DO HUMANS USE MUSCLE ACTIVATION OR ENERGY COST TO SELECT WALKING SPEED? WHAT WE CAN LEARN FROM ANKLE EXOSKELETON INTERVENTIONS

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Introduction: Although the cause of slower walking with age is still unknown, exoskeletons may provide a viable solution for rapid increases in mobility for older adults. Walking speed declines as we age and has been correlated to reductions in quality of life and independence. Humans typically walk at speeds that minimize energy consumed per unit distance (cost of transport; COT) but this may not hold in older adults [1]. Changes in metabolic cost per unit muscle activation accompanying the distal-to-proximal shift in lower-limb joint power output with age [2] may dissociate the relationship between COT and lower-limb cumulative muscle activity per distance (CMAPD) in older adults. The resulting divergence in CMAPD vs. COT cost landscapes could help identify the underlying mechanism driving self-selected walking speed (SSWS) in humans. Exoskeletons provide a tool to modulate the COT [3] and muscle activity needed to walk at a given speed. Together, measuring changes in COT and CMAPD with exoskeleton assistance applied to younger and older adults could determine whether COT or CMAPD better correlates with changes in SSWS. We hypothesize that changes in the CMAPD rather than COT optimal speed will better correlate with changes in SSWS due to exoskeleton assistance.

Methods: We used Dephy ExoBoots to apply assistive ankle torque to 3 younger adults (YA) and measured their overground SSWS without the exoskeletons (NoExo) and with optimized assistance (Exo). To compare optimal COT and CMAPD speeds, we measured whole-body metabolic cost and muscle activity in 8 lower limb muscles (tibialis anterior, soleus, medial gastrocnemius, vastus medialis, rectus femoris, biceps femoris, gluteus maximus, gluteus medius) across 5 different speeds ($SSWS_{NoExo}$, $SSWS_{NoExo}$ +/- 33% & 67%, and $SSWS_{Exo}$). We fit a quadratic curve to the COT & CMAPD data across speeds for each Exo condition per each participant. Using the optimal speed (i.e., speed at minimum COT or CMAPD) for each curve, we plotted the percentage difference (Exo from NoExo) in COT and CMAPD vs. percentage difference in SSWS and fit a linear regression to the across participant data.

Results & Discussion: Despite tuning to optimize exoskeleton (Exo) assistance for increased SSWS, upon validation we found that Exos did not change SSWS (Fig. 1 A&C). Nevertheless, Exo assistance did lead to measurable changes in the speed for min COT and min CMAPD (Fig. 1, A-D). Optimal speeds for min COT and min CMAPD were slower than the associated SSWS, likely due to measurement location (treadmill for COT and CMAPD, overground for SSWS). Overall, Exo use decreased COT at optimal speeds, increased COT at the slowest and fastest speeds (Fig. 1A) and did not have a large effect on CMAPD across speeds (Fig. 1C). Changes in optimal COT speed were negatively correlated with changes in SSWS (Fig. 1B), while changes in CMAPD were positively correlated (Fig. 1D). Overall, CMAPD more strongly correlated with changes in SSWS than COT.

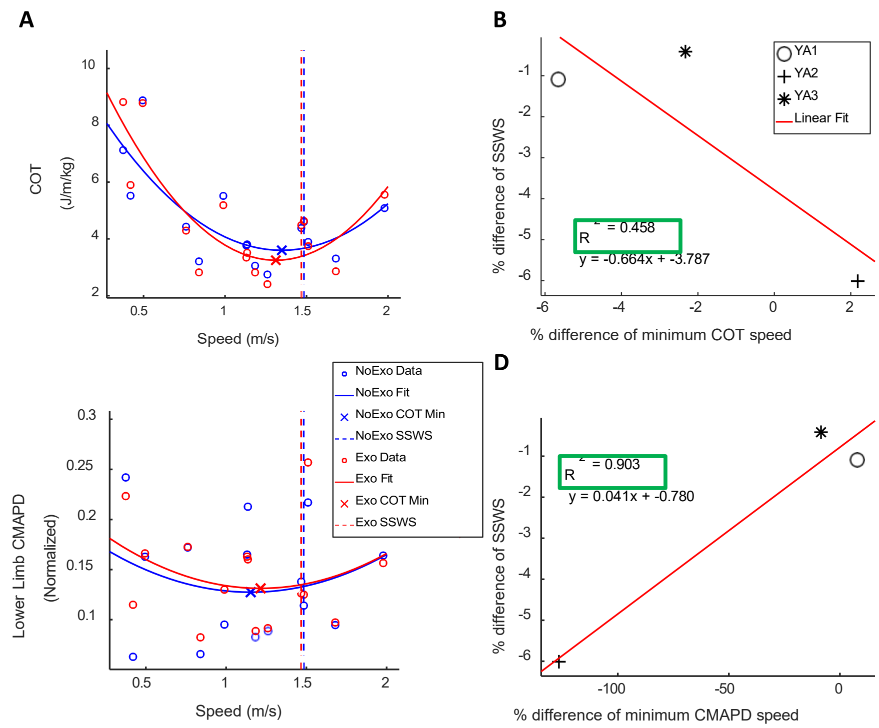

Figure 1: (A) COT vs Speed for all subjects (N = 3) for Exo (red) and NoExo (blue), each fit with a quadratic curve and its minimum marked. (B) Linear regression between percentage change between Exo and NoExo in optimal COT speed and SSWS per subject. (C) Lower Limb CMAPD vs Speed for all subjects (N = 3) for Exo (red) and NoExo (blue), each fit with a quadratic curve and its minimum marked. (D) Linear regression between percentage change between Exo and NoExo in optimal Lower Limb CMAPD speed and SSWS per subject.

Significance: Exoskeletons can be used to understand more about human behaviour by driving changes in users' physiological response. Here we have shown that COT may not be the best predictor for SSWS compared to CMAPD. This may be intuitive, as the body has no way of directly measuring energy consumption, but does have sensory organs that correlate with muscle loading (e.g., spindles, Golgi tendons). Interventions that reduce relative muscle activation (i.e., making muscles 'stronger') could more directly affect walking speed selection. A follow-up study with older adults that includes hip Exo assistance will compare changes in SSWS across target joints.

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