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The Effect of Muscle Activation in Trunk Stabilization Exercise According to the Joint Angle of Normal Adults

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Abstract

The quadruped position is one of the trunk stabilization exercises. This improves the pelvic stability and muscle strength during performing the complicated movements. There was no study about the comparisons of the trunk muscle activation according to the hip joint angles. The purpose of this study was to analyze trunk muscle activity in quadruped posture according to the hip flexion angle (70°, 80°,90°). The subjects were 30 healthy young adults (15males, 15females). They performed 2 different postures of trunk stabilization exercises (with one leg raise and with contralateral arm and leg raise) in the quadruped position. The surface Electro-Myography (sEMG) was bilaterally recorded from Rectus Abdominis (RA), External Oblique (EO) and Erector Spinae (ES). As a result, the ES muscle activation(%MVIC) showed a significant difference in the quadruped position according to the hip flexion angles between 70° and 90°(p<0.5). There was no significant difference in RA and EO muscle activation according to the hip flexion angles. This study suggests that we can selectively facilitate the muscle activity and exercise more effectively by considering the hip flexion angle when performing the quadruped position for enhancing the trunk stability.

Keywords: Component, Hip Flexion Angle, Muscle Activation, Quadruped Position, Trunk Stabilization

1. Introduction

It has been reported that trunk stabilization exercises support the efficacy of movement and functionality of general physical activities by increasing the stability of the spine and pelvis in a functional posture and complex exercise performance and enhancing muscle strength[11,20,23]. Moreover, recently previous studies have reported that trunk stabilization exercises in various forms play an important role in the prevention and treatment for low back pain[5,21,25]. Trunk muscle can be divided into large and small muscles. Large muscle contains more superficial trunk muscles such as rectus abdominis muscle, erector spinae muscle, and small muscle contains deeper muscles such as multifidus muscle, transverse abdominal muscle, and internal oblique muscle[13]. Trunk stabilization is caused by the interaction of large and small muscles[3,4]. These muscles play a key role in trunk motion and achieve stabilization by being activated before breathing and performing extremity movement[16,29]. When trunk stabilization is not preceded and order of muscle contraction recruitment changes because of the use of specific muscles or failure of proper interaction between muscles, wrong compensation may cause micro damage to the body in extremity movement[7,8]. Thus, trunk stabilization exercises contribute to maintaining the selective motor control during proper spinal alignment and functional activities[17].

Recently, various kinds of trunk stabilization exercise are widely used in order to enhance exercise performance capacity by improving the interaction between trunk muscles to sports activities beyond musculoskeletal and nervous system disorders in clinical practice[1,18]. In many previous papers, the effect of trunk stabilization exercises was studied by performing various postures such as quadruped position and bridge position on the unstable surface and using exercise equipment such as sling and

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exercise ball[4,9,10]. Among them, quadruped position is often recommended in clinical practice as an antigravity position capable of relatively reducing the load on the spine and maintaining a balance easily compared with other positions because this position makes it easier to maintain the spine in a neutral position[12,19,22].

Beith et al.[2] reported that training in the quadruped position was useful for the activation of internal oblique muscle that was one of the muscles forming trunk[2]. In addition, muscular activities vary according to the change in trunk stabilization exercise in the quadruped position, and arm and leg rising can activate trunk muscles[28]. In other previous studies, when doing trunk stabilization exercises in basic quadruped position at a hip joint angle of 90° and that at a hip joint angle of 120°, remaining abdominal muscles except the internal oblique muscle on the same side showed a low muscle activity in the latter quadruped position, and gluteus maximus muscle showed a high muscle activity[28].

Although many studies have been conducted to examine the correlation between trunk stabilization exercise in the quadruped position and muscle activity, it is considered that there are not enough objective data whether a hip joint angle in the quadruped position is effectively recruited to specific muscles. Additionally, muscle activity was measured by changing a hip joint angle in previous studies, but the measurement was performed by flexing the hip joint at a 120° angle without comparing it at various angles. Therefore, the purpose of this study was to investigate the effect of changes in hip joint angle on trunk muscle activity when performing trunk stabilization exercises in the quadruped position. This study aimed to help to select the proper angle for spinal stabilization by observing the muscle activity according to the hip joint angle and to provide basic data tor rehabilitation research.

2. Method

2.1 Subjects

Thirty healthy adults (15 male, 15 female) of S university participated in this study. All participants received verbal and written information about the details of the experiment and they all gave their informed written consent. The exclusion criteria included a history of neurological disorder, musculoskeletal disorder, a congenital deformity, spine surgery and lumbar spine disorder. All procedures were approved by Institutional Review Board committee of Sunmoon university.

The general characteristics of the subjects are as follows Table 1.

2.2 Procedures

This study helped the subjects to focus on the experiments by creating comfortable surroundings. A surface Electromyography (sEMG) system with disposable bipolar sEMG electrodes was used to measure the electrical activity of the both sides of Rectus Abdominis (RA), External Oblique muscle (EO) and Erector Spinae (ES). The subjects performed the quadruped position on three different hip flexion angles (70°, 80°, 90°) measured by a electro-goniometer, as shown in Figure 1. In the quadruped position, the two motions of trunk stabilization exercises were performed: First, they raised the left leg in the quadruped position. Second, they were instructed to raise the left leg and then to extend the right arm forward, as shown in Figure 2. All subjects

Table 1. General characteristics of the subject

Characteristic	Male (n=15)	Female (n=15)
Age(years)	21.07 ± 1.20	20.33 ± 0.97
Height(cm)	173.25 ± 5.51	161.25 ± 5.24
Weight(kg)	67.54 ± 9.43	54.32 ± 7.55

All variables are mean±standard deviation

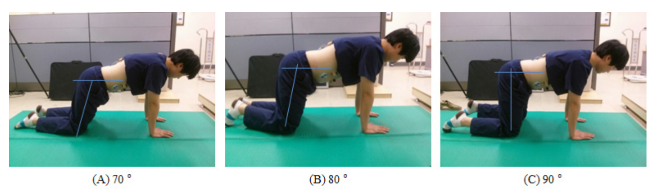
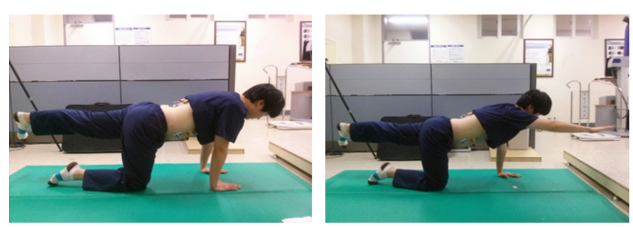


Figure 1. Quadruped position with three different hip flexion angles 70 °, 80 °, 90 °.



(a) **(b)**

Figure 2. The postures of trunk stabilization exercise, **(a)** Left leg raising in quadruped position and **(b)** Left leg and right arm raising in quadruped position.

endured this position with aligning the head, trunk, pelvis, and raised their left leg by fully extending the knee joint and elbow and neutralizing the ankle. The measurement was repeatedly performed three times and performed again when failing to maintain the quadruped position, as also shown in Figure 1. Quadruped position with three different hip flexion angles due to an imbalance.

2.3 Instrumentation and Attachment Method of Electrodes

To measure the electrical activity of the RA, EO and ES muscles, a surface electromyography system OQUS100 (Zero WIRE EMG, Italy) was used during trunk stabilization exercises in the quadruped position. The raw data were collected at a sampling frequency of 1,000Hz and band-pass filtered between 8 and 500Hz and full-wave rectified using analysis software. For analysis, the collected EMG signals were processed by means of Root Mean Square (RMS) value[21]. The skin was prepared by shaving excess hair and rubbing the skin with alcohol and sandpaper to reduce impedance. The sEMG electrodes were attached parallel to each other on the skin above the RA, EO and ES muscle fibers as shown in Figure 3. Here, we attach the electrodes as follows: The RA (1 cm above umbilicus and 2 cm lateral to midline), the EO (15cm lateral to umbilicus) and the ES (3cm lateral to L3 spinous process)[1,21]. Electro-goniometer (Authorized CE representative RMS, UK Ltd.) was used to maintain the hip joint flexion angles (70°, 80° and 90°) in the quadruped position, as shown in Figure 4.

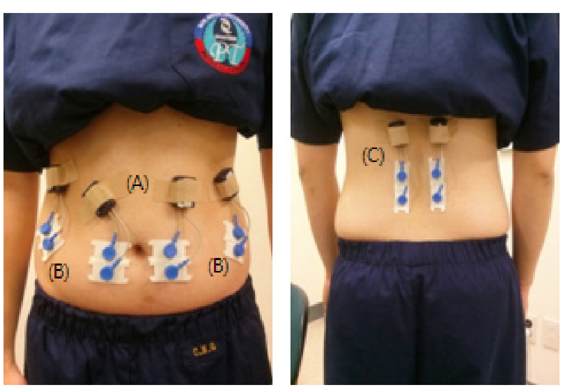


Figure 3. Electrodes of the RA, EO and ES muscle. **(a)** RA (Rectus abdominal muscle), **(b)** EO (External oblique muscle) and **(c)**: ES (Erector spinae muscle)

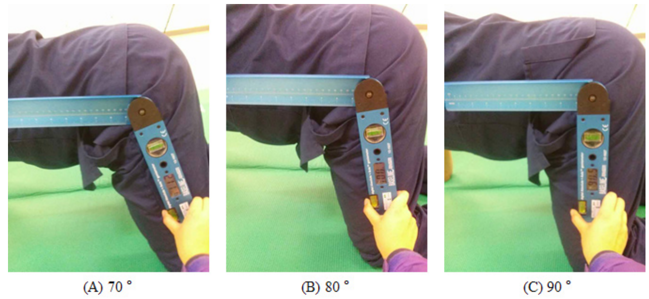


Figure 4. Angle of Hip with Electro-goniometer.

2.4 Maximal Voluntary Isometric Contractions (MVICs) Measurement

Three different isometric exercises against manual resistance were performed to provide a basis EMG signal amplitude normalization. With regard to the measurement, this study averaged electromyographic signals for 3 seconds except the first and last two seconds after processing the data values performed for 5 seconds with the RMS value to use them as MVIC. For the RA, the upper trunk was maximally flexed with maximum resistance applied to the shoulders in the trunk extension direction, with knees flexed 90°. For the EO, the trunk was maximally flexed and rotated, with maximum resistance at the shoulders in the opposite direction of rotation with knees flexed 90°in the supine position. The MVIC of the ES was obtained during the isometric extension exertion in the Biering-Sorensen position. Verbal commends were given to ensure maximal effort. The MVC values of the muscles were measured in three trials before the experimental tasks. 2minutes rest allowed between each trial. All subjects were familiarized with the tasks before data were recorded. The average of the 3 MVIC trials provided the value for normalization.

The %MVIC value was calculated using the following formula to determine muscle activity of RA, EO and ES.

$$\text{MVIC}(\%) = \text{Exercise mean amplitude} / \text{MVIC} \times 100 \quad (1)$$

2.5 Statistical Analysis

All statistical analysis was performed using the SPSS v18.0 for windows program (SPSS NC. Chicago. IL). The mean and standard deviations of variables were calculated by descriptive statistics. One way repeated ANOVA was used to compare the muscle activation during the trunk stabilization exercise in quadruped position according to the hip flexion angle 70, 80, 90. Paired t-test was used to compared muscle activation between left and right trunk muscles (RA, EO, ES). A post hoc test was performed using Bonferroni correction. The significance of level was set at $p<.05$.

3. Results

3.1 The Activations of the Trunk Muscles According to the Postures

The EO muscle activation between left and right side showed significant differences during the stabilization exercises in the quadruped position ($p<.05$). In raising the left leg, the %MVIC values of the ES muscles was significantly difference according to the hip flexion angles between 70° and 80° ($p<.05$). It was observed the activations of trunk muscles according to the postures in Figure 5, 6. The activity of the left ES muscles were significantly higher than that on the right side in %MVIC between left and right side muscles with raising the left leg according to each hip flexion angle raising the left leg and right arm left leg with the hip flexion angle 80° ($p<.05$). The EMG activities of the left and right RA muscle were not significant differences during the motion in the quadruped position, as shown in Figure 5, 6 ($p>.05$).

3.2 The Activations of the Trunk Muscles According to the Different Hip Flexion Angle

According to Table 2, the %MVIC values of the ES muscles was significantly difference in raising the left leg according to the hip flexion angles in the quadruped position ($p<.05$). The activity of the ES muscle showed activation in the quadruped position was higher at a hip flexion angle of 90°(22.86±11.28) than that of 70°(13.93±7.80). In raising the right arm and the left leg, it can be seen from Table 3 that the %MVIC values of the ES muscles was significantly difference according to the hip joint flexion angles($p>.05$). When performing the stabilization exercises motion in the quadruped position, the activity of the ES muscle showed activation was higher at a hip flexion angle of 90°(30.34 ± 13.85) than that of 70°(17.25 ± 8.38). The EMG activities of other muscles, RA and EO, were not significant difference among the hip flexion angles ($p>.05$) as shown in Table 2, 3.

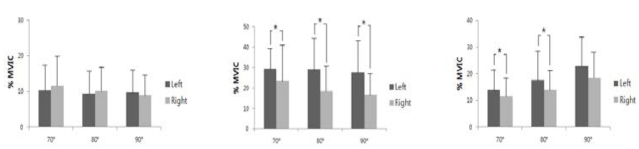


Figure 5. %MVIC between left and right side muscles with raising the left leg according to each hip flexion angle.

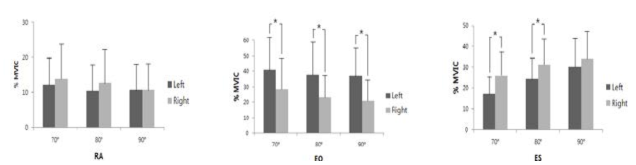


Figure 6. %MVIC between left and right side muscles with raising the left leg and right arm according to each hip flexion angle.

4. Discussion

The muscle activations of RA and EO were decreased and that of ES were increased with increasing the hip joint flexion angle. In the quadruped position, the RA and EO muscle showed highiest activation at hip flexion angle 70° and the ES muscle showed the highiest activation at 90°. The muscle activity is correlated with muscle length and joint angle. Therefore, we suggested that it is more effective to exercise in quadruped position by considering the hip flexion angle. The Trunk stabilization precede extremity movement as the ability to control the trunk position and movement in the pelvic[16]. Among them, quadruped position is often recommended in clinical practice because it maintains the neutral spine position in order to avoid the excessive load on the spine and prevent damage[14,15,19,29].

Many studies have been conducted to examine the muscle activity in the quadruped position according to the use of exercise equipment such as exercise ball or ground conditions. However, there were insufficient studies with which conducted to examine the muscle activity of quadruped position according to changes in hip joint angle. This study analyzed muscle activation while performing trunk stabilization exercises in quadruped position at hip flexion angles of 70°, 80°, and 90° by using sEMG.

Previous studies have reported that activity of rectus abdominis, external oblique, transverse abdominis/internal oblique, and multifidus muscle when performing trunk stabilization exercises was promoted[6,27]. Some author has studied the activity of rectus abdominis, external and internal oblique muscles when performing trunk stabilization exercises in supine and quadruped positions[26]. According to the results, the oblique muscles

Table 2. Muscle activations (%MVIC) of the trunk muscles in the quadruped position with raising the left leg according to the different hip flexion angle (%MVIC)

	RA		t	EO		t	ES		t
	Left	Right		Left	Right		Left	Right	
70°	10.32 ± 7.05	11.58 ± 8.38	−1.07	29.30 ± 13.05	23.49 ± 18.35	2.52*	13.93 ± 7.80	11.43 ± 7.31	3.65*
80°	9.39 ± 6.29	10.15 ± 6.82	−1.67	29.09 ± 15.97	18.55 ± 12.61	3.88*	17.56 ± 11.19	13.96 ± 7.37	2.58*
90°	9.76 ± 6.41	8.85 ± 5.83	− .09	27.86 ± 15.98	16.75 ± 10.85	4.77*	22.86 ± 11.28	18.38 ± 9.83	1.60
p	.88	.39		.93	.23		.01*	.01*	

*$p < .05$ All values are mean±standard deviation, RA (rectus abdominis muscle), EO (external oblique muscle), ES (erector muscle of spine)

Table 3. Muscle activations (%MVIC) of the trunk muscles in the quadruped position with raising the left leg and right arm according to the different hip flexion angle (%MVIC)

	RA		t	EO		t	ES		t
	Left	Right		Left	Right		Left	Right	
70°	12.17 ± 7.84	13.85 ± 10.03	− .09	40.78 ± 21.45	28.60 ± 20.28	4.76*	17.25 ± 8.38	26.01 ± 11.32	1.60
80°	10.40 ± 7.54	12.70 ± 9.69	−1.67	37.76 ± 21.13	23.12 ± 14.72	3.87*	24.29 ± 10.20	31.21 ± 12.27	2.58*
90°	10.66 ± 7.53	10.75 ± 7.58	− .09	36.96 ± 18.53	21.02 ± 13.57	4.77*	30.34 ± 13.85	34.07 ± 13.18	1.60
p	.66	.47		.77	.23		.00*	.06	

*$p < .05$ All values are mean±standard deviation, RA (rectus abdominis muscle), EO (external oblique muscle), ES (erector muscle of spine)

showed higher muscle activity than the rectus abdominis muscle during the exercise in the quadruped position[26]. The results of this study also showed that the external oblique muscle showed relatively higher activity than the rectus abdominis muscle.

Moreover, in this study the activity of the left external oblique muscle was higher than the right one during the motion in the quadruped position. These result agree with those of previous studies that showed high activity of external oblique muscles on the side the raised leg with the left leg and right arm raised[9,26,28]. It is considered that external oblique muscles keep the spine neutral to gravity by controlling[26,28] the trunk rotation generated in the process of raising an arm and leg because the external oblique muscle on the side of the raised leg contracts more in the direction of trunk rotation.

Previous studies have reported that internal oblique muscle on the same side of the raised arm and opposite external oblique muscle play a role in stabilizing in when raising the arm and at the same time the erector spinae muscle on the side of the raised leg showed higher muscle activity[26]. In addition, some author has reported that the muscle activity of the raised leg was higher than that on the opposite side when raising the leg in the quadruped position because muscle strength increased by the mass of the raised leg[11]. Furthermore, in this study, there was a significant difference in the activity of the erector spinae muscles, and the results of this study were similar to those of previous studies in that the activity of the left erector spinae muscles were higher than that on the right side in raising the left leg and right arm left leg.

Some research has studied the activity of trunk and gluteus maximus muscles in healthy adults when performing trunk stabilization exercises in the quadruped position and compared the basic quadruped position at a hip joint flexion angle of 90° with that of 120°[27]. As a result, the remaining abdominal muscles such as rectus abdominis, external oblique, and opposite internal oblique muscles except the internal oblique muscle on the same side showed a low muscle activity in the latter quadruped position. Moreover, in this study, the activity of erector spinae muscle increased with increasing the hip flexion angle. Muscle strength is correlated with muscle activity and varies according to joint angle. Muscle strength varies depending on the angle of proximal joint, and this can be described by the relation between muscle length and tension[24]. It is considered that erector spinae muscle is more activated with increasing the flexion angle to prevent hip joints from leaning backward in maintaining the quadruped position.

For the limitations of this study, the subjects were limited to healthy adults in their 20s, so it is hard to generalize the study results to various age groups. Furthermore, this study could not perform an analysis by gender despite that the male female ratio was appropriate and select various hip joint angles. Based on them, it is considered that further research needs to investigate the effects of trunk stabilization exercises at various hip joint angle considering various age and the continuous effects through the long-term study in the future.

5. Conclusion

The muscle activations of RA and EO were decreased and that of ES were increased with increasing the hip joint flexion angle. In the quadruped position, the RA and EO muscle showed highiest activation at hip flexion angle 70° and the ES muscle showed the highiest activation at 90°. The muscle activity is correlated with muscle length and joint angle. Therefore, we suggested that it is more effective to exercise in quadruped position by considering the hip flexion angle.

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