BAPO 2019
ANNUAL CONFERENCE • 15-17 MARCH • HARROGATE

The Benefits of Current Hydraulic Ankles

Mike McGrath[1], Saeed Zahedi[1], David Moser[1]

1 - Blatchford, Basingstoke, UK

Correspondence: saeed.zahedi@blatchford.co.uk

Presented at the British Association of Prosthetists and Orthotists (BAPO) conference 2019. Harrogate, UK, Friday 15th March – Sunday 17th March (invited podium presentation).

Introduction and aims

In order to prove the efficacy of a prosthetic technology, the concept of 'patient benefit' ought to be constrained to improvements in the user's short or long-term health. The 'Four Pillars' of amputee rehabilitation define these health benefits to those affecting the risk of falls (ROF), osteoarthritis (OA), lower back pain (LBP) and residual limb tissue injuries (LTI). This review examines the evidence for hydraulic ankles (HYD) and microprocessor-controlled hydraulic ankles with variable resistances (MPF), compared to rigidly-attached or elastic feet (FIX), in the context of the Four Pillars.

Methods

At initial contact, the viscoelastic design of HYD 'cushions' the impact, so less energy is transmitted to the vulnerable residuum soft tissues. HYD and MPF finish stance phase with the 'ankle' in a dorsiflexed position, which is maintained during swing phase. This intends to improve toe clearance compared to FIX and reduce the risk of trips. Adaptation of the ankle to slopes when walking downhill is designed to provide secure kinematics and reduce gait compensations, while MPF adjust resistance to apply a 'brake' effect, controlling adverse momentum build up. When standing, the ankle adaptation of HYD and MPF allow 'self-alignment', especially when on sloped or uneven ground.

Results

In terms of ROF, an 18% increase in prosthetic minimum toe clearance during swing with HYD compared to FIX[1] is likely to reduce trip-based falls, and ground compliance adaptation improves static balance on non-level surfaces[2]. The 'braking' effect of MPF has been shown to increase negative work done by the prosthetic ankle and reduce the angular velocity of the shank by up to 9%, compared to passive HYD when walking downhill, indicating improved control of momentum[3].

OA and LBP are linked with excessive reliance on the sound limb and kinetic asymmetries. The ground compliance provided by HYD and MPF during standing[2] and walking[4] has shown a decrease in the load on the sound limb and improved symmetry between the two limbs. These improved biomechanics reduce the metabolic cost of movement, when using HYD, by approximately 12% on level ground and 20% on slopes[5]. Symmetry also improves for K2 amputees when using HYD[6-7]. MPF further reduce the load on the sound limb by 7-8%, when walking up or downhill[8].

The damping provided by HYD at initial contact reduces the peak pressures on the residual limb by up to 81% and the loading rate by up to 87%, on various walking surfaces, compared to FIX[9].

Conclusion

There is an abundance of scientific evidence to show that hydraulic ankles provide short and long-term health benefits. When discussing the efficacy of a prosthetic technology, the conversation should be in the context of quantifiable user health benefits.

References

1. Johnson L, De Asha AR, Munjal R, Kulkarni J, Buckley JG. Toe clearance when walking in people with unilateral transtibial amputation: effects of passive hydraulic ankle. J Rehabil Res Dev. 2014;51(3):429.
2. McGrath M, Laszczak P, Zahedi S, Moser D. Microprocessor knees with “standing support” and articulating, hydraulic ankles improve balance control and inter-limb loading during quiet standing. J Rehabil Assist Technol Eng. 2018;5:2055668318795396.
3. Struchkov V, Buckley JG. Biomechanics of ramp descent in unilateral trans-tibial amputees: Comparison of a microprocessor controlled foot with conventional ankle–foot mechanisms. Clin Biomech. 2016;32:164–170.
4. De Asha AR, Munjal R, Kulkarni J, Buckley JG. Walking speed related joint kinetic alterations in trans-tibial amputees: impact of hydraulic’ankle’damping. J Neuroengineering Rehabil. 2013;10(1):1.
5. Askew GN, McFarlane LA, Minetti AE, Buckley JG. 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. J NeuroEngineering Rehabil. 2019;16(1):39.
6. Barnett CT, Brown OH, Bisele M, Brown MJ, De Asha AR, Strutzenberger G. Individuals with Unilateral Transtibial Amputation and Lower Activity Levels Walk More Quickly when Using a Hydraulically Articulating Versus Rigidly Attached Prosthetic Ankle-Foot Device. JPO J Prosthet Orthot. 2018;30(3):158–64.
7. Moore R. Effect on Stance Phase Timing Asymmetry in Individuals with Amputation Using Hydraulic Ankle Units. JPO J Prosthet Orthot. 2016;28(1):44–48.
8. McGrath M, Laszczak P, Zahedi S, Moser D. The influence of a microprocessor-controlled hydraulic ankle on the kinetic symmetry of trans-tibial amputees during ramp walking: a case series. J Rehabil Assist Technol Eng. 2018;5:2055668318790650.
9. Portnoy S, Kristal A, Gefen A, Siev-Ner I. Outdoor dynamic subject-specific evaluation of internal stresses in the residual limb: hydraulic energy-stored prosthetic foot compared to conventional energy-stored prosthetic feet. Gait Posture. 2012;35(1):121–125.