The Effect of Prosthetic Foot and Ankle Stiffness Changes on Gait and Standing in People with Unilateral Transtibial Amputations

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Overview: The purpose of this investigation is to determine how systematically varying the prosthetic foot keel stiffness and prosthetic ankle joint stiffness affects standing and walking in persons with unilateral, transtibial amputations. Specifically, we will identify and weigh the different benefits and consequences of combining stiffer prosthetic footplates with more compliant ankle dorsiflexion bumpers, and vice versa, to determine how to best serve the needs of the prosthesis user.

Introduction

Background
- Incidence of Transtibial amputation (approx. 346,520 unilateral transtibial amputees in the US).
- Conducted in parallel with the mechanical characterization of the prosthetic feet.
- Provide prescription guidelines for prosthetists to consider.
- Rotation of Ankle joint is critical for progression and joint absorption
- Able-bodied persons vary their ankle joint stiffness with walking speed (Hansen et al., 2004).
- Previous studies have shown that modular prosthetic ankle components improve walking (Su et al., 2010).
- A previous pilot study suggested that decreased prosthetic ankle stiffness reduces stability during standing.

Specific Aims:
1. To determine the effects of different prosthetic foot and ankle stiffness combinations on gait biomechanics of unilateral, transtibial prosthesis users.
2. To determine the effects of different combinations of prosthetic foot and ankle stiffness on standing stability of unilateral, transtibial prosthesis users.

Methods

College Park Venture Foot: The Venture foot was selected because its design enables relatively easy substitution of different footplates and ankle bumpers that the manufacturer provides with different stiffness.

Procedure:

Results

A mechanical characterization were performed on a previous study to determine the combined Ankle-Foot Stiffness providing the order from low stiffness to high stiffness:

MS < HS < SH < MM < MH

Gait Analyses:
1. Temporal Spatial Parameters
2. Kinetic and kinematic Data of the ankle
3. Roll-Over Shape (ROS)

Balance Analyses:
1. Root Means Square Distance (RDIST)

Discussion

• Despite the small sample size, there is a trend that suggests conditions with higher foot-ankle stiffness influence gait patterns of transtibial amputees.
• Data suggests that ankle angle is inversely proportional to ankle-foot stiffness and ankle moment is directly proportional to ankle-foot stiffness.
• During the standing balance experiment for eyes close the RDIST of COP is smaller for the MH condition and larger for the MS condition in support of our hypothesis.
• The youngest participant show a distinct behavior during trials of different stiffness conditions, which may provide insights into future prosthetic design.
• High variability was observed across subjects’ data for the intermediate conditions.

Conclusions:
• The results demonstrate that prosthetic foot–ankle stiffness affects both gait and standing performance.
• An aspect that should be considered is the ambulatory capability of the subjects. For example, a younger, athletic user readily adapted to the different conditions.
• The systematic variation of the ankle-foot stiffness increases understanding about how prosthetists could potentially fine-tune user performance.
• Each subject demonstrated specific gait strategies for the different stiffness combinations, which is an important point to consider for the fitting process.

References & Acknowledgements

