Exercise Effect on Electromyographic Activity of the Vastus Medialis Oblique and Vastus Lateralis Muscles

The purpose of this study was to determine whether the vastus medialis oblique muscle (VMO) had greater electrical activity than the vastus lateralis muscle (VL) when hip adduction and medial (internal) tibial rotation exercises were performed. Electrical activity of the VMO and VL was measured on 25 healthy subjects during maximal-effort isometric contractions of hip adduction and medial tibial rotation. The results showed that the electromyographic activity of the VMO was significantly greater than that of the VL during the hip adduction exercise. Differences noted with medial tibial rotation were not significant. The results suggest that the VMO may be selectively activated by performing hip adduction exercises. Resistive hip adduction exercises, therefore, may be advisable in the treatment of patients with lateral malalignment of the patella with accompanying pain or instability. [Hanten WP, Schulthies SS. Exercise effect on electromyographic activity of the vastus medialis oblique and vastus lateralis muscles. Phys Ther. 1990;70:561-565.]

Key Words: Electromyography, Exercise, strengthening, Knee rehabilitation.

Stabilizing the patella against excessive lateral excursion is one of the main purported functions of the vastus medialis oblique muscle (VMO).1,2 Because patellofemoral pain may be a result of laterally malaligned patellae,3 attempts have been made to selectively strengthen the VMO in order to reduce patellofemoral pain.4-7 This selective strengthening is usually attempted by performing knee extension exercises, often within a limited range of motion (ROM).4-7 Uncertainty exists, however, as to whether the VMO can be selectively strengthened.

In theory, in order to selectively strengthen the VMO, one must perform exercises in which the VMO is significantly active and the other muscles of the leg are significantly less active. Because of its lateral pull on the patella, the activity of the vastus lateralis muscle (VL) is often compared with the activity of the VMO.6,7 A review of the literature reveals no studies that show a significant increase in VMO EMG activity compared with VL EMG activity at any portion of the ROM during knee extension. We believe that knee extension exercises will strengthen the more powerful VL as well as the VMO. In patients with lateral malaligned patellae, knee extension exercises therefore may have little effect on the VMO contraction intensity when compared with VL, and thus little effect on patellar alignment.

In light of previous research involving extension exercises, alternative methods of selectively strengthening the VMO have been suggested. Bose et al8 showed that the oblique fibers of the VMO arise mainly off the tendon of the adductor magnus muscle and somewhat off the tendon of the adductor longus muscle. They also found disruptions in the fibers attaching the VMO to the adductor tendons in each of 10 patients with recurrent patellar dislocations and concluded that treatment for patellar instability should make use of the connection between the VMO and the hip adductors.8 Brownstein et al4 suggest
performing hip adduction exercises as a possible method of selectively strengthening the VMO because of its attachment to the adductor magnus muscle. In an EMG study by Wheatley and Jahnke,9 the VMO showed increased action potentials with hip adduction, possibly “due to the inertia of the leg.” Reynolds et al.10 in discussing methods to facilitate the VMO while inhibiting the VL, state that “the addition of abduction while performing knee extension exercises might facilitate the VMO.” This suggestion has been disputed by Andreuchi et al.,11 who found decreased EMG readings of all quadriceps femoris muscles when, using a pulley system, a 24-N·m abduction torque was added to the legs of four subjects as they performed weighted knee extensions.

Medial (internal) tibial rotation exercises might possibly strengthen the VMO selectively compared with the VL. In discussing rotary instability, Sclocum and Larson12 stated that the VMO inserts into the anteromedial aspect of the tibia via the medial extensor aponeurosis and can effectively prevent lateral (external) rotation of the tibia in the first 60 degrees of knee flexion. Accordingly, the VMO might work as a medial rotator of the tibia within the first 60 degrees of knee flexion. Engl13 suggests that the VMO works as a medial rotator of the knee if the knee is in a slightly extended position. In a descriptive study, Duarte-Cintra and Furlani found no activity of the quadriceps femoris muscles during active rotation of the tibia with the knee flexed to 90 degrees. Duarte-Cintra and Furlani, however, did not test resisted rotation, nor did they test rotation at flexion angles other than at 90 degrees.

Because hip adduction and medial tibial rotation exercises have not been extensively evaluated relative to their effects on the quadriceps femoris muscles, this study was designed to determine whether the VMO EMG activity differs from that of the VL during hip adduction and medial tibial rotation. The null hypothesis tested was that there would be no significant differences in the EMG activity of the VMO and VL during maximal isometric contractions of hip adduction and medial tibial rotation.

**Method**

**Subjects**

Twenty-five healthy volunteers participated in this study. The subjects reported no history of previous knee pathology, previous knee surgery, or current symptoms of retropatellar pathology. Subjects ranged in age from 21 to 34 years (X = 25.08; SD = 3.03). All subjects read and signed an institutionally approved informed consent form before testing.

**Equipment**

We constructed indwelling fine-wire electrodes according to the procedure described by Basmajian and Stecko15 (using 0.0014 size wire and 27-gauge hypodermic needles) to acquire the EMG signal. Epoxy-mounted preamplifiers* (gain, x 35) were used to provide initial amplification of the EMG signal, thus reducing background noise.16 A Hewlett-Packard Model 1222 oscilloscope1 was used to visually monitor the EMG signal for artifacts. The EMG signal was processed by the GCS 67 multichannel EMG signal acquisition and processing system.* A DATASAMP-IBMP custom software package* was used for data collection and reduction. A Cybex® II isokinetic dynamometer was used only to provide resistance during the maximal isometric contractions. A goniometer was used to measure joint angles.

**Procedure**

Each subject attended one orientation session and one testing session. The two sessions were between 1 and 7 days apart and consisted of maximal voluntary isometric contractions (MVICs) of hip adduction, medial tibial rotation, and knee extension of the left lower extremity. We chose to test the left lower extremity on all subjects to maintain consistency and to avoid moving the equipment. The isometric knee extension exercise was used to normalize the EMG activity of the VMO and the VL.

**Orientation session.** An orientation session was used to familiarize the subjects with the exercises to be performed as well as with the positioning and stabilization accompanying each exercise. For the knee extension exercise, the subject was seated on a chair that was firmly attached to the dynamometer. We adjusted the backrest to provide 70 degrees of hip flexion. The subject's thighs were supported by the padded seat, which extended to approximately 2.5 cm proximal to the popliteal fossa. We placed spacers between the subject and the backrest for those subjects with femurs shorter than the padded seat. We then stabilized the subject to the chair with two belts: a thoracic belt at approximately the third rib, extending under the axillae and encircling the chair's backrest, and a pelvic belt attached to the chair and fastened around the subject's pelvis just inferior to the anterior superior iliac spines. We instructed the subject to grasp the sides of the padded seat for added stabilization.

We aligned the mechanical axis of rotation of the dynamometer lever arm with the lateral femoral condyle. The resistance pad at the end of the lever arm was attached on the ante-
rior tibia approximately 2.5 cm superior to the medial malleolus. We then secured the pad using a 5.08-cm (2-in) Velcro® strap encircling the lower leg. The dynamometer maintained the subject's knees at 50 degrees of flexion. Although a great deal of controversy exists concerning the angle of knee flexion where the electrical activity of the quadriceps femoris muscle is the greatest,17 we chose to use 50 degrees of knee flexion. This angle coincides with the angle Brownstein et al12 found to have the greatest electrical output.

Following the positioning and stabilization of the subject, the dynamometer velocity was set at 0°/sec, and the subject was instructed to extend the knees with maximal force (for approximately 2 seconds) until instructed to relax. We verbally encouraged each subject to contract with maximal force. Each subject practiced isometric knee extension, with 30-second rest periods between contractions, until we observed that the subject was able to perform the desired exercise with ease and no extraneous motion.

For the hip adduction exercise, we seated and secured the subject to the chair as described for the knee extension exercise. Each subject's right leg was extended and rested on a padded seat. The limb was secured to the seat with a belt placed proximal to the medial joint line of the left knee. We then instructed the subject to medially rotate the tibia with maximal effort. Each subject practiced isometric medial tibial rotation, with 30-second rest periods between contractions, until we observed that the subject was able to perform the desired exercise with ease and no extraneous motion.

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For the medial tibial rotation exercise, we positioned and stabilized the subject as described for knee extension, except the resistance pad was placed behind the subject's left leg to allow the subject's leg to be stabilized at 30 degrees of knee flexion. In this position, the dynamometer acted only to stabilize the knee at the desired angle of knee flexion. We supplied manual resistance to the medial aspect of the subject's left foot (over the head of the first metatarsal) and maintained counter pressure to the lateral side of the subject's heel, maintaining zero degrees of medial tibial rotation. We then instructed the subject to medially rotate the tibia with maximal effort. Each subject practiced isometric medial tibial rotation, with 30-second rest periods between contractions, until we observed that the subject was able to perform the desired exercise with ease and no extraneous motion.

Testing session. Immediately prior to data collection, we prepared the left thigh of each subject by cleansing, with alcohol, an 8-cm-diameter area over the VMO 4 cm superior and medial to the superomedial border of the patella and over the VL 10 cm superior to the lateral epicondyle of the femur. We then inserted the sterilized fine-wire electrodes into the VL and VMO and connected the fine-wire electrodes to the preamplifiers, secured with adhesive tape near the electrode insertion site. Each subject performed a warm-up consisting of 10 submaximal contractions for each of the three exercises described. The average voltage, termed the “EMG read-
ing,” was recorded for each muscle at each exercise. The processed data were normalized by using the EMG readings of both the VMO and the VL that were generated with knee extension at 50 degrees of knee flexion. All normalized readings, therefore, were recorded as a percentage of the EMG reading recorded for each muscle with knee extension (MVIC of exercise/MVIC of knee extension × 100).

Data Analysis

We were concerned with the significance of the simple main effects; that is, we examined the manipulation of one independent variable at the levels of another as if they were separate experiments. We therefore used a nested hypothesis model.18,19 Means and standard deviations were computed for the normalized EMG readings of the VL and the VMO for the exercises of hip adduction and medial tibial rotation. The means were then analyzed using a two-way analysis of variance for repeated measures on both factors to determine the mean square residual. The mean square residual was used to compute the standard error of the means. The standard error of the means was used to compute post hoc comparisons using

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Table. Means and Standard Deviations of Normalized Electromyographic Readings (as Percentage of Knee Extension) of the Vastus Medialis Oblique Muscle (VMO) and the Vastus Lateralis Muscle (VL) During Hip Adduction and Medial Tibial Rotation (N = 25)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Adduction*</th>
<th>Medial Rotation</th>
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<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
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<tr>
<td>VMO</td>
<td>61.75</td>
<td>45.69</td>
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<tr>
<td>VL</td>
<td>45.63</td>
<td>29.33</td>
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*A significant difference existed between the means of the VMO and VL for the hip adduction exercise.

The results of this study show that volitional hip adduction will significantly increase the proportional electrical discharge of the VMO when compared with the VL. We found normalized EMG readings of 61.75% and 45.63% for the VMO and VL, respectively (Table). The results of this study also showed that volitional medial tibial rotation will not significantly increase the proportional electrical discharge of the VMO when compared with the VL. We found normalized EMG readings of 47.12% and 45.32% for the VMO and VL, respectively (Table).

Hip adduction has been espoused by some authors as a means of selectively strengthening the VMO. Wheatley and Jahnke found that the VMO showed increased electrical activity during hip adduction. It may be argued that Wheatley and Jahnke's results were affected by cross talk, because they used surface electrodes in the detection of the EMG signal. Although surface electrodes are optimal when gross muscular activity is studied, they are less selective in their electrical detection than fine-wire electrodes. With pilot data, we found that the normalized readings of the VMO surface electrodes were higher than the simultaneous readings collected with the underlying fine-wire electrodes. We were obliged, therefore, to use fine-wire electrodes in order to ensure that our collected EMG readings were specific to the VMO and VL.

Andriacchi et al. tested the effect of adding an abduction torque simultaneously with a flexion torque to the lower leg, thus requiring a simultaneous knee extension and hip adduction contraction. Our results differ from the findings of Andriacchi et al. in that they found a decrease in the electrical output of the VMO as well as the VL and the rectus femoris muscle. These different results may be attributable to several differences in methodology. Andriacchi et al. tested a combination of hip adduction and knee extension. They tested submaximal values. They applied the abduction torque to the lower leg, hypothesizing that this procedure caused the patella to ride higher on the lateral femoral condyle and increased the quadriceps femoris muscle extensor moment arm, thus reducing the output requirements of the quadriceps femoris muscle to maintain the static contraction. They also tested only four subjects.

Medial tibial rotation has also been suggested as a possible means of selectively strengthening the VMO. Engle states that the VMO can work as a medial tibial rotator if the knee is in slight extension. We tested medial tibial rotation at 30 degrees of flexion and found no significant differences in the normalized EMG amplitudes of the VMO and the VL.

Our results differ from those of Duarte-Cintra and Furlani, who found no quadriceps femoris muscle activity during active tibial rotation at 90 degrees of knee flexion. The difference is probably attributable to the fact that Duarte-Cintra and Furlani's subjects performed rotation with no resistance, whereas our subjects performed maximal-effort isometric contractions.

Attempts to selectively strengthen the VMO have used the motion of knee extension, often limited to the terminal degrees of extension. Although knee extension exercises remain popular in the treatment of patellofemoral pain or instability secondary to lateral alignment of the patella, they nonetheless lack a sound biomechani-
The performance of hip adduction exercises serves two functions in the rehabilitation of patients with patellofemoral pain or instability. First, by strengthening the VMO, one can reduce the lateral pull on the patella. Second, we speculate that strong hip adductors give the VMO a stable origin from which to contract. A strong VMO originating from weak adductors would serve only to draw the adductor tendons toward the patella, having no effect in reducing the lateral malalignment. The role that the hip adductors play in patellar stabilization is supported by the fact that the hip adductors exhibit "great amounts of activity" when resisted knee extension is performed. Resistive hip adduction exercises, therefore, may be advisable in the treatment of patients with lateral malalignment of the patella with accompanying pain or instability.

Conclusion

The purpose of this study was to determine whether the electrical activity of the VMO, when compared with the VL, would significantly differ during hip adduction and medial tibial rotation exercises. We found that, during hip adduction, the electrical activity of the VMO was significantly greater than that of the VL. Differences noted during medial rotation were not significant. The results suggest that the VMO may be selectively strengthened by performing hip adduction exercises.

References