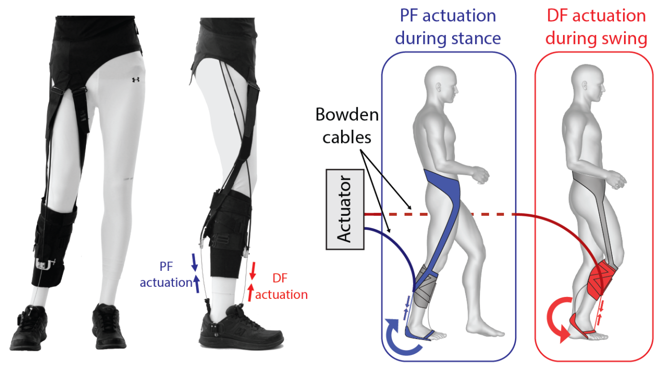
- **Title:** Exosuit-induced improvements in walking after stroke: comprehensive analysis on gait energetics and biomechanics

- **Background & Purpose:** Walking after stroke is characterized by slow, asymmetric, and inefficient gait. A major contributor to walking deficits after stroke is impaired paretic ankle function. During pre-swing phase, impaired paretic ankle plantarflexion reduces the paretic limb's contribution to forward propulsion. During swing phase, impaired paretic ankle dorsiflexion inhibits ground clearance by the paretic limb. Our laboratory developed a lightweight, soft wearable robot (an exosuit) that interfaces with the paretic limb via functional textiles to actively assist ankle plantarflexion (PF) and dorsiflexion (DF) during walking. The objective of this study was to evaluate how exosuit assistance influences poststroke gait energetics and mechanics.

Soft exosuit for paretic ankle assistance after stroke



- **Subjects:** Seven individuals in the chronic phase of stroke recovery (Age: 49±4 y; Time poststroke: 4.38±1.37 y; 3 females; 4 left hemiparetic)

- **Methods:** Participants completed two 8-minute treadmill walking bouts at speeds comparable to their usual overground walking speeds. During the first bout, the exosuit was unpowered and did not provide assistance. During the second bout, the exosuit was powered on and provided PF and DF assistance during walking. Net metabolic power, body center of mass (COM) power, and ankle joint power were calculated based on biomechanical and energetic data. Average COM power and ankle joint power generated from each limb during the step-to-step transition were calculated because this period is important in determining metabolic power expenditure. Circumduction and hip hiking were also measured using motion capture. Symmetry indices (*SIs*) were calculated as

$$SI = \left|2 \cdot \frac{X_{np}-X_p}{X_{np}+X_p}\right| \cdot 100(\%),$$

  where X_{np} is the nonparetic variable and X_p is the paretic variable. Zero percent indicates perfect symmetry.

- **Results:** When walking with the exosuit powered, participants spent 10.43±1.48% less net metabolic power compared to walking with the exosuit unpowered (unpowered: 4.18±0.43W/kg, powered: 3.72±0.34W/kg, P = 0.005). Also observed were: increased inter-limb symmetry of the body COM power ($SI_{unpowered}$=56.35±15.48%, $SI_{powered}$=33.99±10.47%, P=0.012) and ankle power generated during the step-to-step transition ($SI_{unpowered}$=66.74±18.69%, $SI_{powered}$=54.50±17.35%, P=0.026), as well as 20±5% less circumduction (unpowered: 4.83±0.71 cm, powered: 3.88±0.74 cm, P=0.004) and 27±6% less hip hiking (unpowered: 3.65±0.77cm, powered: 2.72±0.64cm, P=0.004).

- **Conclusions:** Exosuit assistance during gait can reduce the metabolic requirements of hemiparetic walking and contribute to more symmetric body COM power and ankle power generation during the step-to-step transition and a reduction in compensatory gait patterns.

- **Clinical Relevance:** The present findings will guide future development of gait-assisting wearable robots for clinical use.

References
1) Awad et al, *A soft robotic exosuit improves walking in patients after stroke*, Science Translational Medicine, 2017
2) Awad et al, *Reducing Circumduction and Hip Hiking During Hemiparetic Walking Through Targeted Assistance of the Paretic Limb Using a Soft Robotic Exosuit*, American Journal of Physical Medicine & Rehabilitation, In Press