

The effects of dynamic exercise utilizing PNF patterns on abdominal muscle thickness in healthy adults

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Abstract. [Purpose] The purpose of this study is to examine the effects of dynamic exercise utilizing the PNF (proprioceptor neuromuscular facilitation) patterns accompanied by abdominal drawing-in exercises on abdominal muscle thickness in healthy adults. [Subjects] The total number of subjects was 30; 15 were randomly placed in the training group (TG), and the remaining 15 made up the control group (CG). [Methods] The subjects in the TG conducted 3–5 sets of dynamic exercises utilizing the PNF patterns each day, 3 times a week for 6 weeks. The thickness of the abdominal muscles was measured by ultrasonography. [Results] When the TG's abdominal muscle thickness pre-test and post-test were compared in this study, there was a statistical significance in all of the external obliquus abdominis (Eo), the internal obliquus abdominis (Io), and the transversus abdominis (Tra). [Conclusion] Dynamic exercise utilizing the PNF patterns increased the thickness of the abdominal muscles that are the basis of trunk stabilization.

Key words: Dynamic exercise, PNF patterns, Abdominal muscle thickness

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INTRODUCTION

In modern life, people perform fewer physical activities than they did in the past because of changes in industrial and economic activities and the utilization of information and knowledge tools, such as computers. It has been reported that excessive biomechanical burdens due to sedentary lifestyles cause chronic muscle weakening phenomena, such as abdominal muscle atrophy, muscle weakness, and spinal joint instability, which lead to lumbar pain, reduction in endurance, and restrictions of flexibility and the range of motion of joints¹⁾. Lumbar stability is a preceding element that allows people to maintain the spine properly during postural changes and varying load conditions so that extremity movements can be performed²⁾. Abdominal muscles that contribute to lumbar stability include the external obliquus abdominis (Eo), the internal obliquus abdominis (Io), and the transversus abdominis (Tra)³⁾. In particular, the Tra is activated earlier than other muscles when the human body moves to control trunk balance, and the Ios on both sides are important for lateral spinal stability and spinal flexion⁴⁾. Therefore, the present study is intended to implement dynamic exercises utilizing PNF patterns for the development

of the Eo, the Io, and the Tra that play important roles in lumbar stability. Similar exercises include circuit training, Swiss ball exercises, core stabilizing exercises, and sling exercises. Circuit training, the most frequently used method of enhancing muscle strength, consists of arranging (circuit) multiple exercise items or motions to continuously train many muscle groups in turn, following the circuit in order without any rest between the items⁵⁾. Swiss ball exercises have been used as a rehabilitation tool for postural correction, deep lumbar muscle treatment, and prevention of problems. They are reported to be capable of enhancing muscle strength, stabilizing the trunk, and developing spinal flexibility as a core strengthening exercise tool⁶⁾. Core stabilizing exercises can maximize the coordination both between and within segments to promote the ability to have loads cross the lumbar vertebrae and the sacral vertebrae of the human body⁷⁾. In addition, sling exercises enable sensory-motor training and have been reported to offer proprioceptive stimulating effects due to the nature of suspension devices so that larger effects are evident compared to general lumbar stabilizing exercises performed on stable bearing surfaces. These exercises have been commonly reported to promote enhanced trunk stability⁸⁾.

However, because circuit training, Swiss ball, core stabilizing, and sling exercises require the systematic guidance of experts and must be performed in specific places with specialized equipment, most adults are greatly restricted in performing these exercises. On the other hand, dynamic exercises utilizing PNF patterns can be easily repeated by patients after they have received education by experts, and they can be performed anywhere at any time. They can in-

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Fig. 1. Dynamic exercise utilizing the PNF patterns

crease thickness of the abdominal muscles, which is a basic requirement for enhancing trunk stability, and they can improve physical functions by stimulating the proprioceptors of muscles and tendons. In addition, the exercise patterns consist of spiral patterns: diagonal patterns that are known to be more appropriate for improving the performance capabilities of muscles than single-plane, single-direction training programs⁹). Therefore, in the present study, the effects of dynamic exercises utilizing PNF patterns on abdominal muscle thicknesses that are a basic requirement for the enhancement of trunk stability will be examined in healthy adults using ultrasonic imaging.

SUBJECTS AND METHODS

Thirty students from N University in South Korea participated in the present study. Inclusion criteria were normal, healthy adults. Exclusion criteria were as follows: those who had any structural abnormality in the spine before participating in the experiment; those who had spinal pain, such as lumbar pain; those who were taking prescription or illegal drugs; those who had any neurologic disease; those who drank before the experiment; those who were overweight; and those who regularly exercised. The subjects were randomly assigned to either a training group (TG, M=1, F=15) that would participate in dynamic exercises or a control group (CG, M=1, F=15) that would not participate. The TG's mean age was 22.4 ± 1.0 (mean \pm SD) years, while the average height was 163.1 ± 7.0 cm and the mean weight was 59.5 ± 8.7 kg. The CG's average age was 21.7 ± 0.8 years; the mean height was 161.5 ± 5.4 cm, and the average weight was 55.7 ± 6.0 kg. The χ^2 test was used for sex analysis, and the independent t-test was employed to analyze ages, heights, and weights. These analyses showed statistically insignificant ($p > 0.05$) differences between the groups, so the two groups could therefore be considered homogeneous. This study regarding dynamic exercises utilizing the PNF patterns was approved by the university's Institutional Review Board, and the subjects were safely protected during all of the processes of the experiment. All subjects understood the purpose of this study and provided written informed consent prior to their participation in accordance with the ethical standards of the Declaration of Helsinki.

The subjects' trunks were first stabilized through abdominal drawing-in exercises before the exercises began, and then the subjects performed the dynamic exercises utilizing the PNF patterns. First, the left foot was fixed at a point before the exercises began and was maintained there during the exercises. The left lower extremity was placed in the state

of hip extension, knee extension, and ankle plantar flexion to bear the patient's entire weight without shaking. Then, the right lower extremity was put into a state of hip flexion, hip adduction, hip external rotation, knee flexion, and ankle dorsiflexion, while the left upper extremity was put into a state of shoulder flexion, adduction, external rotation, and elbow flexion. The right upper extremity was placed into a state of shoulder extension, shoulder abduction, shoulder internal rotation, and elbow extension. Thereafter, when putting down the right foot, which had been lifted, the left lower extremity was placed into a state of hip flexion, knee flexion, and ankle dorsiflexion to lower the posture, while the right lower extremity was put into a state of hip extension, hip abduction, hip internal rotation, knee extension, and ankle plantar flexion so that the end of the foot ended up approximately 70–80 cm away both diagonally backward and rightward from the left, allowing the foot to bear the full weight.

At this time, the right upper extremity was put into a state of shoulder flexion, adduction, external rotation, and elbow flexion, and the left upper extremity was placed into a state of shoulder extension, shoulder abduction, shoulder internal rotation, and elbow extension (Fig. 1)¹⁰). Then, the right foot was fixed at a point, and exercises were performed in postures opposite to the above postures. These exercises were defined as one cycle of dynamic exercises utilizing PNF patterns. During the exercises, the subjects were requested to make sure that their trunk maintained neutral positions, their trunk and bearing foot did not shake, and the foot was placed on a point diagonally backward and leftward or rightward from the weight-bearing foot, which was always placed on one point.

To set exercise intensities appropriate for the subjects during the six-week program and to apply the principle of graded exercise, 10 cycles of both left and right side exercises were defined as one set for a total of 20 cycles, and two sets were performed during the first and second weeks. Then 20 cycles of left and right side exercises, for a total of 40 cycles, were defined as one set, and three sets were performed. Therefore, the subjects performed a total of five sets in the first two weeks. From the third week until the sixth week, 10 cycles each of left and right side exercises for a total of 20 cycles were defined as one set, and four sets were performed. Then 20 cycles of both left and right side exercises, for a total of 40 cycles, were defined as one set, and four sets were performed. Therefore, a total of eight sets were completed. The participants rested for 30 seconds every time a set was completed. Warm-up exercises were performed for five minutes before the main exercises, and



Fig. 2. Abdominal muscle thickness

cool-down exercises were carried out for five minutes following the main exercises. The total exercise time per session was approximately 25–30 minutes, and the exercises were performed three times per week for six weeks. The CG performed no particular exercises, and the subjects' values were measured two times after daily living activities.

Ultrasonography (MysonoU5, Samsung Medison, Korea) was used to examine changes in the thickness of the abdominal muscles both before and after the dynamic exercises utilizing PNF patterns. To attain the measurements, one measurer assessed abdominal muscle thickness using ultrasonography with 12-MHz linear probes. The measurer was blinded to which patients were in which groups. First, the subject was instructed to lie comfortably in a supine position. A triangle pillow was placed below the knees of the subject so that the subject could relax his or her lower extremities. The probe was placed transversely on the top of the iliac crest and moved toward the center of the abdomen. The screen was stopped when the Eo, Io, and Tra were all visible, and the muscle thicknesses of the Eo, Io, and Tra were measured at a point 25 mm away outward from the point where the muscle fascia of the Io and that of the Tra meet (Fig. 2)^{11, 12}. To get the abdominal muscles to contract with the same abdominal muscle strength when abdominal muscle thicknesses were being measured, a pressure bio-feedback unit (Chattanooga Group, Australia) was placed below the lower back of the subject and abdominal muscle thicknesses were measured when the pressure gauge was maintained at 40 mmHg when the abdomen was tightened both before and after the experiment.

The experimental results were statistically analyzed using SPSS 12.0 KO (SPSS, Chicago, IL, USA). After the general characteristics of the subjects were determined, paired t-tests were used to compare the changes in Eo, Io, and Tra for the pre-test and post-test in each group. The differences between the two groups were tested using independent t-tests. The statistical significance level, α , was set at 0.05.

RESULTS

According to the results of the comparisons both before and after the experiment between the groups, the TG showed statistical significance for the Eo, Io, and Tra ($p < 0.05$), but the CG showed no statistical significance for any of

Table 1. Comparison of Eo, Io, and Tra between the pre-test and post-test in each group (mean \pm SD) (unit: cm)

Category	Group	Pre-test	Post-test
Eo	TG*	0.41 \pm 0.09	0.56 \pm 0.13
	CG	0.38 \pm 0.05	0.42 \pm 0.07
Io	TG*	0.78 \pm 0.10	0.88 \pm 0.10
	CG	0.79 \pm 0.12	0.78 \pm 0.10
Tra	TG*	0.54 \pm 0.09	0.65 \pm 0.18
	CG	0.54 \pm 0.10	0.55 \pm 0.11

* $p < 0.05$, TG: training group (M=1, F=15), CG: control group (M=1, F=15), Eo: external obliquus abdominis, Io: internal obliquus abdominis, Tra: transversus abdominis

Table 2. Comparison of Eo, Io, and Tra between TG and CG (mean \pm SD) (unit: cm)

	Category	TG	CG
Pre-test	Eo	0.41 \pm 0.09	0.38 \pm 0.05
	Io	0.78 \pm 0.10	0.79 \pm 0.12
	Tra	0.54 \pm 0.09	0.54 \pm 0.10
Post-test	Eo*	0.56 \pm 0.13	0.42 \pm 0.07
	Io*	0.88 \pm 0.10	0.78 \pm 0.10
	Tra	0.65 \pm 0.18	0.55 \pm 0.11
Change between pre- and post-test	Eo*	0.15 \pm 0.13	0.03 \pm 0.09
	Io*	0.10 \pm 0.14	-0.01 \pm 0.15
	Tra	0.10 \pm 0.15	0.01 \pm 0.13

* $p < 0.05$

the items ($p > 0.05$) (Table 1). In addition, no statistically significant differences were found between the TG and the CG before the experiment ($p > 0.05$), but there was statistical significance in the Eo and the Io after the experiment and also between the differences before and after the experiment ($p < 0.05$) (Table 2).

DISCUSSION

The present study was intended to examine the effects of dynamic exercises utilizing PNF patterns on the abdominal muscle thicknesses in normal adults. Similar exercises include core muscle strengthening exercises using Swiss balls, mats, or slings. Ainscough-Potts et al. had 30 healthy adult women perform core exercises using Swiss balls for five weeks to improve their stability in sitting positions. Ultrasonography measurements demonstrated that the muscle thicknesses of the Io and the Tra increased considerably⁶. In addition, it has been reported that sling exercises stimulate muscles around the lumbar-pelvic-hip area so that the core is stabilized to reduce the angle of inclination of the pelvis due to any muscle imbalance⁸. Myer demonstrated that plyometric training and core stabilizing exercises performed by female high school athletes three times per week for seven weeks were effective for muscle power and neuromuscular control¹³. Brill stated that core stabilizing exercises could strengthen the lumbar muscles and enhance stability by maintaining spinal balance based on the Tra contraction¹⁴.

Pilates is a form of exercise that strengthens the core of the body through repeated muscle contraction along with deep breathing. It has been reported to stabilize the trunk by increasing the activity of the Tra, the diaphragm, the multifidus, and the pelvic floor muscles¹⁵). Although these exercises have similar effects to those of PNF pattern exercises in that they increase abdominal muscle thickness, trunk stabilization, and postural alignment, they must be performed using systematic programs under the guidance of experts and using specialized equipment in appropriate places. However, dynamic exercises utilizing PNF patterns have the advantage of being easy to repeat after practicing under the guidance of experts; students and office workers can perform them anywhere and at anytime without the need for equipment. According to the results of the comparison of the abdominal thickness of the experimental group both before and after the experiment, the Eo, Io, and Tra all showed statistical significance.

The results of the present study are considered attributable to the fact that the deep abdominal muscles, or the core, were activated when abdominal drawing-in and diagonal and spiral exercises of the pelvis, shoulder blades, and the upper extremities were performed continuously while trunk stability was maintained. In particular, the abdominal drawing-in exercises increased the muscle thickness of not only the Eo, which is a superficial muscle, but also the Io and Tra, which are deep muscles. These results can be considered identical to the effects on abdominal muscle thickness reported in previous papers. Therefore, the dynamic exercises that utilize PNF patterns accompanied by abdominal drawing-in that were performed in the present study are considered to be a good exercise method for developing the abdominal muscles of those with insufficient trunk stability and also those who complain about low back pain due to abdominal muscle weakening.

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