A Simple Exoskeleton That Assists Plantarflexion Can Reduce the Metabolic Cost of Human Walking

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1 Motivation

Even though walking can be sustained for great distances, considerable energy is required for plantarflexion around the instant of opposite leg heel contact.

2 State of the Art

Different groups attempted to reduce the metabolic cost of walking with powered exoskeletons (e.g. [1,2]) but none could achieve a reduction beyond the level of walking without exoskeleton, possibly because there is no consensus on the optimal actuation timing.

3 Own Approach

The main research question of our study was whether it is possible to obtain a higher reduction in metabolic cost by tuning the actuation timing.

Ten subjects (♀, 23±1 years, 1.70±0.03 m, 66±4 kg (s.e.m.)) walked with a simple pneumatic exoskeleton. The onset of the actuation was set at different increments of the stride cycle in different conditions. The offset of the actuation was fixed at toe off (~63%). We measured metabolic cost by means of respiratory gas analysis. In order to account for differences in actuation duration we also expressed the metabolic effects as a ratio versus exoskeleton power which is called exoskeleton performance index.

4 Current Results

We found a pattern in metabolic cost and exoskeleton performance index with an optimum timing that concurs with the prediction from the walking model of Kuo [3].

We also found that the exoskeleton can reduce metabolic cost by 0.18±0.06 W kg^{-1} or 6±2% (standard error of the mean) ($p = 0.019$) below the cost of walking without exoskeleton if actuation starts just before opposite leg heel contact.

5 Best Possible Outcome

While the present exoskeleton was not ambulant, measurements of joint kinetics reveal that the required power could be recycled from knee extension deceleration work that occurs naturally during walking. This demonstrates that it is theoretically possible to build future ambulant exoskeletons that reduce metabolic cost, without power supply restrictions.

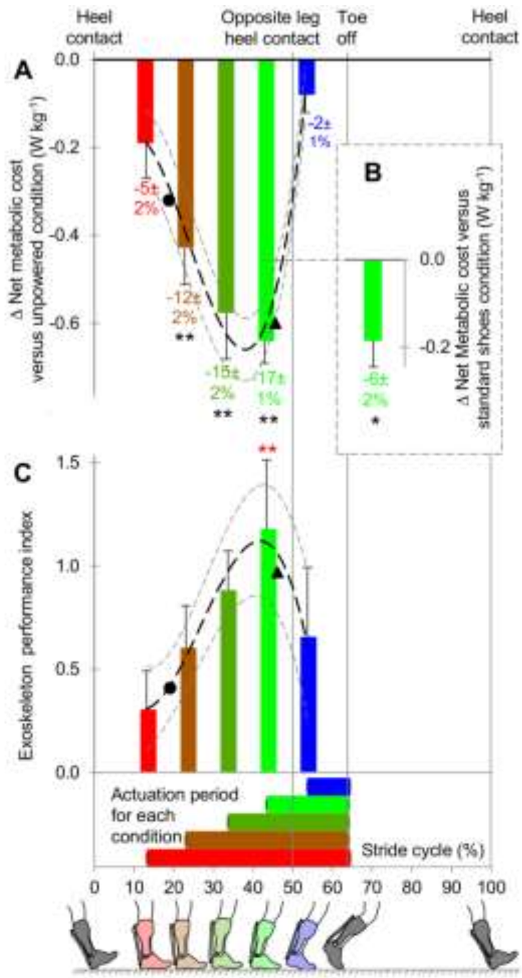

Fig. 1: (A) Δ Net metabolic cost versus unpowered condition. (B) 43% condition versus without exoskeleton. (C) Performance index. Horizontal bars indicate actuation duration. Vertical lines indicate heel contact and toe off. Filled circles (●) and triangles (▲) respectively indicate results derived from Sawicki and Ferris [1] and Norris et al. [2]. Error bars indicate inter-subject s.e.m. ** $p \leq 0.01$, * $p \leq 0.05$. From [4]

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References

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