Step responses of self-paced treadmill controllers

Cesar R. Castano
Dept. of Mechanical and Aerospace Engineering
University of Central Florida
Orlando, FL
castanocesar@knights.ucf.edu

Helen J. Huang
Dept. of Mechanical and Aerospace Engineering; Bionic Materials, Implants, and Interfaces (Biionix) Cluster; Disability, Aging, and Technology (DAT) Cluster
University of Central Florida
Orlando, FL
hjhuang@ucf.edu

I. Background

Self-paced treadmills adjust their belt speeds to match a subject's self-selected walking speed whereas typical treadmills impose a set fixed speed that the subjects must match. There are multiple approaches for designing a self-paced controller. In general, level self-paced treadmills are successful in producing walking speeds of 1.1-1.4 m/s [1-4], which match overground walking speeds [5] and minimize metabolic cost [6]. However, walking speed variability for nearly the same walking speed could be up to 2x larger, depending on the self-paced treadmill controller and its sensitivity (Fig. 1A). To explore the behavior of different algorithms, we examined the responses of the "old" and "new" self-paced controller algorithms on a Motek Medical M-Gait treadmill to a single step and walking.

II. Methods

We used the "new algorithm" with low, medium, and high sensitivities [1] and the "old algorithm" [2] provided by Motek Medical in their D-Flow software version 3.28 for their M-Gait treadmill. We tested 2 conditions, taking a single forward step and walking. For the step condition, the subject (n=1) took a single step forward and then stood still on the treadmill belt, removing the person's response to the controller. For the walking condition, the subject started from a standing position and then walked at a comfortable pace. We collected motion capture (OptiTrack) and treadmill speed data. We estimated the center of mass (COM) position as the average of the four pelvis markers and differentiated COM position to get COM velocity.

III. Results

The single step condition revealed that the new algorithm had COM position oscillations that slowly decayed and had a long settling time, whereas the old algorithm produced rapid large adjustments to quickly settle to the steady state position (Fig.1B). The COM oscillations also increased in frequency with higher sensitivities. For the walking condition, the old algorithm had more frequent changes in the COM position, COM velocity, and treadmill belt velocity compared to the new algorithm (Fig. 1B), which could be because the old algorithm tries to quickly settle to the steady state position (Fig. 1A).

IV. Conclusion

Differences in the behavior of the self-paced controllers were evident in the response to a single step during which the person was not contributing to changes in their COM position relative to the treadmill. Step responses could help characterize and compare the behavior of various self-paced controllers.

Acknowledgments

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References

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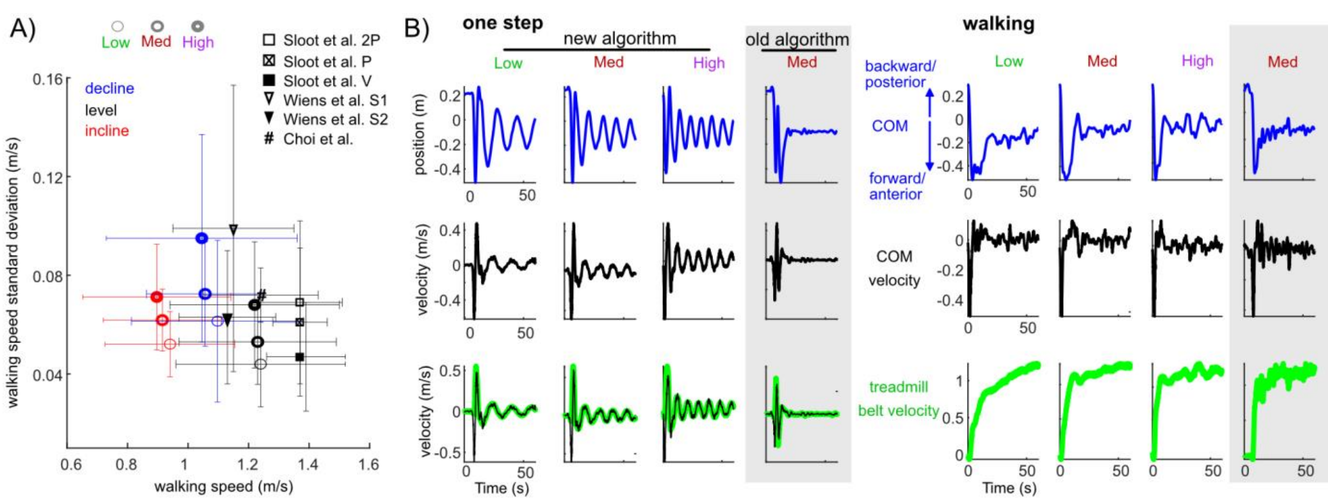

Figure 1: (**A**) Self-paced treadmill walking speed variability in previous studies and with (**B**) Motek Medical's "new" and "old" algorithm . Motek Medical's "new" algorithm controller sensitivities shown as low, medium (med), and high. Sloot et al. V, P, and 2P represent the three different controllers used in the study. Wiens et al. S1 (session 1) and S2 (session 2) are results based on a study that was performed on two separate days and published two separate results. The Sloot et al. study used a Motek Medical treadmill with the "old" self-paced algorithm. The Wiens et al. and Choi et al. studies used a custom written self-paced controller.