O0443

Increasing walking speed decreases the lower-limb endpoint wrench space: implications for fall prevention

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Abstract

Introduction:

According to the WHO, gait and balance disorders are a leading cause of falls, resulting in approximately 646,000 annual deaths globally. The significant and growing costs require a better understanding of normal gait and its disorders. During all human motion, the set of feasible neural command inputs is larger than the set of feasible mechanical outputs [1] and different sets of neural commands can achieve the same motion (e.g., walking at a selected speed). The culmination of mechanical actions that a multijoint system produces is the endpoint wrench space (EWS) [2], which bounds potential foot-to-ground (lower-limb endpoint) forces and moments necessary for fall prevention. We hypothesized that lower-limb EWS will decrease as walking speed increases.

Methods:

Experimental gait analysis data was collected from 7 subjects (7-18 yrs.) walking overground at extra slow, slow, free, and fast walking speeds [3]. We used a simplified OpenSim model with 10 degrees of freedom and 18 muscle-tendon actuators along with inverse kinematics to compute joint kinematics. EWS was determined for each frame of the gait cycle by the Minkowski sum of the columns of $\mathbf{w} = \mathbf{J}^{-T}\,\mathbf{R}\,\mathbf{F}$, where $\mathbf{J}^{-T}$ is the limb inverse transpose Jacobian (mapping joint torques to endpoint forces and moments), $\mathbf{R}$ is the muscle moment arms (mapping muscle forces joint torques), and $\mathbf{F}$ is the muscle strength (mapping maximal muscle activations to peak isometric muscle forces). Since vertical and horizontal reaction forces are critical in balance recovery, EWS areas were computed and then normalized against peak EWS for each subject across all trials. Paired t-tests identified significant differences in EWS area across speeds.

Results:

Increasing walking speed decreased average EWS for subjects in this study (Fig. 1a&b). During swing phase and the entire gait cycle, faster speed EWS's were significantly reduced from extra-slow-speed ones(p<.0001). During stance phase, on average, free-speed EWS's were greater than fast-speed and less than extra-slow-speed (p<0.001), but free-speed and slow-speed EWS's were not statistically different (p=0.161).

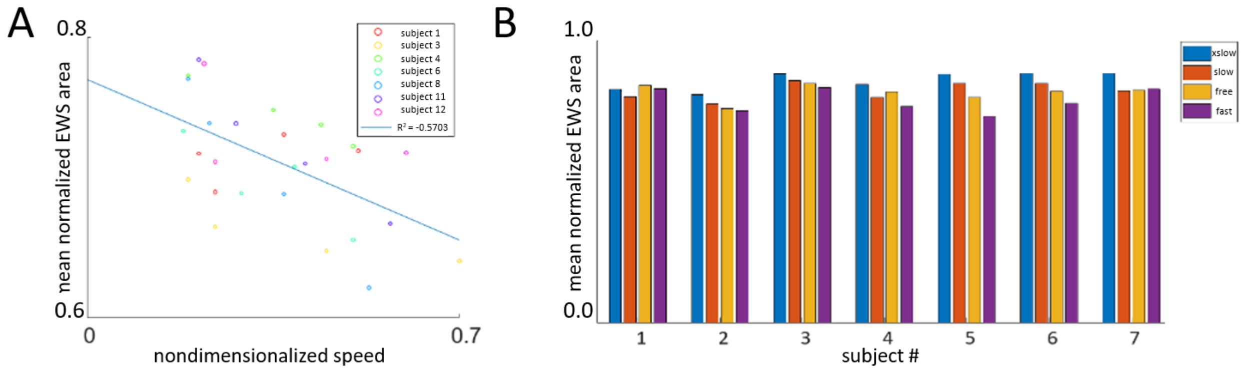

Fig.1: mean EWS plotted **(A)** against nondimensionalized walking speed **(B)** separated by subject and trial

Discussion:

Our goal was to identify the relationship between walking speed and EWS to better understand potential corrective forces necessary to prevent falls. Increasing walking speed substantially decreases the lower-limb EWS. We investigated EWS in the sagittal plane alone using pseudo-static approaches. Future work will investigate contributions of inertial forces and muscle physiology effects on three-dimensional EWS using models with more muscles and degrees of freedom to gain new insights and improve balance disorder treatments to prevent falls.

Acknowledgements:

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References:

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