SOFT ROBOTIC EXOSUIT ASSISTANCE FACILITATES HIGH INTENSITY GAIT TRAINING AFTER STROKE

Anna Roto Cataldo[1], Johanna Spangler[1], Lillian Braga-Ribeirinha[1], Karen Hutchinson[1], and Louis N Awad[1*]
[1]College of of Health and Rehabilitation Sciences, Boston University, Boston, Massachusetts, USA
email: *louawad@bu.edu

Introduction

Stroke-induced gait deficits often limit gait training intensity and repetition—training parameters known to drive experience-dependent neuroplasticity. We posit that soft robotic exosuits[1] that provide paretic plantarflexor and dorsiflexor force assistance during the appropriate phases of the gait cycle have the potential to facilitate gait training at higher intensities and for longer durations than may be achieved without exosuit assistance. Our prior work shows that exosuit assistance leads to greater energetic efficiency, improved propulsion symmetry and ground clearance[1], and reduced gait compensations[2] during steady-state treadmill walking. People post-stroke also self-select faster overground walking speeds and walk farther distances with exosuit assistance[3]. Taken together, these orthotic benefits have potential to be applied during gait training to enhance therapeutic outcomes. However, gait training often does not occur at comfortable, self-selected walking speeds. Fast training speeds are often prescribed not only to address speed deficits after stroke, but to also increase training intensity and, in turn, enhance experience-dependent neuroplasticity. We hypothesize that exosuit assistance will provide the propulsive support required to achieve faster walking speeds and the ground clearance support needed to reduce or delay gait instabilities at faster speeds, thus facilitating faster walking for longer durations, and consequently, a higher training intensity and dose, as measured by exercise test time and VO_2 peak achieved before physiological deterioration, gait instability, or fatigue require that testing be terminated.

Methods

We evaluated the effects of exosuit assistance using two speed-based maximal effort graded exercise tests[4] that spanned participants' self-selected speed range, up to the maximum walking speed they could safely tolerate. Participants completed one with and one without exosuit assistance (no-exosuit). Tests started at 80% of comfortable overground walking speed for 2 minutes followed by an increase in treadmill speed by 10% of the starting speed every 2 minutes until test termination. Stopping criteria included reaching peak volitional fatigue or meeting any physiological or physical (e.g., gait instability judged to be unsafe by a licensed physical therapist) criteria[4,5]. Indirect calorimetry and electrocardiogram data were collected continuously during the tests. The final 30 seconds of steady-state walking—identified based on standard deviation[6] and visual inspection of indirect calorimetry data—were averaged and normalized to body mass to compute VO_2 peak (ml O_2/kg/min). Test duration is presented in minutes. Maximum walking speed refers to the final treadmill speed (m/s) achieved.

This study is ongoing. Available data for test duration, fastest walking speed, and VO_2 peak achieved for all completed subjects are presented in this preliminary report. Descriptive statistics and individual data are reported as median ± semi-interquartile range.

Results and Discussion

Data from 8 individuals >6 months post-stroke (58±13 yrs. old, 2 females, 2 right paretic) are presented. Participants walked a median two stages longer (range: -2 to +5 stages) with exosuit assistance compared to no-exosuit, resulting in a longer test duration (+17%; 14±2.8 vs. 10±1.5 minutes) (Fig. 1A), faster maximum speed (+7%; 1.01±0.12 vs. 0.95±0.13 m/s) (Fig. 1B), and higher VO_2 peak (+9.5%; 16.6±2.5 vs. 14.7±1.3 ml O2/kg/min) (Fig. 1C). At the individual level, six out of eight participants increased both test duration and fastest walking speed achieved, one reduced both measures (Fig. 1A & 1B, red), and one had no change in either measure (Fig. 1A & 1B, black). In addition, five participants achieved a higher VO_2 peak (range: +1.8% to +24%), and three achieved a lower VO_2 peak (range: -3.1% to -21%) (Fig. 1C, red). During no-exosuit testing, three participants were stopped due to gait instability, three due to physiological deterioration, and two because of volitional fatigue. For two participants, the reason for stopping the test was altered by exosuit assistance: one continued to a later stage without physiological deterioration and was later stopped due to gait instability, and one stopped at an earlier stage due to gait instability. A third participant presented with physiological deterioration during the same stage as the no-exosuit condition. For all other participants, tests were stopped for the same reasons across conditions, with exosuit assistance delaying the onset of stopping criteria.

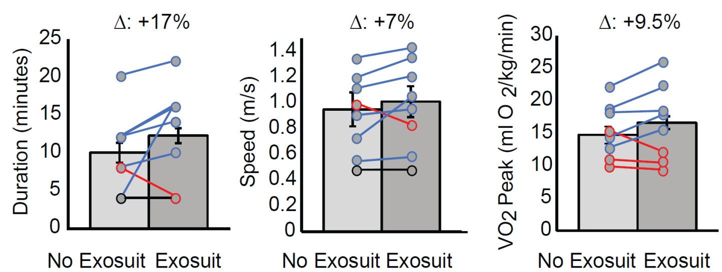

Figure 1: Median test duration (A), maximum speed (B), and VO2peak (C) between conditions.

Significance

These preliminary results suggest that soft robotic exosuits may enable individuals with post-stroke hemiparesis to walk for longer durations and at faster training speeds, and thus facilitate clinical gait training at the intensities and durations necessary to drive experience-dependent neuroplasticity and maximize locomotor recovery.

Acknowledgments

We thank our participants for their generous donation of time.

References

1. Awad, L. *et al.* 2017 *Sci. Transl. Med.* DOI: 10.1126/scitranslmed.aai9084
2. Awad, L. *et al.* 2017 *Am. J. Phys. Med. Rehabil.* DOI: 10.1097/PHM.0000000000000800
3. Awad, L. *et al.* 2020 *IEEE Open J. Eng. Med. Biol.* DOI: 10.1109/ojemb.2020.2984429
4. Fletcher, G. F. *et al.* 2013 *Circulation*. DOI: 10.1161/CIR.0b013e31829b5b44
5. Macko, R. F. *et al.* 1997 *Stroke*. DOI: 10.1161/01.str.28.5.988
6. Taylor, H. L. *et al.* 1955 *J. Appl. Physiol.* DOI: 10.1152/jappl.1955.8.1.73