Asymmetry, Instability and Functional Deficits in Transtibial Prosthesis Users During Squatting, Lifting and Sit-to-Stand

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Introduction

Lower limb prosthesis users (LLPUs) experience mobility challenges that can impair their ability to carry out activities of daily living, affecting quality-of-life and independence [1]. The vast majority of LLPUs use a passive ankle-foot prosthesis where the ankle joint or foot keel is locked at a fixed angle relative to the shank. Extensive research has characterized the ability of these devices to replicate biological movement and function during walking [2]. However, it is less well understood how conventional prosthetic feet perform during functional transitions and other movements, such as standing up from a chair, picking up an item off the ground, or squatting down. These tasks involve ankle and/or toe flexion in healthy individuals–degrees of freedom that are not included in most passive prosthetic feet. We expect that the lack of ankle and toe joint mobility may contribute to the task performance deficits LLPUs experience. For instance, prosthetic device limitations may lead unilateral LLPUs to perform tasks in a highly asymmetric manner; overloading their intact lower limb and thus contributing to overuse injury or degenerative joint disorder risks. Prosthetic design modifications could potentially improve their comfort, safety, and ability to complete these tasks without overloading their intact lower limb. To investigate this, we aim to (1) characterize lower limb loading asymmetry, stability, and functional deficits of LLPUs during essential everyday movements while wearing their prescribed passive ankle-foot device and (2) investigate if prosthetic design modifications improve symmetry and perceived stability, or overcome functional deficits. We predict that restoring ankle flexion will improve functional movements such as squatting and lifting and toe flexion will assist in lunging and reaching tasks.

Methods

Through reviewing the scientific literature and interviewing local LLPUs, physicians, and prosthetists, we identified several tasks that LLPUs completely avoid or find challenging, and have the potential to be improved by modifying prosthetic ankle-foot design. We are now conducting a comprehensive human movement study evaluating transtibial LLPUs during these identified tasks: sit-to-stand (and stand-to-sit), lifting, squatting, lunging, and reaching. To address the first objective, we are collecting data with users performing variations of all tasks in their prescribed passive prosthesis. We then use the Vanderbilt Powered Ankle [3] to emulate specific device design modifications that are expected to improve the ability of LLPUs to complete these tasks, i.e., adding ankle and/or toe articulation. For each task, we are collecting participant feedback on perceived effort, stability, and comfort in addition to collecting full motion capture (Vicon) and ground reaction force (GRF; AMTI) data.

Results and Discussion

Preliminary vertical GRF data from one participant performing representative sit-to-stand, lifting, and squatting tasks wearing his prescribed prosthesis (Fillauer AllPro) is presented in Figure 1. During each of these tasks, the participant's intact lower limb experienced forces more than twice the magnitude of force on their prosthetic limb. This was consistently seen across multiple trials and variations of these tasks. In pilot testing using the powered prosthesis, there were noteworthy improvements in subjective feedback related to effort, stability and comfort when utilizing increased ankle dorsiflexion during the sit-to-stand task (Fig. 1B). Data collection is ongoing with expanded analyses (e.g., stability, lower limb joint kinematics/kinetics) expected to be completed for multiple subjects prior to the conference.

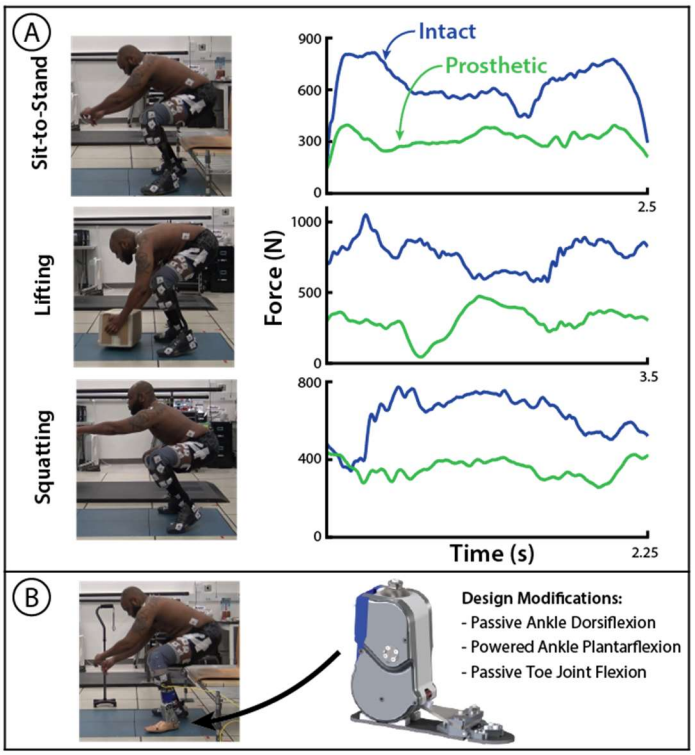

Figure 1: (A) Transtibial LLPU performing sit-to-stand, lifting (10 kg), and squatting wearing his prescribed prosthesis with corresponding vertical GRF. (B) The Vanderbilt Powered Ankle allows us to investigate device modifications by modulating ankle and toe mobility.

Significance

Biomechanical assessments of functional movement deficits in LLPUs are lacking. Understanding how users complete these tasks in their current passive devices and identifying prosthetic design modifications that increase functional ability is an essential step towards improving the standard of care for LLPUs. New devices that increase stability, symmetrical loading, and/or comfort could lead to reduced falls and overuse injuries.

Acknowledgments

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References

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