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

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MOTIVATION

- Chronic stroke patients often walk slow and energetically inefficient, due to reduced push-off power (stance) and foot clearance (swing)
- A soft wearable robot developed in our lab has shown to improve biomechanical deficits in hemiparetic gait during treadmill walking [1,2]
- An overground system is needed to maximize the ability of the technology to enhance gait training in stroke patients, since it is known that treadmill and overground walking vary substantially [3,4]

AIM: To develop and validate a mobile adaptive wearable exosuit that enhances paretic gait during overground walking

SOFT WEARABLE ROBOT (EXOSUIT)

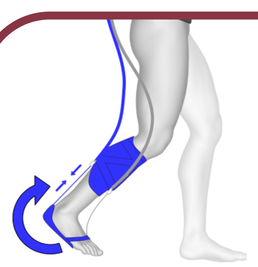
Lightweight

Actuator:	2.6 kg
Battery:	0.6 kg
Textile:	1.6 kg
Total:	*4.9 kg*

Adaptive Control
Enabled by real-time gait event detection using two IMUs attached to the feet.

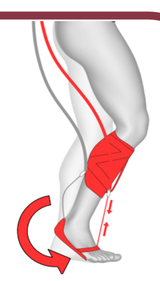
Lightweight body worn actuation system for assisting overground walking. Functional textile anchors (waist belt, calf wrap, and optional lateral support module) interact with an in-shoe insole to generate assistive ankle plantarflexion and dorsiflexion forces when the contractile elements of the exosuit (i.e Bowden Cables) contract.

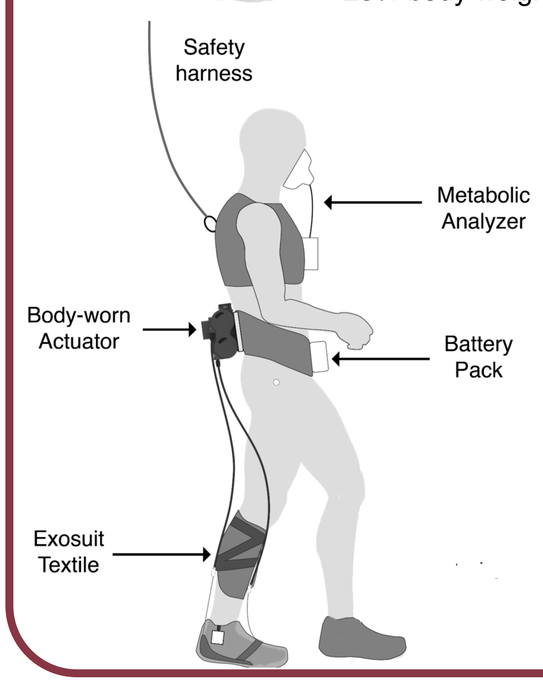
METHODS



Assist plantar flexion during stance with peak PF force 25% body weight

Assist dorsiflexion during swing, with peak DF force adjusted per subject to achieve neutral angle





Protocol

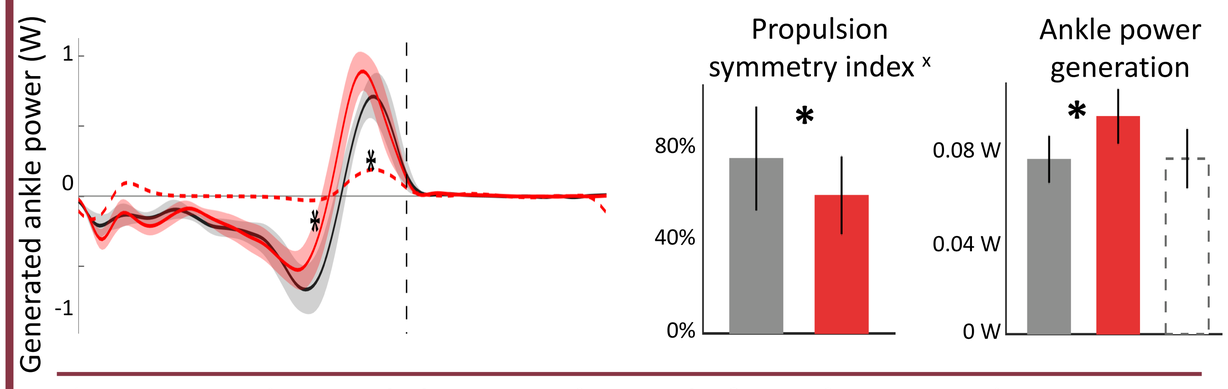
- 9 participants (4 female; 49±13 y; 4±2 y since stroke)
- **Walking conditions:**
  1) exosuit unpowered (**UNPOW**)
  2) exosuit powered (**POW**)
- Walking speed: 1.0±0.1m/s (individual comfortable walking speed)
- Collected ground reaction forces, kinematics & kinetics; at least 5 good strides per condition

RESULTS & DISCUSSION

TOTAL UNPOW
TOTAL POW
EXOSUIT POW
SUBJECT POW

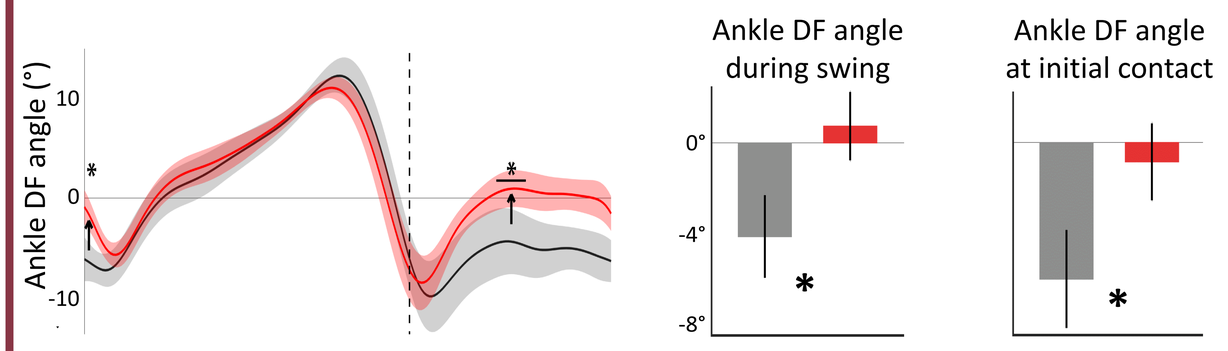
The powered **exosuit improved paretic push-off** during stance

- 21±9% improvement in *propulsion symmetry,* due to 14±5% improvement propulsion impulse paretic side (p=0.03), with no changes in the non-paretic side (p=0.04)
- 24±10% improvement ankle *power generation* during push-off (p=0.04*),* without a reduction in biological ankle power (p=0.99*)*



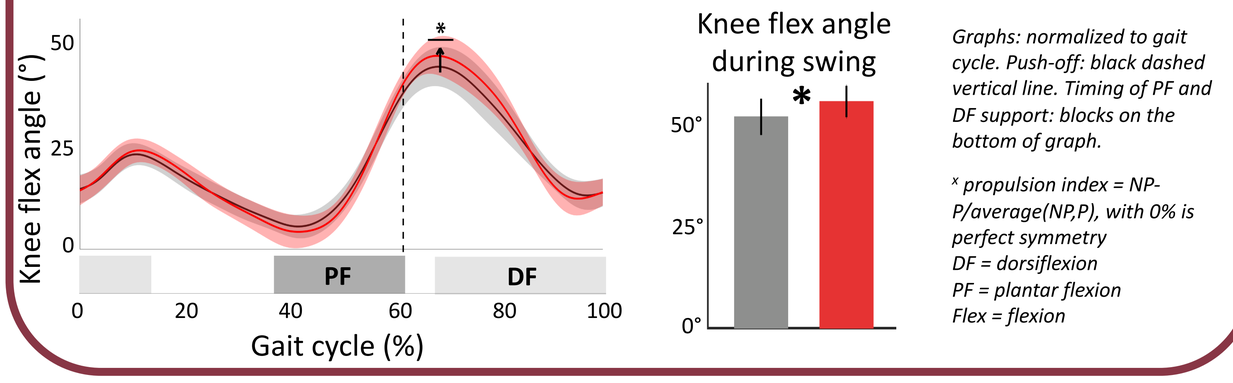
The powered **exosuit improved paretic foot clearance** during swing

- 4.9±1.1° improvement peak ankle dorsiflexion during swing (p=0.002), 8 out of 9 participants improve more than the minimal detectable difference (MDC [5])
- 5.2±1.4° (or 6 x MDC) improvement ankle dorsiflexion at initial contact (p=0.003)
- Effect was larger for patients with more plantarflexion UNPOW (r=0.62, p=0.04)



The powered **exosuit's effect was not isolated to the ankle**

- 3.7±1.5° increased peak knee flexion during swing (p=0.04), 6 participants > MDC
- 3.7±1.4° increased hip extension (p=0.03), 6 participants > MDC



Graphs: normalized to gait cycle. Push-off: black dashed vertical line. Timing of PF and DF support: blocks on the bottom of graph.

[x] propulsion index = NP-P/average(NP,P), with 0% is perfect symmetry
DF = dorsiflexion
PF = plantar flexion
Flex = flexion

CONCLUSION

- The exosuit was able to improve paretic push-off and foot clearance during overground walking, similar to our tethered system during treadmill walking [1,2]
- Improvements indicate that the technology is able to correctly identify gait events and timely assist the paretic ankle, while the benefits are not limited to the targeted ankle
- The results support the suitability of the exosuit for overground gait training in post stroke rehabilitation and assistance during community walking in stroke patients

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