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Comparison of the Effects of Abdominal Bracing Exercises and Abdominal Hollowing Exercises on Lumbar Flexibility and Pulmonary Function in Healthy Adults

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Abstract

Background: Abdominal bracing exercise (ABE) and abdominal hollowing exercise (AHE) improve the lumbar flexibility and pulmonary function in various patients, yet the efficacy of ABE or AHE have not yet been evaluated.

Objects: The purpose of this study was to compare the lumbar flexibility and pulmonary function during both ABE and AHE in healthy adults.

Methods: The study included 40 healthy adults, who were randomly divided into the experimental group and control group, each with 20 subjects. All subjects performed ABE (experimental group) and AHE (control group). The lumbar flexibility such as trunk flexion test (sitting and standing position) and schober test and pulmonary function such as the spirometer including forced vital capacity (FVC) and force expiratory volume in one second (FEV_1) and chest circumference measurement (middle and lower chest) were measured, respectively. Two-way repeated analysis of variance was used to compare the lumbar flexibility and pulmonary function, respectively.

Results: No significant effects of lumbar flexibility were observed on trunk flexion test from the sitting position (P=.478) and standing position (P=.096) in the ABE than in the AHE. However, the length of ABE was longer significantly than it of AHE (P=.024). No significant effects of lung function were observed on the FVC (P=.410) and FEV_1 (P=.072) in the ABE group than in the AHE group. And also, no significant effects of chest circumference measurement were observed on the inspiration (P=.468) and expiration (P=.563) in middle chest circumference and inspiration (P=.104) and expiration (P=.346) in lower chest circumference.

Conclusion: This study indicated that the ABE is only more effective in lumbar flexibility by lumbar length difference than AHE in healthy adults.

Key Words: Abdominal bracing; Abdominal hollowing; Lumbar flexibility; Pulmonary function.

Introduction

Abdominal bracing exercises (ABE) and abdominal hollowing exercises (AHE) are typical methods of neuromuscular rehabilitation for lumbar stabilization in clinical practice. Both methods have been used to activate the deep and surface muscles of spine-related structures, but their differences are not well understood. Lee and Kim (2015) reported that ABE were more effective than AHE at strengthening and improving the function of the deep muscles of patients with low back pain. Jang (2016) reported that AHE were more effective than ABE on respiratory function in healthy adults in their 20s. In addition, Kim (2015) observed that AHE were more effective at improving trunk muscle strength and static balance ability in older patients with nonspecific chronic low back pain.

ABE stabilize the body by strengthening the spinal joint through the raising of abdominal pressure and

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coordination of both the deep and superficial muscles (McGill, 2001), giving them the advantage of simultaneously shrinking both slow twitch fiber and fast twitch fiber muscles (Kim, 2015). This technique makes the abdominal muscle tight by reflexively pushing the whole abdominal muscle when someone tries to hit the abdomen. It tightens and fixes the lumbar joint and thoracolumbar fascia by increasing abdominal pressure and the stability of the lumbo-pelvis (McGill, 2001).

AHE are frequently used to improve the stability of the lumbar spine through neuromuscular re-education of the transverse abdominalis and internal oblique muscles (Macedo et al, 2009). These exercises involve selectively contracting muscles made of slow twitch fibers (Kisner and Colby, 2002). They are also effective at stabilizing the transverse abdominalis and multifidus muscles (Kisner and Colby, 2002). This method increases intra-abdominal pressure by pulling the abdomen inward, without any movement of the spine, and reducing lumbar lordosis (Hodges and Richardson, 1999; Kisner and Colby, 2002).

Slow twitch fibers organize primarily the local muscle system of the deep muscle layer. These muscles are shorter in length and are appropriate for controlling intersegmental motion and responding to alteration in posture and external loads. Key local muscles are included in transverse abdominalis, multifidus, internal oblique, deep transversospinalis, and the pelvic floor muscles (Hodges and Richardson, 1999; Kisner and Colby, 2002). On the other hand, fast twitch fibers comprise the global muscle system of the superficial muscle layer. These muscles are long and have large lever arms, allowing them to produce plenty of torque and gross movements. Key global muscles are included in rectus abdominis, external oblique, erector spinalis, and quadratus lumborum (Hodges and Richardson, 1999; McGill, 2001).

Spinal stabilization exercises such as ABE and AHE have been reported to be closely related to thoracolumbar flexibility as well as stability of the trunk (Hodges and Richardson, 1999). Kibler et al (2006) reported a high correlation between the stability and flexibility of the lumbar spine, particularly, emphasized the importance of lumbar flexibility. Hodges et al (2007) reported that the non-contraction force between the transverse abdominalis and multifidus muscles may result in lumbar instability associated with pain. Bø et al (2009) reported that there is a strong correlation between lumbar flexibility and back pain. Although the ABE and AHE are positive for the stability and flexibility of the spine, the study of the differences between the two exercises is not sufficient.

The movement involved with respiration improves exercise performance related to respiration by normalizing the diaphragm and increasing the movement of the chest wall (Troosters et al, 2005). The respiratory muscles are divided into the inspiratory muscle group, including the diaphragm and the outer intercostalis, and the expiratory muscle group, including the rectus abdominalis, transverse abdominalis, and inner intercostalis. These respiratory muscles can enhance pulmonary function by causing contraction and expansion of the lungs through strong contractile forces during deep breathing (Kilding et al, 2010; Klimathianaki et al, 2011). Therefore, deep breathing should be preceded for training the respiratory muscles (Troosters et al, 2005). Pulmonary function tests are the most commonly used method of respiratory movement (Choi et al, 2016). Representative indices of the pulmonary function test are forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1).

Although ABE and AHE studies have reported improvement in respiratory muscle function and pain control in various subjects, there are few studies related to problems with flexibility of the lumbar spine and pulmonary function are very limited, particularly, comparative studies both ABE and AHE are still lacking. In addition, the comparison of the two exercise methods is important because the two exercise methods are often used and similar in clinical practice. Therefore, this study aims to compare the effects of ABE and AHE on the flexibility of the lumbar spine

Table 1. General characteristics of subjects (N=40)

	ABE[a] group (n_1=20)	AHE[b] group (n_2=20)	t	p (two-tailed)
Gender (male/female)	4/16	5/15		
Age (year)	21.0±1.8[c]	20.3±.9	.530	.132
Height (㎝)	164.5±8.4	164.7±8.9	-.030	.971
Weight (㎏)	57.4±10.0	60.4±11.2	-.900	.362

[a]abdominal bracing exercise, [b]abdominal hollowing exercise, [c]mean±standard deviations.

and pulmonary function in healthy adults.

Methods

Subjects

This study was based on a two-group pre-test/posttest design. Forty healthy adults were randomly assigned to the experimental group, comprising 20 subjects who were prescribed ABE, or the control group, consisting of 20 subjects who were prescribed AHE. All the procedures were explained to the subjects, and each subject signed an informed consent form. The university Institutional Review Board approved this research (approval number: 2017-035). The criteria for selection were 1) no history of respiration or circulation problems, 2) no abnormal breathing capacity, 3) no hypertension, 4) no heart disease, including arrhythmia, 5) no history of cardiovascular or cardiopulmonary disease, and 5) no orthopedic disease. Table 1 shows the general characteristics of the study subjects. All subjects underwent spinal flexibility tests, including the trunk flexion test and Schober test, and pulmonary function tests, including the pulmonary capacity test and chest circumference test, both before and after the intervention.

Interventions

Abdominal bracing exercise (ABE)

Subjects were trained for 30 minutes on how to perform ABE. The legs were placed in the neutral-spine position, with the feet shoulder-width apart, 45° in the hip joint and 90° in the knee joint, in supine hook-lying position (Park et al, 2010). Subjects were instructed to maximally activate the abdominals without hollowing the lower abdomen. ABE consists of simply tensing (contracting) the abdomen as if the subject is about to be hit in the stomach. The abdomen will automatically pull the stomach in slightly, but the exercise does not involve pulling in or pushing out the abdomen. ABE activate all layers of the abdominal muscles along with the deep muscles in the low back. The pressure biofeedback unit (PBU) was located under the lumbar spine area was set 70 ㎜Hg (Hodges and Richardson, 1999) (Figure 1).

Abdominal hollowing exercise (AHE)

Subjects were trained for 30 minutes on how to perform AHE. The legs were widened to shoulder width, 45° in the hip joint and 90° in the knee joint, in supine hook-lying position (Park et al, 2010). Subjects were instructed to draw the navel in maximally, in the lower area of the stomach, toward the spine. This activates the deep abdominal muscles but requires very little activation of the superficial abdominal muscles. In order to maintain the neutral curvature of the lumbar spine, the subjects were instructed to pull the navel upward and backward so that the lower abdomen could enter, and the PBU was placed under the lumbar vertebra was increased from 10 ㎜Hg to 60 ㎜Hg (Critchiey, 2002; Hodges and Richardson, 1999) (Figure 2).

Instruments

Lumbar flexibility test

This test measured the range of motion of trunk flexion in both the sitting and standing positions. In the standing position, the subject was placed on a

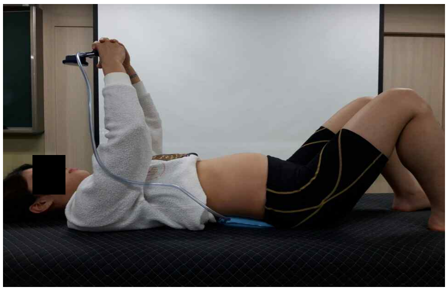

Figure 1. Abdominal bracing exercise.

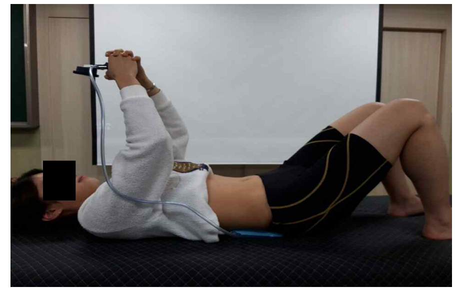

Figure 2. Abdominal hollowing exercise.

stepbox measuring 35 ㎝ in height to allow the spine to bend forward as far as possible. In the sitting position, attach a pair of feet to the test plate and bend the trunk as far as possible with the knee extended. The distance between the foot and the middle finger was measured three times before and after the intervention. This test has a high reliability of .97.

Schober test

The Schober test was performed to measure the range of motion of the lumbar spine. The subject's fifth lumbar vertebra was marked with a black pen in the standing position, and then marked upwards 10 ㎝. The distance between two points was measured when the subject's trunk was flexed as far as possible in the standing posture. The greater the difference in length between the points, the higher the flexibility (Consmüller et al, 2012).

Pulmonary capacity test

A spirometer (Spirobank G, Medical International Research, Rome, Italy) and software system (Winspiro PRO, Medical International Research, Rome, Italy) were used for the pulmonary capacity test. The subjects were asked to measure FVC and FEV_1 three successive times, with the knee and hip joints flexed 90° in a sitting position. Only the maximum value was used (Engel et al, 2007).

Chest circumference length test

Chest circumference was measured to evaluate the movement of the chest during inspiration and expiration, respectively. The middle and lower circumferential lengths of the chest were measured with a tape measure, with the subject in a sitting position. The middle thoracic circumference length was measured in parallel by connecting the tenth thoracic spinous process and the xiphoid process (Bockenhauer et al, 2007), and the lower thoracic circumference length was measured by connecting the center line of both axes and the intersection of the twelfth ribs (Shim et al, 2002). The middle and lower chest circumference length was measured three times, and the mean value was used.

Statistical analysis

The data were analyzed using SPSS version 18.0 (SPSS Inc., Chicago, IL., USA). All variables were tested using the Kolmogorov-Smirnov test, which showed a normal distribution of the data. An independent t-test was used to determine significant differences in the general characteristics of the subjects between the two groups. Two-way analysis of variance with repeated measures was used to assess the main effects (group and time effects) and interaction effects of lumbar flexibility, the Schober and pulmonary capacity tests, and chest circumference in the two groups. The significance level was set at p-value of $<.05$.

Results

Lumbar flexibility

No significant main effect ($F=2.323$, $p=.136$) or interaction effect ($F=.514$, $p=.478$) was found for the trunk flexion test in the sitting position between the groups.

Table 2. Comparison of trunk flexion test

		ABE[a] (n_1=20)	AHE[b] (n_2=20)	Group effect		Time effect		Interaction effect	
				F(1,38)	p	F(1,38)	p	F(1,38)	p
Sitting	pre	8.40±10.01[c]	12.67±7.44	2.323	.136	35.891	.001	.514	.478
	post	11.81±8.57	15.36±6.65						
Standing	pre	5.52±10.72	10.92±7.77	2.703	.108	47.217	.001	2.918	.096
	post	9.43±9.28	13.27±7.97						

[a]abdominal bracing exercise, [b]abdominal hollowing exercise, [c]mean±standard deviations.

Table 3. Comparisons of Schober test

	ABE[a] (n_1=20)	AHE[b] (n_2=20)	Group effect		Time effect		Interaction effect	
			F(1,38)	p	F(1,38)	p	F(1,38)	p
Pre	13.72±1.33[c]	14.60±0.95	4.279	.045	53.073	.001	5.504	.024
Post	14.70±0.87	15.10±0.88						

[a]abdominal bracing exercise, [b]abdominal hollowing exercise, [c]mean±standard deviations.

Table 4. Comparison of pulmonary capacity test

		ABE[a] (n_1=20)	AHE[b] (n_2=20)	Group effect		Time effect		Interaction effect	
				F(1,38)	p	F(1,38)	p	F(1,38)	p
FVC[c]	pre	3.27±.88[d]	3.34±1.26	.227	.636	3.163	.083	.694	.410
	post	3.38±1.01	3.65±1.50						
FEV_1[e]	pre	1.36±.65	2.82±3.90	2.121	.154	5.558	.024	3.419	.072
	post	1.76±.78	2.86±3.88						

[a]abdominal bracing exercise, [b]abdominal hollowing exercise, [c]forced expiratory vital capacity, [d]mean±standard deviation, [e]forced expiratory volume in one second.

However, a significant time main effect (F=35.891, p=.001) was found for the trunk flexion test in the sitting position (Table 2). There was no significant group main effect (F=2.703, p=.108) or interaction effect (F=2.918, p=.096) for the trunk flexion test in the standing position. On the other hand, there was a significant time main effect (F=47.217, p=.001) for the trunk flexion test in the standing position (Table 2).

There was a significant group main effect (F=4.279, p=.045), time main effect (F=35.891, p=.001), and interaction effect (F=5.504, p=.024) for the Schober test (Table 3).

Pulmonary function

No significant group main effect (F=.227, p=.636), time main effect (F=3.163, p=.083), or interaction effect (F=.694, p=.410) was found for the FVC in the pulmonary capacity test (Table 4), nor was any significant group main effect (F=2.121, p=.154) or interaction effect (F=3.419, p=.072) found for the FVC_1 in the pulmonary capacity test. However, a significant time main effect (F=5.558, p=.042) was found for the FVC_1 in the pulmonary capacity test (Table 4).

No significant group main effect (F=.785, p=.381), time main effect (F=.677, p=.416), or interaction effect (F=.538, p=.468) was found in the chest circumference length test of the inspiration of the middle chest (Table 5), nor was any significant group main effect (F=1.788, p=.189) or interaction effect (F=.340, p=.563) found in the chest circumference length test of the expiration of the middle chest. However, a significant time main effect (F=8.802, p=.005) was found with respect to the chest circumference length test of the expiration of the middle chest (Table 5). No sig-

Table 5. Comparison of chest circumference length test

			ABE[a] (n_1=20)	AHE[b] (n_2=20)	Group effect		Time effect		Interaction effect	
					F	p	F	p	F	p
Middle chest	inspiration	pre	79.60±7.02[c]	81.04±12.37	.785	.381	.677	.416	.538	.468
		post	79.71±6.90	82.87±8.68						
	expiration	pre	75.70±6.43	78.86±9.61	1.788	.189	8.802	.005	.340	.563
		post	74.30±6.68	77.92±9.24						
Lower chest	inspiration	pre	75.46±6.26	78.88±8.99	1.554	.220	1.462	.234	2.776	.104
		post	76.22±6.04	78.76±8.65						
	expiration	pre	70.01±16.52	76.26±9.77	2.299	.138	.013	.907	.909	.346
		post	71.66±6.27	74.97±9.22						

[a]abdominal bracing exercise, [b]abdominal hollowing exercise, [c]mean±standard deviation.

nificant group main effect (F=1.554, p=.220), time main effect (F=1.462, p=.234), or interaction effect (F=2.776, p=.104) was found with respect to the chest circumference length test of the inspiration of the lower chest (Table 5). Finally, no significant group main effect (F=2.299, p=.138), time main effect (F=.013, p=.907), or interaction effect (F=.346, p=.909) was found with respect to the chest circumference length test of the expiration of the lower chest (Table 5).

Discussion

The purpose of this study was to compare the effects of ABE and AHE on lumbar flexibility and pulmonary function using quantitative assessment tools. The results demonstrate that ABE were more effective than AHE in terms of the comparison of lumbar flexibility through the Schober test method, but no difference was detected between the two exercise groups in terms of lumbar flexibility by the trunk flexion test, the pulmonary function test using a spirometer, or the chest circumference test. The data, therefore, show that ABE are significantly more effective at improving lumbar flexibility as measured by the Schober test. Intervention-related changes in altered lumbar flexibility and pulmonary function were successfully quantified by tape measure and spirometer.

Differences in lumbar flexibility measurements in the standing and sitting positions were not statistically significant, but the Schober test in the standing position showed that ABE increased flexibility by 1.0 ㎝ (from 13.7 ㎝ to 14.7 ㎝) and AHE by .5 ㎝ (from 14.6 ㎝ to 15.1 ㎝), indicating that ABE were more effective. These results suggest that of the ABE is more trunk bended by increasing the expansion of the abdominal muscles, which are the primary muscles involved in trunk flexion. Above all, the reason for the significant results in Schober test only is because the ABE and AHE methods are centered on the abdomen and lumbar spine, and also, it is measured more intensely of the lumbar spine area than lumbar flexibility test, which measures the overall flexibility of the spine.

McGill (2001) reported that lumbar flexibility was increased because ABE improved intra-abdominal pressure and pelvic floor muscle strength through the coordinated contraction of the deep and surface muscles of the trunk. On the other hand, McGill and Karpowicz (2009) observed that selective strengthening exercises such as AHE could reduce the stability of the lumbar spine. For their part, Koumantakis et al (2005) emphasized the balance and strength of the overall abdominal muscle because the selective activation of the transverse abdominal muscle may reduce the efficiency of trunk stability and flexibility. Further, Bø et al (2009) suggested that ABE are more effective at lumbar stabilization because they improve intra-abdominal pressure in conjunction with the internal oblique and pelvic floor muscles as well as the transverse abdominal and multifidus muscles. Therefore, it appears that, in this study, ABE increased lumbar flexibility better than AHE by improving the mutual contractility of the deep muscles, such as the transverse abdominalis and multifidus.

No statistically significant difference was found between the two groups in terms of the FVC and FEV_1 pulmonary function measurements, but there was a significant difference in the time effects of FVC and FEV_1. FVC and FEV_1 are representative measures of pulmonary function, with the rectus abdominal and external oblique muscles working together with the prime muscle at the time of exhalation, together with the transverse abdominal muscle enhanced by the lumbar stabilization effect (Choi et al, 2016; Klimathianaki et al, 2011). FVC is the volume of air that is measured when a breath is exhaled as quickly as possible, and FEV_1 is the maximum amount of air expired per second. In related fashion, Koopers et al (2006) reported that breathing intensification training was positive for improving endurance and quality of life, while McConnell and Romer (2004) reported that aerobic capacity training using feedback breathing equipment aids lung function in healthy adults. In the present study, no significant difference between the two exercise groups was found. However, in spite of the short intervention period, each exercise type tended to be positively related to pulmonary function through the increase of FEV_1.

No statistically significant difference was found in the middle and lower thoracic circumference lengths of the two exercise groups, but there was a significant difference in the time main effect of the measurement of the middle thoracic circumference length. It is possible that ABE may affect the middle thoracic circumference length more than AHE due to the increase of abdominal contractibility. This measurement of chest circumference can be easily used by quantifying the changes in the pulmonary function measurements FVC and FEV_1 in the clinical field. This result is supported by Fregonezi et al (2005), who reported that diaphragm respiratory movement increased the mobilization of the thoracic vertebrae and lung volume in patients with myasthenia gravis. Likewise, Troosters et al (2005) suggested that trunk stabilization exercises through abdominal deep breathing may improve the overall volume of pulmonary function related to the chest muscles.

In this study, it was found that ABE, through the lumbar stabilization associated with neuromuscular control, was partially beneficial to lumbar flexibility and pulmonary function more than AHE. In a clinical setting, it has been reported that there is a practical difficulty involved with AHE selectively enhancing the transverse abdominalis muscle in patients with low back pain (Kahlaee et al, 2017). To compensate for this problem, a method has been introduced to improve the operability of the diaphragm (Park et al, 2010). However, this study has the following limitations. First, we measured the initial effect as a short-term comparative study. Second, the experiment included only healthy adults. Third, only partial effects of lumbar flexibility and pulmonary function were measured. Therefore, in future studies, it will be necessary to apply various measurements to the subjects over a longer-term intervention period.

Conclusion

This study compares the effects of ABE and AHE using quantitative lumbar flexibility assessments and pulmonary function testing with a spirometer. The results demonstrated that ABE were more effective than AHE, as measured by the Schober test, measured more intensely of the lumbar spine area. However, no difference between the two exercise groups was found when using the other lumbar flexibility and pulmonary function tests. This study suggests that ABE training for the general abdominal muscles may be helpful for lumbar flexibility versus AHE for emphasizing the selective strengthening of the transverse abdominalis.

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