A UNI-LATERAL SOFT EXOSUIT FOR THE PARETIC ANKLE CAN REDUCE GAIT COMPENSATIONS IN PATIENTS POST-STROKE

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INTRODUCTION

Our group has been developing soft wearable robots (exosuits) made from garment-like, functional textiles to augment healthy individuals carrying heavy loads [1] and to assist individuals who have gait impairments due to hemiparesis following a stroke [2]. We have demonstrated that an ankle-joint assisting robot can reduce the metabolic cost of walking in healthy individuals [3]. In patients post-stroke, we have shown that by providing uni-lateral force assistance to the paretic ankle joint during ambulation, we can assist and improve key gait metrics such as foot clearance and paretic propulsion [4].

The goal of this study was to investigate the effects of exosuit provided ankle assistance on common post stroke gait impairments such as reduced step length and compensatory walking strategies resulting from a hemiparetic gait. With this in mind, we sought to evaluate changes in hip hiking, circumduction, and spatiotemporal gait parameters of individuals in the chronic phase of stroke recovery. We hypothesized that walking with the ankle assistance provided while wearing the exosuit will lead to reductions in hip compensations as well as in improvements in spatiotemporal parameters (e.g. longer step length) compared to walking with the exosuit in its unpowered state.

METHODS

Nine participants with hemiparesis (4F, 49±4y, time since stroke 4.4±1.4y) completed two walking trials on an instrumented treadmill (Bertec Corp., Columbus, OH; 2160Hz) in a motion capture lab (VICON, Oxford Metrics, UK; 120Hz). Each walking trial was 8 minutes in length with the last two minutes used for analysis. Participants walked on the treadmill at a predetermined overground comfortable walking speed [4]. Patients first walked with the suit unpowered (no assistance) followed by a powered condition. During the exosuit powered condition, assistive forces (approximately 25% body-weight for plantarflexion assistance) from an off-board actuation system were transmitted to the exosuit textile (Fig. 1). The tethered exosuit assisted ankle plantar flexion during the end of stance phase and ankle dorsiflexion during swing phase. Foot mounted IMUs were used to detect the specific gait events with which onset and offset times for the assistive forces were determined [2].

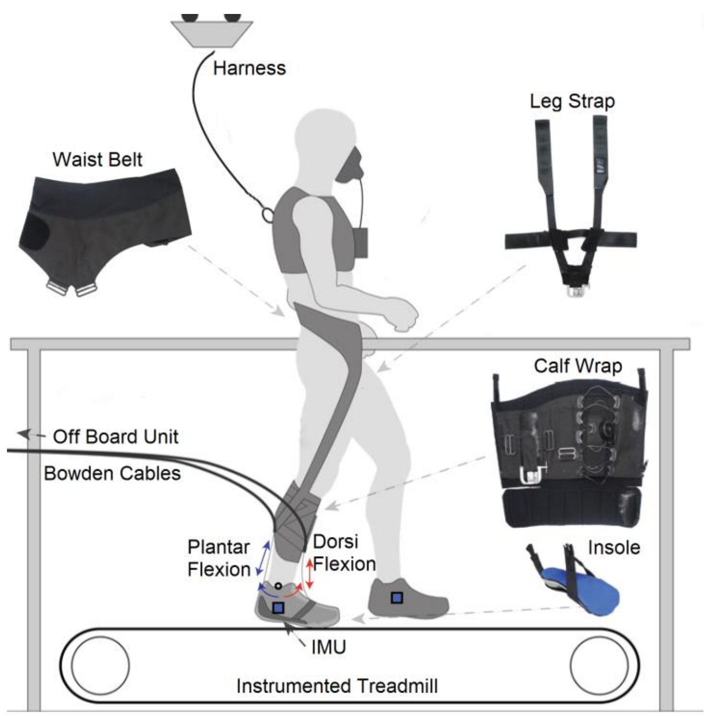

Figure 1: Experimental setup and exosuit components

To calculate circumduction, the center of gravity (CoG) of the foot taken from the link-segment model in Visual 3D (C-Motion, Rockville, MD, USA) was used. The difference between the position of the CoG during stance phase and its maximum lateral displacement during swing phase defined the amount of circumduction (Fig.2A) [5]. To calculate the amount of hip hiking, the vertical position of the anterior superior iliac spine (ASIS) markers calculated during quiet standing (static calibration pose taken for kinematic analysis prior to each walking trial) was compared to the maximum vertical position during swing phase (Fig.2B). Lastly, spatiotemporal measures were calculated using heel marker data. Conditions were compared on a group and individual level using a paired t-test ($p<0.05$).

RESULTS AND DISCUSSION

Compared to unpowered, walking with the exosuit powered reduced hip hiking by an average of 27±6% (*p*=0.004, Fig. 3A) and circumduction by an average of 20±5% (*p*=0.004, Fig. 3B) on the paretic side.

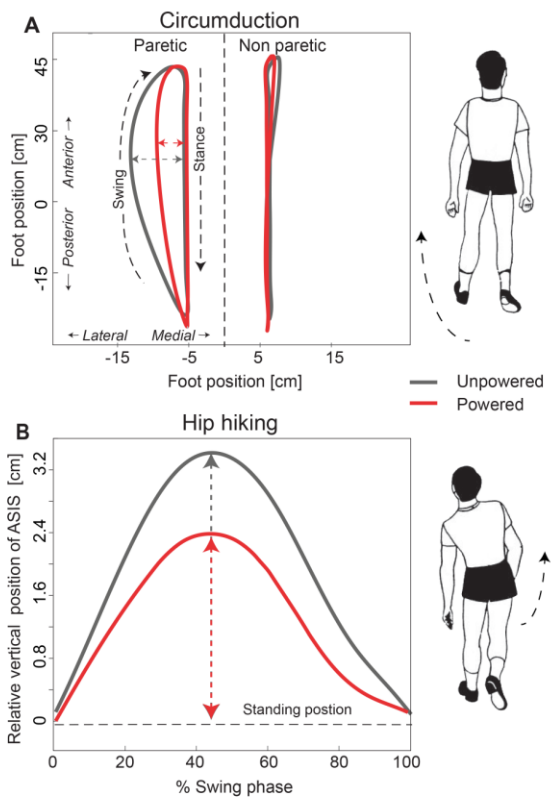

Figure 2: Compensatory gait pattern of representative subject showing **A.** Circumduction and **B.** Hip Hiking during exosuit unpowered and powered conditions

At the individual level, each participant presented with a significant decrease in paretic hip hiking and/or circumduction. Step length during the exosuit powered versus unpowered condition increased by 3±1% (*p*= 0.002) on the non-paretic side. No significant changes in other spatiotemporal parameters were observed.

These preliminary results suggest that compensatory measures are at least in part secondary deviations resulting from deficits in ankle function. With the known heterogeneity of poststroke walkers, the exosuit provides a platform suitable for subject specific interventions during gait retraining.

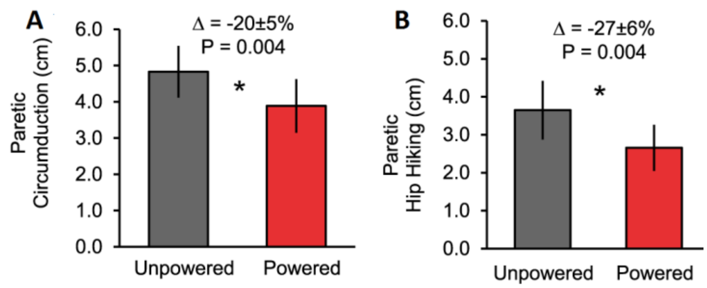

Figure 3: Group results showing **A**. Circumduction and **B**. Hip Hiking for the paretic limb comparing exosuit unpowered and powered conditions (mean±SE).

CONCLUSIONS

This study demonstrated that gait compensations in patients poststroke can be reduced by targeting the paretic ankle with a lightweight, soft wearable robot. This is an important step in evaluating and developing a soft exosuit targeting paretic ankle deficits. Further work will focus on translating these findings to overground studies using a body-worn actuator system. With the ability to control applied forces and timing, such technology can potentially extend to gait impairments related to other neurological conditions.

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