J Korean Soc Phys Med, 2022; 17(3): 1-10
https://doi.org/10.13066/kspm.2022.17.3.1

Online ISSN: 2287-7215
Print ISSN: 1975-311X

Research Article

Open Access

Effects of the Abduction Resistance of the Hip Joint during Bridge Exercise in Patients with Chronic Back Pain: A Cross-Over Study

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Received: July 3 2022 / Revised: July 12 2022 / Accepted: August 2 2022

ⓒ 2022 J Korean Soc Phys Med

| Abstract |

PURPOSE: This study examined the effects of the resistance levels on the muscle activities around the hip and spine during bridge exercise with hip abduction resistance in patients with chronic back pain.
METHODS: A cross-over study design was used. Twenty subjects with low back pain were enrolled in this study. The subjects performed bridge exercises with hip abduction resistances (20 mmHg, 40 mmHg, and 60 mmHg). A Narrow Sling was used to provide resistance. Surface electromyography was used to measure the activity of the erector spinae, biceps femoris, gluteus maximus, and gluteus medius.
RESULTS: The muscle activity of the gluteus maximus and gluteus medius increased significantly with increasing resistance levels. There was a significant difference in the muscle activity of the biceps femoris with a resistance level between 20 mmHg and 40 mmHg, but there was no significant difference in the other resistance levels. There was no significant difference according to resistance level in the erector spinae. The muscle activity ratios of the gluteus medius/erector spinae and gluteus maximus/erector spinae increased significantly with increasing resistance strength.
CONCLUSION: The different levels of abduction resistance for hip abduction during bridge exercise will help activate the gluteus maximus selectively in patients with chronic back pain.

Key Words: Hip joint, Low back pain, Muscle strength

Ⅰ. Introduction

Low back pain is a common musculoskeletal disorder [1,2], that is a problem worldwide with a lifetime prevalence of 84% [2]. Low back pain that has been present for longer than three months is considered chronic, even though there is still no consensus about the definition of chronic low

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back pain [3]. Chronic low back pain has a high incidence, incurs high cost, and causes musculoskeletal disorders, making it one of the most serious public health problems worldwide [4]. Several studies have reported a relationship between abnormal hip mechanics and changed hip muscle performance and various lower extremity and lower back conditions [5-6].

The gluteus medius is the major abductor of the hip, and the gluteus maximus is the major extensor of the hip that is also involved in hip abduction and external rotation [8,9]. Many studies reported that the weakness of the gluteus maximus and gluteus medius cause abnormal compensatory motion, such as altered hip and knee positioning and abnormal muscle activation [5,10-13]. This change in mechanics can lead to several musculoskeletal problems, including various painful conditions in the lower back [5]. A weak gluteus maximus and gluteus medius are associated with chronic lower back pain [7,14,15]. Therefore, several studies suggested that strengthening the gluteus maximus and performing neuromuscular retraining exercises are necessary for rehabilitation and preventing low back pain [7,16,17].

Studies recommended side bridge, wall squat, forward step-up, quadruped upper and lower extremity lift, standing hip abduction (weight bearing on the target/opposite extremity), and side-lying hip abduction to activate the gluteal muscles [13, 18-22]. In addition, previous authors examined the effects of exercises that activate the gluteus maximus and gluteus medius [13,20,23-25]. Previous studies used surface electromyography during specific exercises in various positions for specific strengthening of the gluteus maximus and gluteus medius while decreasing the activities of the tensor fascia latae and lumbar extensor [22,24]: weight-bearing hip abduction exercise [20]; and elastic resistance on the knee, ankle, and foot [26,27]. Gluteus muscle setting exercise, forward bending leg lifts, and quadruped leg raise were recommended for strengthening the gluteus maximus [28]. Bridge exercise with hip abduction is effective in strengthening the gluteus maximus [29]. Bridging with 30° hip abduction selectively facilitate gluteus maximus activity, minimize compensatory erector spinae activity, and decrease the anterior pelvic tilt angle [29].

Although previous studies have reported that it is advantageous to activate the gluteus maximus selectively during bridge exercise [29], no study has examined the selective activation of the gluteus maximus and the gluteus medius and compared the muscle ratio according to the different levels of abduction resistance on the hip joint.

Many patients with low back pain have weakness of the gluteus maximus [6-7]. If there is a change in the gluteus maximus activation, we can recommend the hip abduction resistance during bridge exercise. Therefore, this study examined the effects of resistance levels on the muscle activities around the hip and spine during bridge exercise with hip abduction resistance in patients with chronic back pain.

Ⅱ. Methods

1. Participants

Twenty adult females in their 24.0 ± 2.8 years old with chronic back pain, were included in this study. All subjects agreed voluntarily to participate in this experiment. Before starting the study, all subjects understood its content and signed an informed consent form. This study complied with the ethical standards of the Declaration of Helsinki and was approved by the Research Ethics Committee of Daegu University (1040621-201811-HR-007-02).

The subjects were required to meet the following criteria for inclusion in the study: (1) a patient diagnosed with chronic back pain and low back pain lasting for more than three months by an orthopedic surgeon or rehabilitation medicine doctor; (2) no history of low back surgery due to orthopedic problems; (3) no malformations or fractures of the spine on radiographs; (4) no sensory dysfunction, vestibular disorders, nervous system disorders, respiratory diseases, musculoskeletal disorders in the legs, or neck problems, and not wearing orthosis; and (5) not having performed regular or systematical exercise during daily activities for the last three years [30].

2. Experimental Procedures

This cross-over study design was conducted to compare the muscle activities according to the level of resistance during hip abduction with general bridge exercises. Randomization was needed to minimize a bias in the resistance level. The order of applying resistance was randomized using sealed envelopes were prepared in advance and marked inside with A, B, or C representing 20, 40, and 60 mmHg. A third party who was unaware of the study performed the randomization. Before and after the intervention, Physical therapist 1, who was blinded to the order of applying resistance to the subjects, assessed the subject characteristics and all outcome measures.

The interventions were performed in a closed room by Physical therapist 2, who was not involved in assessing the subjects. Both physicians were instructed not to communicate with the subjects about the study goals or treatments. Fig. 1. presents a flow diagram of the study. The sample size for this study was calculated using the G* Power program 3.1.0 (G power program Version 3.1, Heinrich-Heine-University Du¨sseldorf, Du¨sseldorf, Germany). Based on data from a pilot study, the estimated sample size required to obtain a minimum power of 80% at a significant alpha level of 95% was 16. Accordingly, 20 subjects were recruited to account for a potential dropout rate of 20% (Fig. 1).

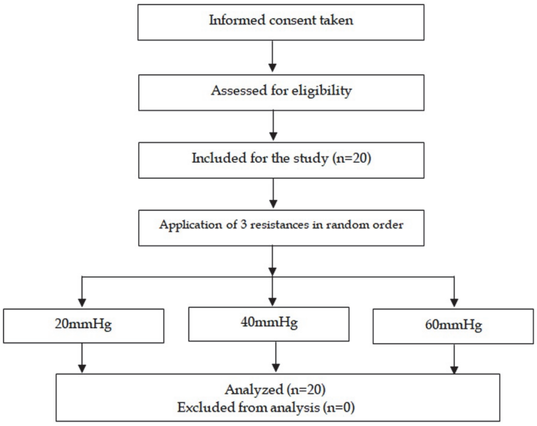

Fig. 1. Study flow chart.

3. Intervention

The muscle activities at three different resistances (20 mmHg, 40 mmHg, and 60 mmHg) during hip abduction with general bridge exercise were compared using a Narrow Sling (Redcord Narrow Sling, Redcord, Norway) was used to provide resistance on the hip abduction [31]. A biofeedback device (Pressure Biofeedback Unit, Chattanooga, USA) was used to determine the amount of the resistance of the hip abduction during bridge exercise. The experimenter put a biofeedback device next to the subject's knee joint. The subjects performed bridge exercise with the resistance of hip abduction (20 mmHg, 40 mmHg, and 60 mmHg) given by the band (Fig. 2).

The experiment was conducted over three days, and the subjects performed one of three interventions to prevent a learning effect. In this study, the bridge exercise was performed by the general method currently used for most patients [32]. The bridge exercise was performed in the following sequence. Before the bridge exercise, an

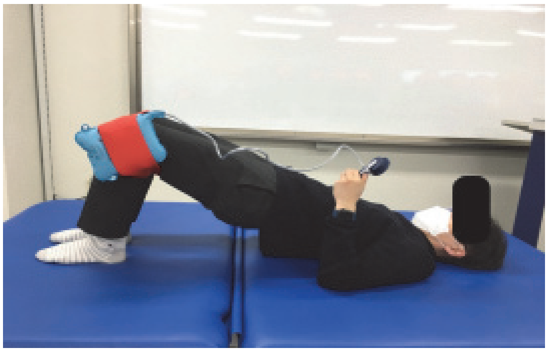

Fig. 2. Bridge exercise during hip abduction resistance.

abdominal drawing-in maneuver with biofeedback device was performed in order to prevent an excessive lumbar flexion caused by the contraction of the rectus abdominis. In the starting position of the bridge, the therapist asked subjects to pull their tummy button toward their spine and hold the position for five seconds during exhalation while maintaining a 70 mmHg pressure. The subjects commenced the bridge exercise lying in the supine position with the knees bent 90°, arms away from the body at approximately 30°, and the palms facing downward on the floor. The feet were placed flat on the floor, shoulder-width apart, and the pelvis was put in a neutral position. The subjects were then instructed to lift their hips off the floor at a hip extension angle of 0°and knee flexion angle of 90° [33]. The biofeedback device was placed on the subject's left knee joint. The subjects were educated about bridge exercises for 10 minutes before the experiment, and each position was performed for seven seconds with three repetitions. Feedback was given continuously given to the subjects during the experiment to ensure that the subjects performed each posture accurately.

4. Measurement

1) Surface Electromyography (EMG)

The surface electromyography device (TeleMyoDTS, Noraxon Ins, Az, USA) was used to measure the activity of the erector spinae, biceps femoris, gluteus maximus, and gluteus medius during hip abduction with the bridge exercise. EMG data were collected and analyzed on the left leg. The centers of the EMG electrodes were kept at a distance of 2 cm, and the EMG electrodes were attached parallel to muscle fibers to obtain the EMG signals with the least possible noise (Fig. 3). At the point of attachment, hair was first removed using a disposable razor, followed by rubbing off the dead skin cells to reduce the skin resistance, and foreign substances were removed with alcohol swabs [34]. For normalization of the EMG data, a maximum voluntary isometric contraction (MVIC) was performed for each muscle and the EMG amplitude was recorded. To measure the activity of the gluteus maximus, the subjects were instructed to perform hip extension with knee flexion at 90° in the prone position. At this time, the resistance was applied to the posterior part of the femur, and the subjects were required to withstand the resistance [35]. To measure the gluteus medius, the subjects were instructed to bend the hip and knee on the lower side in the side-lying position and lift the leg on the upper side. At this time, the subjects were required to withstand the manual resistance applied to the ankle [36].

To measure the biceps femoris activity, the subjects performed knee flexion in the prone position against a manual resistance applied to the ankle [37,38]. For erector spinae activity, the subjects were asked to raise the trunk against the resistance in the prone position while the lower extremities were stabilized firmly on the table [39]. The mean value of the EMG signal was obtained using measurements for three seconds, excluding the measurement data from the first and last one second.

Interventions using 20 mmHg, 40 mmHg, and 60 mmHg resistances were performed and repeated it three times. The mean values were used to determine the %MVIC value. A five-minute break was given between tests to prevent muscle fatigue [40]. According to resistance levels, we compared the result values (gluteus maximus, gluteus medius, biceps femoris, erector spinae, gluteus medius/erector spinae, and gluteus maximus/erector spinae) were compared, and the changes with increasing the level of resistance were identified. The gluteus medius/erector spinae*100 and gluteus maximus/erector spinae*100 were used to calculate the ratio.

5. Statistical Analysis

Data were analyzed using SPSS version 22.0 (SPSS Inc. Chicago, IL) for Windows software. The Shapiro-Wilk test was used for the normality test. The results of the ShapiroeWilk test indeed suggested that the dependent variable was normally distributed ($p > .05$).

The subjects' general characteristics were analyzed using descriptive statistics. One-way repeated measures ANOVA was performed to examine differences among the three resistances. The LSD test was used as a post-hoc test to examine the within-group differences. The level of significance was set to $p < .05$.

Ⅲ. Results

The muscle activity of the gluteus maximus and gluteus medius increased significantly with increasing resistance strength ($p < .05$) (Table 2). The post hoc comparison test showed that the gluteus maximus and gluteus medius activity were significantly different according to the pressure difference ($p < .05$) (Fig. 4). On the other hand, there were no significant differences according to resistance strength in the biceps femoris and erector spinae ($p > .05$) (Table 2). On the other hand, The post hoc comparison test showed significant differences in the biceps femoris between 20 mmHg and 40 mmHg ($p < .05$) (Fig. 4).

The muscle activity ratios of the gluteus medius/erector

Table 1. General Characteristics of the Subjects

General Characteristics	Subjects	Range
Gender (male/female)	0/20	
Age (yrs)	24.0±2.80[a]	21~27
Height (cm)	161.5±3.20	158~165
Weight (kg)	54.1±5.31	48~60
Body mass index (kg/m2)	20.7±1.80	18~23

[a] Mean ± SD

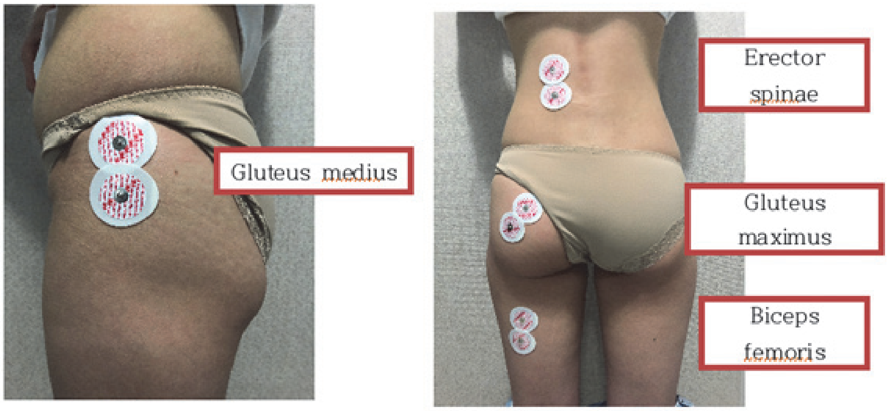

Fig. 3. Location of EMG electrodes.

Table 2. Comparison of the Muscle Activities According to the Resistance Strength

Muscle (% MVIC)	20 mmHg	40 mmHg	60 mmHg	F	P
GMX	15.14 ± 8.80[a]	24.19 ± 12.26	35.24 ± 13.72	21.532	.000*
GM	16.81 ± 12.63	30.15 ± 17.68	52.06 ± 20.89	52.783	.000*
BF	26.26 ± 21.30	22.64 ± 17.80	21.53 ± 20.42	6.392	.751
ES	48.01 ± 18.31	46.42 ± 16.25	49.12 ± 15.60	0.538	.873

[a] Mean ± SD, $*p < .05$

GMX: Gluteus maximus, GM: Gluteus medius, BF: Biceps femoris, ES: Erector spinea

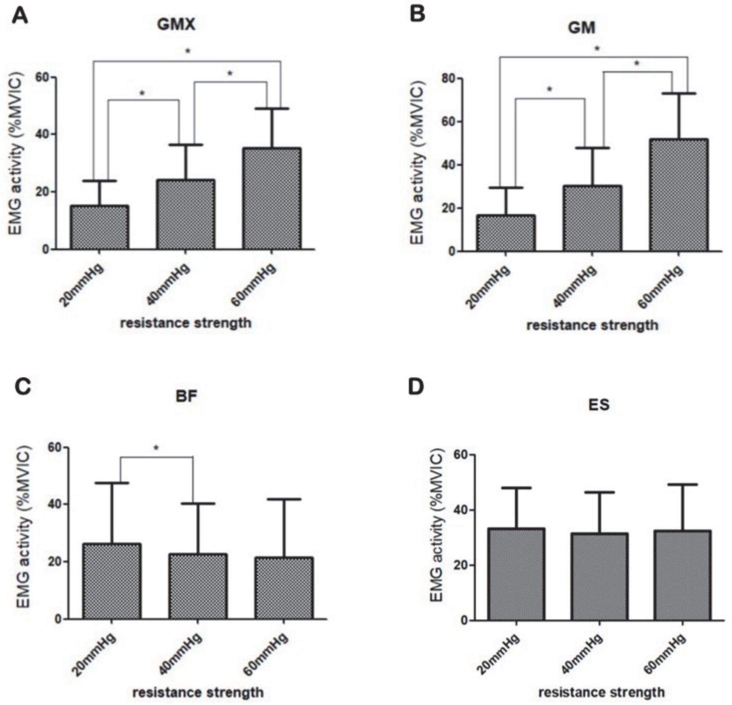

Fig. 4. Comparison of each muscle EMG during resistance strength.
A: gluteus maximus (GMX), B: gluteus medius (GM), C: biceps femoris (BF), D: erector spinae (ES)

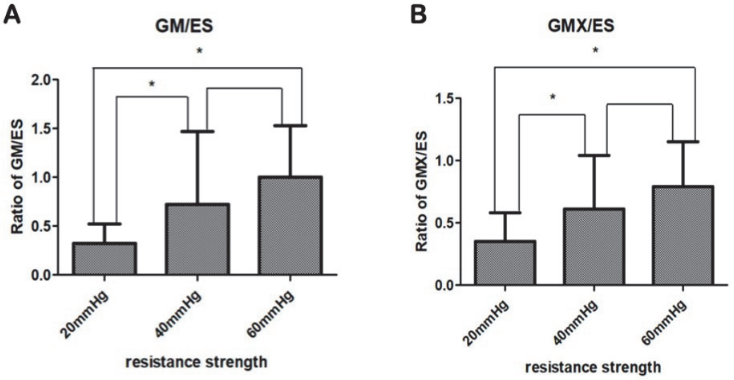

Fig. 5. Comparison of GM / ES and GMX / ES ratios between conditions of bridging exercise.
A: GM/ES, B: GMX/ES

Table 3. Comparison of Muscle Activity Ratios According to the Resistance Strength

Muscle ratio	20 mmHg	40 mmHg	60 mmHg	F	P
GM/ES	0.32 ± 0.20[a]	0.72 ± 0.75	1.00 ± 0.53	16.157	.000*
GMX / ES	0.35 ± 0.23	0.61 ± 0.43	0.79 ± 0.36	21.396	.000*

[a] Mean ± SD, *p < .05

GMX: Gluteus maximus, GM: Gluteus medius, ES: Erector spinea spinae and gluteus maximus/erector spinae increased significantly with increasing resistance strength ($p < .05$) (Table 3). The post hoc comparison test revealed significant differences in the muscle activity ratio of the gluteus medius/erector spinae and gluteus maximus/erector between 20 mmHg and 40 mmHg, and 20 mmHg and 60 mmHg ($p < .05$) (Fig. 5).

Ⅳ. Discussion

This study examined the muscle activities around the hip and spine during bridge exercise with hip abduction resistance in patients with chronic back pain. The key research finding is that different levels of abduction resistance for hip abduction during bridge activated the gluteus maximus selectively in patients with chronic back pain.

The muscle activity of the gluteus maximus increased significantly with increasing resistance level of hip abduction. A previous study reported that the activity of the gluteus maximus could be increased selectively by performing 30° hip abduction during hip joint extension [29]. These results showed that increasing the resistance level of hip abduction could selectively facilitate the gluteus maximus and can increase the activation of the gluteus maximus. Motor unit recruitment refers to the activation of additional motor units to accomplish an increase in contractile strength in a muscle [41]. Muscle control is realized at the level of the motor unit [41,42]. According to the neural mechanisms called the Henneman's size principle, a higher the recruitment indicates a stronger the muscle contraction will be. Motor units are generally recruited from smallest to largest based on the size principle [42-44]. Therefore, when the resistance of the hip abduction is increased, the recruitment of the muscle fibers of the gluteus maximus should be increased to maintain the contraction against hip abduction resistance.

The muscle activity of the gluteus medius increased significantly with increasing resistance level of hip abduction. A previous study examined the effects of various gluteus medius strengthening exercises and reported that of the 11 types of exercises, additional hip joint abduction exercise resulted in the highest activation of the gluteus medius [13]. According to action-reaction law [9] when the same stimulus is given to the human body when an external stimulus is given, it is thought that increasing the resistance to hip abduction increases activation of the gluteus medius.

The muscle activity of the biceps femoris showed no significant changes with increasing resistance level of hip abduction. There was a significant difference in muscle activity in the biceps femoris with resistance level between 20 mmHg and 40 mmHg, but there was no significant difference between 20 mmHg and 60 mmHg, and between 40 mmHg and 60 mmHg. Because the knee angle was limited to 90 degrees in this experiment, hamstring activation was decreased, and the activation of the gluteus maximus was increased. Previous studies confirmed that activation of the hamstring decreased with increasing knee flexion angle [45,46], and when the movement was performed in the same range of motion, decreased activity of one muscle can give rise to increased activity of another muscle to achieve the same range of motion [11]. Thus, it is thought that the increased activity of the gluteus maximus reduced the activity of the biceps femoris. In addition, although the biceps femoris was lowest at an abduction resistance strength of 60 mmHg than at 20 mmHg or 40 mmHg, the post-hoc test revealed no significant difference. These results can be explained by the high standard deviation due to the small sample size.

The muscle activity of the erector spinae showed no significant difference when comparing the value measured at an abduction resistance strength of 60 mmHg with those at 20 mmHg and 40 mmHg. A previous study reported that there were no significant differences in the muscle activity of the erector spinae during bridge exercises on various unstable support surfaces [47]. These results can be explained by the fact that the abdominal drawing-in maneuver suppressed the unnecessary activity of muscles around the spine [48]. In this study, the abdominal drawing-in maneuver decreased the unnecessary muscle activities during bridge exercise. The level of the hip abduction resistance may not have affected the activity of the erector spinae because the bridge exercise with hip abduction resistance was not targeted at the erector spinae.

The gluteus medius/erector spinae muscle activity ratio was significantly higher at a resistance strength of 60 mmHg than at a resistance strength of 20 mmHg, and was significantly higher at 40 mmHg than at 20 mmHg. Similarly, the gluteus maximus/erector spinae muscle activity ratio was significantly higher at 60 mmHg than at 20 mmHg, and at 40 mmHg than at 20 mmHg. A previous study reported that bridging with hip abduction could facilitate gluteus maximus selectively and minimize the compensatory ES muscle activity [29]. Given these findings, it was assumed that increased activity of the gluteus maximus is related to decreased muscle activity of the erector spinae during bridging with hip abduction.

Based on these findings, different levels of hip abduction resistance during bridge exercise can be used to activate the gluteus maximus selectively and decrease the activation of unnecessary muscles in chronic back pain patients. It will be helpful for effective exercise and the selective activation of the gluteus maximus for chronic back pain patients. This study had some limitations. First, it was difficult to generalize the findings of this study because the study was aimed at females in their 20s to 30s. Second, the long-term effects of the bridge exercise with hip abduction resistance were not observed. Third, the standard deviation was high because the number of subjects was too small. Finally, this study could not identify the effects of the core muscles and the interactions among muscles around the trunk, pelvic, hip, and lower extremity. Further studies will be needed to determine the long-term effects, the difference between genders, and the activities of more muscles.

Ⅴ. Conclusion

This study examined the effects of the resistance levels on the muscle activities around the hip and spine during bridge with hip abduction resistance in patients with chronic back pain. The use of different levels of abduction resistance for hip abduction during bridge exercise will help to activate the gluteus maximus selectively in chronic back pain patients. Therefore, if abduction resistance of the hip joint is added to the existing method of bridge exercise for chronic back pain patients, it will be helpful for the selective activation of the gluteus maximus.

Acknowledgement

This research was funded by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT, Ministry of Science and ICT) (No. NRF-2021R1F1A1052333).

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