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RESEARCH / ARAŞTIRMA

Investigation of the Effect of Bridge Exercises Performed at Different Knee Angles on Muscle Strength and Endurance in Healthy Persons: Randomized Controlled Trial

Fettah SAYGILI [1], Güzin KARA [2], Emre BASKAN [3]

[1] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Aydın Adnan Menderes University, Aydın, Türkiye. **ORCID:** 0000-0001-6450-6666
[2] Department of Neurological Rehabilitation Department of Physiotherapy and Rehabilitation, Faculty of Physiotherapy and Rehabilitation, Pamukkale University, Denizli, Türkiye. **ORCID:** 0000-0002-8893-5235
[3] Department of Neurological Rehabilitation Department of Physiotherapy and Rehabilitation, Faculty of Physiotherapy and Rehabilitation, Pamukkale University, Denizli, Türkiye. **ORCID:** 0000-0001-7069-0658

ABSTRACT

Objective: The purpose of this study is to evaluate the impact of bridge exercises performed at various knee angles on muscle strength and endurance in healthy individuals.
Material and Methods: Forty-two healthy individuals between the ages of 18-27 and who do not exercise regularly were included in the study. The strengths of the M. Gluteus Maximus, M. Quadriceps Femoris, and M. Gastrocnemius, back extensors, upper abdominal and lower abdominal were evaluated. Prone Plank Endurance Test and Dynamic Abdominal Endurance Test were applied to the participants to evaluate the endurance of the trunk muscles. Squat Endurance Test was used to evaluate the endurance of the lower extremity muscles. All measurements were taken twice, before and after the intervention. The participants underwent the bridge exercise program at different knee angles (45^0, 60^0, and 90^0), three days a week day for six weeks by a researcher blinded to the evaluation.
Results: Our results suggest that bridge exercises performed at different knee angles increase the strength and endurance of the muscle ($p<0.05$). However, no statistically significant difference was found between the groups ($p>0.05$).
Conclusion: According to the results, bridge exercise can be performed at any knee angle to gain strength and, the most comfortable knee angle position can be preferred by physiotherapists according to the person being exercised.
Keywords: Exercise, muscle strength, physical endurance, trunk.

Sağlıklı Bireylerde Farklı Diz Açılarında Yapılan Köprü Egzersizlerinin Kas Kuvveti ve Endurans Üzerine Etkisinin Araştırılması

ÖZET

Amaç: Bu çalışmanın amacı, sağlıklı bireylerde farklı diz açılarında yapılan köprü egzersizinin kasların kuvveti ve dayanıklılığı üzerindeki etkisini değerlendirmektir.
Gereç ve Yöntem: Çalışmaya 18-27 yaş aralığında, düzenli egzersiz yapmayan 42 sağlıklı birey dahil edildi. Katılımcıların M. Gluteus Maximus, M. Quadriceps Femoris ve M. Gastrocnemius, sırt ekstansörleri, üst abdominal ve alt abdominal kasların kuvvetleri değerlendirildi. Gövde kaslarının enduransını değerlendirmek için katılımcılara Prone Plank Endurans Testi ve Dinamik Abdominal Endurans Testi uygulandı. Alt ekstremite kaslarının enduransını değerlendirmek için Squat Endurans Testi kullanıldı. Tüm ölçümler müdahaleden önce ve sonra olmak üzere iki kez yapıldı. Katılımcılara, değerlendirmeye kör bir araştırmacı tarafından farklı diz açılarında (45^0, 60^0 ve 90^0) altı hafta boyunca haftada üç günlmak üzere köprü egzersiz programı uygulandı.
Bulgular: Sonuçlarımız, farklı diz açılarında yapılan köprü egzersizlerinin kasın kuvvetini ve enduransını artırdığını göstermektedir ($p<0,05$). Ancak, gruplar arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($p>0,05$).
Sonuç: Sonuçlara göre, köprü egzersizi kuvvet ve endurans kazanmak için her diz açısında yapılabilir ve köprü egzersizinde kişiye göre en rahat diz açısı pozisyonu fizyoterapistler tarafından tercih edilebilir.
Anahtar Kelimeler: Egzersiz, kas kuvveti, fiziksel endurans, gövde.

1. Introduction

The term "core" refers to a box-like structure formed by the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the gluteal muscles as the base (1). Core stabilization is defined as the ability of the above-mentioned muscles, which are called "core", to stabilize the lumbar spine and pelvic girdle muscles in static postures and dynamic movements. In light of these theories, "Stabilization Exercises" have been developed to train these muscles in various pathological conditions (2). These exercises are known to have positive effects on balance, walking and endurance (1). One of the most commonly used spinal stabilization exercises is the bridge exercise, which is a closed-chain kinetic exercise. (3). While the bridge exercise is primarily associated with trunk muscles, it also engages muscles throughout the lower extremity (4).

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Corresponding Author
Fettah Saygılı, Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Aydın Adnan Menderes University, Aydın, Türkiye.
E-mail: fsaygili@adu.edu.tr ORCID: 0000-0001-6450-6666
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During exercise, as the length of the muscle gets longer, more tension occurs in the muscle, and the muscle releases more power (5). Therapists can use this principle to enhance muscle strength since increased muscle power leads to greater strength gains (6). The muscle length can be easily modified by adjusting joint angles during exercise (5). One way to alter muscle length in the bridge exercise is by changing the angles of the lower extremity joints. Kim et al. conducted a study examining the activation of the lower extremity muscles at different knee angles in bridge exercise. In their study, they measured the activation of lower extremity muscles with electromyography (EMG) when the knee was flexed at 90º and 60º. As a result of their studies, they reported that many muscles were activated more in the bridge exercise performed with 90º of knee flexion (7). In another study Ho et al. investigated the activation of rectus abdominis, erector spinae, gluteus medius, superior gluteus maximus, inferior gluteus maximus, and biceps femoris muscles using surface EMG during bridge exercise performed at knee angles of 40º, 60º, 90º, 120º (8).

Muscular endurance is defined as the ability to maintain muscle contraction without excessive fatigue (9). It has been proven that core stabilization training, including the bridge exercise, which is frequently preferred in rehabilitation, increases the endurance of the trunk flexor, trunk extensor, and core muscles (10, 11). After rehabilitation programs that include bridge exercises, the standing time and balance of these patients increased, and the pathologies in the walking pattern decreased (12, 13).

When the literature was examined, there are some studies examining muscle activation levels during bridge exercise. (7, 14, 15). Although some studies show the effects of bridge exercises performed at different knee angles on muscle activation levels, there is no study that investigates their effects on lower extremity and trunk muscle strength and endurance. In the light of this, the study aimed to investigate the effect of bridge exercise performed at different knee angles on muscle strength and endurance in healthy subjects.

2. Material and Method

2.1. Participants

Between July 2020 and May 2021, 42 healthy individuals were included in the study. The inclusion criteria for the participants were being between the ages of 18-27, having no health problems, and not exercising regularly. During the study, participants who wanted to leave the study, did not come to the measurements, and did not attend the treatment sessions regularly were excluded from the study.

2.2. Study Design

The subjects participating in the study were divided into three distinct groups through utilization of a simple sealed envelope randomization method. Participants in the first group (Group-45, n = 14) were to exercise at a knee angle of 45º, the participants in the second group (Group-60, n = 13) were to exercise at a knee angle of 60º, and the participants in the third group (Group-90, n = 15) were to exercise at a knee angle of 90º. What we mean by knee angle is the angle between the femur and fibula. They were included in a bridge exercise program at predetermined knee angles (45º, 60º, and 90º), 3 sets of 15 repetitions per day, 3 days a week for 6 weeks by a blinded researcher. For the bridge exercise, after the participants' knee angles were adjusted with a goniometer, they were asked to lift the hip joint to 0º flexion and maintain the position for 5 seconds (7). The evaluations were conducted by a researcher who was unaware of the participant's group allocation throughout the study. This researcher conducted the evaluations one week before the commencement of the six-week exercise program and one week after the program's conclusion. All evaluations were performed by the same physiotherapist, who met with each participant in person.

2.3.1. Muscle Strength Assessment

The muscle strengths of the participants were evaluated with the PowerTrack II Commander device and the Manual Muscle Test.

PowerTrack II Commander: PowerTrack II Commander is a manual muscle testing dynamometer. The back extensor muscle group and M. Gluteus Maximus, M. Quadriceps Femoris, and M. Gastrocnemius muscles of the participants were evaluated in the muscle test position defined for the dynamometer, and the maximum resistance values received were recorded in newtons. Measurements were made as 3 times with rest intervals, and the average of them was calculated (16).

Manual Muscle Test: The upper and lower abdominal muscle strengths of the participants were evaluated by manual muscle testing. Scoring was done between 0 and 5 in the manual muscle test. In the muscle test of the upper abdominals, the participant was placed on his back with the knees flexed. During the test, the participants were asked to raise their trunks to the lower angle of the scapula while performing trunk flexion. In testing the upper abdominals, the weight of the arms and upper body was used as resistance. Muscle strength was decided according to the position of the arms of the participant while doing trunk flexion. To measure lower abdominal muscle strength, the participant was placed on his back on a hard bed with hands on opposite shoulders. The test was used to measure the ability of the abdominal muscles to stabilize the pelvis against the resistance of lowering the legs towards the bed. The hips were flexed to 90º while the knees were extended. The evaluation was made according to the deterioration of the smoothness of the lower back while lowering the legs slowly, no manual resistance was applied. The result of the evaluation was scored according to the degree of the lower extremity with the bed (17).

2.3.2. Core Endurance Assessment

Prone Plank Endurance Test: This test was used to evaluate the isometric endurance of trunk muscles. Participants were asked to stand on their forearms while in the prone position. In this position, with the start of the time, the trunk and hips were lifted off the ground with the toes on the ground. During the test, it was requested to keep the hip and trunk on the same line. The time was stopped when the participant broke this position. The maximum time that the participant could stand in this position was recorded (18, 19).

Squat Endurance Test: The test was used to evaluate the endurance of the lower extremity muscles. It was started with the knees fully extended, the legs shoulder-width apart, and both legs equally weighted. In this position, the participants were asked to bend their knees to 90º of flexion and return to the starting position. The maximum number of repetitions that the person could do was recorded (20).

Dynamic Abdominal Endurance Test: In this test, in which the endurance of the abdominal muscles was evaluated, the knee angle of the participants was measured with a goniometer in a 90º flexion position. Participants were placed in a supine position with both arms at the side of the trunk. Next, a line was drawn horizontally to the bed, connecting the tip of the third finger of both hands. Afterward, a second line was drawn parallel to the first line, 12 cm apart since the participants were under the age of 40 years. Before starting the test, a metronome was set to sound 40 times per minute. Participants were asked to try to reach the 2nd line with their fingertips by flexing their trunk at the first sound of the metronome. When they heard the second sound of the metronome, they were asked to return to the starting position. Each trunk flexion followed by a return to the starting position was considered one repetition. The number of

Table 1. Demographics of the participants

		Group-45		Group-60		Group-90			
		n	%	n	%	n	%	χ^2	p
Gender	Female	9	64.3	9	69.2	9	60.0	0.252	0.881
	Male	5	35.7	4	30.8	6	40.0		
		X±SD	Min-Max	X±SD	Min-Max	X±SD	Min-Max	F	p
Age (years)		22.71±1.20	21-25	21.77±0.83	20-23	22.87±1.68	20-27	2.792	0.074
BMI (kg/m2)		21.56±2.84	17.07-28.70	20.73±2.68	16.96-24.28	21.89±3.44	17.58-29.32	0.519	0.599

BMI: Body Mass Index, X: mean, SD: Standard Deviation.

the trunk flexions performed by the participant was recorded. The test was terminated if the person could not perform the trunk flexion with the fingertip on the 2nd line in line with the metronome sounds two times in a row or if she/he wanted to finish the test (21, 22).

2.4. Statistical Analysis

The sample size was calculated based on the significant improvement of the rectus abdominis muscle activation observed in a similar intervention study (23). Their findings provided a Cohen's d effect size of 0.126. To achieve 80% power with a two-sided level of 5%, the total sample size was estimated at a minimum of 27 for both effect sizes using G*Power 3.1 power analysis software (24). Assuming a dropout rate, we recruited 14 participants per group.

The variables were investigated using visual (histograms, probability plots) and analytical methods (Shapiro-Wilk's test) to determine whether or not they are normally distributed. Since the data show a normally distributed, outcome variables were presented as mean ± standard deviation (SD). Demographic characteristics and baseline variables of participants were compared between the groups using One way ANOVA or the Chi-square test. Paired Sample T-test was used to compare the groups before and after the intervention, and one way ANOVA was used to see if there was a difference between the three groups. The significance level was set at p≤0.05. The SPSS software (version 23.0; SPSS, Inc.) was used for the statistical analysis.

2.5. Ethical Aspects of the Research

The ethical approval was given by Pamukkale University University Non-invasive Clinical Research Ethics Committee (Number: 12, date: 23.06.2020). The study was registered in the ClinicalTrial.gov PRC system. The basis of inclusion in the research will be on a voluntary basis, as outlined in the Helsinki declaration.

3. Results

Demographics of the groups were compared in Table 1. No differences were found among the mean age, BMI, and gender distributions of the groups (p>0.05).

The strengths of right and left M. Gastrocnemius, M. Quadriceps Femoris, M. Gluteus Maximus, back extensors, upper, and lower abdominal muscles were compared among groups before and after the intervention. There were no significant differences between Group-45, Group-60, and Group-90 (p>0.05). In the pre and post-treatment assessments of each group, significant differences were found in the strengths of the lower extremity and trunk muscles (p≤0.05) (Table 2). No significant difference was found in the strengths of upper abdominal muscle between pre and post-treatment of all the groups (p>0.05). In Group-60 and Group-90, there were significant improvements in the strengths of the lower extremity and abdominal muscles between pre and post-treatment except for the upper abdominal muscle (p≤0.05).

There were no differences in the lower extremity and abdominal muscle endurance tests when the groups were compared before and after the treatment (p>0.05). In Group-45 and Group-90, significant improvements were shown in all pre and post-treatment muscle endurance tests, while there were significant differences in Prone Plank Endurance Test (PPET) and Squat Endurance Test (SET) scores of Group-60 after the intervention (p≤0.05). Only the Dynamic Abdominal Endurance Test (DAET) score of Group-60 was not significantly different after the intervention (Table 3).

4. Discussion

In our study, in which we investigated the effect of bridge exercise on different knee angles, an increase in muscle strength and endurance was found in all angle values. However, no statistically significant difference was found between the angle values for muscle strength and endurance, but there was an

Table 2. Comparison of pre and post-treatment scores (x±sd) of muscle strength in and between the groups

	In Groups									Between Three Groups	
	Group-45			Group-60			Group-90			Pre	Post
Muscles	Pre	Post	p	Pre	Post	p	Pre	Post	p	p	p
GC-R	267.2±46.9	292.9±38.8	0.124	234.3±54.0	305.2±69.3	0.007*	245.5±57.9	316.1±54.4	0.012*	0.277	0.532
GC-L	251.5±50.8	281.6±41.9	0.140	222.1±65.1	293.4±56.6	0.009*	23.1±54.9	299.4±52.7	0.005*	0.416	0.635
QC-R	176.5±44.2	237.8±55.8	0.006*	154.8±28.5	239.6±52.7	0.001*	168.4±21.2	242.9±46.2	0.001*	0.230	0.964
QC-L	170.6±35.8	224.9±59.7	0.004*	145.2±27.6	228.7±49.7	0.002*	158.0±27.2	247.1±47.8	0.001*	0.109	0.481
GM-R	210.4±65.9	256.8±74.2	0.006*	178.0±41.5	276.9±97.5	0.003*	187.5±41.3	273.6±71.3	0.001*	0.244	0.785
GM-L	206.6±61.5	252.1±91.0	0.035*	175.9±51.7	270.9±84.6	0.002*	190.9±51.9	272.5±77.2	0.003*	0.361	0.776
BEMs	246.7±45.8	319.8±63.4	0.016*	221.0±40.6	385.0±80.3	0.002*	231.7±38.1	336.1±94.3	0.003*	0.281	0.107
UAM	4.64±0.74	5.00±0.00	0.102	4.54±0.8	5.00±0.00	0.063	4.67±0.62	4.97±0.13	0.066	0.883	0.417
LAM	4.32±0.61	4.93±0.27	0.008*	4.44±0.4	5.00±0.00	0.004*	4.35±0.38	4.97±0.13	0.001*	0.790	0.565

Strength of the muscles were recorded as Newton. GC-R: Right Gastrocnemius; GC-L: Left Gastrocnemius; QC-R: Right Quadriceps Femoris; QC-L Left Quadriceps Femoris; GM-R Right Gluteus Maximus; GM-L Left Gluteus Maximus: BEMs: Back Extensors; UAM: Upper Abdominal Muscles; LAM: Lower Abdominal Muscles; X: mean, SD: Standard Deviation, * p<0.05.

Table 3. Comparison of pre and post-treatment scores (x±sd) of muscle endurance in and between the groups

	In Groups									Between three Groups	
	Group-45			Group-60			Group-90				
	Pre	Post	p	Pre	Post	p	Pre	Post	p	Pre p	Post p
PPET (sec)	53.9±28.1	69.6±26.3	0.022*	67.6±31.3	94.6±52.8	0.011*	74.4±53.3	93.7±44.66	0.005*	0.443	0.225
DAET (rpm)	11.9±7.2	15.0±6.9	0.008*	12.8±6.1	14.5±5.8	0.218	11.1±6.3	13.9±6.64	0.049*	0.805	0.906
SET (mnr)	46.8±22.1	87.7±53.8	0.014*	57.6±29.9	107.4±69.3	0.006*	54.8±25.1	92.5±32.5	0.001*	0.527	0.610

sec: second; rpm: repetition per minute; mnr: maximum number of repetitions; PPET: Prone Plank Endurance Test; DAET: Dynamic Abdominal Endurance Test; SET: Squat Endurance Test; X: mean, SD: Standard Deviation ,*p<0.05.

increase in all muscle groups measured except gastrocnemius and upper abdominal. We found that bridge exercises had no effect on gastrocnemius muscle strength at a 45º knee angle and had no effect on upper abdominal muscle strength in all angle values. This emphasizes that the bridge exercise is an important exercise for increasing the strength and endurance in the lower extremity and trunk muscles.

Bridge exercise is used in patients as well as in healthy individuals to increase strength and endurance in the trunk and lower extremity muscles. It is especially preferred in bedridden patients' physical therapy. During this exercise, individuals or health professionals use different knee angle values. While some health professionals think that reducing the knee angle will increase the effect of the exercise, another group does not attach importance to the angle (25-27). During our experience in the clinic, we observed that people who do the bridge exercise want to adjust their knee angles to a position that is comfortable for them. We determined the knee angles we used in this study based on past studies (7, 8, 32) and our own experiences. In this context, we thought that if there was an effective angle during the exercise, we would contribute to the literature in this direction to increase the effect of the exercise to enhance the strength and endurance.

There are other studies in the literature examining the effects of bridge exercise (28-30). Vaguero et al. stated that during a bridge exercise with double leg support, the antigravity muscles were the most active. When the bridge exercise was performed with an elevated leg, however, rotation torques increased the activation of the trunk rotators, especially internal oblique muscles (28). Stevens et al. said that during all bridge exercises, the ratio of the internal oblique to the rectus abdominis was very high due to minimal relative activity of the rectus abdominis (29). In our study, while an increase in strength was detected in the posterior extensor and lower abdominal muscles, no significant increase in strength was observed in the upper abdominal muscles in all knee angles. This result shows that bridge exercises alone are not sufficient to increase trunk stabilization.

Eom et al. said that in lower extremity muscular activity, there was a significant difference between the experimental group and the control group only in the biceps femoris muscle on bridge exercise (31). Nakae et al. reported that quadriceps femoris muscle activation increased in bridge exercises performed at a 15º knee extension angle (32).

Youdas et al. reported that gluteus maximus muscle activation increased with bridge exercise (33). In their study, Ryu et al. found that there was an increase in strength in the gastrocnemius muscle with bridge exercise (34). Kim et al., in their study examining muscle activations in bridge exercises performed at 60 degrees and 90 degrees, reported that the activation levels of muscles that cross two joints, such as the semimenbranosus muscle, biceps femoris muscle and tensor fascia latae muscle, increased as the angle increased (7). As mentioned in Ho et al.'s study, the findings of their study indicated that the erector spinae and biceps femoris muscles demonstrated heightened activation at narrower knee flexion angles; conversely, other muscles exhibited augmented activation at wider angles. According to these studies, the activation of muscles changes at different knee angles (8). However, in our study, all angle values used in our study were found to cause an increase in strength in the quadriceps femoris, gluteus maximus muscle during bridge exercise. Also in our study, there was no increase in strength in the gastrocnemius muscle in the bridge exercise performed at a 45-degree knee angle, while an increase in strength was observed at 60 and 90 degrees. These results show that an angle of at least 60 degrees should be given to the knee to increase strength in the gastrocnemius muscle during the bridge. Although it is thought that the more actively a muscle works during exercise, the greater the strength gain will be, this was not demonstrated in our study.

5. Conclusion and Recommendations

As a result of our study, we found that bridge exercise was effective in increasing lower extremity and trunk muscle strength. However, there was no difference between groups. This shows that the knee angle has no effect on muscle strength and endurance. For For this reason, the bridge exercise can be performed at any knee angle. On the other hand, the results of our study show that bridge exercise is not sufficient to increase upper abdominal muscle strength.

6. Contribution to the Field

Physiotherapists can perform the bridge exercise in the comfortable position of their patients without any anxiety to gain strength and endurance.

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Conflict of Interest

There is no conflict of interest with any person and/or institution.

Authorship Contribution

Concept: FS, GK; Design: FS, GK, EB; Supervision: FS; Funding: None; Materials: None; Data Collection/Processing: FS, GK; Analysis/Interpretation: FS, GK; Literature Review: FS, GK; Manuscript Writing: FS, GK, EB; Critical Review: FS, GK, EB.

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