



Original Article

Comparison of electromyographic activities of lumbar iliocostalis and lumbar multifidus muscles during stabilization exercises in prone, quadruped, and sitting positions

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Abstract. [Purpose] The purposes of this study were: 1) describe a hierarchy of electromyographic activity production, using percentage maximum voluntary contraction of lumbar iliocostalis and lumbar multifidus muscles during prone, quadruped and sitting exercises; and 2) identify optimal recruitment exercises for both lumbar iliocostalis as a global multi-segmental stabilizer and lumbar multifidus as a segmental stabilizer. [Subjects] Twelve healthy volunteers (six male and six female) aged 24 to 45 participated. [Methods] Surface electromyographic activity data were collected bilaterally from lumbar iliocostalis and lumbar multifidus muscles during exercises. [Results] Two-way ANOVA showed that prone extension, and prone alternate arm and leg lifting exercises produce a statistically significant difference in percent maximum voluntary contraction of lumbar iliocostalis and lumbar multifidus bilaterally compared to other exercises. Quadruped alternate arm and leg lifting exercises produce greater activity in lumbar multifidus muscle than sitting exercises [Conclusion] Prone exercises generate the greatest electromyographic activity and may be the most effective exercises for strengthening both lumbar iliocostalis and lumbar multifidus muscles. Quadruped alternate arm and leg lifting produces electromyographic activity at the recommended percent maximum voluntary contraction for training the lumbar multifidus in its role as a segmental stabilizer and is an effective training exercise for this goal.

Key words: Electromyography, Lumbar stabilization, Exercise

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INTRODUCTION

Back pain is a common problem with annual prevalence of activity limiting low back pain at 38%¹⁾. Of individuals with chronic low back pain, 30% receive physical therapy²⁾. Rehabilitation programs that include stabilization exercises reduce pain and disability in individuals with chronic low back pain³⁾. Both lumbar iliocostalis (LI) and lumbar multifidus (LM) have a role in stabilization of the spine. The LI provides stabilization globally at a multi-segmental region whereas LM is viewed to provide stability at a local segmental level⁴⁾. Both LI and LM electromyographic (EMG) activity have been described for stabilization exercises performed in prone⁵⁻⁷⁾, and quadruped⁸⁾. In standing, the EMG output of LM but not LI was reported during maximum effort shoulder and trunk motions⁹⁾. Seated position stabilization exercise studies are limited to reports of EMG activity for erector spinae⁷⁾ and LM⁶⁾ during shoulder flexion. While standard stabilization exercises are performed in prone and quadruped, medical or musculoskeletal conditions¹⁰⁾ may limit an individual's ability to assume

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these positions. Seated dynamic exercise programs are comfortable and safe for individuals (e.g., those with osteoarthritis) who cannot exercise in upright¹¹). Investigation of EMG activity of LI and LM during performance of seated stabilization exercise using multiple shoulder motions has not been performed. The purpose of this study was to compare the EMG activity of LM and LI during full range and stabilization exercises performed in prone, quadruped, and sitting to identify an exercise hierarchy of percent (%) maximum voluntary contraction (MVC) as well as optimal recruitment exercises for both LI as a global multi-segmental stabilizer and LM as a segmental stabilizer.

SUBJECTS AND METHODS

Twelve healthy volunteers (six male and six female) aged 24 to 45 participated in the study. The average age of subjects was 31.4 ± 7.48 years. Mean height and weight were 171.08 ± 8.22 cm and 66.67 ± 13.10 kg, respectively. Participants who demonstrated full active shoulder flexion motion, at least 50% active trunk extension motion, no spinal deformities, and absence of pregnancy, neuromuscular disease, past spine surgery, or back pain within the past three months were included in the study. All subjects correctly performed the exercises at a training session after instruction by a physical therapist. Data was collected at a subsequent testing session. The Institutional Review Board at Helen Hayes Hospital approved this study. All subjects signed informed consent.

The study was conducted at the Gait Laboratory at Helen Hayes Hospital, West Haverstraw, NY, USA. The EMG data were recorded with surface electrodes (Iomed Inc., Salt Lake City, UT, USA). The electrodes have a differential preamplifier with three stainless steel sensing elements (13 mm in diameter spaced 5 mm apart with the center acting as a ground plate) with a gain of 300, common mode rejection ratio of >100 dB, input impedance of 100,000 Megohms, and a bandwidth of 8 Hz to 27 KHz. Data were collected with a VAX² 3200 computer work station and stored for further analysis.

The skin was cleaned with alcohol prior to electrode placement. Electrodes were placed over bilateral LM and LI muscles. Placement for LM was consistent with methods described by others¹²⁻¹⁵) at 1 to 2 cm lateral to the midline to the spine and adjacent to the fourth and fifth lumbar vertebral bodies. Electrode placement for LI was similar to Ng and colleagues¹⁶) at just proximal to the posterior superior iliac spine, parallel to the line of the lateral “most bulk” of the erector spinae. Prone active trunk hyperextension was used to visualize and mark the outline of this muscle bulk. Additionally, prone resisted isometric shoulder extension confirmed no activity at this electrode during latissimus dorsi muscle contraction. Muscle contraction with a constant weight is reliable for normalization of EMG¹⁷). We predicted that all participants could achieve full extension with 7.3 kg as the resistance. Therefore, active prone hyperextension against a 7.3 kg weight positioned mid scapula was defined as a maximum voluntary contraction (MVC). All exercises lasted six seconds, using a metronome and verbal cues for three equal phases: a two second build up, 2 second hold, and 2 second release. A 30 second rest preceded each exercise. After the preamplifier gain of 300, the EMG signals were sampled at 1,200 Hz and band pass filtered from 40 to 500 Hz. The data were full-waved rectified and the three repetitions averaged for the three phases of the exercises. Only data from the hold phase was analyzed. These exercise data were normalized to a percentage of the average of the MVC.

Three categories of exercise were performed: prone, quadruped and sitting. Subjects were instructed as follows: (a) in prone, move through full active prone trunk extension (PTE) range of motion without extremity motion, full active trunk extension with left arm/right leg lift and with right arm/left leg lift, (b) maintain quadruped with isometric fixed neutral pelvis for quadruped opposite arm/leg lift (QOALL) both combinations, and (c) sit and hold erect posture with isometric fixed neutral pelvis with right arm outstretched at 90 degrees shoulder flexion for isometric arm exercises. Sitting arm exercise was performed using the right arm with a 1.8 kg force applied at the wrist using a strain gauge held perpendicular to the arm in the sagittal plane to produce flexion/extension, and transverse plane for horizontal abduction/adduction isometric shoulder muscle contractions. The sequence of categories was chosen randomly by slips of paper drawn from a box. Each exercise was repeated three times.

A two-way ANOVA (exercise x side) with repeated measures was performed for each muscle to assess differences in EMG activity level among exercises and across sides. Post-hoc analyses was used to analyze main effects and interactions. Scheffe contrast, $\alpha=0.05$ were used to compare specific exercises within each muscle. Tukey HSD confidence intervals $\alpha=0.05$ were used to determine which exercises resulted in significant left/right asymmetry. Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) version 23.

RESULTS

Identical hierarchies were identified for normalized data and are shown in Table 1. Two-way ANOVA analysis showed that significant main effect of % of EMG activity for LI and LM muscles was observed, suggesting that % of EMG activities varies with exercise position ($(F_{1,11})=106$, $(F_{1,11})=150$, $p<0.05$). Post hoc tests revealed that prone extension, prone right UE/left LE, and prone left UE/right LE produces a statistically significant difference with greater LI and LM EMG activity compared to quadruped and sitting positions exercises ($p<0.05$) (Table 1). Additionally, quadruped arm lifting exercise generated a statistically significant difference in LM EMG activity that was greater than that produced in sitting exercises ($p<0.05$).

A statistically significant interaction between exercise and side was found for LI and LM muscles activities ($(F_{1,11})=106$, $p<0.05$). Muscle activity was greatest ipsilateral to side of arm activity for LI for prone and quadruped. In contrast, LM

Table 1. Mean percentage MVC with standard deviation of iliocostalis and multifidus muscles

Muscle	PE	POALL R UE lift	POALL L UE lift	QOALL R UE lift	QOALL L UE lift	SFLEX R UE	SEXT R UE	SABD R UE	SADD R UE
Iliocostalis R	0.93 ± 0.23*	1.06 ± 0.48*‡	0.80 ± 0.33*	0.36 ± 0.18‡	0.27 ± 0.20	0.13 ± 0.08‡	0.08 ± 0.5	0.20 ± 0.07‡	0.09 ± 0.05‡
Iliocostalis L	0.95 ± 0.28*	0.85 ± 0.28*	1.02 ± 0.31*‡	0.25 ± 0.11	0.38 ± 0.26	0.24 ± 0.08	0.07 ± 0.05	0.08 ± 0.03	0.23 ± 0.06
Multifidus R	0.88 ± 0.28*	0.90 ± 0.29*	0.83 ± 0.24*	0.26 ± 0.22	0.46 ± 0.17§‡	0.20 ± 0.13	0.08 ± 0.03	0.14 ± 0.06	0.17 ± 0.09
Multifidus L	0.90 ± 0.16*	0.90 ± 0.24*	0.87 ± 0.19*	0.43 ± 0.09§‡	0.23 ± 0.10	0.25 ± 0.13	0.09 ± 0.07	0.17 ± 0.09	0.16 ± 0.08

R: right; L: left; UE: upper extremity; PE: prone extension; POALL: prone opposite arm leg lift; QOALL: quadruped opposite arm leg lift; SFLEX: sitting flexion; SEXT: sitting extension; SABD: sitting horizontal abduction; SADD: sitting horizontal adduction; *Statistically significant difference from quadruped and sitting position exercises; §Statistically significant difference from sitting position exercises; ‡Statistically significant difference for noted exercise and muscle left and right comparison; p<0.05

activity was higher on side opposite to arm lift (side of leg lift) during QOALL. Sitting exercises did not show consistency in favoring either left or right side muscle activity for either muscle (Table 1).

DISCUSSION

The purpose of this study was to compare full range and stabilization exercises performed in prone, quadruped, and sitting and establish a hierarchy of % MVC of EMG activity of LI and LM, as well as to identify optimal recruitment exercises for both LI as a global multi-segmental stabilizer and LM as a segmental stabilizer. All core muscles are important for providing trunk stability¹⁸, with stabilization of the lumbar spine accomplished by the interaction of local and multi-segmental muscle contraction⁴. The long multi-segmental global muscles function as guy wires during trunk motion while the deep segmental back muscles provide neuromuscular control at a vertebral level, with the LM viewed as a primary segmental stabilizer of the lumbar spine¹⁹. A high resistance generates the need for a large force, produced by the stronger global muscles (e.g., LI)¹⁸. Smaller muscles (e.g., LM) are more efficient in generating a segmental stabilization force and may be sufficient for resisting lighter loads¹⁸. Trunk extensor muscle weakness can be addressed via strengthening by using prone extension exercises through full range against resistance¹⁹. In this study PTE recruited both LI and LM maximally and symmetrically, which is consistent with their primary action in extension of the lumbar spine and consistent with the results of EMG studies by others²⁰⁻²². The high muscle recruitment of 80 to 106% MVC produced during the bilateral recruitment of LI and LM during this exercise indicate it is an optimal exercise for strengthening.

High compressive forces on the spine may be hazardous to individuals with low back pain²³. Decreased compressive forces can be accomplished using quadruped exercises with a neutral spine position¹⁹. Asymmetry during QOALL was observed for both LI and LM, with greater activity occurring ipsilateral and contralateral to arm lift respectively. Previous studies report mixed results for LI with no asymmetry²⁴, asymmetry of muscle activity with LI greater ipsilateral to arm lift^{8, 25}, and contralateral to arm lift²³. Prior studies of quadruped exercise for LM activity have also reported varied asymmetry with greater ipsilateral to arm lift⁸ and contralateral to arm lift^{23, 25, 26}. In this study, during QOALL the LI and LM produced 24 to 38% and 23 to 46% MVC, respectively. This is less than the recommended 60 to 70% of a 1 repetition maximum (and similar % MVC) advocated to achieve a strengthening effect for novice exercisers²⁷. Thus, QOALL is not recommended as a strengthening exercise for these muscles. Consistent with its proposed role as a postural muscle⁴, the LM is composed of mostly type 1 fibers²⁸. In this role, the LM will perform tonic contractions⁴. Low load exercise of 30 to 40% MVC is recommended for targeted endurance training of type 1 muscle fibers⁴. Additionally, success has been achieved using an exercise program for patients with clinical instability, which included targeted recruitment of LM, resulting in decreased pain and improved function²⁹. These results indicate that QOALL will produce low levels of spinal compression and optimally train LM to support its role as a postural muscle.

Some individuals cannot assume a prone or quadruped position to perform spine strengthening exercise. The exercises performed in sitting demonstrated that recruitment of LI was dependent on direction of force. Motions of sitting flexion and adduction produced higher LI EMG values contralateral, while abduction demonstrated a greater ipsilateral LI force. Behm and colleagues⁷ reported a similar pattern of greater contralateral lumbosacral ES EMG activity when performing a unilateral shoulder press using a dumbbell while seated. They proposed that unilateral resisted exercise creates a disruptive torque moment thereby creating an unstable condition with a response by the contralateral ES. However, their use of a Swiss ball as an unstable base did not increase recruitment of contralateral ES when compared to a stable sitting environment during unilateral shoulder press with a dumbbell. Our results demonstrated that recruitment of LM in sitting was symmetrical, with greatest % MVC during shoulder flexion. Aronski and coauthors⁶ also reported LM produced symmetrical contraction

during alternating flexion with dumbbells in high sitting. This study is the first to describe the EMG production of back stabilizing muscles while performing multiple unilateral resisted shoulder exercises in a seated position. Our results indicate that seated arm exercises as performed in this study are insufficient to produce a strengthening or endurance training effect on the trunk stabilizers.

Our study has some limitations. The superficial and deep fibers of LM may exhibit differing EMG recruitment patterns which are not observable with surface electrodes. Results may vary in persons with back pain, older adults, when using different extremity positions or different amounts of resistance. Whereas a standardized MVC of prone extension against 7.3 kg was utilized, an isometric resistance in trunk extension may produce a higher EMG reading.

In conclusion, our study indicates that full range prone exercises generate sufficient EMG output to provide a strengthening stimulus for both LI and LM. For the healthy individual, PTE generates the greatest EMG production, thus providing the best exercise for strengthening the trunk extensors. The quadruped stabilization exercise best trains the LM in its role as a segmental stabilizer. The QOALL exercise produces low spinal loading and recommended % MVC activity for training LM in its role as a segmental stabilizer, thus making this the optimal exercise for an individual with low back pain. Lastly, sitting isometric arm exercises, at the loads used in this study, generate insufficient load for any training effect for either LI or LM. Further research is needed to determine optimal exercise dosage for strengthening and endurance of both global and segmental muscles in a sitting position.

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