

Comparison of selective electromyographic activity of the superficial lumbar multifidus between prone trunk extension and four-point kneeling arm and leg lift exercises

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Abstract. [Purpose] This study examined the selective electromyographic activity of the lumbar paraspinal muscles in healthy male and female subjects in the prone trunk extension (PTE) and four-point kneeling arm and leg lift (FPKAL) exercises to determine the most beneficial exercise for selective activation of the lumbar multifidus (LM). [Subjects and Methods] Twenty healthy male and female subjects participated in this study. Surface electromyographic data were collected from the left-side lumbar erector spinae (LES) and LM muscles during PTE and FPKAL exercises. [Results] The LM/LES ratio related to selective activation of the lumbar paraspinal muscles during the FPKAL exercise was higher than that during PTE. [Conclusion] FPKAL exercise is safe and effective for the selective activation of the LM muscle.

Key words: Lumbar paraspinal muscles, Selective activation, Surface electromyography

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INTRODUCTION

The lumbar multifidus (LM) muscle is an important local stabilizer of the spinal segments¹⁾. Its main function involves stabilizing the “neutral zone” of the lumbar spine²⁾ and controlling the extension moment of the lumbar spine³⁾. A previous study showed that the LM was atrophied on the side of pain in patients with acute⁴⁾ and chronic unilateral low back pain (LBP)⁵⁾. On the other hand, the lumbar erector spinae (LES) muscles are global stabilizers of trunk stability; high LES activity is associated with increased spinal loading⁶⁾ and may induce pain or even be harmful in patients with LBP. Lumbar extensor strengthening or stabilization exercises that focus on the lumbar paraspinal muscles are frequently used by physical therapists for the treatment of LBP entailing dysfunction of the lumbar paraspinal muscles^{7, 8)}. In contrast to lumbar extensor strengthening exercises, which involve activation of the paraspinal musculature at high levels of contraction, lumbar stabilization exercises involve low-load, low-intensity isometric or restricted range-of-

motion techniques⁹⁾. Various exercises have been evaluated to determine whether or not high electromyographic (EMG) activity of the lumbar paraspinal muscles influences LBP treatment outcomes. In particular, recent research has shown high EMG activity of the LM during prone trunk extension (PTE) and four-point kneeling contralateral arm and leg lift (FPKAL) exercises. Mayer et al.¹⁰⁾ recommended trunk extension exercises with gradually increasing load and intensity to improve lumbar extensor strength and endurance. Imai et al.¹¹⁾ reported higher EMG activity of the LM than of the LES during contralateral arm and leg lift, but their study did not focus on selective activation of the lumbar paraspinal muscles. Although recent research has suggested that the lumbar paraspinal muscles play a significant role in stabilizing the lumbar spine during exercise¹²⁾, and previous studies have focused on the effect of lumbar extensor exercises on the lumbar paraspinal muscles, no studies have evaluated the selective activation of the LM muscles during PTE and FPKAL exercises. Moreover, in the clinical field, because lumbar extensor exercises have been frequently utilized in therapeutic approaches for the recovery of LBP by many physical therapists, an experimental study for baseline data with healthy individuals is needed to assess the efficacy of lumbar extensor exercises aimed at selective activation of the lumbar paraspinal muscles. Because experimental data from patients with LBP may show different EMG activity patterns of the lumbar paraspinal muscles, this study examined the selective EMG activity of the superficial LM during PTE

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Table 1. %MVIC and the LM/LES ratio of the EMG activity levels of the LES and LM during PTE and FPKAL exercises

	PTE		FPKAL	
	LES	LM	LES	LM
%MVIC (mean \pm SD)	87.2 \pm 11.7	83.3 \pm 15.8	31.3 \pm 14.9	41.9 \pm 20.0
LM/LES ratio	0.96 \pm 0.18		1.61 \pm 0.51	

PTE: prone trunk extension; FPKAL: four-point kneeling contralateral arm and leg lift; LES: lumbar erector spinae; LM: lumbar multifidus; %MVIC: percentage of maximal voluntary contraction

and FPKAL exercises in healthy male and female subjects.

SUBJECTS AND METHODS

Twenty healthy individuals (nine male and 11 female subjects) aged 20 to 22 years were recruited for this study. The average age of the subjects was 20.14 \pm 0.24 years, and their mean height and weight were 168.90 \pm 7.27 cm and 63.29 \pm 8.08 kg, respectively. The subjects were healthy individuals without LBP who had not participated in lumbar strengthening or stabilization exercises in the past 6 months. All subjects signed an informed consent form approved by the Inje University Ethics Committee for Human Investigations prior to participation.

The EMG data were collected and analyzed using a surface EMG system (MP150; Biopac Systems, Inc., Santa Barbara, CA, USA). After rubbing the skin at the electrode sites with alcohol swabs, pairs of disposable surface electrodes were unilaterally attached over the left LES (2 cm lateral to the L2 spinous process and aligned parallel to the spine)¹³ and LM (2 cm lateral to the midline on a line through the L5 spinal process and parallel to the muscle fibers)¹³, and left-side surface EMG data were recorded from the LES and LM. The raw EMG signals were amplified, sampled at a rate of 1,000 Hz, band-pass filtered between at 20 to 500 Hz, and the root mean square value was calculated. Maximum voluntary isometric contractions (MVICs) were performed against manual resistance for all muscles¹⁴. A 2-min rest period was allowed between contractions to prevent muscle fatigue. MVIC of the lumbar paraspinal muscles were performed three times for 5 s each. The average muscle activity of the middle 3 s of each of the three trials was used for normalization. The LM/LES ratio was calculated to examine selective activation of the lumbar paraspinal muscles during PTE and FPKAL exercises.

The two exercises were PTE and FPKAL. For PTE, the subjects were asked to lie in the prone position while resting their arms on a plinth with the head at the midline. They were then instructed to extend the trunk as far as possible with their hands across the chest and legs resting flat on the plinth. For FPKAL, the subjects started from a four-point kneeling posture with their hands on push-up handles shoulder-width apart and knees positioned at hip width and maintained at 90° flexion. They were then asked to lift their right arm and left leg simultaneously as far as possible until both were approximately parallel to the floor while maintaining normal lumbar lordosis. The subjects were asked to maintain this exercise position with isometric contraction for 5 s, and the exercise was performed five times. EMG data

of the lumbar paraspinal muscles during the two exercises were compared using the paired t-test. Statistical analyses were performed using SPSS (ver. 20.0; SPSS, IBM Corp., Armonk, NY, USA). P-values of <0.05 were considered to indicate statistical significance.

RESULTS

The %MVIC of the activity levels of the left LES and LM were greater during PTE (LES, 87.2 \pm 11.7; LM, 83.3 \pm 15.8) than during FPKAL (LES, 31.3 \pm 14.9; LM, 41.9 \pm 20.0; $p < 0.05$), whereas the LM/LES ratio was significantly higher during FPKAL (mean \pm SD, 1.61 \pm 0.51) than during PTE (0.96 \pm 0.18; $p < 0.05$). The %MVIC as determined from the EMG activity levels of the left LES and LM during the PTE and FPKAL exercises is shown in Table 1.

DISCUSSION

This study investigated the selective activation of the lumbar paraspinal muscles during PTE and FPKAL exercises in healthy male and female subjects performing two lumbar extensor exercise programs.

The EMG activity level of the LES and LM was higher during PTE than during the FPKAL exercise. On the other hand, the LM/LES ratio during the FPKAL exercise was significantly higher than that during PTE. These findings indicate that FPKAL is more beneficial for the selective activation of the LM muscle than PTE, although higher LES and LM muscle activation was observed during PTE than during FPKAL. This outcome indicates the need for higher LES activation to lift the trunk, a high load, during PTE, and the lower requirement for LES activation, about half the activity level observed during PTE, given the lower load during FPKAL. Many researchers have emphasized the safety of exercises for treatment of LBP, with a particular focus on LM and LES function. Richardson et al.¹⁵ suggested that the multifidus must contract independently of the global muscles, and McGill et al.¹⁶ suggested that excessive spine loading related to high activation of global muscles should be avoided in patients with back pain to prevent structural damage. The LM is a lumbar stabilizing muscle that mainly comprises type I fibers¹⁷, and relatively low loads requiring only approximately 30–40% of MVIC are needed to improve LM muscle performance¹⁵. Additionally, in one study that evaluated joint compression and shear force using an EMG-driven model during different exercises, the mean compression values of the lumbar joint (L4/L5) were lower during contralateral arm and leg lift exercises than during

trunk extension exercises, 2500 and 4000 N, respectively¹⁸). Another study noted negative L4/L5 anteroposterior joint shear force values on the lumbar spine during contralateral arm and leg lift (values of approximately -200 N) compared with trunk extension exercises (values of approximately 250 N)¹⁹). Thus, the FPKAL exercise of our study (appropriate EMG amplitude of approximately 40% of MVC) is suitable for exercising the LM muscle function with selective activation of the lumbar paraspinal muscles and is recommended as a safe and effective simple therapeutic exercise for treatment of LBP.

Our study had some limitations. First, we examined LM muscle activation using surface EMG. Accordingly, we were unable to consider the anatomical features of the LM. An EMG recording method that targets the EMG site in the LM could be used for intramuscular EMG. Second, the measurement of MVIC for EMG normalization was performed in prone trunk extension, like the Biering-Sorenson endurance test, and this may have led to the recruitment of other muscles. Third, because we examined healthy young individuals, the results of this study cannot be generalized to older adults or patients with LBP. We may assess the effects of exercise on selective activation of the lumbar paraspinal muscles in older adults or patients with LBP in a further study.

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