INTRODUCTION
The Endolite Echelon ankle-foot system is a purely passive device that incorporates a hydraulic damper to permit up to 9 degrees of motion in the sagittal plane during standing and walking. Although previous studies have claimed that the Echelon ankle improves adaptability to uneven terrain (Portnoy et al., 2012; Sedki et al., 2012), the biomechanical contribution of this feature has not been investigated in a randomized study. Accordingly, the primary goal of this study was to examine the benefits of the Echelon ankle-foot system compared to two non-adaptable feet built on the same modular platform: the Endolite Esprit (same keel, rigid ankle) and the Endolite Epirus (same keel, non-adaptable, multi-axial ankle). Given the potential of the Echelon to adapt to uneven terrain, we hypothesized that:

H1: Persons using the Echelon would experience less pronounced changes in socket reaction torque on sloped surfaces.

H2: Users’ self-reported Socket Comfort Score would be increased when walking with the Echelon on sloped surfaces.

METHOD
Subjects: Five male subjects with unilateral, transtibial amputation (age 58±6 years; mass 100±17 kg; height 181±6 cm). All subjects were classified as K3 ambulators by a certified prosthetist.

Apparatus: Gait data were acquired using a modified Helen Hayes marker set (Kadaba et al., 1990), an 8 camera, Oqus 100 motion capture system (Qualisys Motion Capture Systems, Gothenburg, Sweden), and a dual-belt, instrumented treadmill (Bertec Corporation, Columbus, Ohio). After each experimental condition, subjects were asked to rate their socket comfort using the Socket Comfort Score (Hanspal et al., 2003).

Procedures: Subjects wore a duplicate of their existing socket, a rigid pylon, and each of the three Endolite prosthetic foot-ankle systems. All fittings were performed by a certified prosthetist. Subjects were given a two-week accommodation period between each foot condition. Following this accommodation period, gait data were collected while subjects walked on the treadmill (harnessed and hands free) at a constant, freely-selected walking speed. Subjects walked with each foot on five slopes (-10, -5, 0, 5, 10 deg). Both foot and sloped conditions were randomized.

Data Analysis: A three-dimensional quasi-static analysis was used to estimate socket reaction torque at the distal end of the residual limb during single-limb support (Wells, 1981).

RESULTS
As expected, sagittal-plane torque curves were considerably altered for non-adaptable feet when used on different walking slopes. Contrary to our first hypothesis, no differences were observed in the maximum sagittal-plane socket reaction torque of subjects using the Echelon compared to the Esprit or Epirus. In addition, negligible differences were observed in the Socket Comfort Score across all sloped walking conditions (Fig. 1).

DISCUSSION AND CONCLUSIONS
Preliminary results suggest similar biomechanical characteristics between feet across all walking surfaces (i.e., no terrain adaptation observed with the Echelon ankle). In the future, the roll-over shapes and torque-angle curves of these ankle-foot systems will also be investigated.

CLINICAL APPLICATIONS
While the Echelon ankle-foot system may be an ideal component for some lower-limb prosthesis users, preliminary results suggest that it does not adapt during single-limb support of sloped walking.

REFERENCES

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