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Electromyographic Functional Analysis of the Lumbar Spinal Muscles with Low Back Pain

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Abstract

The lumbar paraspinal muscles were examined by surface electromyography (EMG) in 22 patients with low back pain and 22 healthy volunteers. Surface electrodes were placed bilaterally on the lumbar multifidus and longissimus muscles at the level of the spinous process of the third lumbar vertebra.

Kinesiologic EMG was recorded, in standing resting position, during the following trunk motions: trunk forward flexion and extension, lateral bending and axial rotation.

No muscular activity was observed in the full trunk flexion position in the control group. In contrast, continuous muscle activity was observed in the low back pain group. On axial rotation, an intermuscular time lag was observed at the beginning of the motion in the control group. In the low back pain group, there was no such time lag. Paraspinal muscle activities restricted lumbar range of motion, and protect from injury for movement. This suggests their role as stabilizers.

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Key words: electromyography, low back pain, lumbar paraspinal muscle

Introduction

Paraspinal muscles participate in various motions. Lumbar paraspinal muscles mainly consist of the multifidus, longissimus and iliocostalis muscles. It is generally thought that these muscles work as agonists and antagonists. Research on various aspects of the lumbar paraspinal muscles has been carried out morphologically[1,2], pathologically[3–6] and diagnostic radiologically[7], but their physiological function and role in the maintenance of posture are not well understood. Furthermore, their relationship with low back pain has not been extensively studied[8,9]. The purpose of this study is to compare electromyographic findings between healthy volunteers and patients with low back pain, to assess the relationship between posture and lumbar paraspinal muscles.

Materials and Methods

Twenty-two healthy adult male volunteers (control group; average age, 26.6 years) without low back pain and twenty-two patients (18 men and 4 women; average age, 31.2 years) with low back pain were enrolled in this study. All patients were diagnosed as having myofascial low back pain syndrome without abnormal X-ray findings or neurological findings. All subjects were examined by kinesiological surface

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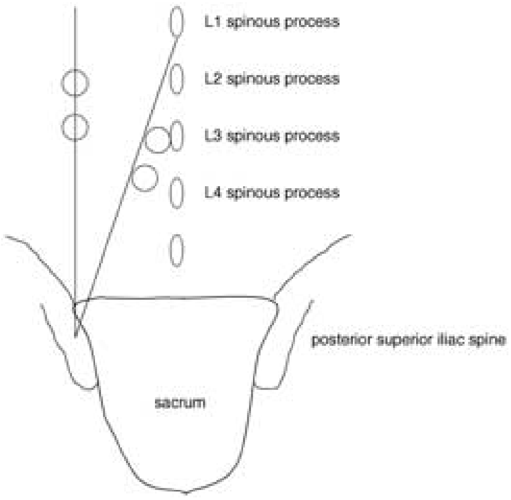

Fig. 1 For the lumbar multifidus muscles, electrodes were placed bilaterally at the level of the spinous process of the third lumbar vertebra, aligned in parallel with the line between the posterior superior iliac spine and the spinous process of the first lumbar vertebra. The distance between the surface electrodes was 3 cm. For the lumbar longissimus muscles, the distance between the surface electrodes was 3 cm. Surface electrodes were placed bilaterally along the line running parallel with the straight line through the spinous process, and on the line through the posterior superior iliac spine at the level of the L2 spinous process. The circles represent surface electrodes in the figure.

EMG. Surface electrodes were arranged according to the method of Lance et al.[10]. For the lumbar multifidus muscles, electrodes were placed bilaterally at the level of the spinous process of the third lumbar vertebra, aligned in parallel with the line between the posterior superior iliac spine and the spinous process of the first lumbar vertebra. The distance between the surface electrodes was 3 cm. For the lumbar longissimus muscles, the distance between the surface electrodes was 3 cm. Surface electrodes were placed bilaterally along the line running parallel with the straight line through the spinous process, and on the line through the posterior superior iliac spine at the level of the L2 spinous process (**Fig. 1**). Kinesiological EMG was performed, in standing resting position, during the following trunk motions: trunk forward flexion and extension, lateral bending and axial rotation. The surface electrodes used were plate electrodes and bipolar configuration. A ground electrode was placed on the ulnar styloid process. The electromyographic activity was observed on the monitor of a Neuropack 8 system (MEM-4200: Nihon Kohden). The mean frequency and maximum amplitude were calculated by Neuropack 8 system in maximal voluntary contraction on trunk forward flexion, lateral bending and axial rotation. Mean and standard deviations were calculated for all descriptive variables and t-tests evaluated differences between groups ($p<0.05$).

Results

1. Standing Resting Position and Trunk Extension (Fig. 2)

No muscular activity was observed in the control group or the low back pain group.

2. Trunk Forward Flexion

In the control group, myoelectrical activity was detected simultaneously in the bilateral lumbar multifidus and longissimus muscles. Myoelectrical activity was not detected in the full trunk flexion position (**Fig. 3**). In the right multifidus muscle, the mean frequency was 79.4 Hz and the average maximum amplitude was 395 μV. In the right longissimus muscle, the mean frequency was 70.3 Hz and the average maximum amplitude was 260 μV. In the left multifidus muscle, the mean frequency was 72.6 Hz and the average maximum amplitude was 387.7 μV. In the left longissimus muscle, the mean frequency was 78.8 Hz and the average maximum amplitude was 321.8 μV (**Table 1**). In trunk flexion maximum amplitude of the bilateral longissimus muscles in the low back pain group was higher than in the control group ($p<0.05$).

In the low back pain group, myoelectrical activity was detected in the bilateral lumbar multifidus muscles and longissimus muscles during trunk flexion. However, continuous muscle activity was observed in the full trunk flexion position (**Fig. 4**). In the right multifidus muscle, the mean frequency was

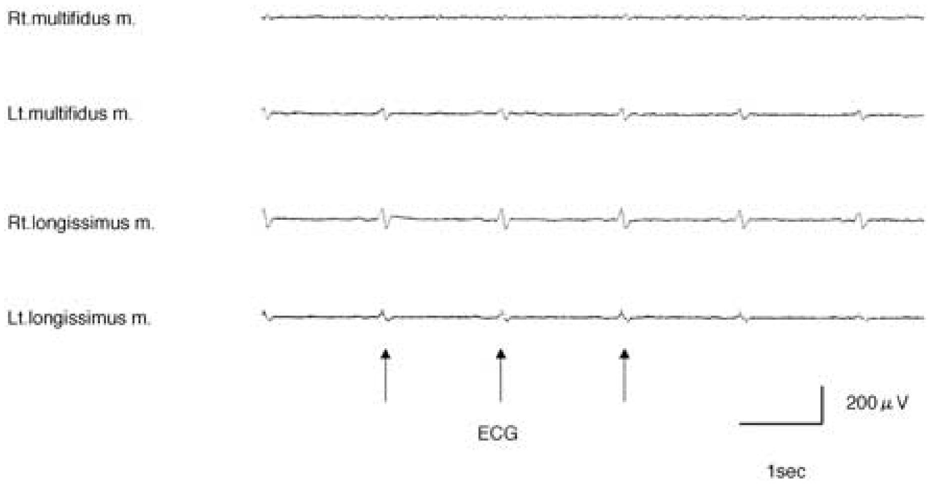

Fig. 2 No muscular activity was observed in the control group or the low back pain group. The arrows represent electrocardiograms. Rt: right, Lt: left, ECG: electrocardiograms, m: muscle.

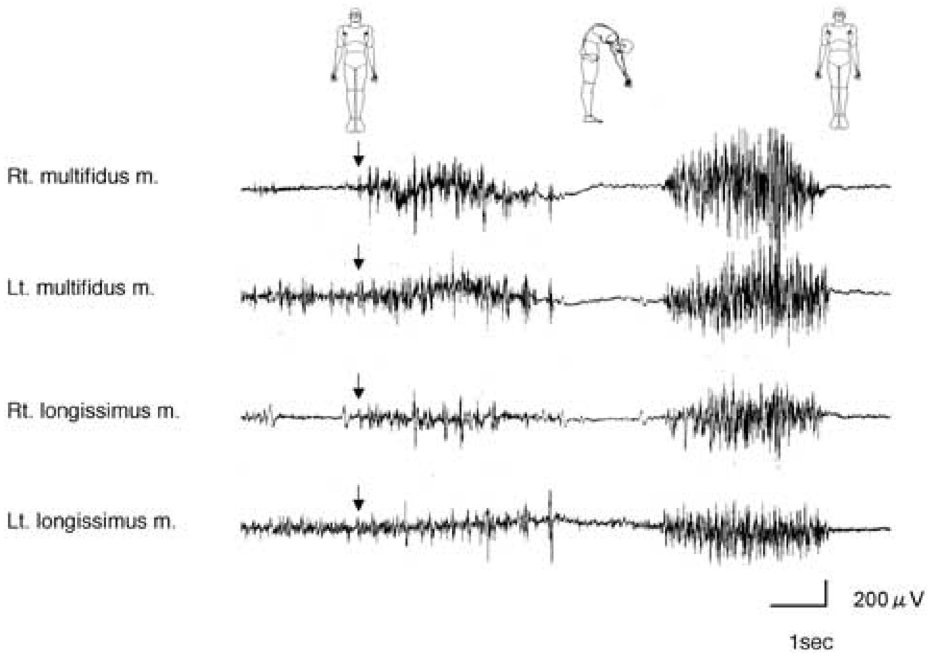

Fig. 3 In the control group, myoelectrical activity was detected simultaneously in the bilateral lumbar multifidus and longissimus muscles. Myoelectrical activity was not detected in the full trunk flexion position. The arrows represent start of the trunk flexion motion, and myoelectrical activity was detected. Rt: right, Lt: left, m: muscle.

83.3 Hz and the average maximum amplitude was 409.5 μV. In the right longissimus muscle, the mean frequency was 78.7 Hz and the average maximum amplitude was 385.9 μV. In the left multifidus muscle, the mean frequency was 77.5 Hz and the average maximum amplitude was 402.3 μV. In the left longissimus muscle, the mean frequency was 79.4 Hz and the average maximum amplitude was 386.8 μV.

3. Trunk Lateral Bending

In 16 members of the control group and 10 members of the low back pain group, myoelectrical activity was detected in the contralateral multifidus

Table 1 Mean frequency and maximum amplitude during trunk flexion

	right multifidus m.	right longissimus m.	left multifidus m.	left longissimus m.
	mean frequency (Hz)			
control group	79.4 ± 19.2	70.3 ± 12.6	72.6 ± 11.3	78.8 ± 12.6
LBP group	83.3 ± 12.3	78.7 ± 12.9	77.5 ± 10.8	79.4 ± 9.8
	maximum amplitude (μV)			
control group	395 ± 19.2	260 ± 56.5	387.7 ± 18.7	321.8 ± 9.6
LBP group	409.5 ± 38.6	385.9 ± 46.0*	402.3 ± 34.2	386.8 ± 43.0*

Maximum amplitude of the bilateral longissimus muscles with low back pain group were higher than control groups during trunk flexion. ($p < 0.05$). ($n = 22$) LBP: low back pain, m: muscle, *: $p < 0.05$

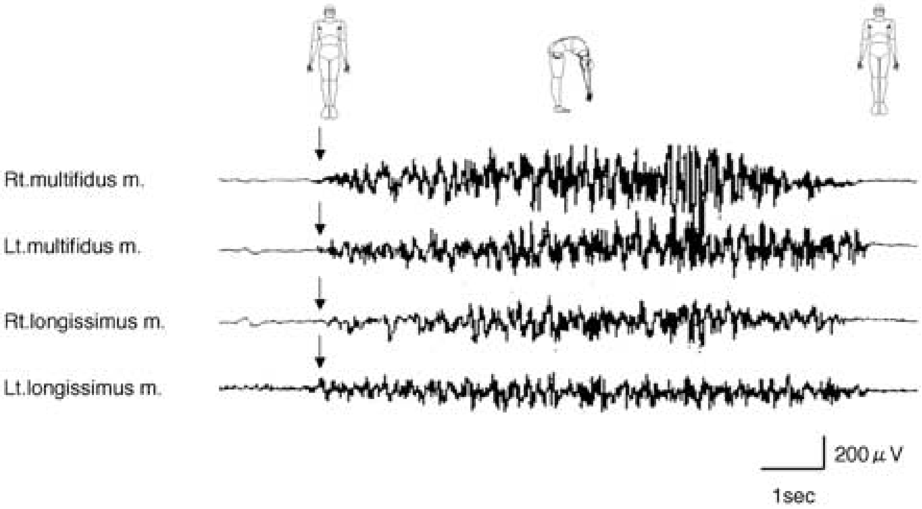

Fig. 4 In the low back pain group, myoelectrical activity was detected in the bilateral lumbar multifidus muscles and longissimus muscles during trunk flexion. However, continuous muscle activity was observed in the full trunk flexion position. The arrows represent start of the trunk flexion motion. Rt: right, Lt: left, m: muscle.

and longissimus muscles during lateral bending, but not in the ipsilateral multifidus or longissimus muscles (**Fig. 5**). In 6 members of the control group and 12 members of the low back pain group, strong myoelectrical activity was detected in the contralateral multifidus and longissimus muscles, whereas weak myoelectrical activity was detected in the ipsilateral multifidus and longissimus muscles (**Fig. 6**).

In the control group, in the right multifidus muscle, the mean frequency was 71.2 Hz and the average maximum amplitude was 203.2 μV. In the right longissimus muscle, the mean frequency was 70.3 Hz and the average maximum amplitude was 144.1 μV. In the left multifidus muscle, the mean frequency was 72.6 Hz and the average maximum amplitude was 213.6 μV. In the left longissimus muscle, the mean frequency was 71.9 Hz and the average maximum amplitude was 144.1 μV.

In the low back pain group, in the right multifidus muscle, the mean frequency was 69.7 Hz and the average maximum amplitude was 203.2 μV. In the right longissimus muscle, the mean frequency was 69.1 Hz and the average maximum amplitude was 144.5 μV. In the left multifidus muscle, the mean frequency was 72 Hz and the average maximum amplitude was 205.5 μV. In the left longissimus muscle, the mean frequency was 69.8 Hz and the average maximum amplitude was 145.5 μV (**Table 2**).

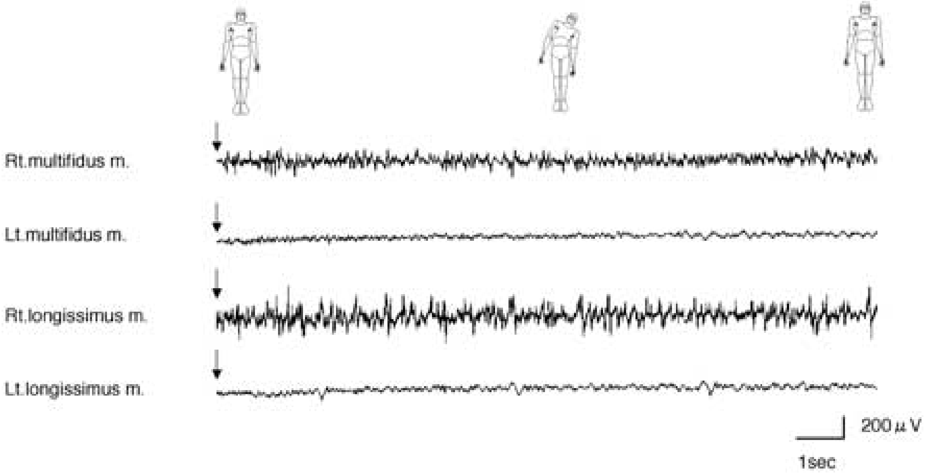

Fig. 5 Myoelectrical activity was detected in the contralateral multifidus and longissimus muscles during lateral bending, but not in the ipsilateral multifidus or longissimus muscles. The arrows represent start of the lateral bending motion. Rt: right, Lt: left, m: muscle.

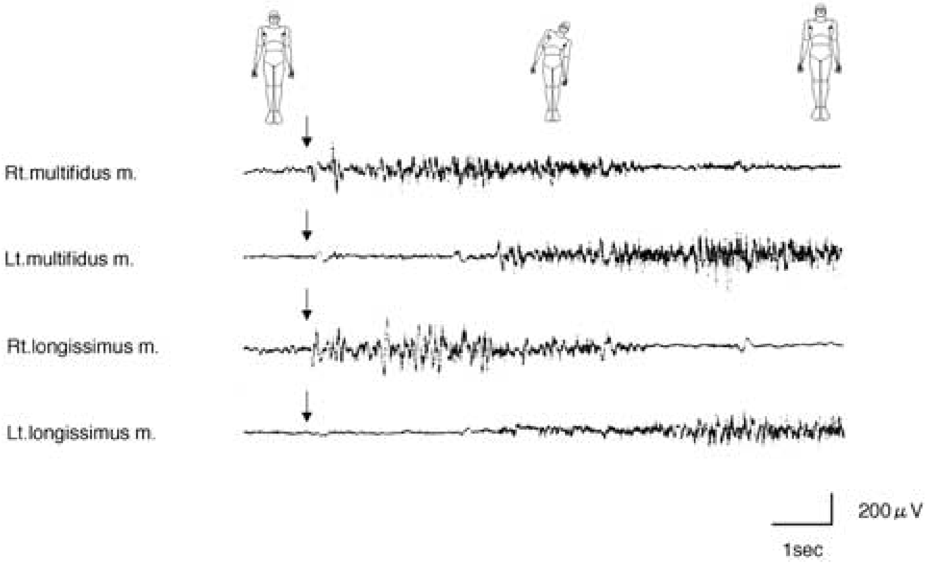

Fig. 6 Strong myoelectrical activity was detected in the contralateral multifidus and longissimus muscles, whereas weak myoelectrical activity was detected in the ipsilateral multifidus and longissimus muscles. The arrows represent start of the lateral bending motion. Rt: right, Lt: left, m: muscle.

4. Trunk Axial Rotation

In the control group, strong myoelectrical activity was detected in the contralateral lumbar multifidus muscles with the progression of axial rotation. In the ipsilateral multifidus muscles, weak myoelectrical activity was delayed at the beginning of motion. In the contralateral longissimus muscles, weak myoelectrical activity was detected. In the ipsilateral longissimus muscles, strong myoelectrical activity was delayed at the beginning of motion. In the control group, on axial rotation, an intermuscular time lag was observed at the beginning of the motion (**Fig. 7**). The average time lag was 0.36 ± 0.05 sec. In the control group, in the right multifidus muscle, the mean frequency was 84 Hz and the average maximum amplitude was 407.7 μV. In the

Table 2 Mean frequency and maximum amplitude during lateral bending

	mean frequency (Hz)			
	right multifidus m.	right longissimus m.	left multifidus m.	left longissimus m.
control group	71.2 ± 8.7	70.3 ± 8.2	72.6 ± 10.9	71.9 ± 11.3
LBP group	69.7 ± 10.1	69.1 ± 7.2	72.0 ± 7.8	69.8 ± 10.2
	maximum amplitude (μV)			
control group	203.2 ± 36.4	144.1 ± 84.9	213.67 ± 36.6	144.1 ± 84.9
LBP group	203.2 ± 33.4	144.5 ± 83.1	205.5 ± 38.1	145.5 ± 83.1

No significant difference were found between control group and low back pain group during lateral bending. (n = 22)

LBP: low back pain, m: muscle

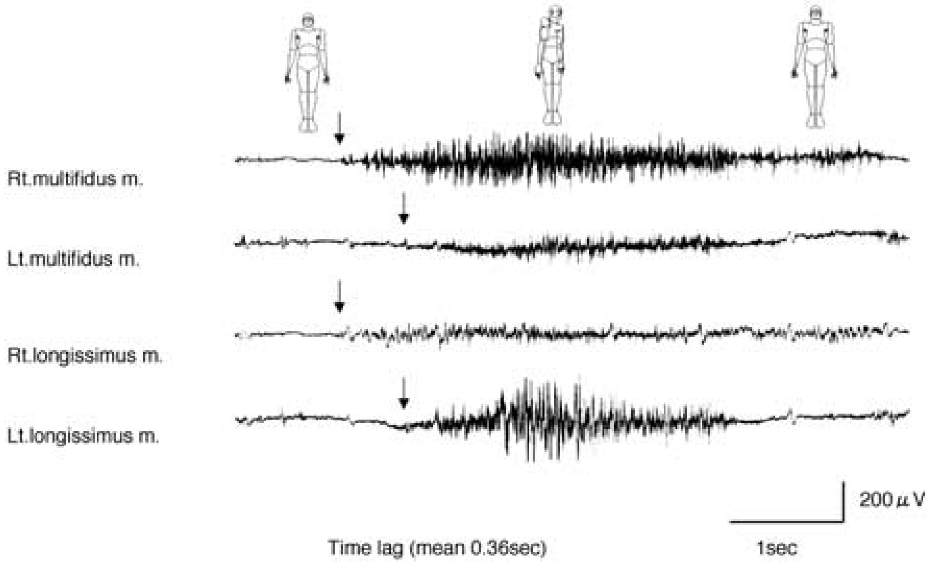

Fig. 7 Strong myoelectrical activity was detected in the contralateral lumbar multifidus muscles with the progression of axial rotation. In the ipsilateral multifidus muscles, weak myoelectrical activity was delayed at the beginning of motion. In the contralateral longissimus muscles, no myoelectrical activity was detected. In the ipsilateral longissimus muscles, strong myoelectrical activity was delayed at the beginning of motion. In the control group, on axial rotation, an intermuscular time lag was observed at the beginning of the motion. The average time lag was 0.36 ± 0.05 sec. The arrows represent an intermuscular time lag. Rt: right, Lt: left, m: muscle.

right longissimus muscle, the mean frequency was 75 Hz and the average maximum amplitude was 110 μV. In the left multifidus muscle, the mean frequency was 71.2 Hz and the average maximum amplitude was 112.7 μV. In the left longissimus muscle, the mean frequency was 84.2 Hz and the average maximum amplitude was 426.8 μV.

In the low back pain group, strong myoelectrical activity was detected in the contralateral multifidus and ipsilateral longissimus muscles on axial rotation, and there was no time lag (**Fig. 8**). In the low back pain group, in the right multifidus muscle, the mean frequency was 81.8 Hz and the average maximum amplitude was 421.8 μV. In the right longissimus muscle, the mean frequency was 79.8 Hz and the average maximum amplitude was 144.5 μV. In the left multifidus muscle, the mean frequency was 82.5 Hz and the average maximum amplitude was 195.5 μV. In the left longissimus muscle, the mean frequency was 88.5 Hz and the average maximum amplitude was 439.5 μV (**Table 3**).

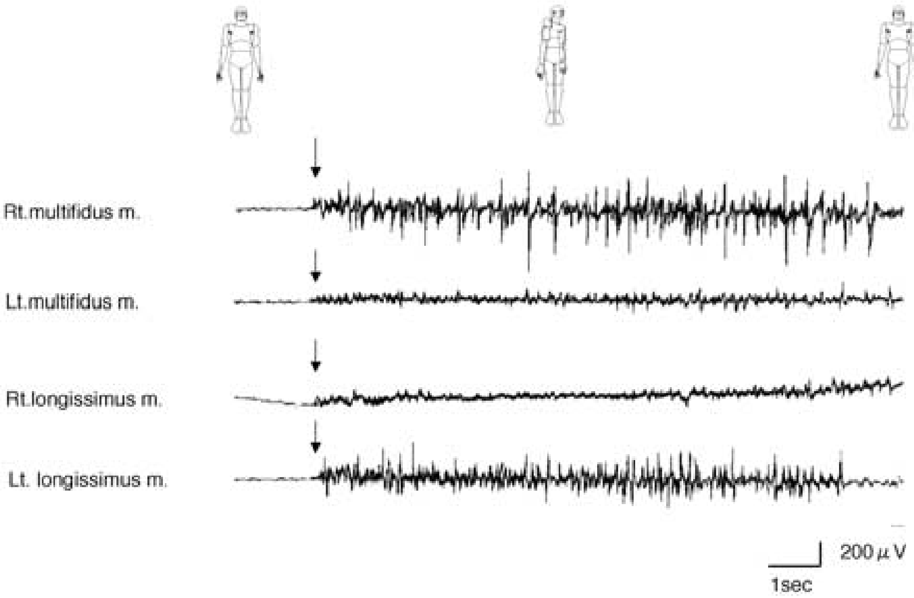

Fig. 8 Strong myoelectrical activity was detected in the contralateral multifidus and ipsilateral longissimus muscles on axial rotation, and there was no time lag. The arrows represent start of the trunk axial rotation. Rt: right, Lt: left, m: muscle.

Table 3 Mean frequency and maximum amplitude during trunk axial rotation

	mean frequency (Hz)			
	right multifidus m.	right longissimus m.	left multifidus m.	left longissimus m.
control group	84.0 ± 12.3	75.0 ± 8.6	71.2 ± 9.9	84.2 ± 10.6
LBP group	81.8 ± 12.1	79.8 ± 13.2	82.5 ± 10.7	88.5 ± 11.6
	maximum amplitude (μV)			
control group	407.7 ± 23.1	110 ± 19.8	112.7 ± 20.7	426.8 ± 28.5
LBP group	421.8 ± 30.4	144.5 ± 14.1	195.5 ± 15.9	439.5 ± 21.0

No significant difference were found between control group and low back pain group during trunk axial rotation.
(n = 22)
LBP: low back pain, m: muscle

Discussion

Morphologically, the lumbar paraspinal muscles mainly consist of the multifidus, longissimus and iliocostalis muscles. The origin of the lumbar multifidus muscles is the lumbar spinous processes, and they attach to the mamillary process of the lumbar vertebra, accessory process, zygapophysial joint capsule, posterior superior iliac spine, and sacrum[1,11]. The lumbar multifidus muscles are innervated by the medial branch of the dorsal ramus that issues from below the vertebra[1,11]. The origin of the longissimus muscles is the transverse process and accessory process, and they attach to the medial posterior superior iliac spine. The lumbar longissimus muscles are innervated by the lateral branch of the dorsal ramus. In a previous study, it was suggested that the erector spinae consists of lumbar and thoracic fibers that function independently[12]. Accordingly, here, we discuss the lumbar and thoracic muscles independently.

Donisch et al.[13] and Morris et al.[14] studied multifidus myoelectrical activity electromyographically during various motions in healthy adults using wire electrodes. In kinesiological EMG using wire electrodes, myoelectrical activity is evaluated only in certain parts of muscles, producing non-quantifiable results. In surface EMG, myoelectrical data reflects total muscle activity, but cross talk is a problem, making it impossible to analyze the function of each individual muscle. Therefore, we analyzed a group of lumbar paraspinal muscles.

Floyd et al.[8] reported that, in healthy adults, as trunk flexion progresses, the trunk is supported by the posterior vertebral muscles, whereas, in a full trunk flexion position, the trunk is mainly supported by the ligaments, zygapophysial joint capsule, gluteus muscles and hamstrings, with the paraspinal muscles electrically silent. Kippers et al.[15] reported the possible existence of nerve expansion receptors in the vertebral column or related structures, and the possibility of their use in the examination of paraspinal muscle activity, and studied the myoelectrical activity of the erector spinae muscles in relation to trunk, vertebral, and hip flexion angles, which were measured using body landmarks and photographic techniques. The onset electrical silence was found to occur at only two-thirds maximum trunk flexion. Jack et al.[16] reported that electrical silence in trunk full flexion was observed always during seated posture in the thoracic muscles, but it was not observed in the lumbar muscles. The lumbar electrical silent muscles did not demonstrate the same quiescence as the thoracic electrical silent. Reduced intervertebral range of motion has been found previously in patients with low back pain with degenerative changes in the lumbar spine[17]. Restricted intervertebral motion in the patients may have been due to continuous muscle activity. Activated muscles may protect from injury of joint, intervertebral disc and ligament. In the present study, the highest level of trunk flexion produced pain and continuous muscle activity was recorded in the low back pain group. We speculate that the continuous muscle activity observed in the full trunk flexion position provides stability to help protect spinal structures, and activated muscles would behave as stabilizers, rather than mobilizers.

During trunk lateral bending, bilateral muscle activity was detected, but contralateral muscle activity was relatively strong. It is thought that contralateral muscles support the trunk and control its motion. It is impossible for the lumbar vertebra to be rotated in isolation. Myoelectrical muscle activity patterns were not different from low back pain groups and control groups.

Lumbar axial rotation requires pelvic fixation and thoracic rotation. The medial and lateral abdominal oblique muscles are the main muscles involved in trunk axial rotation, with the contralateral lumbar multifidus and longissimus muscles functioning in a supplementary capacity[18]. Kumar et al.[19] studied that the magnitude contribution of the muscles in isometric graded axial rotation contraction were increased proportionally to the grades of contraction the latissimus dorsi and the external obliques, but that of the erector spinae decreased. That suggests their role as stabilizers but not as rotators. Eccentric contraction of the ipsilateral lumbar multifidus and longissimus muscles stabilizes the zygapophysial joint. It is assumed that there is an intermuscular time lag. In the present study, in the low back pain group, there was no intermuscular time lag, because the contralateral multifidus and longissimus muscles controlled the zygapophysial joint and restricted lumbar range of motion in axial rotation. Also the present data suggests the existence of a feed-forward mechanism in the neuromuscular system, and protect passive spinal structures from movements.

Conclusions

No myoelectrical activity was detected in the lumbar paraspinal muscles in the full trunk flexion position in the healthy volunteers. In contrast, continuous myoelectrical activity was detected in the low back pain group. On axial rotation, there was an intermuscular time lag (mean, 0.36 sec) at the beginning of the motion in the healthy volunteers. In the low back pain group, there was no such time lag. Results were suggested the lumbar paraspinal muscles behave as stabilizers.

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