Transversus Abdominis Activation During a Side-Bridge Exercise Progression Is Similar in People with Recurrent Low Back Pain and Healthy Controls

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Abstract

Himes, MA, Selkow, NM, Gore, MA, Hart, JM, Saliba, SA. Transversus abdominis activation during a side-bridge exercise progression is similar in people with recurrent low back pain and healthy controls. *J Strength Cond Res* 26(11): 3106–3112, 2012—Low back pain (LBP) affects 70–80% of the population. The transversus abdominis (TrA) has been implicated as part of the cause of LBP. Prevention and rehabilitation of LBP often target the TrA using exercises such as the side bridge accompanied with the abdominal drawing-in maneuver (ADIM). However, it is unknown whether individuals with recurrent LBP, when they are in a period of no pain, are able to activate the TrA and healthy individuals during this exercise. The purpose of our study was to compare the activation ratio of the TrA during a 5-level side-bridge exercise progression. Twenty-three subjects with a history of recurrent, nonspecific LBP, but not experiencing an exacerbation of symptoms and 24 healthy controls volunteered. All the subjects performed the ADIM and side-bridge exercises with clinician feedback (verbal cueing). Each participant performed the side-bridge exercise progression while ultrasound images were taken. The subjects were only progressed if they successfully completed the previous level. The thickness of the TrA was measured in rested and contracted states at each exercise level to find the activation ratio (TrA contracted/TrA rest). Separate analyses of covariance did not reveal a difference in activation ratios between groups ($p > 0.40$) when the ratio at the lowest level was used as the covariate. The results from this study indicate that both groups were able to contract the TrA with verbal cueing during a side-bridge exercise progression. Because the TrA contracted similarly during exercise in both groups, the association of LBP with the TrA may be because of another mechanism, such as delayed activation in the feed-forward mechanism during activity or a lack of endurance of the TrA.

Key Words muscle thickness, ultrasound imaging, verbal cueing

Introduction

Currently, 50% of the population is experiencing low back pain (LBP) (1) and 70–80% of the American population will experience LBP at least once in their lifetime (1,3). Of those who experience LBP, 60% of them will have at least 1 episode of recurrence in their LBP symptoms (3). Rehabilitation for LBP can be challenging and the outcome of conservative treatment poor, especially when the pathophysiological cause of LBP is unknown. The strength and conditioning specialist is often required to implement prevention programs designed to reduce the incidence and severity of LBP recurrence; however, these programs vary widely among professionals.

To treat patients with LBP more effectively, a treatment-based classification system for the conservative treatment of nonspecific LBP was created (1,13). In this system, patients are classified using clinical predictor rules into 4 different categories based on their medical history, the clinical examination, self-reported pain (pain scale), and disability scores (modified Oswestry questionnaire) (12,13). These categories include traction, manipulation, specific exercise, and stabilization (12,13).

The stabilization category has been characterized by poor outcomes compared with the other categories (8,9). To be classified in this category, one must have 3 of the following: average straight leg raise >90°, positive prone instability test, positive aberrant movements, and younger than 40 years.

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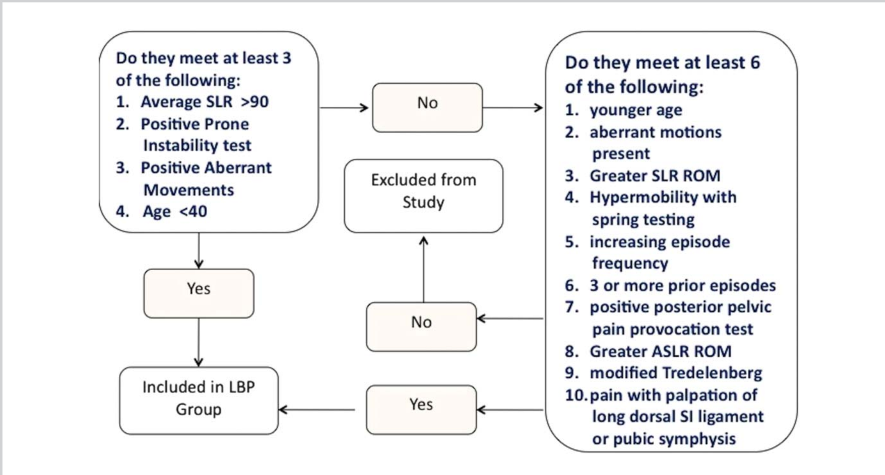

Figure 1. Flow chart for inclusion in the recurrent low back pain group.

If these are not met, then 6 of 10 criteria must be fulfilled (Figure 1) (13). This group often represents a younger population that participates in variable activity levels. For example, some individuals in this category might be high-level athletes or military recruits with recurrent back pain or they may be poorly conditioned individuals who are unable to function because of their pain. Further confounding the outcomes, there is no agreed upon therapeutic exercise regimen and data to reveal which exercises best activate and strengthen the local stabilizing muscles. Work by Hodges and Richardson (20) has identified deficiencies in the ability of the transversus abdominis (TrA) to contract in those with recurrent LBP, along with other deep intrinsic muscle during exercise, compared with a healthy control group. Even in the absence of pain, deficiencies were still identified (11). To combat these deficiencies, core strengthening exercises are commonly prescribed.

One goal of these training programs is to improve the function of the TrA and to incorporate a contraction of that muscle during tasks that require proximal stability and distal mobility during progressively more challenging positions. The most basic exercise is the abdominal drawing-in maneuver (ADIM). Once the patient has become proficient in the basic exercise, positions and tasks become more challenging in an exercise progression. For example, bridging, plank positions, or side-bridge exercises may be used (31). These exercises are commonly used for rehabilitation or for the prevention of future LBP episodes.

Many researchers have tested different exercises to determine whether the spinal stabilizers are activated (14,15,31,34). This assumption is based on the visualization and measurement of muscle thickness using ultrasound imaging (USI). Teyhen et al. (34) found the ADIM in quadruped and supine to best preferentially increase the TrA thickness in healthy subjects, whereas the side bridge and abdominal crunch to preferentially increase the thickness of both the internal oblique (IO) and TrA in healthy subjects. However, it is thought that the TrA of asymptomatic patients with recurrent LBP may activate the TrA differently to these exercises and others commonly used in stabilization programs compared with that of healthy subjects. Therefore, the purpose of this study was to determine if a side-bridge exercise progression would increase the TrA thickness in people with recurrent LBP and if differences in TrA thickness exist between those with recurrent LBP and healthy subjects at each level of the progression. We hypothesized that the TrA would increase as the level of progression increased for each group, but the TrA would be more activated in the healthy subjects.

Methods

Experimental Approach to the Problem

We were interested in examining the differences in the TrA activation ratio between recurrent LBP subjects categorized into the stabilization category and healthy individuals. Therefore, this study used a case-control design by having each subject perform a side-bridge exercise progression to the highest of 5 levels, whereas the investigators recorded images of the TrA during the relaxation and contraction phase of each level during the exercise. The exercise progression in this design is similar to what would be used by a rehabilitation or strength and conditioning specialist to target the TrA during rehabilitation or prevention of further LBP. It is important to determine which exercises people with recurrent LBP can perform effectively to activate the TrA, so strength and conditioning coaches can develop an efficient exercise program.

Subjects

Forty-seven subjects volunteered to participate in this study (demographics can be found in Table 1). For the subjects to be categorized into the recurrent LBP group, they had to be classified into the stabilization category by the clinical predictor rule (Figure 1), experienced 3 episodes of LBP in the last year or 5 episodes over a lifetime that affected activities of daily living and currently pain free. The subjects were prescreened over the phone or email to help determine eligibility. Although each of these individuals reported recurrent LBP, they were asked to schedule the study visit when their LBP was controlled so that their pain would not

Table 1. Subject demographics.*

	Healthy subjects	Recurrent LBP subjects
Men	2	8
Women	22	15
Age (y)	21.0 ± 1.3	24.0 ± 5.4
Height (cm)	169.7 ± 8.2	171.1 ± 0.6
Weight (kg)	68.0 ± 9.3	71.6 ± 12.8
Oswestry score	N/A	17.6 ± 11.9%

*LBP = low back pain.

limit the ability to perform the exercise. The healthy subjects reported that they had never had an episode of LBP that limited their function in any way. The subjects were recruited from a university setting using fliers, email, and word of mouth. Exclusion criteria for both groups were shoulder instability and pain, balance disorders, diagnosis of spine pathology by clinician, upper or lower extremity injury in the last 6 weeks, pregnancy and breast feeding, and open wound or skin rash over the area of USI. This study was approved by the Institutional Review Board of Health Sciences Research (IRB-HSR #14046), and all the subjects signed an approved consent form before participation.

Procedures

The subjects were screened by an investigator to determine eligibility for participation by using health history questionnaires and those who had LBP in the past were administered the Modified Oswestry Disability Index (10). Another investigator, who was blinded to group assignment (recurrent LBP or healthy), instructed the subjects how to contract the TrA by performing an ADIM with verbal cueing. The subjects were given the command to pull their navel to their spine as they exhaled and then to hold the contraction while breathing normally. To ensure that proper contraction was occurring, the investigator used real-time USI (Philips GE LOGIQ Book XP, Milwaukee, WI, USA) to examine how well the TrA contracted, with minimal changes to the IO, and external oblique (34). An 8-MHz liner array transducer was used, and the subject was not allowed to see the screen. The subject was allowed a maximum of 5 minutes to contract the TrA properly. The patient setup for this procedure was in the hook lying position and the transducer was placed on the right side of the abdomen, superior to the iliac crest along the midaxillary line (32). To verify correct placement of the transducer and to standardize the image of the TrA across subjects, the hyperechoic interface between the TrA and thoracolumbar fascia were the right most structures on the screen with the muscle belly running parallel across the screen (34).

Once the subject was proficient at performing the ADIM, baseline images were captured. Three images were taken at rest followed by 3 images during the end of the ADIM contraction. All the images were taken at the end of exhalation to standardize the measurement.

Next, each subject was instructed how to perform the first level of the side-bridge exercise progression. The participant was given a visual example of the end position and verbal instructions of how to perform the exercise. The subjects were instructed to perform an ADIM first, then raise their hips off

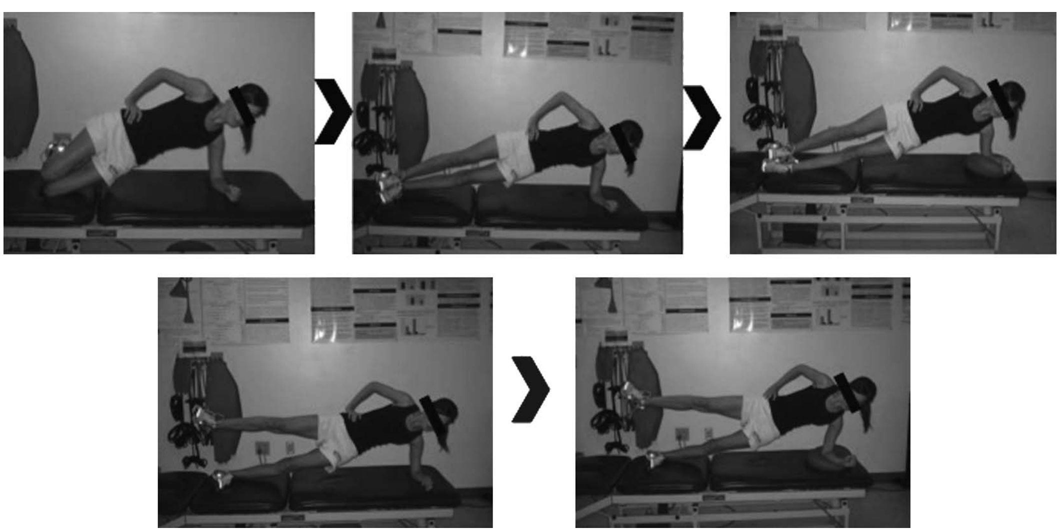

Figure 2. Side-bridge exercise progression.

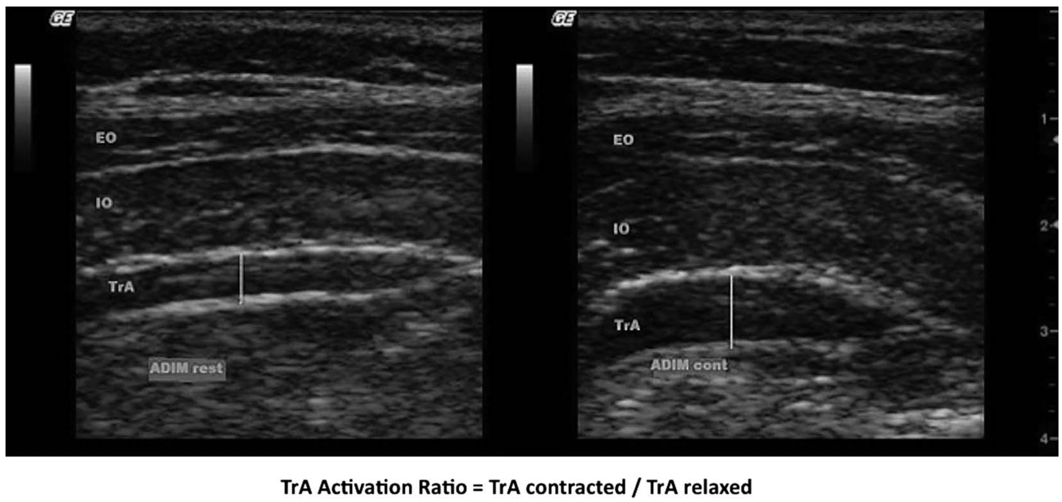

Figure 3. Real-time ultrasound image.

the ground so the knees, hips, and shoulders were in alignment in a side lying position. The subjects were given a maximum of 5 trials, 2 practice with clinician feedback, and 3 with USI at the end of the contraction. The same clinician gave verbal feedback throughout the study, which was only given during the 2 practice sessions. There was no set script, because feedback was based on how the subject performed the exercise and what the clinician observed on the RTUS screen. There was a 30-second rest period between each trial.

The subjects were tested throughout a 5-level exercise progression as depicted in Figure 2. There was a 90-second rest period between the start of the next level. During that time, the subject filled out a visual analog scale to depict the level of pain in the previous exercise. Three resting images were recaptured in the hook lying position to account for any influence of the previous exercise on the TrA resting thickness, and the next exercise was explained using a visual depiction of the end position. The subject was then allowed 2 practice sessions, with clinician feedback on proper technique. If the subject could not perform the exercise correctly, the subject stopped, and the previous exercise level was recorded as a successful completion. The subject failed the level if he or she lost balance, broke form (shoulders, hips, knees, and ankles were no longer in line) or complained of increased pain. During each level, the subject was reminded to perform the ADIM first and hold the contraction during the exercise. If the practice trials were successful, the participant performed 3 more trials with USI. The subject held the end phase of the exercise for 5 seconds to capture the image of the TrA. The transducer was paced on the side closest to the ceiling. All of the testing was performed on the same day. The only familiarization to the exercises was during the 5-minute ADIM practice and the 2 practice sessions at the beginning of each level. Current TrA strength was not considered because thickness of the TrA does not change after 20–30% of a maximal contraction (19,26,33).

To determine the TrA activation ratio, the resting and contracted TrA thicknesses were measured by a third investigator who was blinded to group allocation and did not capture the images. This accounts for different starting thicknesses for each individual. The superior fascial border of the TrA was the starting point, and the inferior fasical border of the TrA was the end point. The TrA activation ratio was found by dividing the contracted thickness by the resting thickness (Figure 3). Image J 1.43 software (National Institutes of Health, Bethesda, MD, USA) was used to analyze the images.

Statistical Analyses

Separate analyses of covariance were used to analyze the TrA activation ratios at each exercise level between each group and within levels because we did not expect all the participants to be able to successfully complete each level of the progression. The covariate for the analysis was the lowest level of the comparison, for example, level 1 was the covariate for the level 1 to level 2 comparison. Alpha was set a priori at $p \leq 0.05$. The number of subjects was estimated to be 24 per group to detect a 0.3 difference in TrA activation ratio between groups. This was based on *SD*s (0.36) from a previous study (34), an a priori significance level of $p = 0.05$ and a power of 0.80. Interimage reliability for TrA thickness measurements using real-time ultrasound was found to have an ICC of 0.93 with a 95% confidence interval (CI) of 0.75–0.99 (33). Cohen's *d* effect sizes with pooled *SD*s were calculated between groups and any significant findings.

Table 2. Transversus abdominis activation ratio between and within groups.

Level	Healthy	Recurrent low back pain	*P* value between groups	Effect size between groups (95% CI)
1	1.57 ± 0.40	1.64 ± 0.52	0.76	0.24 (−0.33 to 0.82)
2	1.52 ± 0.63	1.68 ± 0.70	0.40	0.24 (−0.33 to 0.81)
3	1.43 ± 0.42	1.53 ± 0.55	0.88	0.20 (−0.37 to 0.78)
4	1.46 ± 0.49	1.51 ± 0.58	0.66	0.09 (−0.48 to 0.67)
5	1.24 ± 0.57*	1.38 ± 0.68	0.92	0.22 (−0.35 to 0.80)

*Significant difference within groups between levels 4 and 5, $p = 0.03$. Effect size = 0.39 (−0.18 to 0.96). An effect size with a wide range that crosses 0 questions, the clinical meaningfulness of the difference between the values being compared.

Results

At all levels of the side-bridge exercise, the TrA activation ratios were >1, indicating that the muscle was contracting throughout the exercise. However, there were no significant differences in the TrA activation between groups at any level (Table 2). The only difference within groups was that the healthy group decreased in activation of the TrA from level 4 to level 5. Effect sizes between the groups at each level were small and all 95% CIs crossed zero, further supporting that no differences were found. For the healthy group, between levels 4 and 5, the effect size was also small, and the CI crossed zero, questioning the clinical meaningfulness of the finding (Table 2).

Discussion

This study investigated the changes in TrA activation ratio between healthy and recurrent LBP subjects throughout a side-bridge exercise progression with a twofold purpose. First, we aimed to determine whether the side-bridge exercise progression resulted in a contraction of the TrA and second, we wanted to determine whether there was a difference between recurrent LBP and healthy individuals. Both groups were able to increase the thickness of the TrA, as indicated in an activation ratio >1; however, there were no differences in the activation ratios between groups at each level of the exercise progression. Significant changes in the thickness of the TrA during an ADIM (6,21,23,25–27) and side-bridge (34) exercise have been shown in previous research. However, this is the first study to examine the side-bridge exercise between healthy and recurrent LBP subjects and the first to examine how the progression of an exercise affects the thickness of the TrA.

Upon comparison of multiple abdominal exercises in healthy subjects, Teyhen et al. (34) found the TrA to have the greatest changes in thickness during the side-bridge exercise (1.95 ± 0.69) and the abdominal crunch (1.74 ± 0.48). Our study added a recurrent LBP population and examined a more clinically relevant by progression of the side-bridge exercise through a series of more difficult positions. The finding that active people with recurrent LBP have similar TrA thickness ratios to healthy controls during stabilization exercises is important to both strength and conditioning specialists and rehabilitation clinicians. Because the TrA was recruited effectively during the exercise, the side bridge could be used for prevention of future LBP in active subjects with recurrent back pain. However, the recurrence of LBP may not be because of the ability of the TrA to contract but rather the timing of when the TrA becomes activated during exercise.

Although it appears the TrA can contract properly during exercise, a timing dysfunction of the muscle may be present, which cannot be assessed with the USI method used in this study. To have optimal spinal stability, the dynamic stabilizers must contract before extremity movement (4,5,21,30). When the TrA and other dynamic stabilizers do not contract before extremity movement, the spine cannot keep optimal orientation and will allow movement between segments (2,4,5,21,30). This movement is suboptimal and may lead to pain and degeneration of the joint surfaces (2). Another muscle, the multifidus, has received attention in its role with recurrent LBP. This muscle is a little more challenging to image with ultrasound, but research has shown that elite athletes with unilateral LBP have decreased cross-sectional area of the multifidus on the side of pain (16). More research needs to be conducted to determine the relationship between the spinal stabilizers and the contribution each muscle makes during movement.

The deep abdominal muscles have been the focus of stabilization programs because these muscles function improperly in patients with LBP and may not return to normal function, even in the absence of pain (2,11,24,29,30). This abnormal function is seen clinically when patients are asked to "contract their TrA." Many first time patients are unable to perform this task without proper training. Verbal cueing and biofeedback are effective at training contraction of the TrA (20,32,33). Verbal cueing may have played a factor in the ability of the recurrent LBP group to contract the TrA effectively. Although the patient did not have access to look at the ultrasound screen during the practice sessions, the clinician was able to provide feedback to ensure proper contraction was achieved. Using verbal cueing may be beneficial for rehabilitation and strength and condition specialists when contraction of the TrA is warranted. Spending an extra 5 minutes with a patient could be the difference between correct form and a future episode of LBP.

Following the motor learning model of O'Sullivan (28), the first stage of training the local muscles (TrA) is the cognitive stage. Because the side-bridge exercise with ADIM is a focused exercise, the subject is attentive to performing the exercise correctly and isolating the TrA. This may be another reason why our 2 groups were similar. The next 2 stages of the motor learning model are associative and autonomous (28). We would expect that differences would exist in our 2 groups if the exercises performed were painful for our recurrent LBP group (associative) or if they had to perform a task without proper training (autonomous). Those with recurrent LBP could be advanced to begin the associative stage, where they perform the ADIM during tasks when they feel unstable or anticipate pain (28).

We had hypothesized that there would be an increase in thickness of the TrA through the progressively more difficult positions. However, we did not see an increase in thickness, perhaps because the TrA reaches its max activation (as measured by electromyography) at 20–30% MVIC (19,26,33). This 20–30% may have been achieved when performing the ADIM, so increases beyond baseline would be difficult to detect. This finding, however, does not dispute that strength gains may be made even though cross-sectional area is not increasing. A study by Jones and Rutherford (22) found that after a 12-week isometric training program, there was an increase in force of 35%, whereas cross-sectional area only increased 5%. Therefore, an increase in strength is possible beyond that observed by an increase in cross-sectional area. We did find a significant decrease in TrA activation between levels 4 and 5 in the healthy group. This may be explained by the Dynamical Systems Theory (7). As a task becomes more challenging, the constraints on the system increase. Therefore, the body has limited motor patterns to perform the exercise correctly. It may be that the TrA is not as involved as other muscles in the stability of the spine during more challenging tasks. Another explanation may be from loss of endurance caused by fatigue. More subjects in the healthy group were able to complete the exercise at level 5 than the recurrent LBP group, possibly contributing to the decreased TrA thicknesses from level 4 to level 5. The effect size for this finding was small and crossed zero, so this may not be clinically meaningful.

We recognize our subjects were a convenient sample of healthy, young, and active adults. We also did not account for subjects who may have performed TrA strengthening exercises previously in rehabilitation for their LBP or as core stability work in a gymnasium as the side-bridge exercise is commonly used for both.

Practical Applications

In our population of healthy patients and patients with recurrent LBP, both groups were able to contract the TrA similarly during a side-bridge exercise progression; however, the timing of activation was unknown. Strength and conditioning coaches should not be deterred from using side-bridge exercises in the recurrent LBP population, as long as the progression remains pain free. With the help of verbal cueing, both healthy and recurrent LBP populations were able to contract the TrA properly. Coaches should spend some time reviewing the exercise and encourage proper technique before advancing the exercise to a more difficult level. Furthermore, the side-bridge progression may be used as a training tool in rehabilitation or prevention programs in both healthy and high functioning LBP individuals because there seems to be no difference in the ability to contract the TrA.

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