Towards predictive neuromechanical simulations for pathological gait and assistive devices

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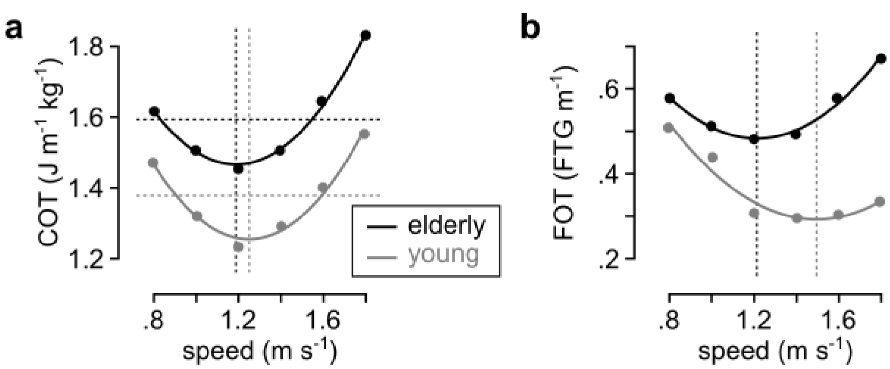
Introduction

Predictive neuromechanical simulations have a potential impact on understanding pathological gait and designing assistive devices. Although current computation and musculoskeletal modeling techniques allow us to make predictions for a given task based on optimality principles, the predictions are often different from human behaviors as the underlying neural controller is not correctly modeled. In previous work, we have proposed a spinal-reflex-based control model that can predict human locomotion in many aspects. The model generates diverse human-like locomotion behaviors such as walking and running on different terrains [1] and reacts to unexpected perturbations similarly to humans [2]. We present our work of extending this model to explain how physiological changes in aging affect gait performance [3] and to predict gait adaptation for ankle-exoskeleton assistance.

1. Neuromechanical model of elderly walking

We adapted the reflex-based neuromechanical model to study elderly gait. We applied segmental, muscular and neural changes observed in healthy people of 80 years old to the neuromechanical model, and investigated whether this elderly model explains the declined performance in elderly walking.

The elderly model consumes about 16% more metabolic energy across all walking speeds (0.8-1.8 m s^{-1}) than the original model (Fig. 1-a, COT: metabolic cost of transport). This result is consistent with elderly walking which is 15-30% more metabolic costly. We also found based on the muscle-fatigue criterion that the optimal walking speed of the elderly model is 0.28 m s^{-1} slower than the original model (Fig. 1-b, FOT: muscle fatigue cost of transport). This observation can explain why elderly people prefer to walk 0.2-0.6 m s^{-1} slower. Further analysis showed that changes in leg muscle properties are the main contributors to the decline in walking performance. We will further discuss the effect of specific muscular properties and the implications of our results.



2. Model prediction for ankle-exoskeleton assistance

We have made initial steps towards a simulation framework to predict how gait adapts to active exoskeletons. We implemented a bilateral ankle-exoskeleton in our neuromechanical simulation. The model can walk with a torque assistance optimized for a human subject, which has a peak of 52 N m around ankle push-off [4]. We will evaluate whether the model makes reasonable predictions for how humans adapt to exoskeleton assistance.

References

[1] Song and Geyer. A neural circuitry that emphasizes spinal feedback generates diverse behaviours of human locomotion. *The Journal of Physiology*. 2015.

[2] Song and Geyer. Evaluation of a Neuromechanical Walking Control Model Using Disturbance Experiments. *Frontiers in computational neuroscience*. 2017.

[3] Song and Geyer. Predictive neuromechanical simulations indicate why walking performance declines with aging. *The Journal of Physiology*. Accepted.

[4] Zhang, Fiers, Witte, Jackson, Poggensee, Atkeson and Collins. Human-in-the-loop optimization of exoskeleton assistance during walking. *Science*. 2017.