

POWERED ANKLE-FOOT PROSTHESIS IMPROVES METABOLIC DEMAND OF UNILATERAL TRANSTIBIAL AMPUTEES DURING WALKING

^{1,2}Hugh M. Herr, ^{1,2}Alena M. Grabowski

¹Massachusetts Institute of Technology, Cambridge, MA, USA

²Department of Veterans Affairs, Providence, RI, USA

email: alenag@mit.edu, web: <http://media.mit.edu/~alenag>

INTRODUCTION

When using conventional prostheses, people with transtibial amputation typically require 10-30% more metabolic energy to walk at the same speeds as non-amputees and this metabolic discrepancy becomes more pronounced at faster walking speeds [1]. A greater metabolic demand implies that amputees fatigue sooner and more often, and are not able to sustain the same walking speeds as non-amputees. Therefore it is not surprising that amputees' preferred walking speeds are typically 30-40% slower than non-amputees [1]. The elevated metabolic demand and slower preferred speeds of transtibial amputees are likely due to the inability of their conventional passive prostheses to produce power at the ankle.

nearly 80% of the mechanical power required during a gait cycle [3]. During ground contact, conventional prostheses behave as passive springs and therefore cannot provide the net positive work normally done by the biological leg muscles during terminal stance in walking.

The MIT Biomechanics Group and iWalk, Inc. have designed a novel, powered ankle-foot prosthesis (Powerfoot) that supplies positive work at the prosthetic ankle joint (Fig. 1). The purpose of this pilot study was to determine how use of the Powerfoot affects metabolic cost during walking across a wide range of velocities. We predicted that amputees using the Powerfoot would have a lower metabolic cost of transport and faster preferred walking speed compared to using a conventional prosthesis.

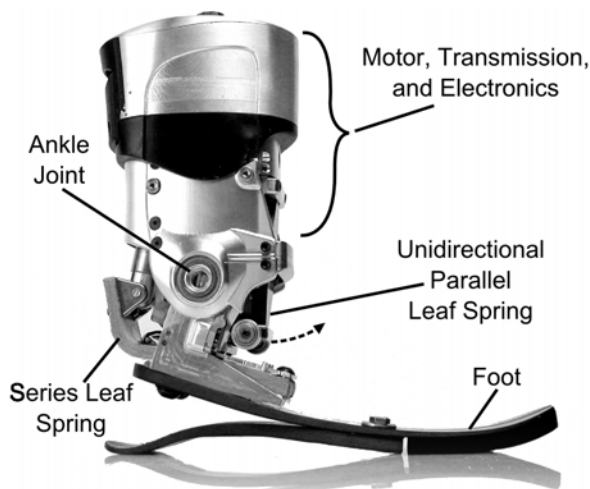


Figure 1: Powerfoot Prosthesis

The restoration of near-normal biological walking in amputees has not been previously demonstrated with any mechanical device [2]. The biological human ankle performs greater positive than negative work during each stance period of walking, especially at fast walking speeds [3,4] and generates

METHODS

Three healthy adult male unilateral transtibial amputees gave informed written consent and participated in the study. All amputees were at least 1 year post-amputation, and at or above a K3 level of ambulation as defined by Medicare. We utilized high functioning amputee subjects with no known cardiovascular, pulmonary, or neurological disease or disorder, and no musculoskeletal problems. Each amputee completed an acclimation session and two experimental sessions.

During the acclimation session, a certified prosthetist adjusted and aligned the Powerfoot for each subject. Then, a technician tuned the Powerfoot to each subject by adjusting the spring stiffness, magnitude of power, and timing of power delivery during walking. We tuned the Powerfoot so

that the prosthetic ankle angle and torque matched biomimetic data across a range of walking speeds.

During the experimental sessions, we measured and compared rates of oxygen consumption and carbon dioxide production using a portable metabolic analysis system (Cosmed K4b², IT) while subjects stood in place and walked at five constant speeds (0.75, 1.00, 1.25, 1.50, and 1.75 m/s) on a treadmill. We averaged steady-state metabolic rates from minutes 4-6 of each standing and walking trial and then used a standard equation to calculate the metabolic cost of transport. Subsequently, we measured each subject's preferred walking speed on the treadmill. Each subject completed one experimental session using his own prosthetic foot and a subsequent session using the Powerfoot.

RESULTS AND DISCUSSION

Compared to using a conventional prosthesis, amputees using the Powerfoot had 6, 7, 10, 13, and 16% reductions in metabolic cost of transport to walk at 0.75, 1.00, 1.25, 1.50, 1.75, respectively. The minimum metabolic cost of transport shifted from 1.25 m/s while subjects used their own foot to 1.35 m/s while subjects used the Powerfoot. Preferred walking speeds were 1.09 m/s while using a conventional prosthetic foot, and 1.37 m/s while using the Powerfoot.

CONCLUSIONS

Supplying biomimetic power at the prosthetic ankle joint reduced the metabolic cost of transport and improved preferred walking speed in three unilateral transtibial amputees. Future studies are planned that target a larger sample size.

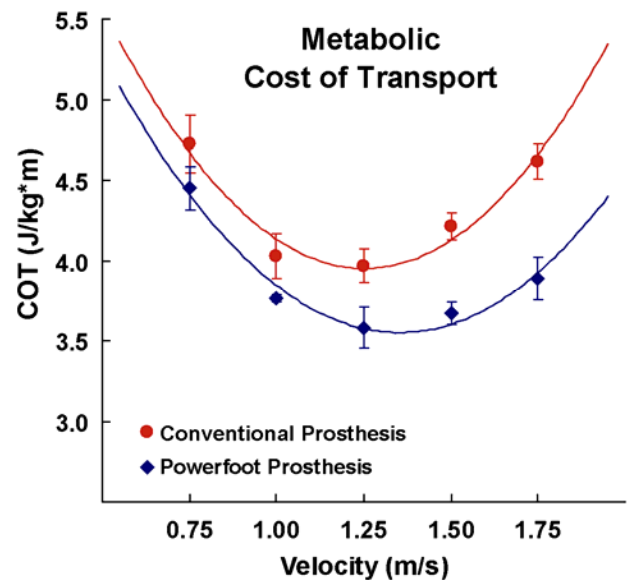


Figure 2: Average metabolic cost of transport (error bars \pm SEM) for amputees using their own conventional prosthesis (red circles) and the Powerfoot prosthesis (blue diamonds) to walk 0.75-1.75 m/s. Using the Powerfoot prosthesis reduced cost of transport by 6-16% compared to using a conventional prosthesis to walk at all speeds.

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