INTRODUCTION
Research has suggested that mono- and biarticular muscles have unique roles in producing movement (van Ingen Schenau 1989). It has been posited that monoarticular muscles act primarily as force generators, while biarticular muscles assist in 1) transferring energy between joints, and 2) directing external forces by distributing joint moments. The present study is a preliminary investigation of possible changes in the activation patterns of mono- and biarticular muscles during the learning of a novel one-legged cycling task. It was anticipated that the activation of the biarticular muscles, but not the monoarticular muscles, would transition from a general to a more specific pattern once the task is learned.

METHODS
Three male recreational cyclists participated in the study. Participants were required to practice one-legged cycling on a bicycle mounted on a computerized ergometer. Prior to the experiment, participants were instructed on the correct way to direct their applied pedal forces. At any given position in the crank cycle, the ideal direction of force application is perpendicular to the crank arm. The goal of the pedaling task was to minimize errors between the applied and ideal force directions. For reference, 0º (360º) represents the crank with the pedal at the highest position, 180º at the lowest position.

Each participant attended a single test session lasting about 90 min. A total of 15 training trials were performed, with an additional post-training trial completed 20 min after the 15th trial. Each trial consisted of a warm-up, followed by 1 min of one-legged cycling using the left leg. Data were collected for 5 s at the beginning, middle, and end of each training trial. A 5 min rest was provided between the trials. During each rest interval, participants were given visual and verbal feedback about their performance on the force-directing task.

Kinematic, kinetic, and electromyographic (EMG) data were collected. The kinematic data were sampled at 200 Hz; the kinetic and EMG data were sampled at 1000 Hz. Five digital cameras were used to collect three-dimensional kinematic data, with markers placed on the bicycle to yield the crank and pedal angles. Kinetic data were measured using a clip-in pedal instrumented with two load washers, mounted on the left crank arm of the bicycle (Caldwell et al. 1998). EMG data were collected via bipolar surface electrodes from 4 monoarticular [tibialis anterior (TA), soleus (SO), vastus lateralis (VL), and glutaeus maximus (GM)], and 3 biarticular [rectus femoris (RF), semitendinosus (ST), and gastrocnemius (GA)] muscles of the left leg.

To quantify the performance of the task, the root-mean-squared error (RMSE) between the direction of the applied force vector and the ideal force vector was calculated. EMG data were rectified, low-pass filtered at 10 Hz, and normalized to the crank cycle. Muscle activation times were then determined relative to crank position (0º – 360º).

RESULTS AND DISCUSSION
Following the practice trials, all participants showed an improvement in their force directing ability (Table 1). Muscle activation patterns changed in both mono- and biarticular muscles (Table 1), although it appears each participant used a unique strategy throughout the learning process (Figure 1).

SUMMARY
The present study provides evidence that participants were able to learn a novel one-legged cycling task, and that the timing of their muscular activations was altered. At this stage of learning, it seems that both mono- and biarticular muscles are involved in the learning process.

REFERENCES

Table 1. Changes in RMSE and muscle activation timing in mono- and biarticular muscles for all participants pre – post training.

<table>
<thead>
<tr>
<th>Participant</th>
<th>RMSE (%)A</th>
<th>Monoarticular Muscles</th>
<th>Biarticular Muscles</th>
<th>[Δ in timing (degrees)]B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>VL On/Off</td>
<td>TA On/Off</td>
<td>RF On/Off/ST On/Off</td>
</tr>
<tr>
<td>1</td>
<td>24.13</td>
<td>1/13</td>
<td>41/10</td>
<td>26/29/30</td>
</tr>
<tr>
<td>2</td>
<td>30.41</td>
<td>95/23</td>
<td>†/†</td>
<td>38/33/28/26</td>
</tr>
<tr>
<td>3</td>
<td>20.87</td>
<td>18/21</td>
<td>127/1</td>
<td>12/25/64/2</td>
</tr>
</tbody>
</table>

APercent improvement in RMSE (between the applied and ideal force directions).
BAbsolute change in muscle activation timing, based on the angular position of the crank arm; †corrupt data.