Quadriceps to Hamstrings Coactivation Ratios During Closed Chain, High Velocity Exercise in Healthy, Recreationally Active Adults

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Background
The anterior cruciate ligament (ACL) has been reported as one of the most commonly injured ligaments of the knee. A high incidence of ACL injuries are non-contact injuries that occur during high velocity, closed chain movements and quick changes in motion, such as accelerating, decelerating, cutting, and pivoting (Noyes & Barber-Westin, 2012). There is a paucity in the current literature regarding quadriceps to hamstrings (Q:H) coactivation ratios among exercises. In addition, a multivariate analysis to identify the effect of jump on peak EMG activation during closed chain, high velocity exercises. These exercises may be useful to prevent future knee injury by increasing the dynamic stability of the knee joint and its surrounding structures.

Research Questions
1. What are the Q:H coactivation ratios during closed chain, high velocity exercises including squat jump, barrier jump side to side, barrier jump front to back, scissor jump, and lateral bounding in recreationally active adults?
2. At what angle of knee flexion does the maximum EMG activity occur of the vastus lateralis (VL), medial hamstrings (MH), and biceps femoris (BF)?

Subjects
Convenience sampling was utilized to recruit 20 healthy recreationally active college students (12 men, 8 women) between the ages of 18-30 years old within the Department of Physical Therapy and Human Performance at Florida Gulf Coast University.

Methods
Collect MVC data of selected muscle groups utilizing bony surface EMG. Qualysis Motion Analysis markers placed on bony prominences of subjects. Subjects performed eight repetitions of five selected exercises. Coactivation ratios calculated from subjects data.

Data Analysis
1. ANOVA is identify differences in Q:H coactivation ratios among exercises. In addition a multivariate analysis was used to identify the effect of jump. These exercises may be useful to prevent future knee injury by increasing the dynamic stability of the knee joint and its surrounding structures.
2. ANOVA is identify differences in peak muscle activity for each of the four muscles during all five exercises. In addition, a multivariate analysis to identify the effect of jump on peak EMG activation.

Results
- Statistically significant differences (p<0.05) were found between the Q:H ratios of lateral bounding and the scissor jump and between lateral bounding and the squat jump.
- There was a statistically significant difference (p<0.05) in peak EMG: medial hamstrings activation during lateral bounding when compared to the other four exercises.
- There was a statistically significant difference (p<0.05) in peak EMG: biceps femoris activation for lateral bounding when compared to barrier jump front to side, scissor jump, and lateral jump.
- There was a statistically significant difference (p<0.05) between the flexion angle of the medial hamstrings compared to the other muscles. The peak EMG flexion angle (58.94˚) for the medial hamstrings was significantly larger than the biceps femoris, vastus lateralis.

Conclusion
- The barrier jump front to back, barrier jump side to side, and scissor jump facilitate earlier activation of the hamstrings in relation to the quadriceps suggesting that these exercises may provide the most stability to the posterior aspect of the knee, thus protecting the ACL.
- In contrast, lateral bounding facilitates earlier quadriceps activation and therefore should be used with caution in the early stages of ACL rehabilitation due to the anterior shear force placed on the ACL from the quadriceps.
- In conclusion, having knowledge of the Q:H ratios as well as the timing of peak muscle contraction allows for better exercise prescription and progression and could also be used by for injury prevention programs.

Clinical Relevance
This study identified exercises that facilitate hamstrings activation and stabilization, as well as exercises that should be used with caution during ACL rehabilitation. Clinicians can use the results of this study to guide their exercise prescription with the ACL rehabilitation and prevention population.

Table 1: Calculated Quadriceps:Hamstrings Coactivation Ratios for Each Pyrometric Exercise (Max = 2.525)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Value</th>
<th>P</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat Jump</td>
<td>1.873</td>
<td>0.025</td>
<td>0.025</td>
<td>1.823</td>
<td>1.923</td>
<td>1.069</td>
</tr>
<tr>
<td>Barrier Jump Side to Side</td>
<td>1.862</td>
<td>0.049</td>
<td>0.049</td>
<td>1.766</td>
<td>1.958</td>
<td>1.381</td>
</tr>
<tr>
<td>Barrier Jump Front to Back</td>
<td>1.826</td>
<td>0.025</td>
<td>0.025</td>
<td>1.776</td>
<td>1.876</td>
<td>1.358</td>
</tr>
<tr>
<td>Scissor Jump</td>
<td>1.773</td>
<td>0.049</td>
<td>0.049</td>
<td>1.678</td>
<td>1.868</td>
<td>1.123</td>
</tr>
<tr>
<td>Lateral Bounding</td>
<td>1.701</td>
<td>0.025</td>
<td>0.025</td>
<td>1.651</td>
<td>1.750</td>
<td>1.168</td>
</tr>
</tbody>
</table>

*Wilks’ Lambda = 0.013, p<0.001, partial η²=0.99*

Multivariate Tests
- Pillai’s Trace = 0.013, F(20, 196) = 1.437, p<0.001
- Roy’s Largest Root = 0.009, F(20, 196) = 1.896, p<0.001
- Hotelling’s Trace = 0.013, F(20, 196) = 1.283, p<0.001
- Wilks’ Lambda = 0.990, F(20, 196) = 1.283, p<0.001

Pairwise Comparisons
- Squat Jump vs Barrier Jump Side to Side: p<0.001
- Squat Jump vs Barrier Jump Front to Back: p<0.001
- Squat Jump vs Scissor Jump: p<0.001
- Squat Jump vs Lateral Bounding: p<0.001

Standardized Contrasts
- Null Hypothesis: The differences (equivalent to no adjustments).
- Alternative Hypothesis: There is a statistically significant difference.

The barrier jump front to back, barrier jump side to side, and scissor jump facilitate earlier activation of the hamstrings in relation to the quadriceps suggesting that these exercises may provide the most stability to the posterior aspect of the knee, thus protecting the ACL.