INTRODUCTION

Recent research has focused on the design of intelligent prosthetic ankle devices with the goal of adapting the behavior of the device to accommodate all walking surfaces that an individual encounters in daily life. One surface that is particularly difficult for persons with transtibial amputation (TTA) is uneven ground. Patients with TTA have an increased frequency of falling on uneven ground [1], possibly because of limited ankle joint mobility on the prosthetic side, and lack of distal muscles and sensory feedback from the lower limb [2].

The BiOM (iWalk, Cambridge, MA) is an ankle/foot prosthesis that claims to provide active power during the stance phase while accommodating for real time terrain changes [3]. Unlike a passive device, it may not always provide exactly the same response to loading, which may lead users to adopt a more cautious strategy. As such, a passive device may be preferable when encountering novel surfaces. The purpose of this study was to determine if individuals with transtibial amputation altered their gait kinematics when wearing the BiOM ankle prosthesis compared to a passive energy storage and return (ESR) prosthesis when walking on a loose rock surface.

METHODS

11 young adults (10 male, 1 female) with traumatic unilateral transtibial amputation participated. Subjects came to the lab for two separate data collections. During the first session, they wore their clinically prescribed ESR prosthesis. After this session, they were given the powered BiOM prosthesis and provided a three week acclimation period. They then returned for a second session while wearing the BiOM.

During each session, subjects walked over a loose rock surface, previously described in [4,5]. Kinematic data from 57 reflective markers were used to track full body kinematics at 120 Hz using a 26-camera motion capture system (Motion Analysis, Santa Rosa, CA). Walking speeds were normalized to each subject’s leg length, l, according to the Froude number, \( F_n \). Subjects walked at three controlled speeds \( (F_n = 0.10, 0.16, 0.23) \) and their self-selected walking velocity (SSWV). A total of five left and five right strides were collected at each speed. All subjects wore their own athletic shoes during data collection.

Comparisons of SSWV were made using paired t-test. Comparison of all other dependent measures were made using repeated measures ANOVAs with prosthetic type (BiOM, ESR), walking speed (1-3, SSWV), and limb (prosthetic, intact) as fixed factors.

RESULTS AND DISCUSSION

Patients had a 10% higher SSWV wearing the powered BiOM than an energy-storage and return (ESR) prosthesis (ESR: 1.05 ± 0.17, BiOM: 1.16 ± 0.018 m/s, \( p = 0.031 \); Fig. 1A). There were no differences in step width (\( p = 0.686 \)) or step length (\( p = 0.058 \)) between prostheses. A significant Limb × Prosthesis interaction indicated that the difference between the limbs was slightly greater when patients used the ESR compared to the BiOM (\( p = 0.039 \); Fig. 1B).

There were several significant differences in the patient’s kinematics when wearing the different devices (Fig. 2). Patients exhibited increased ankle plantarflexion throughout the gait cycle when wearing the BiOM compared to the ESR prosthesis. Specifically, patients increased ankle plantarflexion...
during early stance, and push-off, and decreased ankle dorsiflexion during late stance and swing (p < 0.025). The increased plantarflexion at push-off occurred only on the prosthetic limb (p_{\text{Limb} \times \text{Prosthesis}} = 0.002). Patients also exhibited a small, but significant, decrease in knee flexion during early stance with the BiOM (p = 0.047; Fig. 2).

Changes with walking speed were similar to those reported previously in patients with transtibial amputation walking with ESR prostheses [5]. There were no Prosthesis × Speed interaction effects, indicating that the patients responded similarly to changes in speed when walking in either prosthesis.

CONCLUSIONS

The patients with transtibial amputations in this study were able to successfully traverse the rock surface in both prostheses tested. Patients walked with similar step width in both devices. They also increased their SSWV while using the BiOM. Together, these results suggest that patients did not adopt a more cautious strategy while using the BiOM. When wearing the BiOM, patients exhibited ankle plantarflexion during push-off, similar to that of healthy controls (Fig. 2). The change in ankle kinematics did not result in any changes in hip or knee kinematics between devices, however.

REFERENCES


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