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Measurement Reliability and Kinetic Chain of the Thickness of the Transverse Abdominal Muscle and Action Potential of the Levator Ani Muscle

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Abstract. This study examined the measurement reliability and the kinetic chain of the thickness of the transverse abdominal muscle (TA) and the action potential of the levator ani muscle (LA). In other words, the change in the muscle output was examined during simultaneous contraction of both TA and LA. [Subjects] The subjects were seven healthy adult women (40.1 ± 12.8 years). [Method] Thicknesses of TA and integration electromyograms (iEMG) of LA were measured in five tasks in the supine position. The tasks were: 1) Resting state, 2) Maximal contraction of TA, 3) Maximal contraction of LA, 4) Maximal simultaneous contraction of both TA and LA, and 5) Maximal simultaneous contraction of both TA and LA with resistance added to both knees. To examine the measurement reliability, the tasks were tested twice. [Results] The interclass correlation coefficient (ICC) of the thickness of TA and the iEMG of LA showed high reproducibility during maximal simultaneous contraction. The thicknesses of TA during maximal simultaneous contraction and maximal simultaneous contraction with resistance were greater than during the resting state and maximal contraction of TA. The iEMG of LA during maximal simultaneous contraction was greater than during the resting state, maximal contraction of TA and maximal contraction of LA. In regression analysis, a significant relationship was found between the thickness of TA and iEMG of LA. [Conclusion] The muscle output during simultaneous contraction was larger than that of each individual muscle, suggesting that it is easier to contract LA when TA is contracted from the aspect of the kinetic chain.
Key words: Levator ani muscle, Transverse abdominal muscle, Kinetic chain.

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INTRODUCTION

Urinary incontinence is well-known to have a profound effect on women's QOL (quality of life). Three to five million women are worried by urinary incontinence (UI) from the gravid period, the intrapartum period, the puerperal period, or the postmenopausal period.

Many cases of UI are stress urinary incontinence (SUI), and evidence in support of pelvic floor muscle (PFM) exercises for the management of SUI has been provided by multiple randomized controlled studies. PFM exercise has been reported to be 50% to 69% effective in reducing urine loss episodes in women[1–4]. To isolation contration of the PFM, elimination of abdominal muscle activity is recommended in many guidelines for PFM exercise[5–7]. Isolated PFM contractions are promoted to avoid an increase in intra-abdominal pressure which may provoke or exacerbate symptoms of SUI and prolapse.

Recently, it was reported that the PFM as an inner unit with the transverse abdominal muscle (TA), the multifidus muscle, and the diaphragm act to stabilize the trunk, and this muscle unit has begun to be used in approaches to not only urine incontinence but also lumbar pain[8–10]. The present study examined the measurement reliability and the kinetic chain of the thickness of the TA and the action potential of the levator ani muscle (LA). In other words, the change in the muscle output was examined in simultaneous contraction of both TA and LA.

SUBJECTS AND METHODS

The subjects were 7 healthy adult women: age, 40.1 ± 12.8 y (mean ± standard deviation); height, 158.3 ± 2.1 cm; weight, 55.4 ± 4.7 kg.

The thickness of TA and integrated electromyogram (iEMG) of LA were measured. Five tasks were performed in the supine position, and the starting position was randomly assigned. To examine the measurement reliability, the tasks were tested twice. The five tasks were

1. Resting state.
2. Maximal contraction of TA. Subjects were instructed to draw in the lower abdominal wall toward the spine, action which specifically activates TA. The subject was required to breathe in a relaxed manner. No movement of the lumbar spine was allowed.
3. Maximal contraction of LA. Subjects were instructed to contract the muscle around the vagina "like a drawstring" and to lift them internally. No posterior tilt of the pelvis was allowed. There was no instruction to either use or not use the abdominal muscles.
4. Maximal simultaneous contraction of both TA and LA.
5. Maximal simultaneous contraction of both TA and LA with resistance added to both knees.

In these maximal contraction tasks, subjects were instructed to perform them at maximum effort. Subjects performed the tasks in the supine position with the knees flexed at 90°, and with one pillow under the head. Ultrasound images of the antero-lateral abdominal wall were obtained using an SonoSite (SonoSite 180 PLUS,B mode,5MHz linear transducer). Gel was interposed between the transducer and the skin and the transducer was positioned adjacent and perpendicular to the abdominal wall 25 mm antero-medial to the midpoint between the ribs and ilium on the mid-axillary line and parallel to the muscle fibres of the transversus abdominis[11]. The measurements and recordings were done by the same person, a midwife, to avoid inter-rater errors. Ultrasound images were saved by the SonoSite as still images. All thickness measurements were of the muscle only, that is, between fascia boundaries.

Surface EMG disposable electrodes with an interelectrode distance of 1.5 cm were applied to the LA (1.0 cm lateral and obliquely upward from the anus). A surface EMG (POLYGRAPH SYSTEM, Japan) was used. The EMG signals were converted from analogue to digital then displayed and recorded. All data were sampled at 1 kHz for subsequent analysis. The iEMG was calculated from the amount of the muscular activity three seconds. Chart4 for Windows was used for the analysis.

The resistance force during maximal simultaneous contraction of TA and LA was measured by two hand-held dynamometers (ANIMA uTas MT1, HHD) held in both hands of the measurer, using the tester function of HHD. A resistance force was added to both knees of the subjects. The direction of resistance was the long axis direction of the femur. The resistance force was the maximum resistance that didn't appear as for the trunk shake of the subject. The mean value of the maximum resistance force of the right and left hands was assumed to be a representative value.

In order to reveal the reliability of measurement values, interclass correlation coefficients (ICC) were calculated. One-way analyses of variance and multiple comparisons (Bonferroni test) were used to test for statistically significant differences, and the factors were thickness of TA and iEMG of LA, respectively. In addition, regression analysis of the thickness of TA and iEMG of LA was performed. Data were analyzed using SPSS Ver. 12.0 for Windows.

Table 1. Thickness of TA [b] (mm) and ICC of repeated measurement

State	First measurement	Second measurement	ICC [a]
Resting state	3.5 ± 0.9	3.1 ± 0.9	0.85**
Maximal contraction of TA	4.8 ± 1.9	4.0 ± 1.4	0.58
Maximal contraction of LA[c]	4.5 ± 1.1	4.7 ± 1.4	0.93**
Maximal simultaneous contraction[d]	4.8 ± 1.5	5.1 ± 2.1	0.88**
Maximal simultaneous contraction with resistance[e]	6.2 ± 1.3	5.7 ± 1.6	0.69*

Mean ± SD,*p<0.05, **p<0.01. [a] ICC: interclass correlation coefficient. [b] TA: transverse abdominal muscle. [c] LA: levator ani muscle. [d] Maximal simultaneous contraction of both TA and LA. [e] Maximal simultaneous contraction of both TA and LA with resistance added to both knees.

Table 2. iEMG of LA[b] (μV) and ICC of repeated measurement

State	First measurement	Second measurement	ICC [a]
Resting state	11.0 ± 1.1	10.5 ± 3.3	0.42
Maximal contraction of TA[c]	11.5 ± 1.3	11.6 ± 1.6	0.83**
Maximal contraction of LA	12.6 ± 3.5	12.4 ± 2.8	0.77**
Maximal simultaneous contraction[d]	14.3 ± 3.7	14.1 ± 3.0	0.86**
Maximal simultaneous contraction with resistance [e]	12.0 ± 1.5	12.1 ± 1.3	0.55

Mean ± SD, *p<0.05, **p<0.01. [a] ICC= interclass correlation coefficient. [b] LA: levator ani muscle. [c] TA: transverse abdominal muscle. [d] Maximal simultaneous contraction of both TA and LA. [e] Maximal simultaneous contraction of both TA and LA with resistance added to both knees.

Table 3. Effect of Thickness of TA[a] and iEMG of LA[b] for Each Task

State	Thickness of TA(mm)	iEMG of LA(μV)
a. Resting state	3.1 ± 0.9	10.5 ± 3.3
b. Maximal contraction of TA	4.0 ± 1.4	11.6 ± 1.6
c. Maximal contraction of LA	4.7 ± 1.4	12.4 ± 2.8
d. Maximal simultaneous contraction[c]	5.1 ± 2.1	14.1 ± 3.0
e. Maximal simultaneous contraction with a resistance[d]	5.7 ± 1.6	12.1 ± 1.3

Mean ± SD,*p<0.05, **p<0.01. [a] TA: transverse abdominal muscle. [b] LA: levator ani muscle. [c] Maximal simultaneous contraction of both TA and LA. [d] Maximal simultaneous contraction of both TA and LA with resistance added to both knees.

RESULTS

Table 1 and Table 2 show the values of ICC (1, 1) of the thickness of TA and the iEMG of LA. The ICCs of the thickness of TA during maximal simultaneous contraction, in the resting state and maximal contraction of LA show high reproducibility. The ICC of the iEMGs of LA during maximal simultaneous contraction and maximal contraction of TA also show high reproducibility.

The thicknesses of TA during maximal simultaneous contraction and maximal simultaneous contraction with resistance were greater than during the resting state and maximal contraction of TA.

Table 3 shows the effect of the thickness of TA and the iEMG of LA for each task. The thickness of TA showed a significant main effect among tasks (F (4,24)= 9.01, p<0.01). Moreover, multiple comparisons (Bonferroni test) revealed that the thicknesses of TA during maximal simultaneous contraction and maximal simultaneous contraction with resistance were greater than during the resting state and maximal contraction of TA. The iEMG of LA showed a significant main effect among tasks (F(4,24) =3.38,p<0.05). Moreover, multiple comparison (Bonferroni test) revealed that the iEMG of LA during maximal simultaneous contraction was significantly greater than during the resting state, maximal contraction of TA and maximal contraction of LA ($p<0.05$). The resistance force during maximal simultaneous contraction with resistance was 7.74 ± 1.5 kg the first time and 7.41 ± 0.87 kg the second time with no significant difference.

In the regression analysis, a significant regression line was found between the thickness of TA and the iEMG of LA for the five tasks. The regression equation was: iEMG of LA= 0.06 thickness of TA + 0.09, R= 0.55, R^2=0.30 ($p<0.01$).

DISCUSSION

The interclass correlation coefficients (ICC) of thickness of TA and iEMG of LA show high reproducibility for maximal simultaneous contraction. The iEMG of LA during maximal simultaneous contraction was greater than during the resting state, maximal contraction of TA and maximal contraction of LA. There was no significant difference between maximal simultaneous contraction and maximal simultaneous contraction with resistance, suggesting that the effect of LA contraction is similar for the resistance exercise and the active exercise in the simultaneous contraction task.

The thicknesses of TA during maximal simultaneous contraction and maximal simultaneous contraction with resistance were greater than during the resting state and maximal contraction of TA. The muscle output during simultaneous contraction was larger than that of each individual muscle not only for TA but also for LA. Strong TA contraction invariably activated LA, suggesting that it is easier to contract LA when TA is contracted from the aspect of the kinetic chain. This supports the findings of another study[12], which reported a strong PFM contraction resulted in strong and simultaneous recruitment of TA. Moreover, in the regression analysis, a significant relationship was found for the thickness of TA and the iEMG of LA. Changes in thickness of TA could be used to indicate changes in the electrical activity of LA in all the tasks.

The TA was contracted by “belly-in” and the pelvis was in retroversion, raising the intra-abdominal pressure. We think that TA contraction is a resistance exercise with raised intra-abdominal pressure which increases LA contraction. Therefore, we think that the strength training effect of the LA while TA is contracted is greater than that of individual LA contraction.

Our study did not include women with severe incontinence. Further investigations will need to weigh the training effect for women with urine incontinence in a prospective intervention study.

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