Feet with multi-axial rotation units enhance gait stability over uneven terrain in people with amputation

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INTRODUCTION
Individuals with transtibial amputation face serious challenges when negotiating uneven terrain. Prosthetic foot manufacturers have attempted to minimize these challenges by designing prosthetic feet that can deform and adapt to uneven terrain. Feet incorporating “multi-axial” features have been given a Medicare L-Code reflecting this ability (L-5986) and have been traditionally prescribed to individuals expected to negotiate uneven environments. However, prosthetic reimbursement is changing and third-party payers are now asking for evidence to justify these features (Levinson, 2011). There is currently NO evidence that links multi-axial prosthetic ankle stiffness to gait stability. This lack of evidence could be used by third-party payers to deny reimbursement.

The purpose of this study was to define the effect of prosthetic multi-axial stiffness on gait stability in people with uni-lateral transtibial amputation. Study results should strengthen the evidence-base of prosthetic/rehabilitation interventions.

METHOD
Subjects: Eleven participants with uni-lateral transtibial amputation secondary to trauma (93.2 ± 23 kg, 1.82 ± 0.13 m, 40.0 ± 14.0 yrs) have completed this IRB approved study.

Apparatus: The uneven terrain (Figure 1) consisted of a 7.3 x 0.8m walkway with 80 x 25 x 20 cm blocks specifically placed in a rotating pattern (0°, 45°, 90°, and 135°). The center of each block was spaced 200 cm apart from each other. A 1 cm thick rubber mat was placed over the uneven walkway reducing visual feedback while making the floor appear even.

Procedures: Participants walked ten times over even and uneven terrain to a metronome (108 bpm). The uneven terrain consisted of a 7.3 x 0.8m walkway with 80 x 25 x 20 cm blocks specifically placed in a rotating pattern. A mat was placed over the uneven walkway reducing visual feedback. A full-body marker set (Vicon PlugInGait) in conjunction with an eight camera motion capture system (Vicon Motion Systems, Oxford, UK) recorded limb kinematics. The participant’s regular prosthesis and an Endolite MultiFlex foot with four different ankle unit stiffnesses (soft, medium, firm, and locked out) were tested in random order. This foot was used because it allowed for easy manipulation of multi-axial stiffness, and it only uses the L5986 code (Levinson, 2011). A certified prosthetist performed all prosthetic modifications.

Data Analysis: Matlab 2013b was used to calculate whole body center of mass based on a 14 limb-segment model (De Leva, 1996) and the range of angular momentum about the coronal plane when the amputated limb was in stance (Herr & Popovic, 2008). Angular momentum was normalized to the participant’s mass, velocity, and height. A two factor Repeated Measures ANOVA (terrain x ankle stiffness) with Bonferroni post-hoc tested statistical significance (p < .05).

RESULTS
There was a significant effect of terrain, and ankle stiffness for the range of whole body angular momentum in both the sagittal and coronal planes. A decrease in the range of whole body angular momentum means an increase in gait stability. The locked ankle condition was significantly destabilizing in both terrains and while ankle stiffness had a larger effect on uneven terrain than even terrain (Figure 1).

DISCUSSION & CONCLUSION
Prosthetic feet with multi-axial features significantly increased gait stability over uneven terrain indicating scientific evidence supporting the use of feet utilizing the L5986 code in clinical practice.

CLINICAL APPLICATIONS
Prosthetic designs that incorporate multi-axial foot units provide a measureable benefit by enhancing gait stability and will benefit those with amputation that need to negotiate uneven terrain.

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REFERENCES

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