Microprocessor knees with "standing support" and articulating, hydraulic ankles improve balance control and inter-limb loading during quiet standing

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Summary

The biomechanical differences were measured when trans-femoral amputees use rigidly-attached ankles or hydraulic ankles, while standing on a slope. The activation of MPK-enhanced standing mode was varied between on and off. Both advanced technologies brought about improvements in weight distribution and balance, while the combination of hydraulic ankle and MPK standing mode was determined to provide the best performance.

Method

Components: Echelon VT, Esprit, Orion3 microprocessor knee

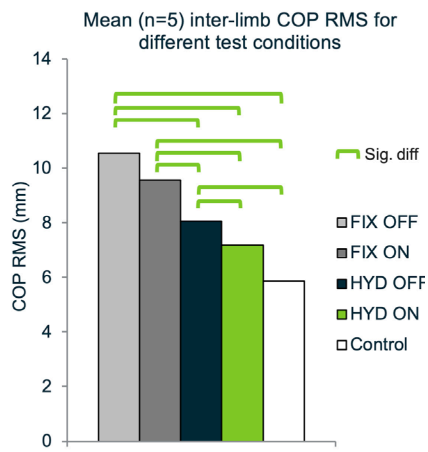
Measurements: Kinematics and kinetics during static standing

Subjects: Five trans-femoral amputees (4 male, 1 female; 41.6±12.8 years; 77.2±20.0kg) and five able-bodied controls (27.4±2.9 years; 66.8±10.3kg)

Data collection protocol: Each amputee was asked to stand still, facing down a 5° decline, for a period of 14 seconds at a time, while their joint angles, ground reaction force (GRF) and centre-of-pressure (COP) were monitored. This was repeated multiple times. The protocol was repeated using a rigidly-attached foot and a hydraulic ankle-foot unit, in a randomised sequence with a 30 minute acclimatisation period between each condition.

Analysis: Degree of asymmetry (DOA) was used to compare inter-limb symmetry. Centre-of-pressure root mean square (COP RMS) was used as a measure of balance. Paired t-tests and non-parametric Wilcoxon tests were used to identify significant differences.

Results



In terms of kinematics, the differences between the two foot types were noticeable. The rigidly attached foot required increased hip and knee flexion on the prosthetic side in order to achieve 'foot-flat', while the hydraulic ankle complied with the slope, allowing a more upright posture. With the MPK standing mode off, the effect of foot type on the GRF distribution was pronounced. Four of the five amputees displayed increased normal GRF on the prosthetic side (7-24%, $p<0.001$) when using the hydraulic ankle, while all five showed increased prosthetic shear GRF (14-99%, $p<0.01$). On the sound side, normal GRF reduced for three (4-20%, $p<0.001$) and shear GRF reduced for four (14-53%, $p<0.001$) when compared to the rigid ankle. For all amputees, DOA of normal GRF was improved when using the hydraulic, indicating a more even inter-limb load distribution. COP RMS was significantly reduced for three amputees when using a hydraulic ankle compared to a rigidly-attached foot, with MPK standing mode off, and was significantly reduced for all five with standing mode on, implying increased balance of the user. The cohort mean inter-limb COP RMS was calculated for each prosthetic condition and the controls. The effect of hydraulic ankle on balance was greater (24-25%) than that of standing mode (9-11%). The combination of the two technologies produced the result closest to that of the able-bodied control participants.

Conclusion

Less kinematic compensation was required to achieve foot-flat on the non-level surface when using the hydraulic ankle, due to its ability to self-align and adapt better to gradient than the rigid ankle. This decreases the loading of the sound limb joints and improves balance.

Products with Related Technology:

Linx, Elan, Echelon, EchelonVT, EchelonVAC, Avalon