INTRODUCTION
Some of the important functions associated with the foot-ankle rocker mechanisms are adversely affected or eliminated during the gait of prostheses users due to reduced or absent ankle motion. However, these functions may be restored or improved by fitting users with prosthetic ankle joints. Appropriate consideration for the net effect of the combined stiffness should be provided when pairing a prosthetic ankle unit with a prosthetic foot. A prosthetic ankle unit that increases ankle motion during stance phase may change the roll-over shape characteristics of the user with walking with the prosthetic foot alone and yield different gait biomechanics. The objective of this study was to determine how foot-ankle roll-over shape was affected by a prosthetic ankle component that increases sagittal-plane motion. By increasing motion at the ankle during stance phase with the addition of a compliant prosthetic ankle joint (Su et al, 2010), we hypothesized that the roll-over shape radius of the prosthetic foot and ankle would be reduced. Similarly, the increased ankle motion was expected to decrease the effective foot length ratio (Hansen et al, 2004) of the ankle-foot system.

METHOD
Subjects: Subjects with bilateral transtibial amputations were recruited for this study. Criteria for inclusion were specified as individuals who were a minimum of two years post-amputation and used prostheses as their primary means of ambulation. Subjects signed consent forms that were approved by Northwestern University’s Institutional Review Board.

Apparatus: Quantitative gait data were acquired using an 8-camera real-time motion capture system (MAC, Santa Rosa, CA) and 6 force-plates (AMTI, Watertown, MA) embedded flush in the floor of a 10m walkway.

Procedures: Data were acquired as subjects walked with and without Endolite Multiflex Ankle Units (Endolite North America, Centerville, OH). In both cases, subjects used Seattle Lightfoot II feet (Seattle Systems, Poulso, WA). Subjects were provided a two-week accommodation period prior to testing.

Data Analysis: EVa RealTime and Orthotrak software (MAC, Santa Rosa, CA) were used to process data and calculate gait parameters. Roll-over shape radii and effective foot length ratios were determined using custom Matlab programs.

RESULTS
Seventeen subjects completed the study. Ankle motion was increased from a mean of 13.0° for the baseline condition to 19.4° while walking at their freely-selected speed with the prosthetic ankle units (p<0.001). Prosthetic ankle stiffness was reduced, evident from the slope of the prosthetic ankle moment vs. motion data. The effective foot length ratio was not significantly affected for the baseline condition (p<0.001) (Figure 1). The effective foot length ratio was not significantly affected by the prosthetic ankle units (p=0.066).

Figure 1. The roll-over shape radius (normalized by body height) was observed to decrease when subjects walked with the Endolite Multiflex Ankle Unit compared to walking without it. The dotted line represents the median roll-over shape radius scaled to height for a group of able-bodied adults.

DISCUSSION & CONCLUSIONS
Prosthetists should carefully consider the effects of combining different prosthetic components on overall functional performance of their clients. The addition of a prosthetic ankle unit will likely alter the roll-over shape from that provided by the prosthetic foot alone. The increased ankle motion provided by the Multiflex Ankle Units in this study decreased the radius of the ankle-foot roll-over shape, supporting our hypothesis. Contrary to our expectations for the second hypothesis, the effective foot length ratio of the ankle-foot system was not significantly affected by the addition of the prosthetic ankle unit. When fitting a prosthetic ankle unit on their client, the prosthetist may consider selecting a prosthetic foot with a slightly stiffer keel than they would normally fit on that individual without an ankle unit in order to provide a more appropriate roll-over shape for the prosthetic foot-ankle combination. Doing so could improve walking biomechanics and ultimately serve to increase the efficiency of gait.

REFERENCES