INTRODUCTION
Cerebral palsy (CP) is caused by an injury to the brain and causes problems with movement and coordination due to impaired voluntary motor control. Past research has shown that muscle activity during human movement can be described by a small set of weighted simultaneous muscle activations known as synergies. Synergies are estimated by measuring muscle activations with electromyography (EMG) and using algorithms, such as non-negative matrix factorization (NMF), to identify muscles that are consistently activated together [1]. Applying these techniques to patients with CP has shown that fewer synergies are required to describe muscle activity during gait than unimpaired individuals [2]. However, it remains unclear if current treatments to improve movement for individuals with CP alter neuromuscular control or synergies. Botulinum toxin type A (BTA) is a common treatment for individuals with CP and aims is to improve mobility by reducing muscle spasticity and normalizing gait kinematics. The purpose of this study was to evaluate whether synergies change after BTA treatment. Secondly, we sought to determine if positive changes in gait kinematics are correlated with changes synergies.

METHODS
EMG from 8 lower limb muscles and motional analysis data for five children (age: 7.5±1.8 yrs; height: 114.8 ± 19.3 cm; mass: 20.86 ± 9.53 kg) with CP were analyzed both before and after BTA treatment. Two patients were treated with BTA in the left leg and three patients were treated in both limbs. Post treatment measurements were taken between 6 and 10 weeks after BTA injection (when BTA is no longer active). Treated muscles varied by patient and were determined by a physiatrist.

Synergies were calculated using NNMF for 1 to 5 synergies. This algorithm determines the weighted groups of muscles that can describe the greatest variance in muscle activity for a given number of synergies. To evaluate changes in synergies after treatment, a summary measure, the dynamic motor control index (Walk DMC), was calculated as the average difference from 1 of the total variance accounted for by 1 to 5 synergies [2]. Smaller values of Walk DMC thus indicate a simplified control strategy where fewer synergies are required to describe variance in muscle activity. Sagittal plane-kinematics were evaluated at the hip, knee, and ankle and compared to unimpaired gait data. Joint angles that more closely matched unimpaired joint angles after treatment were taken as positive changes in kinematics.

Table 1: Correlation between changes in Walk DMC and joint kinematics for right and left limbs.

<table>
<thead>
<tr>
<th>Limb</th>
<th>Hip</th>
<th>Knee</th>
<th>Ankle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extension</td>
<td>Flexion</td>
<td>Extension</td>
</tr>
<tr>
<td>Right</td>
<td>0.783</td>
<td>0.568</td>
<td>0.489</td>
</tr>
<tr>
<td>Left</td>
<td>0.754</td>
<td>0.460</td>
<td>-0.486</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION
There were highly variable changes in Walk DMC between subjects, and even between subject limbs in this study (Figure 1). Subjects 1 and 5 demonstrated a decreased Walk DMC, compared to typically-developing children. Subjects 3 and 4 showed conflicting results between limbs and Subject 2 showed increased Walk DMC following BTA treatment. Furthermore, positive changes in walk DMC did not consistently correlate with positive changes in kinematics (Table 1). These results demonstrate that muscle activity does change after BTA, but the relationship between changes in neuromuscular control, muscle activity, and kinematics will require further investigation.

Figure 1: Change in Walk DMC before and after BTA injection for each subject.

CONCLUSIONS
Currently, improvements in movement after BTA are highly variable between patients [3]. In this preliminary study, changes in muscle activity, as evaluated by muscle synergies, were also highly variable. Although we did not find a consistent relationship between changes in synergies and kinematics, given the limited number of subjects and heterogeneity of individuals with CP, further investigation will be required to better understand changes in neuromuscular control and movement after BTA injection. Future studies will evaluate changes in synergies after BTA injection for a larger patient population from 4 weeks (when BTA is still active) to one year after treatment.

REFERENCES