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The Effects of Deep Abdominal Muscle Strengthening Exercises on Respiratory Function and Lumbar Stability

Eunyoung Kim, PhD, PT[1)], Hanyong Lee, PhD[2)*]

[1)] *Department of Physical Therapy, Gumi College*
[2)] *Department of Health and Fitness Management, Namseoul University: 21 Maeju-ri, Sunghwan-up, Chunan, Chungnam 330-707, Korea. TEL: +82 41-580-2040, FAX: +82 41-580-2912*

Abstract. [Purpose] The purpose of this study was to examine the effects of deep abdominal muscle strengthening exercises on respiratory function and lumbar stability. [Subjects] From among 120 male and female students, 22 whose thoraxes opened no more than 5 cm during inspiration and expiration and whose forced expiratory flow rates were around 300 m/L were recruited. The subjects were randomly divided into an experimental group of eleven, who performed deep abdominal muscle strengthening exercises, and a control group of eleven, who received no particular intervention. [Methods] The subjects were instructed to perform normal breathing in the hook-lying position. They were then directed to hold their breath for ten seconds at the end of inspiration. Ten repetitions of this breathing comprised a set of respiratory training, and a total of five sets were performed by the subjects. [Results] Deep abdominal muscle training was effective at enhancing respiratory function and lumbar stabilization. [Conclusion] The clinical application of deep abdominal muscle strengthening exercises along with lumbar stabilization exercises should be effective for lower back pain patients in need of lumbar stabilization.
Key words: Respiratory function, Lumbar stability, Vital capacity

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INTRODUCTION

The lungs cannot contract by themselves during respiration. Instead, they passively contract and relax as a result of the contraction and relaxation of the thoracic cage respiratory muscles, leading to gas exchange between the air and the lungs[1)]. While relaxed expiration is performed by the passive recoil of the diaphragm, during forced expiration, the air is driven out as the diaphragm is forced upwards by a rise in intra-abdominal pressure induced by contraction of the abdominal muscles[2)]. Moreover, the diaphragm, a component of core stability, plays a role in respiration and trunk stability by controlling intra-abdominal pressure and reducing the stress on the spine through cooperative action with the abdominal and pelvic floor muscles[3, 4)]. The diaphragm is composed of the muscles and tendons that separate the chest from the abdominal cavity, and forms the floor of the thoracic cavity. Beginning from the thoracic outlet, it is divided into three parts—sternal, costal, and lumbar. The costal part of the diaphragm connects with the origin of the transversus abdominis in the shape of a finger on the insides of the costal cartilages on both sides of the last six ribs[5)]. The transversus abdominis is the diaphragm's partner, and its upper part is connected to the inner part of the lower thoracic cage. Moreover, its back is linked to the lumbar vertebra by discs comprised of fibers, while its lower part is joined to the iliac crest and the inguinal ligament in the arched femoral region[6)]. It has been reported that during lumbo-pelvic motion control tests, diaphragmatic activity increases in healthy subjects[7)] and decreases in patients with diaphragmatic injuries[8)]. Moreover, patients with chronic lower back pain have often been reported to have defects in posture and motor control[9, 10)]. Considering the anatomical structure of the diaphragm and the transversus abdominis, we consider that decreased contractility of the diaphragm, which may be caused by diaphragmatic injuries, would lead to a decrease in transversus abdominis activity and lumbar stability.

This study aimed to determine the effects of enhanced diaphragmatic function achieved through deep abdominal muscle strengthening exercises on respiratory function and lumbar stability.

SUBJECTS AND METHODS

For this study, 22 subjects whose thoraxes opened no more than 5 cm during inspiration and expiration and whose forced expiratory flow rates were around 300 m/L were recruited from among 120 male and female students. The subjects were randomly divided into an experimental group of eleven (five males and six females), who engaged in deep abdominal muscle strengthening exercises, and a control group of eleven (four males and seven females), who experienced no particular intervention. Those with muscular, skeletal, or nervous problems, patients with lung

*To whom correspondence should be addressed.
E-mail: lhyong@nsu.ac.kr

diseases or lower back pain, and smokers were excluded. The selected subjects were provided with detailed explanation about the intent and content of this study and signed a voluntary consent form. The mean age, height, and weight of the subjects were 22.55±5.75 years, 166.27±8.65 cm, and 62.64±13.60 kg, respectively, for the experimental group, and 20.82±1.78 years, 159.18±4.7 cm, and 52.18±3.97 kg, respectively, for the control group. The gender of the subjects was analyzed using a χ^2 test, while the age, height, and weight were analyzed using the independent t-tests. There were no statistically significant differences detected in the two analyses ($p>0.05$), which indicates the two groups were homogneous.

The deep abdominal strengthening training method suggested by Richardson et al.[11] was modified and performed by the experimental group. The thoracic and abdominal motion during respiration in the hook-lying position was observed while the subjects engaged in natural breathing, namely deep breathing. By touching the ribs on both sides with the hands, increases in the transverse diameter and the diameter of the thoracic cavity and its frontal opening during inspiration were demonstrated. Normal respiration in a reverse pattern during expiration was also confirmed. The subjects were instructed to hold their breath for ten seconds at the end of inspiration. Ten repetitions of this breathing comprised one set of respiratory training, and a total of five sets were performed by the subjects. A one-minute break was given after each set, and the training was conducted once a day three times a week, for four weeks. A Cardio Touch 3000S (BIONET) was used to measure two pulmonary function indices, FVC (forced vital capacity) and FEV1 (forced expiratory volume for 1 second), of the subjects. The measured values were recorded only when both measurements were obtained without any error. Moreover, three values were recorded, and the average value was used in the analyses. Lumbar stability was measured based on the contractility of the transversus abdominis by using a PBU (pressure biofeedback unit). For this measurement, the subjects were instructed to practice their normal breathing patterns in the hook-lying position. While doing this, the hollowing training method was performed using the transversus abdominis. Then, the subjects were directed to maintain spinal stabilization in the neutral position, and the PBU was placed on the lower back at the level of PSIS. With a basic pressure of 40 mmHg, the changes were measured while the transversus abdominis was contracted during normal inspiration and expiration.

During the measurement, a physical therapist with more than ten years of clinical experience palpated the point 5 cm inside the anterior superior iliac spine of the subjects to evaluate the contraction of the transversus abdominis, thereby controlling the compensation caused by the contraction of the rectus abdominal muscles and the external oblique abdominal muscles, and inducing that of the transversus abdominis as far as possible. Increased pressure during the test indicateed improvement in the contractility of the transversus abdominis, suggesting enhanced stabilization.

Differences in the measured data were tested with the paired t-tests were conducted using SPSS 12.0 for Windows in order to compare the differences within each group before and after the intervention. The differences between the two groups were tested using the independent t-test. The statistical significance level, α, was chosen as 0.05.

RESULTS

In the comparison of FVC and FEV1 before and after the training, the experimental group showed significant increases in both FVC and FEV1. Furthermore, the comparison of the contractility of the transversus abdominis before and after the training revealed that the experimental group displayed significant changes in the contractility of

Table 1. Comparison of FVC, FEV1, PBU between pre-test and post-test in each group (Mean±SD)

	Category	experimental group	control
FVC(ℓ)	Pre-test	2.72±0.95	1.83±0.74
	Post-test	2.90±0.97*	1.86±0.53
FEV1(ℓ)	Pre-test	2.42±0.61	1.81±0.70
	Post-test	2.56±0.70*	1.85±0.53
PBU (mmHg)	Pre-test	41.18±1.32	41.64±1.29
	Post-test	44.09±3.08*	41.27±0.90

* $p<0.05$; FVC, Forced vital capacity; FEV1, Forced expiratory volume in 1 second; PBU, Pressure biofeedback unit

Table 2. Comparison of FVC, FEV1, PBU between the experimental group and the control group (Mean±SD)

	Category	experimental group	control
FVC(ℓ)	Pre-test	2.72±0.95	1.83±0.74
	Post-test*	2.90±0.97	1.86±0.53
	difference between pre- and post-test*	0.18±0.72	0.03±0.39
FEV1(ℓ)	Pre-test	2.42±0.61	1.81±0.70
	Post-test*	2.56±0.70	1.85±0.53
	difference between pre- and post-test*	0.15±0.91	0.04±0.38
PBU (mmHg)	Pre-test	41.18±1.32	41.64±1.29
	Post-test*	44.09±3.08	41.27±0.90
	difference between pre- and post-test*	2.90±2.55	0.36±0.81

* $p<0.05$

the transversus abdominis (Table 1). The independent t-tests was carried out to examine differences in FVC, FEV1, and the contractility of the transversus abdominis in the two groups before and after the training and the before-and-after changes. The results showed that the values before the training were not statistically significant, while the experimental group exhibited significant before-and-after changes (Table 2).

DISCUSSION

The diaphragm, the main muscle of inspiration, is involved in trunk stability and posture control[12], and the transversus abdominis engages in posture and motor control and respiration[13]. Among studies on respiratory muscle training, Hall et al.[14] suggested a respiratory muscle training method, while Richardson et al.[11] examined a deep abdominal muscle training method, and Roussel et al.[15] looked into the changes in breathing patterns experienced by chronic lower back pain patients.

Lumbar instability is a major cause of lower back pain[9], and spinal stability is crucial for the prevention of lumbar injuries[16]. Akuthota and Nadler[17] described the core muscles that stabilize the trunk and the spine regardless of the movements of the extremities as being the diaphragm, the multifidus muscle, the transverse muscle of abdomen, and the pelvic floor muscle, and also stated that these muscles act as one unit at the center of functional kinetic chains. In other words, spinal stability is achieved by the co-contraction of the trunk muscles, and such contraction is necessary in order to maintain a proper level of spinal stability to prevent and treat lower back pain[18]. Michael et al.[19] noted that the co-contraction of the abdominal muscles and the diaphragm increases intra-abdominal pressure, fixes the trunk, and reduces the stress on the spine, especially the lumbar region. It automatically happens when a subject lifts a heavy object, decreasing the load by about 50% in the high lumbar region, and about 30% in the low lumbar region. It also reduces the load experienced by the back muscles by more than 50%. These results suggest that well-built abdominal muscles may be important for the prevention and treatment of spinal diseases.

The results of the present study indicate that the deep abdominal muscle strengthening exercise was effective at increasing vital capacity. The contractility of the diaphragm and the transversus abdominis in particular influences the partial stabilization of the lumbar spine and functions as a type of regulatory mechanism, causing changes in breathing patterns.

To conclude, enhanced diaphragmatic function achieved via deep abdominal muscle strengthening exercises not only increased respiratory volume but also played a role in stabilizing the lumbar spine through the co-contraction of the transversus abdominis. Thus, this method can be reduce lower back pain and enhance respiration and trunk stability when lumbar stabilization exercises are clinically administered for patients with a low level of stability. Furthermore, this method needs to be compared with other methods in future studies.

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