JAE-SEOP OH, PT, MSc[1] • **HEON-SEOCK CYNN,** PT, MA[2] • **JONG-HYUK WON,** PT, MSc[3]
OH-YUN KWON, PT, PhD[4] • **CHUNG-HWI YI,** PT, PhD[5]

Effects of Performing an Abdominal Drawing-in Maneuver During Prone Hip Extension Exercises on Hip and Back Extensor Muscle Activity and Amount of Anterior Pelvic Tilt

Hip extension exercises in the prone position are often performed in the rehabilitation of individuals with back and hip pathologies. Patients performing these exercises are often seen doing both hip and excessive lumbar spine movements, inducing unwanted anterior pelvic tilt and lumbar lordosis. To prevent such movement of the lumbar spine, therapists often ask patients to stabilize the spine using an abdominal drawing-in maneuver (ADIM).

STUDY DESIGN: Comparative, repeated-measures study.

OBJECTIVES: To examine the effects of an abdominal drawing-in maneuver (ADIM) using a pressure biofeedback unit on electromyographic (EMG) signal amplitude of the hip and back extensors, and the angle of anterior pelvic tilt during hip extension in the prone position.

BACKGROUND: Prone hip extension is a commonly used position for testing hip extensors strength and performing hip extension exercises. Performing an ADIM during hip extension exercise in prone may reduce the activity of erector spinae and angle of anterior pelvic tilt and increase the activity of hip extensors.

METHODS: Twenty ablebodied volunteers (10 male, 10 female), aged 19 to 26 years (mean ± SD, 22.3 ± 3.4 years), were recruited for this study. The EMG signal amplitude and angle of anterior pelvic tilt were measured during prone hip extension with and without performing an ADIM. Surface EMG signal was recorded from the erector spinae, gluteus maximus, and medial hamstrings. Kinematic data for anterior pelvic tilt were measured using a motion analysis system. Data were analyzed using 2-way ANOVAs.

RESULTS: When performing an ADIM during hip extension exercises done in a prone position, the EMG signal amplitude decreased significantly in the erector spinae (mean ± SD, 49 ± 14 %MVIC versus 17 ± 12 %MVIC; P<.001), and increased significantly in both the gluteus maximus (mean ± SD, 24 ± 8 %MVIC versus 52 ± 15 %MVIC; P<.001) and medial hamstrings (mean ± SD, 47 ± 14 %MVIC versus 58 ± 20 %MVIC; P = .008). The angle of anterior pelvic tilt decreased significantly during prone hip extension with an ADIM (mean ± SD, 10° ± 2° versus 3° ± 1°; P<.001).

CONCLUSIONS: Based on these findings, an ADIM could be used as an effective method to disassociate erector spinae activation from gluteus maximus and medial hamstrings during prone hip extension exercise. *J Orthop Sports Phys Ther 2007;37(6):320-324. doi:10.2519/jospt.2007.2435*

KEY WORDS: electromyography, low back, lumbar spine, lumbar stabilization

To prevent unwanted lumbar spine and pelvic movement substitution, many researchers have emphasized lumbar stabilization during limb movements and functional activities.[6,17] The lumbar spine can be stabilized either internally or externally, with internal stabilization achieved using an isometric action of the abdominal musculature during leg movement.[10] External lumbar stability during resistive exercise and manual or mechanical muscle testing can be achieved with the therapist's hands, therapeutic belts, or straps. However, it has been difficult to evaluate the effect of lumbar stabilization during exercise because of the lack of appropriate measurement methods.[14] A pressure biofeedback unit—an inflatable inelastic bag connected to a pressure gauge and an inflation device—has been shown to be a useful clinical tool to assess and enhance training in lumbar stabilization exercises.[8] In addition, a pressure biofeedback unit can be used to monitor the amount of abdominal muscle action indirectly by recording a change in pressure.[1]

Though many therapists use an ADIM to prevent substitution and excessive lumbar spine movement, there is no information on how effectively an ADIM with a

[1]Doctoral Student, Department of Rehabilitation Therapy, The Graduate School, Yonsei University, Wonju, South Korea. [2]Associate Professor, Department of Physical Therapy, Hanseo University, Seosan, South Korea. [3]Clinical Instructor, Department of Rehabilitation Therapy, Wonju Christian Hospital, Wonju College of Medicine, Yonsei University, Wonju, South Korea. [4]Associate Professor, Department of Rehabilitation Therapy, The Graduate School, Yonsei University, Wonju, South Korea. [5]Professor, Department of Rehabilitation Therapy, The Graduate School, Yonsei University, Wonju, South Korea. The protocol for this study was approved by the Yonsei University College of Health Science Human Studies Committee. Address correspondence to Oh-Yun Kwon, PT, PhD, Department of Rehabilitation Therapy, The Graduate School, Yonsei University, 234 Maji-li, Hungob-myon, Wonju, Kangwon-do 222-710, South Korea. E-mail: kwonoy@yonsei.ac.kr

pressure biofeedback unit may control motion and how it may alter the activation level of related muscles. Therefore, the purpose of this study was to measure the electromyographic (EMG) signal amplitude (ie, muscle activity) of the hip extensors and erector spinae, and the angle of anterior pelvic tilt during hip extension in the prone position. Investigating the effects of an ADIM for the prone hip extension exercise will provide beneficial information to the clinician for designing and implementing protocols for hip extension exercise.

We hypothesized that prone hip extension while performing an ADIM using a pressure biofeedback unit would reduce erector spinae activity and anterior pelvic tilt and increase the activity of gluteus maximus and medial hamstrings, compared with prone hip extension without performing an ADIM. We also examined whether there was a gender-related difference of muscle activation and angle of anterior pelvic tilt during hip extension in the prone position.

METHODS

Subjects

TWENTY HEALTHY, YOUNG SUBJECTS (10 men, 10 women) were recruited from the Department of Physical Therapy, Yonsei University, Korea (**TABLE**). The exclusion criteria were past or present neurological, musculoskeletal, or cardiopulmonary diseases, hip flexion contracture, and significant weakness of the gluteus maximus that would preclude hip extension in the prone position. Prior to the study, the principal investigator explained all the procedures to the subjects. All subjects signed an informed consent form approved by the Yonsei University College of Health Science Human Studies Committee.

EMG Recording and Data Analysis

EMG data were collected using a Biopac MP100WSW (Biopac Systems, Inc, Goleta, CA) and Bagnoli EMG System (Delsys, Inc, Boston, MA). The electrode sites were shaved and cleaned with rubbing alcohol to prepare the skin. Double differential Ag-AgCl bar electrodes (DE-3.1; Delsys, Inc, Boston, MA) were positioned using an electrolyte gel and adhesive skin interfaces at a fixed interelectrode distance of 1 cm. The reference electrode was attached to the styloid process of the ulna on the dominant upper extremity. EMG data were collected for the following muscles of the dominant lower extremity and corresponding lumbar region side: erector spinae (parallel to the spine, approximately 2 cm lateral to the spinous process of L1, over the muscle belly), gluteus maximus (half the distance between the greater trochanter and second sacral vertebra, in the middle of the muscle, on an oblique angle at, or slightly above, the level of the trochanter), and medial hamstrings (parallel to the muscle fibers, on the posterior aspect of the thigh, approximately half the distance between the gluteal fold and the popliteal fold).[4]

The sampling rate was 1000 Hz. The EMG signal was amplified with an overall gain of 1000 and digitized using Acqknowledge 3.7.2 software (Biopac Systems, Inc, Goleta, CA). Bandpass (20-450 Hz) and notch filters (60 Hz) were used. The raw data were processed into the root-mean-square (RMS) and converted to ASCII files for analysis. For normalization, the mean RMS of 3 trials of 5-second maximal voluntary isometric contraction (MVIC) was calculated for each muscle. The manual muscle testing positions for the MVIC were those recommended by Kendall et al.[9] For the testing of hip extension exercise, the EMG signal was collected for 5 seconds, while the hip was maintained in 10° of hip extension (isometric action of the muscles monitored). The data for each trial were expressed as a percentage of the calculated mean RMS of the MVIC (%MVIC), and the mean %MVIC of 3 trials was used for analysis.

Anterior Pelvic Tilt

A 3-dimensional ultrasonic motion analysis system (CMS-HS; Zebris Medizintechnik GmbH, Isny im Allgau, Germany) was used to measure the anterior pelvic tilt during hip extension in prone position. The reliability and validity of the ultrasonic motion analysis system used in this study was moderate to high, based on previous studies.[5,19] One set of 3 external active markers was secured to the pelvis on the side of the dominant lower extremity by fastening a belt around the pelvis at the level of the posterior superior iliac spines. The measurement sensor, consisting of 3 microphones facing the 3 markers, recorded the ultrasound signal. The angle of anterior pelvic tilt before hip extension was calibrated to zero as a reference position, and the amount of anterior pelvic tilt during the 5-second, 10° hip extension exercise was calculated from the reference position. The sampling rate was 20 Hz. Spatial marker positions were derived by using the method of triangulation.[11,18] The kinematic data were analyzed using WinData 2.19 software (Zebris Medical System, Tübingen, Germany). The mean angle of 3 trials was used for analysis.

DESCRIPTIVE DATA FOR PARTICIPANTS*

Variable	All	Men	Women
Age (y)	22.3 (3.4)	23.9 (4.0)	20.7 (1.3)
Body mass (kg)	67.4 (4.1)	72.5 (2.0)	62.3 (1.9)
Height (cm)	162.4 (6.2)	169.0 (2.3)	155.8 (1.8)

** Data are mean (SD).*

Procedure

Before testing, the subjects were familiarized with the use of an ADIM. The training session was approximately 30 minutes. Each subject practiced the abdominal hollowing using a pressure biofeedback unit (Chattanooga Group, Hixson, TN) and was informed of the role and pressure monitoring mechanism of a pressure biofeedback unit. The EMG activity and angle of anterior pelvic tilt were measured during prone hip extension, performed with and without doing an ADIM. The hip extension end-range movement used for data collection was sustained for 5 seconds. A target bar was placed at the level of 10° hip extension, as measured using an inclinometer, and subjects were instructed to extend their hip without knee flexion until the popliteal region of the dominant lower extremity touched the target bar. Each subject, in random order, performed the hip extension exercise with and without doing an ADIM. A 5-minute rest was given between the 2 conditions.

Prone Hip Extension Without an ADIM The subject assumed a prone position on a therapeutic table with the upper trunk, pelvis, and lower extremities aligned in a straight line. The head was allowed to extend slightly to maintain normal breathing. The subject was asked to perform hip extension, with the dominant lower extremity in the prone position, to a predetermined target bar.

Prone Hip Extension With an ADIM This testing condition was similar to prone hip extension without an ADIM, except that in this condition, a pressure biofeedback unit was placed between the pad of the therapeutic table and the subject's lower abdomen to monitor abdominal muscle action. The inelastic bag of the pressure biofeedback unit was inflated to 70 mmHg, and the subject was instructed to draw in the abdomen and hold the position. The subject was asked to maintain a pressure of 60 mmHg by visual feedback from an analog pressure gauge during hip extension.[15] Data collected within pressure changes of ±5 mmHg were used for the statistical analysis.

Statistical Analysis

The data were expressed as mean ± SD. Four separate 2-by-2 analyses of variance were used to determine the main effects and their interaction for each tested muscle and the angle of pelvic tilt. The within-subject factor was condition (2 levels: with and without an ADIM). The between-subject factor was gender (2 levels: female and male). A statistical significance level was set at .05.

RESULTS

There were no significant condition-by-gender interactions for the EMG signal amplitude of the erector spinae ($F_{1,18}$ = .202, P = .658), gluteus maximus ($F_{1,18}$ = .274, P = .607), and medial hamstrings ($F_{1,18}$ = .834, P = .373), and for the amount of anterior pelvic tilt ($F_{1,18}$ = .182, P = .675). There was a significant main effect for condition for the EMG signal amplitude of the erector spinae ($F_{1,18}$ = 120.158, $P<.001$), gluteus maximus ($F_{1,18}$ = 72.331, $P<.001$), and medial hamstrings ($F_{1,18}$ = 8.852, P = .008), and for the amount of anterior pelvic tilt ($F_{1,18}$ = 196.723, $P<.001$). For prone hip extension performed with an ADIM, the EMG signal amplitude decreased significantly in the erector spinae (mean ± SD, 17 ± 12 %MVIC compared to 49 ± 14 %MVIC), and increased significantly in both the gluteus maximus (mean ± SD, 52 ± 15 %MVIC compared to 24 ± 8 %MVIC) and medial hamstrings (mean ± SD, 58 ± 20 %MVIC compared to 47 ± 14 %MVIC) (**FIGURE 1**). The angle of anterior pelvic tilt decreased significantly in prone hip extension with an ADIM (mean ± SD, 3° ± 1° compared to 10° ± 2°) (**FIGURE 2**). There was no significant main effect for gender for the EMG signal amplitude of the erector spinae ($F_{1,18}$ = .278, P = .605), gluteus maximus ($F_{1,18}$ = .489, P = .494), and medial hamstrings ($F_{1,18}$ = .009, P = .926), and for the amount of anterior pelvic tilt ($F_{1,18}$ = .277, P = .605).

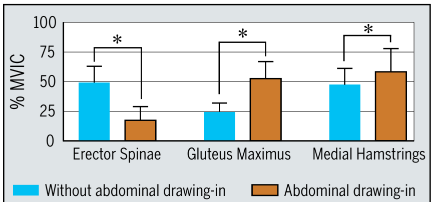

FIGURE 1. Electromyographic signal amplitude during prone hip extension with and without performing an abdominal drawing-in maneuver (mean ± SD). *Significantly different ($P<.05$).

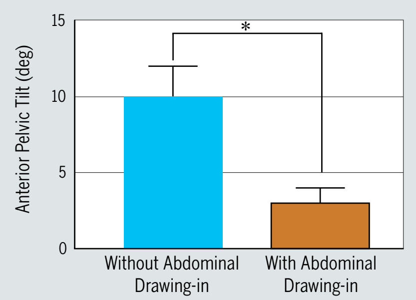

FIGURE 2. Angle of anterior pelvic tilt with and without performing an abdominal drawing-in maneuver (mean ± SD). *Significantly different ($P<.05$).

DISCUSSION

Hip extension exercises are often used in rehabilitation for individuals with hip and lumbar spine pathologies. However, lumbar hyperextension and anterior tilting of the pelvis are often observed during hip extension exercises performed in the prone position. Hip flexor stiffness, weakness of the gluteus maximus, deficit of abdominal control, and dominant muscle activity of the erector spinae may all contribute to excessive anterior pelvic tilt during hip extension in the prone position.[3] Sahrmann[16] stated that a deficit of abdominal control to counteract anterior pelvic tilt during hip extension in the prone position could induce excessive lumbar extension and lumbopelvic dysfunction, and advocated monitoring pelvic motion with the hands to prevent excessive pelvic rotation and anterior pelvic tilt. According to Chaitow,[2] abnormal movement during hip extension in the prone position includes anterior pelvic tilt, lumbar rotation, lumbar hyperextension, delayed gluteus maximus activation, and knee flexion. Accordingly, many authors have recommended abdominal muscle activation during hip extension exercises to prevent unwanted substitution motion of the lumbar spine and pelvic regions.[7,12,13] However, no study has investigated the effects of performing an ADIM with a pressure biofeedback unit on the erector spinae, gluteus maximus, and medial hamstrings muscle activity, and the angle of anterior pelvic tilt during hip extension exercises in the prone position.

In this study, the angle of anterior pelvic tilt was significantly higher during prone hip extension performed without an ADIM (10°), compared to prone hip extension with an ADIM (3°), and the erector spinae muscle activity during prone hip extension without an ADIM was approximately 3 times higher than during prone hip extension with an ADIM. The activity of the gluteus maximus and medial hamstrings muscles were significantly greater during prone hip extension with an ADIM, compared to prone hip extension without an ADIM. Because a target bar was placed at the level of 10° of hip extension to control the amount of hip extension during the exercises with and without an ADIM, these results suggest that performing an ADIM using a pressure biofeedback unit during hip extension in prone decreases erector spinae activity, and that hip extension is performed with increased gluteus maximus and medial hamstrings activity. Thus it is suggested that performing an ADIM during hip extension could be a good strategy when anterior pelvic tilt and lumbar spine motion is to be minimized. These results also suggest that using an ADIM during hip extension in prone promotes activation of the hip extensors, while reducing activation of the erector spinae.

However, it could not be determined in this study whether an ADIM with a pressure biofeedback unit activated abdominal muscles, pelvic floor muscles, and the diaphragm, because the activities of these muscles were not measured directly. The increased EMG signal amplitude of the gluteus maximus and medial hamstrings during prone hip extension performed with an ADIM can be explained by various concepts. Increased muscle activity can be induced from biomechanical alterations caused by reduced anterior pelvic tilt. Because the angle of anterior pelvic tilt was 3° during a 10° hip extension exercise performed while doing an ADIM with a pressure biofeedback unit, compared with 10° while performing hip extension without doing an ADIM, and both the pelvis and hip contribute to 10° hip extension (ie, hip extension is a composite movement), it could be thought that the relatively higher EMG signal amplitude of the hip extensors was required to achieve 10° hip extension when an ADIM was performed. A second possibility is that the increased hip extensors activity during hip extension while doing an ADIM can be related to the need of passively stretching the anterior structures of the hip, given the lesser contribution of the pelvis to elevation of the limb in extension. A third explanation is that the difference in the angle of anterior pelvic tilt between the 2 hip extension conditions could have affected the length-tension relationship of the erector spinae (less shortening) and the hip extensors (more shortening). While this is a possibility, a difference of 7° of anterior pelvic tilt is likely to create only a small difference in muscle length. Finally, even though abdominal muscle activity was not measured in this study, if abdominal muscle activity was increased with an ADIM, less erector spinae activity could potentially be explained by reciprocal inhibition.

There were several limitations to this study. First, our results cannot be generalized to other populations because all the subjects who participated in the study were healthy young individuals. Therefore, the changes related to performing an ADIM using a pressure biofeedback unit during hip extension in the prone position should be confirmed in other patient populations. Second, surface EMG was used to monitor muscle activity, leaving the possibility of crosstalk from adjacent muscles. Third, the activity level of the abdominal muscles, diaphragm, and pelvic floor muscles was not measured. Fourth, because hip joint extension angle was not measured in our study, the lumbopelvic hip movement patterns, with and without an ADIM, were not fully described.

CONCLUSION

This study examined the effects of doing an ADIM with a pressure biofeedback unit on the EMG signal amplitude of the erector spinae, gluteus maximus, and medial hamstrings, and the angle of anterior pelvic tilt, when performing prone hip extension exercises. Our results would indicate that when using the ADIM with the pressure biofeedback unit, while performing hip extension in prone, the EMG signal amplitude of the erector spinae decreased significantly, while the activity of the gluteus maximus and medial hamstrings increased significantly, and the amount of anterior pelvic tilt was significantly reduced. Therefore, an ADIM with a pressure biofeedback unit during prone hip extension exercise is recommended as an effective method for preventing excessive anterior pelvic tilt. It may also be beneficial if the goal of the hip extension exercises is to increase the contribution of the hip extensors while reducing the activation of the lumbar erector spinae. ◉

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