Determining Metabolic Cost Reduction and Step-Time Asymmetry for Split-Belt Treadmill Walking and Wheeled Prosthesis

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Introduction

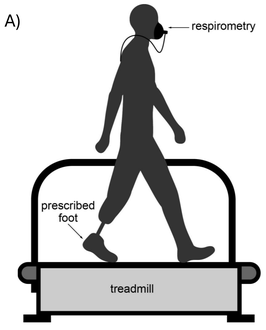
Individuals with lower-limb amputation experience higher walking energy cost and discomfort using traditional passive prostheses.

- Passive prostheses typically result in:
  - Slower preferred walking speed
  - Discomfort at the residual limb
  - Too little time on prosthetic limb
- Amputees experience a 20-30% higher energy cost.
- Powered ankle-foot prosthesis decreases the penalty only by 5-10%.

The goal of this study is to determine the metabolic costs of amputee split-belt walking with the prosthetic leg on the slow belt and a similar wheeled prosthesis.

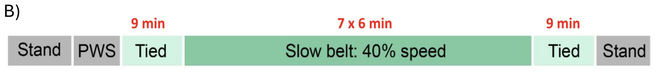
Methods

A)



b)

B)



C)

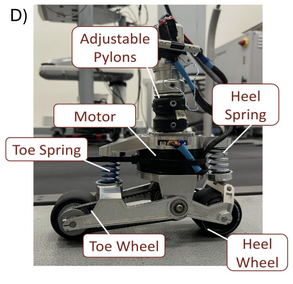
Split-Belt

- Ten adults with unilateral transtibial amputation and ten height-, mass-, sex-, and age-matched able-bodied controls completed a single experimental session.
- 40% ratio was achieved through pilot testing to maximize metabolic cost reduction.

Wheelie

- Six adults with unilateral transtibial amputation completed a single experimental session.
- Randomized the order of walking with the wheels locked, unlocked, and with the participant's prescribed device to minimize the effect of fatigue on data collection.
- For the bout with the wheels unlocked, the toe and heel wheels moved forward at 0.6 · PWS, so the participant experience walking at 0.4 · PWS, like the Split-Belt study (Fig. C).

D)



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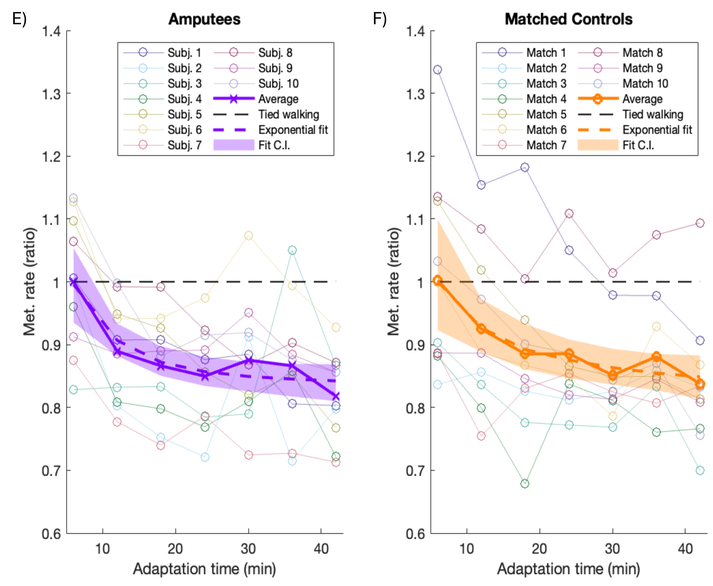
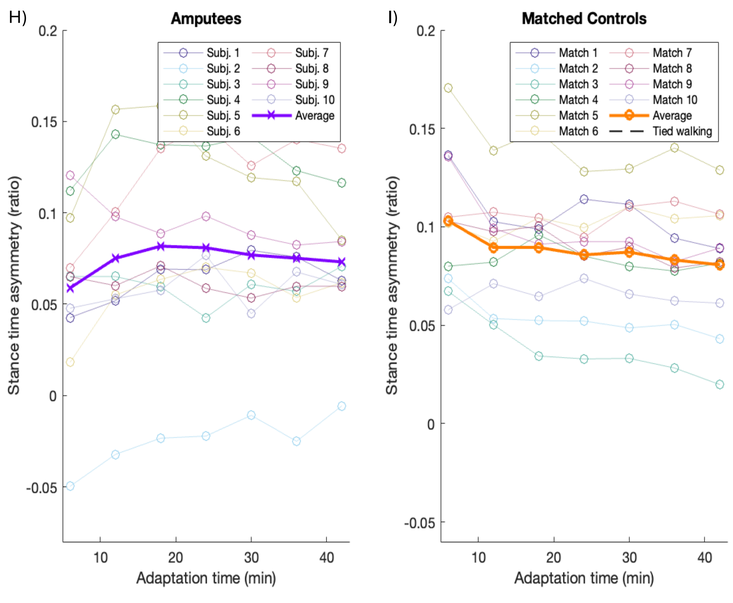
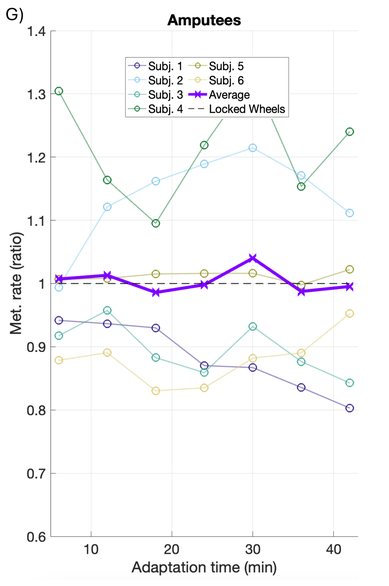
Results

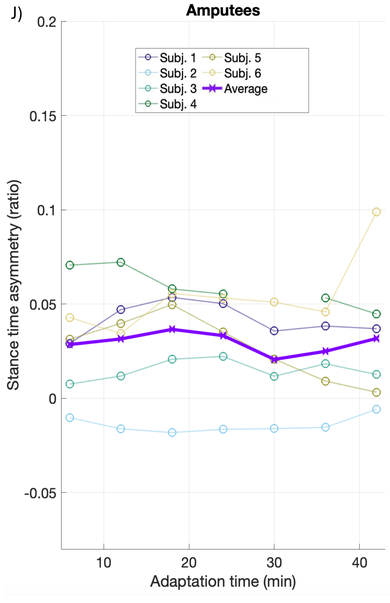
Split-Belt

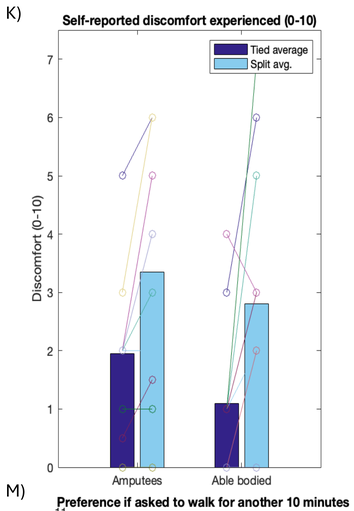


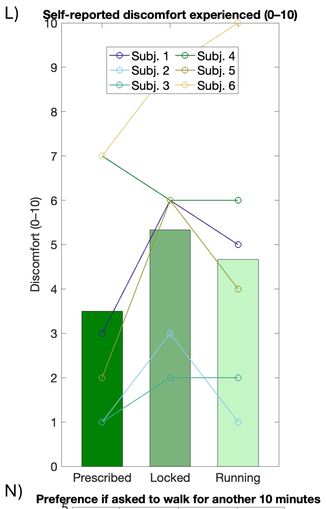


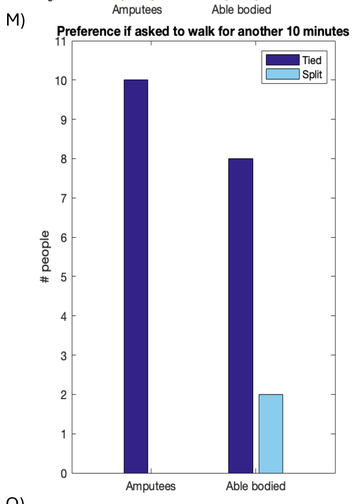
Wheelie

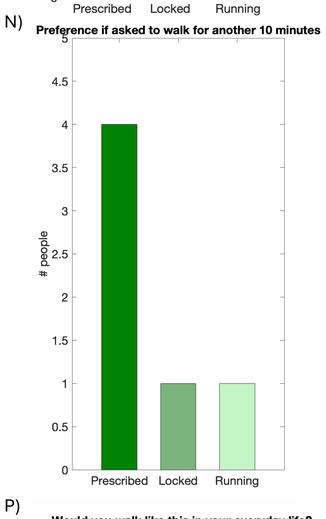


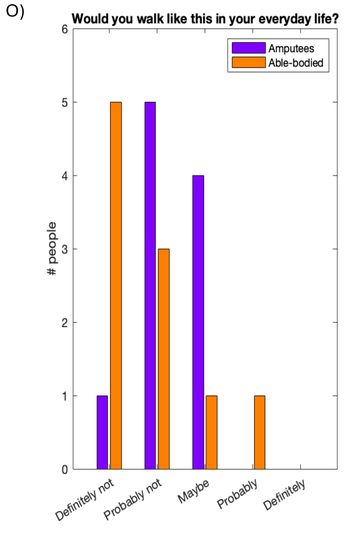


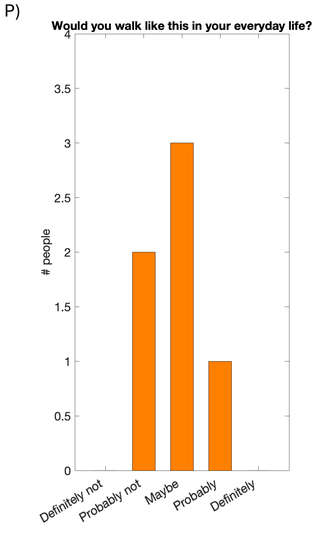












Results & Conclusions

- Net metabolic cost was reduced compared to tied walking by 18% ± 7% in amputees and 16 % ± 11% in able-bodied controls (p = 1.7e-05; Fig. E, F) for Split-Belt and 0.4% ± 14% for Wheelie (Fig. G).
- Stance time asymmetry (STA) was similar for Amputees and Matched Controls for Split-Belt, averaging between 0.05 and 0.1 (Fig. H, I). The average STA ranged between 0 and 0.05 for Wheelie (Fig. J).
- Discomfort rose by ~1–2 points in both Amputees and Matched Controls (Fig. K) in Split-Belt. Similarly, discomfort rose by ~1-2 points from prescribed devices (Fig. L) for Wheelie. 18 of 20 participants chose tied walking when offered an extra bout in Split-Belt (Fig. M), and 4 of 6 participants chose their prescribed device when offered an extra bout in Wheelie (Fig. N).

The discrepancy between Split-Belt and Wheelie could be from an internal contradiction: spending more time on Wheelie is needed to gain its benefits, but doing so causes imbalance, which increases energy spent on stabilizing rather than reaping those benefits.

Next Steps

- Translate asymmetric assistance into comfortable wearable devices so the metabolic advantages can be incorporated into amputees' everyday lives.

Acknowledgements

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