J. Phys. Ther. Sci. 30: 892–895, 2018

The Journal of Physical Therapy Science

Original Article

The effect of trunk stabilization circuit exercise using a rubber mat on the thickness and white area index of transverse abdominis in healthy young adults

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Abstract. [Purpose] The purpose of this study was to investigate the effect of trunk stabilization circuit exercise using a rubber mat on the thickness and white area index of the transverse abdominis in college students in their 20's. [Subjects and Methods] The subjects were randomly assigned to the experimental group and the control group. Those exercises were provided to twenty eight healthy adults in their 20s for four weeks and the thickness of transverse abdominis was measured before study and after 4 weeks. [Results] There were significant differences in interaction between two groups. Paired t-test for thickness and white area index of transverse abdominis showed statistically significant differences to experimentals than controls. Independent t-test for white area index of transverse abdominis also showed statistically significant differences to experimentals than controls. [Conclusion] In conclusion, there was statistically significant difference between the effects of trunk stabilization circuit exercises on back muscles according to types of the surface, and it is expected that this result will be used as a basic data in studies of abdominal muscle stabilization in the future.

Key words: Stabilization, Transverse abdominis, Ultrasonography

(This article was submitted Feb. 19, 2018, and was accepted Mar. 28, 2018)

INTRODUCTION

Stabilization is defined as the ability of a person to control large or fine movements in the joints consciously or unconsciously[1)]. Given that the back muscles involved in the stability of the lumbar region play a role in maintaining the stability of the vertebra while maintaining the body alignment and that they are essential elements for the execution of bodily functions[2)], the stability of the lumbar region not only provides efficiency during the performance of complex movements and prevents injuries, but also facilitates overall functional activities throughout the body[3)].

Looking into the importance of the lumbar stabilization system, failure in the stabilization of the vertebrae leads to the instability of the back bone due to the disturbance in the movement of the pelvis and vertebrae[4)]. The instability of the back bone delays nerve conduction, leading to the reduction of the muscle strength in the trunk muscles, which in turn may cause the instability and pain of the back bone. The limitation of the physical activity due to the pain can cause the decrease in the surface area of the muscles surrounding the backbone and myoatrophy, resulting in secondary damages[5)].

According to many studies, local back muscle strengthening exercises have been utilized continuously as a way to maintain lumbar stabilization. These exercises are intended to strengthen muscle strength in the abdomen, lower back and pelvic regions, thereby restoring the ability to regulate the movement of trunk muscles. They are more effective for increasing muscle

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strength of the back muscle than simple mobilization exercises. In addition, trunk stabilization exercises have been studied more recently as an exercise that can reduce the risk of accidents during exercise compared to other conventional muscle function strengthening methods[6], activate the deep muscles in the abdomen and small multifidus muscles in the vertebrae simultaneously[7] and help strengthening muscles[8]. Although there have been many reports on the functional improvement effect of the trunk stabilization exercise through many studies[9, 10], few studies have been done on changes in thickness of the transversus abdominis (TA) through trunk stabilization circuit exercise on an unstable surface.

Therefore, this study aims to investigate the effect of trunk stabilization circuit exercise using a rubber mat on the structural changes in the muscles through an image analysis method and to utilize the underlying mechanism. It also aims to provide the data that can be applied to vertebrae stabilization exercise in the clinic setting.

SUBJECTS AND METHODS

This study was conducted from May 5, 2017 to July 5, 2017 for two months. A total of 28 people participated in this study, consisting of 15 men and 13 women, and 14 subjects per group were randomized to either the experimental group or the control group. The subjects were limited to those who had consented to participate in this study in writing and those who have not exercised regularly without any pathological or orthopedic disease were selected. This study was approved by the Clinical Bioethics Committee at Korea Nazarene University (KNU IRB 17-1021-05) and was reviewed according to the Declaration of Helsinki. The general characteristics of the subjects are shown in Table 1.

In this study, all subjects were subjected to the exercise session five times per week for four weeks and 30 minutes per day. The experimental group was subjected to the trunk stabilization circuit exercises using a rubber mat and the control group was subjected the trunk stabilization circuit exercises on floor without using a rubber mat. The experimental group performed the Dead bug exercise, Bridging exercise, Side-bridge exercise and Bird dog exercise in the order listed using a rubber mat[11]. The control group performed the Dead bug exercise, Bridging exercise, Side-bridge exercise and Bird dog exercise in the order listed on a stable surface of regular floor. First, the dead bug exercise started in a supine position on a rubber mat on the ground, with both arms raised up at 90 degrees and both knees bent at 90 degrees. Then, the subject was asked to stretch the left arm behind and to stretch the right leg downward at the same time, to go back to their original position, and to stretch the opposite arm and leg. Second, the bridging exercise was performed while a subject was in a supine position on a rubber mat on the ground bending their legs and raising and putting down their hips repeatedly. Third, the side-bridge exercise was performed when a subject lay on their side on a rubber mat on the ground. The subject bent the elbow joint of the beneath-the-body arm with the forearm touching the mat while unfolding the elbow joint of the opposite arm with the arm putting on the trunk side. Increasing the posterior tilt of the pelvis by contracting the abdominal muscles and the glutei, the subject raised the pelvis while flattening the waist. Fourth, the bird dog exercise was performed when a subject lay down on their hands and knees on a rubber mat on the ground. Their arms and thighs were perpendicular to the ground by adjusting the spaces, and the distances between the arms and legs were shoulder-wide. Then, the subject simultaneously raised the right arm and the left leg and then the left arm and the right leg repeatedly, with the trunk and the pelvis maintained in a neutral position between the two movements. The investigators taught the subjects each exercise two or three times. One physical therapist per three subjects tough and supervised.

An ultrasound imaging system (Lab 25 gold, Esaote, Italy) was used as the experimental measuring equipment. The frequency displacement range and the gain range of this device were set to 6–9 MHz and 20–80, respectively. For ultrasonic transducer, a linear transducer was used in the range of 7.5 MHz. The investigator applied ultrasonic gel to a linear transducer and the skin of a subject, determined where the TA was located by ocular inspection from the ultrasonic imaging and palpation with their hands, and then identified the muscular image sharpness. To measure the TA, the straight distance between the navel and the 1/3 point toward the navel from the anterior superior iliac spine (ASIS) was measured when a subject was in a supine position. Ultrasonography was used to measure the thickness of the TA after resting and at maximal isometric contraction at sagittal plane[12]. For the thickness of the TA, the diameter of 2 cm was measured from the beginning where the linea alba was connected to the muscles. To minimize differences among the subjects, a physical therapist who had professional knowledge in ultrasound imaging performed this experiment as an investigator based on the knowledge of fundamental anatomy of the waist muscles[10]. To determine the thickness and white area index of the TA, the ultrasonography was performed three times and the mean of the values was considered the result value. To reduce errors in the measurements of the TA, the subjects performed slow respiration and shallow respiration within the range that did not interfere with the abdominal movements during measuring.

In order to analyze the results obtained by the ultrasound imaging, the data were transferred to an imaging program (Image-Pro Plus 4.1 Media Cybernetics, USA), and the parts to be analyzed were extracted in a rectangular shape with care not to include the fascia or tendon transitions[13]. As a method to measure the density of the transverse abdominis, light intensity analysis was employed, in which pixel values were calculated by precisely selecting the coordinates in the rectangular area without including the fascia and the muscle image density was established. According to the pixel reference value, the mean pixel value of pure black was 0 and that of pure white was 255, and more black areas indicated normal muscle. The white area index (WAI) was defined as the number of pixels present in all regions that visually appeared as white in the selected rectangular area divided by the total number of pixels[14].

Table 1. General participant characteristics

	Experimentals (n=14)	Controls (n=14)
Gender (male/female)	7/7	8/6
Age (years)	21.3 ± 2.3	21.5 ± 2.3
Height (cm)	169.3 ± 2.3	170.5 ± 2.8
Weight (kg)	63.4 ± 5.3	66.3 ± 7.4

Values are presented as the mean ± SD.

Table 2. Comparison of abdominal muscle area of each experimentals and controls

	Experimentals		Controls	
	Pre-test	Post-test	Pre-test	Post-test
TA thickness (mm)	2.4 ± 1.1	3.2 ± 0.1*	2.5 ± 0.4	2.7 ± 0.6
TA WAI (%)[a]	0.5 ± 0.1	0.3 ± 0.0*	0.5 ± 0.2	0.4 ± 0.1

Values are presented as the mean ± SD.
*Significant difference from pre-test at<0.05; [a]Significant difference in gains between two group at p<0.05.
TA: Transverse abdominis; WAI: White area index.

All data were analyzed using SPSS 16.0 statistical program. In order to examine the difference between before and after the experiment in each measurement item, a T-test of matching samples was conducted. Also, in order to determine the difference in the changes between before and after the experiment in each group, an independent comparative t-test was performed. The significance level α was set to 0.05.

RESULTS

A comparison of the results of the abdominal muscle before and after the experiment in the experimental group and the control group revealed that there was a significant difference in the TA thickness and TA WAI in the experimental group ($p<0.05$), but not in the control group ($p>0.05$). There were significant differences in the changes of the and TA WAI between before and after the experiment in each group, but no significant difference was observed in the TA thickness ($p>0.05$) (Table 2).

DISCUSSION

In this study, the effect of stabilization exercise using a rubber mat was evaluated in 28 healthy adult subjects for four weeks. The results of the digital image analysis were compared and the changes in the thickness and WAI of the transverse abdominis muscle were analyzed. The comparisons of thickness and white area index of the transverse abdominis muscle revealed that there were significantly higher increases in the experimental group after the exercise than the control group. This result shows that the muscle activity of multifidus is increased in order to maintain the central axis of the body by the isometric contraction of repeated upper and lower extremity through the trunk stabilization circuit exercise on the unstable rubber mat surface rather than the stable surface.

Ko et al.[15] showed that after lumbar stabilization exercise, there was a significantly different muscle thickness of the transverse abdominis muscle, which was measured by ultrasound, in elderly women in their 60s or older. Jung et al.[16] showed that lifting of a leg in a lying position on a form roller with an unstable surface, significantly increased the thickness of the transverse abdominis muscle. In addition, Lee[17] reported that the muscle activation levels of the trunk muscles were higher in the experimental group where both arms and legs were lifted simultaneously in a four-point kneeling position on a stable surface compared to the experimental group where only legs were lifted.

The muscle image density was analyzed using the light intensity analysis method and the white area index (WAI) was calculated by dividing the number of pixels that were displayed as white with a pixel value of 70 or more on the digital image program (Image-Pro Plus) by the total number of pixels[12]. For digital image analysis, Jung et al.[18] chose only the rectangular region because the whole muscle could not be transferred and there was no need to analyze the whole image. The reliability of this method has been proven by several subsequent studies. In the study of Maurits et al.[14], characteristic values for normal adults were quantified by using this method. It was found that among the digital image analysis items, the muscle image density exhibited a highly reflective intensity in non-muscle fiber such as lipids and connective tissues[19]. In well-trained muscles, there were bright, distinct and dark lines, whereas the structure of diseased muscles was more in disarray and more white areas were observed[20]. In addition, the results of a study[21] showed that the muscle image density and white area index

of well-trained muscles free of diseases with neurological damages had the pixel values close to normal, which is consistent with the results of this study.

The results of this study were limited in that all the subjects were healthy people in their 20's that the period of the exercises was short (four weeks) could be insufficient.

Trunk stabilization circuit exercise on an unstable surface do not include excessive movements, an exercise that anyone can perform repeatedly at any time. The subjects of this study showed improvements in the thickness and white area index of the TA after performing the exercise. Thus, circuit exercise can be provided as a rehabilitation method to strengthen and lumbar stabilization the weakness of the abdominal muscles.

Funding

This research was supported by the Korean Nazarene University Research Grants 2018.

Conflict of interest

None.

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