Energy cost of ambulation in trans-tibial amputees using a dynamic-response foot with hydraulic versus rigid 'ankle': insights from body centre-of-mass dynamics

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Summary

Trans-tibial amputees, walking at various speeds and over different gradients, displayed a greater energy efficiency when using a hydraulic ankle unit than when they were using a fixed ankle prosthesis.

Method

Components: Hydraulic ankle-feet (HyAnk – Echelon) and energy-storage-and-return feet (ESR – Esprit)

Measurements: O_2 uptake and CO_2 production, motion capture during treadmill walking

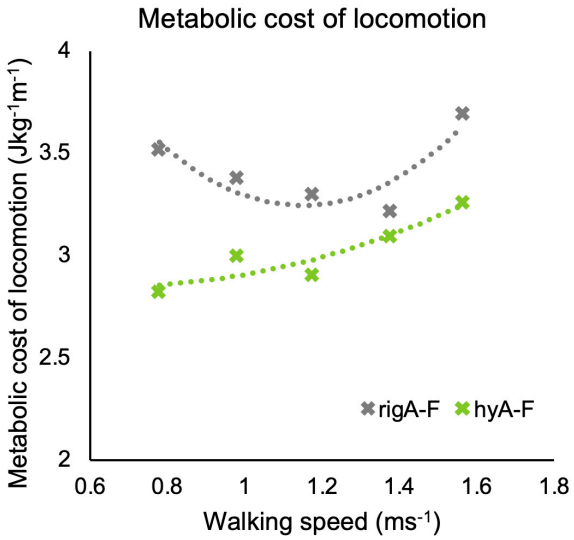
Subjects: Nine unilateral trans-tibial amputees (all male, mean±SD: age 41.3±14.3 years, mass 79.6±13.3kg, height 1.79±0.07m)

Data collection protocol: The participants walked on a level treadmill (at 0.8, 1.0, 1.2, 1.4, and 1.6 of customary walking speed) and on at two angles of decline (5° and 10°) for customary walking speed only. The participants repeated the protocol with an ESR and a HyAnk.

Analysis: 3D motion capture measured body segment kinematics, from which whole body centre-of-mass dynamics (BCOM), inter-limb symmetry and energy recovery potential could be derived. O_2 uptake was also used to quantify metabolic cost. Random intercepts modelling and chi-squared tests between models were also applied.

Results

The metabolic cost of locomotion was significantly reduced ($p<0.001$) by HyAnk compared to the ESR foot. Averaged across all level walking speeds, the metabolic cost of locomotion reduced was by 11.8±2.5% with HyAnk. Averaged across all gradients at the customary speed, the metabolic cost of locomotion reduced was by 20.2±3.4% with HyAnk. At metabolic costs of 14 ml kg^{-1} min^{-1} and 17 ml kg^{-1} min^{-1}, the mean customary walking speeds with the ESR foot were 1.09 and 1.37ms^{-1}, respectively. With HyAnk, these speeds increased by 6-7%, to 1.18 and 1.45ms^{-1}, respectively. HyAnk use also significantly reduced the total mechanical work done on a gradient and increased the interchange between the mechanical energies of the BCOM (recovery index), leading to a significant increase in locomotor efficiency ($p < 0.001$). Finally, it also increased inter-limb symmetry and reduced compensations.



Conclusion

The authors conclude that their findings suggest that hydraulic ankle use should provide meaningful benefits to the user's everyday walking by improving energy efficiency. They state that this will be particularly beneficial to those who can walk at different speeds and over different gradients.

Products with Related Technology:

Linx, Elan, Echelon, EchelonVT, EchelonVAC, Avalon