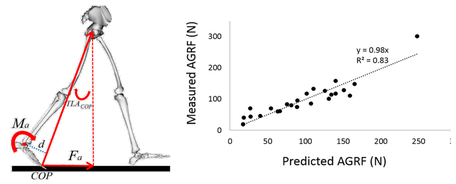
NRI: Goal-Oriented, subject-Adaptive, robot-assisted Locomotor Learning (GOALL)

Robert L. McGrath[1], Andria Farrens[1], Maria Lilley[1], Joshua Jacob[1]
PI: Fabrizio Sergi[1] co-PI: Jill S. Higginson[2], Darcy Reisman[3]
[1] Human Robotics (HuRo) Laboratory, University of Delaware; [2] Neuromuscular Biomechanics Laboratory, University of Delaware, [3] Physical Therapy Department, University of Delaware contact: fabs@udel.edu

Background

- About 50% of stroke survivors are left with hemiparesis [1]
- Self-selected speed (SSS) is a primary outcome measure of gait neurorehabilitation
- SSS in post-stroke individuals does not minimize metabolic cost [2]
- SSS is determined by the capability to apply horizontal forces to the ground.
- Propulsion depends on propulsive force and push-off kinematics (i.e. trailing limb angle TLA), but there is a scarcity of intervention methods that are specifically focused on propulsion

This project focuses on formulating robot-assisted training strategies focused on propulsion during walking



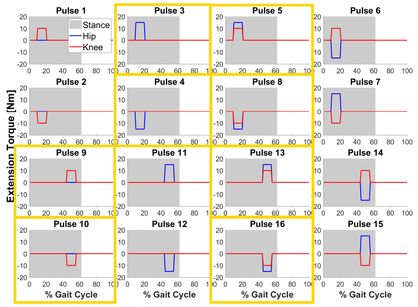
(Left) Schematic of push-off kinematics with the definition of Trailing Limb Angle (TLA). **(Right)** A regression model including only TLA angle predicts 83% of the variance in the measured anterior ground reaction force (AGRF). From [3]

Project goal

To develop subject-adaptive control strategies for a gait training robot to train propulsion

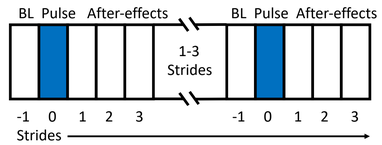
Pulsed Torque Assistance

(above) Healthy control subject wearing the ALEX II exoskeleton while walking on the instrumented treadmill. **(below)** repeated pulse application paradigm



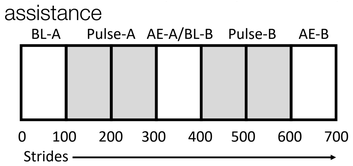
(above) Graphical representation of the sixteen torque pulse conditions for single-pulse application and the selected subset of eight conditions for repeated-pulse application, derived from our previous work [5], **(below)** single pulse application paradigm

Experiment 1: Single stride pulsed torque assistance [6]



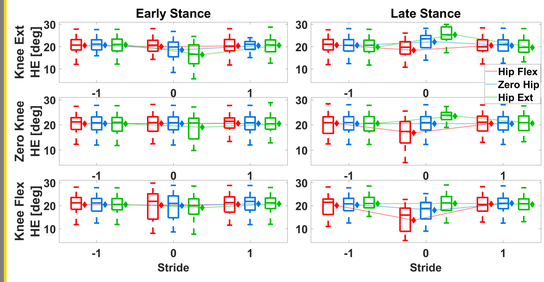
- N=16, all 16 pulses tested
- 10 repetitions per pulse type
- Outcome measures: peak hip extension and propulsive impulse
- Analysis based on linear mixed models with fixed effects of pulse time (early vs. late stance), hip torque, knee torque, stride

Experiment 2: Repeated pulsed torque assistance

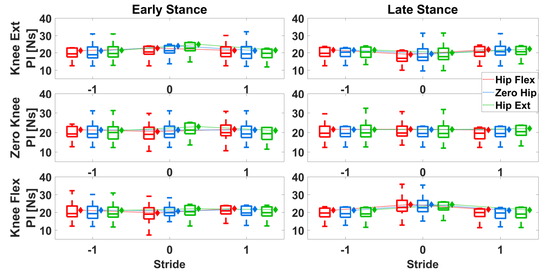


- N=16, 8 pulses tested (those showing strongest effect in single pulse experiment)
- Pulses A and B randomized
- Outcome measures: peak hip extension and propulsive impulse
- Analysis based on linear mixed models

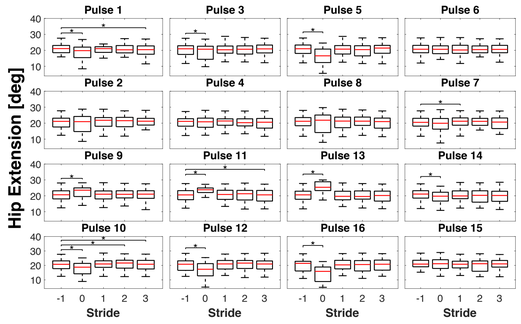
Single Stride Pulsed Torque Assistance

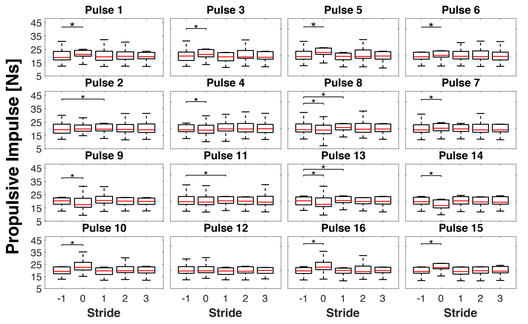


(above) Group four-way interaction for hip extension. During late stance, at stride 0, knee and hip extension torques increased HE and hip flexion torque decreased HE.



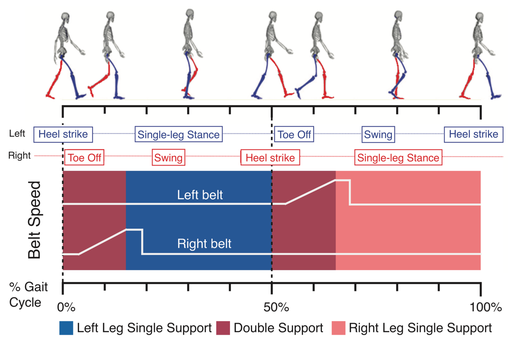
(above) Group four-way interaction for propulsive impulse. During early stance, at stride 0, knee and hip extension torques increased PI. During late stance, at stride 0, knee flexion torque and combined knee and hip extension torques increased PI.





Group hip extension data **(top left)** and propulsive impulse data **(top right)** by stride for all pulse conditions. Wilcoxon-signed-rank tests were performed between the baseline stride (-1) and the following four strides stride (0, 1, 2, 3); statistically significant comparisons are indicated with asterisks.

Accelerating the Trailing Limb to Train Propulsion



(above) Timing diagram of the belt velocity profile. The belt supporting the trailing limb is subject to constant acceleration α during double support.

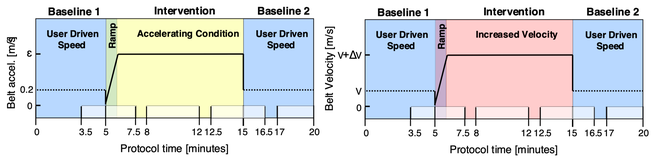
Novel strategy: use a split belt treadmill to accelerate the treadmill belt supporting the trailing limb during double support to train **posture** and **ankle plantarflexion** during push-off.

Experimental groups

1. Perceptible (α = 7 m/s^2): 19 subjects
2. Imperceptible (α = 2 m/s^2) : 20 subjects
3. Velocity Control (Δv = 0.05 m/s) : 20 subjects

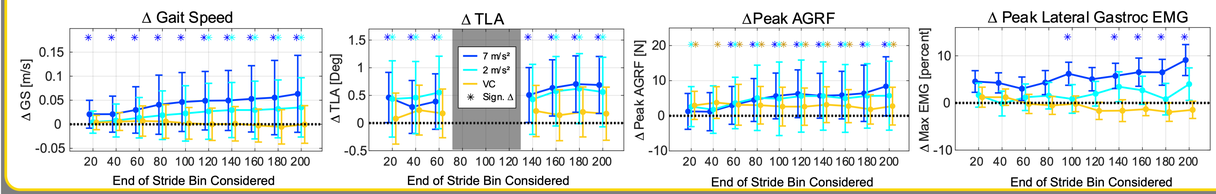
Outcome measures

1. Peak anterior ground reaction force (Peak AGRF)
2. Gait speed
3. Peak lateral gastrocnemius EMG
4. TLA

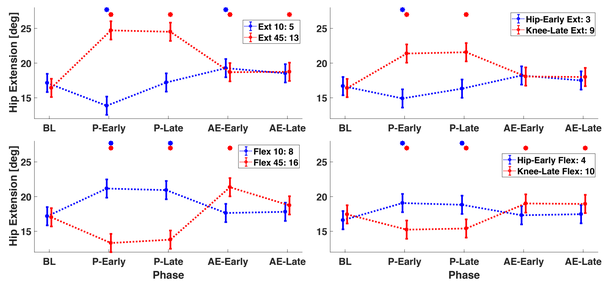


Results

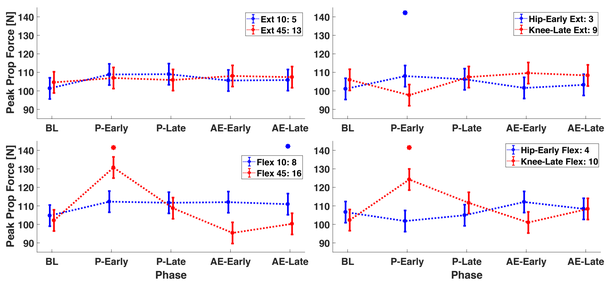
Two-way mixed effects ANOVA revealed **significant effect of training on the outcome measures** after training. Post-hoc analysis revealed greater change in the perceptible training group than the imperceptible training group and no change in the velocity matched control group. **(Below)** Mean change in gait parameters from baseline 1, partitioned into 20 stride bins spanning strides 1-200 of baseline 2. Asterisk indicate significance of paired t-tests at the p<0.05 uncorrected level.



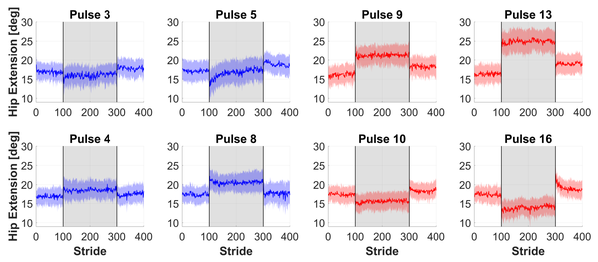
Repeated Pulsed Torque Assistance

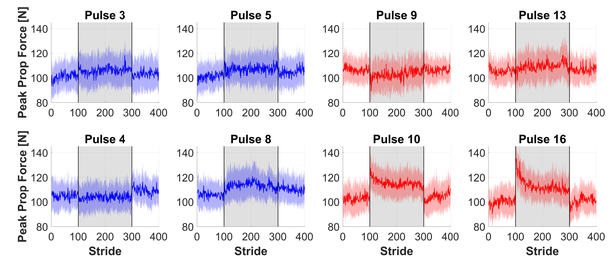


(above) Three-way interaction means produced by linear mixed models for hip extension, asterisks indicate significant difference from baseline **(below)** group individual stride means for hip extension shown for each pulse condition



(above) Three-way interaction means produced by linear mixed models for peak prop force, asterisks indicate significant difference from baseline **(below)** group individual stride means for peak prop force shown for each pulse condition





Acknowledgment

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[6] McGrath et al., IEEE 16th ICORR, 874-879, June 2019.