Modeling and exploring elderly walking with neuromechanical simulations

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Background

The walking of elderly adults have prominent features compared to that of young adults: higher metabolic energy cost and slower preferred walking speed. Understanding the physiological origin of these features is essential for enhancing the mobility of elderly people.

Despite previous efforts, the origin of both increased energetic cost (15-30% for the ages of 70-90, Fig-A, [1]) and slower preferred walking speed (0.2-0.5 ms^{-1} for the same ages) remains obscure. For example, it has been shown that none of the basal metabolism, mechanical work, and stability measures explain this inefficiency of elderly walking. Similarly, the cost of transport (CoT, metabolic energy cost per walking distance), a widely used criterion for preferred walking speed of animals, do not explain the slower preferred walking speed of elderlies, since the CoT-speed curve of elderlies does not shift towards slower speed (Fig-A). Identifying the origin of elderly gait remains a challenging problem, since it is difficult to control each physiological properties independently as all changes occur simultaneously along aging.

Methods

Neuromechanical simulations provide the opportunity of investigating the effect of individual physiological changes. To this end, we use a previously proposed spinal control model (that can generate various human locomotion behaviors [2] and explain disturbance reactions [3]), apply segmental, muscular, and neural changes commonly observed in healthy elderlies, and investigate the contribution of physiological changes to elderly gait in simulation.

Main Results

We find that, as observed in elderly gait, the model simulating the common physiological changes shows an increased CoT (16%, Fig-B). However, optimizing for CoT does not suggest a slower preferred walking speed. Instead, we find that a slower preferred speed (by about 0.25 ms^{-1}) in line with experimental observations emerges if the model is optimized for fatigue of transport (FoT, muscle fatigue per walking distance, Fig-C) or stress of transport (SoT, muscle stress per walking distance, Fig-D).

Our detailed model analysis of the contributing physiological changes further suggests that both the metabolic cost increase and the slower walking speed are mainly related to a reduction in muscle strength and mass in the elderly population. We also discuss the effect of other physiological changes and potential ramifications of these findings for improving mobility in elderlies.

References

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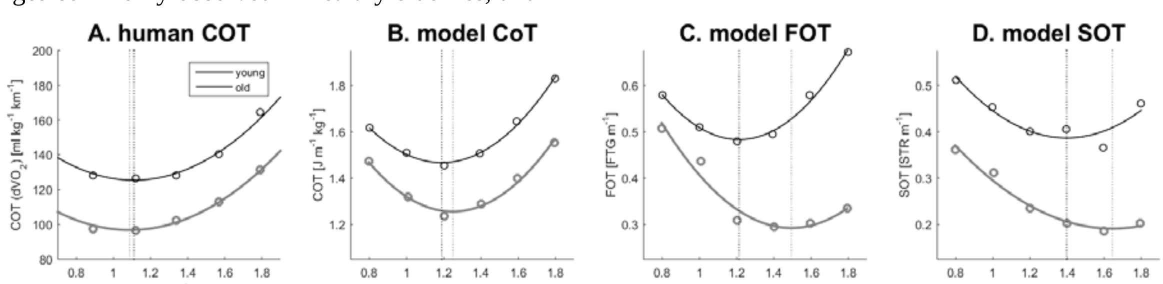

Figure. Human and model walking data. Walking data of young (gray) and elderly (black) adults are shown. The walking speeds of each minimum are marked with dotted lines. A. CoT of humans [1]. B. CoT of model. C. FoT of model calculated as square of muscle activations for walking distance, $\frac{\sum\int A^2 dt}{d}$. D. SoT of model calculated as square of normalized muscle forces, $\frac{\sum\int \bar{F}^2 dt}{d}$.