Can Abdominal Drawing-In Maneuver Using a Pressure Biofeedback Unit Change Muscle Recruitment Pattern During Prone Hip Extension?

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Abstract

This study examined the effects of the abdominal drawing-in (ADI) maneuver using a pressure bio-feedback on muscle recruitment pattern of erector spinae and hip extensors and anterior pelvic tilt during hip extension in the prone position. Fourteen able-bodied volunteers, who had no medical history of lower extremity or lumbar spine disease, were recruited for this study. The muscle onset time of erector spinae, gluteus maximus, and medial hamstring and angle of anterior pelvic tilt during hip extension in prone position were measured in two conditions: ADI maneuver condition and non-ADI maneuver condition. Muscle onset time was measured using a surface electromyography (EMG). Kinematic data for angle of anterior pelvic tilt were measured using a motion analysis system. The muscle onset time and angle of anterior pelvic tilt were compared using a paired t-test. The study showed that in ADI maneuver during hip extension in prone position, the muscle onset time for the erector spinae was delayed significantly by a mean of 43.20 ms (SD 43.12), and the onset time for the gluteus maximus preceded significantly by a mean of -4.83 ms (SD 14.10) compared to non-ADI maneuver condition (p<.05). The angle of anterior pelvic tilt was significantly lower in the ADI maneuver condition by a mean of 7.03 degrees (SD 2.59) compared to non-ADI maneuver condition (15.01 degrees) (p<.05). The findings of this study indicated that prone hip extension with the ADI maneuver was an effective method to recruit the gluteus maximus earlier than erector spinae and to decrease anterior pelvic tilting.

Key Words: Abdominal drawing-in maneuver; Anterior pelvic tilt; Hip extension; Muscle onset time; Pressure biofeedback unit.

Introduction

The concept of spinal and lumbo-pelvic stability has progressed significantly over time (Mills et al, 2005). Panjabi et al (1989) described the spine as a series of spinal segments, and spinal stability as the ability of each segment to resist translation or rotation in any of three anatomical planes: sagittal, frontal and coronal. Because of its multi-segmental nature, the spine is particularly prone to the effects of reactive forces from limb movements (O'Sullivan, 2000). Maintaining stability of the spine during active limb movements requires coordinated muscle contraction controlled by the central nervous system (Ebenbichler et al, 2001; Hodges and Richardson, 1997; Kaigle et al, 1995).

To maintaining and increasing coordinated lumbar stabilization, many researchers have emphasized

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selective muscle contraction during active limb movements in various functional activities (Hides et al, 1996; Hodges and Richardson, 1996; Richardson et al, 2004). Although the selective muscle contraction during active limb movements have been emphasized, less attention has been given to monitoring the methods of selective muscle contraction. A pressure biofeedback unit, an inflatable inelastic bag connected to a pressure gauge and an inflation device, has been proven to be useful clinical tool for assessment and to enhance training in selective muscle contraction in lumbar stabilization exercise (Jull et al, 1993). In addition, a pressure biofeedback unit can monitor the movement of the abdominal wall indirectly by recording a change in pressure (Cairns et al, 2000).

Whereas many studies using a pressure biofeedback unit were performed in the supine position during hip flexion (Ng and Richardson 1994; Wohlfahrt et al, 1993), hip extension in the prone position has not been extensively studied. Clinical experiences on the function of low back muscles suggested that the lumbar extensor muscles may be important factors in the development of low back pain. In addition, hip extension in prone position is regarded as a important exercise which is used to evaluate strength and recruitment order for erector spinae, medial hamstring, and gluteus maximus muscle (Vogt and Banzer, 1997). According to Janda et al (2006), back injury is associated with an earlier activation of the postural muscle. In patients whose gluteals are inhibited, earlier activation of the hamstrings and erector spinae muscles occurs during active hip extension.

If the hip extensors are weak, it is possible for the erector spinae to be overactive to compensate for insufficient hip extension. In addition, weakness of the abdominal muscles and shortness of the iliopsoas muscles will contribute to anterior pelvic tilt during hip extension in prone position (Sahrmann, 2002). Van Dillen et al (2001) stated that an active hip extension performed during the examination primarily resulted in increased low back pain symptoms in pa-

tients with low back pain because of abnormal hip extension patterns. Hodges (1999) postulated that deficiencies in movement patterns and motor regulation play a primary role in the development of musculoskeletal dysfunction. To prevent unwanted compensatory lumbar hyperextension and changed muscle recruitment pattern during hip extension in the prone position, many clinicians have emphasized the need to use selective exercise of hip extensors in the treatment of low back pain (Liebenson, 2004). However, to the authors' knowledge no study has confirmed the effect of an abdominal drawing-in maneuver on muscle recruitment pattern of the erector spinae, gluteus maximus, and medial hamstring muscle during active hip extension in prone position. Since hip extension in prone position is the commonly using exercise protocol in low back pain patients, investigating the role of an abdominal drawing-in maneuver in the prone position will provide beneficial information to the clinician for designing and implementing exercise therapy of low back pain.

We hypothesized that the ADI maneuver using a pressure biofeedback unit will stabilize lumbar region, thereby recruit the gluteus maximus faster than the erector spinae and decrease anterior pelvic tilt during hip extension in the prone position. Therefore, we compared the EMG onset of lumbar erector spinae and hip extensors and angle of anterior pelvic tilt during hip extension in the prone position with and without the ADI maneuver using a pressure biofeedback unit.

Methods

Subjects

Fourteen healthy young man were recruited from the Department of Physical Therapy, Yonsei University, Korea. The subjects had a mean age of 24.3±2.8 years, a mean weight of 69.8±4.3 kg, and a mean height of 171.2±5.2 cm. The subjects participated regularly in physical activities and had no history of low back pain,

or of neuromuscular disorders. The subjects were able to perform painless limb extension in prone position. Before the study, the principal investigator explained all the procedures to the subjects in detail.

Surface Electromyographic Recording and Data Analysis

EMG data were collected using a Biopac MP100WSW[1] data acquisition system and a Bagnoli EMG system[2]. The skin was cleansed with rubbing alcohol, and disposable Ag-AgCl surface electrodes were positioned at an interelectrode distance of 2 ㎝. 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 on the dominant side as the lower extremity: erector spinae (parallel to the spine, 2 ㎝ apart, approximately 2 ㎝ from L1 over the muscle belly), gluteus maximus (half the distance between the greater trochanter and second sacral vertebrae in the middle of the muscle on an oblique angle at or slightly above the level of the trochanter), and medial hamstring (parallel to the muscle fibers on the back of the medial thigh, approximately half the distance from the gluteal fold to the back of the thigh) (Cram, 1998). The EMG signals were amplified and digitized with AcqKnowledge software, version 3.7.2.[3] Bandpass (20~450 Hz) and lowpass filters (cutoff frequency: 2 Hz) were used. The raw data were processed into the root mean square (RMS). A 1000 Hz sampling rate per channel was selected. The foot switch under the patella used to determine was time (reference time: zero) of leg lifting. The plus value of onset time means later onset of muscle action than reference time. The minus value of onset time means earlier onset of muscle action than reference time. The velocity of hip extension was controlled by a metronome. EMG

signal deviated by more than 2 SD for a minimum of 25 ㎳ for maintaining muscle contraction above the baseline level The mean onset time of three trials in both conditions was used for statistical analysis.

Kinematic study of anterior pelvic tilt

A three-dimensional ultrasonic motion analysis system, CMS-HS[4], was used to measure the angle of anterior pelvic tilt during hip extension in the prone position. One triplet bearing three external active markers that send position information was secured at the pelvis of the lower extremity to be lifted by a fastening belt passing around at the level of posterior superior iliac spines. The measurement sensor consisted of three microphones that record the ultrasound and determine a local coordinate system were positioned in the right side of the subjects. The sampling rate was 20 Hz. The orientation and position of a body segment is determined by the three markers per segment (Knoll et al, 2004). These three points produce a reference frame and act as fundamental points of the reference frame. Spatial marker positions (x, y, z) were derived by using the method of triangulation, and anterior pelvic tilt in sagittal plane was calculated in degrees at each moment of time during the measurement. The coordinate information recorded by the sensor was analyzed by the Win-data 2.19 software. The mean angle of three trials was determined for comparison.

Procedures

Before testing, the subjects were instructed to familiarize themselves with the ADI maneuver which consisted of abdominal hollowing using a pressure biofeedback unit[5]. The EMG was measured during prone hip extension with the ADI maneuver and prone hip extension without the ADI maneuver. To control the individual variability of hip extension

1) Biopac System Inc, 42 Aero Camino, Goleta, CA 93117, U.S.A.
2) Delsys Inc, 650 Beacon St., Boston, MA 02215, U.S.A.
3) Biopac System Inc, 42 Aero Camino, Goleta, CA 93117, U.S.A.
4) Zebris Medizintechnik GmbH, D-88305 Isny im Allgäu, Max-Eyth-Weg 42, D-88316 Isny im Allgau, Germany.
5) Chattanooga Group, 4717 Adams Road, Hixson, TN 37343, U.S.A.

range, a target bar was placed at the level of 10-degree hip extension using an inclinometer so that the popliteal region of the dominant side of lower extremity touches the target bar during hip extension. Each subject performed active hip extension between the two conditions in a random order. A 5-minute rest period was given between the two conditions.

Statistical Analysis

The data are expressed as the mean±standard deviation (SD). The significance of the difference between two conditions was assessed using a paired t-test with the significance level set at .05.

Results

The muscle onset time with and without the ADI maneuver is presented in Table 1 and Figure 1, and the angle of anterior pelvic tilt during two conditions is shown in Table 2 and Figure 2. In the ADI maneuver condition, the muscle onset time for the erector spinae was delayed significantly by a mean of 43.20 ms (SD 43.121), whereas the muscle onset time for the gluteus maximus preceded significantly by a mean of -4.83 ms (SD 14.10) compared to non-ADI maneuver condition (p<.05). The angle of anterior pelvic tilt decreased significantly in the ADI maneuver condition by a mean of 7.03 degree (SD 2.59) compared to non-ADI maneuver condition (p<.05).

Discussion

Although many previous studies have reported lumbar stabilization methods during hip flexion in the supine position (Manniche et al, 1991; Richardson et al, 1992), our study is the first to determine the effects of the ADI maneuver with a pressure biofeedback unit on recruitment pattern of erector spinae, gluteus maximus, and medial hamstrings and angle of anterior pelvic tilt during hip extension in the prone position.

The results of this study support the hyposthesis that the ADI maneuver performed during prone hip extension can activate the gluteus maximus faster than the erector spinae. Despite of recruited healthy

Table 1. EMG onset time in muscles during abdominal drawing-in maneuver and without abdominal drawing-in maneuver

	ADI[†] (ms)	Without ADI (ms)	t	df	p
Erector spinae	43.20±43.12[a]	-.94±20.10	3.11	13	.008*
Gluteus maximus	-4.83±14.10	7.44±10.19	-3.05	13	.009*
Medial hamstring	-8.85±8.74	-4.67±5.80	-2.10	13	.056

[†] Abdominal drawing-in maneuver.
[a] Mean±SD.
*p<.05.

Table 2. Anterior pelvic tilt during abdominal drawing-in maneuver and without abdominal drawing-in maneuver

	ADI[†] (°)	Without ADI (°)	t	df	p
APT[‡]	7.03±2.59[a]	15.01±2.57	14.70	13	.000*

[†] Abdominal drawing-in maneuver.
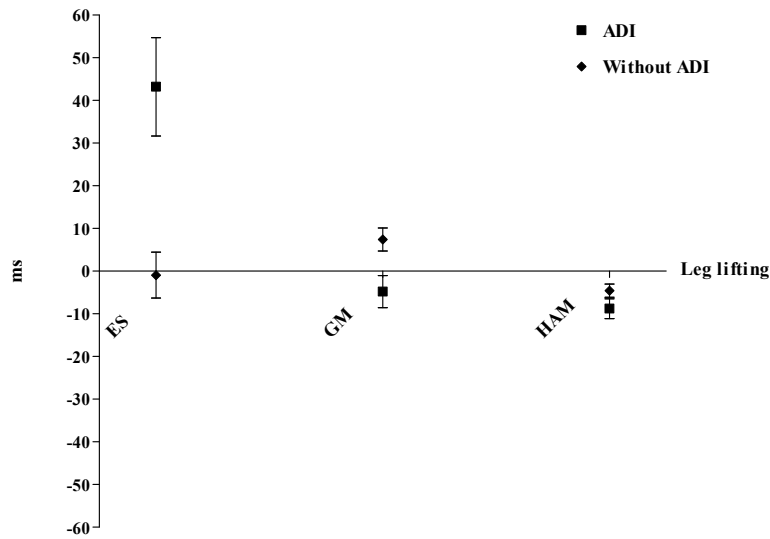[‡] Anterior pelvic tilt.
[a] Mean±SD.
*p<.05.

Figure 1. EMG onset time between abdominal drawing-in maneuver (ADI) and without abdominal drawing-in maneuver (without ADI). ES: erector spinae, GM: gluteus maximus, HAM: hamstrings.
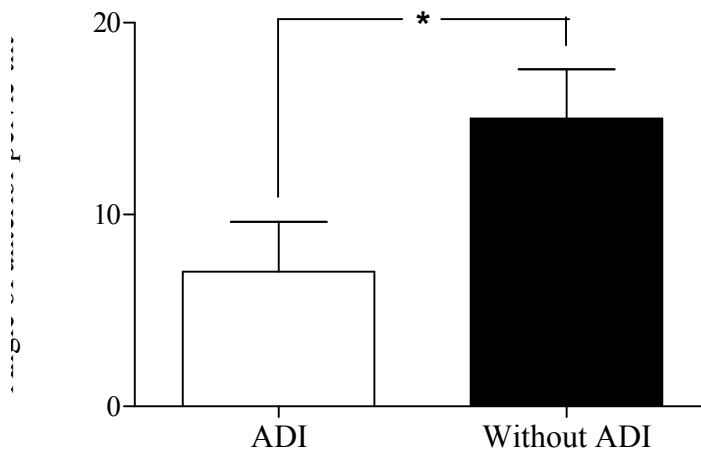

Figure 2. Angle of anterior pelvic tilt between abdominal drawing-in maneuver (ADI) and without abdominal drawing-in maneuver (without ADI). Data are means and standard deviations. *Significant difference between the two conditions. The error bar represents one standard deviation.

subjects, our study revealed anticipatory activation of the lumbar erector spinae and medial hamstring and before hip extension and the activation of gluteus maximus after hip extension in without abdominal drawing-in conditoin. It is noteworthy to acknowledge that healthy subjects without symptoms of low back pain could produce an anticipatory activation of the lumbar erector spinae before hip extension and

the activation of gluteus maximus after hip extension in without abdominal drawing-in maneuver conditoin. According to a statement of Janda et al (2006) named the gluteus maximus the prime mover in normal hip extension firing pattern. However, this pattern is contrary to findings Vogt and Banzer (1997) in healthy subjects. The mentioned authors described the onset of gluteus maximus after hip extension in prone position.

Previous studies have reported that subjects with back pain have significant gluteal delay during hip extension (Bullock-Saxton et al, 1994; Nadler et al, 2002). Subjects with back pain showed relatively faster recruitment of the erector spinae compared with gluteal recruitment. This altered hip extension synergy with compensatory hyperextension of the lumbar spine will lead to over stressing the lumbar facets and movement dysfunction (Comerford and Mottram, 2001). Repetitive lumbar hyperextension during hip extension exercise would contribute to inducing lumbar extension syndrome and lower back pain (Sahrmann, 2002). Therefore, we think that the ADI maneuver using a pressure biofeedback unit can be applied to prevent motor control dysfunction by recruiting the gluteus maximus faster than the erector spinae during hip extension in the prone position.

Abdominal muscle contraction is considered an essential component for maintaining lumbar and pelvic stability during leg movements. Previous studies have reported that drawing the lower abdomen up towards the spine facilitates transverse abdominis and lumbar stability (Herrington and Davies, 2005; Hodges, 1999). Abdominal muscle contraction increases intra-abdominal pressure preventing a spine shift anteriorly. In addition, abdominal muscle contraction can prevent anterior pelvic tilt (Cresswell et al, 1992). We used the method of lumbar stabilization using a pressure biofeedback unit in the ADI maneuver condition. The subjects were instructed to draw the lower abdomen up and maintain 60 ㎜Hg pressure during hip extension in the ADI maneuver condition. Since the angle of pelvic anterior tilt de-

creased significantly in the ADI maneuver condition compared to the non-ADI maneuver condition, it can be stated that the results of our study also support the hypothesis that the ADI maneuver using a pressure biofeedback unit improve lumbar spine stability resulted from the increment of intra-abdominal pressure and prevention of anterior pelvic tilt.

Our study has some limitations. Because all subjects participated in the study were young and able-bodied, our results cannot be generalized in other populations Therefore, the benefits of the ADI maneuver using a pressure biofeedback unit during hip extension in the prone position should be confirmed in a patient population. In our study, abdominal muscle activity and intra-abdominal pressure were not measured directly, thereby necessitating further studies to assess abdominal muscle activity during hip extension exercise with lumbar stabilization in the prone position.

Conclusion

This study investigated the effects of the ADI maneuver with a pressure biofeedback unit on muscle recruitment pattern of lumbar erector spinae and hip extensors and angle of anterior pelvic tilt during hip extension in the prone position. We found that the onset time for the erector spinae was delayed significantly and the onset time for the gluteus maximus preceded significantly with the ADI maneuver using a pressure biofeedback unit during hip extension in prone position. Additionally, the angle of anterior pelvic tilt decreased significantly with the ADI maneuver using a pressure biofeedback unit. Therefore, hip extension with the ADI maneuver using a pressure biofeedback unit in the prone position can be recommended for an earlier recruitment of the gluteus maximus than the erector spinae and decreasing anterior pelvic tilting.

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