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Original Article

Comparison of Abdominal Muscle Thickness with Vaginal Pressure Changes in Healthy Women

Bo-In Kim, MS, PT[1)], Gak Hwang-Bo, PT, PhD[2)*], Ha-Roo Kim, MS, PT[1)]

[1)] *Department of Physical Therapy, Graduate School, College of Rehabilitation Science, Daegu University, Republic of Korea*

[2)] *Department of Physical Therapy, College of Rehabilitation Science, Daegu University: 201 Daegudaelo, Gyungsan-si, Kyoungbuk 712-714, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to verify the efficacy of a pelvic floor muscle exercise program by comparing subjects' muscle thickness with changes in vaginal pressure. [Subjects] Two groups of female participants without a medical history of pelvic floor muscle dysfunction were evaluated. The mean age of Group I was 33.5 years and that of Group II was 49.69 years. [Methods] The participants were instructed to perform a pelvic floor muscle contraction. While measuring the vaginal pressure of the pelvic floor muscle, biofeedback was given on five levels, and the thicknesses of the transversus abdominis, external oblique, and internal oblique muscles were measured with ultrasound. [Results] The thickness of the transversus abdominis muscle was significantly increased at 30 cmH_2O in Group I, and at 20 cmH_2O in Group II. The thickness of the internal oblique abdominal muscle significantly increased at maximum contraction in Group II. [Conclusion] Different abdominal muscles contracted depending on vaginal pressure. The result may be used to create and implement an exercise program that effectively strengthens the pelvic floor muscles.

Key words: Pelvic floor muscle contraction, Vaginal pressure, Abdominis muscle

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INTRODUCTION

The most prevalent cause of pelvic floor muscle dysfunction in females is the attenuation of the pelvic floor muscle, resulting in a state in which the pelvic floor muscle is unable to be independently recognized and contracted. This results in pelvic girdle relaxation, pelvic organ prolapse, or stress urinary incontinence. The pelvic floor muscle, in the form of the pelvic floor and abdominal cavity, has the dual function of controlling cystic incontinence and stabilizing the radial region[1)]. Dysfunction of the pelvic floor muscle is generally associated with dysuria and radial pain[2)].

A recent study has shown that the pelvic floor muscles are fundamentally important for trunk core muscle strength and stabilization[3)]. Perri[4)] reported that the transversus abdominis muscle, pelvic floor muscle, and deep spine intrinsic muscle function in harmony with each other, and that dysfunction in one of them can produce related effects, influencing spinal stability, and causing pain. Sapsford et al.[5)] found that during maximum contraction of the pelvic floor muscles, all the abdominal muscles, including the transversus abdominis, internus obliquus, externus obliquus, and rectus abdominis, were activated.

Recently, ultrasonography has become one of the instruments used widely in research and clinical settings, since it allows muscle shape and reaction to be quantified, especially the contraction of the abdominal muscles, in a non-invasive manner. Ultrasonography employs a novel method to evaluate the provided morphological information of deep muscles[6)]. It acquires objective and highly reliable information, since the measurement is performed while visually checking the location and shape of the deep muscles. Kiesel et al.[7)] reported that an ultrasonogram is useful for evaluating muscle thickness as the changes in a muscle are measured related to contraction. Hence, this study employed unltrasonography in order to objectively evaluate abdominal muscle contractions related to changes in vaginal pressure.

In cases of dysfunction (e.g., stress urinary incontinence), it is generally advised that the rehabilitation of pelvic floor muscles be done in isolation[8)]. However, it is now known that abdominal muscle activity occurs in conjunction with pelvic floor muscle contraction, and there is preliminary evidence that the reverse may also occur (i.e., pelvic floor muscle activity in response to specific abdominal maneuvers).

Many clinical exercise methods have been developed to use abdominal muscles in pelvic floor muscle exercises. However, studies have rarely been conducted to measure abdominal muscle thickness in response to vaginal pressure generated by pelvic floor muscles. In this study, normal adult females were divided into different age groups,

*Corresponding author. Gak Hwang-bo (E-mail: hbgak@daegu.ac.kr)

and changes in abdominal muscle thickness in response to changing vaginal pressure were comparatively analyzed.

SUBJECTS AND METHODS

The subjects of this study were classified by age into two groups comprised of 11 subjects in their 20s and 30s (Group I), and 13 subjects in their 40s and 50s (Group II). The average ages of Group I and Group II were 33.55 and 49.69 years, respectively, with a significant difference. However, there were no significant differences between the two groups in vaginal pressure, height, weight, and body mass index (BMI). This study was approved by Hospital, and all the participants provided their written informed consent. Vaginal pressure was measured with a perineum vaginal pressure meter (perineometer, Peritron 9300, Cardio Design Australia).

Subjects were placed in a supine position with their hips flexed at approximately 60°. Each subject was instructed to strongly tighten her vagina as if pulling it into her body. While avoiding lumbar and pelvic motions, subjects received visual feedback about their contraction force through a pressure gauge connected to a pressure biofeedback device. The pelvic floor muscle contraction was performed at five levels: resting (0 cmH_2O), 10 cmH_2O, 20 cmH_2O, 30 cmH_2O, and maximum contraction. The subjects maintained the target pressure for five seconds and took a 10-second rest before the next measurement as the muscles may have tired during each contraction. Three measurements were taken for each subject, and the average values were calculated.

An ultrasonography instrument (HDI 5000, Philips ATL) was used with a linear array transducer, which could be operated at 7 MHz. The static muscle cross-sectional area was represented by a B (brightness)-mode scan. To minimize inter-observer variations, a physical therapist who was skilled in ultrasonography performed the measurements on the basis of basic anatomical knowledge of the abdomen. Gel for ultrasonography was applied between the linear array transducer and the skin, and the right abdominal muscle was checked by inspection through the ultrasonogram, and palpation by the hands of the tester. The thicknesses of the transversus abdominis muscle, internal oblique abdominal muscle, and external oblique abdominal muscle were measured at the same position, which was 1 cm from the boundary of the fascia to the center of the muscle[9]. The measurement position was in the anterolateral position of the axillary line between the iliac crest and costal inferior horn[10]. The subjects were in the supine position with a triangular support under the knee joints so that the position would remain fixed for the duration of the measurement.

The mean and standard deviation of the general characteristics of the subjects were calculated using descriptive analysis. One-way ANOVA was performed to compare the muscle thickness changes between the isometric contractions at the five levels of vaginal pressure. A least-square difference (LSD) method was performed as a post hoc significance test. The independent t-test was performed to compare muscle thicknesses between the age groups. The reliability of the abdominal muscle thickness measurement by the tester according to vaginal pressure was analyzed using the intraclass correlation coefficient (ICC). All the statistical processing was performed with SPSS version 12.0 software, and a significance level of 0.05.

RESULTS

The ICCs of the tester's three times measurements of muscle thickness at each vaginal pressure ranged from 0.90–0.98 for the transversus abdominis muscle, from 0.87–0.99 for the internal oblique abdominal muscle, and from 0.88–0.97 for the external oblique abdominal muscle. These are all very high values.

In Group I, the change in abdominal thickness dependent on vaginal pressure was significant for the transversus abdominis muscle ($p<0.05$) but not significant for the external oblique abdominal muscle and the internal oblique abdominal muscle ($p>0.05$). The change in abdominal muscle thickness dependent on vaginal pressure was significant from resting to a vaginal pressure of 30 cmH_2O, from resting to maximum contraction, and from 10 cmH_2O to maximum contraction for the transversus abdominis muscle ($p<0.05$). However, no significant differences were found for the external oblique abdominal muscle and internal oblique abdominal muscle ($p>0.05$) (Table 1).

In Group II, the change in thickness dependent on vaginal pressure was significant for the transversus abdominis muscle and internal oblique abdominal muscle ($p<0.05$) but not significant for the external oblique abdominal muscle ($p>0.05$). The change in abdominal muscle thickness dependent on vaginal pressure was significant from resting to vaginal pressures of 20 cmH_2O, 30 cmH_2O, and maximum contraction, and from vaginal pressures of 10 cmH_2O to 30 cmH_2O and maximum contraction for the transversus abdominis muscle ($p<0.05$). Additionally, a significant change was found from resting to maximum contraction, and from 10 cmH_2O to maximum contraction for the internal oblique abdominal muscle ($p<0.05$). However, no significant difference was found for the external oblique abdominal muscle ($p>0.05$).

A comparison of the muscle thickness changes in the transversus abdominis muscle and internal oblique abdominal muscle dependent on vaginal pressure between the two groups showed that the thickness increase was greater in Group II, but the increase was not significant ($p>0.05$). For the external oblique abdominal muscle, while no thickness change was found in Group I, muscle thickness gradually decreased as vaginal pressure increased in Group II, but the decrease was not significant ($p>0.05$).

DISCUSSION

The analysis of transversus abdominis muscle thickness depending on vaginal pressure showed that the resting thickness was 0.24 cm in Group I, and 0.23 cm in Group II, indicating a similar starting line. A significant difference was found in Group I from resting to a vaginal pressure of 30 cmH_2O, and from resting to maximum contraction. A significant difference was found in Group II from resting

Table 1. Abdominal muscle thicknesses of each age group (unit=cm)

GI Muscle	VP	Thickness	Resting	10 cmH_2O	20 cmH_2O	30 cmH_2O	Maximum
	Resting	0.24±0.01				*	*
	10 cmH_2O	0.26±0.02					
TrA	20 cmH_2O	0.30±0.02					
	30 cmH_2O	0.32±0.03					
	Maximum	0.35±0.03					
	Resting	0.59±0.02					
	10 cmH_2O	0.61±0.03					
EO	20 cmH_2O	0.61±0.03					
	30 cmH_2O	0.60±0.03					
	Maximum	0.59±0.02					
	Resting	0.43±0.04					
	10 cmH_2O	0.44±0.04					
IO	20 cmH_2O	0.46±0.04					
	30 cmH_2O	0.47±0.04					
	Maximum	0.50±0.04					
GII Muscle	**VP**	**Thickness**	**Resting**	**10 cmH_2O**	**20 cmH_2O**	**30 cmH_2O**	**Maximum**
	Resting	0.23±0.01			*	*	*
	10 cmH_2O	0.30±0.02				*	*
TrA	20 cmH_2O	0.34±0.03					
	30 cmH_2O	0.38±0.04					
	Maximum	0.42±0.04					
	Resting	0.55±0.04					
	10 cmH_2O	0.53±0.04					
EO	20 cmH_2O	0.51±0.04					
	30 cmH_2O	0.51±0.04					
	Maximum	0.51±0.04					
	Resting	0.44±0.02					*
	10 cmH_2O	0.44±0.03					*
IO	20 cmH_2O	0.47±0.02					
	30 cmH_2O	0.59±0.03					
	Maximum	0.53±0.02					

VP: vaginal pressure, TrA: Transversus abdominis, EO: External oblique muscle, IO: Internal oblique muscle
*$p<0.05$

to 20 cmH_2O, 30 cmH_2O, and maximum contraction, and from 10 cmH_2O to 30 cmH_2O and maximum contraction. This was consistent with the finding of Sapsford[5] that the pelvic floor muscle and transversus abdominis muscle activate together when the pelvic floor muscle is contracted. This result is also in agreement with the result that the muscular activity of the pelvic floor muscle can be increased to a greater degree when the pelvic floor muscle is contracted using the abdominal muscle rather than when only the pelvic floor muscle is contracted[11, 12].

In our study, the thickness of the external oblique abdominal muscle increased slightly or did not change in Group I, while it gradually decreased from resting to maximum contraction in Group II. The thickness of the internal oblique abdominal muscle significantly increased from resting to maximum contraction, and from 10 cmH_2O to maximum contraction in Group II. The result of Group II is consistent with previous results that the thickness of the internal oblique abdominal muscle increases by 10–20% in the performance of a hollowing exercise, but, that the thickness of the external oblique abdominal muscle increases only slightly or decreases[13]. In Group II, the result of the pelvic floor muscle exercise was similar to that of a hollowing exercise, indicating that vaginal pressure was increased when the internal abdominal muscle was used during the pelvic floor muscle contraction.

A morphometric study on the rhabdo-urethral muscle reported that the volume of the levator anti-muscle decreases with age[14]. A histological study found that as age increases, the transverse muscles decrease along the back of the urethra and the bladder neck[15]. Thus, we assume that the middle-aged women in this study increased vaginal contraction pressure by using their abdominal muscles rather than their attenuated pelvic floor muscles.

A comparison of the two age groups showed that the pelvic floor muscles were contracted without using the transversus abdominis muscle from resting to 30 cmH_2O in Group I, and from resting to 20 cmH_2O in Group II. The transversus abdominis muscle was used at a vaginal pressure that was 10 cmH_2O lower in Group II than in Group I, but the difference was not significant.

The childbirth delivery method was not considered in the categorization of subjects. In future studies, abdominal contraction during pelvic floor muscle contraction should be compared by considering how the childbirth delivery method affects pelvic floor muscle contraction, and studies should also be conducted with patients with pelvic floor muscle dysfunction.

Hung et al.[16] suggested the retraining of the combined functions of the diaphragm, deep muscle, and pelvic floor muscles as an alternative treatment for urinary incontinence. Bo et al.[17] also recommended the synergistic effects of the co-contraction of the pelvic floor muscles and transversus abdominis in the treatment of urinary incontinence. On the basis of our result, it may be necessary to develop an exercise program that maximizes the effect of the contraction of the abdominal muscle and pelvic floor muscle by appropriately controlling the strength of the pelvic floor muscle contraction.

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