A UNILATERAL ANKLE ASSISTING SOFT ROBOTIC EXOSUIT CAN IMPROVE POST-STROKE GAIT DURING OVERGROUND WALKING

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INTRODUCTION

Stroke is the leading cause of long-term disability, often resulting in a slow and energetically inefficient gait due to a reduction in push-off power at the end of stance and the inability to lift the foot from the ground during swing (i.e. foot clearance). To improve the quality of life of stroke patients, a soft wearable robot (exosuit) has been developed, which has demonstrated the capacity to improve paretic propulsion, foot clearance and walking efficiency during treadmill walking [1,2].

The long term vision for the exosuit is that it can be used for overground gait training and to improve gait in a community setting. However, it is well known that stroke patients' ambulatory ability on the treadmill and overground are different [3,4]. During overground walking, there is an increase in gait variability due to a lack of an imposed speed, a less restricted walking area and more visual distractions. It is currently unknown if the same benefits observed on the treadmill would be seen during overground walking. Therefore, the objective of this study was to determine if the soft exosuit can improve push-off and foot clearance in patients post stroke during overground walking.

METHODS

Nine patients with hemiparetic stroke (4 F, 49±13y, time since stroke 4±2y) walked overground at preferred walking speed. They wore a soft robotic ankle-assisting exosuit (Fig. 1) that was designed to transmit assistive forces from a specially designed lightweight body worn actuation system (3.2 kg) to the shank-mounted textile. The soft exosuit provided

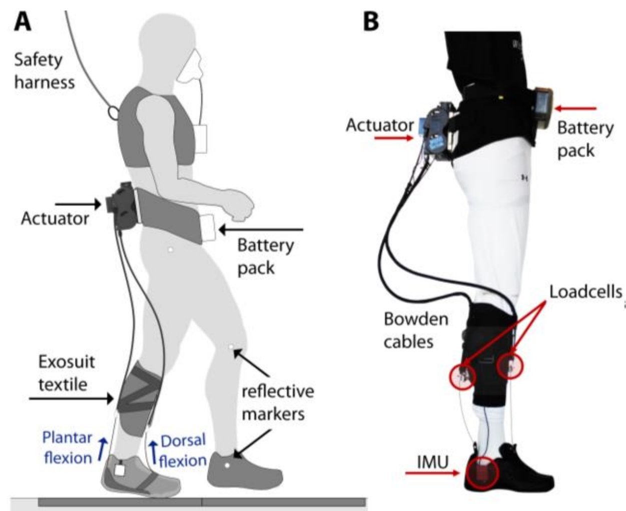

Fig. 1: Experimental setup (A) and exosuit components (B)

ankle plantarflexion assistance during push-off (peak applied force of 25% bodyweight) and ankle dorsiflexion assistance to achieve at least a neutral angle during swing phase [1,2].

Ground reaction forces (ground embedded force plates, AMTI, Watertown, MA) and kinematics (motion capture system, VICON, Oxford, UK) were measured. To understand the effect of exosuit assistance, subjects first walked with it unpowered, followed by a powered exosuit condition. Subjects walked until at least 5 strides were captured per condition with good landing on the force plate.

The propulsion impulse (i.e. the integral over the propulsion force), peak ankle torque during stance, average positive and negative ankle power during second double support, and maximal ankle dorsiflexion during swing and at initial contact were calculated for both the paretic and non-paretic leg. Conditions were compared on a group level using paired t-test (significance set at $p<0.05$).

RESULTS AND DISCUSSION

On the paretic side, walking with the powered exosuit improved push-off (Fig. 2). We observed a 14.0% increase in propulsion impulse (p=0.03), a 24.5% increase in average positive ankle power (p=0.04) and a 41.3% decrease in average negative ankle power (p=0.006). The powered exosuit also assisted foot clearance during swing and foot placement on the paretic side in terms of a 5.2° increase in maximal ankle dorsiflexion during swing (p=0.002) and a 4.9° increase at initial contact (p=0.003). No differences were found for the peak paretic ankle torque or any of the variables from the non-paretic leg (Fig. 3).

These results are similar to our prior work with a tethered soft exosuit that was shown to improve push-off and foot clearance during treadmill walking [1,2]. Taken together, these results suggest that soft wearable exosuit is able to assist post-stroke patients in different walking conditions. Moreover, it provides encouraging evidence that the exosuit technology is able to correctly identify gait events and timely assist paretic ankle deficits during the more variable overground walking.

Overall, the results support the suitability of the exosuit for common overground gait training. Given the known heterogeneity of stroke patients, the wearable exosuit provides exciting opportunities for subject specific gait training, with the potential of tuning the level of assistance to *a patient's* progress.

CONCLUSIONS

This study demonstrates the capability of a body worn exosuit that targets the paretic ankle to assist push-off and foot clearance in post-stroke patients during overground walking. This builds on past work that demonstrated similar capabilities during treadmill walking. These results are an important step in evaluating and optimizing a wearable soft exosuit for overground gait training in stroke patients and in translating the technology to community-based use. Moreover, we expect that the exosuit can also similarly benefit patients with other gait deficits and neurological disorders.

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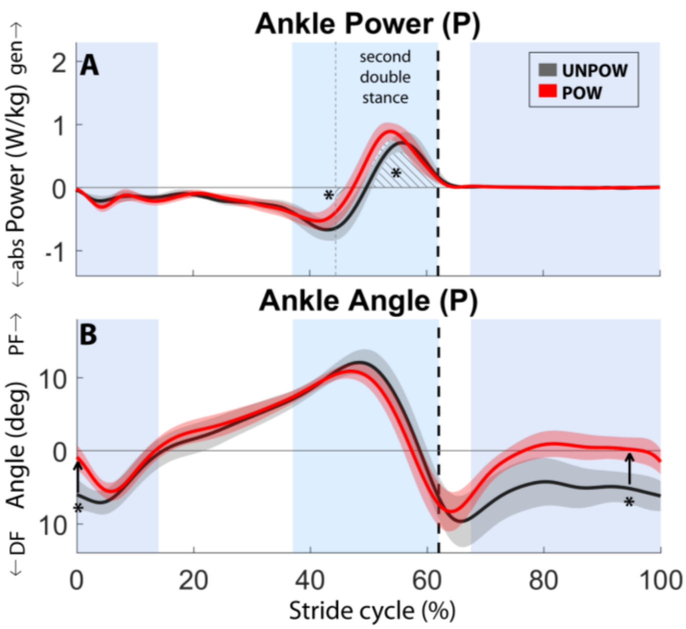

Fig. 2: Ankle power (A) and angle (B) for the paretic (P) limb. Mean values, standard error, toe off (dashed vertical line) and timing of support (plantar flexion support: light blue shade; dorsiflexion: blue shade) are indicated.

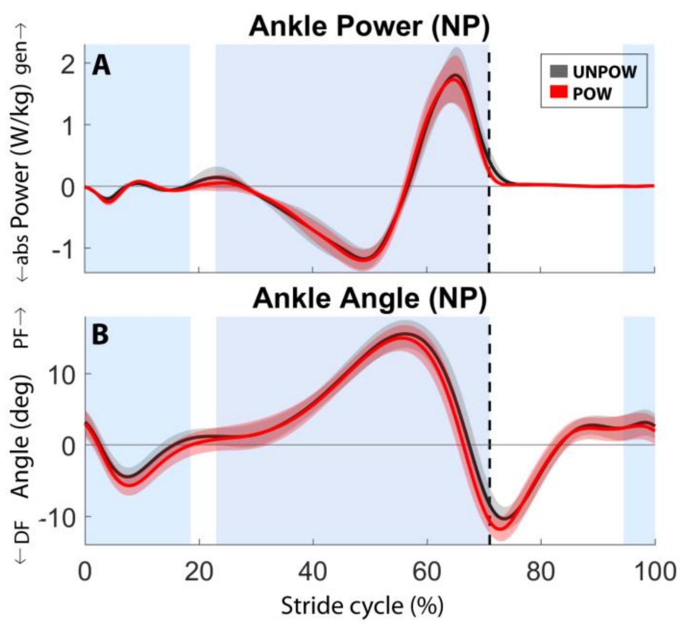

Fig. 3: Ankle power (A) and angle (B) for the non-paretic (NP) limb. For explanation see caption of Fig. 2.