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Effects of Different Knee Flexion Angles According to Three Positions on Abdominal and Pelvic Muscle Activity During Supine Bridging

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Abstract

This study analyzes how different knee flexion angles affect the abdominal and pelvic muscle activity during supine bridging. Twenty healthy subjects participated in the study. We used surface electromyography (EMG) to measure how three different knee flexion angles (100°, 70°, and 40°) affected the activity of the transverse abdominis/internal oblique (TrA/IO), external oblique (EO), biceps femoris (BF), rectus femoris (RF), and gluteus maximus (GM) muscles on the dominant side during supine bridging. The one-way repeated analysis of variance (ANOVA) was used to determine the statistical significance of TrA/IO, EO, BF, RF and GM muscle activity and the GM/BF activity ratio. For the TrA/IO, EO, BF, and GM muscles, supine bridging with different knee flexion angles resulted in significant differences in abdominal and pelvic muscle activity. For the TrA/IO muscles, the post-hoc test demonstrated that muscle activity significantly increased at 40° compared to 70°; however, there were no significant differences between 100° and 70° or 100° and 40°. For the EO muscle, the post-hoc test demonstrated that muscle activity significantly increased at 40° compared to 100° and 70°; no significant difference was observed between angles 100° and 70°. For the BF muscle, the post-hoc test demonstrated that muscle activity significantly increased according to the knee flexion angle (40°>70°>100°). For the GM muscle, the post-hoc test demonstrated that muscle activity significantly increased according to the knee flexion angle (100°>70°>40°). However, for the RF muscle, there was no significant difference. Additionally, the GM/BF activity ratio significantly increased according to the knee flexion angle (100°>70°>40°). From these results, we can conclude that bridging with a knee flexion of 100° can strengthen the GM muscle, whereas bridging with a knee flexion of 40° is recommended to strengthen the IO, EO, and BF muscles. We can also conclude that knee flexion angles should be modified during supine bridging to increase the muscle activity of different target muscles.

Key Words: Abdominal muscles; Electromyography; Muscle strength.

Introduction

Bridging, also known as the bridge exercise, is commonly used in clinical settings to reinforce lumbopelvic stability by increasing trunk muscle activity (Marshall and Murphy, 2005; Stevens et al, 2006). Bridging involves holding the pelvis off the floor in either the supine (back bridges), prone (front or ventral bridges), or lateral position (side bridges) (Bjerkefors et al, 2010; Ekstrom et al, 2007; Imai et al, 2010; Kavcic et al, 2004; Lehman et al, 2005; McGill and Karpowicz, 2009; Stevens et al, 2006).

Patients suffering from low back pain (LBP) (García-Vaquero et al, 2012) or hemiplegia (Kozol et al, 2010) typically employ bridging to strengthen their trunk and hip muscles. Bridging is also used for resistive exercises, including various methods to control body weight. Depending on the client's condition, the complexity of bridging can be modified by a rehabilitation specialist. Previous studies have suggested that exercises using unstable devices, such as a therapeutic ball (Marshall and Murphy, 2005;

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Stevens et al, 2006) or a round foam roll (Kim et al, 2011), increase the trunk's muscular activity, which helps to stabilize the lumbopelvic spine during bridging.

Previous studies suggested that bridging can strengthen the hip extensor (Andersen et al, 2006; Ekstrom et al, 2007; Myklebust and Engebretsen, 2004). Clinicians often modify the bridge exercise with different methods to allow for a gradual increase in the intensity of the exercise (Lehman et al, 2005). Despite many studies on bridging, no study has investigated how different angles of knee flexion with double leg support affect abdominal and pelvic muscle activity during bridging.

Though the complexity of bridging has been modified for use with various patient populations, the majority of electromyographic (EMG) studies have only analyzed the trunk's muscular response during conventional bridging. The effects of different knee flexion angles on the abdominal and pelvic muscle activity during bridging has not been examined in previous studies. To our knowledge, the effect of these leg support strategies has only been studied for supine bridging with single or double leg support (Bjerkefors et al, 2010; Ekstrom et al, 2007; Kavcic et al, 2004; Stevens et al, 2006; Stevens et al, 2007). Previous studies indicated that leg support strategies during bridging exercise could constitute a major challenge to the neuromuscular system and possibly result in higher loads on the spine (Kavcic et al, 2004). In order to help rehabilitation specialists determine progressive exercise protocols for the abdominal and pelvic musculature, an additional research is needed to clarify the effect of leg support using strategies that include knee flexion angle in the supine position. To the best of our knowledge, this is the first study to investigate the effects of different knee flexion angles on abdominal and pelvic muscle activity during supine bridging.

The purpose of this study is to analyze how different knee flexion angles (100°, 70°, and 40°) affect the activity of abdominal [transverse abdominis/internal oblique (TrA/IO) and external oblique (EO)] and pelvic [rectus femoris (RF), biceps femoris (BF), and gluteus maximus (GM)] muscles during supine bridging. The hypothesis of this study is that the abdominal and pelvic muscle activity during supine bridging will differ in various knee flexion angles.

Methods

Subjects

Based on our pilot data and using G*Power 3.1.5 software (Franz Faul, University of Kiel, Kiel, Germany) (Faul et al, 2007), an a priori power analysis was performed to estimate the sample size. The pilot data of 13 asymptomatic subjects were used to achieve an effect size of .43, an alpha level of 5%, and a power of 80%. The estimated desired sample size was 10. Twenty asymptomatic subjects (13 men and 7 women) volunteered to participate in this study (Table 1). Individuals were excluded from participation in this study if they had a history of abdominal or low back pain within six weeks prior to the test or if they were unable to correctly perform a supine bridge.

Instrument

Surface EMG signals were collected using the Noraxon TeleMyo DTS Telemetry system (Noraxon Inc., AZ, USA). EMG data were collected at a sampling rate of 1000 ㎐ and analyzed using the Noraxon MyoResearch Master Edition 1.08 XP software (Noraxon Inc., Scottsdale, AZ, USA). The raw signal was filtered using a digital band-pass filter (Lancosh FIR) between 20 and 450 ㎐ and was also

Table 1. General characteristics of subjects (N=20)

Parameters	Mean±SD[b]
Age (year)	21.5±1.4
Height (㎝)	170.6±7.6
Weight (㎏)	62.4±10.1
BMI[a] (kg/㎡)	21.3±2.7

[a]body mass index, [b]mean±standard deviation.

notch filtered (60 ㎐, 120 ㎐). The root-mean-square (RMS) values were calculated using a moving window of 50 milliseconds.

Before positioning the electrodes over each muscle, the skin was shaved, abraded, and then cleaned with isopropyl alcohol wipes to reduce the skin resistance. Disposable Ag/AgCl surface electrodes were positioned parallel to the muscle fibers with a center-to-center spacing of 2 ㎝. All electrodes were placed on the right side of the following muscles and locations. For the TrA/IO muscles, the electrode was positioned midpoint between the anterior superior iliac spine and the pubic tubercle. For the EO muscle, the electrode was positioned 45° obliquely parallel to a line connecting the most inferior point of the costal margin of the ribs and the contralateral pubic tubercle above the anterior superior iliac spine near the level of the umbilicus (Escamilla et al, 2006). For the BF muscle, the electrode was positioned parallel to the muscle fibers on the lateral aspect of the thigh, two thirds of the distance between the trochanter and the back of the knee. For the RF muscle, the electrode was positioned on the center of the anterior surface of the thigh, approximately half the distance between the knee and the iliac spine. For the GM muscle, the electrode was positioned in the middle of the muscle below the level of the trochanter and 1 to 2 inches above the gluteal fold (Criswell, 2011).

Procedures

Each subject was instructed to lie supine with knees flexion. The investigator measured the angle of the knee joint and then placed the participant in the hook-lying position using a 14-inch goniometer (Baseline stainless steel 180° Conzett goniometer, Fabrication Enterprises Inc., NY, USA). The knee joints were bilaterally flexed to 100°, 70°, or 40° (Figure 1). A target bar was placed so that the subject's middle aspect of the thigh would slightly touch the bar when the hip joint was fully extended. The subject was asked to touch the target bar with each supine bridge, which lasted 8 seconds (the initial 3 seconds were the subject moving to the target bar; and the last 5 seconds were the subject holding the target position). A metronome was used to control the time and speed of the subject's movement. In order to prevent abduction and adduction of both hip joints, lope guides were aligned with the lower extremities (Kim et al, 2011).

Prior to testing, 30 minutes were spent familiarizing the subjects with the standard position and movement. During the familiarization session, each subject received verbal instructions explaining how to correctly perform the supine bridge. Once the subject correctly performed the supine bridge, a testing session was scheduled after a 30-minute rest. During data collection, all subjects performed the bridge under the close supervision of the researcher. When the subject's middle aspect of the thigh

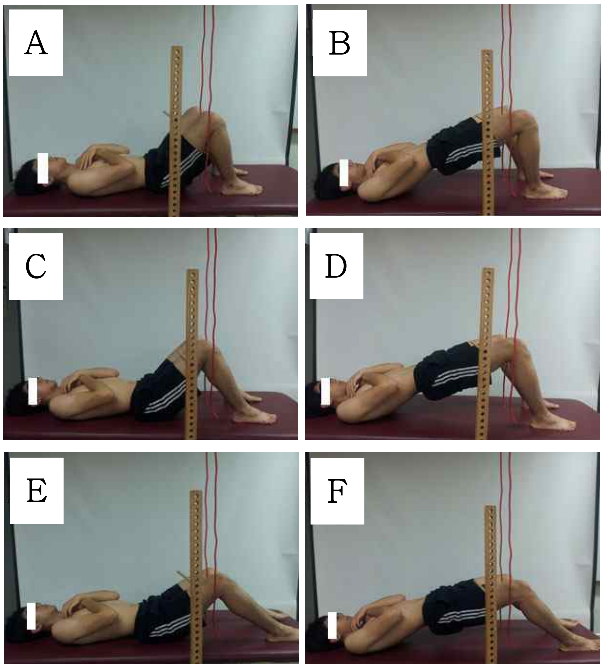

Figure 1. Supine bridge combined with different knee flexion angles (A: knee flexion 100° start, B: knee flexion 100° finish, C: knee flexion 70° start, D: knee flexion 70° finish, E: knee flexion 40° start, F: knee flexion 40° finish).

touched the target bar, the subject isometrically maintained the end position for 5 seconds. This process was performed three times with a 1-minute rest period between each trial. A 3-minute rest was given between each exercise trial to prevent muscle fatigue. Using random numbers generated by the website Randomization.com (available from http://www.randomization.com; accessed 10 June 2013), subjects were randomly assigned to perform the supine bridge at a certain knee flexion angle. This randomization was done to minimize threats to the study's internal validity (Youdas et al, 2008).

Data collection

Data on the EMG activity of the TrA/IO, EO, RF, BF, and GM muscles were collected during the supine bridge. The mean EMG activity data obtained during the middle 3 seconds of each trial was used for statistical analysis. For normalization, the maximal voluntary isometric contraction (MVIC), as described by Kendall et al (2005), was used to determine the reference contraction. For the TrA/IO, each subject was positioned supine and performed a resisted crossed curl-up. The assistant stabilized the subject's legs. Manual resistance was applied to the left shoulder by the examiner. For the EO, the same procedure was repeated. Manual resistance was applied to the right shoulder. For the RF, the subject seated on the side of the table while they performed knee extension against maximal resistance. For the BF, the subject was positioned prone and performed knee flexion against maximal resistance. For the GM, the subject performed unilateral hip extension from the prone position, while the examiner applied manual resistance proximal to the 90° knee flexion. EMG data were recorded during a 5 second reference contraction, repeated three times, and stored for data analysis. A resting interval of 30~50 seconds was provided between the test trials. The muscle activity was expressed as a percentage of the calculated RMS of MVIC (%MVIC).

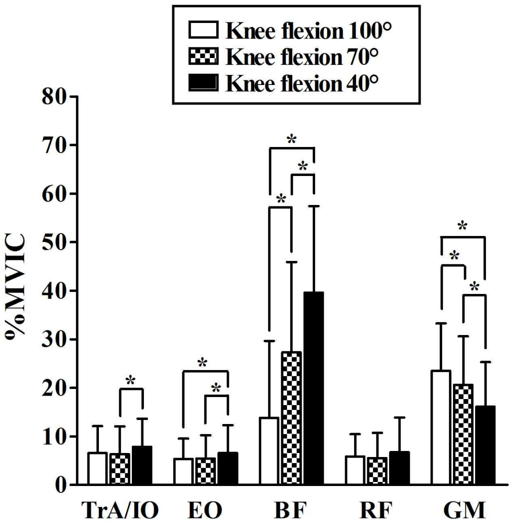

Figure 2. The comparison of EMG activity during the different knee flexion angles (TrA/IO: transverse abdominis/internal oblique, EO: external oblique, BF: biceps femoris, RF: rectus femoris, GM: gluteus maximus, %MVIC: %maximal voluntary isometric contraction, error bars: standard deviation, $^{*}p<.016$).

Statistical analysis

The Kolmogorov-Smirnov Z-test was performed to investigate whether continuous data approximated a normal distribution. We used a one-way repeated ANOVA to compare the differences in the normalized EMG activity of the TrA/IO, EO, RF, BF, and GM muscles and GM/BF activity ratio (dependent variables) during supine bridges performed at different knee flexion angles (independent variables) with double leg support. Post-hoc analyses were performed using the Bonferroni test to evaluate the significance of between-exercise pairwise comparisons. The statistical significance level was set at α=.05. SPSS ver. 20.0 software was used for all data analysis (SPSS Inc., Chicago, IL, USA).

Results

The comparison of the EMG activity during the

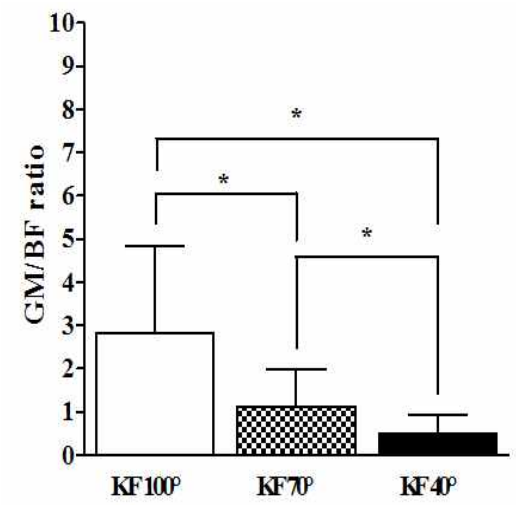

Figure 3. The comparison of GM/BF activity ratio during the different knee flexion angles (GM: gluteus maximus, BF: biceps femoris, KF: knee flexion, error bars: standard deviation, $^{*}p<.016$).

different knee flexion angles is presented in Figure 2. A significant difference (F=4.561, p=.025) was noted in TrA/IO muscle activity when the supine bridge was performed at different knee flexion angles. The post-hoc test demonstrated that TrA/IO muscle activity significantly increased at the 40° knee flexion angle when compared to the 70° knee flexion angle (p=.019). However, there were no significant differences observed between the 100° knee flexion angle and the 70° knee flexion angle (p=1.000) or the 100° knee flexion angle and the 40° knee flexion angle (p=.115).

The difference in the EO muscle activity during the supine bridge performed at different knee flexion angles was significant (F=6.593, p=.007). The post-hoc test demonstrated that the EO muscle activity significantly increased at the 40° knee flexion angle when compared to the 100° knee flexion angle (p=.033) and the 70° knee flexion angle (p=.004). However, no significant difference was observed between the 100° knee flexion angle and the 70° knee flexion angle (p=1.000).

The difference in BF muscle activity during the supine bridge performed at different knee flexion angles was significant (F=39.960, p<.001). The post-hoc test demonstrated that BF muscle activity significantly increased in the order of knee flexion angle (40°>70°>100°; 100° knee flexion angle vs. 70° knee flexion angle, p<.001; 100° knee flexion angle vs. 40° knee flexion angle, p<.001; 70° knee flexion angle vs. 40° knee flexion angle, p=.002).

The difference in RF muscle activity during the supine bridge performed at different knee flexion angles was not significant (F=2.776, p=.089).

The difference in GM muscle activity during the supine bridge performed at different knee flexion angles was significant (F=12.559, p<.001). The post-hoc test demonstrated that the GM muscle activity significantly increased in the order of knee flexion angle (100°>70°>40°; 100° knee flexion angle vs. 70° knee flexion angle, p=.030; 100° knee flexion angle vs. 40° knee flexion angle, p=.001; 70° knee flexion angle vs. 40° knee flexion angle, p=.042).

The difference in GM/BF activity ratio during the supine bridge performed at different knee flexion angles was significant (F=18.649, p<.001). The post-hoc test demonstrated that the GM/BF activity ratio significantly increased in the order of knee flexion angle (100°>70°>40°; 100° knee flexion angle vs. 70° knee flexion angle, p<.001; 100° knee flexion angle vs. 40° knee flexion angle, p<.001; 70° knee flexion angle vs. 40° knee flexion angle, p=.001) (Figure 3).

Discussion

The purpose of this study was to analyze how different knee flexion angles (100°, 70°, and 40°) affected abdominal (TrA/IO and EO) and pelvic (RF, BF, and GM) muscle activity during supine bridging. The hypothesis of this study was that using different knee flexion angles during a supine bridge would generate different activity in the abdominal and pelvic muscles. The results showed that there were significant differences for the TrA/IO, EO, BF, and GM muscles during the supine bridge according to different knee flexion angles. However, there was no significant difference in the RF muscle during the supine bridge with different knee flexion angles (Figure 2). Thus, the findings of this study partially validated the research hypothesis.

For the TrA/IO muscle, the post-hoc test showed that muscle activity in the position of knee flexion 40° increased significantly compared to that of 70° flexion. However, there were no significant differences between 40° and 100° and between 70° and 100°. These results may indicate that the extended lumbar position at 40° causes greater lumbopelvic instability, which is caused by decreased action in the GM muscle and plantar flexor of the ankle at more than 100°. Therefore, through the use of lumbar flexion, the activity of the TrA/IO muscle could be increased to improve lumbopelvic stability. However, our conclusions should be confirmed by further research that includes using kinematic data to investigate how different angles affect the lumbopelvic stability of flexed knees and ankle joints.

The other mechanism is that the 40° knee flexion position could be lengthened by moving the arm position than 100° knee flexion in the lever system. The lengthened moving arm would need greater abdominal muscle activity for the dynamic equilibrium. A previous study reported that a more challenging environment and trial can induce greater activity of abdominal muscle during bridging exercises (Santos and Aruin, 2009). The participants expressed physical exertion to perform bridging at 40° knee flexion. However, this explanation is not adequate because there was no kinematic data and participant's exertion scale was not measured in this study. Hence, a suitable experimental design for the finding of correlation with kinematic and kinetic data is needed in further study.

For the EO muscle, the post-hoc test demonstrated that muscle activity in the position of knee 40° flexion increased significantly compared to that of 70° flexion and of 100° flexion. However, there was no significant difference between 70° flexion and 100° flexion. These results could be explained by the fact that the activity of EO decreased in the position of knee 100° flexion. On the other hand, the activity of the GM muscle increased in the position of knee 100° flexion. This result could be explained by the same methods that were used for TrA/IO muscles. Additionally, there could be considerable causes for the increase in the EO muscle's activity. We observed that during the start position of the bridge, the participant's pelvis was tilted more anteriorly in knee 40° flexion than in 70° and 100° flexion. From this start position, participants used their pelvis posteriorly to lift the hip during flexed lumbar position. This trial might increase the activity of the EO muscle in the 40° flexion position than in the 70° and 100° flexion position.

For the RF muscle, there were no significant differences among the supine bridge with different knee flexion angles. These results may indicate that bridging with different knee flexions seem to be controlled by hip extensors, such as the GM or BF muscles, instead of the hip flexor, the RF. Because the trunk and the pelvis are lifted and maintained against gravity, hip extensors are likely to play a critical role during bridging. This finding agree with previous studies (Bergmark, 1989; Ekstrom et al, 2007).

For the BF muscle, the post-hoc test revealed significant differences with different knee flexion angles. The muscle activity of the BF muscle increased significantly in the order of the knee flexion angle (40°>70°>100°). These results may be the result of the active insufficiency of BF muscles; in other words, the length of the BF muscle is influenced by the angle of the knee flexion. In the 100° of knee flexion, the BF muscle may be under a state of active insufficiency, and, as a result, it cannot generate enough active tension. Conversely, the active insufficiency of the BF muscle may explain the significantly increased activity of the GM muscle in the 100° of knee flexion. For the GM muscle, the post-hoc test demonstrated that the GM muscle activity significantly increased according to the order of the knee flexion angle (100°>70°>40°). Because the GM muscle is a one-joint muscle, it is not affected by the degree of the knee flexion range and can produce enough active tension. Compared with 40° of knee flexion, the GM muscle is placed at the lengthened muscle range in the 100° of knee flexion. Bridging is a commonly used in clinical settings and, in previous studies was recommended to strengthen hip extensors (Andersen et al, 2006; Ekstrom et al, 2007; Myklebust and Engebretsen, 2004).

For the GM/BF activity ratio, the post-hoc test demonstrated that the GM/BF activity ratio significantly increased according to the order of the knee flexion angle (100°>70°>40°). The reason for this finding can be explained by the reciprocal inhibition. Reciprocal inhibition is when the central nervous system sends a message to the agonist muscle to contract, the tension in the antagonist muscle is automatically inhibited by impulses from alpha motor neurons (Crone, 1993). Increasing RF activation during the supine bridging exercise may decrease the role of the BF activation during hip extension and thus enhancing the GM activation.

This study has several limitations. First, the leg support strategies during bridging exercise may be used in clinical rehabilitation programs of subjects with LBP or hemiplegia. However, the limitation of this study was that the assessed subjects did not suffer from LBP or hemiplegia. Further research is needed to clarify exactly which patients with LBP or hemiplegia should be applied the leg support strategies during bridging exercise. Second, kinematic data while performing the supine bridging with different knee flexion angles was not obtained. Thus, the amount of hip extension and lumbopelvic movements cannot be quantified. Third, although iliofemoral ligament tightness and the degree of physiological angle in the hip joint can affect how different knee flexion angles affect the supine bridge, data were not collected for each subject. In order to generalize the findings of this study, a kinematic analysis of a patient population is warranted.

Conclusion

The abdominal and pelvic muscle activity was investigated during supine bridging with different knee flexion angles in this study. The findings of the study indicate that bridging with knee flexion 100° may increase the GM muscle activity and the GM/BF activity ratio, while bridging with a knee flexion of 40° may increase the IO, EO, and BF muscle activity. Therefore, using different knee flexion angles when performing the supine bridge may be used to selectively activate target muscles in the abdominal and pelvic area.

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