Author
Bhatti, Jawaad (Basingstoke UK) | PhD
Blatchford - New Product Development

Title
Prototype powered ankle prosthesis improves biomechanical outcomes for trans-tibial amputees

Coauthors
McGrath M, Calligaris M, McGuigan P, Seminati E, Iravani P, Zahedi S, Moser D

Summary
A prototype powered ankle prosthesis was fitted to a cohort of trans-tibial amputees. Gait analysis was used to measure the biomechanical effects when external power was applied at specific points in the gait cycle. Powered movement increased prosthetic toe clearance and reduced sound limb loading.

Introduction
Conventional prosthetic feet/ankles are passive in mechanical terms and, as a consequence, they are unable to completely mimic the biological performance of the biological ankle joint. In recent years, powered ankle prostheses have been developed as a way of restoring propulsive push-off to amputees' gait. Many studies have suggested that the application of external power reduces the metabolic cost of transport [1,2] and decreases the dependence on the sound limb [3]. A prototype powered ankle prosthesis has been developed using additive manufacture techniques and novel powering algorithms [4,5]. This study provides a biomechanical assessment of the effects of power application by this device, with a focus on identifying clinical patient benefits.

Methods
Six trans-tibial amputees underwent gait analysis. A 3D motion analysis system was used to capture kinematic data and two force plates recorded kinetic data. Measurements were taken on level ground, at three different walking speeds, and when ascending and descending a 5° slope. A minimum of six clean trials were collected for each participant, for each testing condition. This protocol was performed twice: once with no external power and once with power applied. Each participant completed these tasks, in each testing condition, in a randomised

order. In addition to the conventional marker model, extra virtual markers were defined on the inferior, distal tip of the feet. These virtual markers were created so that the ground clearance during swing phase could be tracked.

Results

The application of power altered the kinematic behaviour of the prosthetic ankle closer to that of the sound ankle. In terminal stance, the ankle moved to plantarflexion, before returning to dorsiflexion during swing phase (Figure 1, top left). By contrast, without power the ankle remained in dorsiflexion. The propulsive effects of power were clear in the peak ankle power generation in terminal stance phase which increased by between 83% (fast walking) and 152% (slow walking) compared to the unpowered condition.

Minimum toe clearance on the prosthetic limb was increased when power was applied by up to 41% on level ground (slow walking), 18% when walking uphill and 27% when walking downhill.

Powering also affected the sound limb. The first peak of the vertical ground reaction force component was reduced by approximately 8% and peak knee extension moment on the sound limb reduced by approximately 20%.

All observations were consistent across all walking speeds and terrains.

Conclusion

The findings of this preliminary study highlight the clinical benefits of this prototype powered ankle prosthesis. The power helps to provide propulsion and lifts the ‘toes’ during swing phase, which leads to improved ground clearance. This reduces the likelihood of tripping and, consequently, the likelihood of falling. Furthermore, amputees are prone to kinetic asymmetry during walking so a reduction in forces on sound limb indicates an improvement in the inter-limb distribution in body-weight support. This might help to reduce the incidence of degenerative bone and joint problems in the sound limb of these users.

References

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