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Effect of the Abdominal Bracing Maneuver on Muscle Activity of the Trunk and Legs during Walking in Healthy Adults

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Objective: This study aimed to investigate the effect of the application of abdominal brace techniques on muscle activity of the trunk and lower extremities when walking.

Design: Cross-sectional study

Methods: This study was conducted on 26 healthy adults in their 20s, and the subjects performed two conditions in random order: walking with the abdominal bracing technique and walking in an abdominal relaxation state (normal gait). Muscle activity was measured on the dominant side of all subjects using surface electromyography, and the attachment sites were the erector spinae, external oblique, internal oblique, vastus lateralis, and vastus medialis oblique muscles. Each condition was measured three times to calculate and analyze the average value.

Results: When walking using the abdominal brace technique, the muscle activity of the erector spinae, external oblique, internal oblique, and vastus lateralis increased significantly ($p < 0.05$), and the muscle activity of the vastus medialis increased as well but was not significant.

Conclusions: The results of this study indicate that it is possible to be used as an effective guide to increasing the muscle activity and stability of the trunk and lower extremities through the application of the abdominal bracing technique during walking.

Key Words: abdominal muscles, electromyography, walking

Introduction

Gait is one of the most important human abilities, and the loss of walking ability is the most fatal disability in human history and a decline in quality of life [1]. Low back pain reduces walking speed [2] and reduces the quality of life by changing the trunk muscle activity through a protective mechanism. It was found that low back pain increases the muscle activity of the abdominal muscles and lumbar spine [3], and the activity of the erector spinae muscle in patients with low back pain does not adapt to changes in walking speed like it occurs in healthy people [4]. Large muscles on the trunk surface, such as the erector spinae, act as major compensatory muscles for core muscle weakness. The compensatory action increases the risk of muscle fatigue or injury and the load on the spine will result in damage to the spinal structures. Therefore, insufficient core muscle strength is likely to increase the occurance of back pain [5].

The abdominal bracing technique is a method used to increase the stability of the trunk by increasing abdominal pressure [6], and is used to improve the activity of all abdominal muscles [7, 8]. Koh [9] reported that the abdominal bracing technique was more effective in activating the abdominal muscles than the abdominal hollowing technique, and Grenier& McGill [10] stated that lumbar spine stability was

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increased by the abdominal bracing technique than the abdominal hollowing technique. During straight leg raise and knee fallout using the abdominal bracing technique, the pelvic rotation angle is significantly reduced compared to the hollowing technique and relaxation technique, so the abdominal bracing technique is more effective in improving radial pelvic stability[10, 11, 12].

Studies on abdominal bracing and abdominal hollowing techniques have been conducted on subjects in standing to supine position [13], supine position, quadruped posture [14], side-lying position [15], and standing in place [16]. Comparative studies on abdominal hollowing techniques are frequently conducted with subjects in place, however, studies conducted on subjects with abdominal bracing while out of place, such as gait, are lacking. Abdominal bracing is effective in strengthening core muscles and increasing lumbopelvic stability, and since walking has been shown to be just as effective as back strengthening exercises in improving pain, quality of life, fear-avoidance, and trunk muscular endurance [17], walking exercise can be considered as an alternative to physical activity for patients with low back pain [18, 19]. Hence, walking with the abdominal bracing technique will be effective in strengthening core muscles and reducing back pain.

Therefore, the purpose of this study was to investigate the effect of the application of the abdominal bracing technique on the muscle activity of the trunk and lower extremities when walking on a flat surface.

Methods

Participants

This study was conducted on 26 healthy adults in their 20s who had met the selection criteria. The selection criteria for the study subjects were 1) adults in their 20s, 2) those who had no musculoskeletal abnormalities in the upper or lower extremities in the last 6 months, 3) those who had no congenital anomalies, orthopedic diseases, or deformities in the upper or lower extremities, 4) those who did not have abdominal or lower extremity muscle weakness and 5) those who were able to walk normally. An exclusion condition was 1) those who showed pain in the lower back while walking [20, 21]. In advance of proceeding with the experiment, the experimental process and standards were sufficiently described to the subject, and after the subject entirely comprehended and signed the consent form, the experiment was conducted. This study was conducted after receiving approval from the Bioethics Committee of Sahmyook University (2-1040781-A-N-012021085HR).

Procedure

The subjects walked a distance of 10 meters while in a relaxed state or with use of the abdominal bracing technique, and this was repeated three times in random order for each condition in order to obtain the average values of their muscle activity. In order to minimize muscle fatigue that may occur during the experiment, the subjects were given a 1-minute rest time after the subject walked 10 meters and then returned to the origin starting position, and after repeating each motion 3 times the subjects were allowed to rest for 3 minutes.

Intervention

Pressure Biofeedback Unit

The pressure biofeedback unit (Chattanooga Group Inc, Hixson, U.S.A., 2008) which unit is mmHg consists of a pressure gauge, an elastic bag, and a tube connecting them. In this study, the pressure of the elastic bladder was set at 70 mmHg so that the center was placed on the navel and that the far edge of the elastic bag was on the line linking the left and right anterior superior iliac spines. When practicing the abdominal bracing technique, the muscles of the trunk were contracted at the same time while keeping the spine in neutral position without changing the position of the spine, the abdomen was contracted in a state as if someone was about to strike the stomach while breathing naturally [22], and the elastic bag was set so that the pressure only increased by 4 to 10 mmHg [23] (Figure 1). The subjects were asked to practice abdominal bracing technique 3 times in total and 3 times each, and to maintain it for 5 seconds during the practice.

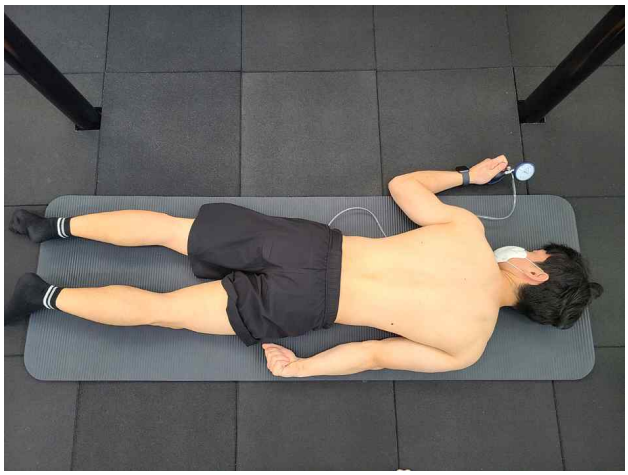

Figure 1. Abdominal bracing technique practice using pressure biofeedback device

Figure 2. Pressure 70mmHg before applying bracing

Waist Circumference Change Sensor (Keeping Core Band)

The waist circumference change sensor (Keeping Core Band, The Core Inc., Korea) provides biofeedback to conveniently detect waist circumference changes using vibration. When the waist circumference increases by 1.5 cm or more as the contraction of the trunk muscles decreases, vibration stimulation is applied to the trunk to induce active contraction of the trunk muscles. In this study, waist circumference was reduced during abdominal bracing compared to when no abdominal bracing was applied. Accordingly, use of the abdominal bracing technique was induced while walking by wearing a waist circumference change sensor.

Outcome measures

Electromyography

To assess muscle activity during gait, the muscle activity of the external oblique, internal oblique, erector spinae, vastus medial, and vastus lateralis muscles on the dominant side was assessed using the Telemyo 2400 G2 Telemetry EMG system (Noraxon, USA, 2011). The sampling rate of the EMG signal was set to 1,000 Hz, the band pass filter was set to 20 to 500 Hz, and after treatment with full wave rectification, it was treated with a root mean square (RMS) value of 250 ms. In addition, the EMG signal was normalized during each movement using the %MVIC value [21]. In order to minimize skin resistance prior to measurement, the hair on the electrode attachment site was removed and the electrode was attached after wiping the attachment site with an alcohol swab [24]. The electrodes were attached to the muscle belly so as to keep a distance of 2 cm from each other and parallel to the muscle fiber direction. As for the electrode attachment sites, the electrodes for the external oblique muscle were located on the outside of the rectus abdominis muscle, just above the anterior superior iliac spine, midway between the iliac crest and the ribs, and parallel to the muscle fibers. For the internal oblique muscle, the electrodes were placed 2 cm below the iliac crest in the inward direction. The electrodes for the erector spinae were placed at a point 2 cm away from the 3rd lumbar vertebrae with the subject in trunk flexion with their hands placed on their knees to support their weight. The electrodes for the vastus lateralis were located at a point that was diagonally outward from the center, about 3-5 cm above the patella, and for the vastus medialis, the electrodes were placed 2 cm inward from the upper edge of the patella at an oblique angle of 55 degrees [20, 24] (Figure 2).

Data and statistical analysis

For all statistical analyses, the mean and standard deviation were calculated using the Windows statistical program PASW version 18.0 (SPSS Inc., Chicago, U.S.A.), and descriptive statistics were used for the

Figure 3. 4∼10mmHg increase in pressure after applying bracing

Figure 4. Electrode attachment sites(Front)

Figure 5. Electrode attachment sites(side)

Figure 6. Electrode attachment sites(Back)

general characteristics of the subjects. In order to investigate the effect of the abdominal bracing technique on the muscle activity of the trunk and lower extremities during walking, a paired t-test was conducted for two conditions: abdominal relaxation and abdominal bracing technique. The statistical significance level of all data was set to $p < 0.05$.

Results

The general characteristics of the subjects are shown in Table 1 (Table 1).

There was a significant increase in erector spinae, external oblique, and internal oblique muscle activity when walking with the abdominal bracing technique

Table 1. General characteristics of study subjects(N=26)

		Subjects
Sex (male/female)		12/14
Age (yrs)		25.92(2.68)
Height (cm)		170.54(9.82)
Weight (kg)		67.36(15.32)
Affected side (right/left)		24/2
Waist circumference (cm)		
	Relaxation	80.21(11.27)
	Bracing	77.22(10.46)

Values are presented as number or mean (standard deviation).

applied compared to walking in the relaxed state (normal gait) (Table 2) ($p < 0.05$).

The vastus lateralis showed a significant increase when walking with the abdominal bracing technique applied compared to walking in the relaxed state (Table 3) ($p < 0.05$). On the other hand, the vastus medial muscle increased when walking with the abdominal bracing technique applied, compared to walking in the relaxed state, but was not statistically significant (Table 3).

Discussion

The purpose of this study was to investigate the difference in the muscle activity of the trunk and lower extremities according to the presence or absence of the abdominal bracing technique when walking on flat ground. As a result of this study, when the abdominal bracing technique was applied, the muscle activity of the erector spinae, external oblique, internal oblique, and vastus lateralis was significantly increased ($p < 0.05$). McGill [25] reported that the abdominal bracing technique, which is one of the trunk stabilization methods, simultaneously contracts the trunk muscles and activates the large and small muscles in and around the spine to improve the stability of the spine. In addition, when the abdominal bracing technique is applied, as the abdominal muscles

Table 2. Trunk muscle activity according to normal and abdominal bracing gait (N=26)

	Muscle activity (%MVIC)		
	Normal Gait	Bracing gait	t (p)
ES	14.8(8.9)	18.7(9.1)	−3.258(0.003)
EO	12.7(9.4)	21.4(15.8)	−4.102(0.001)
IO	19.3(11.0)	41.6(23.0)	−6.923(0.001)

Values are presented as number or mean (standard deviation).
ES=erector spinae; EO=external oblique; IO=internal oblique; MVIC=maximal voluntary isometric contraction.

Table 3. Lower extremity muscle activity according to normal and abdominal bracing gait (N=26)

	Muscle activity (%MVIC)		
	Normal Gait	Bracing gait	t (p)
VL	15.8(11.9)	18.2(13.5)	−3.267(0.003)
VM	15.4(14.1)	16.4(13.1)	−0.751(0.460)

Values are presented as mean (standard deviation)
VL=vastus lateralis; VM=vastus medialis; MVIC=maximal voluntary isometric contraction.

are activated, the waist flexion moment arm increases and the activity of the extensor muscles of the back increases to maintain the waist extension [26]. It was reported that as the activity of the abdominal muscle, which is the prime mover, increased, the activity of the antagonist muscle also increased in order to establish a mechanical balance, and it was increased because the abdominal bracing induced the muscles adjacent to the spine to contract simultaneously [27]. According to Saunder et al. [28], during walking, the transversus abdominis muscles contracted with tension, increasing intra-abdominal pressure and tension of the thoracolumbar fascia in order to increase lumbar spine stability, and the external obliques, internal obliques, erector spinae, and multifidus were said to undergo phase-phase contractions. Therefore, in this study, it is considered that walking with the application of the abdominal bracing technique significantly increases the muscle activity of the abdominal muscles and erector spinae muscles. This supports the results of this study that the application of the abdominal bracing technique while walking on a flat surface increased the activity of the abdominal muscles. In this study, when walking on a flat surface with the abdominal bracing applied, the muscle activity of the vastus lateralis increased significantly ($p<0.05$). Ahn Suhong et al. [20] researched muscle activity of trunk and abdominal by applying abdominal hollowing technique when walking on flat ground and the electrode attached to rectus abdominis, external oblique, internal oblique, erector spinae, vastus medialis, vastus lateralis. As a result, muscle activity of external oblique, transverse abdominis and vastus medialis was significantly increased. Harput et al. [29] measured quadriceps muscle activity during unilateral extremity exercises that applied abdominal hollowing technique. The muscle activity of vastus medialis and vastus lateralis were increased in every exercises, but rectus femoris was not. Therefore, this study was to investigate the effect of abdominal bracing technique on the muscle activity of vastus medialis and vastus lateralis during walking on a flat surface. The abdominal bracing technique can increase the muscle activity of the rectus femoris [30] and increase the muscle activity in multi-joint exercises using the lower extremities through core stabilization training [31, 32]. For stabilization of the pelvis, the abdominal muscles must be activated which then allows the stabilized pelvis to efficiently transmit the force of the trunk to the lower extremities [33], and the activated trunk muscles increases the strength and muscle activity of the lower extremities through the dissipation effect [34]. Therefore, in this study, the application of the abdominal bracing technique applied during walking enhanced the muscle activity of the abdominal muscles, which internal led to the stabilization of the pelvis, and the stabilized pelvis transferred the force of the trunk to the lower extremities, thereby increasing the muscle activity of the vastus lateralis.

In this study, the muscle activity of the vastus medialis muscle was enhanced, but it was not significant. Ahn Suhong et al. [20] reported that the application of the abdominal hollowing technique when walking on flat ground increased the muscle activity of the rectus abdominis, external oblique, transverse abdominis, and vastus medial muscles. Sookyung Lee [35] found that the application of the abdominal hollowing technique increased the muscle activity of the rectus abdominis, transversus abdominis, vastus medial, and vastus lateralis when going up an incline, and when going down on a decline, the muscle activity of the rectus abdominis, external oblique, transverse abdominis, vastus medialis, and the vastus lateralis increased. These two studies showed contradictory results from the present study due to enhanced muscle activity of the vastus medialis muscle and therefore, follow-up studies are needed. Since this study was conducted on a small sample size of healthy adults in their 20s, it is difficult to generalize the results as it is not yet known how the application of the abdominal bracing technique will affect gait in the patient population or other age groups. Therefore, future studies are necessary in order to conduct research on a larger sample size and in subjects with special characteristics. In addition, since this was a cross-sectional study, studies that will further examine the treatment effect will be required in the future. Abdominal bracing technique is developed by being used in clinical trials, but none of the researches were related to walking. This research is highly valuable in terms of pursuing further research on treatment for back pain.

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