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Biomimetic Prosthetic Design Principles and the use of Technology and Innovation to Improve Patient Gait

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Introduction and aims

The prevalence and consequences of lower limb amputations present a global challenge for prosthetic designers. Commonly, biomimetics – the replication of natural human movement – is the leading principle informing this design. However, it is clinical outcomes that should lead the conversation of whether a prosthetic technology is cost-effective, namely, the ‘Four Pillars’ of amputee rehabilitation; the risk of falls (ROF), osteoarthritis (OA), lower back pain (LBP) and residual limb tissue injury (LTI).

Methods

Replicating the mechanical behaviour of muscle is achieved through viscoelasticity – combining spring-like and damper mechanisms. A hydro-pneumatic microprocessor knee (MPK) uses hydraulics to control resistance to flexion during weight bearing, before allowing knee flexion during terminal stance, preparing for swing phase. Pneumatics behave like a spring, extending the knee at a rate proportional to walking speed. A microprocessor-controlled hydraulic ankle (MPF) combines variable hydraulic resistances with carbon fibre foot springs. These resistances can independently adapt to different slopes, providing ‘braking’ and ‘assistance’ when walking down or uphill, respectively. Combining these technologies into an integrated limb allows communication between ankle and knee, meaning the two can work in unison.

Results

Past literature has shown the security of MPKs compared to mechanical knees, reducing the number of stumbles and semi-controlled falls by 49% and 76%, respectively, for K3 amputees, and by 33% and 63% for K2 amputees[1]. A biomechanical analysis of an MPF with and without microprocessor-control showed that the ‘braking’ effect increased the support moment integral under the prosthetic limb by a mean of 26%, while reducing that under the sound limb by 8% when walking downhill[2]. The ‘assist’ mode reduced sound limb support moment integral by a mean of 7% when walking uphill[2]. When descending a slope with an integrated limb, with and without microprocessor-control, another study showed that the asymmetry of work done by the joints of each limb was reduced during gait termination and participants *‘became more assured using their prosthetic limb’*[3]. Further integration might be achieved through integrated sockets or direct skeletal fixation (DSF), but all innovation will rely on the ‘Four Pillars’ and justify their cost-effectiveness[4].

Conclusion

The use of outcome measures and biomechanical analyses are essential for justifying the costs of prosthetic devices. Patient improvements in the context of the ‘Four Pillars’ provide good evidence of user benefit and cost-effectiveness.

References

1. Hafner BJ, Smith DG. Differences in function and safety between Medicare Functional Classification Level-2 and-3 transfemoral amputees and influence of prosthetic knee joint control. Journal of Rehabilitation Research & Development. 2009;46(3):417-34.
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. Abdulhasan ZM, Scally AJ, Buckley JG. Gait termination on a declined surface in trans-femoral amputees: Impact of using microprocessor-controlled limb system. Clin Biomech. 2018;57:35–41.
4. Frossard LA, Merlo G, Burkett B, Quincey T, Berg D. Cost-effectiveness of bone-anchored prostheses using osseointegrated fixation: Myth or reality? Prosthet Orthot Int. 2018;42(3):318-27.