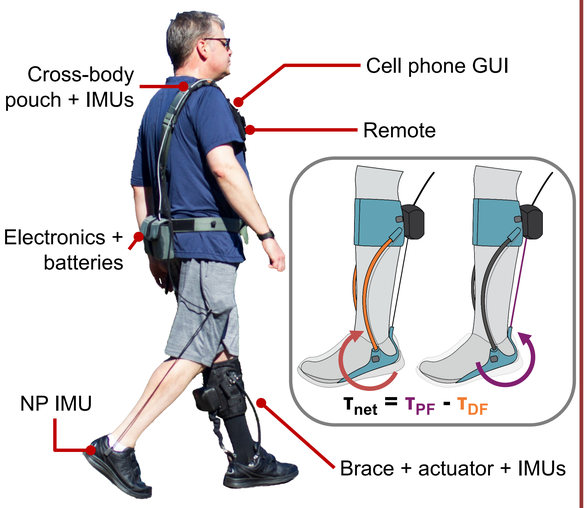
Wearable Robots for the Community: Personalized Assistance using Human-in-the-loop Optimization

Jinsoo Kim[1], Christopher Siviy[1], Chih-Kang Chang[1], Brendan T. Quinlivan[1], Richard W. Nuckols[1], Lauren Baker[1], Terry Ellis[2], Louis Awad[2], Conor Walsh[1]

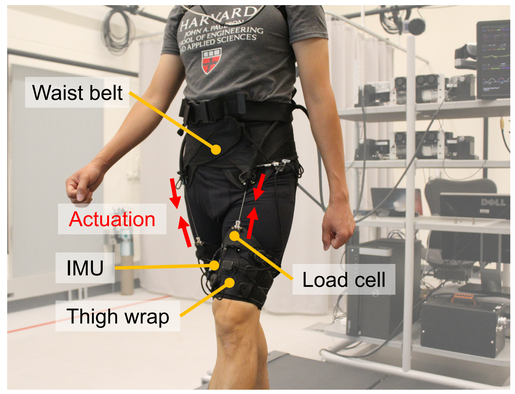
[1] Harvard University John A. Paulson School of Engineering and Applied Sciences, Cambridge, MA
[2] Boston University Department of Physical Therapy & Athletic Training, Boston, MA

Soft exosuits

Rehabilitation poststroke



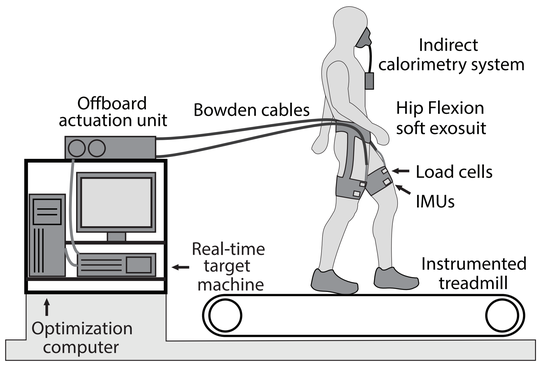
Exosuits for unimpaired populations

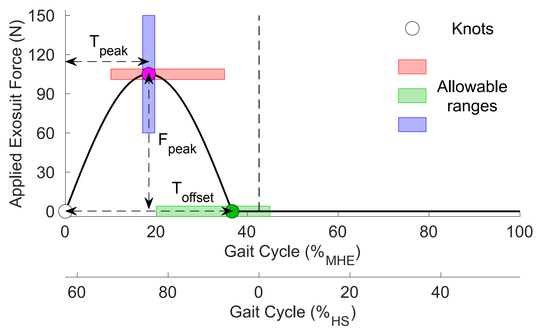


Our group's **soft exosuits** can improve gait quality in people poststroke [1-4] and enhance the mobility of healthy individuals during multiple activities [5-8]

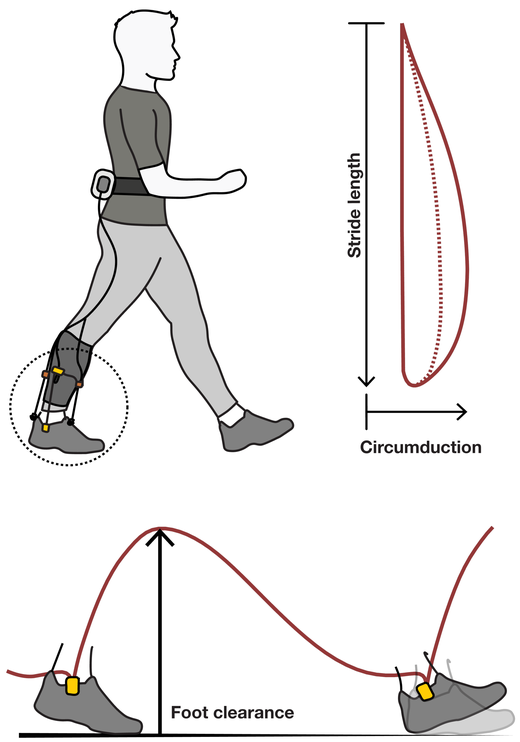
Suit-human system

Human-in-the-loop optimization[8]





Spatial-temporal gait metrics from foot IMUs[9]



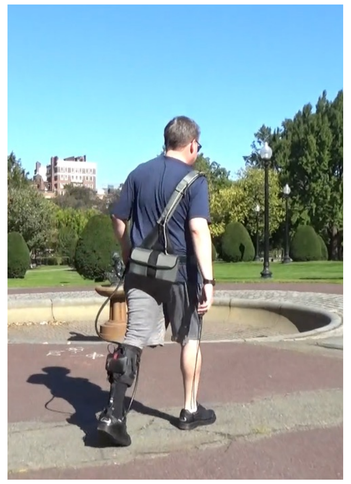
Exosuits in the lab and community

Community-use exosuits for people poststroke

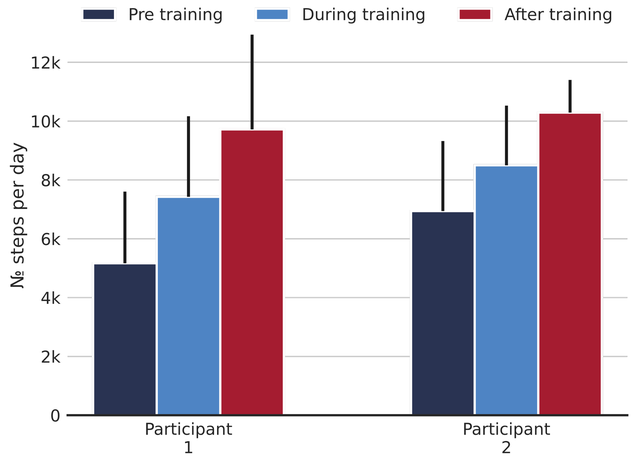
Two people poststroke used an exosuit independently in community settings near their home. Participants were able to put on the exosuit without assistance and operate the exosuit via a phone app without researcher supervision. Participants walked significantly more after one month of exosuit based training.

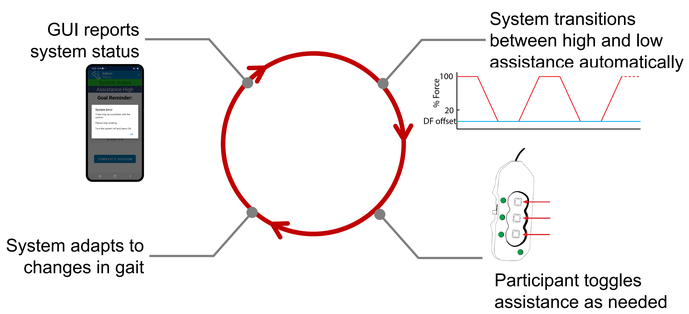
Participant	Sex	Age	Height	Weight	Stroke	Assist Device	LE FM	FGA	Hand FM	CWS	Walking Location
1	M	49	1.75	86	Left	Ace Wrap	32/34	21/30	14/14	1.36	Urban community walking path - paved; curbs; turning
2	M	63	1.77	76	Left	No	26/34	18/30	13/14	1.12	Rural neighborhood paved road w/ incline/decline

Participant donning system independently



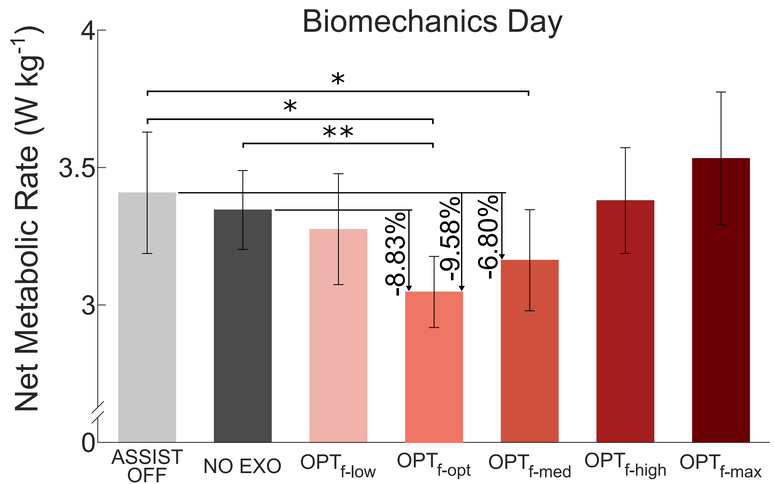
Participant walking in the community





Validated that higher force is not always better with a sweep of force magnitude

Low forces can lead to significant metabolic reductions. The optimal force profile achieved a 9.6% and 8.8% metabolic reduction compared to no assistance and not wearing the suit, respectively.



References

1. Bae et al, *Biomechanical mechanisms underlying exosuit-induced improvements in walking economy after stroke*, J Exp Biol, 2018.
2. Bae et al, *A lightweight and efficient portable soft exosuit for paretic ankle assistance in walking after stroke*, Proceedings in ICRA, 2018.
3. Awad et al, *A soft robotic exosuit improves walking in patients after stroke*, Sci Transl Med, 2017.
4. Awad et al, *Reducing Circumduction and Hip Hiking During Hemiparetic Walking Through Targeted Assistance of the Paretic Limb Using a Soft Robotic Exosuit*, Am J Phys Med Rehabil, 2017.
5. Kim and Lee et al, *Reducing the metabolic rate of walking and running with a versatile, portable exosuit,* Science, 2019.
6. Quinlivan and Lee et al, *Assistance magnitude versus metabolic cost reductions for a tethered multiarticular soft exosuit*, Science Robotics, 2017.
7. Lee et al, *Autonomous multi-joint soft exosuit with augmentation-power-based control parameter tuning reduces energy cost of loaded walking.* J Neuroeng Rehabil, 2018.
8. Kim and Quinlivan et al, *Reducing the energy cost of walking with low assistance levels through optimized hip flexion assistance from a soft exosuit*, Scientific Reports, 2022 (under review).
9. Arens and Siviy et al, *Real-time gait metric estimation for everyday gait training with wearable devices in people poststroke,* Wearable Technologies, 2021.