Changes in thickness of the transversus abdominis during the abdominal drawing-in manoeuvre and expiratory muscle training in elderly people

J. Phys. Ther. Sci. 30: 119–123, 2018

The Journal of Physical Therapy Science

Original Article

Changes in thickness of the transversus abdominis during the abdominal drawing-in manoeuvre and expiratory muscle training in elderly people

Takamune Sugimoto, RPT, MSc[1, 2)*], Masami Yokogawa, RPT, PhD[3)],
Hiroichi Miaki, RPT, PhD[3)], Sachiko Madokoro, RPT, PhD[3)], Takao Nakagawa, MD, PhD[3)]

1) Department of Functional Training, Day Service Center Tokinoen Saiwai-cho: 3-35 Saiwai-cho, Kanazawa, Ishikawa 920-0968, Japan
2) Division of Health Sciences, Graduate School of Health Sciences, Kanazawa University, Japan
3) Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, Japan

Abstract. [Purpose] It has been reported that exercises focusing upon the transversus abdominis (TrA) ameliorate low back pain (LBP). We investigated whether expiratory muscle training (EMT) can promote activity of the TrA to the same degree as the abdominal drawing-in manoeuvre (ADIM) in elderly individuals. [Subjects and Methods] Twenty-one elderly subjects (9 males, 12 females; mean age, 84.9 ± 6.6 years) without LBP symptoms were included. Using ultrasound imaging we measured changes in thickness of the lateral abdominal muscles, TrA, internal oblique muscle (IO), and external oblique muscle (EO) during ADIM and EMT. The load in EMT was set to 15% of maximal expiratory pressure. [Results] TrA showed a significant increase in muscle thickness during ADIM and EMT compared with at rest. A significant increase in muscle thickness was noted for EMT in comparison with ADIM. No significant differences were found for IO and EO. [Conclusion] In elderly people, EMT may be an effective alternative to ADIM for promoting activity of the TrA and can be used as an exercise to maintain TrA function.
Key words: Transversus abdominis, Abdominal drawing-in manoeuvre, Expiratory muscle training

(This article was submitted Oct. 1, 2017, and was accepted Oct. 18, 2017)

INTRODUCTION

The transversus abdominis (TrA) is located deep in the abdominal muscle group. The main function is to regulate intra-abdominal pressure, thoracolumbar fascia tension, and sacroiliac joint and pubic symphysis compression. Through these interactions, fine adjustment of the movement between the spinal segments contributes to lumbopelvic stability[1)]. Although the factors causing low back pain (LBP) remain unclear, a reduction and delay in TrA activity has been reported as one of the key characteristics of patients with LBP[2, 3)]. It has recently been reported that motor control exercise to promote TrA activity is more effective than general exercises and manual therapy for the amelioration of pain and the impairment of activities of daily living in patients with chronic LBP[4)], and that there is a moderate correlation between the improvement of the TrA function and the amelioration of the impairment of activities of daily living in LBP patients[5)].

Normally, various age-related changes occur in the body, such as age-related muscle atrophy[6–8)], increasing of the non-contractile tissue[8, 9)], changes in posture such as kyphosis[10, 11)], and reduced respiratory function[11, 12)]. These age-related changes may ascribe to reduction and delay of the TrA activity associated with the lumbopelvic region instability inducing

*Corresponding author. Takamune Sugimoto (E-mail: mune-0715-lord@po5.nsk.ne.jp)

LBP. Therefore, it may be important to perform exercise, such as the abdominal drawing-in manoeuvre (ADIM), to maintain TrA function of in order to prevent LBP in elderly people.

ADIM, drawing-in the lower abdomen without the pelvic and the spinal column movement, promotes TrA activity while suppressing activity of the superficial trunk muscles, including the external oblique muscle and the rectus abdominis[13]. However, the TrA is covered by the superficial trunk muscles, and it is not easy for subjects to perceive subtle contractions of this muscle. Oral instructions, which can best stimulate isolated muscle activity of the TrA, have been discussed[14], but have not been established yet. In comparison with younger people, it is more difficult for the older individuals to consciously separate and contract the TrA, and it may be difficult to provide instructions for this cohort of people to encourage them to perform the exercise. Therefore, it is necessary to consider a method to promote TrA activity more conveniently and effectively.

Because the TrA works during forced expiration, we think that expiratory muscle training (EMT) can be used as a movement to promote TrA activity. Our previous study suggests that muscle thickness change in the TrA during EMT in younger people is equivalent to ADIM and could be used as a form of TrA training[15]. EMT does not require detailed instructions concerning how to perform the exercise, and represents a simple method of breathing, thereby providing a key advantage in that it is easy to master, even in the elderly people.

The principal aim of the present study was to ascertain whether EMT can promote TrA activity to the same degree as ADIM, even when the subjects are elderly.

SUBJECTS AND METHODS

This study involved 21 subjects who had no LBP symptoms (9 males and 12 females). Mean age of the subjects was 84.9 ± 6.6 years (males: 84.4 ± 5.5 years; females: 85.3 ± 7.6 years), mean height was 155.2 ± 10.0 cm (males: 163.9 ± 6.1 cm; females: 148.6 ± 6.8 cm), mean weight was 54.3 ± 8.9 kg (males: 56.3 ± 9.2 kg; females: 52.8 ± 8.6 kg), mean maximal expiratory pressure (PEmax) was 54.8 ± 20.0 cm H_2O (males: 65.4 ± 21.8 cm H_2O; females: 46.9 ± 15.0 cm H_2O), and mean kyphosis index (KI) was 11.9 ± 3.4 (males: 10.5 ± 2.9; females: 13.0 ± 3.5). There is no general definition of kyphosis posture in KI, and no clear cutoff value has been defined[16, 17], but referring to the kyphosis evaluation of Teragaki et al.[10], the degree of kyphosis falls within the category of normal to mild kyphosis.

The details of the present study were explained to all subjects orally and in writing, and consent was obtained from all subjects. The present study was approved by the medical ethics review committee of the affiliated institution (approval number: 670-1).

Because the subjects were elderly, we performed separate experiments over two days with the aim of reducing the burden on the subjects. First, evaluation of kyphosis and measurement of PEmax were performed on the first day. In order to evaluate kyphosis, we performed posture evaluation using a flexicurve ruler[10]. While the subjects maintained an erect posture, we traced the curvature of the back from the 7th cervical vertebra to the spinous process of the 4th lumbar vertebra on paper using a flexicurve ruler (Uchida, Tokyo, Japan). KI (H/L × 100) was then calculated by using a straight line connecting the 7th cervical vertebra and the 4th lumbar vertebra traced on the paper as 'L', and the perpendicular line from the straight line 'L' to the apex of the curve as 'H'. A Spirometer HI-801 (Chest M.I., Inc., Tokyo, Japan) was used to measure PEmax.

The thickness of the lateral abdominal muscles for ADIM and EMT was measured at a later date. Prior to the start of the experiment, we marked the muscle thickness measurement sites and allowed the subjects to practice the exercise. Under ADIM conditions, the examiner verbally instructed the subjects to 'pull your navel back to your spine while exhaling. Please do not move your pelvis and back, and please keep breathing normally while holding that position.' At that time, the examiner palpated the lateral side of the rectus abdominis inferomedial to the anterior superior iliac spines of subjects and instructed them not to perform compensatory motion of the pelvis and back while contraction of the TrA was confirmed. In the EMT condition, subjects held a Threshold™ PEP (Philips Respironics, Tokyo, Japan) in the right hand and performed EMT with a load pressure of 15% PEmax. Furthermore, when the 15% PEmax of subjects fell below the lower limit of 5 cm H_2O of Threshold™ PEP, the load pressure was set as 5 cm H_2O. The examiner verbally instructed the subjects that 'After inhaling, please exhale for about twice as long as you inhaled.' Both exercises were repeatedly practiced until the subjects could understand the exercises. Expiratory pressure during EMT was monitored on the screen of a personal computer. A tube was connected between the Threshold™ PEP and the mouthpiece to be attached to the mouth, and expiratory pressure was recorded by a transducer BIOTRANS (Biosensors Japan Co., Ltd. Tokyo, Japan) and converted into a voltage. Next, the A/D converted digital signal was sent from the transducer to the A/D converter via the amplifier and the A/D converted digital signal was sent to a personal computer used as a recording device. Using the recording software, Vital Recorder 2 (Kissei Comtec Co., Ltd. Nagano, Japan), time was plotted on the horizontal axis and expiratory pressure on the vertical axis and monitored in real time. Furthermore, in order to perform pressure calibration, a calibration circuit was made using a transducer, and pressure was applied with a manometer to calibrate the voltage of 5.8 V at 100 mmHg and the voltage of −5.8 V at −100 mmHg for measurement.

Subjects were placed in the supine position in the experiment, and measurement was first performed while the subjects were at rest. Subsequently, ADIM and EMT conditions were performed in random order for each subject. After performing one exercise condition, the next exercise condition was performed with a break of 3 minutes in between. When the respiration of the subjects stabilised at rest, a video of the lateral abdominal muscles was recorded twice. In ADIM and EMT conditions,

Table 1. Changes in the thickness of the lateral muscles in males

	Resting	ADIM	EMT
EO	3.1 ± 0.7	3.0 ± 0.7	3.0 ± 0.7
IO	6.1 ± 1.7	7.3 ± 1.6	7.6 ± 1.4
TrA	1.8 ± 0.5	3.1 ± 0.6*	3.5 ± 0.5*†

ADIM: abdominal drawing-in manoeuvre; EMT: expiratory muscle training; TrA: transversus abdominis; IO: internal oblique muscle; EO: external oblique muscle. The table shows means ± standard deviation (in mm). *p<0.05, compared with resting condition. †p<0.05, compared with ADIM condition

Table 2. Changes in the thickness of the lateral muscles in females

	Resting	ADIM	EMT
EO	3.6 ± 0.9	3.8 ± 0.8	3.7 ± 0.9
IO	5.9 ± 1.5	7.1 ± 1.9	7.2 ± 2.0
TrA	2.0 ± 0.9	3.0 ± 1.1*	3.4 ± 1.1*†

ADIM: abdominal drawing-in manoeuvre; EMT: expiratory muscle training; TrA: transversus abdominis; IO: internal oblique muscle; EO: external oblique muscle. The table shows means ± standard deviation (in mm). *p<0.05, compared with resting condition. †p<0.05, compared with ADIM condition

exercise was performed 3 times: the first time was for practice, and the lateral abdominal muscles were recorded on video during the second and third exercises.

The diagnostic ultrasound imaging system, MyLab25 (Hitachi Medical Corporation, Tokyo, Japan), was used to record a video of muscle thickness of the lateral abdominal group under each condition. A 7.5 MHz probe was used, the setting was B mode, and there was one examiner present. Three muscles, the TrA, internal oblique muscle (IO), and external oblique muscle (EO), were measured. The probe was gripped so that the left side of the screen showed the umbilical side and the abdominal fascia was most clearly observed; the probe angle was adjusted so as to be parallel on the screen, and a moving image was recorded while the marked skin on the left side of the abdomen was maintained at a constant level. The video recording time for each exercise was set to 10 seconds. From the recorded video, a still image at the time of the thickest muscle at end tidal was extracted, and using the measurement function of the ultrasonic diagnostic device, the muscle thicknesses of the TrA, IO, and EO were measured in units of 0.1 mm. Measurement of muscle thickness involved the distance from the end of the inferior fascia to the end of the fascia above the screen centreline. The mean value of two recorded times was taken as the measurement value.

Table 3. Changes in the thickness of the lateral muscles in all subjects

	Resting	ADIM	EMT
EO	3.4 ± 0.8	3.5 ± 0.8	3.4 ± 0.9
IO	6.0 ± 1.5	7.2 ± 1.7	7.3 ± 1.8
TrA	1.9 ± 0.7	3.0 ± 0.9*	3.5 ± 0.9*†

ADIM: abdominal drawing-in manoeuvre; EMT: expiratory muscle training; TrA: transversus abdominis; IO: internal oblique muscle; EO: external oblique muscle. The table shows means ± standard deviation (in mm). *p<0.05, compared with resting condition. †p<0.05, compared with ADIM condition

For statistical processing, measured values under each condition were compared by Bonferroni's multiple comparison test. Statistical significance was defined as p<0.05.

RESULTS

The results are shown in Tables 1 (males), 2 (females) and 3 (all subjects). Similar results were observed in these. The TrA showed a significant increase in muscle thickness for both ADIM and EMT compared with at rest (p<0.05). Moreover, a significant increase in muscle thickness was noted for EMT in comparison with ADIM (p<0.05). No significant differences regarding conditions were noted for the IO and EO (Tables 2 and 3).

DISCUSSION

In the present study, we investigated whether similar changes in thickness of the lateral abdominal muscles in elderly individuals could be obtained on EMT as ADIM. Although muscle thickness is considered to be influenced by both height and weight, we exhibited actual measurement values, not corrected ones, because we obtained same results. Furthermore, because there were no differences due to gender in the results, we discuss the overall results of males and females combined.

It the present study, we demonstrated that the thickness of the TrA significantly increased during both ADIM and EMT compared to at rest in elderly people. Furthermore, we showed that muscle thickness increased more in the case of EMT than with ADIM. This result suggests that EMT may be more effective in promoting TrA activity. Our previous study in younger people, both movements revealed approximately the same degree of TrA activity[15)]. Because ADIM does not involve any articulation of the limbs, draws in the abdomen without moving the pelvis and spinal column and promotes contraction of the TrA, it may be less likely to create a feeling of contraction of the TrA in the deepest part of the abdominal muscle group. In contrast, because EMT is a convenient way to perform expiration, and is easier for elderly people to understand how to perform, resistance during exhalation with Threshold™ PEP acted as feedback to encourage muscle activity and appears to have increased thickness of the TrA.

The muscle thickness values of the TrA at rest obtained in the present study were smaller than those of younger people[15)]. There are few previous studies on the presence of age-related muscle atrophy in the TrA. Age-related muscle atrophy tends to occur in type II fibres[6)]. Because TrA has a high ratio of type I fibres[18)], muscle atrophy may not commonly develop.

However, muscle atrophy in elderly people occurs due to not only aging but also inactivity and/or bed rest. In this situation, the type I fibres undergo atrophy[6], and the TrA may be involved. EMT may be an effective training to prevent muscle atrophy of the TrA in elderly people.

Muscle thickness of IO did not significantly differ with either ADIM or EMT compared with at rest; these findings were inconsistent with the results of a previous study involving younger people in whom muscle thickness significantly increased for both exercises[15]. Previous studies which measured the muscle thickness and echo intensity of the IO and estimated the noncontractile tissue mass of the skeletal muscle using an ultrasonic diagnostic imaging system, showed that muscle thickness significantly decreased[7, 8] while echo intensity was significantly higher[8] in elderly persons, as compared with in younger persons. In the present study, atrophy and the increased noncontractile tissues of IO of subjects may have influenced the muscle thickness measurements. In addition, the presence of kyphosis, which is a typical posture change in elderly persons, was noted. Following chest depression, reduction or loss of lordosis in the lumbar spine and/or posterior pelvic incline by kyphosis, the IO length is shortened. In general, shortening of the muscle length reduces muscle contraction force. Therefore, the subjects' IO in the present study, whose mean KI fell under the category of mild kyphosis, appeared to have failed to obtain sufficient contractive force during exercise. Similar to TrA, IO is involved in supporting the contents of the abdomen, regulating intraperitoneal pressure, and compressing the sacroiliac joint[1, 19]. It may be necessary to improve the function of not only TrA, but also that of IO for preventing LBP in elderly people.

Mean PEmax in the present study was 54.8 ± 20.0 cm H_2O (males: 65.4 ± 21.8 cm H_2O; females: 46.9 ± 15.0 cm H_2O) and was lower in comparison with that of younger people (97.5 ± 27.4 cm H_2O)[15]. There is a negative correlation between kyphosis and expiratory muscle strength, and kyphosis is considered to be a factor that further deteriorates reduced respiratory function[11]. The EMT load was set at 15% PEmax in the present study, but in two subjects, who had especially low PEmax, the values fell below the lower limit of Threshold™ PEP (5 cm H_2O). Both of these subjects had a KI of 16 or higher, and the extent of kyphosis was significantly higher than the mean value observed for other subjects in the present study. It is possible that reduced IO function may potentially cause a reduction in PEmax. Kaneko et al.[20] reported that muscle thickness of IO increased in addition to TrA, as the expiratory pressure increased, and suggested that the activity of IO is important for increasing expiratory pressure. Improving muscular function of IO must also have a positive effect on respiratory function.

As described earlier, some elderly persons show low PEmax. Therefore, a tool that can set a weaker load pressure is required. Furthermore, when EMT is repeatedly performed, the respiratory muscles may become fatigued and gradually become unable to withstand load pressure. Therefore, on performing EMT, it is necessary to pay attention to the number of performances and allow for a break period.

The results of the present study suggest that EMT in elderly people may be an effective alternative to ADIM for promoting activity of the TrA and could be used as an exercise to maintain TrA function. In the future, we will try to clarify whether EMT will become a treatment option for patients with LBP who have reduced muscle function of the TrA, or not.

REFERENCES

1) Richardson C, Hodges P, Hides J, et al.: Therapeutic exercise for lumbopelvic stabilization: a motor control approach for the treatment and prevention of low back pain. Edinburgh: Churchill Livingstone, 2004, pp 31–34, 54.
2) Ferreira PH, Ferreira ML, Hodges PW: Changes in recruitment of the abdominal muscles in people with low back pain: ultrasound measurement of muscle activity. Spine, 2004, 29: 2560–2566. [Medline] [CrossRef]
3) Hodges PW, Moseley GL, Gabrielsson A, et al.: Experimental muscle pain changes feedforward postural responses of the trunk muscles. Exp Brain Res, 2003, 151: 262–271. [Medline] [CrossRef]
4) Byström MG, Rasmussen-Barr E, Grooten WJ: Motor control exercises reduces pain and disability in chronic and recurrent low back pain: a meta-analysis. Spine, 2013, 38: E350–E358. [Medline] [CrossRef]
5) Ferreira PH, Ferreira ML, Maher CG, et al.: Changes in recruitment of transversus abdominis correlate with disability in people with chronic low back pain. Br J Sports Med, 2010, 44: 1166–1172. [Medline] [CrossRef]
6) Verdijk LB, Dirks ML, Snijders T, et al.: Reduced satellite cell numbers with spinal cord injury and aging in humans. Med Sci Sports Exerc, 2012, 44: 2322–2330. [Medline] [CrossRef]
7) Ota M, Ikezoe T, Kaneoka K, et al.: Age-related changes in the thickness of the deep and superficial abdominal muscles in women. Arch Gerontol Geriatr, 2012, 55: e26–e30. [Medline] [CrossRef]
8) Kitamura T, Sato N: Age-related changes in muscle thickness of the trunk muscles. Niigata Phys Ther Association, 2015, 18: 7–12 (in Japanese).
9) Watanabe Y, Yamada Y, Fukumoto Y, et al.: Echo intensity obtained from ultrasonography images reflecting muscle strength in elderly men. Clin Interv Aging, 2013, 8: 993–998. [Medline] [CrossRef]
10) Teragaki Y, Araya K, Sueki K, et al.: Reliability and validity of the index of kyphosis on sitting. Rigakuryoho Kagaku, 2004, 19: 137–140 (in Japanese). [CrossRef]
11) Teramoto S, Suzuki M, Matsuse T, et al.: [Influence of kyphosis on the age-related decline in pulmonary function]. Nihon Ronen Igakkai Zasshi, 1998, 35: 23–27 (in Japanese). [Medline] [CrossRef]
12) Suzuki M, Teramoto S, Sudo E, et al.: [Age-related changes in static maximal inspiratory and expiratory pressures]. Nihon Kyobu Shikkan Gakkai Zasshi, 1997, 35: 1305–1311 (in Japanese). [Medline]
13) Saliba SA, Croy T, Guthrie R, et al.: Differences in transverse abdominis activation with stable and unstable bridging exercises in individuals with low back

pain. N Am J Sports Phys Ther, 2010, 5: 63–73. [Medline]
14) Dema J, Oba A, Oe A, et al.: The influence of differences in verbal instruction on transversus abdominis exercise. Rigakuryoho Kenkyu Nagano, 2007, (36): 58–60 (in Japanese).
15) Sugimoto T, Yokogawa M, Miaki H, et al.: Changes in the thickness of transversus abdominis muscle during "drawing-in" of the abdominal wall and expiratory threshold loading according to posture. Rigakuryoho Kagaku, 2015, 30: 385–388 (in Japanese). [CrossRef]
16) Chow RK, Harrison JE: Relationship of kyphosis to physical fitness and bone mass on post-menopausal women. Am J Phys Med, 1987, 66: 219–227. [Medline] [CrossRef]
17) Cutler WB, Friedmann E, Genovese-Stone E: Prevalence of kyphosis in a healthy sample of pre- and postmenopausal women. Am J Phys Med Rehabil, 1993, 72: 219–225. [Medline] [CrossRef]
18) Ito J: Myofibrous organization in human abdominal muscles. J Showa Med Assoc, 1988, 48: 471–483 (in Japanese).
19) Urquhart DM, Barker PJ, Hodges PW, et al.: Regional morphology of the transversus abdominis and obliquus internus and externus abdominis muscles. Clin Biomech (Bristol, Avon), 2005, 20: 233–241. [Medline] [CrossRef]
20) Kaneko H, Sato H, Maruyama H: Evaluation of lateral abdominal muscle activity during expiratory threshold loading by ultrasonography. J Phys Ther Sci, 2006, 18: 187–191. [CrossRef]