

OVERGROUND OPTIMIZATION OF ANKLE EXOSKELETON ASSISTANCE FOR SELF-SELECTED WALKING SPEED

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Introduction

As we age, our mobility decreases leading to decreased independence and quality of life. Self-selected walking speed (SSWS), a clinical measure of mobility, has been successfully increased in younger adults using a tethered ankle exoskeleton (exo) on a treadmill but the mechanism for this change is still unknown [1]. Humans intuitively minimize metabolic cost of transport (COT) when selecting walking speed, and rapidly discover novel optima when the COT landscape shifts [2]. In theory, ankle exo mechanical assistance could horizontally shift the COT landscape, placing the minimum at a faster speed, enabling users to converge on a faster SSWS. To increase translation for older adult communities outside the lab, we developed a novel, overground assistance optimization protocol applying an autonomous, commercially available ankle exo. We hypothesized optimal ankle torque assistance (Opt) will result in faster SSWS compared to walking in normal shoes (NoExo) by increasing minimal COT speed.

Methods

Users (N = 3M, 21+/-1 y/o, 66.6+/-2.89 kg, 1.79+/-0.05 m) were habituated to max-torque, spline-based ankle exo assistance (Fig. 1A) for 20 minutes on a treadmill and 200m overground. After habituation, we used a Surrogate Bayesian optimizer to generate torque control parameters seeking to maximize SSWS over 30 iterations by applying suggested optimal parameters and measuring the associated SSWS using a 4m walk test. Finally, SSWS was measured for NoExo and Opt in a validation session. To examine whether shifts in COT landscape drove changes in SSWS, users walked with Opt and NoExo conditions at 5 randomized speeds each (0.65, 1.0, 1.7, Opt SSWS, and NoExo SSWS) while we recorded metabolic cost. We normalized gross metabolic power by speed and mass to calculate COT (J/m/kg) then applied a quadratic fit to calculate the minimum COT speed for each condition.

Results and Discussion

Our novel overground HILO protocol to optimize ankle exoskeleton assistance provided torque profiles that increased SSWS by 8.4% compared to walking in normal shoes (Opt: 1.55+/-0.05 m/s; NoExo: 1.43+/-0.06 m/s) (Fig. 1B). Opt exo assistance increased COT at all speeds, with larger increases at slower speeds, re-shaping the COT curve and increasing the minimal COT speed compared to NoExo by 8.3% (Opt: 1.43 m/s; NoExo: 1.32 m/s). Interestingly, SSWS for each condition was faster than the minimum COT speed, but the shift in the minima on the new COT landscape mirrored the shift in SSWS (SSWS: 0.12 m/s; Min. COT speed: 0.11 m/s).

These results suggest our protocol can be used to personalize exo assistance to increase walking speed performance in community settings by shifting the speed that minimizes COT. Interestingly, increasing SSWS does not seem tied to reducing metabolic effort. We note SSWS was systematically faster than minimal COT speed, suggesting other factors may be important (e.g., local muscle fatigue, stability).

Significance

This is the first demonstration that an exoskeleton can be optimized to impact SSWS while user's freely select gait overground. This feasibility study suggests a framework for individualization of exo assistance that can be successfully conducted outside the lab. Future interventions for older adults should focus on decreasing COT at faster speeds to further increase SSWS.

Acknowledgments

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References

- [1] Song et al., 2019 *IEEE Trans Neural Syst Rehabil Eng* 29
- [2] Selinger et al., 2015. *Curr Biol* 25

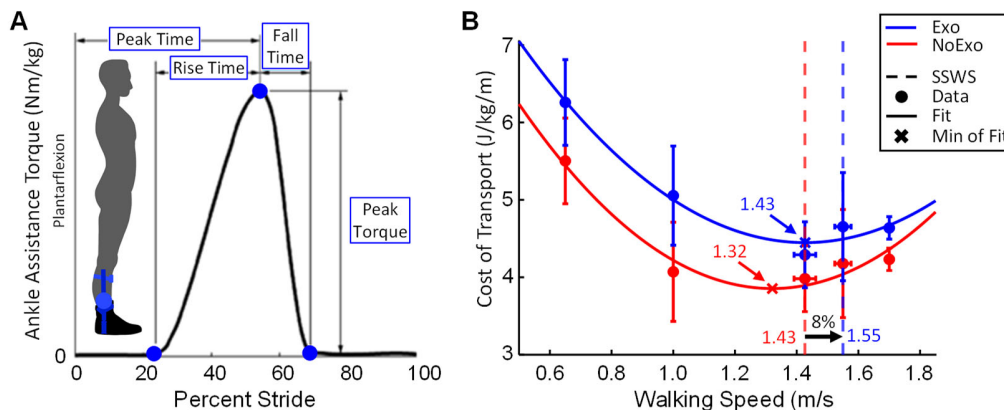


Figure 2: (A) Ankle exoskeleton torque profile and optimization parameters applied at each gait cycle. (B) Metabolic Cost of Transport (COT) across walking speeds with optimized ankle exoskeleton assistance (Exo) (blue) and NoExo (red). Across-participant (N=3) averaged data points shown for each condition and speed. A quadratic curve was fit for each condition across speeds. Self-selected walking speed (SSWS) averaged across participants is shown for each condition.