ARTICLE IN PRESS

Gait & Posture xxx (xxxx) xxx

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Short communication

O 089 - A soft robotic exosuit assisting the paretic ankle in patients post-stroke: Effect on muscle activation during overground walking

L. Sloot[a,*], J. Bae[a], L. Baker[a], K. O'Donnell[a], N. Menard[a], F. Porciuncula[a], D. Choe[a], T. Ellis[b], L. Awad[b], C. Walsh[b]

[a] *Harvard University, School of Engineering and Applied Sciences, Cambridge, USA*
[b] *Boston University, Department of Physical Therapy & Athletic Training, Boston, USA*

ARTICLE INFO

Keywords:
Stroke
Gait
Exosuit
Exoskeleton
Muscle activity
Kinematics
Kinetics
Paretic propulsion
Actuator

ABSTRACT

This study compared overground walking with and without exosuit assistance in post-stroke patients. Exosuit-assisted walking was found to improve paretic propulsion and ground clearance during swing, two common gait deviations in stroke patients. No changes in leg muscle activity was found, motivating further study of the exosuit as a tool for gait training during stroke rehabilitation.

1. Introduction

Stroke, the leading cause of long-term disability, often results in slow and energetically inefficient gait. Our group has developed a body-worn soft robot (exosuit) that provides ankle plantar- and dorsiflexion assistance, which has been demonstrated to improves paretic propulsion, foot ground clearance, and efficiency during treadmill walking [1–3]. For the exosuit to be an effective tool for gait training during stroke rehabilitation, these effects need to translate to overground walking and with minimal slacking, i.e. reduction in effort during assisted walking [4]. While trends of reduced muscle activation have been shown in able-bodied subjects using similar assistance [5,6], we hypothesize that the exosuit helps patients normalize their gait which fosters voluntary muscle activation.

2. Research question

This study used comprehensive gait analysis to compare walking overground with and without exosuit assistance in post-stroke patients.

3. Methods

Eight hemiparetic patients walked on an indoor track at comfortable walking speed for 5 min with and without exosuit (randomized). The exosuit (Fig. 1A) transmitted mechanical power generated by a body-worn actuation system (2 kg) to the paretic ankle, providing plantar-flexion forces of 25% body-weight during push-off and sufficient ankle dorsiflexion force during swing to achieve ground clearance [1,2]. We recorded EMG from the paretic and non-paretic tibialis anterior (TA), medial gastrocnemius (MG) and soleus (SO). We compared walking speed and energy cost of walking; forward propulsion (integral of the for-aft ground reaction force) and peak ankle moment during push off; ground clearance (peak dorsiflexion ankle angle during swing), and maximum EMG values during push-off and swing between conditions using paired t-tests.

4. Results

While no difference in walking speed or energy cost was observed (7% increase, $p = 0.60$ and 11% reduction, $p = 0.31$, respectively), exosuit-assisted walking did improve the quality of walking, with an 8% increase in paretic propulsion ($p = 0.03$), an 11% increase in maximum

* Corresponding author.
E-mail address: lsloot@seas.harvard.edu (L. Sloot).

https://doi.org/10.1016/j.gaitpost.2018.06.124

Available online 26 June 2018

Please cite this article as: L. Sloot, *Gait & Posture*, https://doi.org/10.1016/j.gaitpost.2018.06.124

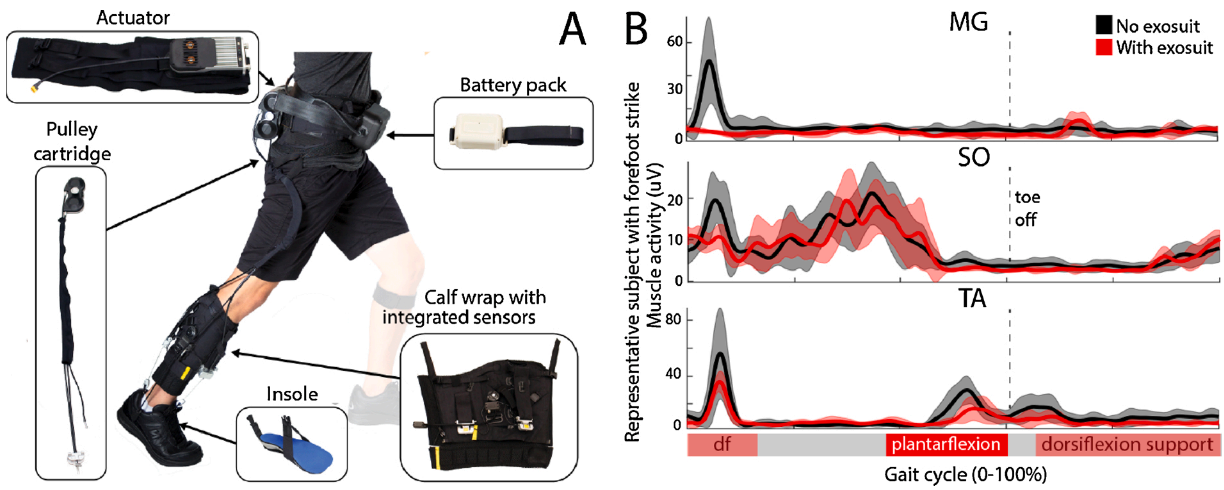

Fig. 1. (A) The mobile exosuit consists of a body-worn actuator on the back, a battery pack worn on the front, and Bowden cables that exert forces between the garment worn around the calf and the insole in the shoe. (B) Results for a representative subject, showing average EMG signal over strides for the NoSuit (black) and WithExosuit (red) conditions for the MG, So and TA muscle. The relative duration of the dorsiflexion and plantarflexion support are indicated below the graphs.

ankle moment during push-off ($p = 0.048$), and a 9° improvement in ground clearance during swing($p = 0.003$). We found no statistical change in paretic or non-paretic muscle activity during swing and push-off. Interestingly, the exosuit assistance changed the subset of forefoot strike gait patterns to heel strike (n=4) and reduced their abnormally high muscle activity during early stance (24 ± 28% TA, 10 ± 16% SO, 15 ± 53% MG; Fig. 1B).

5. Discussion

The improved propulsion and ground clearance are consistent with previous observations during treadmill walking. The results show that the exosuit's assistance is complementary to the patient's own effort, as patients do not reduce their TA activity during swing or calf muscle activity during push-off. These findings motivate further study of the exosuit as a tool for gait training during stroke rehabilitation, including more (severe) patients, thigh muscles and synergy analysis.

References

[1] Bae, ICORR, 2015.
[2] Awad, STM, 2016.
[3] Awad, Am. Phys. Med. Rehabil., 2017.
[4] Reinkensmeyer, EMBS, 2009.
[5] Ding, TNSRE, 2016.
[6] Panizzolo, JNER, 2016.