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The effect of co-contraction exercises of abdominal bracing combined with ankle dorsiflexion on abdominal muscle thickness and strength in patients with chronic low back pain

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Objective: The purpose of this study was to determine the effect of the abdominal bracing (AB) and abdominal bracing combined with ankle dorsiflexion (ABDF) on abdominal muscle thickness and strength in patients with chronic low back pain (LBP).
Design: Two group pretest posttest design.
Methods: Sixteen subjects were divided randomly into two group: ABDF group (n=8), and alone AB group (n=8). The ABDF group practiced AB exercise with additional ankle dorsiflexion. AB group practiced only AB exercises. Subjects in both groups received ABDF exercise and AB exercise for 40 min per day, three days per week during a period of three weeks, respectively. All the subjects were evaluated for abdominal muscle thickness and strength before and after intervention using ultrasonography and MedX machine.
Results: The external oblique (EO), internal oblique, transverse abdominis (TrA) muscle thickness and the strength produced at 48^o, 60^o, 72^o showed a significant increase in the ABDF group after intervention, with a more significant improvement in EO and TrA muscle thickness in the ABDF group compared with the AB group ($p<0.05$). Also, the strength at 48^o strength showed a significant improvement in the ABDF group than the AB group ($p<0.05$).
Conclusions: The study results showed that abdominal muscle contraction exercises with AD in patients with LBP had an influence on abdominal muscle thickness and strength. Therefore, these findings suggest that ABDF may be useful approach for enhancement of abdominal muscle thickness and strength in patients with chronic low back pain.

Key Words: Abdominal muscle, Low back pain, Ultrasonography

Introduction

Low back pain (LBP) is defined that as pain, tension or tonus of muscle from lower ribs through the hip line with or without leg pain (sciatica) [1]. Approximately 10%-40% of acute LBP patients become chronic and most of them are classified as nonspecific. Patients who develop chronic nonspecific LBP are responsible for more than 80% of health care costs that are spent for spinal problem [2]. It has an effect on making appropriate trunk action suitable for its physical and functional activities. This could have an effect on the co-activation and the changes in superficial and deep muscles of trunk [3].

Decreased deep muscle activity commonly occurs in patients with relapsed back pain [4,5]. On the other hands, superficial muscles get activated more than usual [3]. People who are at a risk for the LBP also have the changes in those muscles [6-8].

Exercises for strengthing abdominal lumbar extensors could assist in pain relief as well as performing tasks. It rep-

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resents that LBP is related to the deep muscle dysfunction caused by the instability of hyper-mobile spine segments which is resulted from muscle control [9].

Recent studies about non-surgical treatment for LBP supports that it is a necessary to restore neuro-muscular control of the transverse abdominal muscle and minimize the use of superficial abdominal muscles during an initial stage of rehabilitation [5,10,11]. Selective movement in the transverse abdominal muscle that plays a major role in core stability may be helpful in treating for LBP [12]. Therefore stabilization exercise has to be applied for the treatment of dysfunction neuro-muscular control [9].

Abdominal bracing (AB) promoted the activities of three abdominal layers; external/internal oblique (EO/IO), transverse abdominis (TrA) and rectus abdominis which stabilize lumbar spines [13]. Abdominal muscle contraction is a key to place the lumbar spines in the neutral range. Deliberate abdominal activities reinforce the stabilization process during daily activities, work activities, and even sports. Abdominal muscles activate against external forces to enhance a series of muscles surrounding lumbar spines. Stability in the lumbar spines which possibly could reduce the chances of mechanical damage, must be considered and are needed for restoring in LBP patients. That is to say, building up abdominal muscle strength in LBP patient is not an option but a must [14].

Lumbar spine stability is emphasized when the muscles are co-activated against trunk muscles [5,15,16]. Stability is summed up when deep muscle training on the trunk and training in the upper/lower extremities are performed at the same time [17]. TrA and IO are part of deep muscles, providing stability while the tasks are assigned [13]. Active muscle contraction in those muscles leads to protect the supine structures [18]. The pattern of muscle contraction in the patients with LBP is different from those who without LBP [19,20]. Previous research has demonstrated that people with back pain have neuromuscular dysfunction of the back and abdominal muscles [21]. Studies of LBP have suggested that intervention using motor control exercise can improve both objective and subjective outcomes of treatment [22].

The motor control exercise has become very popular as a clinical practice method for the treatment of nonspecific LBP. The evidence of motor control exercise is that the deep abdominal muscle wall has a key role in the dynamic control of the lumbar spine. The AB exercise using pressure biofeedback unit (PBU) is a one method of motor control exercise for treatment in LBP [23]. The PBU is a device developed by physiotherapists to aid the training and measurement of abdominal muscle activity using visual biofeedback. Recent study has demonstrated that the AB exercise using PBU by useful visual biofeedback used to improve to LBP [24].

Another method to augment the abdominal muscle is in co-contraction of active ankle dorsiflexors and deep abdominal muscles. This approach was derived from the concept of irradiation in proprioceptive neuromuscular facilitation, which emphasizes the important contribution of the important contribution of the relatively stronger distal muscle group [25]. Previous studies reported that the co-contraction of the rectus femoris muscles and ankle dorsiflexors effectively augmented the activation of deep abdominal muscle [12].

Therefore, the purpose of our study was to determine the effects of the pressure biofeedback training and pressure biofeedback combined with ankle contraction on abdominal muscles thickness and strength in people with chronic LBP.

Methods

Subjects

This study used a pretest-posttest design, and the sixteen participants with symptoms of chronic nonspecific LBP were randomly recruited from an outpatient musculoskeletal physical therapy service unit within the Wooridul Spine Hospital.

General characteristics such as sex, age, height, and weight of participants were obtained from patient interview, and confirmed via review of medical records (Table 1), and also participants were determined to be in the experimental group by drawing cards inscribed from 1 to 10. Inclusion criteria for participants were: (1) a diagnosis of nonspecific LBP of non-traumatic causes; (2) age 20-40 years; (3) LBP persisting for at least 3-month or more; ability to perform the movement of the experimental intervention. Exclusion criteria included participants who had previous abdominal wall or spinal surgery, and other neurologic conditions.

Sixteen subjects were randomly assigned to either the AB exercise group or abdominal bracing combined with ankle dorsiflexion (ABDF) group.

The study was approved by the Sahmyook University institutional review board, and all the participants provided their informed consent.

Table 1. General characteristics of subjects (N=16)

Characteristic	ABDF group (n=8)	AB group (n=8)	X^2/t	p
Sex (male/female)	3 (38)/5 (62)	3 (38)/5 (62)	1.000	1.000
Age (y)	23.38 (3.46)	25.25 (4.03)	0.693	0.511
Height (cm)	164.63 (8.58)	165.00 (6.91)	1.369	0.276
Weight (kg)	59.38 (10.27)	59.28 (7.13)	0.520	0.602

Values are presented as n (%) or mean (SD).
ABDF: abdominal bracing combined with ankle dorsiflexion, AB: abdominal bracing.

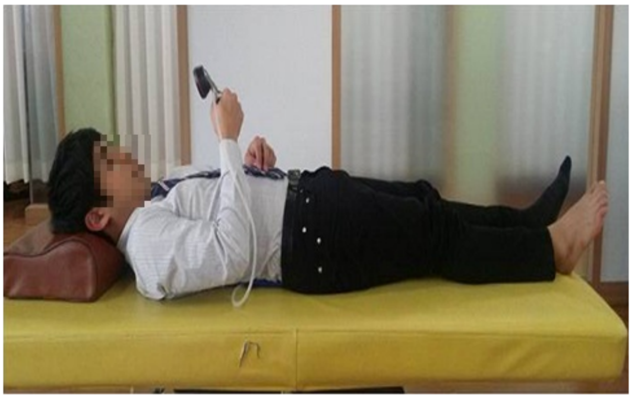

Figure 1. Abdominal muscle contraction using pressure biofeedback unit.

Figure 2. Abdominal muscle contraction using pressure biofeedback unit with ankle dorsiflexion.

Procedures

All participants were previously instructed twice for test and training methods prior to test.

In the present study, the contraction method of each abdominal muscle was composed of based previous studies [25].

All participants were measured using the ultrasonography (SEQUOIA 521; Siemens Inc., Erlangen, Nürnberg, Germany, 2002) and the MedX Medical Lumbar machine (MedX Inc., Ocala, FL, USA, 1993) in order to assess their abdominal muscle thickness and strength before and after intervention of each group. The AB group training was as follows. The contraction of abdominal muscles were controlled by a PBU, and the pressure of the biofeedback unit were used which standardized the contractile force of an abdominal muscle [26]. The biofeedback unit is a simple pressure transducer consisting of a three-chamber air-filled pressure bag, a catheter and a sphygmomanometer gauge [27]. The pressure bag is 16.7×24 cm in size and made from inelastic material. The biofeedback unit has an excellent in inter-rater and intra-rater reliability (intraclass correlation coefficient [ICC]=0.74, 0.76, respectively) [28]. The measured value has a range from 0 mmHg to 200 mmHg, with 2-mmHg intervals on the scale. The pressure changes along with the postural changes were measured by the sphygmomanometer of the biofeedback unit.

Before starting the contractions, the inflatable bag from the biofeedback unit was placed under the lumbar curvature between first lumbar vertebra and second sacrum, and the bag was inflated to a pressure of 70 mmHg with the valve closed. For abdominal contraction, all participants were instructed to produce a smooth contraction without moving the spine and pelvis, and the pressure reduction was not to exceed from 4 to 10 mmHg, and maintain these contractions for 10 seconds [29] (Figure 1). During abdominal muscle contraction, the breathing was to have normal play without a visible movement the lumbar vertebrae and pelvis, and rib [26].

The AB exercise combined ankle dorsiflexion group pulled the ankle toward the head in order to create ankle dorsiflexion during contraction of the abdominal muscle in the same manner with the AB group (Figure 2).

Each participant of both group were instructed to maintain the contraction for 10 seconds, relax for 10 seconds, were given a 1 minute rest period after performing the contraction and relaxing 10 times, 1 set (1 session). 3 set performed overall 10-session, 1 set. This intervention method received for 40 minutes per day, three days per week during a period of three weeks, respectively [30].

Clinical measures

Muscle thickness

Ultrasonography is a reliable and valid method of assessing the structure of the functions and activities being used by physical therapists [31,32]. This technique is important to research the activity of deep muscles such as deep abdominal muscles and muscle contractions can be studied in real time [33,34]. During measurement with the ultrasonography, abdominal muscle thickness changes can be measured as an indicator of the abdominal muscles activity. A comparison of magnetic resonance imaging (MRI) and ultrasonography measurements showed a high correlation in one study [35], electromyography (EMG) activity of the low-intensity muscle contractions in comparison with the thickness variations were correlated [4,7].

Ultrasonography as an indicator of muscle activity is a non-invasive method to measure the thickness of the muscle and is a reliable tool [36]. Diagnostic ultrasonography unit used was B-mode, 4.0 MHz. Based on that described in other studies, abdominal muscle thickness change during muscle contraction was measured [36-38].

For measurement purposes, the Convertor to measure was placed on the horizontal axis between the 12th rib and iliac crest over right anterior axillary line. The anteriolateral abdominal muscle layer was located so that it appears clearly.

Participants were trained on exactly how to produce the abdominal muscle contraction by the physical therapist during the pretest. The cursor displayed on the screen for the ultrasonography was used to measure the thickness of the muscle between the fascia band. Muscle thickness by the cursor in the still image was measured in centimeters. Converter has been placed during the examination. The abdominal muscle contraction (EO, IO, TrA) was to occur three times for analysis. All measurements were carried out by one observer to increase the intra-rater reliability [39].

The transducer head for measurement was positioned transversely 2.5 cm anteromedial to the midway point between the 12th rib and iliac crest.The head of the transducer was maneuvered until the sharpest images of all lateral abdominal muscles (EO, IO, TrA) had been obtained. [40].

Muscle strength

The subject seat on the MedX (MedX Inc.) with in trunk

Table 2. The changes in abdominal muscle thickness during contraction after exercise (N=16)

Abdominal muscle	ABDF group (n=8)		AB group (n=8)		t^b	*p*
	Pre-test	Post-test[a]	Pre-test	Post-test		
External oblique (cm)	0.46 (0.12)	0.53 (0.12)*	0.50 (0.12)	0.53 (0.11)	−2.342	0.031
Internal oblique (cm)	0.68 (0.25)	0.73 (0.25)*	0.90 (0.32)	1.01 (0.26)	1.001	0.330
Transverse abdominis (cm)	0.42 (0.11)	0.49 (0.11)*	0.55 (0.17)	0.57 (0.12)	−2.185	0.042

Values are presented as mean (SD).
ABDF: abdominal bracing combined with ankle dorsiflexion, AB: abdominal bracing.
[a]Paired t-test, [b]Independent t-test.
*$p<0.05$.

Table 3. The changes of abdominal muscle strength (N=16)

MedX angle	ABDF group (n=8)		AB group (n=8)		t^b	*p*
	Pre-test	Post-test[a]	Pre-test	Pre-test		
MedX 48° (Nm)	117.65 (69.39)	132.51 (63.70)*	129.39 (54.16)	133.71 (56.83)*	−2.575	0.019
MedX 60° (Nm)	129.67 (70.11)	153.17 (57.33)*	153.17 (57.33)	157.94 (57.16)	−1.817	0.086
MedX 72° (Nm)	139.55 (65.58)	158.91 (14.42)*	168.40 (59.14)	179.70 (31.79)	−0.730	0.475

Values are presented as mean (SD).
ABDF: abdominal bracing combined with ankle dorsiflexion, AB: abdominal bracing.
[a]Paired t-test, [b]Independent t-test.
*$p<0.05$.

in vertical upright position and about 15 degrees of femoral maintained. The upper front side of the femur by using the belt was firmly is fixed, the femoral fixation pad was firmly fixed on above the knee and infront of the femur. Such fixation of the pelvis and the femur prevents unnecessary vertical movements. In addition, the upper body movement against gravity was quantified as the value of the weight. When the test was ready to start, movement of the arm of the machine was fixed in an appropriate joint angle of the machine and it was measured using a goniometer of the machine. After subjects is increased up to maximal tension during 2-3 seconds, the contractions were maintained for approximately 1 second. The torque value was measured by the loading point attached to the movement arm. Validity and reliability of measurement procedures and regulations are well established [41,42]. The measured torque values at any angle during the measurement and the re-measurement showed a very high reliability as of r=0.63-0.96 in patients with LBP [43], r=0.94-0.98 in patients without LBP [44]. Isometric lumbar extension torque values were measured at every 12 degrees up to the maximum lumbar extension (0 degree) from the maximum lumbar flexion (72 degree).

The subjects relaxed at between each measurement angle for about 10 seconds, while strength test was being conducted in each joint angle. All subjects were required to produce make maximum power at each angle. When the power was not maximum power, it was measured again [42,45].

Data analysis

The IBM SPSS Statistics ver. 19.0 (IBM Co., Armonk, NY, USA) was used for statistical analysis. Results are presented as mean (standard deviation). The Shapiro-Wilk test

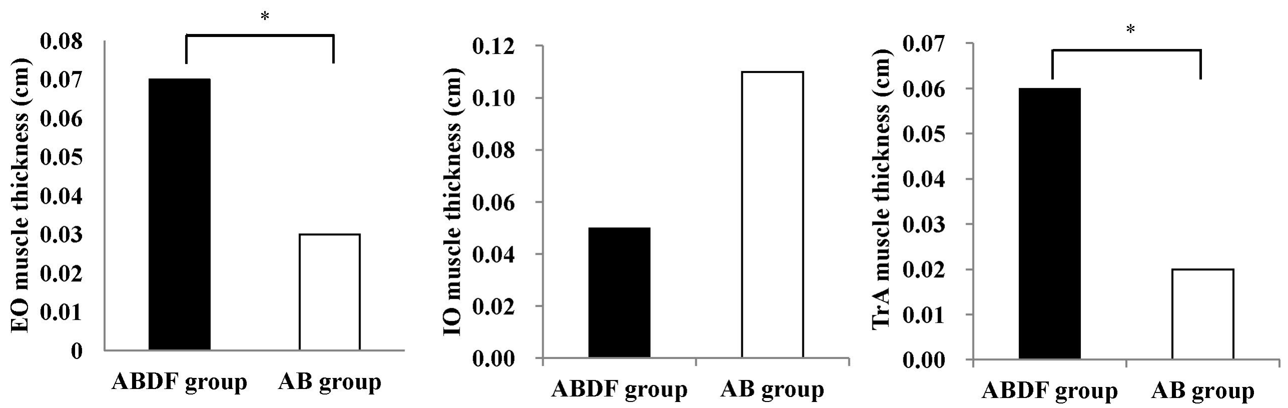

Figure 3. Differences of abdominal muscle thickness within and between abdominal bracing combined with ankle dorsiflexion (ABDF) group and abdominal bracing (AB) group. *Significant difference within and between both groups (p<0.05). EO: external oblique, IO: internal oblique, TrA: transverse abdominis.

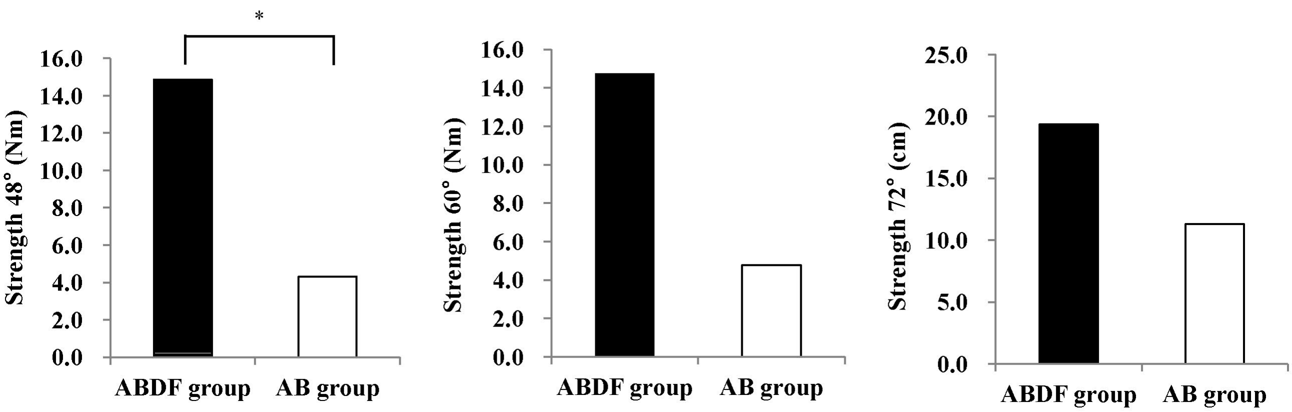

Figure 4. Differences of lumbar extensors strength within and between abdominal bracing combined with ankle dorsiflexion (ABDF) group and abdominal bracing (AB) group. *Significant difference within and between both groups (p<0.05). MedX Medical Lumbar machine (MedX Inc., Ocala, FL, USA).

was used to normalize the data. Chi-square analysis was used to calculate the frequency of difference for categorical variable (gender). The paired t-test was used to compare before and after of intervention within groups. The independent samples t-test was performed to investigate the significances of differences between groups. The significance level was set at 0.05 for all analyses.

Results

The general characteristics of the subjects were not significantly different between the ABDF group and AB group (Table 1).

For comparison within the group, the ABDF group showed significant improvement in EO, IO, TrA muscle thickness and strength values at 48^o, 60^o, 72^o for abdominal muscle strength, whereas the AB group showed only significant improvement the strength value at 48^o for abdominal 48^o abdominal muscle strength after intervention (p<0.05; Tables 2, 3; Figures 3, 4).

For comparison between the both groups, only EO and TrA muscle thickness and the strength value at 48 for abdominal 48^o abdominal muscle strength showed a significantly greater difference in the ABDF group than the AB group (p<0.05; Tables 2, 3; Figures 3, 4).

Discussion

The aim of this study was to compare the efficacy of ABDF exercise and AB exercise in the muscle thickness and strength of chronic LBP patients. Both exercises were effective in change of abdominal muscle thickness and muscle strength but the ABDF produced greater improvements in abdominal muscle thickness, and abdominal muscle strength in MedX 48^o.

The important risk factor of LBP is weakness of superficial trunk and abdominal muscles, and strengthening of these muscles is often related to significant improvement of chronic LBP [46]. For this reason, various AB exercise studies with PBU have been conducted in an effort for improve muscle strength and motor control in persons with LBP. This study examined changes in abdominal muscle thickness using ultrasonography after 10 session of ABDF exercise in persons with LBP.

The abdominal muscle thickness after ABDF exercise was 0.06 cm, a 12.8% (EO), 0.05 cm, 8.3% (IO), and 0.06 cm, 13.2% (TrA) improvement. Thus, the changes of abdominal muscle were found to be significantly improved by ABDF exercise. Also, the results of ABDF exercises demonstrated greater effectiveness as show by the EO and TrA muscle thickness changes than with AB exercises, which underwent only PBU exercises for the same duration.

Chon *et al*. [12] reported that the thickness of TrA was 0.24 cm, which increased in ABDF exercise with ankle dorsiflexion compared to AB exercise without ankle action, and TrA and IO EMG peak amplitude was greater after the abdominal draw-in maneuver (ADIM) with ankle dorsiflexion was applied.

Hungerford *et al*. [47] reported that patients with lumbopelvic pain have been shown to have altered muscle recruitment patterns of the lateral abdominal muscles, which included the TrA, IO, and EO.

Kumar *et al*. [48] reported that the ADIM combined with core exercise for 5 weeks in patients with chronic LBP decreased visual analogue scale scores from 7 to 1, and Stuge *et al*. [49] demonstrated that the AB exercise combined isolated training was beneficial for painful and functional improvement in patients with LBP.

In the present study, in accord with a previous study, the ABDF exercise showed a treatment evidence to improve of abdominal muscle thickness and strength in patients with chronic LBP.

In this study, the abdominal strength of the ABDF group showed a significant increase after the intervention period at strength values at 48^o (p<0.05), 60^o (p<0.05), and 72^o (p<0.05). In MedX training, trunk flexion had ABDF activated compared to trunk extension, especially EO [50]. Advanced ABDF thickness which provides stability on spines are capable of leading to adequate AB contraction against the trunk muscle.

The abdominal muscle is the leading muscle of expiratory. A recent study has monitored the activity of respiration related to ABDF. IO and TrA became much thicker during maximal expiratory action than single TrA action through ultrasonography as well as the EO in EMG [51].

This study proved that muscle contraction training of AB with ankle dorsiflexion was more effective for improving abdominal muscle activation and strength by increasing EO muscle, IO muscle and TrA muscle thickness in patients with chronic LBP.

There were some limitations to this study. First, due to a small sample size, it is difficult to make any generalizations. Second, there has not been considered the effects of respiration on changes in muscle thickness and muscle strength in the study. Therefore, further studies are warranted that will include all of the above considerations.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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