

Original Article

# Effects of abdominal drawing-in during prone hip extension on the muscle activities of the hamstring, gluteus maximus, and lumbar erector spinae in subjects with lumbar hyperlordosis

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**Abstract.** [Purpose] The purpose of this study was to compare the effects of an abdominal drawing-in maneuver (ADIM), measured using a pressure bio-feedback unit, on the activities of the hamstring, gluteus maximus, and erector spinae muscles during prone hip extension. [Subjects and Methods] Thirty healthy adult subjects (14 male, 16 female), were recruited. Subjects' lumbar lordosis and pelvic tilt angles were measured, and based on the results, the subjects were divided into two groups: a hyperlordotic lumbar angle (HLLA) group (n=15) and a normal lordotic lumbar angle (NLLA) group (n=15). The muscle activities of the hamstring and gluteus maximus, and of the erector spinae on the right side of the body, were recorded using surface electromyography. [Results] When performing ADIM with prone hip extension, the muscle activity of the gluteus maximus of the HLLA group significantly improved compared with that the NLLA group. [Conclusion] This study demonstrated that ADIM with prone hip extension was more effective at eliciting gluteus maximus activity in the HLLA group than in the NLLA group. Therefore, ADIM with prone hip extension may be useful for increasing the gluteus maximus activity of individuals with lumbar hyperlordosis.

**Key words:** Abdominal drawing-in maneuver, Hyperlordotic lumbar angle, Prone hip extension

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## INTRODUCTION

Normal alignment of the pelvis is critical for balance and for the maintenance of correct spinal posture<sup>1)</sup>. This alignment is affected by pelvis position, which is in turn determined by the contractile strengths of the muscles surrounding the pelvis, and by the lengths of the anterior and posterior ligaments<sup>2)</sup>. Sahebozamani et al.<sup>3)</sup> suggested that pelvis problems could be accurately identified by investigating the activity ratios of the lumbar and pelvic muscles. In other studies of the relationship between the abdominal muscles and lumbar lordosis, the activity ratio of the trunk flexor and hip extensor muscles was found to be associated with the angle of lumbar lordosis, which by extension could be a risk factor for low back pain<sup>4)</sup>.

Lumbar hyperlordosis limits the range of motion of the spine and weakens the hip extensors<sup>5, 6)</sup>. A general clinical method for improving the muscle strength of weakened hip

extensors is hip extension exercise<sup>7)</sup>. This type of exercise is often recommended for patients with pain in the pelvis, hip, or lower back, and is also used to strengthen the gluteus maximus<sup>8, 9)</sup>. However, hip extension exercise may lead to a hyperlordotic lumbar angle and excessive pelvic tilt, because of instability in the lumbar and pelvis and imbalances in surrounding muscles<sup>10)</sup>. In a clinical setting, the abdominal drawing-in maneuver (ADIM) is used during hip extension movements to prevent abnormal movements of the lumbar region and pelvis<sup>10)</sup>. Previous studies have reported that ADIM stabilizes the lumbar region and pelvis during hip extension, and also reduces pain and/or dysfunction in the lumbar region and pelvis, as well as promoting re-education of muscular function<sup>10, 11)</sup>. Oh et al.<sup>10)</sup> investigated the effects of ADIM, during hip extension, on the muscle activities of the trunk and hip extensors, and the degree of anterior pelvic tilt, and found that the muscle activity of the hip extensors improved, and the angle of pelvic tilt decreased.

Previous studies of the effects of ADIM during hip extension on the muscle activities of the hamstring (HAM), gluteus maximus (GM), and lumbar erector spinae (LES) were principally concerned with low back pain, and did not consider lumbar lordosis *per se*. Therefore, the objective of the present study was to examine the effects of ADIM on HAM, GM, and LES muscle activities in subjects with hyperlordosis during hip extension, as well as the clinical

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usefulness of ADIM during hip extension.

## SUBJECTS AND METHODS

### Subjects

Thirty adults, with *a priori* understanding of the study objectives, consented to participate in this study. The subjects were given detailed verbal and written explanations of the study procedures and voluntarily signed a letter of consent. This study complied with the ethical principles of the Declaration of Helsinki, and our Institutional Ethics Committee also approved the experimental protocol. An inter-group comparison experimental design was used, in which subjects were divided into hyperlordotic lumbar angle (HLLA) and normal lordotic lumbar angle (NLLA) groups. A paired design was used, so that subjects in the NLLA group demonstrated similar general and medical characteristics to their counterparts in the HLLA group. Before the experiment began, lumbar lordosis and pelvic tilt angles were measured. Subjects with a lumbar lordosis angle of 45° or below, and a pelvic tilt angle of 15° or above, were assigned to the HLLA group; the remaining subjects were assigned to the NLLA group. Subjects who had received muscle strengthening training in the past 6 months, that may have affected muscle activities in the trunk and lower limbs, were excluded. The general characteristics of the subjects are provided in Table 1. There were no statistically significant group differences in age, sex, height, or weight ( $p > 0.05$ ). However, significant group differences in average lumbar lordosis and pelvic tilt angle were observed ( $p < 0.05$ ).

### Methods

Measurements of lumbar lordosis and pelvic tilt angle were conducted with subjects standing with their feet at shoulder width apart, with their arms folded and hands on the chest, and their sides were photographed. The experimenter palpated subjects' T12, L3, and L5 vertebrae, anterior superior iliac spine, and posterior superior iliac spine, and attached 13-mm marker points before taking photographs. Photographs were taken at a distance of 2.4 m from the subject, with the tripod height horizontally aligned with subjects' pelvises. Lumbar lordosis and pelvic tilt angle were measured with the photogrammetry postural analysis. The reliability of measurements of lumbar lordosis and pelvic tilt angles was reported to be high ( $r = 0.86-0.98$ ) using this method<sup>12</sup>).

A Delsys-Tringno EMG system was used to collect EMG data. EMG signals collected from each muscle were converted to digital signals and processed by Works Acquisition, an EMG analysis software application for PCs. The sampling rate of EMG signals was 2,000 Hz, and the EMG frequency bandwidth was restricted to 20–500 Hz. The muscle activity of each muscle was converted to RMS for analysis purposes. The maximum voluntary isometric contraction (MVIC) of each muscle was measured for the normalizing the data. For the MVIC of the LES muscles, subjects were asked to raise the trunk to the level of maximum resistance encountered below the scapula. For the GM, the hip joint was placed in the extension position, with the knee flexed at 90°. Then, resistance was applied to the distal aspect of the posterior

**Table 1.** Descriptive characteristics of the participants (n = 30)

	HLLA (n = 15)	NLLA (n = 15)
	Mean ± SD	Mean ± SD
Age (years)	23.5 ± 3.4	25.3 ± 3.0
Gender		
Male	5 (33%)	9 (60%)
Female	10 (67%)	6 (40%)
Height (cm)	166.6 ± 8.0	169.9 ± 8.4
Weight (kg)	58.9 ± 7.8	63.7 ± 6.0
Lumbar lordosis angle (°)	37.2 ± 2.4	58.1 ± 3.6*
Pelvic tilt angle (°)	17.9 ± 1.8	6.2 ± 2.0*

HLLA: hyperlordotic lumbar angle; NLLA: normal lordotic lumbar angle, \* $p < 0.05$

part of the thigh. The MVIC of the HAM muscle was measured while the hip joint was maintained in the extension position, with the knee flexed to almost 70°. Resistance was applied to the distal aspect of the posterior part of the shank during knee flexion. The MVIC of each muscle was measured for 7 s, three times, and the mean value of the middle 3 s (excluding the first and last 2 s) was converted to RMS and considered equivalent to 100% MVIC. To prevent muscle fatigue, subjects were allowed a 2-min break between measurements<sup>13</sup>. Before measuring EMG signals, hair on the skin was shaved, and the skin was cleaned with an alcohol swab before electrodes were attached for EMG measurement. Three EMG electrodes were attached to the GM, HAM, and LES muscles according to the EMG guide book<sup>14</sup>. Before beginning the experiment, all subjects were educated about the experimental method. The experiment was conducted with subjects lying prone, and a horizontal bar was placed over the subjects' ankle joints, so that they touched the horizontal bar when hip extension reached 10°, as measured by a goniometer. To maintain a constant speed during hip extension by each subject, an electronic metronome was used, which provided visual information by displaying each second on the screen. Subjects were directed to perform hip extension, and maintain for 5 s before returning to the start position. The RMS value of the middle 3 s, excluding the first and last 1 s, was used. Prior to measurement, subjects were allowed to practice the hip extension motion three times. Three measurements were then taken, and the mean values of the activity of each muscle were calculated.

ADIM was performed by both the HLLA and NLLA groups, monitored by a pressure bio-feedback unit (PBFU; Chattanooga Group, Hixson, TN, USA). The PBFU was positioned under the lower abdomen of subjects in the prone position. With the pressure set to 70 mmHg, subjects commenced the ADIM as soon as the metronome started. They lowered the pressure to, and maintained it at, 60 mmHg.

IBM SPSS (ver. 20.0., Armonk, NY, USA) was used for analysis purposes, and the Kolmogorov-Smirnov test was performed to verify that data were normally distributed. The independent t-test was conducted to examine differences in the general characteristics of the two groups. The paired t-test was conducted to examine intra-group differences in the activity of each muscle during hip extension, and the

**Table 2.** Within group comparison of mean and SD of %MVIC with and without ADIM (n = 30)

	HLLA (n = 15)		NLLA (n = 15)	
	Without ADIM	With ADIM	Without ADIM	With ADIM
HAM	48.1 ± 23.5 <sup>a</sup>	57.4 ± 26.2	41.2 ± 19.5	53.1 ± 24.0*
GM	32.5 ± 21.3	45.9 ± 33.7*	23.9 ± 18.5	24.4 ± 14.3
LES	34.5 ± 20.4	23.9 ± 27.6*	45.2 ± 17.6	28.7 ± 23.3*

MVIC: maximum voluntary isometric contraction; ADIM: abdominal drawing-in maneuver; HAM: hamstring; GM: gluteus maximus; LES: lumbar erector spinae; HLLA: hyperlordotic lumbar angle; NLLA: normal lordotic lumbar angle

<sup>a</sup>Mean ± SD, \*p < 0.05

independent t-test was conducted to examine inter-group differences. Significance was accepted for values of p < 0.05.

## RESULTS

Comparison of the activity of the HAM muscle in the HLLA group, with or without ADIM, revealed that %MVIC of the HAM increased from 48.1 ± 23.5%, prior to performance of ADIM, to 57.4 ± 26.2% during performance of ADIM. However, this change was not significant (p > 0.05). For the GM, %MVIC significantly increased from 32.5 ± 21.3% prior to performance of ADIM, to 45.9 ± 33.7% during performance of ADIM (p < 0.05). For the LES, %MVIC decreased significantly from 34.5 ± 20.4%, prior to performance of ADIM, to 23.9 ± 27.6% during performance of ADIM (p < 0.05; Table 2). Comparison of activity of the HAM muscle in the NLLA group, with or without ADIM, revealed that %MVIC increased significantly from 41.2 ± 19.5%, prior to performance of ADIM, to 53.1 ± 24.0% during performance of ADIM (p < 0.05). For the GM, %MVIC increased from 23.9 ± 18.5% prior to performance of ADIM, to 24.4 ± 14.3% during performance of ADIM. However, this change was not significant (p > 0.05). For the LES, %MVIC decreased significantly from 45.2 ± 17.6% prior to performance of ADIM, to 28.7 ± 23.3% during performance of ADIM (p < 0.05; Table 2).

Inter-group comparison of the difference activities of the HAM, GM, and LES muscles, between with or without ADIM, revealed that the activity of the HAM muscle in the HLLA group was 9.2 ± 20.7%, compared with 11.9 ± 10.9% in the NLLA group, and the difference was not significant (p > 0.05). The %MVIC value of GM in the HLLA group (13.4 ± 20.2%) was significantly less than that of the NLLA group (45.9 ± 33.7%) (p < 0.05). There were no significant group differences in LES between with or without ADIM (p > 0.05; Table 3).

## DISCUSSION

This study examined the effects of AIDM on the activities of the HAM, GM, and LES muscles during hip extension, as well as its clinical usefulness during hip extension.

The intra-group comparison of muscle activities during performance of ADIM, revealed that the HLLA group exhibited significantly increased activity of the GM muscle, but the activity of the LES muscle decreased (p < 0.05). We

**Table 3.** Comparison of the mean and SD of the differential value of %MVIC between with and without ADIM in each group (n = 30)

	HLLA (n = 15)	NLLA (n = 15)
HAM	9.2 ± 20.7 <sup>a</sup>	11.9 ± 10.9
GM	13.4 ± 20.2	0.6 ± 13.3*
LES	-10.6 ± 16.4	-16.6 ± 24.1

MVIC: maximum voluntary isometric contraction; ADIM: abdominal drawing-in maneuver; HAM: hamstring; GM: gluteus maximus; LES: lumbar erector spinae; HLLA: hyperlordotic lumbar angle; NLLA: normal lordotic lumbar angle

<sup>a</sup>Mean ± SD, \*p < 0.05

consider the positive change in GM muscle activity resulted from the maintenance of normal muscle length in the shortened LES and lengthened GM, because the lumbar and pelvis misalignment due to hyperlordosis was greatly improved by ADIM. Comerford and Mottram<sup>15</sup>) reported that lumbar hyperlordosis causes greater hyperextension and overload of the lumbar spine during hip extension, which can weaken the GM. Additionally, weakening of GM precipitated lumbar hyperlordosis or misalignment of the pelvis, and increased the load on the lumbar spine and pelvis<sup>16</sup>). In another study, GM muscle activity was increased by performance of ADIM using a PBFU during hip extension, because movement of the lumbar region under lordosis conditions, and pelvic tilt angle, were limited<sup>10</sup>). ADIM using a PBFU is effective at adjusting the movements of the lumbar spine and pelvis during hip extension muscle strength training<sup>10</sup>).

The LES are distributed in the lumbar vertebrae, and the degree of lumbar lordosis affects muscle strength; also GM is weakened by excessive hypertension in LES<sup>17</sup>). In the present study, decreased activity of the LES muscle, and increased activity of the GM muscle, was observed in the HLLA group. This appears to be due to hyperlordosis is prevented by the increased abdominal pressure engendered by ADIM. Moreover, the activity of the LES muscle was restricted by the increased internal stability.

In the NLLA group, the performance of ADIM significantly increased the activity of the HAM muscle, and decreased the activity of the LES muscle (p < 0.05). It appears that performance of ADIM by subjects with a normal lumbar lordosis angle decreases their normal lumbar

lordosis angle, causing posterior tilting of the pelvis, which in turn alters the activities of the HAM and LES muscles. Pelvic tilt and lumbar hyperlordosis are caused by weakened abdominal muscles, and both were reduced by the increased abdominal muscle contraction elicited by ADIM<sup>18, 19)</sup>. Been and Kalichman<sup>20)</sup> reported that pelvic retroversion promoted muscle contraction in HAM. Sherry and Best<sup>21)</sup> reported that the performance of ADIM during hip extension affected the strength and tone of the HAM muscle, and limited the degree of pelvic anterior tilt.

When group differences in muscle activities between with or without ADIM were assessed, only GM was found to exhibit a significant difference ( $p < 0.05$ ). It appears that performance of ADIM normalizes the alignment of the lumbar spine and pelvis. This has the greatest influence on GM, which appears to be the major protagonist during hip extension. Lewis et al.<sup>22)</sup> also reported that GM plays the most important role during hip extension, and that weakening of GM muscle strength resulted in hip dysfunction and pelvic imbalance. Queiroz et al.<sup>23)</sup> reported that pelvic tilt angle was closely correlated with the activity of the GM muscle, and that the activity of the GM muscle improved when pelvic tilt angle was normal.

This study had several limitations. First, because subjects with hyperlordosis but no low back pain were selected, it is difficult to generalize the results to patients with general back problems. Second, although efforts were made to standardize hip extension speed, by using a metronome, the execution speed was nonetheless not identical for every subject. Third, the activities of the abdominal muscles, diaphragm, and pelvic floor muscles were not measured during performance of ADIM, and the influence of these muscles could not be quantified. Future studies should conduct ADIM with a greater number of subjects, and measure the EMG of the abdominal and pelvic floor muscles, as well as the trunk and hip extensors.

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