



Original Article

## The effect of the trunk and gluteus maximus muscle activities according to support surface and hip joint rotation during bridge exercise

CHAN-MYEONG KIM, MSc, PT<sup>1)</sup>, YONG- SOO KONG, PhD, PT<sup>2)</sup>, YOON-TAE HWANG, PhD, PT<sup>2)</sup>,  
JI-WON PARK, PhD, PT<sup>1)</sup>\*

<sup>1)</sup> Department of Physical Therapy, College of Medical Science, Catholic University of Daegu:  
13-13 Hayang-ro, Hayang-eup, Gyeongsan-si, Gyeongbuk 712-702, Republic of Korea

<sup>2)</sup> Department of Physical Therapy, Gangneung Yeongdong College, Republic of Korea

**Abstract.** [Purpose] The purposes of this study were to strengthen gluteus maximus and trunk muscles depending upon the hip joint direction by bridging exercise on an unstable and stable surface, and to suggest an intervention method for efficient and selective exercise. [Participants and Methods] The test measured the muscle activities with the external rotation and internal rotation of 25 degrees and hip joint neutral position of 0 degree on a stable and unstable surface each exercise 3 times for 9 seconds. [Results] External oblique abdominis showed a higher muscle activity on the unstable surface and internal rotation. Erector spinae showed no significant difference on the surfaces and demonstrated the highest muscle activity at the internal rotation. Gluteus maximus showed a higher muscle activity on the stable surface and external rotation and the interaction effect between the surface and the angle indicated a statistical significance as well. [Conclusion] Muscle activities appear different depending upon the change of surface and joint angle, and it can be said that the correct mobilization of muscle fiber relying on the muscle arrangement direction and muscle contraction direction is the most important factor for gluteus maximus.

**Key words:** Bridging exercise, Unstable surface, Electromyography

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### INTRODUCTION

At least once in a lifetime, 50 to 90 percent of the population experience low back pain<sup>1)</sup>. Lumbago gets worse and becomes chronic, physical activities get restricted since the cross sectional area of muscle around the spine comes to decrease and the disuse muscle atrophy incurs<sup>2)</sup>. It is very important to determine the hazard factors of chronic lumbago, and studies that can be very important contributions to the patients of chronic lumbago are actively being under way to prevent the factors such as muscle imbalance, malfunction, smoking, obesity and so forth<sup>3)</sup>. When curing lumbago, medication, physical treatment, etc. are effective for pain relief at acute and sub-acute stages, but an exercise cure is mostly used to strengthen muscles and ligaments since drug treatment and physical therapy only temporarily ease the pain in case of chronic lumbago but they cannot solve the fundamental causes<sup>4)</sup>. In addition, since lumbago can cause muscle weakness, endurance deterioration, flexibility loss, and restriction of joint exercise range of waist and lower limb, exercise treatment is performed for lumbago patients<sup>5)</sup>. Bridging exercise is widely used as a body stabilization program in clinical treatment, can retrain global muscles and local muscles to coordinate in proper ratio<sup>6)</sup>, and it is reported as a crossed chain muscle strengthening exercise and a weight bearing exercise that produces shearing force, increase of joint pressure, growth of joint stability and consistency, increase of dynamic stability, stimulus of myoreceptor, etc<sup>7)</sup>. Kong et al.<sup>8)</sup> chose the bridging exercise as a training method to improve the proprioceptive sensibility function to the chronic lumbago patients suffered from spinae instability and de-

\*Corresponding author. Ji-won Park (E-mail: mylovept@daum.net)

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generative disease, and they said that bridging exercise is a useful exercise to control fine movements through adjustment and maintenance of balance. And bridging exercise is reported to help strengthen the muscle of gluteus maximus at hip joint extensor group<sup>9</sup>). Weakening of gluteus maximus and decreased activity can cause excessive activity of hamstring muscle and erector spinae when performing functional movement<sup>10, 11</sup>), and deterioration of gluteus maximus can bring about the instability of sacroiliac joint<sup>12</sup>). Gluteus maximus provides pressure power for the stability of sacroiliac joint at the beginning stage of gait<sup>13</sup>), so it is used in relief of backaches or rehabilitation of patients with leg damage since the exercise strengthening the muscle of gluteus maximus improves a positive result for the disease mentioned above<sup>14</sup>), and especially it can help the stability of sacroiliac joint, strength for lifting, and gait control<sup>15</sup>). Muscular power strengthening exercise is an important exercise since injuries to nether extremities, patellar femoral pain syndrome, sprain of anterior cruciate ligament, chronic injuries to ankle and lumbago can be progressed if an imbalance between muscles occurs due to deterioration of gluteus maximus muscle<sup>16-18</sup>). There are many studies on the influence to trunk muscle activities and the change of activity ratio of global muscle and local muscle in case that a Swiss ball is applied when performing bridge exercise, which is executed through various postures when performing bridging exercise for core stabilization<sup>19, 20</sup>), and the exercise using Swiss ball, one of dynamic stability therapies, has been reported to be able to strengthen the power, endurance and flexibility of muscle<sup>21</sup>), so people can relatively simply and friendly approach this exercise without resistance than other fitness equipments because this exercise is a low impact exercise that gives little impact to the body<sup>22</sup>). Stanton et al.<sup>23</sup>) reported that the Swiss ball exercise is effective for the stabilization of trunk core muscles, and O'Sullivan et al.<sup>24</sup>) said that exercises such as the treatment ball with dynamic core stability is a little more strong exercise than the exercise on the fixed ground with static core stability, and these exercises improve maintenance ability and sense of balance since they galvanize the proprioceptor and stimulate the organs of locomotion in the brain. It's because various trunk muscles are used to maintain balance when exercising due to the instability of Swiss ball by nature<sup>25</sup>). Sakamoto et al.<sup>26</sup>) reported that the exercise with knee bending at prone position and with hip joint at external rotation posture shows a high muscular activity of gluteus maximus. Many studies have been made to strengthen gluteus maximus all the while, but the study comparing the muscle activities of gluteus maximus by change of surface and rotation angle of hip joint is insufficient. The purpose of bridge exercise is to perform activities functionally by improving muscular strength, and it is very important to understand the effect activities of abdominal muscles and gluteus maximus muscle after bridge exercise are performed. Therefore, we tried to check the change of muscle activities depending upon the rotation angle on the stable surface using table and the rotation angle of hip joint on the unstable surface using a Swiss ball when performing bridging exercise that is widely used for muscular exercise of gluteus maximus and trunk muscle.

This study was intended to demonstrate the surface condition and hip joint rotation angle are affected in abdominal muscles and gluteus maximus muscle.

## PARTICIPANTS AND METHODS

Participants for this study are 28 normal persons who are in Y College located at Gangwon-do Province, and the researcher classified the participants for study in random allocation method. Participants have general characteristics of average age of  $26.43 \pm 3.42$ , average height of  $174.45 \pm 4.19$  cm, and average weight of  $73.96 \pm 8.47$  kg (Table 1). This study was made after explaining the purpose and method of study and preparing participants' consents prior to experiment, and the consents were prepared according to the ethics standard of Declaration of Helsinki, and we proceeded this study after getting the approval (approval number: CUIRB-2016-0048) through the application to the institutional review board) of Daegu Catholic University. For the consistency of experiment, three experienced therapists conducted the tests. We made participants both arms open around 30 degrees wide, let the palms place on the surface, had the head and neck straight, and made them to look at the ceiling. We set up the bending angle of knee joint at 0 degree, ankle joint at 90 degrees, maintained the width between feet at 25 cm, and placed the ankle above the surface. After that attached the OB-goniometer to the sole of the foot and then hip joint was placed to the angle of the experiment. Above stable surface and unstable surface, we measured the muscle activities at the hip joint angle with neutral position of 0 degree, external rotation of 25 degrees and internal rotation of 25 degrees. When the tester said "Raise your hips", the participants raised their pelvis. When they heard "Stay", they maintained that position for 9 seconds. When the instruction "Put your hips down" was given, they put their pelvis down and rested for 60 seconds. Each type of bridge exercise was performed three times, and the measurements were made repeatedly in a random order. To take a look at the muscular activities of trunk muscle and gluteus maximus, we used an radio-electromyogram (Telemyo 2400T-G2, Noraxon, USA). The bipolar snap electrode composed with ground electrode, active electrode, and reference electrode is connected as a measuring electrode with the system of electromyogram. Surface electromyogram signals were received from 2 channels, transformed into digital signals by remote control system, and transmitted to the computer in the Bluetooth method. In addition, the surface electromyogram signals that are treated digitally at electromyogram system were processed through MR-XP program in personal computers. Sampling rate of electromyogram signals was 1,024 Hz, and we used a notch filter for the band pass filter between 20 Hz and 500 Hz and for 60 Hz, and treated and analyzed the collected signals by root mean square (RMS) after full wave rectification. To decrease skin resistance, we sandpapered 3 to 4 times and removed the dead skin cells on the areas where electrodes are to be attached, cleaned the skin by soaked absorbent cotton with rubbing alcohol, placed ground electrodes on the anterior superior iliac spine (ASIS), and attached bipolar surface electrodes on the dominant muscles of the experiment participants depending on the driving direction of muscular fiber. We placed electrodes

**Table 1.** General characteristics of the participants (n=28)

Gender	28 males
Age (years)	26.4 ± 3.4
Height (cm)	174.5 ± 4.2
Weight (kg)	74.0 ± 8.5
All values are means ± standard deviation (SD).	

**Table 2.** Comparison of muscle activities according to support surface and hip joint rotation (M ± SD)

Muscle	Group	Condition		
		NT 0°(A)	ER 25°(B)	IR 25°(C)
EO	SB	8.8 ± 5.4	7.4 ± 5.1	9.1 ± 5.3
	UB*	10.5 ± 6.4	9.6 ± 5.4	12.8 ± 8.5
ES	SB	42.6 ± 21.3	40.7 ± 20.2	46.8 ± 19.0
	UB	43.5 ± 17.8	43.1 ± 19.5	46.6 ± 17.6
GM	SB**	7.0 ± 4.2	19.3 ± 15.8	5.5 ± 2.2
	UB	5.1 ± 1.7	9.3 ± 7.1	5.1 ± 1.9

\*p<0.05, \*\*p<0.001, SB: Stable surface; UB: Unstable surface; NT: Neutral position; ER: External rotation; IR: Internal rotation.

1 Significantly different compared with condition A.

2 Significantly different compared with condition B.

3 Significantly different compared with condition C.

on three muscles in total and measured the muscular activities of trunk muscle depending upon intervention methods, and attached the electrodes on the spot 15 cm out from navel for external oblique (EO), on the spot 2 cm out from L2 neural spine for erector spinae (ES), and on the middle point of the line that linked the lower outer angle of sacrum with the femoral greater trochanter for gluteus maximus (GM). For standardization of each muscular action potential, we used maximal voluntary isometric contraction (MVIC), and employed the method of Kendall et al.<sup>27)</sup> for the manual muscle pose for maximal voluntary isometric contraction. We performed the motion of each pose for 9 seconds, and analyzed the muscle activities through measured values for 3 seconds excluding the first 3 seconds and the last 3 seconds in order to diminish errors at the beginning and in the final parts. We measured three times of muscle electromyogram of all movements and calculated an average figure from the measurements. Through SPSS ver 20.0, a commercialized program for statistics, we calculated and analyzed the mean values and standard deviations of each variable for the processing of the data collected from this study. We analyzed muscle activities through the repeated measure of two way analysis of variance (ANOVA), used LSD for the post-hoc test when finding the core effect on the groups and conditions, and set up p<0.05 for the significant level ( $\alpha$ ).

## RESULTS

External oblique showed a higher muscle activity on the unstable surface (p<0.05), and indicated the highest muscular activity at the hip joint inversion of 25 degrees. However, the interrelations between surface and rotation angles showed no statistically significant difference. Erector spinae showed no significant difference depending on the surface (p<0.05), and indicated the highest muscle activity at the internal rotation of 25 degrees. However, interrelations between surface and rotation angle showed no statistically significant difference. Gluteus maximus showed a higher muscle activity on the stable surface (p<0.05), indicated the highest muscular activity at the external rotation of 25 degrees, and the effect of interaction between surface and rotation angle of hip joint appeared statistically significant as well (Table 2).

## DISCUSSION

It is important to improve pose control ability through figuring out the correct factors of the weakened muscles and reeducation of muscle for treatment of the musculoskeletal disease these days. It is particularly reported that the damage of soft tissues of trunk muscle and deterioration of muscular force can be the main causes of lumbago which is a typical musculoskeletal disease, and thereby causes pain, endurance decline, flexibility decrease, and restriction of trunk joint exercise<sup>28)</sup>. Many discussions have been made in the meantime on how to strengthen the trunk stabilization and gluteus maximus for the treatment and cure of lumbago, but it is desired to study comparing the activities of gluteus maximus depending upon the change of surface and rotation angle of hip joint. So, this study was performed to check the change of muscle activities of trunk and gluteus maximus according to the rotation angles at neutral position of 0 degree, external rotation of 25 degrees, and inversion of 25 degrees of hip joint on the unstable surface using a Swiss ball and on the stable surface using a table through the bridge exercise that is widely used as a muscle strengthening exercise of gluteus maximus and trunk muscle. External oblique (EO) showed a higher muscle activity on the unstable surface than the stable surface, and indicated the highest muscle activity at the inversion of 25 degrees of hip joint. It was reported that when exercising with a Swiss ball on the unstable surface, muscle activities come to increase due to the occurrence of external oblique joint contraction that is caused by their struggle to overcome the bilateral instability<sup>29)</sup>. It also showed a result in this experiment that the muscle activity of external oblique which is an abdominal muscle, increased significantly for the stabilization of trunk on the unstable surface. Myers et al.<sup>30)</sup> reported that if a bridge pose of hip joint adductor is exercised, the hip joints are connected with fine

muscles through spina iliac anterior superior, and can transfer power to abdominal muscles. In addition, it was reported that adductor muscle of hip joint works as inversion and adjusts the location of joints, improves the stability of trunk through making a good condition for abdominal muscles to contract, and can promote the functional activities between hip joints, spine and nether extremities<sup>31, 32</sup>), and we think that it also shows the highest muscle activities at the inversion of 25 degrees in this experiment due to these influences.

Erector spinae (ES) showed no significant difference depending on the surface, and indicated the highest muscle activities at the inversion of 25 degrees of hip joint. Studies by Stevens et al.<sup>33</sup>) and by Imai et al.<sup>34</sup>) also indicated that when a bridging exercise is performed on the unstable surface, multifidus muscles and erector spinae show no change in the ratio of trunk muscle activities because the trunk outer muscles are contracted and block the potential of spine and pelvis in order to maintain the trunk stability when applying the unstable surface, and they reported that the multifidus muscles and erector spinae are not influenced from the instability of surface since they do not play a leading role on the unstable surface. We also found the highest muscle activities in the external oblique and erector spinae at the inversion of 25 degrees of hip joint on both stable surface and unstable surface, and thus we think it as a result from the same reason as the foresaid theses that the locations of joints come to be adjusted into a condition which is good for the contraction of adductor and trunk muscles when inversion of hip joints is applied. Gluteus maximus showed a higher muscle activity on the stable surface than the unstable surface, and indicated the highest muscle activity at the external rotation of 25 degrees of hip joint. It is reported that arrangement direction of muscular fiber contributes to muscular contraction, and gluteus maximus comes to be efficient and to reach the maximum muscle activities when the arrangement and contraction direction of muscle are identical<sup>35-37</sup>), so we think that gluteus maximus shows a higher muscle activity on the stable surface than the unstable surface since muscle fiber of gluteus maximus accomplishes the correct muscle contraction mobilization when making the external rotation based on the trunk stabilization on a stable surface like this. In addition, when exercising on the Swiss ball, joint contraction of external and internal oblique occurs, and thus the muscle activities of external oblique increase significantly in order to overcome the instability, so we think on this account that gluteus maximus does not show the relatively high muscle activity due to the positive joint contraction of activity for stabilization of trunk muscles in order to overcome the instability on the unstable surface. Selkowitz et al.<sup>38</sup>) reported that gluteus maximus comes to be active when the exercises including external rotation and straightening of hip joints which are arranged in the same direction as the arrangement direction of gluteus maximus are performed, and this experiment also produced the same results that gluteus maximus shows a higher muscle activity at the external rotation of hip joint as the results of the studies introduced earlier. Since the measurements in this study were made through the participants with good health and in their twenties, we can think it as the first restrictions of this study that generalizing and applying the result of this study for the patients with the pain at waist and pelvis could encounter a restriction. Secondly, we could not fully exclude the influence that muscular movement affects on the electromyogram signal in order to maintain posture during exercising. Thirdly, measurements on the diverse muscles working for the trunk stabilization were insufficient, and femur torsion angle and pelvis angle were not taken into consideration. Therefore, we think it necessary to study further on the local muscles and the global muscles related to trunk stabilization and the various muscles related to the hip joint rotation with consideration for femur torsion angle and pelvis angle targeting diverse gender and age. Bridge exercises activate the superficial and deep trunk muscles at an appropriate ratio and strengthen the gluteus and lower leg muscles and then it helps reduce back pain. It is important exercise. Many bridge exercise studies have shown that the unstable surface is effective. It can be said that the most important factor for the muscle activities of global muscles such as gluteus maximus is muscle arrangement direction and correct mobilization of muscle fiber rather than surface change. Therefore, we think that this study would be used as a valuable data in order to selectively exercise the muscles that try to strengthen the diverse surfaces and rotation angles when taking an exercise to strengthen trunk muscles and gluteus maximus. Consequently, it is considered that this study will provide useful data for training the muscles to be strengthened selectively considering different supporting surfaces and rotation angles.

### *Conflict of interest*

None.

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