Speed-based changes to walking stability and economy may explain preferred walking speed after stroke

Louis N. Awad[1,2], Brian A. Knarr[3], Pawel Kudzia[2], Thomas S. Buchanan[4]

[1]Sargent College of Health and Rehabilitation Sciences, Boston University, Boston, MA, USA
[2]Wyss Institute for Biologically Inspired Engineering, Harvard University, Boston, MA, USA
[3]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE, USA
[4]Delaware Rehabilitation Institute, University of Delaware, Newark, DE, USA

Introduction. The preferred walking speed (PWS) of healthy individuals is typically the most economical and stable[1]; however, the PWS of individuals post-stroke is commonly not the most economical. Indeed, if made to walk faster, individuals post-stroke consume less energy per meter walked[2], suggesting that non-energy based optimization strategies underlie their selection of PWS. It is not clear if the complementary relationship between walking stability and the energy cost of walking (EC) that is seen in healthy bipedalism exists in the face of the neuromotor impairments characteristic of post-stroke hemiparesis. The objective of this study was to evaluate the effect of changing walking speed on both the walking stability and EC of individuals post-stroke. We hypothesized that walking stability and EC would have antagonistic relationships with walking speed such that walking faster than PWS would be less energetically costly, but more unstable and irregular, and walking slower than PWS would be more energetically costly, but less unstable and irregular.

Methods. Seven individuals post-stroke completed four 2-min trials of treadmill walking. Different speeds—PWS, a speed ~20% slower (Slow), a speed ~20% faster (Fast1), and a speed ~50% faster (Fast2)—were tested with a randomized order across trials. During each trial, EC was computed as mass-normalized oxygen consumption per meter. Concurrently, walking stability was measured using three approaches. The sample entropy (SE) and maximum Lyapunov exponent (LyE) of the time series of body center of mass (CoM) motion were computed to quantify, respectively, CoM regularity and stability across strides>. Additionally, the anterioposterior and mediolateral margins of stability (MOS) were computed to quantify CoM movement relative to the base of support[4]. Pairwise comparisons compared Slow, Fast1, and Fast2 to PWS.

Results. As hypothesized, compared to PWS, EC was 13% higher during the Slow trial and up to 16% lower at speeds faster than PWS (Fig 1B). In contrast, mediolateral CoM motion was 16% more stable and 5% more regular during the Slow trial and 10% more irregular at Fast1 (Fig 1C). Of the stability measures, only the MOS data were complete at Fast2. Consistent with our hypothesis, mediolateral MOS during nonparetic limb steps (MOS_{NP}) was 12% less at Fast2 compared to PWS (Fig 1D). Interestingly, changes in anterior MOS tracked the observed changes in EC, with anterior MOS_{NP} and MOS_{P} being, respectively, 12% and 10% lower during the Slow trial and 24% and 30% higher during Fast2 (Fig 1D).

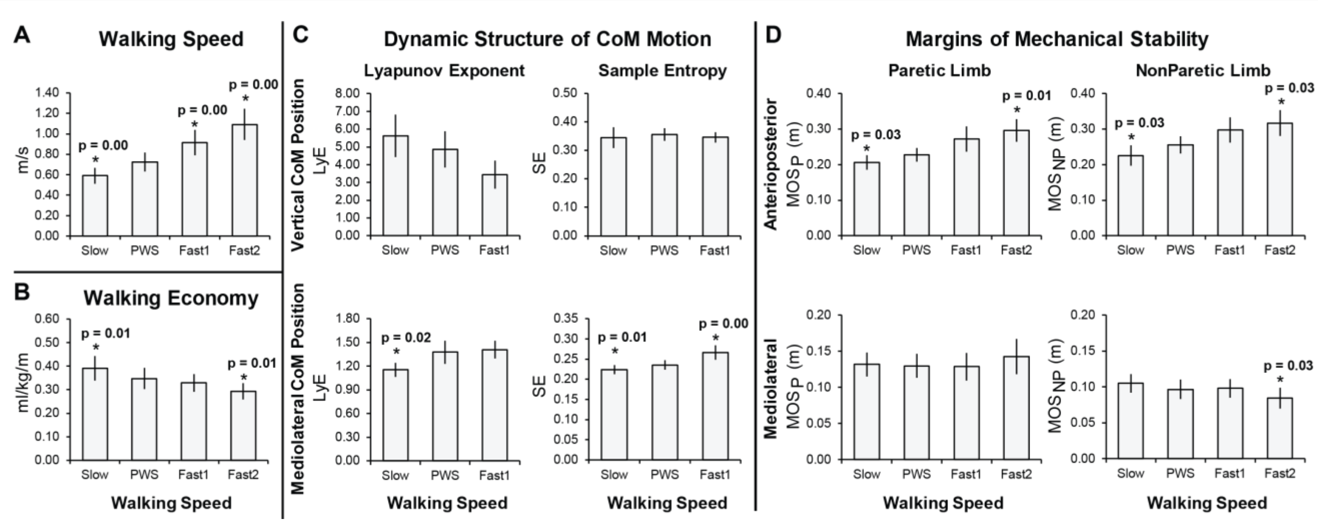

Figure 1. Concurrent changes in **(A)** walking speed, **(B)** economy, **(C)** CoM motion stability and regularity (lower values indicate more stability), and **(D)** mechanical stability during hemiparetic walking. *Error bars are standard error. * p < 0.05*

Discussion. Previous investigations have examined the relationship between walking speed versus stability[5] and EC[2] separately. This study reveals that the complementary relationship between stability and EC commonly observed during healthy locomotion is not present after stroke. Post-stroke PWS appears to balance, not optimize, stability and EC.

References

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