



Original Article

Effects of prone trunk extension exercise using different fixations and with and without abdominal drawing-in maneuver in healthy individuals

YONG-WOOK KIM, PhD¹⁾

¹⁾ Department of Physical Therapy, College of Medical Sciences, Jeonju University: 303 Cheonjam-ro, Wansan-gu, Jeonju, Jeonbuk-do 560-759, Republic of Korea

Abstract. [Purpose] The purpose of this study was to investigate the differential effects of fixation of the thoracolumbar junction on the activity of the thoracic and lumbar muscle groups with and without the abdominal drawing-in maneuver (ADIM). [Subjects and Methods] The participants were 40 healthy adults. During trunk extension, thoracic and lumbar muscle activities were assessed using surface electromyography when fixing the pelvic and popliteal areas and the thoracolumbar junction, with and without the ADIM. [Results] The activity of the thoracic extensors at the T9 level applying thoracolumbar fixation with ADIM was significantly higher than with only pelvic fixation or pelvic fixation with ADIM during prone trunk extension. However, the activity of the lumbar extensors at the L3 level with pelvic fixation alone, without ADIM, was significantly higher than pelvic fixation with ADIM or additional thoracolumbar fixation with ADIM during prone trunk extension [Conclusion] This study demonstrated that fixation of the thoracolumbar junction with ADIM during trunk extension was more effective at eliciting thoracic extensor and minimising lumbar extensor activity than other conventional fixation methods.

Key words: Abdominal drawing-in maneuver, Thoracolumbar fixation, Trunk extension exercise

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INTRODUCTION

Trunk extensor strengthening exercises are important to maintain good alignment of spinal posture and are recommended for the management of back pain¹⁾. Trunk extension exercises in the prone position are often used in the rehabilitation of individuals with back pain and spinal pathologies, such as kyphosis or lordosis^{2, 3)}. In the sagittal plane, slightly kyphotic and lordotic curvatures are a normal aspects of the spine. Kyphosis is characterised by excessive outward curvature of the thoracic spine; whereas lordosis occurs when there is excessive inward curvature of the lumbar spine^{4, 5)}.

Although prone trunk extension exercises have been used for rehabilitation of spinal problems, selective recruitment of the trunk extensor muscles is important in managing kyphosis or lordosis during back extension exercises^{6, 7)}. Studies have reported that pelvic fixation is needed to activate lumbar extensors and most studies including trunk extension exercises, examined electromyography (EMG) of the extensors in the lumbar region⁷⁻⁹⁾. Previous studies have investigated the activity of the trunk extensors with pelvic fixation, but these studies did not examine the regional activities of the trunk extensors using a segmental fixation. To prevent extension movement of the lumbar spine, therapists often have patients perform an abdominal drawing-in maneuver (ADIM) for lumbar spinal stabilisation^{10, 11)}. Many studies have confirmed that ADIM prevents compensatory movement of the lumbar spine¹⁰⁻¹²⁾. However the effects of ADIM using a pressure biofeedback unit on the activity of the back extensors during prone trunk extension exercises remain unknown. Therefore, this study evaluated

Corresponding author. Yong-Wook Kim (E-mail: ptkim@jj.ac.kr)

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the effects of fixation at the thoracolumbar junction and pelvic region with and without ADIM during prone trunk extension on the activity of the thoracic extensor muscles (TEM) and the lumbar extensor muscles (LEM).

SUBJECTS AND METHODS

This study recruited 40 healthy male volunteers who consented to participate in the study and met the selection criteria. Participants were given a detailed explanation of the study procedure and written informed consent was obtained. This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Institutional Review Board of Jeonju University (jjIRB-2015-0108).

Volunteers who were able to maintain trunk extension for longer than 10 s to check back extensor activity were recruited for this study. Volunteers who had any neurological, musculoskeletal, or cardiopulmonary problems or whose trunk extensor strength was insufficient to maintain the experimental posture were excluded. The mean age, height, and weight of all participants were 22.8 ± 0.63 years, 174.9 ± 5.1 cm, and 69.2 ± 8.8 kg, respectively.

Before measuring the EMG signals, any hair on the skin was shaved, and the skin was then cleaned with an alcohol swab before attaching the electrodes^{10, 13}. EMG electrodes were attached to the TEM and LEM, in line with published recommendations¹⁴. The TEM electrode was attached 5 cm from the right side of the ninth thoracic spinous process, and the LEM electrodes were located 3 cm away from the right side of the third lumbar spinous process¹⁴. ADIM was performed using a pressure biofeedback unit (Chattanooga Group, Hixson, TN, USA), which was positioned under the lower abdomen of the subjects during trunk extension.

The experiment was conducted with participants lying prone, and a horizontal bar was placed 10 cm above the plinth, so that subjects touched the horizontal bar for a constant trunk extension motion. An electronic metronome provided auditory information so that each subject maintained a constant speed during trunk extension. Participants were directed to perform trunk extension, and maintain it for 5 s before returning to the start position. For trunk extension, two types of fixation were applied in each subject: 1) at the popliteal fossa of the knee joint and posterior superior iliac spine of the pelvic area and 2) to fix the thoracolumbar junction in addition to the first fixation.

For prone trunk extension without ADIM, participants were instructed to adopt a prone position on a plinth with the right side of the body in a straight line. Participants were asked to perform trunk extension to the predetermined target bar. ADIM was performed with the pressure set to 70 mmHg, and participants were instructed to draw in the abdomen to keep a pressure of 60 mmHg using visual feedback from an analogue pressure gauge during trunk extension. Each type of fixation, with and without ADIM, for EMG data collection was performed in a random order in each subject.

To prevent muscle fatigue, subjects were allowed a 2-min break between measurements¹⁵. The root mean square (RMS) of the EMG was used to measure the activity of each trunk extensor muscle, using the middle 3 s, excluding the first and last 1 s. Before the measurements, participants were allowed to practice the trunk extension motion three times. Three measurements were then taken, and the mean values of the RMS of each muscle were calculated.

A Delsys Trigno EMG system (Delsys, Inc., Wellesley, MA, USA) was used to collect EMG data. EMG signals were converted to digital signals and processed using Works Acquisition (Delsys, Inc., Wellesley, MA, USA) EMG analysis software for personal computers. The sampling rate of the EMG signals was 2,000 Hz, and the EMG frequency bandwidth was restricted to 20–500 Hz. The common mode rejection ratio was set to 110 dB. All analyses were conducted using SPSS (ver. 21.0; IBM, Armonk, NY, USA). The Kolmogorov-Smirnov test was used to confirm that the data were distributed normally. One-way repeated-measures analysis of variance (ANOVA) was used to compare the differences in muscle activity among each condition during trunk extension. The contrasts test of repeated measures was used as a *post hoc* test to confirm the differences in each muscle activity. Significance was accepted for values of $p < 0.05$.

RESULTS

There were significant differences with the condition in the EMG activities of the TEM ($F_{1,39}=93.299$, $p < 0.01$) and LEM ($F_{1,39}=57.398$, $p < 0.01$). During prone trunk extension the EMG activities of the TEM when thoracolumbar fixation was applied with ADIM were significantly higher than with only pelvic fixation or pelvic fixation with ADIM ($p < 0.05$; Table 1). In contrast, the RMS values of the LEM when pelvic fixation was applied without ADIM were significantly higher than when pelvic fixation was applied with ADIM and when additional thoracolumbar fixation was applied with ADIM during prone trunk extension ($p < 0.05$; Table 1).

DISCUSSION

Trunk extension is achieved through the cooperative contraction of the hip extensors and trunk extensors. Trunk extension exercises are often used in the physical training and rehabilitation of individuals with thoracic and lumbar spine pathologies, such as kyphosis, lordosis, and low back pain^{6, 16, 17}. However, prone trunk extension exercises to correct kyphosis should be applied with caution because lumbar hyperextension and excessive pelvic anterior tilting often develop during trunk extension exercises in the prone position¹¹. Nevertheless, many studies describing trunk extension exercises have reported

Table 1. EMG activities of the trunk extension muscles according to various fixations during prone trunk extension (N=40)

Muscle activity (RMS)	Fixation			
	Pelvic	Thoracolumbar	Pelvic + ADIM	Thoracolumbar + ADIM
TEM (mV)	2.46 ± 0.90*	2.91 ± 1.93	2.41 ± 0.90*	2.87 ± 1.36
LEM (mV)	1.93 ± 1.16	1.78 ± 0.99	1.73 ± 1.01 [†]	1.72 ± 1.02 [†]

RMS: root mean square; TEM: thoracic extensor muscles; LEM: lumbar extensor muscles; ADIM: abdominal drawing-in maneuver

*Significant difference from thoracolumbar fixation + ADIM ($p < 0.05$)

[†]Significant difference from pelvic fixation ($p < 0.05$)

that pelvic and leg fixation are suitable for isolating the training of trunk extensors and minimising the muscle activity of hip extensors^{9, 17, 18}). Therefore, this study examined the additional effects of thoracolumbar fixation and ADIM on thoracic and lumbar extensor muscle activity.

In this study, the activities of the TEM with ADIM and thoracolumbar fixation were significantly higher than with pelvic fixation with or without ADIM ($p < 0.05$). However, the activities of the TEM with thoracolumbar fixation and no ADIM, did not differ significantly from the other fixation conditions ($p > 0.05$). Therefore, our results indicate that thoracolumbar fixation is one of the most useful methods to improve the selective activity of the TEM, regardless of the application of ADIM, during prone trunk extension exercises.

In the case of the activity of the LEM, pelvic fixation without ADIM resulted in significantly higher muscle activity than pelvic fixation or thoracolumbar fixation with ADIM ($p < 0.05$). There was, however, no significant difference in the LEM between pelvic and thoracic fixation. These results suggest that performing ADIM using a pressure biofeedback unit during prone trunk extension decreases LEM activity regardless of the fixation applied. The reason for this may be that ADIM application prevents lumbar hyperextension and inhibits contraction of the LEM, such as reciprocal inhibition, via abdominal muscle contraction which prevents the forward movement of the lumbar spine and improves the stability of the lumbar region. Therefore, it is suggested that using ADIM is a good strategy to reduce the activity of the LEM during prone trunk extension¹⁰).

Considering the muscle activities relative to the fixation conditions in this study, the TEM showed significantly higher muscle activity and the LEM showed significantly lower muscle activity with thoracolumbar fixation plus ADIM. Therefore, thoracolumbar fixation with ADIM may be the most suitable intervention for specific training of these muscles during trunk extension exercises. Muscle specific therapeutic training is important for the treatment of musculoskeletal dysfunction^{17, 19}). Prone trunk extension exercises are often used clinically to strengthen the trunk extensors and have been recommended for managing the natural progression of kyphosis²⁰). Although this study examined healthy male participants, the results showed that thoracolumbar fixation with ADIM was a more useful method for training the thoracic extensors specifically, minimising lumbar extensor activity. Therefore, it may be a useful clinical intervention to improve muscle strength selectively in individuals with weakness in the thoracic extensors, such as those with kyphosis.

There are several limitations to this study. First, although we used a predetermined target bar to control the trunk extension movement, the speed of trunk extension which may affect EMG signals was not controlled for each subject. Second, all participants were consist of only male because they had to take off the upper clothes to check the surface EMG signals. Finally, surface EMG was used to monitor muscle activity, leaving the possibility of crosstalk from adjacent muscles. Therefore, further studies are needed to investigate the effects of thoracolumbar fixation with ADIM on the activity of the trunk extensors in individuals with spinal abnormalities, such as kyphosis or lordosis.

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