Manipulating self-selected gait patterns with an adaptive exoskeleton

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1 Motivation

Neurological injuries, such as stroke, result in weakened neural connections to distal muscles, specifically those that act about the ankle. Consequently, post-stroke patients experience gait deficiencies, which reduce stability and increase the overall energetic cost of walking [1,2]. Gait rehabilitation techniques have been developed to help patients relearn normal gait patterns by encouraging active engagement of the affected limb and muscles, with the hopes of improving day-to-day functionality and quality of life. However, these techniques still leave room for improvement.

2 State of the Art

The current state of the art in gait rehabilitation is manual assistive therapy, in which multiple physical therapists help move a patient's leg through a desired trajectory while verbally motivating active engagement. This approach, though effective, is physically laborious and expensive, thereby reducing the duration and intensity of rehabilitation sessions [3]. Robotic gait trainers have been developed to try to overcome the shortcomings inherent in manual assistive therapy. These devices, however, result in passivity as patients utilize the repetitive, robust nature of the trajectory following the robots perform and completely disengage their own muscles [4]. Our goal is to develop a robotic rehabilitation tool that addresses the downsides of manual assistive therapy while still attaining active use of the affected muscles and achieving the same, if not better, rehabilitation outcomes.

3 Own Approach

We have developed an ankle-foot orthosis (AFO) that is capable of producing large plantarflexor torques during stance. We want to utilize this device to manipulate the cost landscape and entice people to adopt new gait patterns. Specifically, for this study, our goal was to first create a situation in which walking with increased muscle activity was more energetically efficient than walking with normal levels of muscle activity due to the amount of assistance provided by the device. If we were successful at creating such a scenario, we wanted to use this result to alter the cost landscape such that a fully-assisted gait with increased muscle activity corresponded to the new metabolic minimum. We used the subject's muscle activity to control the level of assistance provided by the device. If the subject increased muscle activity above a baseline threshold, the device provided assistance. Otherwise the device remained passive. We were interested in observing if people would self-select to walk with the new energetically optimal gait, i.e. increased muscle activity plus full assistance.

Our approach is unique and potentially favorable because we are trying to tap into and harness innate tendencies rather than demand behaviors, namely gaits, which are unnatural.

4 Current Results

We can successfully manipulate the cost landscape such that minimum energy corresponds to walking with a new muscle activity pattern, specifically increased use of plantarflexor muscles in the unassisted limb (Figure 1). This result is possible because the energetic benefits afforded by the assistance outweigh the energetic costs of increased muscle use.

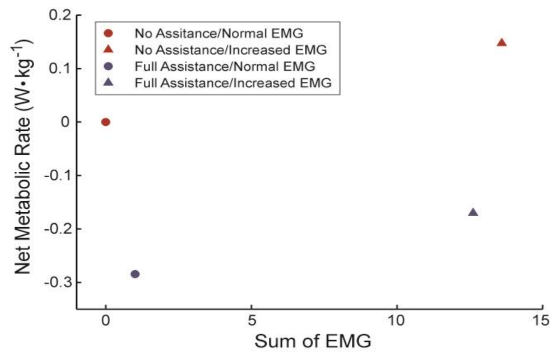

Figure 1. 2x2 results for n = 6 subjects. Muscle activity is defined as the integral of plantarflexor EMG of the unassisted limb over stance time.

The results of the enticement experiment were not so clear. Although we were able to show that walking with full assistance and increased muscle activity was the most energetically efficient gait, very few subjects self-selected such a gait. Instead, most subjects reduced their muscle activity and rejected the assistance.

5 Best Possible Outcome

Ideally we want to develop a technique that entices, or less-favorably forces, subjects to naturally self-select a new, desirable walking pattern. For our study, and for the purpose of rehabilitation, this would correspond to a gait with increased muscle activity. Such a technique could be used for gait rehabilitation.

Acknowledgements

This work is supported by NSF.

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