REDUCING LOADING ON THE CONTRALATERAL LIMB USING HUMAN-IN-THE-LOOP OPTIMIZATION

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Introduction

In most everyday activities, we head towards a specific goal by updating our choices for a more direct path. For instance, when navigating toward a tall building, we can constantly update our road selection to get there. However, there are specific clinical tasks where taking the direct path is more challenging. Clinical investigations of optimizing a prosthesis involve the assessment of multiple parameter settings through trial and error rather than goal-directed optimization.

Human-in-the-loop optimization algorithms allow devices to directly change in response to physiological changes (i.e., metabolic cost) of the user [1]. This methodology has proven very useful in advancing the optimization of robotic exoskeletons [2]. However, to our knowledge, this method has not yet been used for applications that involve manual alterations to a device. We investigate if a human-in-the-loop optimization algorithm can guide manual alterations to a prosthesis-simulating device to reduce the ground reaction force on the contralateral limb [3]. We hypothesized that the optimal parameter setting would reduce the loading rate on the contralateral limb compared to the initial tested parameter setting. If effective, this method could reduce the time taken for prosthetic fitting consultations.

Methods

To simulate walking with a prosthesis, eight healthy participants were asked to walk with a knee-crutch. Participants walked on the treadmill at $0.8 ms^{-1}$ while wearing the knee-crutch for a minute for each different parameter setting. After completing a parameter setting, the human-in-the-loop optimization algorithm prescribed modifications to make to the device (e.g., adjusting the pylon height, etc.). The optimization algorithm used parabolic fitting to continuously estimate the settings that minimize the objective parameter, analogous to a ball rolling towards the lowest point of a valley (Figure 1). In this instance, the objective was to find parameter setting that produces the lowest loading rate of the ground reaction force.

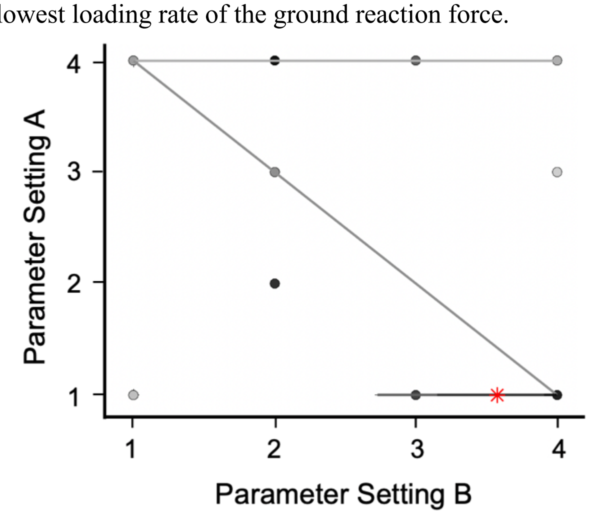

Figure 1: Example from one participant progressing from an initial parameter setting (light grey) to a final parameter setting (black). The circles, line, and asterisk represent the tested conditions, updates of the estimated optimal, and the final estimated optimal, respectively.

Results and Discussion

We used a paired t-test to determine if there is a reduction in loading rate from the initial parameter setting toward the optimal parameter setting. In most participants, the optimal condition reduced the loading rate on the contralateral limb compared to the initial condition tested (*P*<.061, Figure 2). However, when the first condition was already close to the optimal, the algorithm produced no further decrease in the loading rate, as expected.

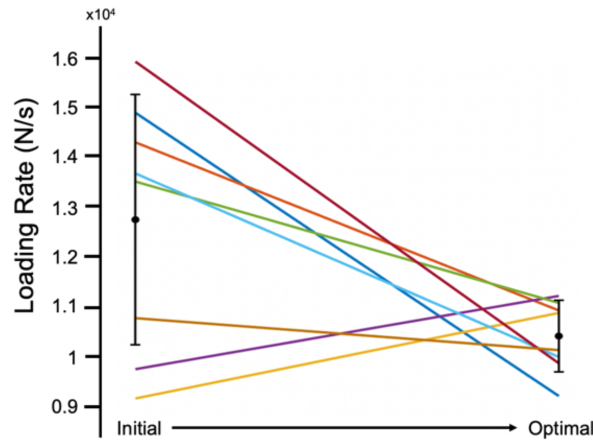

Figure 2: Comparison of the loading rate from the initial parameter setting to the optimal parameter setting from the optimization algorithm. Each participant is represented by a different color.

Significance

These preliminary outcomes suggest that human-in-the-loop optimization could guide prosthetic fitting procedures for reducing the loading rate on the contralateral limb. Additional analyses revealed several challenges. For example, we observed high variability in loading rates of repeated parameter settings. In contrast to exoskeletons, where the changes are made in real-time, participants were required to stop walking to make manual adjustments. This could explain some of the variability. Further analyses are needed to determine if developed methods could save time compared to a trial-and-error approach and if the results are applicable in persons with an actual amputation.

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