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# An Approach to Assessment of Female Urinary Incontinence Risk Using the Thickness of the Transverse Abdominal Muscle

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**Abstract.** [Purpose] This study examined physical factors associated with urinary incontinence (UI) in women. We hypothesized that, women with UI would show decreased thickness of the transverse abdominal muscle (TA) during maximal co-contraction of both TA and the pelvic floor muscle (PFM) compared with women with no history of UI. [Subjects] The subjects were seventy-one women who were divided into two groups: the UI group and the No-UI group. [Methods] We evaluated the thickness of TA and obliquus internus muscle (OI) using ultrasound, and measured hand-grip strength. The thickness of TA was measured while subjects performed 5 tasks: (1) at rest, (2) maximal contraction of TA, (3) maximal contraction of PFM, (4) maximal co-contraction of both TA and PFM, and (5) bridging motion. [Results] The No-UI group had many subjects who had thicknesses of TA which the UI group had in the tasks 2, 3 and 4. In logistic regression analysis with UI as the dependent variable, the thickness of TA during maximal co-contraction was identified as an independent factor, and the cut-off value of the thickness of TA was 5.00 mm as determined by the Receiver-Operating-Characteristic (ROC) curve. [Conclusion] We demonstrated that the thickness of TA in maximal co-contraction of both TA and PFM is reliable and useful for evaluating the risk of UI in women.

**Key words:** Urinary incontinence, Transverse abdominal muscle, Pelvic floor muscle

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## INTRODUCTION

Urinary incontinence (UI) is well-known to profoundly affect women's QOL (quality of life). From three to five million women are worried by UI beginning at the gravid period, the intrapartum period, the puerperal period, or the postmenopausal period.

Many cases of UI are stress urinary incontinence (SUI), and the success of pelvic floor muscle (PFM) exercise in the management of SUI has been confirmed by multiple randomized controlled studies. PFM exercise has been reported to be from 50% to 69% effective at reducing urine loss episodes in women[1–4)]. In previous studies of female UI, we found that there are several ways of assessing the severity of UI, such as a bladder diary, the pat test, and the urodynamic test. However, few studies have evaluated the risk of UI. Many UI cases are the result of PFM weakness, suggesting that risk of UI can be evaluated by PFM. Recently, several studies reported that PFM as an inner unit with the transverse abdominal muscle (TA), the multifidus muscle and the diaphragm acts to maintain the stability of the trunk, and PFM has begun to be used in approaches for not only UI but also lumbar pain[5–7)]. In our previous study, we found a significant relationship between the thickness of TA and the iEMG of the levator ani muscle[8)]. This result suggests that changes in the thickness of TA may be used to indicate changes in the electrical activity of PFM.

In this study, we examined factors of physical function associated with UI. The hypothesis was that women with UI would show decreased thickness of TA during maximal co-contraction of both TA and PFM compared with the women with no history of UI.

## SUBJECTS AND METHODS

The subjects were seventy-one women. The subjects were divided into two groups. The subjects in the UI group (n=26) had experienced one, or more UI event in the past 1 month, and the subjects in the No-UI group (n=45) had no history of UI. The UI rate was 36.6% (Table 1). All subjects gave their informed consent to participate in this study.

The subjects in the UI group completed a questionnaire

**Table 1.** Subject Characteristics

| | UI[a] (n= 26) | No- UI[b] (n= 45) | Sum total (n= 71) |
|---|---|---|---|
| Age (y) | 48.6 ± 5.3 | 46.0 ± 8.1 | 46.9 ± 7.3 |
| Height (cm) | 160.4 ± 5.5 | 162.4 ± 5.0 | 161.7 ± 5.3 |
| Weight (kg) | 60.0 ± 7.2 | 59.0 ± 6.8 | 59.4 ± 6.9 |

Note: values are mean ± standard deviation. There were no significant differences between groups at the 0.05 level. [a]. UI group: women with urinary incontinence. [b]. No-UI group: women with no history of urinary incontinence.

**Table 2.** Delivery history

| | UI | No- UI | Sum total |
|---|---|---|---|
| Primiparity | 19 | 42 | 61 |
| Para | 7 | 3 | 10 |
| Sum total | 26 | 45 | 71 |

$\chi^2$ test. p<0.05.

**Table 3.** Delivery method

| | UI | No- UI | Sum total |
|---|---|---|---|
| Natural childbirth | 24 | 35 | 59 |
| Caesarean section | 2 | 10 | 12 |
| Sum total | 26 | 45 | 71 |

$\chi^2$ test. There were no significant differences between groups at the 0.05 alpha level.

**Table 4.** Menstrual cycle

| | UI | No- UI | Sum total |
|---|---|---|---|
| Steady | 8 | 33 | 41 |
| Irregular | 3 | 4 | 7 |
| Menopause | 15 | 8 | 23 |
| Sum total | 26 | 45 | 71 |

$\chi^2$ test. There were no significant differences between groups at the 0.05 alpha level.

about UI, delivery history, delivery method and menstrual cycle.

We evaluated the thickness of TA and the thickness of the obliquus internus muscle (OI) using ultra sound and measured hand-grip strength.

All the subjects performed five tasks at random in the supine position, during which the thicknesses of TA and OI were measured. The measurements were repeated to examine the measurement reliability. 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, an action which specifically activates TA. The subjects were asked to breathe in a relaxed manner. No movement of the lumbar spine was allowed. 3) Maximal contraction of PFM. Subjects were instructed to contract the muscles 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 co-contraction of both TA and PFM. 5) Bridging motion.

Subjects performed all tasks on the supine position with the knees flexed at 90°, and a pillow under the head. A Biofeedback Stabilizer was used to provide visual feedback. The three-chamber pressure cells were placed under the lumbar spine and subjects were asked to keep the baseline at 40 mmHg. If the pressure of the Stabilizer decreased, when subjects performed task 2, 3 or 4, abdominal muscle re-education was given by a physical therapist.

Ultrasound images of the antero-lateral abdominal wall were obtained using a SonoSite (SonoSite 180 PLUS,B mode,5 MHz linear transducer). Gel was interposed between the transducer and the skin. The transducer was positioned adjacent to 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[9)]. The same person, a midwife, made the measurements to avoid inter-rater errors. Ultrasound images were saved as still images. All thickness measurements were of muscle only, that is, between the fascia boundaries.

To examine the reliability of the thickness of TA and OI, nine subjects (47.0 ± 7.3 yr; 54.2 ± 4.4 kg; 159.9 ± 4.5 cm) were selected at random from among the subjects. Three subjects who had experienced one or more UI events in the past 1 month were in the nine subjects. The retest was implemented on the following day.

In order to determine the reliability of the measurement values of the thickness of TA and OI, the interclass correlation coefficient (ICC) was calculated. To determine differences between the UI group and the No-UI group, the chi-square test were performed on the results of our questionnaire; the independent t-test was performed on each measure. To determine correlations between items, Pearson’s correlation coefficient was used. Logistic regression analysis and the Receiver-Operating-Characteristic (ROC) curve were used to investigate the accrual of urinary incontinence and its relation to each factor. The Hosmer and Lemeshow test was used to judge the suitability of the logistic regression analysis. The data were analyzed using SPSS Ver. 12.0 for Windows.

## RESULTS

Table 2 shows the delivery history, the UI group had more multi-parous women than the No-UI group (p<0.05). The delivery method and the menstrual cycle were not significantly different between the UI group and the No-UI group (Table 3 and 4).

Tables 5 and 6 show the values of the test-retest coefficients (ICC). The ICCs of the thickness of TA ranged from 0.87 to 0.96 for all tasks, and the ICCs of the thickness of OI ranged from 0.78 to 0.96 for all tasks, showing high reproducibility (p<0.01).

The UI group had significantly smaller thicknesses of TA during maximal contraction of TA, maximal contraction of PFM and maximal co-contraction of both TA and PFM (p<0.01) than the No-UI group. The UI group had significantly smaller thicknesses of OI during the resting state, maximal

**Table 5.** Measurements and ICC [a] (1, 1) of Thickness of TA [b] (mm) (n=9)

| | First measurement | Second measurement | ICC |
|---|---|---|---|
| Resting state | 2.6 ± 1.2 | 2.7 ± 1.0 | 0.87** |
| Maximal contraction of TA | 5.0 ± 2.0 | 5.5 ± 2.6 | 0.92** |
| Maximal contraction of PFM [c] | 4.8 ± 2.2 | 4.6 ± 1.9 | 0.93** |
| Maximal co-contraction [d] | 5.9 ± 3.5 | 5.5 ± 3.0 | 0.96** |
| Bridging motion | 3.6 ± 1.4 | 3.6 ± 1.6 | 0.90** |

Note: values are mean ± standard deviation. ** p<0.01. [a] ICC: interclass correlation coefficient. [b] TA: transverse abdominal muscle. [c] PFM: pelvic floor muscle. [d] Maximal co-contraction: Maximal co-contraction of both TA and PFM.

**Table 6.** Measurements and ICC [a] (1, 1) of Thickness of OI [b] (mm) (n=9)

| | First measurement | Second measurement | ICC |
|---|---|---|---|
| Resting state | 5.2 ± 1.5 | 5.2 ± 1.5 | 0.81** |
| Maximal contraction of TA [c] | 7.4 ± 2.8 | 7.6 ± 2.8 | 0.94** |
| Maximal contraction of PFM [d] | 6.4 ± 2.3 | 5.9 ± 1.8 | 0.78** |
| Maximal co-contraction [e] | 7.4 ± 2.8 | 7.7 ± 2.6 | 0.90** |
| Bridging motion | 5.6 ± 1.8 | 5.6 ± 2.0 | 0.96** |

Note: values are mean ± standard deviation. ** p<0.01. [a] ICC: interclass correlation coefficient. [b] OI: obliquus internus muscle. [c] TA: transverse abdominal muscle. [d] PFM: pelvic floor muscle. [e] Maximal co-contraction: Maximal co-contraction of both TA and PFM.

**Table 7.** Results of physical tests performed by the UI group and the No-UI group

| | UI group (n= 26) | No-UI group (n= 45) |
|---|---|---|
| Thickness of TA [a] (mm) | | |
| Resting state | 2.6 ± 1.1 | 3.1 ± 0.8 |
| Maximal contraction of TA | 3.8 ± 1.3 | 4.9 ± 1.8** |
| Maximal contraction of PFM [b] | 3.7 ± 1.0 | 5.1 ± 1.6** |
| Maximal co-contraction [c] | 4.3 ± 1.1 | 5.7 ± 1.9** |
| Bridging motion | 4.6 ± 1.5 | 5.1 ± 1.4 |
| Thickness of OI [d] (mm) | | |
| Resting state | 4.6 ± 1.1 | 5.3 ± 1.4* |
| Maximal contraction of TA | 5.0 ± 1.7 | 6.2 ± 2.5* |
| Maximal contraction of PFM | 4.9 ± 1.6 | 6.3 ± 2.7* |
| Maximal co-contraction | 5.3 ± 1.7 | 6.8 ± 2.8* |
| Bridging motion | 5.7 ± 1.8 | 6.4 ± 2.9 |
| Pressure of spinal stabilizer (mmHg) | | |
| Maximal contraction of TA | 60.4 ± 13.7 | 61.9 ± 14.2 |
| Maximal contraction of PFM | 46.0 ± 7.7 | 48.6 ± 10.8 |
| Maximal co-contraction | 58.5 ± 12.9 | 59.4 ± 15.8 |
| Hand-grip strength (kg) | 25.0 ± 5.0 | 26.0 ± 5.3 |

Note: values are mean ± standard deviation. *p<0.05, **p<0.01. [a] TA: transverse abdominal muscle. [b] PFM: pelvic floor muscle. [c] Maximal co-contraction: Maximal co-contraction of both TA and PFM. [d] OI: obliquus internus muscle.

contraction of TA, maximal contraction of PFM and maximal co-contraction of both TA and PFM (p<0.05) than the No-UI group. The hand-grip strength and the pressure of spinal stabilizer were not significantly different between the UI group and the No-UI group (Table 7).

There were high correlations between the thickness of TA during maximal contraction of PFM and maximal co-contraction of both TA and PFM (r= 0.80, p<0.01), the thickness of OI during maximal contraction of PFM and maximal co-contraction of both TA and PFM (r= 0.93, p<0.01), and the thickness of OI during maximal contraction of TA and maximal co-contraction of both TA and PFM (r= 0.80, p<0.01).

**Table 8.** Result of Logistic Regression Analysis with UI as the Dependent Variable

| Item | Odds Ratio | 95% CI [b] | p |
|---|---|---|---|
| Delivery history | 6.570 | 1.391–31.018 | <0.05 |
| Menstrual cycle | 3.349 | 1.457–7.700 | <0.01 |
| Maximal co-contraction [a] | 0.184 | 0.070–0.480 | <0.01 |
| The Hosmer- Lemeshow Test | $\chi^2$=9.801 | p>0.05 | |

Note: Stepwise way. [a] Maximal co-contraction: Thickness of TA of maximal co-contraction of both TA and PFM. [b] CI= Confidence interval.

Logistic regression analysis with urinary incontinences as the dependent variable and age, the delivery history, the menstrual cycle, the thicknesses of TA during maximal contraction of TA, and maximal co-contraction of both TA and PFM, and thicknesses of OI during resting state, and maximal co-contraction of both TA and PFM as the independent variables was performed by the stepwise method. To prevent multicollinearity, we excluded the thickness of TA during maximal contraction of PFM, the thickness of OI during maximal contraction of PFM, and TA. The delivery history, the menstrual cycle, the thickness of TA during maximal co-contraction of both TA and PFM gave significant results (Table 8). For urinary incontinence as a variable of state, the ROC curve of the thickness of TA during maximal co-contraction of both TA and PFM was plotted. The area under the curve (AUC) was 76% and the cut-off value was 5.00 mm (Fig. 1). The sensitivity was

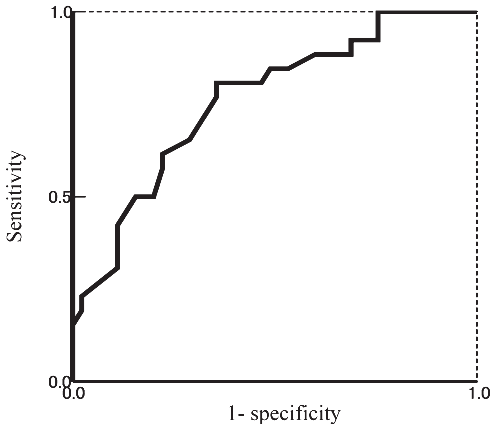


**Fig 1.** The Receiver-Operating-Characteristic (ROC) curve of the thickness of TA during maximal co-contraction of both TA and PFM. The area under the curve (AUC) was 76%, and the cut-off value was 5.00 mm; the sensitivity was 81% and the specificity was 64%. (Asymptotic significance probability <0.05)

**Table 9.** The cross-table of the cut-off value of the thickness of TA during maximal co-contraction of both TA and PFM

| | UI [a] group | No-UI group | Sum total |
|---|---|---|---|
| <5.00 mm | 21 | 16 | 37 |
| ≥5.00 mm | 5 | 29 | 34 |
| Sum total | 26 | 45 | 71 |

[a] UI: urinary incontinence. The sensitivity= 21/26= 0.81. The specificity= 29/45= 0.64. The positive predictive value= 21/37= 0.57. The negative predictive value= 29/34= 0.85. The predictive accuracy= (21+29) /71= 0.70.

81% and the specificity was 64% according to the cross-table of the cut-off value (Table 9).

## DISCUSSION

The ICC of the thickness of TA and OI was high, and showed high reproducibility. The purpose of this study was to examine physical factors associated with urinary incontinence in women. Supporting our hypothesis, the UI group had significantly decreased thicknesses of TA during maximal contraction of TA, maximal contraction of PFM and maximal co-contraction of both TA and PFM compared with the No-UI group. The hand-grip strength was not different between the groups.

In logistic regression analysis, the thickness of TA during maximal co-contraction of both TA and PFM was identified as significant, indicating that the thickness of TA is useful for the evaluation of the risk of UI. This finding is consistent with our previous study[10]. In the present study, the cut-off value of the thickness of TA during maximal co-contraction of both TA and PFM was 5.00 mm, as determined from the ROC curve, and the sensitivity was 81% and the specificity was 64%. This result indicates that the detectability of the risk of urinary incontinence is high, and quantitative assessment of the risk of UI is possible through measurement of the thickness of TA during maximal co-contraction of both TA and PFM. In addition, the negative predictive value was 85 percent and the predictive accuracy was 70 percent, greatly exceeding the percentage of women with UI, 21.9 percent. This demonstrates that a high-precision UI forecast is possible using this model. In conclusion, the thickness of TA during maximal co-contraction of both TA and PFM is useful for the evaluation of the risk of female urinary incontinence.

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