KINEMATIC AND KINETIC ANALYSIS OF A BIARTICULAR CLUTCHED SPRING PROsthesis

INTRODUCTION

In lower-limb amputees, the loss of function of the biarticular GAS muscle is associated with elevated activation of knee and hip flexors as well as decreased ankle push-off power. These differences can lead to secondary conditions such as back pain and knee pain [1]. No current prostheses have a biarticular component to replicate the functional role of the GAS. To help improve amputee gait we have developed a foot-ankle prosthesis with a clutched spring that spans both the knee and ankle joints. We hypothesize that this spring element can partially emulate GAS function and reduce gait compensations to improve amputee walking.

METHODS

The biarticular prosthesis (BP) is shown in Figure 1. With IRB approval, data was collected and analyzed for one amputee subject, female age 54, wearing the BP. Vicon motion capture data along with ground reaction forces, BP spring force, and pylon data (from iPecs) were recorded during bouts of treadmill walking. EMG signals were also collected for major gait muscles of the lower limb. The subject first walked on their prescribed prosthesis, then the BP with various spring conditions: off mode (spring disconnected), recoil spring only, then 1.8 N/mm, 3.7 N/mm, and 10.5 N/mm springs attached respectively. Finally, we collected data using the subject’s preferred spring configuration, while providing them with biofeedback via a real-time plot of the BP spring force. Subjects were instructed to try to maximize the spring force peak as they walked. The subject presented here chose the stiffest spring for the feedback condition.

OpenSim [2] was used to analyze the kinematics and kinetics of the collected data. We developed an amputee musculoskeletal model based on the full body model from Rajagopal et al. [3]. Mass and inertial properties of the residual limb/prosthesis were modified to match typical amputees [4,5], and the residual limb was scaled based on the socket to pylon length. The model was scaled to the subject, then inverse kinematics and inverse dynamics were performed with the spring force applied to the model as an external force.

RESULTS AND DISCUSSION

The inverse kinematics results show that as the BP spring stiffness increased, knee extension in late stance decreased. Additionally, the BP had a substantial effect on the knee moment of the affected limb (Fig. 2). The BP pulls the knee toward flexion, particularly in mid and late stance (40-60% of gait cycle), and this flexion moment increases in magnitude as the BP spring stiffness increases. However, the net knee flexion moment is smaller in magnitude at the higher spring stiffness, which is likely due to kinematic deviations. As the BP spring stiffness increased, the BP contribution to net ankle moment increased, but overall the BP ankle contributions were relatively small (< 0.2 Nm/kg).

Data for 6 additional subjects is currently being collected to further understand the effects of the BP on amputee gait and the impacts of feedback training. Understanding how mimicking the biarticular action of the GAS can enhance prosthetic function and will inform future design device.

REFERENCES