The Influence of Knee Rotation on Electromyographic Activity of Medial and Lateral Heads of the Quadriceps Femoris Muscle during Isometric Knee Extension Effort

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Abstract. Background and Purpose: The purpose of this study was to determine the difference in the muscle activities of the Vastus Medialis Oblique (VMO), Vastus Medialis Longus (VML), Vastus Lateralis Oblique (VLO) and Vastus Lateralis Longus (VLL) with internally rotated, neutral, and externally rotated knee joint positions during isometric knee extension strength effort at 60° of knee flexion. Subjects: Seven healthy males, aged 24 to 34 years (29.3 ± 4.1), participated in this study. Methods: The subjects performed isometric knee extension with internally rotated, neutral, and externally rotated knee positions. Electromyographic (EMG) activity was detected using bipolar fine wire electrodes and was recorded from VMO, VML, VLO, VLL and the Adductor Magnus (AM). Results: The normalized integrated EMG (IEMG) of VMO, VML and AM were significantly greater in the internally rotated knee position than in the neutral knee position. The normalized IEMG of the VLO and VLL were not significantly different at each knee position. Discussion and Conclusion: VMO, VML and AM muscle activity may be altered by knee rotation position during isometric knee extension effort. Key words: Electromyography, Vastus Medialis Oblique, Knee rotation.

INTRODUCTION

Electromyographic (EMG) analysis of the quadriceps femoris has been studied1–4). At this time, the relationship of the activity of each portion of the quadriceps femoris with knee rotation has not been well studied5, 6). The quadriceps femoris does not contribute to knee rotation according to Cintra and Furlani5), but some researchers have stated that activity of the quadriceps femoris is influenced by various foot positions and is correlated with knee rotated postures during isometric knee extension.
effort. Müller\(^7\) stated that the Vastus Medialis (VM) rotated the tibia medially via the patellar ligament. However, Signorile et al.\(^6\) stated that activity of VM and the Vastus Lateralis (VL) in the neutral knee position was greater than that in the externally rotated or internally rotated knee position. There has been no agreement about the relationship between knee rotation position and activity of the quadriceps femoris.

The purpose of this study was to determine the difference in muscle activity of the Vastus Medialis Oblique (VMO)\(^8\)–\(^10\), Vastus Medialis Longus (VML), Vastus Lateralis Oblique (VLO)\(^8,\)\(^11\) and Vastus Lateralis Longus (VLL) with a maintained internally rotated, neutral, and externally rotated knee position during an isometric knee extension effort.

**METHODS**

**Subjects**

Seven healthy males participated in this study. None of them had a history of a knee joint disorder. The average age, body weight and height of the subjects were 29.3 ± 4.1 years, 72.2 ± 11.3 kg, 174.0 ± 5.8 cm respectively. In all subjects, the right lower extremity was used for testing. Each subject signed a statement of informed consent prior to participation in this study.

**Testing procedure**

EMG activity was detected using bipolar Teflon coated stainless steel fine wire electrodes (AM Systems, USA). The diameter of the electrode was 75 μm. The coating of the electrode was bared about 2 mm from the tip. The distance between the two electrode tips was five millimeters. The fine wire electrodes were inserted into VMO, VML, VLO, VLL and AM using a 23-gauge guide needle. A common reference electrode was placed on the trochanter subcutaneously. The electrode placement for VMO, VML, VLO and VLL was done as described by Weinstabl et al.\(^8\). The fine wire for AM which provided an attachment for VMO\(^7\)–\(^10\) was inserted midway between the medial femoral epicondyle and the pubic tubercle\(^12\).

Each subject was secured on a chair with a belt across the trunk and thigh. The hip and knee were stabilized at 80° and 60° of flexion respectively. The ankle was stabilized at 0° with an ankle-foot-orthosis. Since knee extension torque is greatest at approximately 60° of knee flexion\(^13\)–\(^16\), we decided on it as the test angle. As shown in Fig. 1, rotation of the knee was passively carried out until the terminal range of knee rotation was produced using a gum band. This rotation allowed positioning prior to isometric testing.

First, an isometric maximal voluntary contraction (IMVC) during knee extension effort for three seconds duration was performed in the neutral knee position, and the force and EMG were recorded. Next, ramp contraction was randomly performed in each knee position, and EMG was recorded. Maximum intensity of ramp contraction was based on the IMVC of the neutral knee position (100% IMVC). The subject was asked to extend his knee joint steadily, increasing quadriceps effort from 0 to 80% IMVC for five seconds duration in each knee position while watching muscle activity feedback on a TV monitor showing a target line from 0 to 80% IMVC using a color string. A two-minute interval was recorded for each trial.

The EMG signals were amplified with a multichannel differential amplifier (BIOTOP, NEC San-ai, Tokyo). The data were recorded on a data recorder (SR-90, TEAC, Tokyo). At the same time, the EMG activities were monitored with a pen...
recorder (8K26, NEC San-ei, Tokyo). Knee extension force was measured by a tension meter (GT-30, OG GIKEN, Okayama) and was recorded on a data recorder.

**Data analysis**

The EMG signals were digitized at a 2500 Hz sampling frequency. EMG analysis, for the ramp contraction, was performed on after 250 msec of EMG signal corresponding to the following force levels: 10, 20, 30, 40, 50, 60, 70% IMVC. Then, the EMG signals for 250 msec were filtered with a bandwidth of 10–1000 Hz, and integrated (IEMG). The EMG signals were processed by EMG analysis software (KISSEI COMTEC, Tokyo). The IEMG value for each muscle was normalized to the maximum contraction of knee extension effort in the neutral knee position. The purpose of data normalization was to allow comparison of EMG activity at each knee position. Further, we compared the EMG activities of VM and VL using normalized IEMG and VM:VL ratios. The knee extension torque was calculated by multiplying individual knee extension force by the muscle’s moment arm length being the distance from the lateral joint gaposis of the knee to the force sensor of the tension meter.

A one-way analysis of variance test was used for the analysis of the knee extension torque. A two-way analysis of variance test (knee positions × force levels) was used to detect significant differences of IEMG values. Fisher’s PLSD post hoc test was used to identify significant comparisons. The accepted alpha level of all statistical processing was the 0.05 level. The Stat View statistical package (Abacus Concepts, Inc., Berkeley, CA, 1996.) was used for these analyses.

<table>
<thead>
<tr>
<th>Knee position</th>
<th>Knee extension torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>154.3 ± 41.4</td>
</tr>
<tr>
<td>Ext.R</td>
<td>141.3 ± 43.9</td>
</tr>
<tr>
<td>Int.R</td>
<td>127.6 ± 26.8</td>
</tr>
</tbody>
</table>


## RESULTS

**Torque**

The average and standard deviation of knee extension torque in each knee position during isometric maximal voluntary contraction are shown in Table 1. The knee extension torque in the neutral knee position tended to be greater than that of the other knee positions. However, results of a one way analysis of variance test revealed that the main effect of the knee extension torque was not significantly different among the knee positions (F(2, 18)=0.860).

**Normalized IEMG**

The average and standard deviation from 0 to 70% IMVC of normalized IEMG for each muscle in each knee position during ramp contraction are shown in Table 2. Results of a two way analysis of variance test revealed that there was no interaction between knee position and force level. The main effect of the knee rotation was as follows: VMO: F(2, 126)=4.472, p<0.05; VML: F(2, 126)=4.202, p<0.05; VLO: F(2, 126)=2.946, p<0.05; and VLL: F(2, 126)=0.099. Also the main effect of the force level was: VMO: F(2, 126)=38.778, p<0.05; VML: F(2, 126)=30.424, p<0.05; VLO: F(2, 126)=50.812, p<0.05; and VLL: F(2, 126)=31.048, p<0.05. The

<table>
<thead>
<tr>
<th>Knee position</th>
<th>VMO</th>
<th>VML</th>
<th>VLO</th>
<th>VLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>47 ± 29**</td>
<td>53 ± 29**</td>
<td>43 ± 24</td>
<td>46 ± 24</td>
</tr>
<tr>
<td>Ext.R</td>
<td>48 ± 26**</td>
<td>55 ± 27**</td>
<td>37 ± 18</td>
<td>46 ± 21</td>
</tr>
<tr>
<td>Int.R</td>
<td>62 ± 35**</td>
<td>68 ± 35**</td>
<td>48 ± 27</td>
<td>47 ± 24</td>
</tr>
</tbody>
</table>

NR = neutral knee position, Ext.R = externally rotated knee position, Int.R = internally rotated knee position. **p<0.01.
post hoc test revealed that the normalized IEMG of VMO and VML in the internally rotated knee position was significantly greater than that in the neutral knee position (p<0.01) and that the normalized EMG of VMO and VML in the externally rotated knee position was not significantly different from that in the neutral knee position. Also the normalized IEMG of VLO and VLL was not significantly different among the knee positions.

VM:VL ratio

Average and standard deviation from 0 to 70% IMVC of VM:VL ratio in each knee position during ramp contraction are indicated in Table 3. Results of a two way analysis of variance test revealed that there was no interaction between knee position and force level. The main effect of VM:VL ratio were as follows: VMO:VLO ratio: F(2, 126)=4.770, p<0.05; VMO:VLL ratio: F(2, 126)=3.663, p<0.05; VML:VLO ratio: F(2, 126)=2.743; and VML:VLL ratio: F(2, 126)=4.616, p<0.05. Also the main effect of the force levels were: VMO:VLO ratio: F(2, 126)=0.508; VMO:VLL ratio: F(2, 126)=0.474; VML:VLO ratio: F(2, 126)=0.479; and VML:VLL ratio: F(2, 126)=0.464. The post hoc test revealed that the normalized IEMG of the AM in the internally rotated knee position was significantly greater than in the neutral knee position (p<0.05), but that of the AM between external and neutral knee positions was not significantly different.

AM activity

The average and standard deviation from 0 to 70% IMVC of normalized IEMG of AM in each knee position during ramp contraction are shown in Table 4. Results of a two way analysis of variance test revealed that there was no interaction between knee position and force level, but the main effect of the knee position showed a significant difference (F(2, 126)=4.472, p<0.05). Also the main effect of the force level showed a significant difference (F(2, 126)=38.778, p<0.05). The post hoc test revealed that the normalized IEMG of the AM in the internally rotated knee position was significantly greater than in the neutral knee position (p<0.001), but that of the AM between external and neutral knee positions was not significantly different.

DISCUSSION

Signorile et al. stated that activity of VM and VL with knee extension effort in the neutral knee position was greater than that in other knee positions. Whetley and Jahnke stated that active external rotation of the knee produced the highest level of electrical activity in VM, while active internal rotation produced the highest level of activity in VL. Cerny stated that voluntary rotation of the knee with slight knee extension effort did not change the activity of VMO and VL. There have been no reports about EMG activity of the quadriceps femoris with isometric knee extension effort during passively maintained positions of the knee.

<table>
<thead>
<tr>
<th>Knee position</th>
<th>VMO:VLO</th>
<th>VMO:VLL</th>
<th>VML:VLO</th>
<th>VML:VLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>1.07 ± 0.33</td>
<td>1.10 ± 0.43</td>
<td>1.33 ± 0.71</td>
<td>1.26 ± 0.56</td>
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<tr>
<td>Ext.R</td>
<td>1.27 ± 0.67</td>
<td>1.13 ± 0.73</td>
<td>1.58 ± 0.88</td>
<td>1.24 ± 0.49</td>
</tr>
<tr>
<td>Int.R</td>
<td>1.44 ± 0.65</td>
<td>1.70 ± 1.46</td>
<td>1.67 ± 0.92</td>
<td>1.81 ± 1.56</td>
</tr>
</tbody>
</table>

NR = neutral knee position, Ext.R = externally rotated knee position, Int.R = internally rotated knee position, **p<0.01, *p<0.05.

<table>
<thead>
<tr>
<th>Knee position</th>
<th>AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>13 ± 8</td>
</tr>
<tr>
<td>Ext.R</td>
<td>10 ± 7 ***</td>
</tr>
<tr>
<td>Int.R</td>
<td>27 ± 18</td>
</tr>
</tbody>
</table>

NR = neutral knee position, Ext.R = externally rotated knee position, Int.R = internally rotated knee position, ***p<0.001.

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Table 3. Average and standard deviation from 0 to 70% IMVC of VM:VL ratio in each knee position during ramp contraction

Table 4. Average and standard deviation from 0 to 70% IMVC of normalized IEMG (%) of AM in each knee position during ramp contraction
foot coupled with knee rotation.

In our results, VMO:VLO, VMO:VLL and VML:VLL, in the internally rotated knee position were significantly greater than in the neutral knee position. In the externally rotated knee position, the ratios were not greater than in the neutral knee position. The cause of the difference between these VM:VL ratios among knee positions, with the normalized IEMG of VLO and VLL not being significantly different among knee positions, was that VMO and VML were significantly greater in the internally rotated knee positions. Knee extension exercise with an internally rotated knee position might activate VMO selectively compared with VL\textsuperscript{24}).

The attachment of VMO to AM could explain some of this study’s results. The origin of VMO is the medial condyle of the femur, vasto-adductor lamina\textsuperscript{8}, including AM, the Adductor Longus and the intermuscular septum. However, most of the origin for VMO is the vasto-adductor lamina\textsuperscript{10}). Hodges and Richardson\textsuperscript{22}) stated that the activity of VMO was closely related to the activity of AM, because the VMO:VL ratio increased with voluntary hip adduction effort. In our results, activity of VMO strongly correlated with the activity of AM, because activity of VMO and AM both increased with knee extension effort in the internally rotated knee position. Probably, in the internally rotated knee position, AM assists activation of VMO. The shortening and tension of AM may pull on and slightly elongate VMO, allowing a better length tension relationship for VMO during a knee extension effort. The AM may become activated during a knee extension effort as a stabilizer for the hip joint or may be needed as a stable attachment for strong VM activity.

**CONCLUSION**

We analyzed the activity of VMO, VML, VLO, VLL and AM with internally rotated, neutral, and externally rotated knee positions during isometric knee extension effort at 60° of knee flexion. The EMG activities of VMO, VML and AM were significantly greater in the internally rotated knee position than in the neutral knee position, but there were no significant differences in these muscle activations between the externally rotated and neutral knee positions.

**ACKNOWLEDGMENTS**

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