

# Outdoor dynamic subject-specific evaluation of internal stresses in the residual limb: Hydraulic energy-stored prosthetic foot compared to conventional energy-stored prosthetic feet

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## Summary

The pressure between the prosthetic socket and stump of nine trans-tibial amputees was measured during a range of walking activities, with conventional energy storage and return feet and with a hydraulic ankle foot. The authors found significantly lower pressures with the Echelon compared to the other feet, which they attribute to the hydraulic mechanism. They suggest the Echelon may help protect against deep tissue injury in trans-tibial amputees.

## Method

**Components:** Echelon foot and the subjects' own energy-storage-and-return feet (3x Trias, 1x Venture, 2x Trustep, 1x C-walk, 1x Pathfinder and 1x Esprit were used).

**Measurements:** Socket interface pressure measured using a 3-element FlexiForce thin film sensor (Tekscan).

**Subjects:** Nine male unilateral traumatic trans-tibial amputees, with 6 to 36 post amputation and a mean age of 42.7 years.

**Data collection protocol:** Subjects wore their own prosthetic feet and were asked to walk at their natural speed for 1 minute on a paved surface indoors, followed by a slope ascent and descent outdoors, then 1 minute walking on grass plus a stair ascent and descent outdoors. Pressure measurements were logged in real-time. Subjects were then fitted with an Echelon foot, which they used for 1 month before being invited back to repeat the measurements. Subjects were also interviewed at the end of the study.

**Analysis:** Five subsequent steps were taken from each walking trial. Parameters of interest included: Cadence, the averaged peak and RMS internal von Mises stresses, and the loading rate (calculated). Loading rate was defined as the ratio of peak stress over the time interval from heel strike to peak stress.

## Results

All subjects were satisfied with the Echelon, with no reports of abnormal pressure or discomfort. There was a significant decrease in peak stress and loading rate with the Echelon (the loading was at least 3 times lower). The internal stresses decreased with the Echelon significantly whilst on the paved floor and ascending stairs.

## Conclusion

The authors attribute the reduction in stress to the hydraulic ankle mechanism. Loads transferred more slowly, preventing sudden impacts. Residuum less likely to be injured, hence the hydraulic design may protect against deep tissue injury. The energy storage and return feet users may be compensating for high stress impacts elsewhere in their gait.

## Products with Related Technology:

Linx, Elan, Echelon, EchelonVT, EchelonVAC, Avalon

