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Original Article

The impact of the pelvic floor muscles on dynamic ventilation maneuvers

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Abstract. [Purpose] The aim of the present study was to examine the impact of the pelvic floor muscles (PFM) on dynamic ventilation maneuvers. [Subjects and Methods] The subjects were 19 healthy female adults in their 20s who consented to participate in the present study. Electromyography (EMG) was used to examine respiratory muscle activity, and a spirometer was used to examine vital capacity before and during contraction of the PFM. [Results] There were statistically significant differences in the sternocleidomastoid (SCM), rectus abdominis (RA), external oblique (EO), transverse abdominis/internal oblique (TrA/IO), and maximal voluntary ventilation (MVV) when the PFM was contracted. [Conclusion] Contraction of the PFM can be effective in promoting activation of the respiratory muscles and vital capacity. Therefore, the PFM should be considered to improve the effects of respiratory activity.
Key words: Pelvic floor muscles, Respiratory muscles, Maximal voluntary ventilation

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INTRODUCTION

Commonly, the muscles of the pelvic floor (PFM) support the abdomen and pelvic viscera. During periods of increased intra-abdominal pressure (IAP), such as coughing or breathing, the PFM are engaged to maintain the position of the bladder neck and assist with urethral and anal closure[1)]. Additionally, when IAP is increased, the PFM play a significant role in the maintenance of IAP. Furthermore, PFM activity may also indirectly contribute to breathing[2)]. Contractions of the PFM are always combined with activity of the abdominal muscles because the abdominal cavity acts like a “balloon”[3)]. Thus, the PFM work in synergy with the anterolateral abdominal muscles and diaphragm to modulate and respond to changes in IAP[4)]. Hodges et al.[5)] reported that when IAP is increased by talking, deep breathing, and coughing, pressure is distributed in all directions due to the organs and ascites in the abdominal cavity. Therefore, the PFM, diaphragm, and abdominal muscles contract together to protect the organs against the pressure and thus contribute to respiration. These muscles also act as one unit at the center of functional kinetic chains[6)]. Sapsford and Hodges[3)] confirmed that the increases in vaginal electromyography (EMG) and pressure during this strong abdominal maneuver were the same as the increases that occur during a maximal PFM contraction.

As a result, co-activation of the abdominal muscles and PFM is consistent with the pattern that they work together in a coordinated manner to increase pressure in the abdomen and support the pelvic organs. In addition, co-activation of these muscles has been reported during lifting, coughing, and forced expiratory efforts[3, 4)]. Therefore, contraction of the PFM modulates breathing and is involved in changes of IAP with the diaphragm[5)]. In other words, both the diaphragm and PFM move caudally during inspiration and cranially during expiration[7)], however, even though the PFM are related to breathing, most studies of the PFM have investigated urinary system diseases, and there is a lack of studies regarding the PFM and the respiratory system. The present study therefore attempted to identify the effect of respiratory muscle activity and maximal voluntary ventilation (MVV) on the contraction of the PFM.

SUBJECTS AND METHODS

The subjects were 19 female adults in their 20s who consented to participate in the present study. They were provided with detailed instructions about the purpose and method of the present study, and written informed consent was received from each participant. The characteristics of the subjects were as follows: age, 23.3 ± 0.9 years; height, 163.6 ± 4.8 cm; weight, 55.1 ± 5.4 kg. Subjects were excluded if they had a history of major abdominal or pelvic surgery, any neurological or respiratory condition, smoking, and low

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Table 1. The changes in respiratory muscles activity and vital capacity between before contraction and during contraction of the PFM during MVV (N=19)

Variables		Before contraction	During contraction
Muscle activity of MVV (%RVC)	SCM	741.1±259.9[a]	1,084.4±397.8*
	RA	285.8±96.8	354.2±193.0*
	EO	458.5±94.0	675.3±199.4*
	TrA/IO	559.1±353.0	682.9±554.8*
MVV (l/min)		101.3±20.2	110.4±21.3*

[a]Mean±SD *p<0.05
SCM: sternocleidomastoid, RA: rectus abdominis, EO: external abdominal oblique, TrA/IO: transverse abdominis/internal abdominal oblique, MVV: maximum voluntary ventilation

back pain. The present study was approved by the Daegu University Institutional Review Board and in accordance with the ethical principles of the Declaration of Helsinki.

All the experiments were conducted under 2 conditions during randomized trials: before and during contraction of the PFM during MVV. The average of three measurements was used to avoid biased results. A 5 minute rest was given after each trial to prevent muscle fatigue. In the present study, a spirometer (Spiropalm, A-M Systems, USA) was used to examine vital capacity. The subjects were asked to sit comfortably on a chair and place their hands on their shoulders to reduce compensation by the trunk. A clip was placed on the bridge of the nose to prevent breathing through the nose. The subjects were then asked to breathe out through their mouth carefully while holding a mouthpiece to prevent air from leaking. For the MVV measurement, the subjects were asked to breathe as quickly and deeply as possible at a ratio of 90–110 times/min for 12 seconds.

An EMG (Telemyo DTS, Noraxon, USA) was used to measure the activities of the respiratory muscles during MVV. The EMG data were band-pass filtered between 20 Hz and 400 Hz. The notch filter was set at 60 Hz. The sampling rate for the signals was set to 1,000 Hz. The collected data were analyzed after calculating the root mean square (RMS) values. The reference voluntary contraction (RVC) was used for the standardization of the EMG. The muscle contraction of a specific movement was standardized relative to the RVC. The baseline EMG activity was recorded for 3 seconds in a sitting position before the performance of the PFM activity. The EMG data for the MVV were recorded for 12 seconds. To reduce skin resistance, excessive hair was removed from the skin, the corneum was removed by rubbing the skin with a piece of sandpaper, and the skin was cleaned with disinfectant alcohol. Surface EMG electrodes were placed on the right side of the abdomen. The transverse abdominis/internal abdominal oblique (TrA/IO) electrode was placed 2 cm medial and superior to the anterior superior iliac spine; the external abdominal oblique (EO) electrode was positioned halfway between the iliac crest and the rib cage in the midaxillary line; the rectus abdominis (RA) electrode was situated 2 cm lateral to the midline at the level of the anterior superior iliac spine[8]; and the sternocleidomastoid (SCM) electrode was put over the muscle's belly[9]. All the participants listened to an explanation of the PFM activity method before the measurement was performed. Instructions for the PFM activity method were as follows: 1. Empty the bladder before performing the exercises; 2. Wear comfortable clothing; 3. Take a deep breath first and focus on relaxing the body and concentrate on the muscles in the vagina-anus area; 4. Contract the muscles around the vagina-anus as if you are trying to prevent yourself from urinating or breaking wind and pull the muscles inward (consisted of 6–8 seconds of contraction with 6 seconds rest in between); 5. Do not hold your breath during the contractions, do not contract your buttocks or abdominal muscles[10].

Wilcoxon's signed rank test was used to compare the contraction of the PFM and respiratory muscle activity or vital capacity. SPSS WIN (ver. 21.0) was used for statistical analysis with a significance level of p=0.05.

RESULTS

There were statistically significant differences during contraction of the PFM both respiratory muscles activity and vital capacity. Activation of the SCM, RA, EO and TrA/IO significantly increased during contraction of the PFM ($p<0.05$), and MVV significantly increased during contraction of the PFM ($p<0.05$) (Table 1).

DISCUSSION

Postural control and respiration use similar muscles. The diaphragm, the principal muscle of respiration, has been reported to act as one of the spinal stability muscles, and the IO, EO, and PFM are also activated to increase respiratory capacity with the diaphragm. The spinal stability provided by these muscles is generated from their co-contraction, which increases IAP; these muscles also function as respiratory muscles by increasing their activities when respiratory demand increases[11]. The present study examined the effect of contraction of the PFM (act as respiratory muscles or stabilize the trunk) on respiratory muscle activity and vital capacity. A significant increase in muscle activity in RA, EO, TrA/IO (expiration muscles) and in SCM (an accessory muscle for inspiration) was seen during contraction of the PFM. Muscle recruitment was increased in SCM and TrA/IO. A previous study by Sapsford[4] suggested that voluntary contraction of the PFM increases IAP and brings about contraction of IO, resulting in stability of the spine and an increase in expiration. In addition, a study of the thickness of the abdominal muscles through precise contraction of the PFM confirmed that PFM` contraction increased the thickness of TrA and IO[12]. Some studies have observed that contraction of the PFM prompts activation of the TrA and IO[13], and that the SCM is progressively activated during incremental static and dynamic maneuvers to maximal ventilation in healthy adults. Thus, the SCM is an important accessory muscle of inspiration and becomes active during ventilation at high lung volumes and elevated levels of inspiration tasks[14]. Consequently, the activity of these muscles increases during forced expiration tasks. Therefore, the present study confirmed that contraction of the PFM in breathing causes cooperative contraction of the surrounding abdominal muscles and the accessory muscle of inspiration. Thus, an effect was expected on vital capacity due to the increase in IAP.

The present study identified a significant increase in MVV measured during contraction of the PFM. MVV is an important indicator in evaluating motor capacity and it depends on vital capacity (maximum breathing capacity of the lung at a given time) and the speed at which that amount of air is inhaled and exhaled. It also depends on the elasticity of the lung, thorax and on the strength of the breathing muscle and resistance of the airway and thorax[15]. Contraction of the PFM resulted in an increase in MVV, suggesting that contraction of the PFM is very important in maintaining dynamic breathing capacity during exercise; that is, contraction of the PFM resulted in an increase in muscle recruitment of the respiratory muscles and diaphragm[4], thereby affecting the strength of the breathing muscles and increasing the speed at which air is inhaled and exhaled. This brings about an increase in MVV, which requires constant activity of the breathing muscles. Therefore, contraction of the PFM helps postural stability of the lumbopelvic region as well as ventilation[16]. Consequently, It is necessary to breathe make advantage of contraction for the PFM. However, vital capacity and respiratory muscles activity were only observed during a temporary contraction of the PFM, so the correlation between PFM strengthening exercise and respiratory muscles and vital capacity remains undefined. Therefore, invigoration of breathing exercise programs using PFM is necessary and further studies are required on activity of respiratory muscles and vital capacity through the PFM strengthening exercise.

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