Effect of Prosthetic Stiffness on Impact Forces during Walking and Sudden Limb Loading

Erin Boutwell, M.S., and Steven Gard, Ph.D.
Northwestern University Prosthetics-Orthotics Center, Chicago IL, USA
Jesse Brown VA Medical Center, Chicago, IL, USA

Introduction

Shock-absorbing components are often included in transtibial prostheses to cushion the residual limb from forces transmitted within the prosthesis during gait. Subjective data typically indicates increased comfort and preference for these components [1-2]. Quantitative gait analyses have not demonstrated that altering prosthetic stiffness substantially changes ground reaction forces (GRFs) during walking [1-3]. The reasons for this discrepancy have yet to be fully explained. Two likely possibilities include:

- Insufficient magnitude of changes in prosthetic limb stiffness
- Active compensation by the prosthesis user to stiffness changes

Methods

Subjects with a unilateral transtibial amputation are recruited to participate in a quantitative gait analysis and a sudden limb loading experiment. Prosthetic stiffness is varied using a shock-absorbing pylon:

Four stiffness conditions:
- Manufacturer-recommended (“normal”)
- 50% normal (“soft”)
- 75% normal (“medium”)
- Rigid (“rigid”)

Variables of interest:
- GRF loading peaks during walking
- Peak impact forces during sudden limb loading
- Lower-limb kinematics

Results – Gait Analysis

Experimental setup for gait analysis

Mean GRF loading peak for each stiffness condition

Results – Sudden Limb Loading

Experimental setup for sudden limb loading test

Mean peak forces for each stiffness condition

Discussion

Preliminary data from a single subject with a transtibial amputation show that changing prosthetic stiffness appears to influence peak forces substantially. Therefore:

- Possibility #1 (insufficient magnitude)
  \[ \Delta \text{peak forces during limb loading} \neq \text{insufficient magnitude} \]

- Possibility #2 (active compensation)
  \[ \Delta \text{peak forces during limb loading} \neq \Delta \text{peak forces during walking} \]

Clinical Significance

Increased understanding of how prosthetic stiffness affects shock absorption during gait will permit the development of more effective prescription guidelines and improved design of shock-absorbing components.

References


Acknowledgements

The authors acknowledge the use of the Jesse Brown Dept. of Veterans Affairs Medical Center Motion Analysis Research Laboratory (JBVAMC-MARL) for data collection and the support of the National Institute on Disability and Rehabilitation Research (NIDRR).