Can we escape optimization purgatory? A study on whether people are sensitive to customized versus generalized exoskeleton assistance

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I. Introduction

Optimized exoskeleton assistance can produce large metabolic reductions [1]. However, human-in-the-loop optimization experiments are time consuming and have resulted in a wide range of optimized torque profiles [1-3]. Even when normalized to body mass, the optimized torque magnitudes for one participant have been as large as double the magnitudes of another [2]. These large differences may indicate that exoskeleton assistance is most effective when customized to the individual. Alternatively, they may suggest that there are a wide variety of useful assistance profiles. In this study, we tested if a user's personally-optimized assistance was more effective for them than optimized strategies for other participants or the average of strategies.

II. Methods

We studied if participant's metabolic reductions are sensitive to their customized hip-knee-ankle exoskeleton assistance. We used the previously optimized exoskeleton assistance [2,3] for the three participants (1F 2M, age 26-36 years, 60-90 kg, 170-188 cm, expert users). Participants walked in a hip-knee-ankle exoskeleton emulator [4] which applied their optimized assistance profiles, the optimized profiles of the other two participants, and the average of the three profiles (Fig. 1). We measured metabolic cost, muscle activity, applied exoskeleton torques, exoskeleton joint angles, and ground reaction forces.

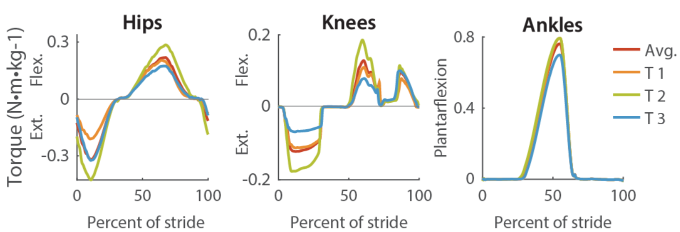

Figure 1. Applied torque profiles. Torque profiles were defined as a percent of stride. We applied the optimized profiles for participant 1 (orange), participant 2 (green), participant 3 (blue) and the average of the three (red) to all participants.

III. Results and Discussion

Participants experienced similar metabolic reductions for all tested profiles (Fig. 2), and two participants experienced the largest reductions with the average profiles. Relative to walking in the device without assistance, participant 1 experienced a 52% metabolic reduction (range 48%-53%), participant 2 experienced a 49% metabolic reduction (range 45%-51%) and participant 3 experienced a 39% metabolic reduction (range 38%-40%). The ranges of metabolic reductions are within noise levels of metabolic cost measurements. Participant 3 is 10 years older than the other participants and has had an ACL reconstruction surgery which may have contributed to the smaller metabolic reductions.

For expert users, it seems that there is a range of hip-knee-ankle exoskeleton assistance profiles that are equally effective. This could be useful for future exoskeleton products since they may not need to be customized to the individual. However, naïve participants may benefit more from customized assistance, for example lower torque magnitudes may be helpful for novice users.

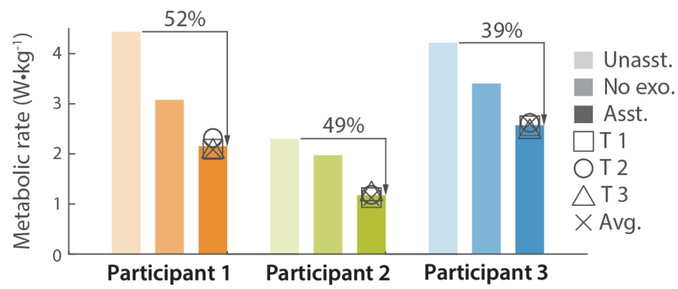

Figure 1. Metabolic rate for participant 1 (orange), participant 2 (green) and participant 3 (blue). The lightest shade represents metabolic rate while walking in the device without assistance, the medium shade while walking without the device, and the darkest shade while walking with the different assistance profiles. The symbols show the results of the individual profiles, where □ is the optimized profile for participant 1, ○ is the optimized profile for participant 2, Δ is the optimized profile for participant 3, and X is the average of the optimized profiles.

IV. Conclusion

A range of exoskeleton assistance profiles were equally effective to reduce the metabolic cost of walking. After optimizing exoskeleton assistance with enough participants, we may find generally effective assistance strategies that future exoskeleton products could use without further need for optimization.

Acknowledgment

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References

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