# Electromyographic Analysis of Training to Selectively Strengthen the Lumbar Multifidus Muscle: Effects of Different Lifting Directions and Weight Loading of the Extremities During Quadruped Upper and Lower Extremity Lifts

Mitsuhiro Masaki, PT, MS,[a] Hiroshige Tateuchi, PT, PhD,[b] Rui Tsukagoshi, PT, MS,[c] Satoko Ibuki, PT,[d] and Noriaki Ichihashi, PT, PhD[e]

## Abstract

**Objective:** The lumbar multifidus muscle (LMF) is a lower back muscle that contributes to spinal stability. Several electromyographic analyses have evaluated LMF activity during various types of training. The present study examined the activity of the back muscles during quadruped upper and lower extremity lifts (QULELs) with different lifting direction and weight loading of extremities.

**Methods:** Seventeen healthy men were included as subjects. The exercise conditions comprised raising the upper extremity of one side and the lower extremity of the opposite side in a quadruped position with different lifting direction and weight loading. The various combinations of lifts were modifications of conventional QULEL, in which the upper extremity is raised to 180° shoulder flexion and the lower extremity to 0° hip extension. The effects of different lifting directions and weight loading on LMF and lumbar erector spinae (LES) muscle activities were measured using surface electromyography.

**Results:** The LMF activity and the LMF/LES activity ratio on the side of lower extremity lifting were higher during QULEL with the upper and lower extremities in abduction than during conventional QULEL. The LMF/LES activity ratio was lower during QULEL with weight loading on the upper and lower extremities than during conventional QULEL.

**Conclusion:** The results of the present study suggest that QULEL with shoulder and hip abduction is more effective to selectively strengthen LMF on the side, where the lower extremity is lifted. Loading weight onto both the lifted upper and lower extremities during QULEL is disadvantageous as a selective LMF training method because the LMF/LES activity ratio is low. (J Manipulative Physiol Ther 2015;38:138-144)

**Key Indexing Terms:** *Electromyography; Paraspinal Muscles; Exercise Therapy*

The lumbar multifidus muscle (LMF) contributes to spinal stability.[1-3] Several electromyographic analyses have evaluated LMF activity during various types of training.[4-10] Lumbar multifidus muscle atrophy in acute[11,12] and chronic low back pain (LBP) patients has been observed in studies using computed tomography and magnetic

[a] PhD Course Student, Department of Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

[b] Assistant Professor, Department of Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

[c] Associate Professor, Department of Physical Therapy, Faculty of Rehabilitation, Hyogo University of Health Sciences, Kobe, Japan.

[d] Research Assistant, Department of Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

[e] Professor, Department of Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

Submit requests for reprints to: Mitsuhiro Masaki, PT, MS, PhD Course Student, 53 Kawahara-cho, Shogoin, Sakyo-ku, Kyoto 606-8507, Japan.
(e-mail: *masaki.mitsuhiro.27w@st.kyoto-u.ac.jp*).

Paper submitted November 28, 2013; in revised form July 8, 2014; accepted July 8, 2014.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2014.07.008

resonance imaging images.[13-16] In patients with LBP, the selective atrophy of LMF compared with that of lumbar erector spinae (LES) muscle has been demonstrated,[17] and the proportion of fatty tissue in LMF increases in them.[18,19] Therefore, the importance of effective strengthening of LMF is attracting attention in the rehabilitation of patients with LBP.

Previous studies[20-22] revealed that the activity of LMF, which is a member of the deep muscles of the back, decreases, whereas the activity of LES, which is a member of the superficial muscles of the back, increases in individuals with LBP or those with LBP history (LBPH). Decreased LMF activity causes lumbar spine instability, which may contribute to LBP recurrence.[23] A previous study has also examined the effect of training on the strengthening of lower back muscles in patients with LBP,[24] revealing that selective training of LMF immediately increases LMF activity and decreases LES activity during spinal movement in a standing position compared with training of all lower back muscles (including both LMF and LES). Therefore, training to selectively strengthen LMF is considered to be effective in increasing LMF activity in individuals with LBP or LBPH.

There are various different types for training of the low back muscles including LMF and LES. Quadruped upper and lower extremity lift (QULEL), in which the subject raises the upper extremity on a side and the lower extremity on the other side to a horizontal position in the quadruped position, is known to activate LMF. Ekstrom et al[10] compared the muscle activities during various exercises in healthy subjects and found that QULEL resulted in relatively high activity of the LMF muscle on the side, where the lower extremity was lifted (lower extremity side) and that the percent maximum voluntary contraction (MVC) of LMF was higher than that of LES. On the other hand, LMF activity on the side, where the upper extremity was lifted (upper extremity side) was lower than LES activity. Therefore, it is considered that QULEL is an adequate exercise to selectively activate the LMF muscle on the lower extremity side. However, because the muscle activity was expressed as percent MVC in their study, the selectivity of the muscle activity among exercises cannot be compared.

Therefore, the purpose of this study was to identify a method to train the LMF muscle more selectively and strongly. This study examined the effect of modifying a specific exercise by adding rotation moment of the spine by changing the direction of lifting upper and lower extremities and weight loading of the extremities. In addition, to estimate the selectivity, we examined the activity ratio of LMF and LES (LMF/LES activity ratio). The muscle activity ratio has been calculated in some studies examining the activity of the shoulder girdle[25,26] or the scapular[27] muscles. However, to our knowledge, this is the first study to examine the activities of LMF and LES in terms of the activity ratio.

## Methods

### Participants

The subjects comprised 17 healthy young men (age, 22.4 ± 1.3 years; height, 173.1 ± 5.7 cm; and weight, 65.5 ± 11.7 kg). All subjects were volunteers recruited from Kyoto University. Individuals with musculoskeletal conditions or those with neurologic or cardiovascular disorders that would limit their ability to perform the exercises were excluded. All subjects provided informed consent, and the protocol was approved by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine.

### Experimental Procedure

The experiment was broadly divided into 2 parts: lifting extremities in (*a*) different directions and with (*b*) different weight loading. Conventional QULEL is performed by lifting the right upper and the left lower extremities to a horizontal position. In the present study, variants of conventional QULEL were performed in which the extremities were lifted in different directions as follows (Figure 1): (1) right upper extremity lifted to 180° shoulder flexion and left lower extremity lifted to 0° hip extension (F-E), (2) right upper extremity lifted to 90° shoulder abduction and left lower extremity lifted to 0° hip extension (A-E), (3) right upper extremity lifted to 180° shoulder flexion and left lower extremity lifted to maximum hip abduction (F-A), and (4) right upper extremity lifted to 90° shoulder abduction and left lower extremity lifted to maximum hip abduction (A-A). The exercise conditions with different weight loading of the lifted extremities were further divided as follows (Figure 1): (1) F-E (2) F-E with a weight belt weighing 2.5% of the body weight (BW) attached to the right wrist (F2.5-E), (3) F-E with a weight belt weighing 5.0% of BW (F-E5) attached to the left ankle, and (4) F-E with a weight belt weighing 2.5% of BW attached to the right wrist and weight belt weighing 5.0% of BW attached to the left ankle (F2.5-E5).

Exercises were assigned in a random order to each subject. Each exercise was performed thrice, with adequate rest periods between the different exercises.

### Electromyography Recording and Data Analysis

Electromyography (EMG) data were collected by sampling at 1500 Hz, using the Telemyo 2400 T (Noraxon USA, Scottsdale, AZ). After the electrode sites were cleaned with a scrubbing gel and washed with alcohol, bipolar surface electrodes (Ambu, Baltorpbakken, Denmark) with a 2-cm center-to-center interelectrode distance were applied to the 4 muscles: LMF (at the level of the L5 spinous process on a line extending from the posterior superior iliac spine to the interspace between L1 and L2)[28] bilaterally and LES (4 cm lateral to the L1 spinous process)[10] bilaterally. The ground electrode was affixed to the skin over the iliac crest. In each exercise, the EMG signals were measured for 3 seconds, after the subjects raised their extremities and were able to