

Kinematic and biomimetic assessment of a hydraulic ankle-foot in level ground and camber walking

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Summary

The biomechanical effects of a hydraulic ankle, compared to a rigidly-attached foot, were measured during level walking at normal and fast speed and during cambered walking. The hydraulic ankle showed improved inter-limb symmetry and produced joint moments closer to those of able-bodied control subjects.

Method

Components: Echelon, Esprit

Measurements: 3D gait analysis on a level walkway and a 2.5° cambered walkway and a feedback questionnaire.

Subjects: Five active unilateral, trans-femoral amputees (42.4±15.7years, 107.4±12.1kg) and 12 non-amputee subjects (5 male, 7 female; 26±2 years; 68±15kg)

Data collection protocol: Each of the amputees used a fixed ankle or a passive hydraulic ankle with their habitual prosthetic knee. 3D gait analysis recorded kinematic and kinetic data as the subjects walked at normal and fast speeds on a level surface. They also walked on a surface with a 2.5° camber. Trials were recorded with the prosthetic foot higher up the slope and with the sound foot higher up the slope. The control subjects also performed these tests. The amputees were also asked to complete a feedback questionnaire.

Analysis: Trend Symmetry Indices (TSI) were calculated for symmetry between prosthetic and sound limbs and for 'normalcy' (compared to control subjects). Repeated measures two-way ANOVA tests were performed for walking condition and for prosthetic foot. Post-hoc analyses were conducted with post-hoc Tukey tests.

Results

The amputees walked with significantly longer strides when using the Echelon ($p=0.026$) and at faster walking speeds, although this parameter was not statistically significant. Significant differences were found between the prosthetic ankle moments of the hydraulic and fixed devices, in both symmetry and normalcy TSI ($p<0.001$ in two TSI parameters), where the Echelon foot showed higher TSI values than the Esprit foot. This held true for all four walking conditions. The questionnaire feedback indicated that the hydraulic ankle felt more stable, made swing phase easier, provided a more balanced feeling, was less limiting to movement and provided an overall safer feeling. This was the case for all walking conditions.

Conclusion

The authors conclude that the improved ankle moment symmetry and bio-fidelity indicate a major advantage for hydraulic ankle users. These advantages can be measured consistently, across different walking speeds and non-level ground, which relates to real world scenarios. The increased stride length achieved with the hydraulic ankle indicates improved performance while the questionnaire shows a user preference for the hydraulic device.

Products with Related Technology:

Linx, Elan, Echelon, EchelonVT, EchelonVAC, Avalon

