the subject was enrolled in the study would have been ideal. Additionally, 4 patients received spinal manipulation prior to their RUSI exam, which has been shown to immediately improve muscle thickness change in both muscles tested in separate case reports.[6,27]

We did not control for days of onset of current LBP episode, and 31% (17) of subjects had chronic LBP (greater than 12 weeks), by the classic duration-of-symptoms definition. Although the entire TBC system has not been previously tested in subjects with chronic LBP and further study is needed, the clinical predictive rule for stabilization training by Hicks et al[29] included subjects with symptom duration longer than 90 days. Of the 17 subjects with chronic LBP included in this study, 8 were classified into the stabilization category. When subjects were grouped by chronicity, there was a significantly smaller LM thickness change when compared to controls, again on the loaded test only, for the chronic group at the L4-L5 level and the acute group at the L5-S1 level, demonstrating that duration of symptoms is not the only factor that affects muscle thickness change. For the TrA, thickness change was significantly less in all groups when compared to the control group; but the greatest deficit was seen in subjects classified as chronic (46% change), which was significantly less than the subacute (75%) but not different from the acute (64%) group. These findings are consistent with those reported by Critchley and Coutts,[11] who found significantly less thickness change in the TrA muscle in subjects with chronic LBP when compared to asymptomatic controls.

CONCLUSION

The findings of this study suggest that muscle thickness change can be measured clinically utilizing RUSI and that deficits exist in subjects with LBP. In those with LBP, there were consistent findings that the LM and TrA muscle response was attenuated when subjects performed a prone upper extremity lifting task with a small load and a preferential activation through performance of the ADIM, respectively. These differences were not consistent for subjects based on their TBC system classification. When subjects were grouped based on duration of symptoms, the muscle response was again attenuated for the LM when the load was added to the upper extremity lifting task for acute and chronic subjects and for all subjects during TrA preferential activation. Intervention studies should be performed to determine if muscle thickness change deficits can be reversed and if this has a meaningful relationship with clinical outcomes.

ACKNOWLEDGEMENTS

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MORE INFORMATION
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APPENDIX

TREATMENT-BASED CLASSIFICATION FORM

Subject ID____ Date:____________________

Age:______ M/F

Mechanism Gradual Sudden Traumatic

*Number of days since the onset of this low back pain (LBP) episode ______

*Previous LBP episodes in last 3 years 0 1-3 3-5 >5

*Does the pain extend past the knee? Yes No

*Oswestry Score ______% Current Pain Level 0-10 ______

*Fear-Avoidance Beliefs Questionnaire (FABQ) Activity Score______ *FABQ Work Score______

EXAM PROTOCOL

***Neurological Screen** **Negative** **Positive**____________________

Straight-Leg Raise (SLR) (positive if lower extremity [LE] pain reproduced 45° or below) **R** **pos** **neg** **L** **pos** **neg**

Femoral Nerve Stretch **R** **pos** **neg** **L** **pos** **neg**

***Active Range of Motion (AROM):**

Flexion Normal Restricted Pain Aberrant (painful arc, catch, thigh climb, pain on return, reversal of lumbopelvic rhythm)

Extension Normal Restricted Pain

Side Bend R Normal Restricted Pain L Normal Restricted Pain

Repeated Movement Testing:

Standing Extension x 10 Centralize Peripheralize No change

Seated Flexion x 10 Centralize Peripheralize No change

Sustained Prone Extension (30 sec) Centralize Peripheralize No change

***Other Tests**

Passive SLR ROM R >90° <90° L >90° <90°

Segmental Mobility Hypomobile Normal Hypermobile Pain__________

Prone Instability Test Positive or Negative

Prone Hip Internal Rotation ROM R > 35° L > 35°

Classification Algorithm

Centralization or Peripheralization? — **YES** → **Specific Exercise**: Flexion Extention Lateral shift Classification

NO

Onset < 16 days and no symptoms below knee?
Or
Opening or Closing pattern?
Sacroiliac Test Cluster Positive?
— **YES** → **Mobilization/Manipulation** Classification

NO

(at least 3 of the following)
SLR > 90°
Positive Prone Instability Test
Aberrant Movements
Age < 40 Years
— **YES** → **Stabilization** Classification

NO

Which Fits Best?

Manipulation		**Stabilization**		**Specific Exercise**	
Factors For	Factors Against	Factors For	Factors Against	Factors For	Factors Against
Recent onset	Pain below knee	Younger	Asymmetrical SLR ROM	Preference for sitting or standing	No LE symptoms
Hypomobililty	High frequency	Increasing episode			No change with repeated movement testing
No LE Symptom	Peripheralization	Any factors from above	FABQ Activity <9	Centralization	
FABQ Work < 19	Pain-free PAs			Peripheralization in opposite direction	

AUTHORS' RESPONSE

J Orthop Sports Phys Ther 2008;38(3): 159-161. doi:10.2519/jospt.2008.0204

We would like to thank Dr O'Brien for his thoughtful commentary on our recent case describing a patient referred to physical therapy for knee pain which was caused by a slipped capital femoral epiphysis (SCFE).[2] We would like to address the issue raised by Dr O'Brien regarding post-surgical correction in this patient. Following surgery, hip anterior-posterior and lateral frog leg views were taken by the patient's orthopaedic surgeon. In the paper,[2] **FIGURE 3** presented the anterior-posterior radiograph of the patient's involved right hip following surgical fixation of her SCFE. As Dr O'Brien notes, this postsurgical radiograph does not definitely show correction of the problem because the distal tip of the surgical screw does not clearly cross the physis into the epiphysis. In this response, we have included the lateral frog leg radiograph of the patient's involved right hip following surgical fixation of her SCFE that shows the surgical screw crossing the physis into the epiphysis (**FIGURE**). Both anterior-posterior and lateral frog leg views of the hip are recommended to assess for a SCFE and evaluate the hip following surgical fixation.[1]

FIGURE. Lateral frog leg radiograph of the patient's involved right hip following surgical fixation of her slipped capital femoral epiphysis, showing the surgical screw crossing the physis into the epiphysis (arrow).

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ERRATUM

CORRECTION

In the October 2007 article by Kiesel et al,[1] the name of coauthor Carl G. Mattacola was misspelled as "Matacolla" (page 596). This error was repeated in the Author Index of the December 2007 issue, on pages 776 and 778. Please accept our apology for this error. Corrected reprints of the article are available to members and subscribers for download on the *JOSPT* web site (www.jospt.org).

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