Experimental Investigation of Passive Prosthetic Feet Designed for Multiple Walking Activities Using the Lower Leg Trajectory Error Methodology

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***Abstract*—Though our lower leg trajectory error (LLTE) framework enables the quantitative design of prosthetic feet, previous work only optimized foot designs for level ground walking. Amputees encounter a range of walking activities, and few multi-activity passive prosthetic feet exist; to meet these needs, we created a multi-activity framework based on the LLTE metric. To further validate the LLTE as a clinical and design tool, we conducted a clinical study with transtibial amputees to compare a prosthetic foot designed for multiple walking activities with one designed for level ground walking only. Preliminary results indicate that subjects can more closely replicate able-bodied gait in multiple activities when they wear a prosthesis designed for these activities compared to when wearing a device designed for level ground walking only.**

Keywords—prosthetic feet, biomechanics, design metric

I. Introduction

While the mobility needs of amputees span many activities [1], current passive prostheses are primarily designed for level ground walking. The systematic design and testing of passive devices for walking on ramps and at varied speeds have not been the focus of many studies. The lower leg trajectory error (LLTE) is a design metric that quantitatively describes how well a passive prosthetic foot allows a user to replicate a target walking activity [2]. We have previously used the LLTE framework to customize single part, plastic prosthetic feet which enable individual transtibial users to closely replicate able-bodied, level ground walking patterns at self-selected speed [3]. In level ground clinical testing, the LLTE model accurately predicted lower leg kinematics, and subjects achieved similar biomechanics in both our plastic LLTE feet and high-end carbon fiber feet. These results give confidence in the LLTE framework. To improve the usefulness of the LLTE as a design tool, we have extended it to additional walking activities. In this work, we experimentally compare feet designed using the LLTE for a single walking activity with those designed for multiple walking activities.

II. Methods

Five high-activity level transtibial subjects with weights ranging from 54 to 102 kg were selected for this study. We used the LLTE framework to optimize the geometry and stiffness of two prosthetic feet for each subject: one designed using a single-keel architecture and optimized for level ground walking; and one designed using a novel, multi-keel architecture and optimized for walking on level ground at varied speeds as well as up and down ramps. Nylon 6/6 prototypes were mechanically tested and used for *in-vivo* clinical testing. Subjects walked over level ground at self-selected, slow, and fast speeds, and walked up and down ramps. Subjects walked first in the single-keel foot and then in the multi-keel foot. Kinetic and kinematic data were collected for each activity and foot condition.

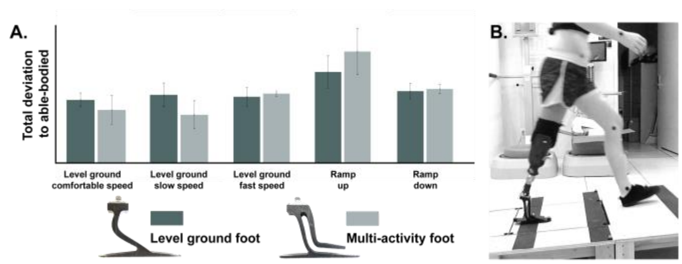

Fig. 1. Clinical evaluation of two LLTE-optimized prototype feet for one subject. A) Plot showing the total kinematic and kinetic deviation to the able-bodied target walking pattern for each foot condition. B) Photo of a subject walking up the instrumented ramp with the multi-activity foot prototype.

III. Results and Discussion

Preliminary data is included in Fig. 1, and we will present the remaining data at Dynamic Walking. We will first use this data to validate the constitutive model for the multi-keel architecture and then evaluate the ability of the LLTE multi-activity framework to quantitatively design prosthetic feet for multiple walking activities. We anticipate results will show that users more closely replicate able-bodied walking patterns in a variety of activities when wearing the multi-keel foot, which was designed for multiple walking activities, compared to the single-keel foot, which was only designed for level ground walking. These results will demonstrate that prosthetic feet designed for multiple activities have better LLTE values across multiple activities and improved clinical outcomes compared to prostheses designed only for level ground walking.

References

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