Should Ankle Exoskeletons Also Provide Assistance During Swing Phase?

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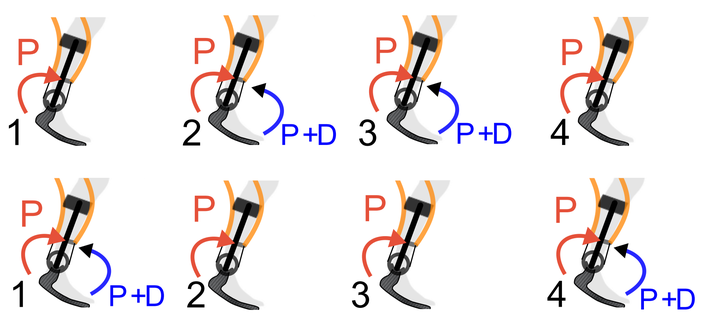
Introduction

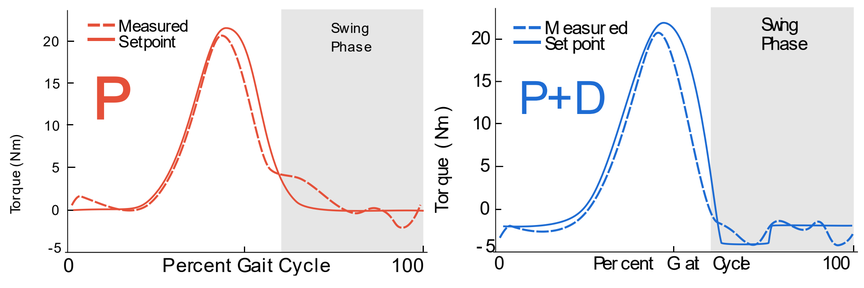
- Powered exoskeletons have the potential to enhance human locomotion, yet optimizing assistance strategies remains a challenge [1].
- While many successful exoskeletons are tethered, untethered devices that improve metabolic efficiency are rare [2-4].
- Understanding individual responses to assistance can refine control strategies and maximize benefits [5].
- **The goal of this study** was to determine the effects of adding swing phase dorsiflexion assistance when walking with stance phase plantar flexion assistance, comparing metabolic power, muscle activity, and gait mechanics to inform personalized exoskeleton design.

Methods

- A lightweight, bilateral exoskeleton assisted both plantar and dorsiflexion. Maxon brushless DC motors drove a carbon fiber footplate.
- Participants a zero-torque condition and then one of two testing orders: either (A) plantar flexion assistance first, followed by combined plantar and dorsiflexion assistance, or (B) the reverse. Both groups completed a final zero-torque trial.
- Real-time calorimetry, surface EMG, and motion tracking (during the sixth minute) were used to assess metabolic power, muscle activity, and gait mechanics.

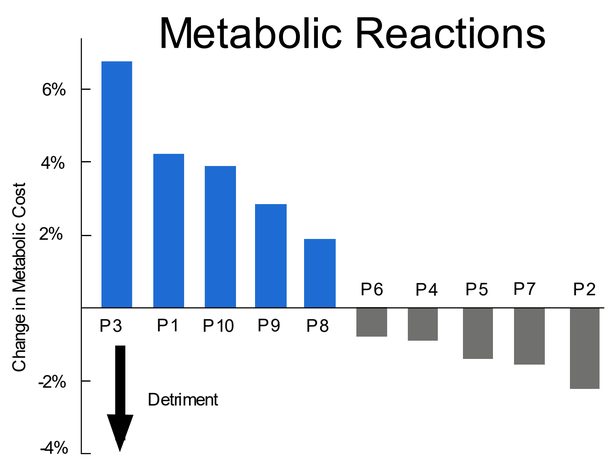


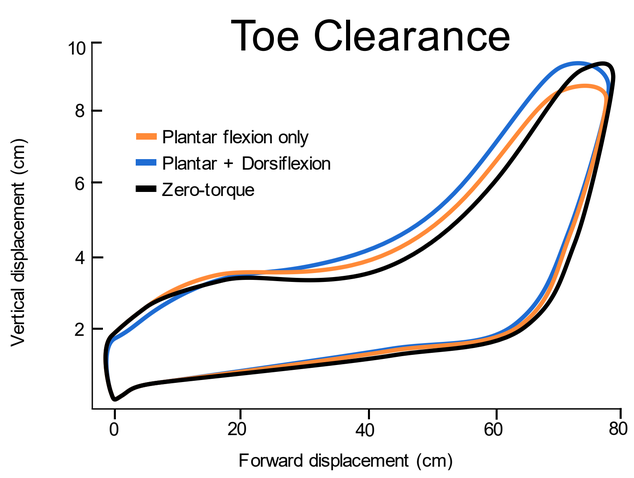




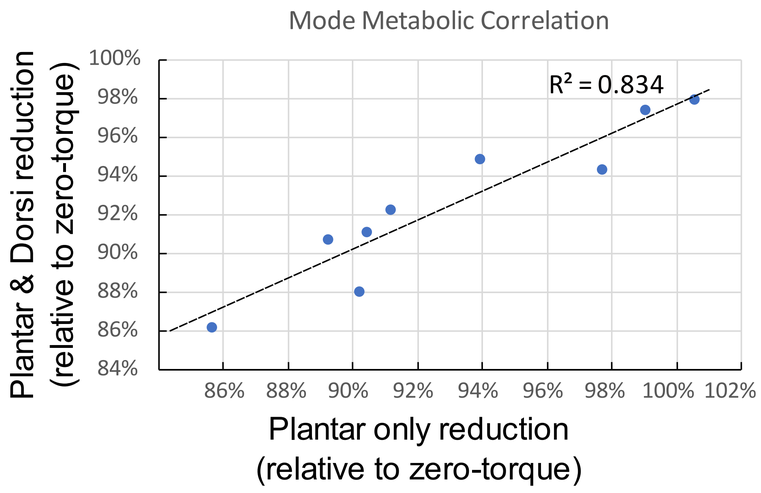
Results

Plantar flexion-only assistance reduced metabolic power by 10.66% ($p = 0.003$), while adding dorsiflexion assistance improved it by 12.51% ($p < 0.001$) compared to the zero-torque condition. No significant difference was found between the two assistance modes ($p = 0.051$), with individual responses varying. Muscle activation and toe clearance remained similar across conditions ($p > 0.05$). Joint kinetics and dynamics showed no significant differences in hip, knee, or ankle excursion.





Individual responses to exoskeleton assistance varied, but a strong correlation (CC = 0.913, R^2 = 0.834) was found between metabolic improvements in plantar flexion-only and combined assistance conditions.



This strong correlation suggests that users who benefit from one mode are likely to benefit from the other. While group-level differences in toe clearance and muscle activity were not significant, individual trends indicate potential for optimizing dorsiflexion assistance.

Conclusion

- While no significant group-level differences were observed, individual responses revealed promising avenues for future development.
- Personalized assistance, trust-building measures, and training protocols aimed at promoting beneficial movement strategies could significantly improve outcomes in powered exoskeleton use.
- These findings underscore the importance of tailoring exoskeleton systems to the unique needs and characteristics of users to maximize their potential for enhancing mobility and reducing metabolic cost.

References

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