# ExerExo: Exploring the Effects of Assistive and Resistive Ankle Exoskeleton Torque on Walking Mechanics and Energetics

***Arshad Mandani***[1], Zachary Lerner[2], Zachary Graham[3], Gregory Sawicki[1]

[1]Physiology of Wearable Robotics Lab, School of Mechanical Engineering, Georgia Tech, Atlanta, Georgia | [2]Biomechatronics Lab, School of Mechanical Engineering, Northern Arizona University, Flagstaff, Arizona | [3]Institute for Human and Machine Cognition, Pensacola, Florida

E-mail: amandani3@gatech.edu

## Introduction

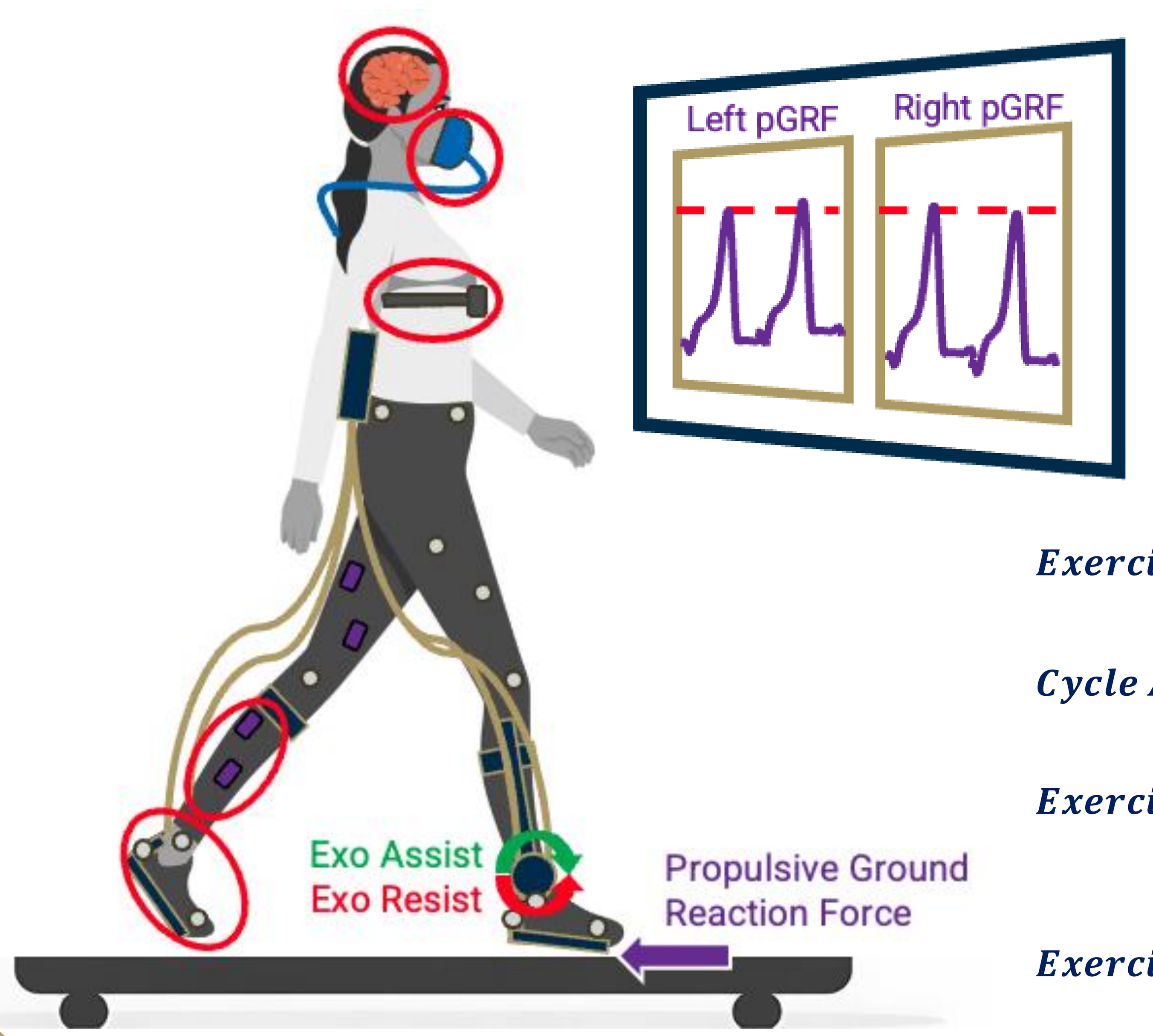
- Can ankle exoskeletons modulate exercise effort via assistive and resistive intervention?
- 24% of adults meet ACSM guidelines for aerobic and muscle strengthening activities (cardio 30 min, 5 days/week and resistance training 2-3 days/week) [1]
- Combining walking with resistance training can prevent mobility disorders [2]
- Reduction in calf power related to mobility decline. Need to strengthen plantarflexors [3]
- Dual-mode powered ankle exoskeleton (PAE) can modulate exercise effort in real-time, offering a real-world solution to muscle-specific training while walking

## Hypothesis

1. **Exercise effort can be increased by: *i.* manipulating exo resistance at a fixed speed or *ii.* manipulating speed (= stride frequency) at a fixed exo resistance**
2. **Equivalent exercise rates can be achieved across multiple conditions**

## Methods

- **Exo Conditions**: Zero Torque (ZT), Assistive PAE (aPAE), and Resistive PAE (rPAE)
- **Speeds**: 1.00 m/s, 1.25 m/s, 1.50 m/s
- **Propulsive GRF biofeedback** w/ speed-matched baseline targets to maintain ankle dynamics across conditions
- aPAE and rPAE at 1.25 m/s conducted **w/ and w/o biofeedback**
- **Measure of Exercise Effort**
  - Perceptual – Perceived Exertion
  - Physiological – Heart Rate & Metabolic Power
  - Mechanical – Ankle Torque & Power
  - Neuromuscular – Muscle Activation




$$\textit{Total Torque} = \textit{Biological Torque} + \textit{Exo Torque}$$

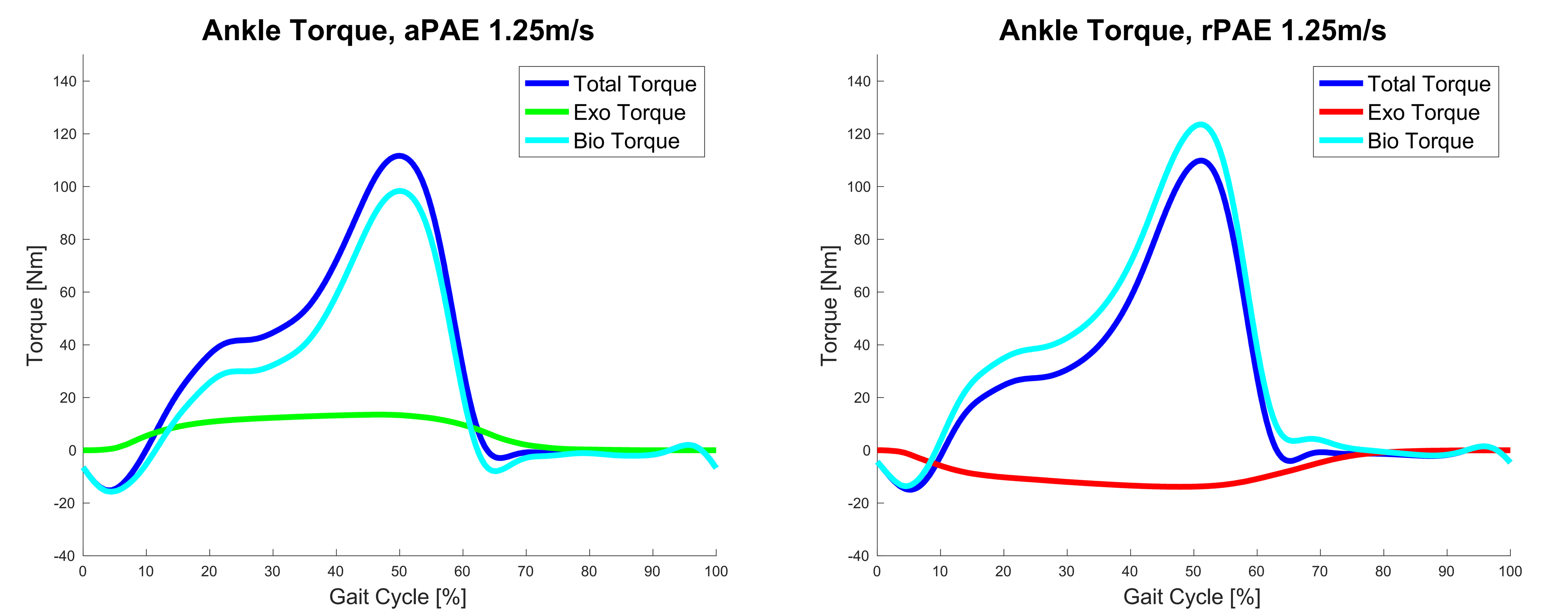
$$\textbf{\textit{Exercise Volume}} = \textit{Load} \times \textit{Reps}$$

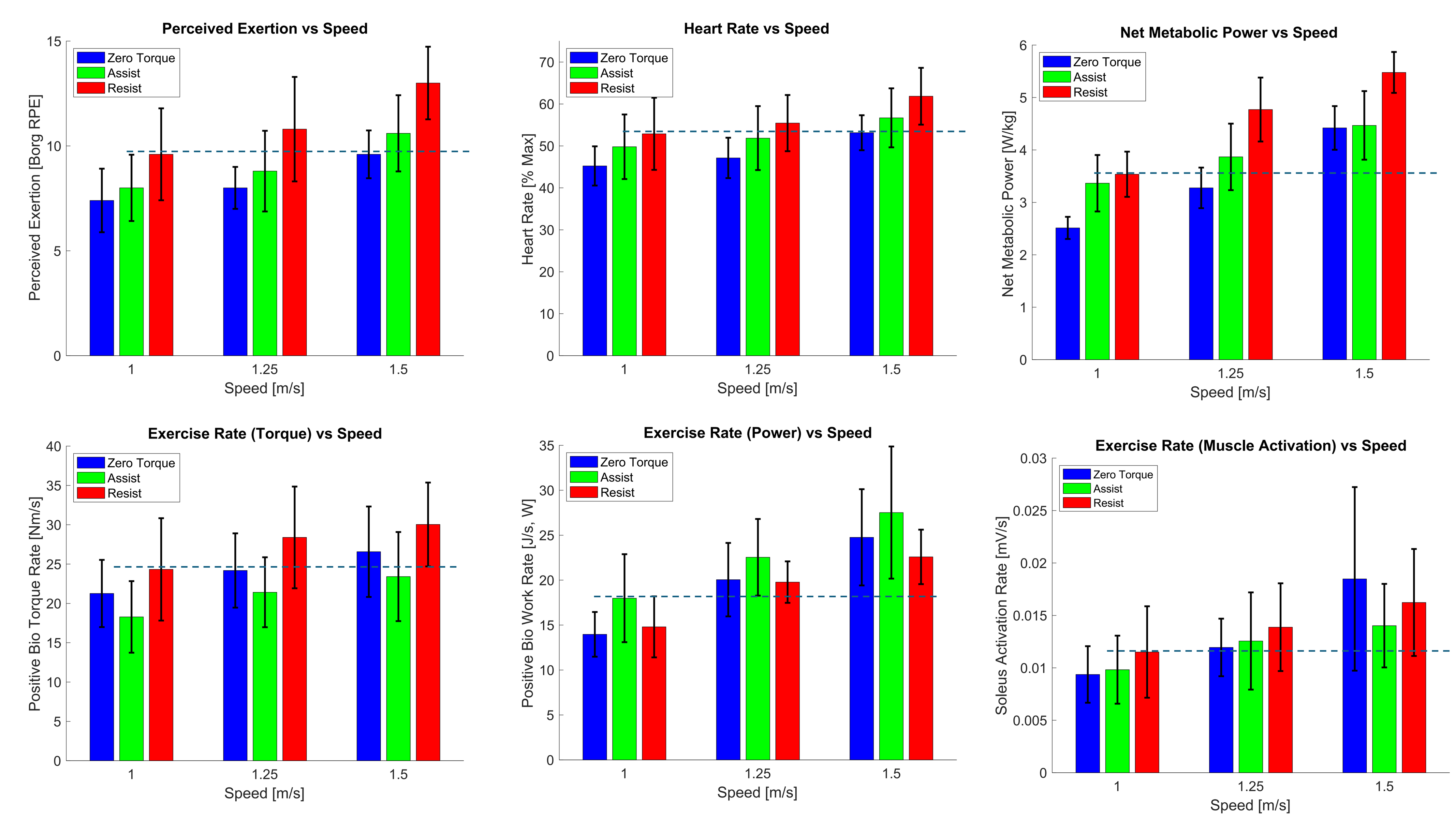
$$\textbf{\textit{Cycle Average Load}} = \frac{\textit{Effort}}{\textit{Cycle}}$$

$$\textbf{\textit{Exercise Rate}} = \textit{Cycle Average Load} \times \textit{Stride Frequency}\left[\frac{\textit{Cycle}}{\textit{Second}}\right]$$

$$\textbf{\textit{Exercise Volume}} = \textit{Exercise Rate} \times \textit{Time}$$

## Results (N=5)




- Speed (stride frequency) and exoskeleton condition significantly impacted measures of RPE, HR, NMP, and biological ankle torque rate
- Exercise effort experienced under resistance at low speeds (= low stride frequency) can be achieved at higher speeds (and higher stride frequencies) under different exoskeleton conditions (dashed lines)
- Biofeedback helps to ensure the participant is fully engaging with exoskeleton actuation, --> co-contraction of tibialis anterior results in higher measures of effort
- PAE simulates traditional resistance training, but during walking (load x reps = exo user effort x strides)

## Significance

- Innovative use case for ankle exoskeletons by leveraging both assistive and resistive torque to modulate exercise effort during walking
- In clinical populations, wearable resistance could provide targeted low-impact and low-speed strength training for individuals with tailored exercise dose demands

**[1] Elgaddal et al. (2022), NCHS Data Brief; [2] Pashor et al. (2014), JAMA 311; [3] Stenroth et al. (2015), J. Gerontol. Biol. Sci. Med. Sci. 70**