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Lumbar Multifidus Muscle Thickness Does Not Predict Patients With Low Back Pain Who Improve With Trunk Stabilization Exercises

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Abstract

Objective—To understand lumbar multifidus (LM) muscle activation as a clinical feature to predict patients with low back pain (LBP) who are likely to benefit from stabilization (STB) exercises.

Design—Prospective, cohort study.

Setting—Outpatient physical therapy clinics.

Participants—Persons with LBP were recruited for this study. Subjects (N=25) were classified as either eligible to receive STB exercises or ineligible on the basis of current clinical prediction rules.

Interventions—Six weeks of STB treatment.

Main Outcome Measures—Before and after treatment, subjects underwent rehabilitative ultrasound imaging to quantify LM-muscle activation and completed disability and pain questionnaires. Analyses were performed to examine the (1) relation between LM-muscle activation and current clinical features used to predict patients with LBP likely to benefit from STB exercises, (2) LM-muscle activation between the STB-eligible and STB-ineligible groups before and after STB treatment, and (3) relation between LM-muscle activation before STB treatment and (a) disability and (b) pain outcomes after treatment for both groups.

Results—No relation was found between LM-muscle activation and the number of clinical features. Before STB treatment, LM-muscle activation between the STB-eligible and STB-ineligible groups did not differ. After STB treatment, LM-muscle activation differed between the groups; however, this interaction was because the LM-muscle activation for the STB-eligible group decreased after treatment while that for the STB-ineligible group increased after treatment. Finally, only the STB-eligible group had a significant reduction in disability following treatment;

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Suppliers

however, no relation was found between LM-muscle activation before treatment and (a) disability or (b) pain outcomes after treatment in the STB-eligible group.

Conclusions—LM-muscle activation does not appear to be a clinical feature that predicts patients with LBP likely to benefit from STB exercises.

Keywords

Clinical prediction rule; Exercise; Low back pain; Rehabilitation

Low back pain (LBP) is a common disorder for which management has not reduced disability and recurrence.[1,2] Past outcome studies used heterogeneous groups with LBP,[3] which may be why no clear evidence supports any one treatment. The identification of homogeneous subgroups with LBP—based on relevant measures of impairment[4,5]—may guide research and inform clinicians about appropriate LBP treatments. Mounting evidence suggests that patient function improves if the patient's clinical features (ie, signs and symptoms) are identified initially and then used to match the patient with an efficacious treatment.[6,7]

One treatment for which clinical features have been used to predict patient outcomes is trunk-stabilization (STB) exercises. This treatment aims to reduce LBP by increasing spinal stability through exercises that improve trunk-muscle motor control and strength. Hicks et al[8] have identified 4 clinical features associated with patient improvement following STB treatment: (1) age younger than 40 years, (2) positive score on the prone instability test,[9] (3) more than 90° of hip flexion during a passive straight-leg test[9], and (4) aberrant trunk movements with lumbar-spine flexion[8]. At least any 3 of the 4 clinical features, taken together, now comprise a clinical prediction rule used to identify patients likely to improve with STB treatment.[10] In addition, Fritz et al[11] have identified another clinical feature of patients with LBP who improve with STB treatment: lumbar-spine hypermobility. However, the significance of lumbar-spine hypermobility as a predictor of improved outcomes following STB treatment was not determined in Hicks'[8] study, likely because of biased recruitment resulting in limited numbers of subjects with lumbar-spine hypermobility.

Another potential clinical feature, impaired lumbar multifidus (LM) muscle activation, may predict patients with LBP who will improve with STB treatment. The LM muscle—a deep, dorsal trunk muscle—provides spinal stability.[12] Differences in LM-muscle morphology and function [13–17] exist with LBP as demonstrated by electromyography and rehabilitative ultrasound imaging (RUSI), a valid[18] and reliable[19,20] noninvasive tool used to image trunk muscles. A study using RUSI[21] found that subjects with LBP who have at least 3 of the 4 clinical features identified by Hicks[8] had corresponding impairments in LM-muscle motor control. Further, Hebert et al[22] found a significant relation between LM-muscle activation and the number of clinical features (the 4 features identified by Hicks[8] and lumbar-spine hypermobility[11]): the greater the number of clinical features that the subject with LBP exhibited, the lower the LM activation level.[22] However, the Hebert[22] study needs clarification because there was a negative correlation noted between LM-muscle activation and the total number of predictive clinical features, but positive correlations between LM-muscle activation and each individual clinical feature. The Hebert et al[22] study also did not examine the impact of STB treatment on LM-muscle activation in patients with LBP.

Our study aimed to determine whether LM-muscle activation is a predictive clinical feature that identifies patients with LBP likely to benefit from STB treatment. We predicted that (1) before STB treatment, subjects with LBP who exhibited a greater number of clinical features identified by Hicks[8] and Fritz[11] would exhibit lower levels of LM-muscle activation than would subjects with LBP who had fewer of the clinical features; (2) after STB treatment,

subjects with LBP who exhibited a greater number of clinical features would improve more in their LM-muscle activation than would subjects with LBP who had fewer features; and (3) LM-muscle activation before treatment would correlate more with improvements in (a) disability scores and (b) pain scores after treatment in subjects with LBP who exhibited more of the clinical features than in subjects with LBP who had fewer features.

Methods

Subjects

Subjects in this study were part of a larger clinical trial (R01HD040909) in which subjects with LBP (N=149) were randomized to receive 1 of 2 treatments: STB treatment or Movement System Impairment–based treatment. This smaller study included only those subjects randomized to STB treatment and who had measurable ultrasound images before and after treatment (N = 25). Subjects (1) were between 21 and 55 years old, (2) had a history of chronic LBP (≥12mo) with or without recurrences, (3) could stand and walk independently, (4) had a Modified Oswestry Low Back Pain Disability Questionnaire (OSW) score of ≥19%, and/or a score less than 8 on at least 1 activity from the Patient Specific Functional Scale,[23] (5) could understand English, and (6) were currently employed or actively engaged in daily activities. Exclusion criteria included a structural spinal deformity, spinal fracture, osteoporosis, systemic disease processes, disk herniation with corroborating clinical signs and symptoms, previous spinal surgery, pregnancy or less than 6 months postpartum or postweaning, magnified symptom behavior,[24] and a body mass index of 30 or higher. This study was approved by the Institutional Review Board at the University of Vermont. All subjects provided written, informed consent, and the rights of each subject were protected. Figure 1 gives an outline of subject flow and data-collection procedures in this study.

Assessments before STB treatment

Questionnaire completion—All subjects completed medical history and demographic forms as well as the OSW[25] and Numeric Pain Rating Scale (NPRS).[26]

Standardized clinical exam—All subjects underwent a standardized clinical exam. Based on previous studies,[8,11,22] the exam included the following tests: the prone instability test,[9] straight-leg raise test,[9] the lumbar-spine flexion test,[8] and the lumbar-spine hypermobility test.[8,11,22] Studies [10,27–29] have demonstrated fair-to-good interrater reliability for these tests.

Determination of STB eligibility—Each subject's demographic history and clinical exam were used to determine group assignment: *STB-eligible* for STB exercises or *STB-ineligible* for STB exercises. Subjects who met at least 1 of the following criteria were assigned to the *STB-eligible* group: (1) the presence of lumbar-spine hypermobility identified by Fritz[11] and/or (2) the presence of any 3 of the 4 clinical features identified by Hicks.[8] Those subjects not meeting at least 1 of these 2 criteria were assigned to the *STB-ineligible* group. To minimize bias, 1 examiner (R.O.M.) performed the clinical exam on all subjects and determined the group assignment.

Rehabilitative ultrasound imaging—All subjects performed a contralateral arm-lifting task to activate the LM muscle while this muscle was imaged with RUSI as outlined by Kiesel et al.[18] During this task, images of the LM muscle during the relaxed and contracted states were collected, before and after STB treatment, using 1 of 2 ultrasound machines, depending on the availability of the machines: SonoSite 180 portable ultrasound machine with a 5- to 10-MHz linear array[a] (n = 9) or SonoSite MTurbo ultrasound machine (n = 16)

with a 2- to 5-MHz curvilinear array.[a] The type of ultrasound transducer (linear or curvilinear) does not affect measurements of LM-muscle thickness.[30]

Subjects performed the contralateral arm-lifting task 4 times with the right arm and 4 times with the left arm, for a total of 8 trials. For the first 2 trials on each arm, the subjects held nothing in their hands ("no resistance"). For the second 2 trials, the subjects held a small hand weight—either .68 kilograms or .90 kilograms based on the subject's body weight[18]—which provided some resistance to the arm lift in order to elicit greater LM-muscle contraction. All images were saved for later analysis.

STB treatment

All subjects in both the STB-eligible and STB-ineligible groups attended physical therapy sessions at 1 of 4 physical therapy outpatient clinics. The subjects followed an STB treatment protocol for 6 weeks, 1 treatment session per week. The STB protocol focused on 3 components of spinal stability: (1) motor control of the deep trunk muscles[8,31,32]; (2) strengthening of the flexor, extensor, and oblique trunk muscles[8]; and (3) patient education to teach subjects how to use proper body mechanics and how to protect the spine during activities of daily living. Subjects were instructed to perform these STB exercises daily. All treating physical therapists in this study received training (from S.M.H.) in how to progress the STB exercises and were blinded to the subjects' group assignment.

Assessments after STB treatment

Within a week after treatment was completed, all subjects returned for the same assessments (questionnaires, clinical exam, and RUSI). The same physical therapist conducted the exam, using the same ultrasound machine as before treatment.

Data analyses

To investigate our 3 predictions, we used customized programmable software (MATLAB software version R2010b)[b] to select images of the LM muscles at rest and contracted, marking the anatomical points of interest on each image. To maximize reliability, all image selection, reduction, and analysis was performed by 1 researcher (K.Z.) who was blinded to RUSI and subject details.

Thickness of the LM muscle at rest and during contraction, before and after STB treatment, was measured from the top of the L3/L4 facet joint to the fascial plane between the LM muscle and subcutaneous tissue (fig 2). Intrarater reliability of the researcher (K.Z.) in measuring LM-muscle thickness was assessed—using ultrasound images from 10 randomly sampled subjects (5 subjects from each ultrasound machine)—and was found to be excellent (intraclass correlation coefficient = .97 for each machine).

To investigate our first prediction, LM-muscle activation for each subject before STB treatment was calculated as a percent change in LM-muscle thickness: $[(\text{thickness}_{\text{contracted}} - \text{thickness}_{\text{rest}})/\text{thickness}_{\text{rest}}]\times 100$.[18] Linear regression analyses were performed between the percent change in LM-muscle thickness before treatment and the total number of clinical features identified by Hicks et al[8] and Fritz et al.[11] The data were further analyzed into subsets on the basis of data from the contralateral arm-lifting task with no resistance and with resistance to determine whether differences in analyses existed on the basis of the task.

[a]SonoSite, Inc, 21919 30th Dr Southeast, Bothell, WA 98021.
[b]The MathWorks, Inc, 3 Apple Hill Dr, Natick, MA 01760.

To investigate our second prediction, a mixed model, repeated-measures analysis of variance was performed by comparing the percent change in LM-muscle thickness for subjects in the STB-eligible and STB-ineligible groups before and after treatment. The effect of group, visit, and group×visit interactions was analyzed. The data were further analyzed into subsets on the basis of data from the contralateral arm-lifting task with no resistance and with resistance.

To investigate our third prediction, we used a *t* test to compare the OSW and NPRS scores before and after treatment for each group. We then performed linear regression analyses using each subject's percent change in LM-muscle thickness before treatment as the independent variable and the subject's OSW and NPRS scores before and after treatment as dependent variables. The subject's OSW and NPRS scores before treatment were used as covariates. The data were further analyzed into subsets on the basis of data from the contralateral arm-lifting task with no resistance and with resistance. All analyses were completed using a statistical significance of $P < .05$.

Power analyses showed that for linear regression analyses using LM-muscle data before treatment, the number of subjects required was N = 25 to detect a correlation of .204, with significance level .05, and power of 80%.

Results

Of the 25 subjects included in this study, 11 were identified as STB-eligible and 14 as STB-ineligible (table 1). Differences in baseline characteristics were found in sex ($P = .01$) and OSW scores ($P = .001$) between the 2 groups before they participated in treatment.

Before treatment, those subjects with LBP who exhibited a greater number of clinical features identified by Hicks[8] and Fritz[11] did not exhibit lower levels of LM-muscle activation. No significant correlation was found between the percent change in LM-muscle activation and the total number of clinical features before treatment ($P = .42$ for the no-resistance task, $P = .27$ for the resistance task).

After treatment, the STB-eligible subjects did not improve more than the STB-ineligible subjects in LM-muscle activation (table 2). No significant differences in LM-muscle activation were found between the groups before treatment ($P = .72$ for the no-resistance task, $P = .15$ for the resistance task), but significant differences were found between the groups after treatment ($P = .01$ for the no-resistance task, $P = .02$ for the resistance task). In addition, a significant group×visit interaction ($P = .01$) existed for the no-resistance task, which was due to the STB-eligible group exhibiting a decrease in mean percent change in LM thickness from pre- to posttreatment ($P = .08$) and due to the STB-ineligible group exhibiting an increase in mean percent change in LM thickness from pre- to posttreatment ($P = .05$).

After treatment, STB-eligible subjects significantly decreased their disability, indicated by significantly reduced OSW scores posttreatment ($P = .003$) (table 3). For the STB-eligible group, no significant correlations were found between the percent change in LM-muscle thickness before treatment and the change in OSW scores from pre- to posttreatment (table 4). STB-ineligible subjects did not significantly decrease their OSW scores from pre- to post-treatment ($P = .10$). For the STB-ineligible group, no significant correlation was found between the percent change in LM-muscle thickness before treatment and the change in OSW scores from pre- to posttreatment for the no-resistance task ($P = .65$), but a significant correlation was found for the resistance task ($P = .013$). No significant changes or correlations were found in terms of NPRS scores before and after treatment for either group (tables 3 and 4).

Discussion

The 3 major findings of our study were the following: (1) subjects with LBP who exhibited a greater number of clinical features did not demonstrate greater impaired LM-muscle activation; (2) LM-muscle activation differed between the STB-eligible and STB-ineligible groups after treatment, with the STB-eligible group exhibiting a decrease in LM-muscle activation and the STB-ineligible group exhibiting an increase in LM-muscle activation; and (3) only the STB-eligible group demonstrated decreased disability following treatment; however, no relations were found between LM-muscle activation before treatment and changes in (a) disability or (b) pain after treatment for the STB-eligible group. These results did not support our predictions.

Our first prediction was not supported, and our result also did not support previous results from Hebert et al,[22] who found a correlation between lower levels of LM activation and a greater number of clinical features identified by Hicks et al[8] and Fritz et al.[11] Based on current clinical theories that suggest that the LM muscle provides lumbar stability,[12,33,34] and that LM-muscle activation is impaired in patients with LBP,[13,35] our result was unexpected. However, the results presented in table 3 of Hebert[22] need clarification as the positive correlations between LM-muscle activation and each individual clinical feature in table 3 seemingly contradict the negative correlations between LM-muscle activation and each individual clinical feature depicted in figure 2 and explained in the text. Thus, further research is needed into the relation between the number of clinical features present and LM-muscle activation in patients with LBP.

The clinical features identified by Hicks[8] and Fritz[11] to determine STB eligibility may have influenced our first prediction. Although these clinical features have been used clinically to predict patients likely to improve with STB treatment,[10] they may not be the ideal constellation of features that can identify STB exercise eligibility. Further research is required to evaluate the readiness of this clinical prediction rule for use in practice.[36]

Our second prediction was not supported, which may be because of a difference between the STB-eligible and STB-ineligible groups' resting LM-muscle thickness after STB treatment. Upon further analysis using a mixed model, repeated-measures analysis of variance, we found a significant difference between the pre- and posttreatment mean resting LM-muscle thickness for the STB-eligible group (P=.02) but not for the STB-ineligible group (P=.19). The STB-eligible group displayed a significantly higher mean resting LM-muscle thickness following STB treatment. Given that percent change in LM-muscle thickness was used to reflect LM-muscle activation, a greater resting LM-muscle thickness due to muscle hypertrophy[13] could be reflected as less LM-muscle activation because the change between the resting and contracted states of the muscle is reduced.

Our third prediction was also not supported. The STB-eligible group benefited from STB treatment; however, the improvements noted in the STB-eligible group following treatment did not appear to be associated with LM-muscle thickness. Perhaps the improvements in disability in the STB-eligible group could be associated with other aspects of LM-muscle function that were not measured in this study. For example, treatment could have produced improved endurance of the LM muscle or timing of LM-muscle contraction, which would have been undetectable using RUSI. This explanation is plausible because studies using electromyography have found delayed timing of LM-muscle contraction in patients with recurrent LBP[17] but exercises focused on improving motor control—such as the ones used in this study—produced earlier and greater activity of the LM muscle in patients with recurrent LBP.[37] The use of RUSI to assess LM-muscle function may hold promise, but

additional research is needed to identify relevant aspects of LM-muscle function that could be used as clinical features to predict improvements after STB treatment.

As expected, the type of ultrasound transducer did not impart a bias to our results.[30] We performed analyses comparing LM-muscle thickness for the same group of subjects (pretreatment data, LM muscle resting state) by ultrasound machine with the assumption that similar data could be expected between machines at baseline. We performed a mixed model, repeated-measures analysis of variance comparing the baseline data between those subjects imaged using the SonoSite 180 machine (n = 9) and those subjects imaged using the SonoSite MTurbo machine (n =16), and we found no significant difference (P=.12). Thus, our results are not due to the use of 2 different machines.

Study limitations

Our study used a small sample size (n = 25), which limits the generalizability of our results. In addition, the STB-ineligible subjects, compared with the STB-eligible subjects, demonstrated a lower level of disability before STB treatment (14% vs 25% on the OSW). The lower level of initial disability in the STB-ineligible group may have resulted in a floor effect for OSW improvement in this group.

Conclusions

LM-muscle activation, as quantified by changes in LM-muscle thickness, does not appear to be a clinical feature that clinicians can use to predict patients with LBP who are likely to benefit from STB exercises. Further research is needed to identify other possible aspects of LM-muscle function that may be predictive of STB treatment success.

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List of abbreviations

LBP	low back pain
LM	lumbar multifidus
NPRS	Numeric Pain Rating Scale
OSW	Modified Oswestry Low Back Pain Disability Questionnaire
RUSI	rehabilitative ultrasound imaging
STB	stabilization

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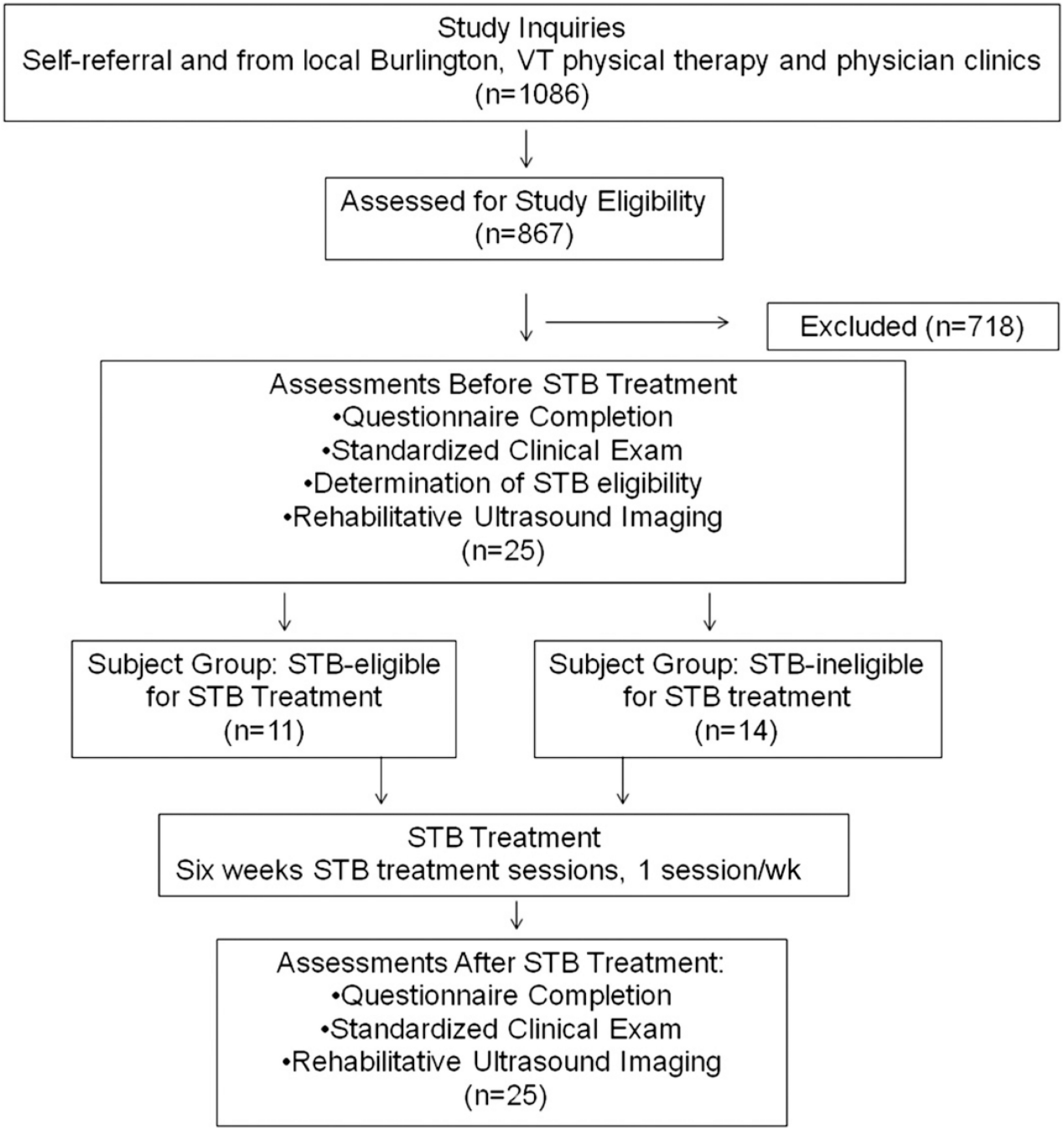

Fig 1.
Data collection and analysis procedures.

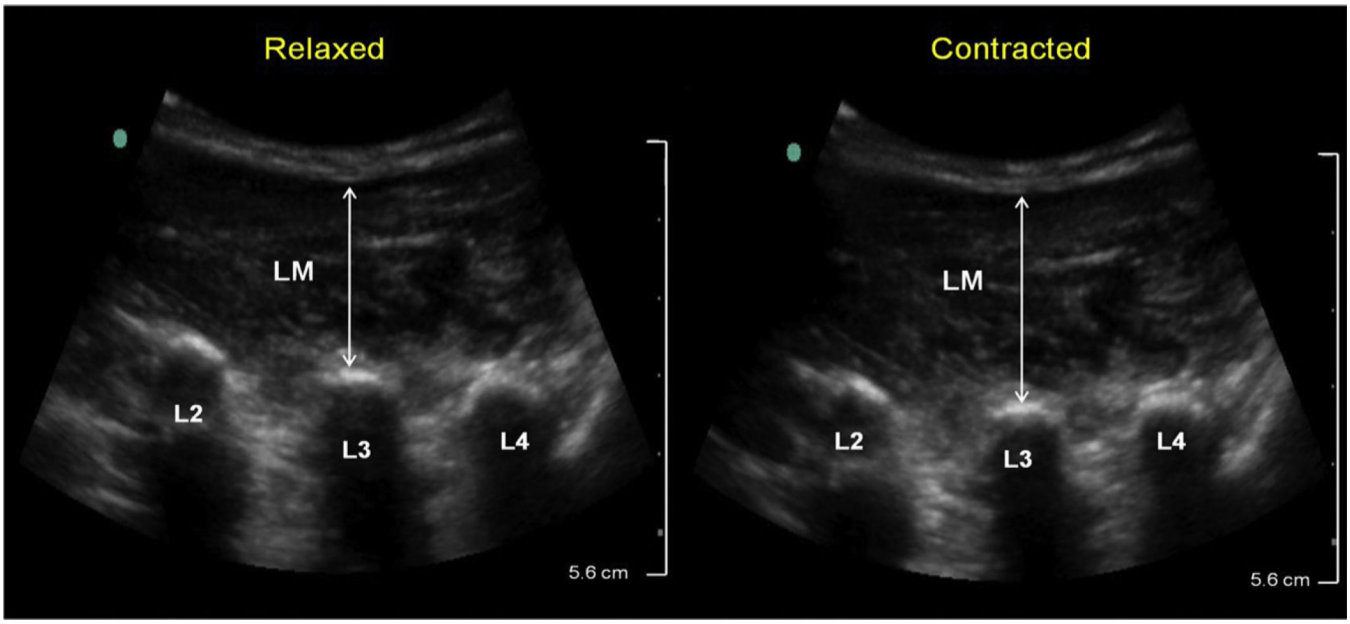

Fig 2.
RUSI measurements of the LM muscle in relaxed and contracted states during a contralateral arm-lifting task before STB treatment. Abbreviations: L2, L2/L3 vertebral facet joint; L3, L3/L4 facet joint; L4, L4/L5 facet joint.

Table 1

Subjects' baseline demographic measures

	Subjects (N=25)		
Demographic Measures	**STB-eligible (n=11)**	**STB-ineligible (n=14)**	***P***
Age (y)	34.3±10.8	42.1±10.0	.07
BMI (kg/m^2)	22.8±2.8	24.6±2.2	.09
Sex (M/F)	3/8	11/3	.01*
Duration of pain (y)	11.0±8.7	9.9±8.1	.74
OSW score (% disability)	25.3±7.7	14.6±5.5	.001*
NPRS score (out of 10)	2.8±1.7	1.8±1.3	.15

NOTE: Values are mean ± SD or as otherwise indicated.

Abbreviations: BMI, body mass index; F, female; M, male.

*Statistically significant value (P <.05).

Table 2

Comparison of mean percent change in LM-muscle thickness before and after STB treatment for the no-resistance and resistance tasks in each group

		Mean Percent Change in LM-muscle Thickness		
Group	**Task**	**Before STB Treatment (%)**	**After STB Treatment (%)**	***P***
STB-eligible (n=11)	No resistance	9.7 (range: −9.4 to 31.4)	5.7 (range: −11.6 to 26.7)	.08
	Resistance	11.2 (range: −0.4 to 31.4)	9.2 (range: −3.3 to 25.8)	.26
STB-ineligible (n=14)	No resistance	10.8 (range: −3.9 to 65.8)	14.7 (range: −3.8 to 37.0)	.05 *
	Resistance	15.3 (range: −0.9 to 40.4)	16.1 (range: −2.7 to 51.3)	.62

* Statistically significant value ($P < .05$).

Table 3

Comparison of OSW and NPRS scores for each group before and after STB treatment

Group	Questionnaire	Before STB Treatment	After STB Treatment	*P*
STB-eligible	OSW score (%)	25.3±7.7	14.6±8.8	.003*
(n=11)	NPRS score (0–10)	2.8±1.7	2.0±1.5	.13
STB-ineligible	OSW score (%)	14.6±5.5	10.3±6.6	.10
(n=14)	NPRS score (0–10)	1.8±1.3	1.4±1.3	.17

NOTE: Values are mean ± SD or as otherwise indicated.

*Statistically significant value ($P < .05$).

Table 4

Regression analyses between percent change in LM-muscle thickness before STB treatment and changes in OSW and NPRS scores before and after STB treatment

			Change in OSW Scores (Pre-post)		Change in NPRS Scores (Pre-post)	
Parameter	**Group**	**Task**	***r***	***P***	***r***	***P***
Percent change in LM-muscle thickness before STB treatment	STB-eligible (n=11)	No resistance	0.36	.06	0.094	.89
		Resistance	0.14	.39	0.13	.81
	STB-ineligible (n=14)	No resistance	0.014	.65	0.065	.94
		Resistance	0.38	.013*	0.094	.08

*Statistically significant value ($P<.05$).