Comparison of the effects of different core exercise on muscle activity and thickness in healthy young adults

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Objective: This study aimed to compare the effects of core exercise methods on muscle activation and muscle thickness in healthy young adults and to propose effective core exercise methods.
Design: Three-group pretest-posttest design.
Methods: A total of 30 healthy young adults (14 males, 16 females) voluntarily participated in the study. Subjects were randomized to the prone plank exercise (n=10), reverse plank exercise (n=10), or bridge exercise (n=10) groups. Muscle activity and thickness of the rectus abdominis (RA), multifidus (MF), external oblique (EO), and internal oblique (IO) muscles were measured using surface electromyography and ultrasound. Subjects from each group participated in the exercises five times a week, with five 20-second sets during week 1. The set time was increased by 10 seconds per week.
Results: Muscle activity and thickness in the prone plank, reverse plank, and bridge exercise group were statistically significant different for RA, MF, EO, and IO changes over time, and interaction between time and groups were also significantly different ($p<0.05$). We analyzed statistically significant differences between groups using a one-way analysis of variance for each period. A significant difference was observed after 4 weeks of exercise ($p<0.05$).
Conclusions: The results suggest that the prone plank exercise is a beneficial method for enhancing muscle activation and thickness of the RA, EO, and IO compared to the reverse plank and bridge exercises. On the other hand, the reverse plank and bridge exercises are effective methods for enhancing the MF compared to the prone plank exercise.

Key Words: Abdominal oblique muscles, Electromyography, Exercise, Paraspinal muscles, Rectus abdominis

Introduction

Physical activity has decreased due to automation and mechanization in the 21st century. It has caused increased body fat and weakened muscle strength and function. Muscle weakness is a major cause of lower back disease, and the need for exercise is emerging. A recent emphasis on active movements has emerged, such as strengthening exercises for the lower back or strengthening muscles around the spine and stabilizing the spine. In particular, core exercises are being used to improve the ability to control the body by securing its center of gravity through strengthening

the core muscles and promoting movement and stability [1,2].

Core exercises are used to strengthen the spinal, abdominal, pelvic floor, and hip muscles, which maintain the core of the body. It contributes to the maintenance of the right body center of pressure, allows for efficient body movement, as well as improves the ability to maintain a stable posture and balance control by stabilizing and providing neutral control of the trunk and the spine, and reduces pain [3,4].

The core of the body is composed of abdominal muscles at the front of the trunk, paraspinal and gluteal muscles on the back, the diaphragm at the upper part of the core, and pel-

vic floor and hip girdle at the lower core. Core muscles are classified into large and local muscles. The former are all segmental muscles that maintain balance against external loads on the body, while the latter are important in maintaining stability of the anterior, posterior, and lateral body [5]. The large muscles include the external oblique (EO), rectus abdominis (RA), paraspinal muscles, and the local muscles include the interspinales, intertransversarii, internal oblique (IO), multifidus (MF), and transverse abdominis muscle. Because core muscle activity plays an important role at the center of the trunk in whole-body movements and postural adjustments, positive changes in the core muscles help maintain body posture alignment and maintain a dynamic balance during functional activity [6-8]. The core muscles also play an important role in the performance of all physical activities and sports [9].

Many studies have been conducted to investigate the effectiveness of core exercises. These predominantly include the treatment of patients with low back pain and exercise performance in athletes. However, there is a lack of studies comparing different core exercises and their effect on physical activity and back pain prevention in the general population.

Thus, the purpose of this study was to compare the effects of prone plank, reverse plank, and bridge exercises on muscle activity and thickness in healthy young adults and propose effective core exercises.

Methods

Subjects

Thirty healthy young adults (14 males, 16 females), from Chunnam Techno University located in Jeonnam, Korea, participated in this study. Subjects were fully informed about the purpose and method of the study before participating and written informed consent was voluntarily provided. The Institutional Review Board of Sahmyook University approved all protocols and procedures (IRB No. 2-1040781-AB-N-01- 2018004HR). The characteristics of the subjects are shown in Table 1.

Subjects were recruited according to the following exclusion criteria: (1) having neurological or orthopedic diseases, (2) taking medication for muscle relaxation, (3) those who participated in a similar study within a year, and (4) those with a skin problem that would be affected by the attachment of the surface electrode and the application of ultrasound gel.

Table 1. General characteristics of the subjects (N=30)

Variable	Prone plank (n=10)	Reverse plank (n=10)	Bridge exercise (n=10)	F (p)
Age (y)	20.83 (1.33)	21.50 (1.97)	20.67 (0.82)	0.553 (0.587)
Height (cm)	166.17 (8.18)	168.5 (10.27)	170.57 (6.21)	0.168 (0.847)
Weight (kg)	66.28 (10.43)	67.63 (11.73)	69.95 (11.95)	0.161 (0.487)

Values are expressed as mean (SD).

Exercise procedures

Sex, age, height, weight, and other general information were recorded for all subjects. The selected subjects were divided into 3 groups by random sampling to minimize selection bias and were randomly assigned to one of 3 groups: prone plank, reverse plank, and bridge exercise. The randomization process was performed using computer-generated numbers produced by a basic random number generator (Random Allocation Software ver. 1.0; Isfahan University of Medical Sciences, Isfahan, Iran) [10].

Before the intervention, all subjects were assessed for maximum voluntary isometric contraction (MVIC) and muscle thickness of the RA, MF, EO, and IO. The intervention was performed in each group for 4 weeks and outcome measures were re-measured at 2 weeks and 4 weeks as in the pre-test. Each group performed 5 sets of 20 seconds in the first week, 5 sets of 30 seconds in the second week, 5 sets of 40 seconds the third week, and 5 sets of 40 seconds in the fourth week. Exercises were performed 5 times a week. A 30-second break was given between each set to reduce muscle fatigue.

Exercise procedures

For the prone plank exercise, study participants were asked to maintain their elbows flexed at 90° in the push-up position, with the forearms and toes on the floor. The width between both arms was as wide as the shoulders, and the width between the feet was as wide as the pelvis. The subjects' hip, pelvis, and lumbar spine were aligned (Figure 1A).

In the reverse plank exercise, subjects lifted their pelvis off the floor in a supine position with elbows extended, and the knees and trunk aligned. Both arms were separated at shoulder width (Figure 1B).

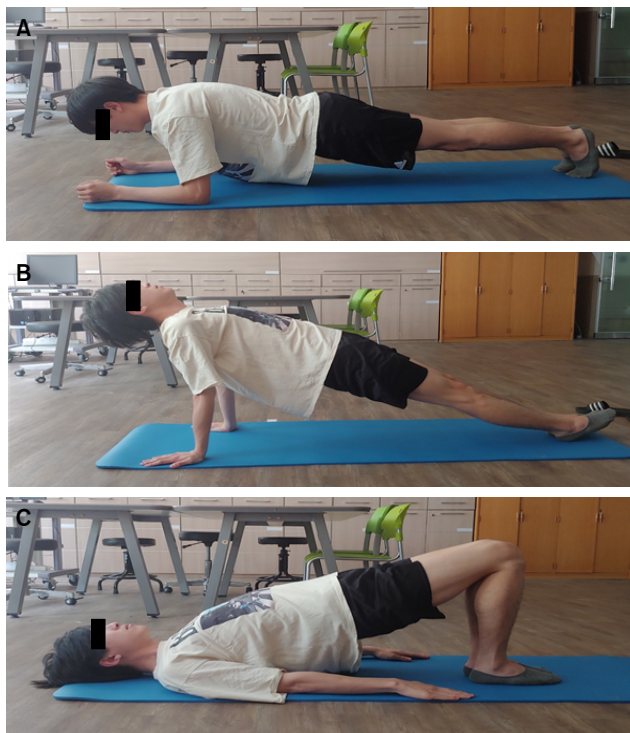Subjects in the bridge exercise group were asked to bend

Figure 1. The position according to the exercise methods. (A) Prone plank exercise method. (B) Reverse plank exercise method. (C) Bridge exercise method.

their knees to 90° with the heel of their feet on the floor. Both arms were at shoulder-width apart, and their palms were faced down. The subject lifted their hips up to keep their pelvis in line with the lumbar spine at 0° according to the verbal instructions of the evaluator (Figure 1C).

Experimental equipment

Muscle activity measure and data processing

We used a surface electromyography (EMG) device (Trigno Wireless EMG; Delsys Inc., Natick, MA, USA) to measure muscle activation of the RA, MF, EO, and IO according to the different intervention methods. The skin was wiped with rubbing alcohol and dried off to minimize skin resistance. Two surface electrodes were use applied with one electrode placed on the muscle belly of the RA, MF, EO, and IO muscles and the other placed within a distance of 2 cm. The MVIC of each muscle was measured after adequate practice and rest period. The electrode placement and MVIC measurements used were similar to those described by Cram *et al.* [11]. To normalize the EMG value of each muscle, the MVIC was measured for 7 seconds in a manual muscle testing position. A 5-minute break was given between each of the 3 repetitions.

Measured electromyographic signals were processed and analyzed using the Delsys EMGworks 4.1.1 (Delsys Inc.). The EMG signals were sampled at a frequency of 1,000 Hz, and a band-pass filter of between 20 to 450 Hz. After undergoing the full-wave rectification process, it was processed with the root mean square and was analyzed. Excluding the first and last 2 seconds of the 7-second measurement period, the mean values from the middle 5 seconds during the maximal contraction data of each muscle were represented as the %MVIC values for normalization.

Muscle thickness measurement

An ultrasound imaging device (MyLab One; Esaote, Genova, Italy) was used to measure changes in muscle thickness. The subjects were prevented from receiving visual biofeedback during the measurement process. In the pre- and post-test, the measurement area was marked with an experimental pen to measure at the same location. The same evaluator performed the measurements, and the maximum value was used after 3 repeated measurements.

Measurements for the RA were performed using the probe transversally while the subject was in a supine position. It was measured inwardly and upward 2 cm at the umbilicus [12]. For the MF measurement, the subject in was prone position, and a pillow supported his or her hip and ankle joints. After palpating the transverse process of the lumbar spine 4 to 5 levels, the probe was positioned lengthwise by vertically placing it on the waist spine center line. The shape of the spinous process was checked on the monitor screen, and the probe was measured with inclination until the facet joint was clearly visible [13]. The EO and IO were measured in the area of the right lower quadrant of the subject, aligned with the anterior superior iliac spine, which was inward and downward 2 cm [12].

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics ver. 19.0 (IBM Co., Armonk, NY, USA). The general characteristics of the subjects were analyzed using descriptive statistics, and results were presented as the mean±standard deviation. The Shapiro-Wilks testing was performed to test for normality, and the normal distribution was satisfied. The one-way placement variance analysis was performed for the group-to-group homogeneity test and group comparison. The repeated measures analysis of variance was performed to compare the difference between groups, the changes between the different time points, and

the interaction between the time and groups. A one-way analysis of variance was performed to compare the groups at each time point. The post-test was conducted using the Duncan test. The statistical significance level was set to $\alpha = 0.05$.

Results

Homogeneity between groups was examined among the 30 subjects (16 males, 14 females). The prone plank, reverse plank and bridge exercise groups were identified as the same group with no difference. The general characteristics of the subjects are listed in (Table 1).

The differences in muscle activity based on the exercise method is listed in (Table 2). Muscle activity (e.g., RA, MF, EO, and IO) was significantly increased in the changes on effect over time ($p<0.05$). Muscle activity (RA, MF, EO, and IO) was significantly different between all groups and the interaction between time and groups ($p<0.05$). Since we observed a difference between the groups, a one-way analysis of variance was period for each time. No statistically significant difference was seen between the results form the

pre-test and after 2 weeks, but a significant difference was seen after 4 weeks ($p<0.05$). The post-hoc analysis showed that the RA, EO, and IO were significantly different in the prone plank exercise group compared with those in the other core exercise groups ($p<0.05$). Alternatively, the MF was significantly different in the reverse plank exercise and prone plank groups compared with that in bridge exercise group ($p<0.05$).

Differences in muscle activity based on exercise groups are listed in (Table 3). Muscle thickness of the RA, MF, EO, and IO was significantly increased in the changes on effect over time points within all groups ($p<0.05$). Muscle thickness of the RA, MF, EO, and IO was significantly different between all groups and interaction between time and groups ($p<0.05$). We further analyzed the difference between groups using a one-way analysis of variance for each time. There was no statistically significant difference in the pre-test and after 2 weeks results, but there was a significant difference after 4 weeks ($p<0.05$). The post-hoc analysis showed that RA, EO, and IO was significantly different in the prone plank exercise group compared with those in the

Table 2. Changes in muscle activation according to the exercise methods (N=30)

Variable	Pre-test	2 weeks	4 weeks	*p*-value
The muscle activation of the RA (%MVIC)				
PP (n=10)	10.11 (28.01)	10.79 (2.85)	14.54 (2.94)	0.001[1]**
RP (n=10)	8379 (2.36)	9.17 (2.22)	10.10 (2.68)	0.037[2]*
BE (n=10)	9.33 (3.44)	9.74 (3.40)	10.56 (3.46)	0.001[3]**
p-value[a]	0.731	0.622	0.045*	A	B, C[b]
The muscle activation of the MF (%MVIC)				
PP (n=10)	19.11 (4.58)	20.60 (3.04)	22.63 (2.66)	0.004[1]**
RP (n=10)	22.22 (5.99)	24.05 (5.78)	30.75 (5.95)	0.017[2]*
BE (n=10)	19.48 (2.87)	20.83 (4.05)	25.17 (4.49)	0.003[3]*
p-value[a]	0.470	0.348	0.022*	A, B	C[b]
The muscle activation of the EO (%MVIC)				
PP (n=10)	4.58 (1.73)	5.52 (1.64)	8.31 (1.83)	0.001[1]**
RP (n=10)	4.05 (1.53)	4.92 (1.20)	6.33 (1.13)	0.031[2]*
BE (n=10)	4.26 (0.57)	4.85 (0.70)	5.86 (0.41)	0.001[3]**
p-value[a]	0.797	0.600	0.010**	A	B, C[b]
The muscle activation of the IO (%MVIC)				
PP (n=10)	7.83 (3.38)	8.87 (3.50)	11.94 (3.79)	0.002[1]**
RP (n=10)	5.44 (1.89)	6.36 (1.92)	7.94 (2.23)	0.014[2]*
BE (n=10)	6.82 (1.66)	7.36 (1.35)	8.48 (1.47)	0.005[3]**
p-value[a]	0.264	0.232	0.042*	A	B, C[b]

Values are expressed as mean (SD).
Repeated measure analysis of variance: [1]within-subjects factors, [2]between-subjects factors, [3]interaction.
RA: rectus abdominis, MVIC: maximum voluntary isometric contraction, PP: prone plank exercise group, RP: reverse plank exercise group, BE: bridge exercise group, MF: multifidus, EO: external oblique, IO: internal oblique.
[a]One-way analysis of variance, [b]post hoc.
*$p<0.05$, **$p<0.01$.

Table 3. Changes in muscle thickness according to the exercise methods (N=30)

Variable	Pre-test	2 weeks	4 weeks	*p*-value
The muscle thickness of the RA (mm)				
PP (n=10)	12.66 (1.85)[a]	13.78 (1.61)	19.85 (1.14)	0.001[1]**
RP (n=10)	12.71 (1.88)	13.21 (1.90)	16.64 (1.37)	0.011[2]*
BE (n=10)	12.41 (1.49)	13.20 (1.29)	15.09 (1.14)	0.001[3]**
p-value[a]	0.950	0.778	0.005*	A | B, C[b]
The muscle thickness of the MF (mm)				
PP (n=10)	4.50 (0.47)	4.90 (0.50)	5.23 (0.59)	0.001[1]**
RP (n=10)	4.48 (0.49)	4.76 (0.62)	7.12 (1.03)	0.016[2]**
BE (n=10)	4.62 (0.56)	4.96 (0.49)	6.23 (0.71)	0.003[3]*
p-value[a]	0.886	0.772	0.004**	A, B | C[b]
The muscle thickness of the EO (mm)				
PP (n=10)	47.61 (2.07)	52.10 (1.67)	78.90 (3.29)	0.001[1]**
RP (n=10)	46.60 (1.65)	50.24 (2.33)	68.27 (3.61)	0.005[2]**
BE (n=10)	45.28 (1.57)	49.34 (1.4)	66.28 (3.09)	0.004[3]**
p-value[a]	0.109	0.057	0.001**	A | B, C[b]
The muscle thickness of the IO (mm)				
PP (n=10)	33.93 (13.2)	36.38 (2.20)	61.78 (3.17)	0.002[1]**
RP (n=10)	34.04 (1.31)	37.14 (1.42)	52.01 (1.81)	0.001[2]**
BE (n=10)	33.73 (1.49)	34.69 (2.14)	48.10 (3.28)	0.002[3]**
p-value[a]	0.906	0.060	0.012*	A | B, C[b]

Values are expressed as mean (SD).
Repeated measure analysis of variance: [1]within-subjects factors, [2]between-subjects factors, [3]interaction.
RA: rectus abdominis, PP: prone plank exercise group, RP: reverse plank exercise group, BE: bridge exercise group, MF: multifidus, EO: external oblique, IO: internal oblique.
[a]One-way analysis of variance, [b]post hoc.
*$p<0.05$, **$p<0.01$.

other core exercise groups ($p<0.05$). The MF was significantly different in the reverse plank and prone plank groups compared with that in the bridge exercise group ($p<0.05$).

Discussion

We compared the effect of prone plank, reverse plank, and bridge exercises on muscle activity and thickness of the RA, MF, EO, and IO.

The main purpose of performing core exercises is to protect the spine from pain caused by repeated micro-damage, prevent instability and degenerative changes of the spine, as well as stabilize the segments of the spine by stabilizing the trunk [14]. Muscle strengthening and promoting stability through core exercises is used for the treatment and prevention of patients with musculoskeletal disorders, and to improve the ability to exercise [6].

The prone plank exercise selectively mobilizes the spinal flexors while at the same time activating the anterior stabil-

izers that are easily affected in the direction of gravity. Reverse plank and bridge exercises selectively mobilize back muscles that are easily affected by the direction of gravity due to the supine posture and the posterior stabilizers priority activate. Depending on the posture of each exercise, the cross-sectional area and activity of the muscles used against gravity are increased. The RA, EO, and IO were more affected by the exercises than MF, which is an anti-gravity muscle. Previous studies have reported that plank exercises increased the activity of stable core muscles by movement of the limb joints according to the degree of difficulty of the motions [15-17]. Barker *et al.* [18] reported that bridge exercises significantly increased muscle activity of the erector spinae, including the MF. Czaprowski *et al.* [19] found that bridge exercises showed lower muscle activity compared to the prone plank exercise. Lehman *et al.* [20] reported that bridge exercises showed higher muscle activation of the MF than the prone plank exercises, while the RA, EO, and IO had higher muscle activation during the prone plank exercises than bridge exercises.

The significant difference in core exercises observed between groups during the fourth week was due to active, not passive, movement, and repetitive training is reprogrammed at the muscle. Saal and Saal [21] reported that repeated exercises provide sensory feedback and stimulate the integration of the spine to maintain normal function. In addition, simultaneous contraction in the core muscle is stored in the motor center and occurs automatically in daily activities and habitual postures without conscious control. A minimum of 4 weeks is necessary for this effect to appear.

Although there was no significant difference between the bridge and reverse plank exercises, the reverse plank exercises increased muscle activity and thickness after 4 weeks compared to the bridge exercises. It is important that the base is widened or that the center of gravity is located at the base to improve posture stability, but the center of gravity is also very important. This is because a lower center of gravity increases stability, while a higher center of gravity reduces it. Reverse plank exercises, which support the arm, increase instability by providing a higher center of gravity than bridge exercises. Therefore, core muscles are used more to maintain body stability.

We acknowledge that our study population is a limitation of the study. We selected males and females in their early twenties, therefore, it is difficult to generalize and apply our results to patients with low back pain and elderly individuals. Follow-up studies should include patients and subjects of various ages. Long-time and ongoing studies are warranted to evaluate core exercises and carryover effects.

Altogether, our results suggest that prone plank exercises are effective in strengthening the RA, EO and IO muscles, while reverse plank and bridge exercises are effective in strengthening the erector spinae.

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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