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Proportional Myoelectric Control of a Bionic Lower Limb Prosthesis with Series Elastic Actuator

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Introduction

Robotic lower limb prostheses enable mechanical emulation of human gait biomechanics, but more biomimetic controllers are needed to achieve dynamic and agile locomotion. Traditional state-based controllers offer a finite number of movement options which make it difficult to adapt to different daily activities, postural challenges, and terrain [1, 2]. In contrast, proportional myoelectric control uses signals directly from a prosthesis user to modulate ankle position and mechanical power output [3]. Our purpose was to develop a proportional myoelectric lower limb prosthesis with a series elastic actuator that allows testing of different prosthetic controllers in real-world environments.

Methods

We developed a bionic transtibial prosthesis using a series elastic actuator (Apptronik P170 Orion) controlled by surface EMG mounted on the gastrocnemius within the socket. The controller produced a motor current proportional to rectified, low-pass filtered EMG of the subjects' gastrocnemius. A male subject age 66 with transtibial amputation practiced treadmill walking with the prosthesis under proportional myoelectric control and visual feedback over multiple testing sessions. We collected kinematic, kinetic, and electromyography data across 7 training sessions.

Results and Discussion

With our proportional myoelectric controller, the subject modified their gastrocnemius activity over the course of training to modify the mechanical output of the bionic prosthesis. **Figure 1** depicts the subjects's initial muscle activity walking with the device compared to after seven sessions with visual feedback. The subject learned to produce a large burst of muscle activity during stance to produce ankle plantar flexion.

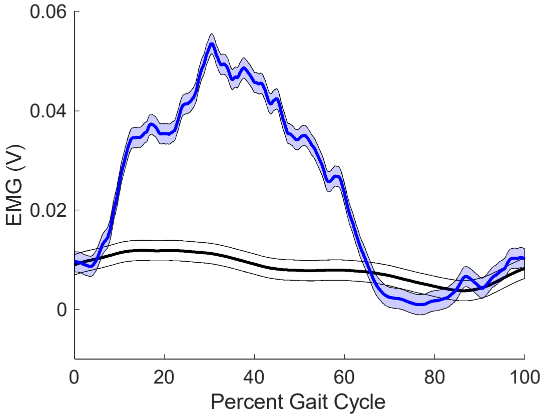

Figure 1: Low-pass filtered gastrocnemius EMG averaged over 10 steps at 0.6 m/s. Black line shows data after 15 minutes practice. Blue line shows data after multiple training sessions with visual feedback. Shaded regions represent 1 SD.

The subject was able to produce plantarflexion pushoff across multiple walking speeds with the prosthesis (**Figure 2**). At 1.0 m/s, the peak plantarflexion at the end of stance occurred earlier than the slower speeds. Walking at faster speeds required training, likely due to the motor adaption in timing of muscle activity. These results suggest that the method of gait training likely plays an important role in learning how to emulate intact lower limb biomechanics with a bionic prosthesis under proportional myoelectric control.

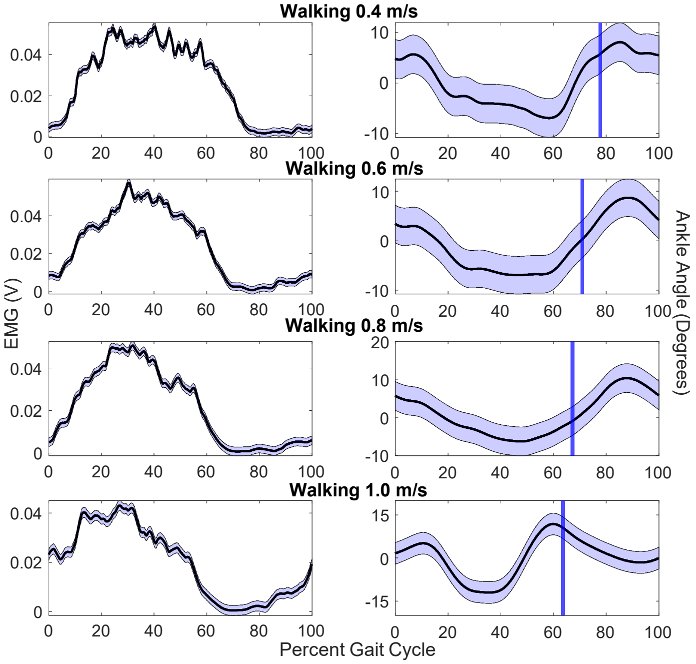

Figure 2: Low-pass filtered gastrocnemius EMG (above left) and prosthesis ankle angle (above right) averaged over five steps across multiple walking speeds (0.4, 0.6 , 0.8 and 1 m/s). For ankle angle, 0 degrees is standing angle and negative is plantarflexion. The vertical blue lines indicate toe off timing for the prosthesis side. Shaded blue region represents 1 SD.

Significance

Three-quarters of daily human walking bouts are less than 40 steps and <1% take more than two minutes [4]. There is a need for bionic prosthesis controllers that can handle non-periodic, volitional movements to enhance maneuverability [1,2]. Adapting feedforward commands from users via proportional myoelectric control allows users to adapt to a wide range of tasks, conditions, and terrain. We are modifying the prosthesis for wireless locomotion outside of lab environments to study how users modify EMG control signals in the real world.

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References

[1] A. Fleming et al. (2019) IEEE Trans Neural Syst Rehabil Eng, 27(7): 1473-1482.
[2] M. Windrich, et al. (2016) Biomed. Eng. Online, 15:140.
[3] S. Huang, et al. (2014) J. Med. Devices, 8(2):024501-024506.
[4] M. S. Orendurff, et al. (2008) JRRD, 45:1077–1090.