GROUND REACTION FORCE AND SHANK ANGLE WAVEFORMS FOR PROSTHETIC FOOT MECHANICAL CHARACTERIZATION

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INTRODUCTION

Recent studies have addressed the need for matching the mechanical properties of a prosthetic foot to the biomechanical needs of patients. However, it is recognized that user preference for a particular component is not well predicted by its laboratory-measured mechanical performance [1]. To address this, alternative characterization methods have been reported that account for the change in shank angle and vertical loading that occur during gait based on ISO-22675 standard gait profiles [2]. While these have proven effective in characterizing device mechanical properties, the vertical loading and shank angle data are not representative of typical prosthetic users.

OBJECTIVE

Are subject specific loading protocols necessary for mechanical characterization of prosthetic foot components?

The objective of this study was to establish representative waveforms describing prosthetic foot loading, for use in mechanical characterization of devices. Specifically, the aim was to describe the sagittal shank angle and vertical ground reaction force (GRF) during stance for lower limb prosthetic users by measuring these variables in a cohort of transtibial prosthesis users.

METHODS

Three K3-K4 transtibial prosthesis volunteers were fit with two keel conditions: their current prosthetic device, and the Niagara Foot. Over-ground gait data were recorded along a level 15m walkway surrounded by 12 optical motion Qualisys™ capture cameras and instrumented with six tandem strain gauge AMTI™ force platforms (Figure 1). Kinematic data were recorded using standard procedures with 5-10 trials for each condition and reduced to anatomical angles using Visual3D™.

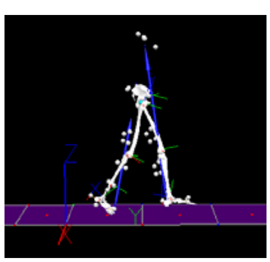
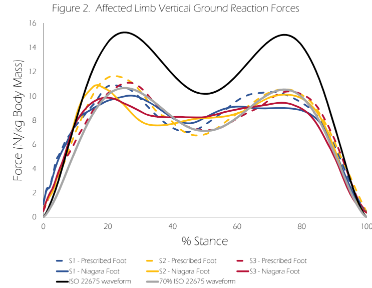


Figure 1.

RESULTS

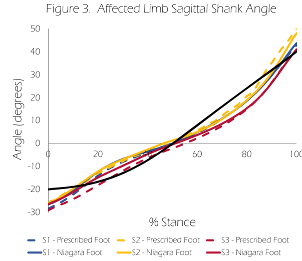
Consistent with previous literature, the vertical GRF waveforms were asymmetrical in the stance phase, with the affected limb exhibiting reduced magnitudes and altered patterns compared to the reference waveform. The affected limb vertical GRF waveforms were compiled across subjects and devices (Figure 2); the overall trend is reasonably approximated by the ISO-22675 vertical GRF waveform with the magnitude scaled to 70%.

Figure 2. Affected Limb Vertical Ground Reaction Forces



The shank angles were similar to the reference waveform in magnitude and overall trend (Figure 3); however, there were multiple inflection points compared to the reference waveform. There was little variation by device or subject.

Figure 3. Affected Limb Sagittal Shank Angle



CONCLUSIONS

In this preliminary study, it was found that the loading of a prosthetic foot component, specifically the sagittal shank angle and vertical GRF, can be reasonably approximated by a generalized waveform specific to lower limb prosthesis users. The vertical loading of prosthetic feet can be generalized by the ISO-22675 waveform, when scaled to 70%. The sagittal shank angles are reasonably approximated by the ISO-22675 waveform. For mechanical characterization of prosthetic foot components it is recommended to use loading protocols that are representative of the gait of lower limb prosthesis users.

REFERENCES AND ACKNOWLEDGEMENTS

[1] Hafner BJ, et al. (2002). Energy storage and return prostheses: Does patient perception correlate with biomechanical analysis? Clinical Biomechanics, 17: 325-344. [2] Haberman, A (2008). Mechanical properties of dynamic energy return prosthetic feet. M.Sc. Thesis, Queen's University, Kingston, ON, Canada. Funding from the Donald and Joan McGeachy Chair in Biomedical Engineering; laboratory assistance from Adam Clancey and Sydney Low; technical support from the Human Mobility Research Laboratory, Hotel Dieu Hospital, Kingston, Canada