GAIT IMPROVEMENTS IN STROKE PATIENTS WITH A SOFT EXOSUIT

Stefano M.M. De Rossi[1, 2], Jaehyun Bae[1], Kathleen E. O'Donnell[1, 2], Kathryn L. Hendron[3], Kenneth G. Holt[3], Terry Ellis[3], Conor J. Walsh[1, 2]
[1] Harvard University, School of Engineering and Applied Sciences, Cambridge, MA, USA
[2] Wyss Institute for Biologically Inspired Engineering, Boston, MA, USA
[3]Boston University, Sargent College of Health & Rehabilitation Sciences, Boston, MA, USA
Corresponding author e-mail: walsh@seas.harvard.edu

INTRODUCTION AND CLINICAL SIGNIFICANCE

Stroke is the major cause of disability in adults in the western world, with 800,000 occurrences each year in the US alone [1]. In the majority of cases, stroke results in hemiparesis leading to severe mobility impairment. In the last years, powered exoskeletons are proving to be a valuable tool in clinic-based gait rehabilitation [2]. These systems can apply high levels of assistance, required for patients with limited or no residual mobility, like early-stage stroke survivors and spinal cord injury patients, but may not be suitable for later-stage patients who have regained limited mobility due to the kinematic restrictions and additional mass imposed by these robots. We recently proposed an alternative to traditional powered exoskeletons, called "exosuits" [3]: clothing-like, soft wearable robots that use textiles to generate forces in parallel with the human musculature. In early load carriage studies in healthy subjects, we have successfully shown that we can reduce muscle activity and energetic cost. We believe that this new class of wearable robots will open up opportunities for enabling robot neurorehabilitation across the continuum of care, spanning the period between intensive, early-stage rehabilitation and the community. Exosuits could be worn underneath clothing during community activities, and would be capable of producing both immediate effects (as an orthotic) as well as therapeutic improvements in walking ability. As a first step towards a portable, wearable system, we have developed a prototype of a medical exosuit that can be used to evaluate the effect of applied assistance in proof-of-concept experiments on stroke patients.

METHODS

Our soft exosuit device setup consists of three components shown in Figure 1: a soft garment worn on the patient's impaired leg; an actuation unit; and a real-time control interface to tailor the timing and level of assistance to the needs of the patient. The current design can provide assistance in both ankle plantar flexion and dorsiflexion, common areas of deficiency in stroke patients. For this early development, assistive torques are provided to the ankle joint by means of a flexible cable-based transmission that connects from the actuation platform beside the treadmill to suit and shoe attachment points. A graphical interface allows the clinician to make real-time adjustments of the type and level of assistance, thus customizing it to the diverse needs of patients. As a proof of concept, the device was tested on a stroke patient (age: 29 y.o., time since stroke: 6 y., good community ambulation with an AFO). The participant walked on a treadmill at a self-selected speed of 0.5 m/s, and assistive torques were delivered to the ankle in accordance with guidance from a physical therapist. Spatial-temporal variables where measured using a BERTEC FIT treadmill, and assistive forces were logged by the device. To evaluate gait symmetry, we calculated a Temporal Stance Symmetry (TSS) index (= % stance duration on impaired side / % stance on sound side).

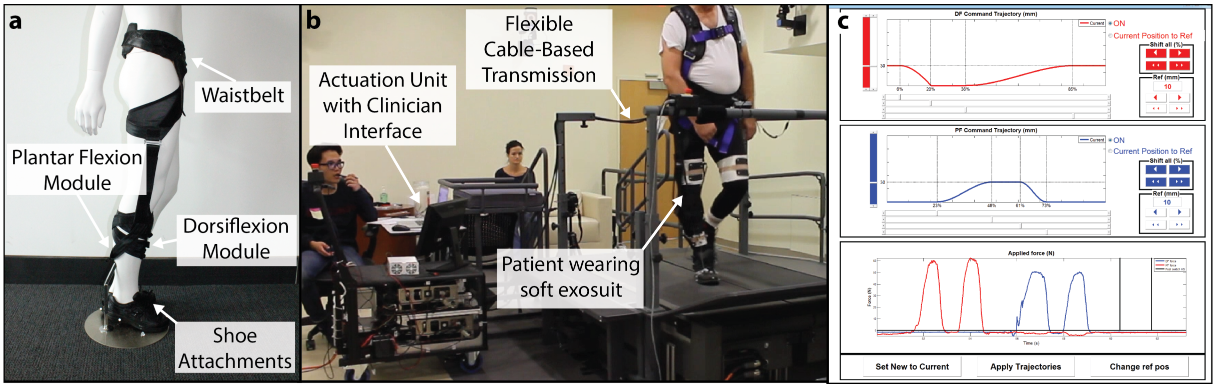

Figure 1: Components of the soft exosuit, including (a) suit textile elements; (b) actuation platform and treadmill setup, and (c) real-time control interface allows personalized assistance to the patient needs.

RESULTS

Plantarflexion torque was delivered by the exosuit to to provide approximately 10% of the physiological plantarflexion torque (see Table 1 and [3]). In terms of dorsiflexion assistance, the exosuit could deliver an order of magnitude greater torque than a reference ankle moment for healthy subjects, allowing approximately 0.1 N m/ kg of normalized torque to counteract patient ankle stiffness in dorsiflexion. Table 1 presents some proof-of-concept results of spatial-temporal variables and stance symmetry. It can be seen that with complete assistance (DF+PF) symmetry improved, a result of increasing stance duration on the impaired side.

Table 1: Level of assistance, spatial-temporal parameters and TSS for different assistance scenarios.

Assistance	**None**	**DF**	**DF+PF**
Stride Length (m)	0.77 ± 002	0.66 ± 0.015	0.74 ± 0.013
TSS (%)	83.69	84.01	88.86
Peak Assistive DF torque (N m/ kg m)	N/A	0.0923	0.0794
Peak Assistive PF torque (N m /kg m)	N/A	N/A	0.0560

SUMMARY

We have presented the first demonstration of a treadmill-based medical exosuit improving gait for a hemiparetic stroke patient, the first step towards a new class of soft, garment-like wearable robots that will enable robot neurorehabilitation to be extended from the clinic to the community. Future work will optimize the system to be able to apply higher assistive torques and integrate the actuation into a body-worn form factor for over-ground use.

REFERENCES

1. V. L. Roger et al., *Circulation* 123: (2011).
2. Pennycott, A et al.. *J. Neuroeng. Rehabil.* **9,** 65 (2012).
3. Asbeck, AT, et al., *IEEE International Conference in Rehabilitation Robotics*, 2013.

ACKNOWLEDGMENTS

This work was supported by the by the Defense Advanced Research Projects Agency (DARPA) Warrior Web Program (Contract No. W911NF-14-C-0051-P00003), the Wyss Institute for Biologically Inspired Engineering and the School of Engineering and Applied Sciences at Harvard University.

DISCLOSURE STATEMENT

Authors have no conflicts of interest to disclose.