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Influence of Neck Flexion on Lumbar Curvature during Bridging Exercises

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Abstract. [Purpose] The purpose of our study was to analyze the influence of passive and active neck flexion on spinal curvatures during bridging exercises. [Subjects and Methods] In experiment 1, thirteen healthy male subjects were instructed to elevate their pelvises until the greater trochanter was in line with the acromion and the epicondylus lateralis femoris at 3 different positions of passive neck flexion: with the head placed on a flat surface, with the head on a 6-cm block and with the head on a 12-cm block. In experiment 2, eleven healthy male subjects were then asked to elevate the pelvis with maximal voluntary exertion in the following 4 different positions of active neck flexion: with the head rested on a flat surface, with the head held slightly above a flat surface, with the head held slightly above a 6-cm block, and with the head held slightly above a 12-cm block. While the subjects performed each bridging exercise, electromyography (EMG) and curvatures of the spine were measured. [Results] No significant differences were observed in the EMG activities of the muscles, but passive neck flexion significantly decreased lumbar lordosis during a bridging exercise with the head placed on a 12-cm block. Elevating the head slightly above a 12-cm block induces moderate contraction of the rectus abdominis and decreases the activity of the lumbar extensors, which significantly decreases lumbar lordosis during bridging. [Conclusion] The neck flexion should be considered when prescribing variations of a bridging exercise.
Key words: Bridging exercise, Electromyography, Neck flexion

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INTRODUCTION

A bridging exercise is commonly used to strengthen the lumbar and hip extension muscles. In some patients receiving physical therapy, bridging exercises increase the activity of the lumbar extensor muscles to a greater extent than that of the gluteus maximus; this then increases lumbar lordosis. In some individuals, trunk performance is impaired, and voluntary control of lumbar curvature becomes difficult. Therefore, effective methods to improve involuntary control of lumbar curvature during bridging exercises may be required.

Most previous studies have focused on investigating the influence of different positions of the lower extremities on electromyographic (EMG) activities of the trunk, hip, and thigh muscles while performing a bridging exercise[1–3)]. It is possible to change posture by controlling the position of the head because the head cannot move without some degree of compensating postural adjustment[4)]. Ishibashi et al.[5)] reported that a bridging exercise with active neck flexion showed an almost equal activity between the rectus abdominis and the lumbar extensor muscles. However, their study demonstrated only relative EMG activity of the lumbar extensor muscles compared with the rectus abdominis. Quantitative data, normalized with respect to maximal voluntary contractions, are required to select the most appropriate bridging exercise. To the best of our knowledge, lumbar curvature during a bridging exercise has not yet been studied. Therefore, little is known about the influence of neck flexion during a bridging exercise. During a bridging exercise in a supine position, the neck can be flexed in 2 ways, passively and actively. We predicted differences in postural effects between these 2 ways even if the neck flexion angles were identical during a bridging exercise. Thus, this study was performed to investigate the influences of passive and active neck flexion on spinal curvatures and EMG activities of the trunk, hip, and thigh muscles during a bridging exercise. Our findings provide basic information regarding methods for performing a bridging exercise.

SUBJECTS AND METHODS

Subjects

Thirteen healthy male volunteers participated in experiment 1. Their mean ± standard deviation age, height and weight were 18.7 ± 0.9 years, 170.5 ± 5.2 cm, and 57.8 ± 13.2 kg, respectively.

Eleven healthy male volunteers participated in experiment 2. Their mean ± standard deviation age, height and weight were 18.3 ± 0.5 years, 171.1 ± 4.9 cm, and 60.2 ± 6.5 kg, respectively.

The protocol for this study was approved by the Ethics Committee at the Kawasaki University of Medical Welfare (#228). Subjects provided written informed consent prior to participation.

Methods

EMG signals were recorded from the cervical extensors (C4), sternocleidomastoideus, lumbar extensors (L3), rectus abdominis, gluteus maximus, semitendinosus, and rectus femoris muscles on the left side. Disposable silver/silver chloride surface electrodes with a recording diameter of 1 cm (Blue Sensor P-00S; Ambu, Denmark) were used. Electrode placement was performed according to that described in a previous study[6]. Bipolar electrode pairs were placed longitudinally over the muscle belly at an interelectrode distance of 3 cm. A grounded electrode was placed over the spina iliaca anterior superior on the left side. Before the electrodes were placed, the skin was abraded with a skin preparation gel (Skin Pure; Nihon Kohden, Japan) and then cleaned with alcohol to reduce skin surface impedance. EMG signals, which were recorded for 5 s while the subjects maintained each position of the bridging exercise, were amplified, band-pass filtered (10–500 Hz), digitized, and stored using a data acquisition system (Myosystem 1200; Noraxon, Scottsdale, AZ, USA) at a sample frequency of 1000 Hz. The integrated EMG (IEMG) over the 5-s sample for each exercise was normalized to isometric maximal exertion tasks using a standard manual muscle test (%IEMG)[7]. Each isometric maximal exertion task was held for 5 s.

Spinal curvature was measured using the "Spinal Mouse" (Idiag, Fehraltorf, Switzerland), a handheld, computer-assisted, noninvasive device that can measure the sagittal curvature and the global and segmental ranges of the spine with an accuracy and reliability comparable to that of radiographic analysis[8]. In this study, the parameters recorded by the "Mouse" were the thoracic curvature (T1–T2 to T11–T12) and lumbar curvature (T12–L1 to the sacrum). For the thoracic and lumbar curvatures, values of less than 0° represent lordosis, whereas those of more than 0° represent kyphosis.

In experiment 1, the subjects wore only underpants and were barefoot. To monitor the elevation of their pelvises, square markers (2 cm × 2 cm) were attached to the left side of the subjects at the acromion, greater trochanter, and epicondylus lateralis femoris. The subjects lay on 2 beds placed slightly apart from each other (10 cm), because we required access to the center of the subjects' backs for obtaining measurements using the "Spinal Mouse". The system records the outline of the subject's spine from C7 to S3 in the sagittal plane when the "Spinal Mouse" is manually guided slightly laterally to the midline of the spinous process. One of the authors measured spinal curvatures immediately after EMG activities were recorded while the subjects maintained each position of the bridging exercise. Subjects' knees were positioned at 90° of flexion, with the feet apart at approximately the width of the shoulders and arms loosely resting beside the trunk. Subsequently, the subjects were instructed to elevate their pelvises until the greater trochanter was in line with the acromion and the epicondylus lateralis femoris at 3 different positions of passive neck flexion: with the head placed on a flat surface (0 cm), with the head on a 6-cm block (6 cm), and with the head on a 12-cm block (12 cm). In a clinical setting, we use approximately 6-cm high pillows. Therefore, in the first position, the head was elevated at 6 cm. The second position was set at double this height, and the control position was set at 0 cm. Subjects were also instructed to change their neck positions passively when resting their head on the blocks so that contraction of the neck muscles was not necessary. One of the authors instructed all subjects on how to elevate their pelvises and measured spinal curvatures immediately after EMG activities were recorded while the subjects maintained each position of the bridging exercise. One physical therapist recorded the EMG activities, and another monitored the markers. The order of performance of the 3 positions was chosen at random. Subjects were allowed to practice until they could perform the movement consistently. Data were collected once for each position.

In experiment 2, the subjects wore only underpants and were barefoot. They were asked to lie on 2 beds placed slightly apart from each other (10 cm) because of the requirement for space at the center of the subjects' backs for obtaining measurements using the "Spinal Mouse". They lay with their knees at 90° of flexion, with their feet apart at approximately the width of the shoulders and arms loosely resting beside the trunk. They were then asked to elevate the pelvis with maximal voluntary exertion in the following 4 different positions of active neck flexion: with the head rested on a flat surface (no contraction), with the head held slightly above a flat surface (0 cm), with the head held slightly above a 6-cm block (6 cm) and with the head held slightly above a 12-cm block (12 cm). Before starting this experiment, we tested the subjects' ability to perform different types of bridging positions during active neck flexion. A few subjects were unable to elevate the pelvis until the greater trochanter was in line with the acromion and the epicondylus lateralis femoris in the 12-cm position. Therefore, in experiment 2, the method of elevating the pelvis during bridging was different from that in experiment 1. The order of the 4 positions was chosen at random. The subjects were allowed practice sessions until they could perform the movement consistently. The data for each position were collected only once.

SPSS 16.0J for Windows was used for performing statistical analysis. One-way repeated-measures analysis of variance (ANOVA) was utilized to assess differences. Post hoc analysis was performed with Bonferroni's test. Values were considered statistically significant at $p<0.05$.

RESULTS

For experiment 1, the means ± standard deviations of the spinal curvatures and the %IEMG are shown in Table 1. In comparison with the 0-cm position, significantly greater thoracic kyphosis was observed during bridging in the 6-cm and 12-cm positions. Thoracic kyphosis in the 12-cm

Table 1. Average EMG activity and the spinal curvatures in passive neck flexion during a bridging exercise

	0 cm	6 cm	12 cm
Spinal curvatures (°)			
TC	38.9 ± 9.0	48.9 ± 8.5[a]	56.6 ± 6.7 [ab]
LC	–22.1 ± 7.3	–20.4 ± 7.8	–15.9 ± 6.6 [ab]
%IEMG (%)			
C4	23.4 ± 18.0	20.3 ± 14.0	21.9 ± 16.0
SM	15.8 ± 7.6	13.5 ± 10.1	15.6 ± 6.4
L3	52.5 ± 19.2	47.6 ± 15.4	47.5 ± 13.8
RA	10.6 ± 2.8	9.2 ± 2.3	9.4 ± 1.9
GM	12.4 ± 6.4	13.0 ± 7.5	12.3 ± 4.3
ST	18.8 ± 8.9	15.0 ± 6.3	16.6 ± 7.1
RF	11.0 ± 10.4	9.7 ± 9.2	11.3 ± 11.0

TC: thoracic curvature. LC: lumbar curvature. C4: C4 cervical extensors. SM: sternocleidomastoideus. L3: L3 lumbar extensors. RA: rectus abdominis. GM: gluteus maximus. ST: semitendinosus. RF: rectus femoris. [a]: Significantly different compared with the control by Bonferroni's test ($p<0.05$). [b]: Significantly different compared with the moderate flexion by Bonferroni's test ($p<0.05$).

Table 2. Average EMG activity and the spinal curvatures in active neck flexion during a bridging exercise

	NC	0 cm	6 cm	12 cm
Spinal curvatures (°)				
TC	41.1 ± 7.1	43.3 ± 10.1	47.3 ± 11.8	51.5 ± 8.3 [a]
LC	–27.0 ± 8.7	–17.5 ± 14.4	–9.5 ± 10.5 [a]	–0.5 ± 13.2 [ab]
%MVC (%)				
C4	24.5 ± 11.4	24.2 ± 10.0	24.2 ± 10.8	22.7 ± 12.6
SM	18.9 ± 11.5	59.1 ± 25.4 [a]	60.2 ± 27.1 [a]	66.0 ± 29.8 [a]
L3	58.4 ± 20.5	50.5 ± 21.5	47.1 ± 20.8	42.2 ± 19.7[a]
RA	9.8 ± 7.5	11.9 ± 7.3	22.9 ± 13.6 [a]	45.9 ± 21.1 [abc]
GM	15.8 ± 10.3	15.1 ± 9.5	14.4 ± 6.6	15.8 ± 8.2
ST	20.2 ± 12.2	19.7 ± 12.6	20.9 ± 13.4	21.3 ± 15.1
RF	9.8 ± 8.1	9.6 ± 7.5	10.1 ± 8.2	8.9 ± 8.5

TC: thoracic curvature. LC: lumbar curvature. C4: C4 cervical extensors. SM: sternocleidomastoideus. L3: L3 lumbar extensors. RA: rectus abdominis. GM: gluteus maximus. ST: semitendinosus. RF: rectus femoris. NC: no contraction. [a]: Significantly different compared with no contraction by Bonferroni's test ($p<0.05$). [b]: Significantly different compared with 0 cm by Bonferroni's test ($p<0.05$). [c]: Significantly different compared with 6 cm by Bonferroni's test ($p<0.05$).

position was significantly greater than that at 6 cm. We observed a significant decrease in lumbar lordosis during bridging in the 12-cm position versus the 0-cm position. The EMG activities of other muscles were not significantly different among the 3 positions.

For experiment 2, the means ± standard deviation values are listed in Table 2. The thoracic curvatures were less significant in the 12-cm position than in the no-contraction position. The lumbar curvatures were less significant in the 6-cm and 12-cm positions than in the no-contraction position and in the 12-cm position compared with the 0-cm position. The activity of the sternocleidomastoideus was more significant in the 0-cm, 6-cm and 12-cm positions than in the no-contraction position. The activity of the lumbar extensors was less significant in the 12-cm position than in the no-contraction position. The activity of the rectus abdominis was more significant in the 6-cm and 12-cm positions than in the no-contraction position and in the 12-cm position versus the 0-cm and 6-cm positions. The EMG activities of other muscles were not significantly different among the 4 positions.

DISCUSSION

In the first experiment, no significant differences were observed in the EMG activities of the muscles, but passive neck flexion decreased lumbar lordosis during a bridging exercise with the head placed on a 12-cm block. During flexion of the spine, the center of rotation of the intervertebral joint lies within the disc. Half flexion of the spine is resisted primarily by the capsular ligaments, intervertebral disc and the ligamentum flavum, with the interspinous and supraspinous ligaments contributing to a lesser extent[9]. The interspinous and supraspinous ligaments are slack at a small angle of flexion but are the first to sprain immediately after the limit of flexion is exceeded[9]. In this study, during full flexion and half flexion of the intervertebral joints, passive structures such as the ligaments and the posterior part of the annulus fibrosus disci intervertebralis contributed to the decrease in lumbar lordosis by transmitting tension from the neck to the lumbar region during the bridging exercise. The results of the first experiment indicated that lumbar lordosis decreased with the head placed on a 12-cm block during a bridging exercise, though no significant differences were observed in the EMG activities of muscles that we examined.

In the second experiment, the lumbar curvatures were less significant in the 6-cm and 12-cm positions than in the no-contraction position, and the activity of the rectus abdominis was more significant in the 6-cm and 12-cm positions than in the no-contraction position. Compared with the no-contraction position, the 12-cm position showed a significant decrease in the activity of the lumbar extensors. Because of reciprocal inhibition, the moderate activity of the rectus abdominis decreased the activity of the lumbar extensors, which possibly decreased lumbar lordosis. The results of the second experiment indicated that elevating the head slightly above a 12-cm block induces moderate contraction of the rectus abdominis and decreases the activity of the lumbar extensors, which possibly decreased lumbar lordosis during the bridging exercise[10]. In this study, no significant differences were observed in the EMG activity of the gluteus maximus among the 4 positions. We believe that the bridging exercise should be performed to recruit the gluteus maximus and not to recruit the semitendinosus because the trunk extensor muscle and the hamstring have a tendency to act more strongly than the gluteus maximus[11]. Akimoto et al.[2] showed that knee flexion angles of 130° during a bridging exercise produced higher EMG activity in the gluteus maximus than in the semitendinosus. A combination of these methods may be effective in decreasing lumbar lordosis and in increasing gluteus maximus activity.

There are several limitations to our study. First, the subjects may not have generated a true maximal exertion of each muscle. This could be due to lack of effort or to the muscle testing positions not being have been optimal for producing the maximum possible EMG signals. Interpretation of the absolute muscular effort expressed as %IEMG may be affected by the isometric maximal exertion task. There was generally a fairly wide variation in muscle activity between the study participants during the different exercises. This may be partially due to the variation in muscle strength among the subjects, which was not measured. Therefore, an exercise not requiring maximum effort, such as lifting a body segment like the trunk, may be easier for one subject and more difficult for another. The large standard deviation observed for the %IEMG simply reflects the difference in exercise intensity between subjects. In addition, because data were collected only once for each position, the reliability of each measure could not be calculated in this study. In the future, several measurements should be obtained at each position to determine the reliability of the data.

The results of this study therefore indicate that passive and active neck flexion should be considered when prescribing variations of a bridging exercise.

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