ELECTRICAL STIMULATION OF THE SEMITENDINOSUS DURING TERMINAL SWING INCREASES KNEE FLEXION EXCURSION DURING EARLY STANCE

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INTRODUCTION

Tight hamstrings are often implicated and targeted for treatment in children who exhibit crouch gait, a gait disorder characterized by excessive hip and knee flexion during stance. Computer simulations have provided insights into the biomechanical influence that the hamstrings have on lower extremity motion during gait [1-3], but must be validated before they can be used for guiding treatment strategies. Electrical stimulation protocols have recently been introduced to test model predictions under tightly controlled conditions [4-5]. In this study, we synchronized electrical stimulation to a gait cycle to measure medial hamstring (ST, the semitendinosus) function during walking. We tested the hypothesis that ST stimulation introduced during terminal swing would increase knee flexion in early stance. We also evaluated the influence that hamstring stimulation had on hip flexion to better understand coupling between the joints.

METHODS

Eight healthy young adults (30±6y, 1.76±0.07m, 77±22kg) participated. Subjects performed 90s walking trials on a split-belt instrumented treadmill at a preferred speed. A real-time controller monitored the subject's heel strike times. This information was used to deliver short-duration electrical stimuli starting at either 90% (terminal swing) or 0% (early stance) of the gait cycle. The ST muscle was stimulated in approximately 10 randomly selected strides per trial. An individual stimulus consisted of four 300µs current (≤50mA) pulses delivered over 90 ms via surface electrodes.

EMG signals were recorded and used to determine the onset of stimulation. Whole body kinematics were simultaneously recorded using a passive motion capture system, and used to compute three dimensional lower extremity joint angles. The stimulation-induced movement was defined as the change in the joint flexion excursion (that starts in terminal swing and ends prior to mid-stance) of the stimulated strides relative to the previous, non-stimulated strides (Fig. 1). These changes were compared between the two stimulus times via paired t-tests.

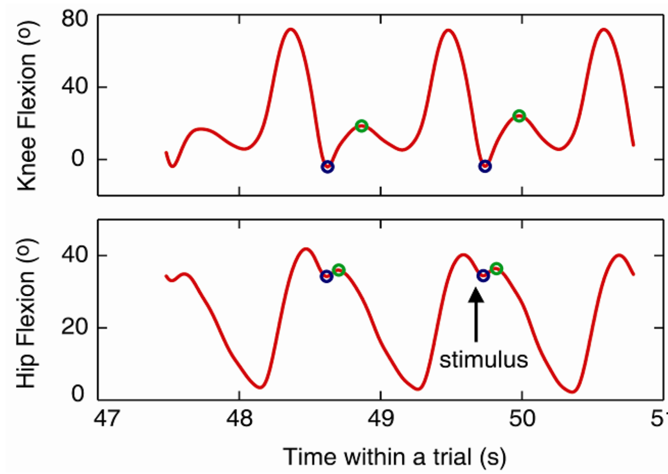

Figure 1: Knee and hip flexion excursions during the late swing-to-early stance transition. **o** = low value and **o** = high value of joint flexions.

RESULTS

Increases in knee flexion excursion (due to increased flexion following the stimulus) averaged 3° across subjects when the stimulus was introduced during terminal swing, compared to 1° when the stimulus was introduced during early stance. The hip flexion excursion changes averaged 0° across subjects for stimulation applied during terminal swing or early stance. Two subjects displayed a small yet significant reduction in hip flexion excursion for stimulation during terminal swing. In these two subjects, the changes in knee flexion excursion were not significantly different from the non-stimulated trials.

DISCUSSION

A computer model of our experimental paradigm predicts that early stance knee flexion should increase as a result of hamstring stimulation, more so if the stimulus is applied during terminal swing than at heel contact. This prediction is generally consistent with our measurements. The gait model also suggests that the influence of hamstring stimulation on hip flexion should be smaller than at the knee. This is also generally consistent with our experiments, in that we could not detect a difference in average hip flexion for 5 of the 7 subjects. However, two subjects did exhibit increased hip extension during stance. Interestingly, these same subjects did not exhibit a significant change in knee flexion as a result of stimulation. These results suggest that hip extension may be induced when the knee trajectory is constrained, perhaps as a result of joint stiffenss due to action of other muscles. Such observations may be important to consider when using models to investigate the gait of individuals with pathologies, who often exhibit abnormal joint stiffness.

We conclude that stimulating the hamstrings during terminal swing can induce knee flexion during stance, but that the magnitude is variable between subjects and seems coupled to the muscle's function at the hip.

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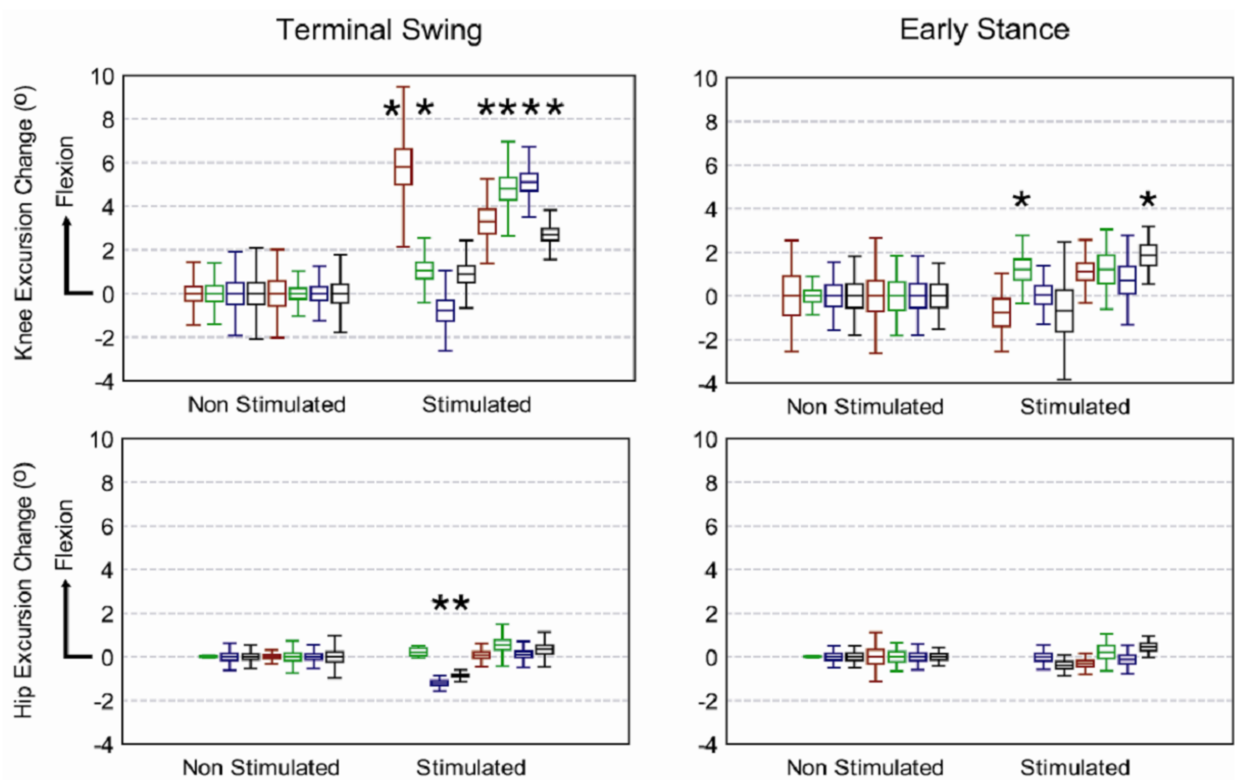

Figure 2: Experimental (stimulated) and predicted knee and hip angle excursion changes relative to non-stimulated strides. The excursions of non-stimulated strides have been zeroed as they represent a baseline level for the comparison of the means. ⋆= statistically significant result, ◊ = change predicted by the simulation.