Effects of exoskeleton assistance applied to the sound leg of individuals with unilateral amputation during walking

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Summary
Higher energy expenditure and asymmetric gait is commonly observed in individuals with lower-limb amputation. Such changes in biomechanics limit mobility, lead to early joint degeneration, and reduce overall user quality of life. Powered assistive devices could potentially alleviate these limitations. Here, we present our approach to optimizing ankle exoskeleton assistance to the intact limb of individuals with unilateral transtibial amputation. We propose that such assistance may reduce peak forces experienced by the sound limb, improve gait symmetry, and reduce overall user energy expenditure.

Introduction
Individuals with unilateral lower-limb amputation often incur greater energetic costs and exhibit pronounced gait asymmetries during walking [1], especially when using passive prosthetic devices. Moreover, gait asymmetries such as longer stance durations [2] and greater ground reaction forces on the sound side [3] are often associated with joint pain and greater instances of osteoarthritis [4]. Active prosthetic devices (e.g. [5]), as well as assistive devices for the unaffected limb (e.g. [6]), could potentially mitigate high ground reaction force magnitudes, improve symmetry, and reduce user energy expenditure. In particular, an ankle exoskeleton device has been shown to significantly reduce the energetic cost of walking for unimpaired individuals when assistance profiles were optimized to each user [7]. To this end, we propose to evaluate the effect of optimized sound-side ankle assistance on the energetic cost and gait symmetry of participants with a unilateral transtibial amputation during walking.

Methods
We will implement a previously developed optimization strategy [7] to systematically adapt exoskeleton assistance to the unaffected leg of participants with unilateral transtibial amputation. All experiments will be conducted using a tethered, experimental ankle exoskeleton device (Fig. 1), that will provide plantarflexion assistance during stance [8]. The control optimization strategy will aim to reduce user energy expenditure during walking by updating the four parameters that will define the assistive torque profile of the device. Participants will walk with their prescribed prosthesis and the exoskeleton on their sound leg for 15 optimization bouts, spread over multiple days of testing and about 18 minutes long each, to ensure proper control optimization and user acclimatization to device assistance. After 6, 9, 12, and 15 bouts of optimization we will evaluate user performance during normal walking, walking with the unpowered device, walking with the device providing the optimized torque profile, and with the device providing the optimized torque profile from the previous set of optimization bouts (when available). Evaluated performance measures will include energy expenditure, ground reaction forces, and joint powers for the affected and unaffected limbs.

Preliminary Results and Discussion
At this point, we have completed 12 bouts of optimization with one participant. Evaluations after 6, 9, and 12 bouts of optimization have demonstrated an energy expenditure reduction of up to 14% when walking with the assistive device compared to walking with normal shoes. Further testing will evaluate the repeatability of such energetic reductions. In addition, ground reaction forces of the sound leg exhibited lower peak magnitudes and higher symmetry when plantarflexion assistance was available. In the upcoming months, we plan to test at least 5 more participants in order to evaluate the general effects of ankle assistance to users with lower-limb amputation.

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References