HAMSTRING CONTRIBUTIONS TO KNEE MOTION DURING TERMINAL SWING IN CROUCH GAIT

Jennifer R. Yong, Katherine Steele, Jennifer L. Hicks, Michael S. Schwartz, Scott L. Delp

1Stanford University, Stanford, CA, USA
2Gillette Children’s Specialty Healthcare, St. Paul, MN, USA
email: jryong@stanford.edu

INTRODUCTION

Crouch gait, a gait abnormality characterized by excessive knee flexion during stance, is common in patients with cerebral palsy. Over-activity of the hamstrings during terminal swing is often implicated as a cause of this gait pathology. If an individual is unable to fully extend the knee before foot strike, he or she may not have the strength to extend the knee during stance and will remain in a crouched posture. One current treatment for crouch gait is surgical lengthening of the hamstrings, but this procedure does not always result in improved knee extension. A previous study showed that the hamstrings generate small contributions to knee angular accelerations during terminal swing of normal gait [1]. The goal of this study was to determine if a crouched posture changes the contribution of the hamstrings to knee motion and to evaluate whether the hamstrings contribute substantially to knee flexion accelerations during the terminal swing phase of crouch gait.

METHODS

Previously reported averaged joint kinematics data of subjects walking in a normal gait (N=83) and in mild (N=89), moderate (N=127) and severe (N=100) crouch gait from Gillette Children’s Specialty Healthcare was used to represent typical body positions [2]. Swing phase was assumed to occur during 60 – 100% of the gait cycle. The kinematics data was used to position a musculoskeletal model with 19 degrees of freedom and 92 musculotendon actuators [3] (Fig. 1). We used an induced acceleration analysis to calculate the angular acceleration of the knee generated by 1 N of force in each of the musculotendon actuators. The acceleration generated per newton of force is referred to as the muscle’s potential [4].

The angular acceleration of the knee was calculated for each gait pattern by double differentiating measured knee angle data. The swing phase was divided into an extension phase, when the knee experiences extension accelerations, and a subsequent braking phase, when the knee undergoes flexion accelerations [1]. For the purposes of this study, we defined terminal swing as the braking phase. The muscles’ potentials were averaged over terminal swing. The primary contributors to knee flexion and extension accelerations on the swing limb were identified and compared to the potentials of the hamstrings for each of the different gait patterns.

RESULTS AND DISCUSSION

We found that the transition to the braking phase of swing occurs later with more severe crouch. In normal gait, the braking phase of the right knee begins at 83% of the gait cycle, whereas it begins at...
89%, 91% and 93% for mild, moderate and severe crouch gait respectively.

The medial hamstring muscles (semimembranosus and semitendinosus) had the potential to generate flexion accelerations at the knee during terminal swing (Fig. 2). For the semitendinosus, the magnitude of the flexion potential increased with increasing crouch severity. For the semimembranosus, we observed the opposite pattern. However, these discrepancies are small since the potentials all have magnitudes between 0.6 and 2.4°/s²/N. In contrast, the biceps femoris long head, a lateral hamstring muscle, had a knee extension potential during terminal swing. The magnitude of these extension potentials decreased with the severity of crouch. Hamstring potentials are somewhat dependent on how degrees of freedom between the pelvis and the torso are modeled; however, the medial hamstrings consistently exhibit a greater knee flexion potential than the biceps femoris long head.

Although the medial hamstrings had flexion potentials in a crouch gait, the magnitudes of the potentials were small relative to other lower extremity muscles (not shown), as has been demonstrated for normal gait [1]. For example, the sartorius muscle, a hip and knee flexor, exhibited the greatest knee flexion potential with values that were an order of magnitude greater than the hamstrings during normal and crouch gait. The range of potentials for the sartorius muscle during terminal swing was 20 – 27°/s²/N. Extension potentials by the vasti muscles were also significantly greater in magnitude. The vasti muscles had extension potentials ranging from 22°/s²/N during terminal swing in severe crouch to 43°/s²/N during normal gait. Thus, although we only calculated the potentials of the lower extremity muscles and not the forces they generated, our results suggest that the hamstrings have a minimal effect on angular knee motion during the terminal swing of crouch gait.

CONCLUSIONS

Subjects walking in an increasingly severe crouch gait exhibited an increasingly delayed braking phase during swing. Individuals walking in a crouch gait experience a reduced range of motion and reduced knee extension accelerations during swing, and therefore do not require as much time to slow the angular velocity of their knee before foot strike. The medial hamstrings had flexion potentials during terminal swing, while the lateral biceps femoris long head had extension potentials. This suggests that during corrective surgery, focusing on the medial hamstrings may result in greater improvements in knee kinematics during swing. Although body position affects the hamstrings’ ability to contribute to knee angle accelerations, potentials during crouch gait are similar to normal gait. Even in crouched postures, the hamstrings appear to be relatively small contributors to knee motion and would require significant force generation to produce excessive knee flexion in terminal swing. While overactive hamstring muscles may contribute through other mechanisms, such as their ability to decelerate the leg, a crucial next step is identifying how other muscles with larger potentials affect angular knee motion and may potentially contribute to crouch gait.

REFERENCES