Vastus Lateralis and Vastus Medialis Obliquus Activity During a Straight-Leg Raise and Knee Extension With Lateral Hip Rotation

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Objective: To compare average electromyogram (EMG) activity of the vastus medialis obliquus (VMO) and vastus lateralis (VL) during straight-leg raise (SLR) and knee extension (KE) with the hip in neutral and lateral rotation. Design: 1 × 4 factorial repeated-measures. Setting: Laboratory. Participants: 13 male college students. Intervention: SLR with hip flexed at 40°, in neutral position, and maximally laterally rotated and KE with hip in neutral and maximally laterally rotated. Main Outcome Measure: Average EMG activity during each of the 4 conditions, normalized against peak muscle activity during that trial. Results: No differences were observed between exercises in VMO activity (F_{3.36} = 0.646, P > .05), VL activity (F_{3.36} = 1.08, P > .05), or VMO:VL ratio (F_{3.36} = 0.598, P > .05). Conclusions: Electrical activity of the VMO or VL and VMO:VL ratio do not change with hip position or exercise. Key Words: electromyography, rehabilitation, exercise


Many knee-rehabilitation programs focus primarily on strengthening the vastus medialis obliquus (VMO). This tends to be the focus because patients with any type of internal knee derangement have been shown to develop atrophy of the VMO and lose the last few degrees of full extension before any other measurable loss of girth. One researcher reported that early atrophy of the VMO is an indicator of general quadriceps weakness and not just weakness in the particular muscle. Smillie postulated that the vastus medialis is the “key to the knee” because it is almost entirely responsible for stabilization and protection. Proper VMO functioning is also extremely important for patients with patellofemoral dysfunction, as well as any patient with knee pathology. The VMO functions to control...
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patella alignment by pulling the patella medially during extension and under normal knee function.\textsuperscript{1,4,5} acts as a dynamic medial stabilizer of the patella once the knee reaches terminal extension.\textsuperscript{6} Because there is evidence supporting the importance of the VMO and because the knee is the most commonly injured joint in sport-related activities,\textsuperscript{7} it is essential to design a rehabilitation program that best achieves the goal of regaining and improving the strength of the VMO.

There is some evidence that rehabilitation programs consisting of isometric quadriceps-setting exercises are more effective for facilitating VMO activity than are straight-leg raises (SLRs).\textsuperscript{8-11} In each of those studies, VMO EMG activity was considerably greater than rectus femoris activity during quad sets than during SLRs. Likewise, rectus femoris activity was significantly greater during SLRs than during quadriceps sets. Skurja et al\textsuperscript{8} went a step farther and compared EMG activity between the rectus femoris and VMO during an SLR and an isolated knee extension. They reported increased VMO activity during the isometric contraction instead of the SLR. More recent studies\textsuperscript{6,12,13} propose that knee-extension exercises provide additional VMO activity and thus have a greater impact on strengthening the VMO than do SLRs.

Most of the existing research evaluated the potential effects of lateral hip rotation on VMO EMG activity during SLRs, but there is very little available examining hip rotation and knee extensions. Recently, it has been proposed that the VMO is preferentially recruited over other quadriceps muscles during either SLRs or knee extensions with lateral hip rotation. In 2 separate studies,\textsuperscript{11,14} investigators compared a quad setting with SLR, SLR with lateral rotation, and an SLR with isometric hip adduction. The outcomes from both studies revealed no difference in VMO EMG activity between an SLR in neutral position and with the hip externally rotated.

In the same studies,\textsuperscript{11,14} rectus femoris, vastus lateralis (VL), and VMO activity were examined during an isometric condition and while participants only performed SLRs. In very few studies has this been examined during an isotonic condition. Furthermore, no known research has evaluated these effects during knee-extension exercises. Therefore, the purposes of this study were (1) to evaluate the VL and VMO muscle activity during an SLR and knee extension with the hip in a neutral and laterally rotated position and (2) to assess the VMO:VL ratios under the same exercise conditions.

**Methodology**

**Design and Setting**

A 1 × 4 repeated-measures design was used in this study. The independent variable was exercise with 4 levels. Each participant completed all 4 exercises: SLR with the hip in neutral position, SLR with lateral hip rotation, knee extension with the hip in neutral position, and knee extension with
lateral hip rotation. A balanced Latin square was used to determine the 
order of exercises. The dependent variable was percent of maximum EMG 
activity for VMO and VL.

**Participants**

Thirteen healthy male college students (age = 24.6 ± 3.7 years, height = 178.3 
± 4.8 cm, mass = 80.4 ± 7.5 kg) with no previous history of significant knee or 
quadriceps injury served as subjects. Before participating in the study, each 
subject completed an informed-consent form and questionnaire regarding 
health status. Approval for this study was obtained from the university’s 
human subjects research committee.

**Instrumentation**

An 8-channeled telemetered EMG system (Telemyo System, Noraxon USA, 
Scottsdale, Ariz) recorded the electrical activity of the VMO and VL mus-
cles. EMG signals were transmitted to a receiver interfaced with a desktop 
computer. The EMG system delivered an analog signal (voltage), which 
was then converted into a digital signal via an analog-to-digital converter 
board in a microcomputer. These signals were digitally converted at 500 
Hz, full-wave rectified, and low-pass filtered with a cut-off frequency set 
at 50 Hz (Myosoft, Noraxon USA).

A metronome set at 60 beats/s provided the cadence at which each subject 
performed the exercises (raise leg on first beat, lower leg on second beat, 
and then rest for 2 beats).

**Testing Procedure**

Each subject arrived at the lab at a scheduled time and completed a health 
questionnaire and informed-consent form and received answers to any 
questions he had regarding the procedure. Height, weight, and skinfold 
measurements were then taken. The skin was prepared by removing excess 
hair and cleansing with an isopropyl-alcohol prep pad. Surface electrodes, 
arranged in a bipolar configuration, were applied to the skin over the VMO 
and VL, with the common reference electrode attached to the radial styloid 
of the subject’s right wrist.15

Each participant completed all 4 conditions, with the only difference 
being the order of the exercises. The procedures for the SLRs both with the 
hip in neutral and in lateral rotation were the same. Each subject assumed 
a supine position on a treatment table for SLRs. A manual goniometer was 
used to determine the amount of hip flexion; a Velcro® strap was then used 
to limit the amount of hip flexion to 40°. One end of the strap was attached 
around the subject’s ankle, and the other was attached to the table. Another 
Velcro strap was used to attach a weight, equal to 5% of the subjects’ lean
body mass, to the subject’s right ankle. The subject then performed a set of 10 repetitions. The technique for performing SLRs was explained as follows: Contract the quadriceps muscles and then lift the leg as far as the strap will allow without tugging on the strap itself. Subjects practiced exercises with the metronome before data collection. The same protocol was followed with the hip in maximum lateral rotation. The subjects were instructed to maintain the lateral hip position throughout the entire exercise, even during rest periods.

Instructions for performing the knee-extension exercises with the hip in neutral position and laterally rotated were the same, as well. When performing the knee extensions, subjects sat at the edge of the table with the heel of the right foot resting on a stack of cones. The number of cones was adjusted so that the subject would have 30° of knee flexion. Subjects were instructed in performing terminal knee extension as follows: Begin each repetition with the heel resting on the stack of cones and end with the knee in terminal extension. Subjects practiced exercises with the metronome before data collection. Resistance, equal to the weight applied for SLR, was attached, and then the subject was asked to perform 1 set of 10 repetitions. The same protocol was used with the hip laterally rotated. The subject was instructed to maintain the hip in a laterally rotated position throughout the entire protocol, even during rest periods. After the testing session was completed, the leads were disconnected from subject’s thigh and the electrodes removed.

The average EMG for a trial was normalized against the peak muscle activity during that trial. The values obtained during each condition represented a percentage of the muscle’s peak activity during the trials for each condition. The 10 normalized repetitions were then averaged to produce a single value for each exercise condition per subject.

**Statistical Analysis**

A repeated-measures analysis of variance (ANOVA) was employed in this study to evaluate the differences between exercise conditions in VL and VMO average EMG and VMO:VL ratio. Experimentwise alpha level was set a priori at the .05 level.

**Results**

Mean average EMG values for all conditions are presented in Table 1. For VMO activity, no differences were observed between any of the 4 exercise conditions ($F_{3,36} = 0.64, P = .59, 1 - \beta = .17$). No differences were observed between exercises on VL activity ($F_{3,36} = 1.1, P = .37, 1 - \beta = .27$) or VMO:VL ratio ($F_{3,36} = 0.60, P = .62, 1 - \beta = .16$), either.
Discussion

The primary focus of this study was to examine whether lateral rotation of the hip would influence the EMG activity of the VMO during an SLR and knee extension. We observed no significant difference in the average EMG during SLRs as opposed to knee extensions, or the amount of rotation occurring at the hip. Earlier studies\textsuperscript{11,16} reported no significant change in the activity of the VMO when the hip position was altered. Wild, Franklin, and Woods\textsuperscript{11} suggested that hip rotation did not enhance the muscle efforts of the vastus group. Similarly, Karst and Willett\textsuperscript{16} suggested that there is no significant difference between the performance of SLRs in a neutral hip position and with the hip laterally rotated or even with the hip adducted. Cerny\textsuperscript{12} reported that, in subjects without patellofemoral pain syndrome, the activity of the VMO was significantly higher in a neutral hip position than when the hip was rotated either medially or laterally during knee extensions.

A significant difference might not have been observed in our study because the weights used during each condition were not heavy enough to cause a meaningful overload in the quadriceps, and the subjects therefore produced less muscle activity. The predetermined weights were selected to model the early stages of the rehabilitation process, when small weights, such as gravity, are the only resistance a patient can overcome. If a larger weight were to be used, an increase in total EMG activity would be expected, although others have suggested\textsuperscript{11,12,16} that a preferential increase in VMO activity would not be seen.

The anatomy and kinesiology of the muscle must also be considered. The exact positioning of the muscle and its nerve innervation help determine its level of function. The increased EMG activity of the rectus femoris over the vastus group during an SLR results, because in addition to extending the knee the rectus femoris provides flexion at the hip.\textsuperscript{8,9,13} It has been hypothesized that by placing the hip in a laterally rotated position, the fibers of the

### Table 1  Average EMG by Condition (Percentage; Mean ± SE)*

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Condition</th>
<th>SLR-N</th>
<th>KE-N</th>
<th>SLR-LR</th>
<th>KE-LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMO</td>
<td></td>
<td>5.2 ± 2.4</td>
<td>4.3 ± 0.16</td>
<td>4.8 ± 1.9</td>
<td>4.5 ± 1.8</td>
</tr>
<tr>
<td>VL</td>
<td></td>
<td>2.7 ± 3.7</td>
<td>2.6 ± 3.8</td>
<td>2.8 ± 3.6</td>
<td>2.6 ± 4.3</td>
</tr>
<tr>
<td>VMO:VL</td>
<td></td>
<td>1.50 ± 0.44</td>
<td>1.29 ± 0.32</td>
<td>1.40 ± 0.38</td>
<td>1.41 ± 0.36</td>
</tr>
</tbody>
</table>

*SLR indicates straight-leg raise; N, neutral hip position; KE, knee extension; LR, hip laterally rotated; VMO, vastus medialis oblique; and VL, vastus lateralis.
VMO could be further stimulated. This theory was based on the fact that some of the fibers of the VMO originate from the tendon of the adductor magnus muscle, so that when subjects stimulated the adductor group they would also stimulate the VMO. The primary action of the adductor magnus is to adduct the thigh, and its secondary action, by the posterior fibers, is to extend and laterally rotate the thigh. The adductor magnus, like most of the adductor muscle group, is innervated by the obturator nerve and tibial portion of the sciatic nerve. Neither of those nerves innervates a single hip flexor. The VMO and other knee extensors and hip flexors are innervated by the femoral nerve. This has 2 implications: In order to produce a contraction in the adductor magnus and the VMO, stimulation must travel via 2 different neural pathways, and because the femoral nerve innervates all the muscles of the quadriceps group it is unlikely to stimulate 1 muscle (ie, the VMO) over another (ie, the VL) in the same muscle group.

Based on the average EMG values calculated during our study, we suggest that the VMO was not preferentially stimulated. We calculated VMO:VL ratios to determine whether a shifting of responsibility had occurred from one muscle to the other. We observed no significant difference, suggesting that no shifting had occurred. This can be explained through the lack of significant difference for the VMO and VL EMG activity independently.

Further research is recommended to determine the effects of hip rotation on isotonic EMG activity in the VMO. We recommend using heavier weights during each condition to generate greater muscle activity. Because our study only included male subjects, another suggestion would be to use female subjects and determine the effects of hip rotation on subjects with greater Q angles.

Conclusions and Clinical Relevance

After injury or trauma, therapeutic exercises such as SLRs and knee extensions have been advocated to strengthen the quadriceps muscles. More recently the addition of hip lateral rotation has been theorized to preferentially strengthen the VMO. The reasoning behind this theory has not held up to scrutiny. We suggest from the results of this study that during the early stages of rehabilitation, preferential activation of the VMO or VL does not occur with respect to hip position or exercise. In addition, there was no difference between exercises in the VMO:VL ratio. Researchers suggest that if selective strengthening does not occur, then exercise should be used to strengthen the entire quadriceps group.

References


