COMPARING THE EFFECT OF ENERGY RETURN AND DAMPING WITHIN PROSTHETIC FEET ON SOUND LIMB KNEE LOADING

Li Jin¹, Peter G. Adamczyk²,³, Michelle Roland¹, Michael E. Hahn¹,
¹Department of Human Physiology, University of Oregon, Eugene, OR USA
²Intelligent Prosthetic Systems, LLC, and ³Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI USA
email: lijin@uoregon.edu, web: bssc.uoregon.edu

INTRODUCTION
Passive prosthetic feet are known to absorb and return small amounts of energy during gait, resulting in kinematic and kinetic asymmetries, which may lead to musculoskeletal overuse conditions such as knee osteoarthritis. Powered prosthetic feet have been reported to reduce peak knee external adduction moments (EAM) in the sound limb compared with passive prostheses [1]. Increased push off work from the trailing limb can reduce collision forces on the leading limb, resulting in reduced Knee EAM [2]. It is unknown whether the relative contribution of energy return will lead to reduced sound limb knee loading at the lower end of the energy spectrum.

We tested two experimental feet of equivalent stiffness and contact point geometry: a woven glass-epoxy composite energy return structure, and a foam-based damping structure, under relative stiffness and walking speed conditions. We hypothesized that sound limb peak knee EAM and loading rates would be greater using the damping foot compared with the energy return foot.

METHODS
Four able-bodied subjects provided written informed consent to participate in this IRB-approved study. The subjects walked on the energy return foot and the damping foot (shown in Fig. 1) using a prosthesis simulator boot. Three stiffness conditions (high, medium and low) were tested at three walking speeds (self-selected fast, normal and slow). Segmental kinematic data were collected at 120 Hz using a 10-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA) and ground reaction force data were collected at 1200 Hz (AMTI, Watertown, MA). Peak knee EAM and loading rates in the sound limb were calculated using inverse dynamics model in Visual 3D (C-Motion, Inc., Germantown, MD). Statistical analysis included two-factor ANOVAs with repeated measures, using SPSS (IBM, Armonk, NY).

RESULTS AND DISCUSSION
Overall, sound limb peak knee EAM and loading rates were greater when using the damping foot than the energy return foot. In the normal walking speed condition, EAM in the sound limb was significantly greater when using the damping foot compared to the energy return foot in high stiffness conditions (P<0.01). Loading rates were significantly greater using the damping foot compared to the energy return foot in the high stiffness condition at fast walking speed (P<0.002), normal walking speed (P<0.002) and slow walking speed (P<0.028) (Fig 2). During the normal walking speed condition, loading rates were significantly greater using the damping foot compared to the energy return foot in low stiffness conditions (P<0.016).

CONCLUSIONS
The findings of this study support and extend previously reported findings of the sound limb knee loading by wearing different prosthetic feet [1, 2]. The peak knee EAM and loading rates in the sound limb were greater using the damping foot, compared to the energy return foot; despite equivalent stiffness levels in the feet. This finding was expected due to the damping effect of the foam foot; capable of storing but not returning energy. These results indicate that the work performed by the prosthetic foot remains inversely linked to sound limb peak knee EAM and loading rates in the sound limb, even at the lower end of the energy return spectrum. Future research should confirm these findings in a sample of lower limb amputees, and explore other prosthetic foot factors that influence the peak knee EAM, which can offer clinical strategies for prevention of knee OA.

REFERENCES
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