A USER-CONTROLLED POWERED ANKLE EXOKELETON TO DRIVE GAIT MODIFICATIONS POST-STROKE

Kota Z. Takahashi[1](ktakaha@ncsu.edu), Michael D. Lewek[2], Gregory S. Sawicki[1]
[1]North Carolina State University, [2]The University of North Carolina At Chapel Hill

Human PoWeR Lab

1 INTRODUCTION

Individuals with **hemiparesis due to stroke** exhibit **decreased ankle joint power generation** in the affected limb during walking [1].

This likely contributes to:

Asymmetric forward propulsion [2]

Impaired swing leg initiation [3]

Within **and** ***across*** **limb compensations** [4]

Decreased self-selected walking speed [1,5]

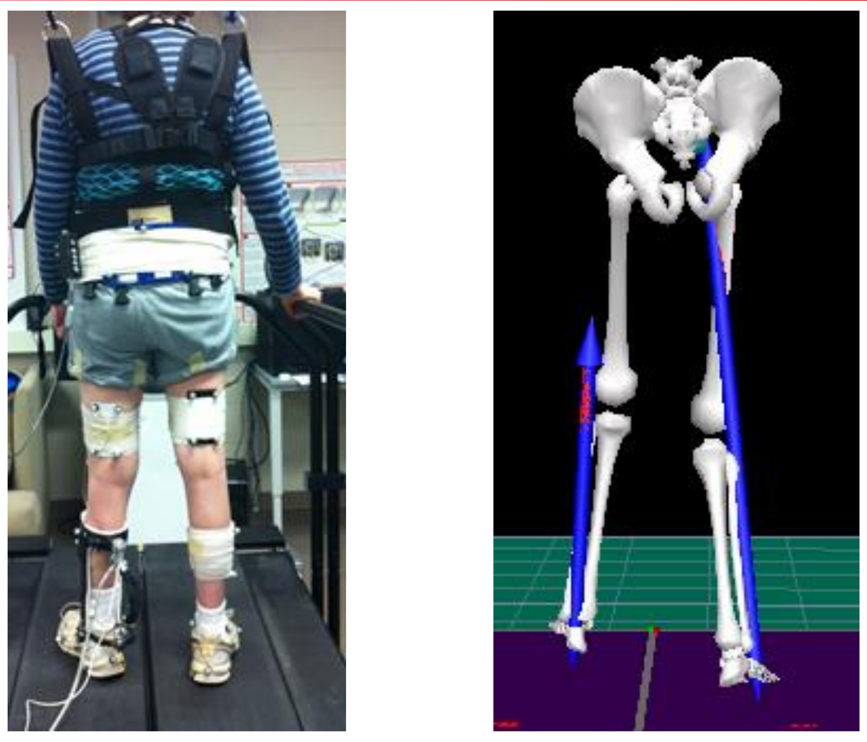
Elevated metabolic cost of walking [5]

*****Restoring normal ankle mechanics in people with stroke may improve gait outcomes*****

2 PURPOSE

Test the feasibility of a user-controlled powered exoskeleton for enhancing paretic ankle joint mechanics during treadmill walking

3 METHODS



5 Subjects with hemiparetic stroke

Time since stroke = 171.6 ± 118.7 months

Preferred walking speed = 0.84 ± 0.21 m/s

Treadmill walking conditions

(5 mins each @ 75% of Preferred speed)

without exoskeleton (NoEXO)

with exoskeleton unpowered (NoPOW)

x3 with exoskeleton powered (POW)

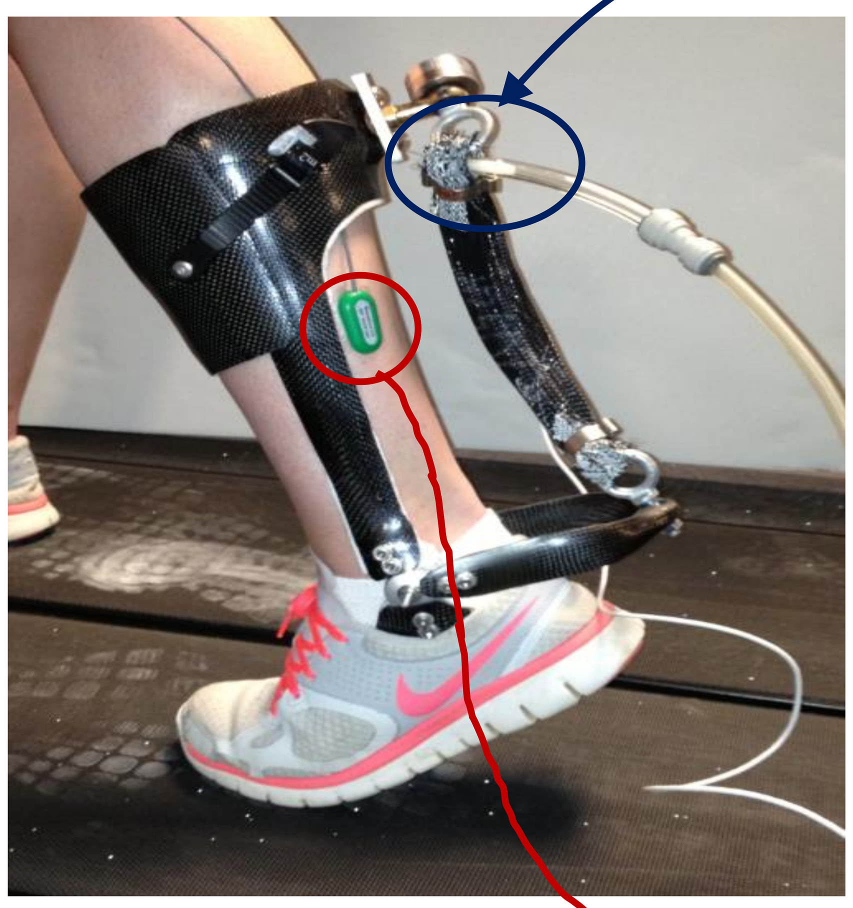
Data analysis:

3D lower limb mechanics

Electromyography (soleus)

Metabolic energy estimates

4 USER-CONTROLLED EXOSKELETON ASSISTANCE



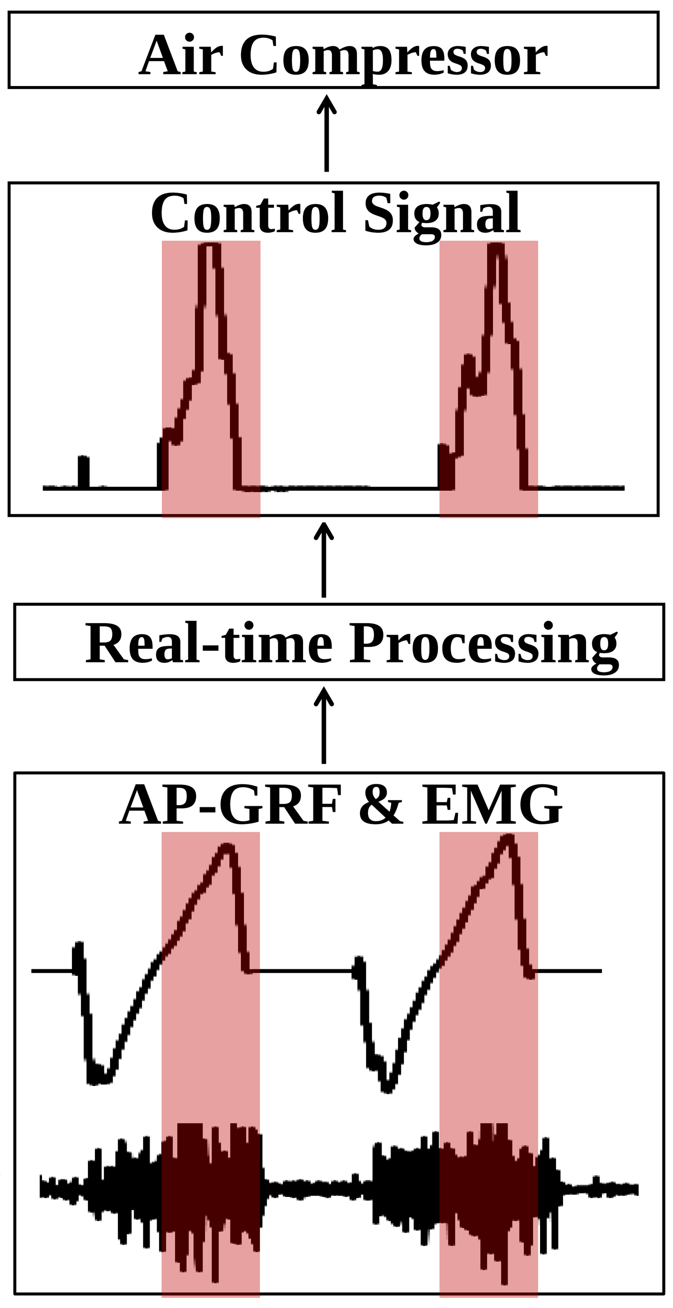


Figure 1: Schematic illustration of the proportional myoelectric propulsion (PMP) control algorithm

Custom-fabricated ankle exoskeleton with pneumatic muscle

(for paretic limb)

Soleus electromyography (EMG) and ground reaction force (GRF) collected in real-time

Plantar flexion assistance proportional to soleus EMG during propulsive phase of stance

(i.e., when anterior-posterior GRF > 0)

Augments propulsive role of ankle plantar flexors

Positive-feedback control algorithm to encourage user participation

6 RESULTS (N = 5)

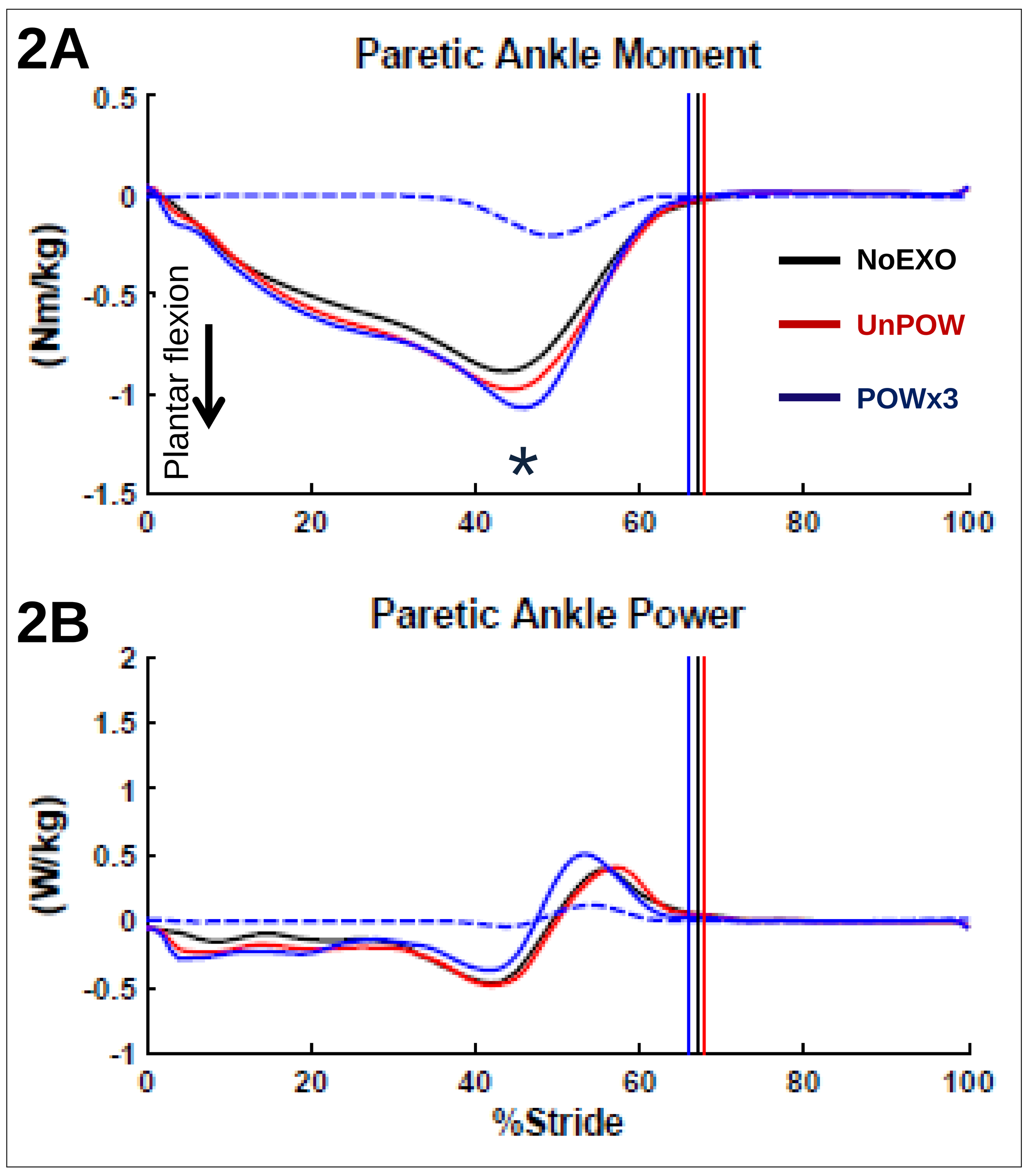
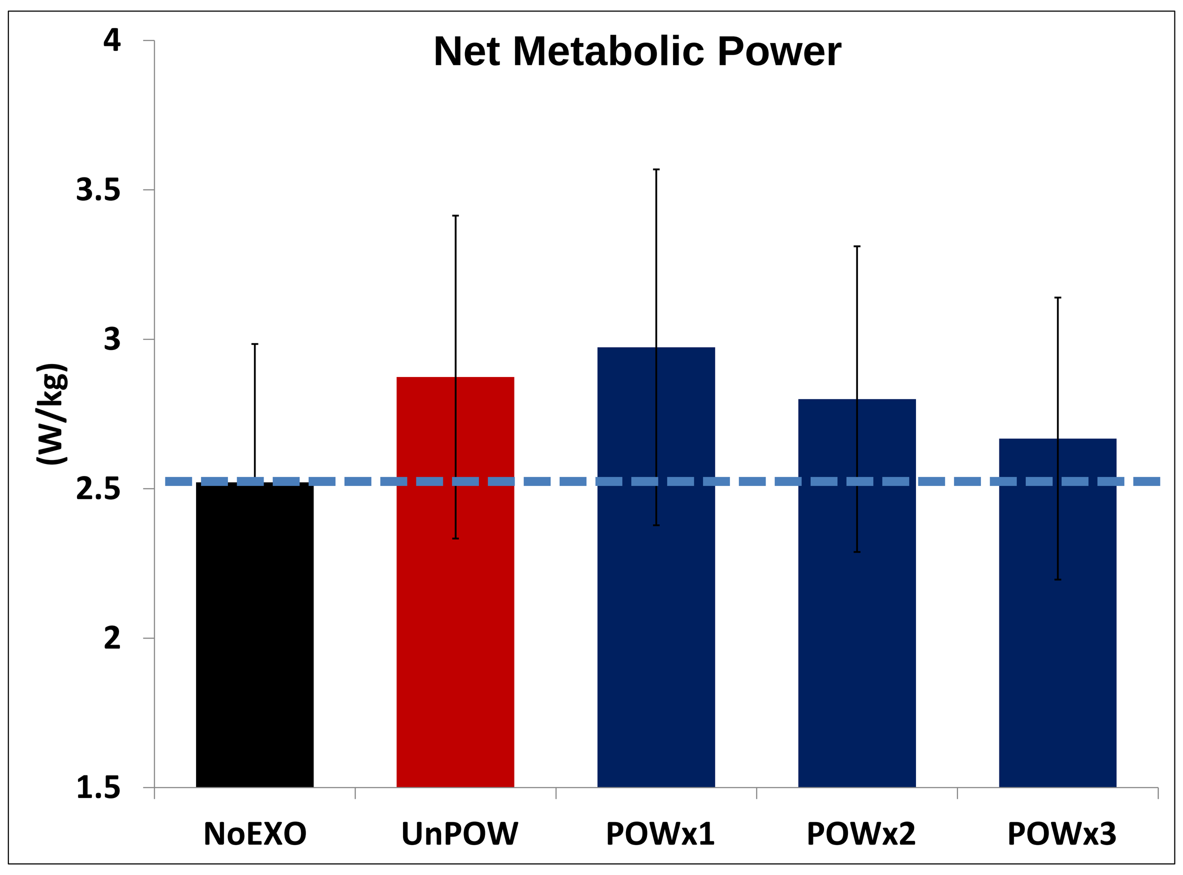


Figure 2: The paretic ankle joint moment (2A) and power (2B) profiles during the NoEXO (black line), UnPOW (red), and the last repetition of the POW condition (blue). The data were averaged from 10 consecutive steps obtained during the last minute of each condition. In the POW condition, the total paretic ankle joint power contains contributions from both the exoskeleton (dotted blue) and the biological muscles (not shown). ***** denotes significant effect of exoskeleton on peak plantar flexion moment

16% increase of peak plantar flexion moment with exoskeleton (POWx3 vs NoEXO, p < .05)

Non significant 9.0% increase of peak plantar flexion power with exoskeleton (POWx3 vs NoEXO, p = .83)

Figure 3: Whole body net metabolic power estimated from indirect calorimetry during NoEXO (black), UnPOW (red), and three repetitions of POW (blue) conditions.



No significant effect of exoskeleton on metabolics

(p = .21), but gradual training effect is evident

7 CONCLUSIONS

A user-controlled exoskeleton can enhance paretic ankle plantar flexion moment.

With repeated training sessions, we expect to see further increase in ankle joint moment and power output, improvement in lower limb mechanical symmetry, and reduction in metabolic cost of walking.

8 REFERENCES

[1] Jonkers I et al. *Gait & Posture* 29, 129-137, 2009
[2] Chen G et al. *Gait & Posture* 22, 51-56, 2005
[3] Chen G and Patten C. *J Biomech* 41, 877-883, 2008
[4] Nadeau S et al. *Clin Biomech* 14, 125-135, 1999
[5] Stoquart G et al. *Gait & Posture* 36, 409-413, 2012

9 ACKNOWLEDGMENTS

Supported by NIH 5R24-HD050821-08 Pilot Grant to GSS. North Carolina State University Office of Postdoctoral Affairs Professional Development Award to KZT.

Thanks to Bruce Wiggin, Audrey Westbrook, Ben Robertson, Christine Gilsdorf, Leighanne Davis, Samuel Ray, and Shiho Goto for exoskeleton fabrication and assistance with data collection.