Human-Machine Interaction with Mobility Enhancing Soft Exosuits

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1. Progress overview

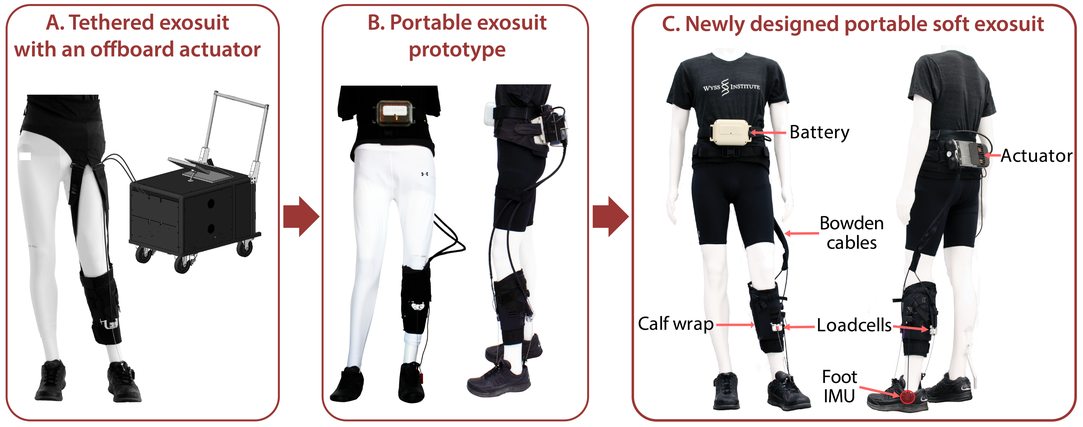

Figure 1. Development trajectory of mobility enhancing soft exosuits.

- We have developed **soft exosuits** that interact with patients having partial mobility to assist walking. [1-5]
- We validated that soft exosuits can improve gait symmetry and economy in patients poststroke with previous exosuit prototypes (Fig. 1a-b) [1-4], and based on the experimental results, we developed a new portable soft exosuit system (Fig. 2c) that is optimized in weight, efficiency, and usability [5].

2. Soft exosuit cyber-physical system

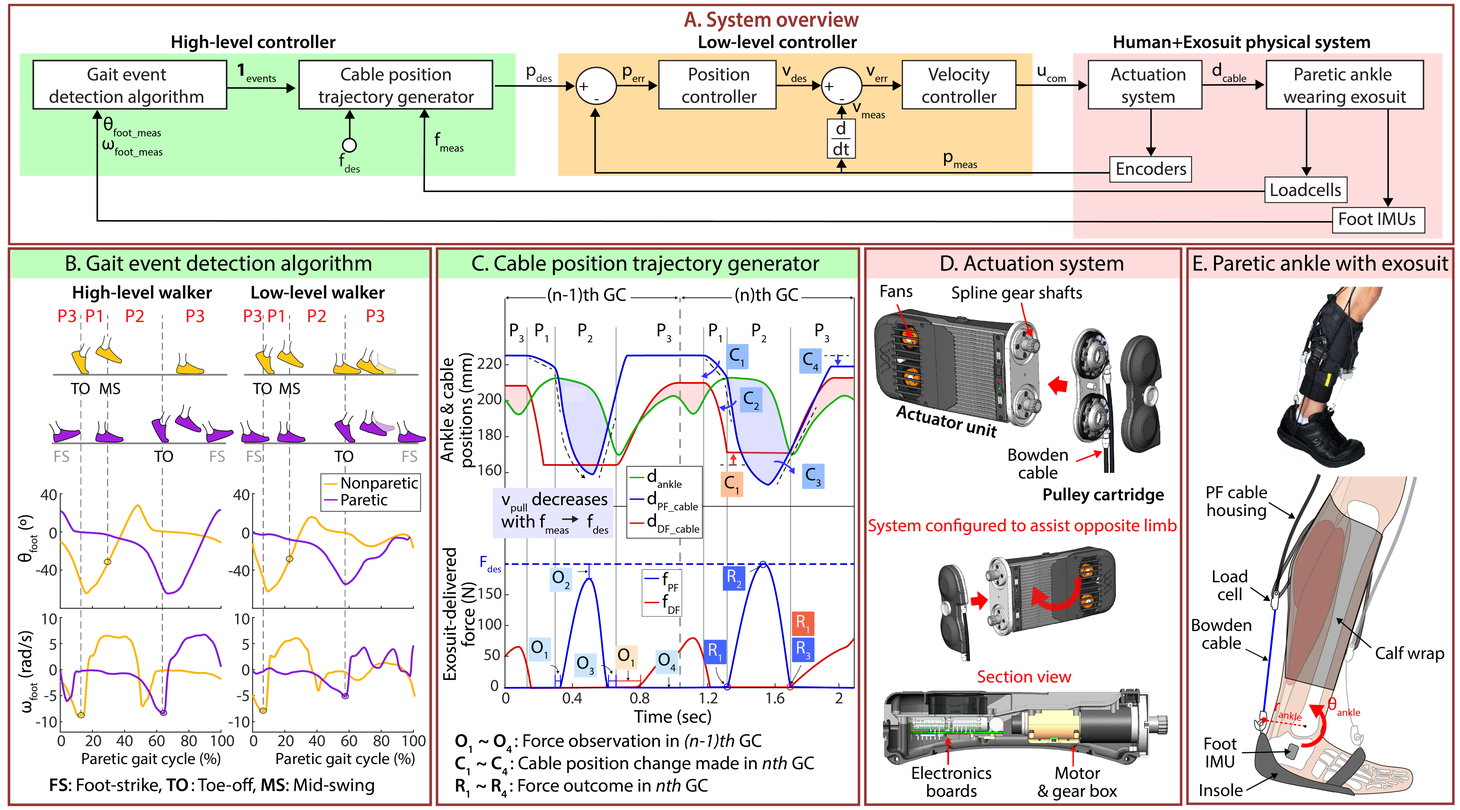

Figure 2. Overview and key components of soft exosuit cyber-physical system [5]

3. Comprehensive biomechanical analysis

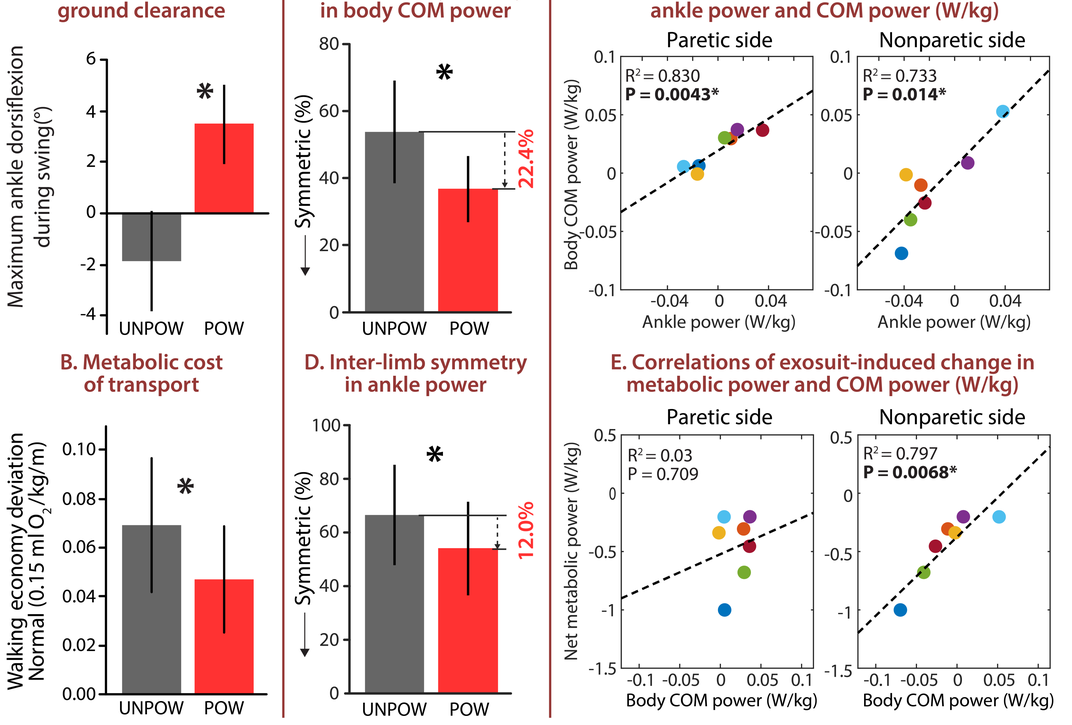

Figure 3. Exosuit-induced changes in gait energetics and biomechanics (a-d) and their correlations (d-e). UNPOW: Suit unpowered. POW: suit powered. * indicates $p < 0.05$

- Patients after stroke reduced metabolic power consumption by 10.43±1.48% when walking on a treadmill with powered exosuit (Fig.1a) compared to walking with exosuit unpowered [2,4].
- Ankle joint power and body center of mass (COM) power was more symmetric, the changes in ankle and body COM power generated during trailing limb support were linearly correlated (Fig. 4d), and nonparetic limb body COM power was linearly correlated with the net metabolic power reduction (Fig. 4e) [4].

4. Feasibility study of new exosuit system

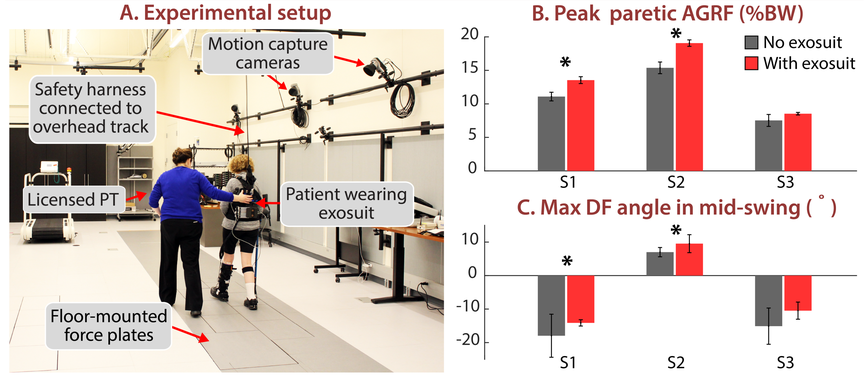

Figure 4. Feasbility study experimental setup and result

During overground walking with new exosuit system (Fig.1c), patients increased paretic forward propulsion and improved ground clearance compared to walking without exosuit (Fig. 4b) [5].

5. Transition to practice

Figure 5. ReWalk Robotics and Harvard Wyss institute presented Soft exosuit in RSS (Robotics: Science and Systems) 2017

Through collaboration with Rewalk Robotics Inc., the development of commercial version of soft exosuit is under progress, with a goal to deliver the product to the market in 2018.

6. Reference

1. Bae et al, *A soft exosuit for patients with stroke: Feasiblility study with a mobile off-board actuation unit*, Proceedings in International Conference on Rehabilitation Robotics (ICORR), 2015
2. Awad et al, *A soft robotic exosuit improves walking in patients after stroke*, Science Translational Medicine, 2017
3. 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 and Rehabilitation, 2017
4. Bae et al, *Biomechanical mechanisms underlying exosuit-induced improvements in walking economy after stroke*, Journal of Experimental Biology, under review
5. Bae et al, *A lightweight and efficient portable soft exosuit for paretic ankle assistance in walking after stroke*, Proceedings in International Conference on Robotics and Automation (ICRA), under review