

Research article

Comparison of trunk muscle activity during bridging exercises using a sling in patients with low back pain

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Abstract

The aims of this study were to compare the activation of global and local muscles of the trunk during bridging with sling exercise (BSE), bridging with ball exercise (BBE), and normal bridging exercise (NBE) and to conduct and analyze these exercises in supine and prone positions to prove the effectiveness of sling exercises. Thirty patients with current low back pain (LBP) were recruited. In the supine and prone bridging exercise, each subject lifted their pelvis with their legs and feet in contact with the sling, ball, or normal surface. The electrical activities of the inferior oblique (IO), rectus abdominis (RA), multifidus (MF), and erector spinae (ES) muscles during the bridging exercises on the 3 surfaces were measured using surface electromyography (sEMG). For normalization, maximum sEMG signals were evaluated during each maximum voluntary isometric contraction (MVIC) maneuver. The root mean square during the exercise was normalized as a percentage of the MVIC (%MVIC). In the supine and prone positions, %MVIC of the IO, RA, MF, and ES during BSE was significantly higher than those during BBE and NBE ($p < 0.05$). In the supine position, %MVIC of the RA and ES during BBE was significantly higher than that during NBE ($p < 0.05$). In the prone position, all %MVIC during BBE were significantly higher than NBE ($p < 0.05$). These results verify the theory that the use of an unstable surface increases the activation of global and local trunk muscles during bridging exercises in the supine and prone positions. In conclusion, the use of BSE in a rehabilitation program may have therapeutic effects for patients with LBP by increasing trunk muscle activation.

Key words: Sling, bridging exercise, sEMG, local trunk muscle, global trunk muscle.

Introduction

Low back pain (LBP) is a major public health problem in industrialized societies, with a lifetime prevalence of 60–85% (Gnjidić, 2011; Unsgaard-Tøndel et al., 2010). LBP is usually defined as pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds with or without leg pain (sciatica) (Costa-Black et al., 2010; Deyo et al., 1992; Verbunt et al., 2010). Various studies point to the beneficial effects of supervised exercise in patients with chronic LBP, but there is no clear evidence that any specific exercise type is better than others (Chou, 2005; Macedo et al., 2009).

The sling exercise was developed for patients with musculoskeletal disease. This exercise is performed while the pelvis or lower extremities are suspended in a sling. Exercises can be made easier using a sling and elastic

cord to offset body weight or made more difficult using an unstable surface to perform the exercises (Johnson et al., 1973). Research shows that sling exercises improve patient strength and proprioception by giving progressive loading using a close kinematic chain (Dannelly et al., 2011). In particular, this exercise is reported to minimize the use of global muscles without pain while activating local muscles (Saliba et al., 2010).

Another exercise for LBP is the bridging exercise. This exercise is often used for lumbopelvic stabilization for patients with LBP. This exercise focuses on retraining muscle coordination patterns in which optimal ratios between the local segmental-stabilizing and global torque-producing muscle activities are assumed to be essential (Stevens et al., 2006). In addition, when executed on an unstable surface, bridging exercises create a higher percentage of maximal voluntary isometric contraction (%MVIC) in the rectus abdominis (RA) and external oblique (EO) muscles than other close kinematic chain exercises, such as squats (Feldwieser et al., 2012).

Sling and bridging exercise have many positive effects alone and have been combined for the rehabilitation of patients with LBP. However, trunk muscle activation during bridging exercises using slings has been compared with regular exercise executed on the ground only. The little available comparative research was on exercise programs performed using other materials and healthy adults, making it difficult to apply the findings to patients with LBP. Muscle activation through therapeutic exercise should also be researched in various positions. To date, however, such research has been conducted in the supine position only, and almost no research was conducted in the prone position. Therefore, the aims of this study were to compare the activation of global and local muscles of the trunk during bridging with sling exercise (BSE), bridging with ball exercise (BBE), and normal bridging exercise (NBE) and to conduct and analyze these exercises in supine and prone positions to investigate the effectiveness of sling exercises.

Methods

Subjects

Thirty patients (17 men and 13 women) aged 25–56 (43.2 ± 7.5) years, 1.63 ± 0.07 m height and 63.7 ± 9.9 kg body weight, with current LBP were recruited from H Orthopedic Hospital. Informed consent was obtained from the patients after the details of the study were explained

through a leaflet provided to the patients. The inclusion criteria were continued nonspecific LBP with or without referred pain for more than 3 months and pain requiring medical attention or absence from work, or intermittent LBP with at least 3 previous symptoms lasting more than 1 week during the year before the study. The exclusion criteria included hip dislocation or fracture, structural deformity, persistent severe pain, neurological symptoms, recent abdominal surgery, or any other corresponding disorders preventing active rehabilitation.

Procedures and instrumentation

After a specific explanation of each exercise followed by a guided trial, the exercises were recorded. The bridging exercises on the 3 surfaces in supine and prone position are presented in Figure 1.

In the supine bridging exercise, the subjects lifted their pelvis until a hip flexion angle of zero degree was produced. In the prone bridging exercise, the subjects lay with only the legs and feet in contact with the sling, Swiss ball, or mat surface. The hands were positioned directly underneath the shoulders, with the fingers facing forward. The angle of the shoulder joint and trunk was approximately 90° and in a lumbar neutral position as measured manually using a goniometer. At the beginning of each exercise, a neutral lumbar spine position was determined by the examiner (anterior and posterior iliac spines in line) and the subject was instructed to maintain this position during all the exercises. To standardize the subject and equipment positions, markers were placed on the floor and the goniometer measured the position. All the exercises were executed in a random sequence. The experimental phases of lifting and lowering the pelvis and extremities lasted 2 seconds. The supine and prone bridging positions in the exercises were held for 5 seconds. Five trials were performed for all the exercises, with a

pause of at least 15 seconds between each trial. The same surface height was used for all the test conditions.

Surface electromyography preparation

To measure the electrical activity of the internal oblique (IO), RA, multifidus (MF), and erector spinae (ES) muscles during the bridging exercises on the 3 surfaces, a surface electromyography (sEMG) system (Telemetry 2400T-G2 Telemetry EMG system; Noraxon, USA) with disposable bipolar sEMG electrodes was used. In preparation of the electrodes, the placement area was abraded, shaved, and cleansed with alcohol to reduce the impedance (typically ≤ 10 k Ω). Disposable bipolar Ag-AgCl disc surface electrodes with a diameter of 1.0 cm were attached bilaterally over the muscle groups studied with a center-to-center spacing of 1.5 cm. The sEMG electrodes were adhered parallel with the muscle fibers on the skin above the IO, RA, MF, and ES on each subject's right side. The electrode placement on the local trunk muscles was as follows: the inferior fibers of the IO (midway between the anterior iliac spine and the symphysis pubis and above the inguinal ligament) and the lumbar MF (lateral to the midline of the body and above and below the line connecting the posterior superior iliac spines) (Danneels et al. 2001; Macintosh and Bogduk 1987). The electrode placement on the global trunk muscles was as follows: RA (3 cm lateral to the umbilicus) and the ES (above and below the L3 level and midway between the midline and lateral aspects of the body). The reference electrode was placed over the superior aspect of the left iliac crest (Stevens et al., 2006).

All the EMG signals were amplified 1000 times with an amplifier (MyoResearch XP Master Edition; Noraxon Inc.). The sampling frequency was 1000 Hz. The raw data were band-pass filtered between 6 and 500 Hz and full-wave rectified using analysis software. The root

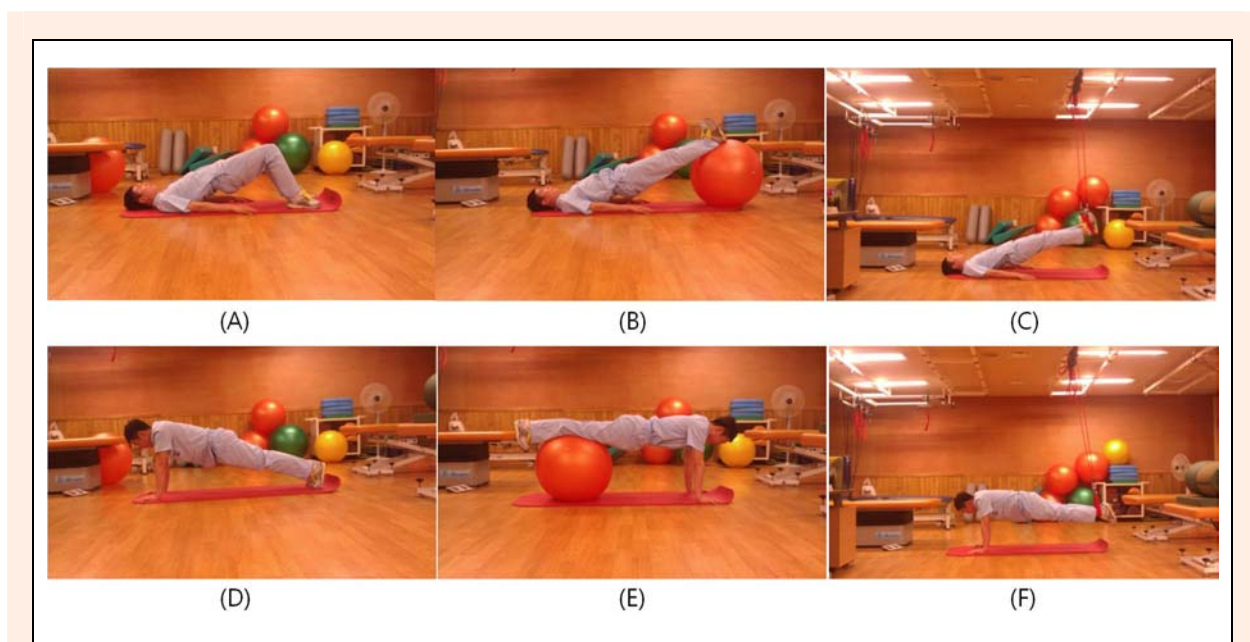


Figure 1. The bridging exercises on the 3 surfaces in supine and prone position. (A) normal bridging exercise in supine. (B) bridging with ball exercise in supine. (C) bridging with sling exercise in supine. (D) normal bridging exercise in prone. (E) bridging with ball exercise in prone. (F) bridging with sling exercise in prone.

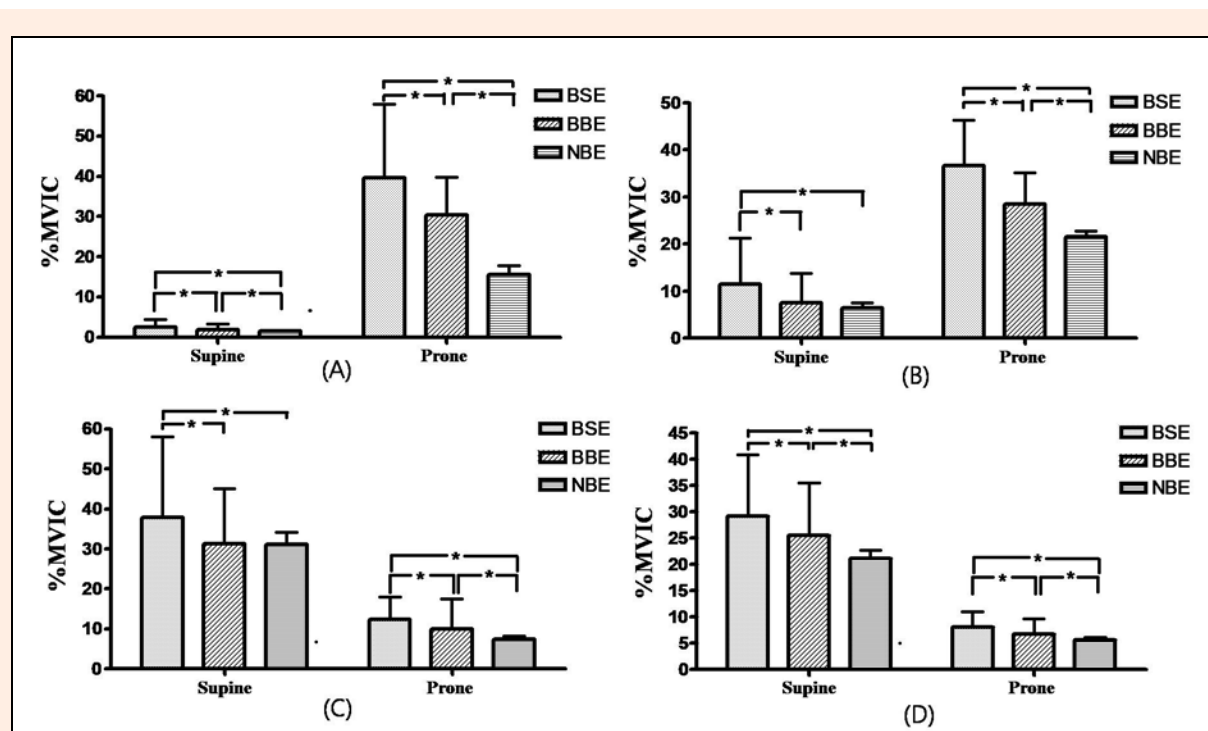


Figure 2. Comparison of %MVIC during bridging exercise. (A) Internal oblique muscle. (B) Rectus abdominis muscle. (C) Multifidus muscle. (D) Erector spinae muscle. %MVIC: percentage of maximal voluntary isometric contraction. BSE: bridging with sling exercise. BBE: bridging with ball exercise. NBE: normal bridging exercise

mean square was calculated for the 3 repetitions of the different exercises, and each subject's posture was kept stable during each exercise. For normalization, maximum EMG signals were evaluated during each MVIC maneuver. The root mean square during the exercise was normalized as a percentage of the greatest root mean square obtained over a 5-second period during the MVIC test (%MVIC), using the Noraxon MyoResearch software 2.10.

MVIC assessment

The MVIC values of the muscles were measured in 3 trials before the experimental tasks. These exercises were executed to supply a basis for signal amplitude normalization. Normalization of the EMG corresponding to maximal EMG amplitude permits comparison of the individual differences to the individual maximum. Four different isometric exercises against manual resistance were performed. Verbal cues were given to ensure maximal effort. Maximal RA activation was obtained using a flexion exertion, whereas maximal IO was obtained using combined flexion-rotation exertion in a supported straight-knee sitting position with the hands placed behind the head and the trunk held in a 45° angle. Manual resistance was exerted to the contralateral shoulder. Concerning the MVICs of the MF and ES, manual resistance was exerted to the posterior aspect of the scapula while the subjects lay in the prone position with their legs strapped to the table to prevent them from moving. The subjects were told to perform a trunk extension.

Statistical analysis

The SPSS 12.0 software program was used for the data

analysis. A repeated analysis of variance was used to compare the differences in trunk muscle activity during the supine and prone bridging exercises on the 3 surfaces. And a post hoc test was performed using Bonferroni correction. The significance level was set at $p < 0.05$.

Results

VAS and ODI scores of patients were 4.28 ± 1.90 and 34.4 ± 16.2 , respectively. The %MVIC of the IO, RA, MF, and ES muscles during the bridging exercises on the 3 surfaces are presented in Figure 2.

In the supine position, the %MVIC values of the IO, RA, MF, and ES muscles during the SBE were significantly higher than those during the BBE and NBE ($p < 0.05$). The %MVIC values of the RA and ES muscles during the BBE were significantly higher than that during the NBE ($p < 0.05$). In the prone position, the %MVIC values of the IO, RA, MF, and ES muscles during the SBE were significantly higher than those during the BBE and NBE ($p < 0.05$). The activities of the IO, RA, MF, and ES muscles during the BBE were significantly higher than those during the NBE ($p < 0.05$).

Discussion

We found several significant results. In both positions, the %MVIC values of the IO, RA, MF, and ES muscles during the SBE were significantly higher than those during the BBE and NBE. In earlier studies, sEMG was used to measure various abilities of patients with LBP (Pitcher et al., 2008; Roy and Oddsson, 1998; Wei et al., 2008). Comparing the trunk muscle activation of LBP patients

with that of healthy people, the %MVIC decreases during gait (Hanada et al., 2011). In standing balance, trunk muscle activation of LBP patients has characteristics such as higher baseline EMG amplitudes of the ES muscles before perturbation onset and less activation of the RA, ES, IO, EO, gastrocnemius, and tibialis anterior muscles (Jacobs et al., 2011). Moreover, LBP is the cause of abnormal sEMG signal in various postures and movements. This research also shows that patients with LBP have lower %MVIC values with trunk muscles during bridging exercises (in the supine and prone positions) compared with healthy adults (Schellenberg et al., 2007).

Trunk muscles are traditionally classified into global muscles (namely, the RA, ES, and EO muscles) and local muscles (namely, the IO, MF, and transverse abdominis muscles) by function (Stevens et al., 2007; Stokes et al., 2011; Sidorenko et al., 2011). The global muscles participate in trunk movements, whereas the local muscles participate in trunk stabilization (Danneels et al., 2001). We chose the IO, MF, RA, and ES muscles to analyze the %MVIC values during the bridging exercises to see each muscle's range of usage based on the exercise methods.

Based on this research, all the muscles showed higher %MVIC values during the supine BSE than during the BBE and NBE. Stevens et al. (2006) conducted bridging exercise (NBE, BBE, and unilateral bridging) research and used healthy adults to compare %MVIC values. The research showed higher %MVIC values in the unilateral bridging than in the NBE and BBE. In addition, the BBE had increased %MVIC values of IO, RA, and ES than the normal bridging. The results from earlier studies should be quite similar to those of this research. However, studies have been conducted with healthy adults, making it difficult to apply their results to patients with LBP. The present study shows that BSE and BBE are stronger exercise methods than NBE for patients with LBP. The BSE was also more efficient than the BBE. In earlier studies, the MF muscle showed no significant differences in the different positions. However, the BSE in our study showed higher %MVIC values in the MF muscle than those in the other positions. This finding means that the sling exercise increased the usage of local muscles compared with the other exercise methods. Stuge et al. (2004) reported that the use of the sling exercise increases the use of local muscles, whereas Dannelly et al. (2011) reported that application of the sling exercise is a close kinematic chain exercise method that contributes to balance improvement because it uses local and global muscles, findings that are similar to our results on the %MVIC values of the MF muscle.

In this research, the prone BSE showed higher %MVIC values than those of the BBE and NBE in all the muscles. Earlier studies conducted in healthy people showed higher %MVIC values in the dorsal muscles, such as the ES and hamstring, during the supine bridging exercise and lower %MVIC values in the ventral muscles, such as the RA and the ES. On the contrary, during prone bridging exercises, the %MVIC values of the ventral muscles were lower than those of the high and dorsal muscles (Schellenberg et al., 2007). Our research showed

similar results, meaning that the sling exercise effectively increased global and local muscle activation even with prone bridging. The BBE also showed higher %MVIC values than did the NBE. Behm et al. (2005) claimed that the unstable surface using the ball during the supine bridging exercise increased the ES %MVIC values, a finding that is similar to that of our research. Marshall and Desai (2010) explained that the prone BBE is a more effective exercise method for healthy adults than other exercises using balls (crunches, rolls, hip extensions, prone holds, and leg squats) because it showed high %MVIC values in the RA, IO and ES muscles. These results show that the BBE would work great as a therapeutic exercise for patients with LBP.

This research shows that the BSE is more effective than the BBE in activating the trunk muscles of patients with LBP. The ball used in this research was 55 cm in diameter. The fact that we always used the same balls can be viewed as a limitation because ball size and elasticity can affect results. In the current study, reasons for sling exercise being better than ball exercise are guessed as followed. In this study's method, patients' lower limb were held up to the same height for both sling and ball. Ball's distance from the ground to the leg was 55cm and sling length from the ceiling to the leg was longer with 2m 30cm. That's the reason why instability increased with increment of moment arm.

But it had a controversy because the mechanism for sling exercise that was better than ball exercise was unclear. Various exercises such as aerobic, flexion, extension, stretching, stabilizing, balance/coordination, and muscle-strengthening exercises may be considered as potential treatments of LBP. The exercises may focus on specific muscle groups, such as the local and global muscles (Rubinstein et al., 2010; Choi et al., 2010; Smith and Grimmer-Somers, 2010). Each exercise type has its advantages and disadvantages, but many people are trying to determine which are the most effective.

Some authors claim that sling exercises show no significant effects compared with traditional physical therapy (Vikne et al., 2007). Through this research, we observed that the most effective exercises for LBP patients as evidenced by increased %MVIC values include the supine and prone BSEs.

Conclusion

This study attempted to compare the activation of global and local muscles in the trunk during BSE, BBE, and NBE. The patients with LBP demonstrated a tendency to activate their trunk (global mobilizer and local stabilizer) muscles to higher %MVIC levels during the BSE than during the BBE, followed by the NBE, in the supine and prone positions. These results verify the theory that the use of an unstable surface may increase the activation of global and local trunk muscles during bridging exercises in the supine and prone positions. Furthermore, the BSE may provide therapeutic effects for patients with LBP by increasing activation of the trunk muscles in rehabilitation programs. Further comparisons of sling exercises should be performed to identify the optimal exercises for patients

with LBP.

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Key points

- Compared with the BBE and NBE, the BSE increased the %MVIC values of the IO, RA, MF, and ES muscles in the supine and prone positions in the patients with LBP.
- We verified that activation of the global and local trunk muscles was increased by the use of unstable surfaces during the bridging exercises in the supine and prone positions.
- The BSE was shown to be an effective exercise method for patients with LBP in a rehabilitation program by increasing trunk muscle activation.

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