IMPORTANCE OF PRESWING RECTUS FEMORIS ACTIVITY IN STIFF-KNEE GAIT

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INTRODUCTION

Stiff-knee gait, a common pathological walking pattern of persons with cerebral palsy, is characterized by reduced and delayed peak knee flexion during the swing phase of gait. This abnormality may lead to tripping or energy-inefficient compensatory movements due to inadequate toe clearance (Sutherland and Davids, 1993). The reduction in knee flexion has commonly been attributed to over-activity of the rectus femoris during swing phase (Perry, 1987). However, abnormal muscle activity during the stance phase, such as excessive force in vasti or rectus femoris, may decrease knee flexion velocity at toe off and limit knee flexion in swing (Goldberg et al., 2006).

Rectus femoris transfer surgery, which is intended to decrease the muscle's knee extension moment while preserving its hip flexion moment, is a common treatment for stiff-knee gait. It is generally indicated when a patient exhibits abnormal rectus femoris excitation during swing phase. However, if stance phase factors also inhibit knee flexion, excessive excitation of rectus femoris during preswing may also be an important indication for rectus femoris transfer surgery. The purpose of this study was to evaluate the relative importance of preswing rectus femoris activity to peak knee flexion in patients with stiff knee gait.

METHODS

We assessed the effects of rectus femoris activity during stance and swing by creating dynamic gait simulations of ten patients with cerebral palsy. These subjects, with an average age of 10.6 years, were each categorized as exhibiting stiff-knee gait in at least one limb by Goldberg et al. (2006). The gait analysis data were collected at Connecticut Children's Medical Center in Hartford, CT, as a routine part of treatment planning. No subject exhibited excessive knee extension moments or diminished hip flexion moments during swing (Goldberg et al., 2006). Most subjects displayed excessive knee extension moments during double support. A musculoskeletal model with 21 degrees-of-freedom and 92 muscle actuators was scaled to represent the size of each subject. Using computed muscle control (Thelen et al., 2003) we determined a set of muscle excitation patterns for each subject that produced kinematics similar to the subject's measured motions when used to drive a forward dynamic simulation. The computed excitation patterns were generally consistent with each subject's measured EMG data. Forward dynamic simulations were performed for the period of preswing through peak knee flexion.

To investigate the relative contribution of rectus femoris activity during preswing and swing on knee flexion, two more simulations were created for each patient; one in which rectus femoris excitation was eliminated during preswing only, and a second in which rectus femoris excitation was eliminated during swing only (Fig. 1). Preswing was defined to be a time period before toe-off equal in length to early swing. Early swing was defined to be the period of gait from toe-off to peak knee flexion. The difference in amount of peak knee flexion

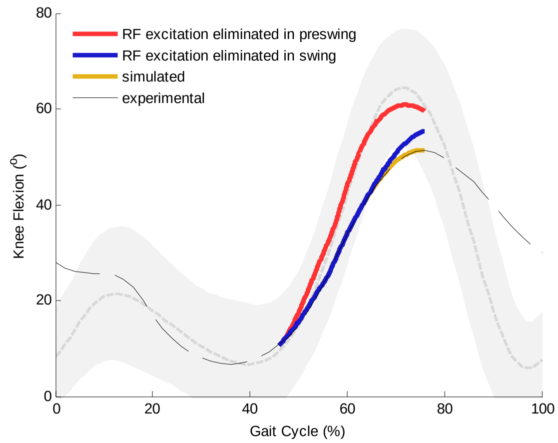

Figure 1: Simulated knee flexion angles when rectus femoris excitation was eliminated during different phases. Shaded region represents normal knee flexion ± 2 SD.

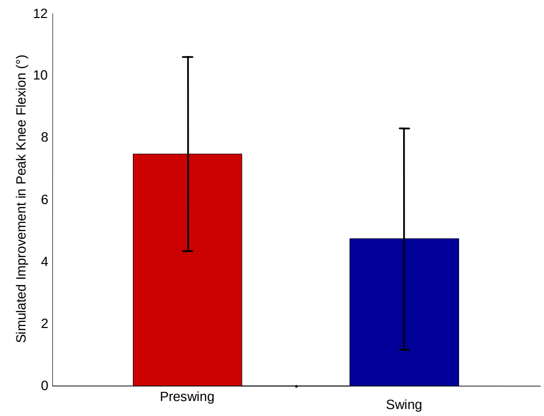

Figure 2: Average simulated improvement in peak knee flexion among all 10 subjects when rectus femoris excitation was eliminated in preswing or swing. Error bars signify ± 1 SD.

improvement between the two cases was compared for each patient.

RESULTS AND DISCUSSION

Simulated improvement in peak knee flexion when rectus femoris excitations were eliminated during preswing was greater than that when rectus femoris excitations were eliminated during early swing in eight out of ten subjects. Using a paired t-test ($p<0.05$), the amount of peak knee flexion improvement attained by eliminating rectus femoris excitations during preswing was significantly greater than the amount of peak knee flexion improvement attained by eliminating rectus femoris excitations during swing (Fig. 2). This result suggests that rectus femoris activity during preswing may have greater influence on peak knee flexion than rectus femoris activity during early swing in some patients with stiff-knee gait. In evaluating the causes of stiff-knee gait, one should examine rectus femoris EMG in preswing as well as early swing (before peak flexion is attained) for abnormal activity.

Dynamic simulations allow one to evaluate the changes in body motions caused by alterations in the timing of muscle activity. This provides a valuable tool for assessing and investigating the mechanisms leading to improvements in some patients following treatment for stiff knee gait. Our future work will focus on simulating the postoperative gait of subjects with good and poor surgical outcomes to determine why some subjects have a dramatic improvement with treatment while others improve very little or get worse.

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