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Original Article

Measurement reliability and cooperative movement of the pelvic floor and transverse abdominal muscles

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Abstract. [Purpose] This study examined the measurement reliability and cooperative movement of the pelvic floor and transverse abdominal muscles. [Participants and Methods] The participants were seven healthy adult females. Transverse abdominal muscle thickness and bladder floor elevation were measured under the following conditions during active exercise and during resistance exercise: the resting state, maximum contraction of the transverse abdominal muscle, maximum contraction of the pelvic floor muscle, and maximum co-contraction of the transverse abdominal and pelvic floor muscles. Measurements were taken at rest and under each exercise condition. [Results] The intraclass correlation coefficients of transverse abdominal muscle thickness and bladder floor elevation showed high reproducibility under all conditions. The maximum contraction of the pelvic floor muscle showed a high correlation with the maximum co-contraction of the transverse abdominal muscle and pelvic floor muscle during resistance exercise. A significant regression line was found between transverse abdominal muscle thickness and bladder floor elevation under all conditions. The regression equation was as follows: transverse abdominal muscle thickness=0.113 bladder floor elevation+0.377 (r^2=0.21). [Conclusion] This study demonstrated that the measurement reliability of the transverse abdominal and pelvic floor muscles is high, and that both muscles exhibit cooperative movement.

Key words: Pelvic floor muscle, Transverse abdominal muscle, Cooperative movement

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INTRODUCTION

Many guidelines on pelvic floor muscle (PFM) exercise recommend elimination of abdominal muscle activity for isolating contraction of the PFM. Isolated PFM contractions are thought to increase intra-abdominal pressure, which may provoke or exacerbate symptoms of stress urinary incontinence and prolapse[1–3].

Recently, it was reported that the PFM, as an inner unit with the transverse abdominal muscle (TAM), multifidus muscle, and diaphragm, acts to stabilize the trunk, and this information is currently being utilized in the treatment of not only urine incontinence but also lumbar pain[4–6]. A previous study reported that the muscle output during simultaneous contraction was larger than that of each individual muscle, suggesting that it is easier to contract the levator ani muscle when the TAM is contracted from the aspect of cooperative movement[7]. Our hypothesis is that PFM and TAM have a cooperative move-

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ment. This study examined the measurement reliability and cooperative movement of the pelvic floor muscle and transverse abdominal muscle.

PARTICIPANTS AND METHODS

The required number of samples was calculated using G*Power software, the effect size was set to 0.8 and power (1-β=0.8), the required number of samples was six. The participants were seven healthy adult females with the following characteristics: age, 21.1 ± 1.6 years (mean ± standard deviation); height, 162.6 ± 2.8 cm; and weight, 54.9 ± 4.0 kg. All participants provided prior written informed consent. Ethical approval was obtained from the International University of Health and Welfare Ethics Review Committee (approval number: 20-Io-167).

Transverse abdominal muscle thickness and bladder floor elevation were measured using ultrasound (Philips EPIQ5, B mode, 5 MHz C5-1 transducer; Philips Ultrasound, Inc., Bothell, WA, USA). The two measurements were taken in all participants under seven conditions at random in the supine position. The first condition was the resting state. The second condition was maximum contraction of the TAM. For this position, the participants were instructed to draw in the lower abdominal wall toward the spine, an action that specifically activates the TAM. The participants were asked to breathe in a relaxed manner. No movement of the lumbar spine was permitted. The third condition was the maximum contraction of the PFM. For this position, the participants were instructed to contract the muscles around the vagina, “like a drawstring”, and to lift them internally. No posterior tilt of the pelvis was permitted. There were no instructions on whether or not to use the abdominal muscles. The fourth condition was maximum co-contraction of the TAM and PFM. Participants were instructed to perform an action that specifically activated the TAM in the lower abdominal wall toward the spine. During sustained isometric contraction of the TAM, the participants were instructed to contract the muscles around the vagina, “like a drawstring”, and to lift them internally, maintaining this position for 5 seconds. For the final three exercise conditions, the participants performed resistance movements using Thera-Band®. Resistance force was measured with two hand-held dynamometers (ANIMA uTas MT1; HHD Japan) held in both knees inside the Thera-Band®, using the tester function of the HHD device. The resistance force was controlled at 1.5 kg.

For each condition, the participants were in the supine position with their knees flexed at 90° and a pillow under the head. To perform correct inner muscle contraction, a biofeedback stabilizer was (CHATTANOOGA GROUP INC, Hixson, TN, USA) used to provide visual feedback. The participants were asked to maintain the baseline at 40 mmHg. Except for in the resting state, if the pressure of the biofeedback stabilizer decreased during the task, abdominal muscle re-education was provided by a physical therapist.

Ultrasound images of the anterolateral abdominal wall were obtained using ultrasound (Philips EPIQ5, B mode, 5 MHz C5-1 transducer, Netherlands). The gel was interposed between the transducer and the skin. The transducer was positioned adjacent to and perpendicular to the abdominal wall, 25 mm anteromedial to the midpoint between the ribs and ilium on the midaxillary line, and parallel to the muscle fibers of the transversus abdominis[8)]. The same person, a physical therapist, made 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.

Pelvic floor elevation was measured according to the procedure of Whittaker et al.[9)], the ultrasound probe was placed 10 cm below the navel and tilted about 15 to 30 degrees to the head side with respect to the horizontal plane to the trunk. The amount of bladder floor elevation was defined as the amount of pelvic floor elevation. The participants urinated 1 hour before the measurement, drank 450 to 500 mL of water, and were measured with urine stored without urinating until the end of the measurement. To examine the reliability of the measurement, a retest was administered the next day. All measurements were performed by a radiologist.

Interclass correlation coefficients (ICCs) were calculated to reveal the reliability of the measurement values. Two-way analyses of variance and multiple comparisons (Bonferroni test) were used to test for statistically significant differences. In addition, regression analysis of TAM thickness and bladder floor elevation was performed. Data were analyzed using SPSS ver. 18.0 for Windows (IBM Corp., Armonk, NY, USA). Statistical significance was set at 0.05.

RESULTS

Tables 1 and 2 show the ICC (1, 1) values for TAM thickness and bladder floor elevation. The ICCs of all the measurement items showed high reproducibility.

The TAM thickness’s results of the two-way analysis of variance showed the main effect between conditions ($p<0.01$). In both the active and resistance exercise tasks, TAM thickness during maximum contraction of the TAM, maximum contraction of the PFM, and maximum co-contraction of the TAM and PFM were greater than during the resting state ($p<0.01$), and maximum co-contraction of the TAM and PFM were greater than during maximum contraction of the TAM and maximum contraction of the PFM (Table 3).

The bladder floor elevation’s results of the two-way analysis of variance showed the main effect between conditions ($p<0.01$). In both the active and resistance exercise tasks, the bladder floor elevation during maximum co-contraction of the TAM and PFM were greater than during maximum contraction of the TAM and maximum contraction of the PFM (Table 4).

Table 1. Repeated measurement and ICC of TAM[b] thickness

State		First measurement	Second measurement	ICC[a]	
Active exercise task	Resting state	2.9 ± 0.4	3.0 ± 0.5	0.93	**
	Maximum contraction of the TAM	3.9 ± 0.6	3.9 ± 0.5	0.94	**
	Maximum contraction of the PFM[c]	4.2 ± 0.6	4.3 ± 0.6	0.93	**
	Maximum co-contraction[d]	4.8 ± 0.7	5.1 ± 0.7	0.81	**
Resistance exercise task	Resting state	2.7 ± 0.5	2.7 ± 0.4	0.8	**
	Maximum contraction of the TAM	4.2 ± 0.5	4.2 ± 0.6	0.89	**
	Maximum contraction of the PFM	4.3 ± 0.4	4.5 ± 0.6	0.83	**
	Maximum co-contraction[d]	5.3 ± 0.5	5.5 ± 0.5	0.87	**

Values are means ± standard deviations. Unit: mm (n=7).
*p<0.05; **p<0.01.
[a]: ICC: interclass correlation coefficient.
[b]: TAM: transverse abdominal muscle.
[c]: PFM: pelvic floor muscle.
[d]: Maximum co-contraction: maximum co-contraction of the TAM and PFM.

Table 2. Repeated measurement and ICC of bladder floor elevation

State		First measurement	Second measurement	ICC[a]	
Active exercise task	Resting state	-	-		**
	Maximum contraction of the TAM[b]	4.8 ± 3.4	5.2 ± 3.2	0.98	**
	Maximum contraction of the PFM[c]	6.8 ± 1.8	7.2 ± 1.6	0.87	**
	Maximum co-contraction[d]	8.2 ± 2.1	9.1 ± 2.2	0.81	**
Resistance exercise task	Resting state	-	-		**
	Maximum contraction of the TAM	3.0 ± 2.1	4.0 ± 2.8	0.85	**
	Maximum contraction of the PFM	6.1 ± 1.8	6.6 ± 2.1	0.86	**
	Maximum co-contraction[d]	8.4 ± 1.6	9.6 ± 2.5	0.8	*

Values are means ± standard deviations. Unit: mm (n=7).
*p<0.05; **p<0.01.
[a]: ICC: interclass correlation coefficient.
[b]: TAM: transverse abdominal muscle.
[c]: PFM: pelvic floor muscle.
[d]: Maximum co-contraction: maximum co-contraction of the TAM and PFM.

Table 3. Thickness of TAM[a] for each task

	Active exercise task	Resistance exercise task
Resting state	2.9 ± 0.4	3.0 ± 0.5
Maximum contraction of the TAM[a]	3.9 ± 0.6	3.9 ± 0.5
Maximum contraction of the PFM[b]	4.2 ± 0.6	4.3 ± 0.6
Maximum co-contraction[c]	4.8 ± 0.7	5.1 ± 0.7

Values are means ± standard deviations. Unit: mm (n=7).
*p<0.05; **p<0.01.
[a]: TAM: transverse abdominal muscle.
[b]: PFM: pelvic floor muscle.
[c]: Maximum co-contraction: maximum co-contraction of the TAM and PFM.

There was a high correlation between maximum contraction of the PFM and maximum co-contraction of the TAM and PFM during resistance exercise (Table 5).

In the regression analysis, a significant regression line was found between TAM thickness and bladder floor elevation for all conditions. The regression equation was as follows: TAM thickness=0.113 bladder floor elevation+0.377 (r=0.46, R^2=0.21, p<0.01) (Fig. 1).

Table 4. Bladder floor elevation for each task

	Active exercise task	Resistance exercise task
Resting state	–	–
Maximum contraction of the TAM[a]	5.0 ± 3.3	3.5 ± 2.4
Maximum contraction of the PFM[b]	7.0 ± 1.7	6.4 ± 1.9
Maximum co-contraction[c]	8.9 ± 2.0	9.0 ± 2.0

(Active exercise task: TAM vs. co-contraction *; PFM vs. co-contraction *. Resistance exercise task: TAM vs. PFM **; TAM vs. co-contraction **; PFM vs. co-contraction **.)

Values are means ± standard deviations. Unit: mm (n=7).
*p<0.05; **p<0.01.
[a]: TAM: transverse abdominal muscle.
[b]: PFM: pelvic floor muscle.
[c]: Maximum co-contraction: maximum co-contraction of the TAM and PFM.

Table 5. Pearson correlation coefficient between TAM thickness and bladder floor elevation

		TAM thickness					
		A	B	C	D	E	F
Bladder floor elevation	A	−0.39	−0.44	−0.36	0.00	−0.04	0.03
	B	−0.23	0.21	0.25	0.09	0.15	0.65
	C	−0.24	0.03	0.04	0.23	0.50	0.52
	D	−0.09	−0.21	−0.21	0.40	0.26	0.67
	E	0.26	0.24	0.17	0.63	0.50	0.84*
	F	0.36	0.49	0.41	0.62	0.55	0.76*

*p<0.05 (n=7).
A: Maximum contraction of the TAM during active exercise.
B: Maximum contraction of the PFM during active exercise.
C: Maximum co-contraction of the TAM and PFM during active exercise.
D: Maximum contraction of the TAM during resistance exercise.
E: Maximum contraction of the PFM during resistance exercise.
F: Maximum co-contraction of the TAM and PFM during resistance exercise.

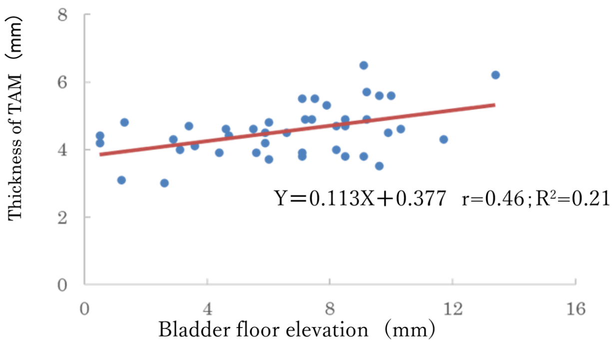

Fig. 1. Regression line of bladder floor elevation and abdominal lateral muscle thickness.

DISCUSSION

The ICCs of TAM thickness and bladder floor elevation showed high reproducibility. Ultrasound imaging was found to be a possibility method for measuring TAM thickness and pelvic floor elevation. Comparison of TAM thickness and bladder floor elevation between conditions indicated a significant main effect for all conditions. In addition, it was suggested that muscle activity of the TAM and PFM was high during maximum co-contraction during resistance exercise using Thera-Band®. Our previous study yielded similar training effects[10].

A significant regression equation was found for TAM thickness and bladder floor elevation. Transverse abdominal muscle thickness and bladder floor elevation were significantly related during maximum co-contraction of the TAM and PFM during resistance exercise, suggesting that TAM thickness can be used to indirectly estimate bladder floor elevation. The TAM was contracted by “belly-in” and the pelvis was in retroversion, raising the intra-abdominal pressure. We believe that TAM contraction is a resistance exercise with increased intra-abdominal pressure, which increases PFM contraction.

This study demonstrated that the measurement reliability of the TAM and PFM is high, and that the TAM and PFM exhibited cooperative movement. Changes in the thickness of TAM could be used to indicate changes in the contraction state of PFM in all the tasks. Our study did not include women with incontinence. Further investigations will need to weigh for females with urine incontinence.

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Conflict of interest

The author declares no conflict of interest.

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