Walking faster, not slower, decreases the energy needed to control balance

Wouter Muijres[1], Maarten Afschrift[2], Renaud Ronsse[3], Friedl De Groote[1]
[1]Department of Movement Sciences, KU Leuven, Leuven, Belgium
[2]Department of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands
[3]Institute of Mechanics, Materials, and Civil Engineering, UCLouvain, Louvain-la-Neuve, Belgium
Email: wouter.muijres@kuleuven.be

Summary

We compared perturbed walking to unperturbed walking to study the energetic cost of balance control. Increases in metabolic energy and alterations in kinematics and muscle coordination were larger at slow than fast walking speeds, suggesting that the energetic cost of controlling walking balance is higher at slower compared to faster walking speeds.

Introduction

There is a metabolic cost associated with controlling walking balance. The relationship between metabolic cost and balance control has been studied in the frontal plane by either stabilizing balance or perturbing sensory input using visual perturbations [1,2]. Increases in the metabolic cost of walking were associated with both anticipatory adjustments in step length or step width [1] and reactive adjustments in foot placement resulting in increased step length and step width variability [2]. However, for stabilizing walking in the sagittal plane, healthy adults also rely on reactive ankle torques, i.e. the ankle strategy [3]. In addition, the ankle strategy is used more at slow speeds, but it is unclear whether this is due to walking being inherently more stable at high speeds or the stepping strategy being used more at high speeds (because the shorter stance time limits the efficacy of the ankle strategy). In the first case, we would expect a lower cost for stabilizing walking at high speeds whereas in the second case, the metabolic cost for stabilizing walking at high speeds would not necessarily be lower if anticipatory or reactive foot placement strategies are indeed important determinants of metabolic cost. Here, we explored the metabolic cost of stabilizing walking in the sagittal plane across speeds and its relationship with balance control strategies.

Methods

Twenty-two healthy adults walked on a treadmill with and without quasi-random treadmill belt speed variations at 0.8, 1.2, and 1.6 m/s. We evaluated changes in metabolic energy consumption, mean step length and width reflecting the use of anticipatory gait adaptations, step length and width variability reflecting the use of a reactive foot placement strategy, and variability in ankle muscle activation reflecting the use of a reactive ankle strategy between perturbed and unperturbed walking. We explored the relationship between adaptations in metabolic cost and balance control strategies by studying intersubject variability using a linear mixed-effect model.

Results and Discussion

Metabolic rate increased due to perturbations (Fig. A). When perturbed, subjects took shorter, wider, and more variable steps (Fig. B-C) and variability in ankle muscle activation increased. This suggests that subjects used a combination of anticipatory and reactive foot placement and ankle strategies to stabilize walking (Fig. D). Perturbations induced larger increases in metabolic rate and changes in balance control measures at slower than faster walking speeds, suggesting that walking at higher speeds is inherently more stable. Metabolic rate increased more upon perturbations in individuals who reduced step length more, especially at lower speeds. This suggests that anticipatory adjustments to the gait pattern might be more costly than relying on reactive strategies.

Conclusions

Controlling walking balance is metabolically more costly at slower compared to faster walking speeds and when relying more on anticipatory step length adjustments. This has important implications for mobility-impaired individuals, who often walk at lower speeds, as well as for amputees who might need to rely more on anticipatory strategies due to the loss of the ankle strategy.

Acknowledgments

This project was supported by FWO (1SF7322N).

References

[1] Ahuja S. and Franz J. R. (2022). *Gait & Posture*, **96**:190–194.
[2] O'Connor S. M. et al. (2012). *Gait Posture*, **36**:102–107.
[3] Afschrift M. et al. (2021). *PLOS Computational Biology*, **17**:e1008369.

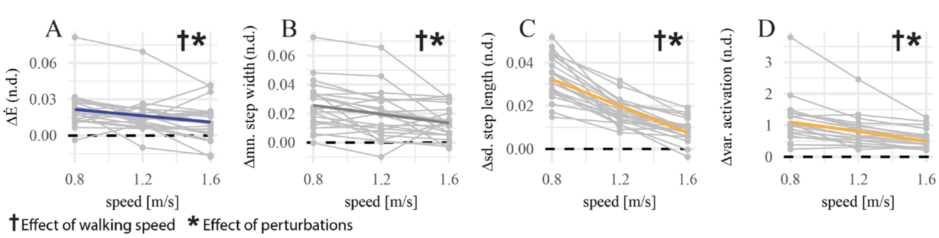

Figure: Pannels A, B, C, and D depict changes in metabolic rate, mean step width, standard deviation of step length, and the pooled standard deviation of ankle muscle activation in response to perturbations. We normalized the metabolic rate and step parameters.