Immediate Effects of Trunk Stabilizer Muscles Training on Muscle Response Time in Individuals with Non-Specific Chronic Low Back Pain

Poramet Earde MSc*,**, Mantana Vongsirinavarat PhD*,
Prasert Sakulsriprasert PhD*, Roongtiwa Vachalathiti PhD*

** Faculty of Physical Therapy, Mahidol University, Nakhon Pathom, Thailand*
*** Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University, Pathumthani, Thailand*

Objective: *To investigate immediate effects of biofeedback training on motor control performance in participants with non-specific chronic low back pain.*
Material and Method: *RCT was conducted. The training group received isolated and co-contraction training of trunk stabilizers in lying on the left side, sitting on stool and sitting on a gymnastic ball, while the control group was asked to rest comfortably on a chair. Trunk muscles response time during rapid arm movement test was recorded using surface electromyography. Two-way ANOVA and Bonferroni post hoc test were used to detect changes within and between groups.*
Results: *In the training group, the trunk muscles response times were significantly decreased after training when compared with those in the control group (p<0.05).*
Conclusion: *Trunk stabilizer training has a beneficial effect on motor response time of the trunk muscles. The long-term effects of exercise should be further considered with a larger sample size.*

Keywords: *Back pain, Biofeedback, Motor control, EMG, Exercise*

J Med Assoc Thai 2014; 97 (Suppl. 7): S89-S94
Full text. e-Journal: *http://www.jmatonline.com*

Low back pain is one of the most common problems found in physical therapy practice. Many impairments, limitations or restrictions are the results of low back pain(1). Impaired motor control has been reported and warranted research to date(2,3). Many studies have indicated a motor delay of trunk muscles in patients with low back pain(2,3) and made the spine more susceptible to injury on sudden load change(4). This evidence lead to the treatment recommendation of spinal stabilization exercise (SSE). Richardson, Julie, and Hodges(5) divided SSE into three stages: local segmental control, closed chain segmental control and opened chain segmental control. The local segmental control of the stabilizer muscles could improve the feed forward control of trained muscles(6). However, the effect of the other two stages of exercise was rarely reported. Therefore, this study aimed to investigate the effect of SSE on the immediate change of feed forward control of the stabilizer muscles. We specifically trained the local segmental control and progressed into closed chain, segmental control in the sitting position in participants with non-specific chronic low back pain (NSCLBP).

Correspondence to:
Vongsirinavarat M, Faculty of Physical Therapy, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand.
Phone: 0-2441-5450 ext. 20803
E-mail: mantana.von@mahidol.ac.th

Material and Method

The right-handed participants with symptoms of low back pain at least three months, aged between 20 and 55 years, were recruited by advertisement. Their body mass index did not exceed 25 kg/m^2. Participants with the following conditions were excluded: symptoms of pain over 7 of 10 from visual analogue scale (VAS), spinal derangement or red flag conditions, neurological conditions, having hip knee or spinal surgery or deformity, pregnancy or condition affecting exercise ability, ongoing analgesic medication, ongoing SSE within six months, and having pre-activation of the transversus abdominis/internal abdominal oblique (TrA/IO) or mulifidus (MF) muscles. This study had been ethically approved by the Mahidol University Institutional Review Board.

Participants were explained the process and asked to sign informed consent forms before participating. Demographic data, questionnaire, history taking and physical examination were taken to screen the participants according to exclusion criteria. Participants underwent rapid arm movement test (RAMT), and maximal voluntary contraction test (MVC). Allocation of participants and exercise training were performed by a research assistant. Participants were asked to draw a slip with group allocation number from an envelope. Fifteen slips were given each group. The control group was asked to sit comfortably on a chair and was provided with a book on back pain to read. The training group was instructed to contract the stabilizer muscles. This process took approximately 90 minutes in both groups. Then RAMT was immediately repeated after the training.

Electromyography (EMG)

The EMGs (Telemyo 2400 G2, Noraxon, USA, Inc) of the trunk and deltoid muscles of the right side were recorded using surface EMG (sEMG). The skin at target muscles was prepared to decrease skin impedance below 5 kW[6,7]. Then a pair of Ag/AgCl surface electrodes (Ambu® Blue Sensor, P-OO-S/50, Denmark) was placed on the skin with 35 mm distant from the center of one electrode to another, parallel to the muscle fibers. The skin area at the target muscles was identified as described below[7-9]. The transversus abdominis/ Internal abdominal oblique (TrA/IO) was approximately 2 cm medially and inferiorly to the right anterior superior iliac spine; the external abdominal oblique (EO) was approximately 12-15 cm from the umbilicus; the rectus abdominis (RA) was 3 cm above and 2 cm lateral to the umbilicus. The erector spinae (ES) was 5 cm lateral to L2 spinous process; the lumbar multifidus (MF) was 3 cm lateral to L5 level; the anterior deltoid was centrally over stomach muscles and the ground electrode was placed over the right iliac crest. MVC trials were conducted on all muscles. The highest signal over one-second period among three trials was used as the MVC. The MVC was used to determine the contraction of target trunk muscles in the training session, and MVC were set at least 5% of MVC (5% RMS_{max}). The EMG data were pre-amplified 1,000 times and the sampling rate was set at 2,000 Hz with band pass filtered between 20 Hz and 1 kHz[6]. Data were analyzed using MyoResearch Master Edition.

RAMT

In the present study, to minimize the effect of hand dominant on the response time of the multifidus muscle, the authors recruited only right-handed participants[10].

The RAMT was adapted from Hodges and Richardson[11]. Theoretically, the TrA provides lumbo-pelvic stability throughout the corset action; therefore, both sides of the TrA are needed to contract during perturbation of the trunk, which may occur during limb movements[12]. To create this perturbation, participants were asked to raise their right arm approximately 45 degrees as fast as possible corresponding to the visual signal. Average response time of the EMG of trunk muscles correspond to the EMG onset of the anterior deltoid muscle over the trials was used for data analysis. The example of response time of the EMG of trunk muscles is shown in Fig.1.

Motor training

The training aimed to activate the stabilizer muscles in non-weight bearing and progress into closed chain exercise in the sitting position. Participants practiced the contraction of the target muscles with at least 5% RMS_{max} of EMG amplitude using EMG as a feedback during exercise[6]. The isolated contraction training of TrA and MF were performed in supine and

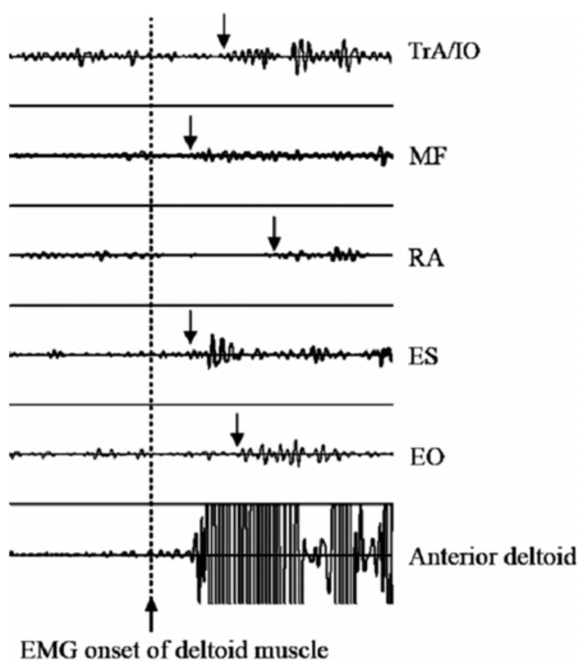

Fig. 1 The response time: EMG onset of trunk muscles corresponding to EMG onset of right anterior deltoid muscle.

prone positions. To prevent spinal movement during exercise, the pressure biofeedback unit was placed under the lumbar and navel region[5]. The co-contraction training was practiced lying on the left side, sitting on a stool, and sitting on a gymnastic ball. During training in the sitting position, the participants were informed to keep the feet in full contact with the ground. Then, participants were informed to hollow the abdomen, contract the pelvic floor muscles and swell out the MF muscle at the same time without spine movement. The exercises were performed in three sets of ten repetitions in each position, holding the contraction for 10 seconds each time. Two-minute rests between sets and 5-second rests within repetitions were provided.

SPSS Version 22 was used. The Kolmogorov-Smirnov test was used to test the data distribution. Two-way ANOVA and Bonferroni post hoc test were used to determine significant differences present within and between groups. The significant level was set at $p<0.05$.

Results

In all, 34 participants were interested to join the study but four were excluded because of having a diagnosis of Lumbar spondylosis. The remainder was randomly allocated into the control and training groups. However, five participants were excluded after RAMT because they had pre-activation of the local trunk muscles (four in the control and one in the training group) and one participant in the control group was excluded because she could not complete the test and wished to terminate. Only 10 (7 females) in the control group and 14 (8 females) in the training group remained. Demographic information of participants is shown in Table 1.

RAMT

When compared between groups, no significant differences were found of response time of trunk muscles before the intervention session except RA ($p = 0.026$). The response time of RA of the training group was longer than that of the control group. After intervention, the response times of the TrA and MF muscles of the training group were significantly shorter than those of the control group ($p<0.05$). The mean values of response time of RA, ES and EO muscles were not significantly different when compared between groups. When compared pre- and post-intervention, no significant differences were found of muscle response time of all muscles of the control group. However, significant decreases were found in muscle response time of the TrA, MF, and RA muscles of the training group ($p<0.05$) (Table 2).

Discussion

Demographic data were not statistically different between groups including pain scale, Modified Oswestry score and period of having back pain. Participants reported mild to moderate pain (VAS <7) in the lower back during the test. However, the pain intensity did not change during the testing or training protocols.

The response time of the TrA and MF muscles corresponding to the EMG of the right anterior deltoid muscle in the training group was reduced after training. This implied an improvement of feed forward control when trained. These results were similar to the findings of Tsao and Hodges[6] using intramuscular fine-wire electrode and reporting that an immediate change was observed after isolated training of the TrA, i.e. shorter response time during RAMT. This might be due to a central nervous system adaptation during dynamic movements[6]. Ideally, response time of TrA/IO and MF should be reduced without any changes in other muscles; however, the present study found the decrease of RA as well, which might be the result of the additional recruitment of those muscles during training.

Table 1. Demographic information of participants

	Control group (n = 10)	Training group (n = 14)
Age (years)	31.20 (9.34)	25.50 (4.76)
Body mass index (kg/m^2)	21.25 (2.63)	21.26 (1.65)
Duration of onset (months)	28.20 (23.33)	21.85 (22.27)
Pain (VAS/10)	3.58 (1.92)	3.82 (1.59)
Modified oswestry score (%)	15.70 (4.24)	14.71 (2.05)

Reported in mean (SD)

Table 2. Response time of trunk muscles corresponding to EMG onset of anterior deltoid muscle during right arm flexion [milliseconds, mean(SD)]

Muscles	Control		p-value within control group	Training		p-value within training group	p-value between groups	p-value between groups
	Pre-test	Post-test		Pre-test	Post-test		Pre-test	Post-test
TrA/IO	208.3 (40.4)	216.0 (34.1)	0.718	204.7 (80.9)	76.8 (59.6)	<0.001*	0.899	<0.001*
MF	132.7 (44.7)	144.5 (36.8)	0.365	150.3 (44.7)	62.0 (47.2)	<0.001*	0.352	<0.001*
RA	216.9 (85.2)	229.7 (66.2)	0.368	283.7 (52.1)	202.9 (66.2)	<0.001*	0.026*	0.339
ES	175.7 (42.7)	175.5 (36.7)	NS	167.0 (50.6)	128.5 (44.3)	NS	NS	NS
EO	202.6 (41.3)	201.0 (27.3)	NS	204.1 (75.0)	168.5 (73.7)	NS	NS	NS

* = statistical significance at $p<0.05$ from the Bonferroni post hoc test
NS = No significant difference of main effect and the interaction effect using Two-way ANOVA test, the multiple comparison was not performed

In the present study, we aimed to activate only stabilizer muscles, i.e. TrA and MF by isolated and co-contraction training. Two possible causes can explain the decrease of RA response time. First, TrA and MF co-contraction training might activate the RA muscle if the stabilizer muscles are weak. Second, the location of the RA muscles might be more easily activated than EO. After training, the response time of TrA and MF of the training group was significantly less than that of the control. The findings were similar to studies of Tsao et al[6,13].

Some limitations were encountered in this study. First, the authors used the surface EMG to measure the activation of TrA/IO and MF muscles. The wire fine technique is required to clarify the true value of EMG on these muscles. The surface EMG could not provide actual value of deeper muscles and could have had 10-15% error[9]. However, the method is non-invasive and convenient. Second, the effect of exercise used long-term are still unknown; long-term effects of this exercise warrants further study.

Conclusion

The results of the present study demonstrated that people with non-specific, chronic low back pain had a significant improvement of response time of trunk muscles when trained with spinal stabilization exercise that progressed into the sitting position.

What is already known on this topic?

Individuals suffering from chronic low back pain were found to be delayed in response time of the stabilizer muscles. However, the response time can be improved immediately after the training by isolated contraction training of those muscles.

What this study adds?

The SSE of local segmental control plus closed chain segmental control in the sitting position can also improve the response time of the stabilizer muscles immediately after the training but the long-term effects should be further investigated.

Acknowledgment

The authors wish to thank all participants for their good cooperation. Great appreciation also goes to Mahidol and Thammasat Universities for the scholarship.

Potential conflicts of interest

None.

References

1. Ayis S, Arden N, Doherty M, Pollard B, Johnston M, Dieppe P. Applying the impairment, activity limitation, and participation restriction constructs of the ICF model to osteoarthritis and low back pain trials: a reanalysis. J Rheumatol 2010; 37: 1923-31.
2. Radebold A, Cholewicki J, Polzhofer GK, Greene HS. Impaired postural control of the lumbar spine is associated with delayed muscle response times in patients with chronic idiopathic low back pain. Spine (Phila Pa 1976) 2001; 26: 724-30.
3. Reeves NP, Cholewicki J, Narendra KS. Effects of reflex delays on postural control during unstable seated balance. J Biomech 2009; 42: 164-70.
4. Radebold A, Cholewicki J, Panjabi MM, Patel TC. Muscle response pattern to sudden trunk loading in healthy individuals and in patients with chronic low back pain. Spine (Phila Pa 1976) 2000; 25: 947-54.
5. Richardson C, Hodges PW, Hides J. Therapeutic exercise for lumbopelvic stabilization: A motor control approach for the treatment and prevention of low back pain. 2nd ed. London: Churchill Livingstone; 2004.
6. Tsao H, Hodges PW. Immediate changes in feedforward postural adjustments following voluntary motor training. Exp Brain Res 2007; 181: 537-46.
7. Marshall P, Murphy B. The validity and reliability of surface EMG to assess the neuromuscular response of the abdominal muscles to rapid limb movement. J Electromyogr Kinesiol 2003; 13: 477-89.
8. Dankaerts W, O'Sullivan PB, Burnett AF, Straker LM, Danneels LA. Reliability of EMG measurements for trunk muscles during maximal and sub-maximal voluntary isometric contractions in healthy controls and CLBP patients. J Electromyogr Kinesiol 2004; 14: 333-42.
9. McGill S, Juker D, Kropf P. Appropriately placed surface EMG electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine. J Biomech 1996; 29: 1503-7.
10. Sung PS, Spratt KF, Wilder DG. A possible methodological flaw in comparing dominant and nondominant sided lumbar spine muscle responses without simultaneously considering hand dominance. Spine (Phila Pa 1976) 2004; 29: 1914-22.
11. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. Spine (Phila Pa 1976) 1996; 21: 2640-50.
12. Hodges P, Kaigle HA, Holm S, Ekstrom L, Cresswell A, Hansson T, et al. Intervertebral stiffness of the spine is increased by evoked contraction of transversus abdominis and the diaphragm: in vivo porcine studies. Spine (Phila Pa 1976) 2003; 28: 2594-601.
13. Tsao H, Druitt TR, Schollum TM, Hodges PW. Motor training of the lumbar paraspinal muscles induces immediate changes in motor coordination in patients with recurrent low back pain. J Pain 2010; 11: 1120-8.

ผลทันทีของการฝึกกล้ามเนื้อทรงลำตัวต่อเวลาการตอบสนองของกล้ามเนื้อในผู้ที่มีอาการปวดหลังเรื้อรัง

ปรเมศร์ เอิร์ด, มัณฑนา วงศ์ศิรินวรัตน์, ประเสริฐ สกุลศรีประเสริฐ, รุ่งทิวา วัจฉละฐิติ

วัตถุประสงค์: *ศึกษาผลทันทีของการฝึกกล้ามเนื้อแบบป้อนกลับต่อการตอบสนองของกล้ามเนื้อลำตัวในผู้ที่มีอาการปวดหลังเรื้อรัง*

วัสดุและวิธีการ: *เป็นการวิจัยเชิงทดลอง โดยกลุ่มฝึกจะได้รับการฝึกกล้ามเนื้อลำตัวแบบแยกมัดและฝึกกล้ามเนื้อ แบบประสานกันในท่านอน นั่ง และบนยิมบอล ขณะที่กลุ่มควบคุมให้นั่งพัก การวัดค่าการตอบสนองของกล้ามเนื้อ ใช้เครื่องวัดกระแสไฟฟ้ากล้ามเนื้อผ่านผิวหนัง ขณะให้ยกแขนขึ้นอย่างรวดเร็วใช้สถิติ Twoway ANOVA และ Bonferroni post hoc test ทดสอบความต่างภายในกลุ่มและระหว่างกลุ่ม*

ผลการศึกษา: *กลุ่มฝึกมีค่าเวลาในการตอบสนองของกล้ามเนื้อลำตัวสั้นลงอย่างมีนัยสำคัญทางสถิติ เมื่อเทียบกับกลุ่มควบคุม ($p<0.05$)*

สรุป: *การฝึกการทำงานของกล้ามเนื้อลำตัว ทำให้กล้ามเนื้อทำงานประสานสัมพันธ์กันดีขึ้น ควรทำการศึกษา เพิ่มเติมถึงผลการฝึกระยะยาวและเพิ่มขนาดกลุ่มตัวอย่าง*