Assisting Balance Recovery with Lower Limb Exoskeleton

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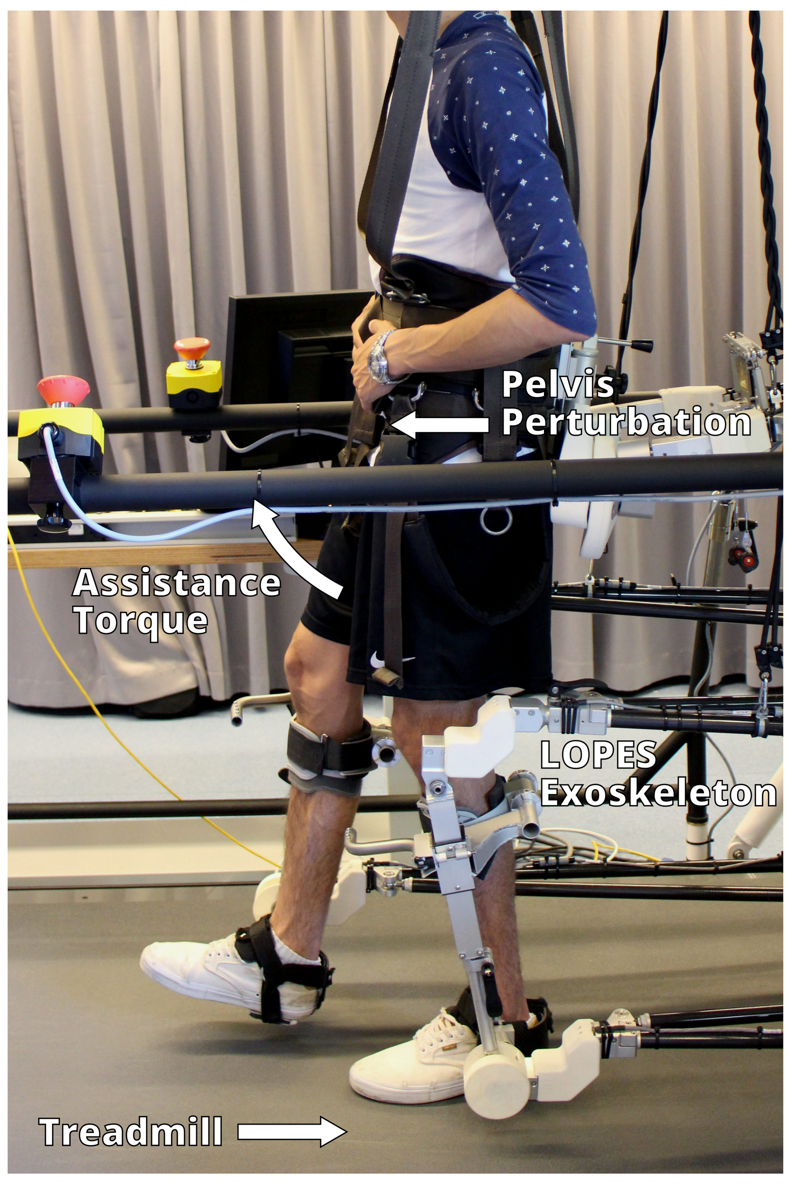
BACKGROUND

BALANCE RECOVERY

Robotic balancing assistance is developed to help humans maintain balance in walking; this ability can be compromised in elderly and neurologically impaired individuals

EXOSKELETON

LOPES (**LO**wer extremity **P**owered **E**xo**S**keleton, University of Twente, Enschede, Netherlands) can actuate and measure interaction torques at the hip and knee, and translational forces at pelvis, at 1 kHz



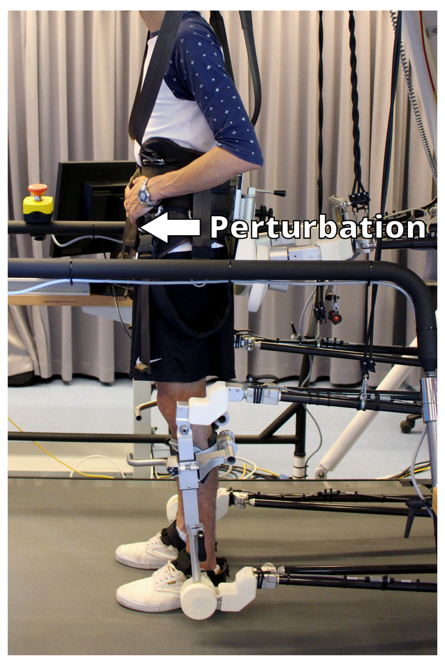
METHODS

STANDING EXPERIMENT

- Subjects stand with weight on left leg
- Forward perturbation (200 ms) applied to pelvis, leading to step with right leg

ASSISTANCE

- 55 ms delay after perturbation
- 200 ms hip flexion
- 200 ms hip extension



PROTOCOL

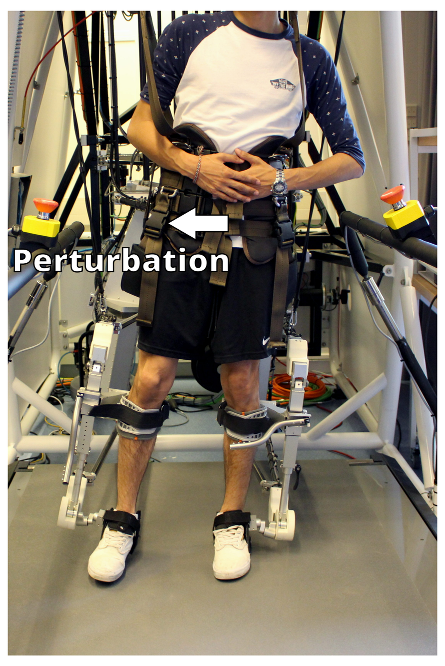
- *Baseline:* 20 trials. No assistance
- *Assistance:* 50 trials. Assistance applied
- *Catch:* 5 trials. No assistance
  Randomly inserted in last 20 *Assistance* trials

WALKING EXPERIMENT

- Subjects walk on treadmill
- Lateral perturbations applied during swing phase
- EMG recorded from right and left gluteus medius

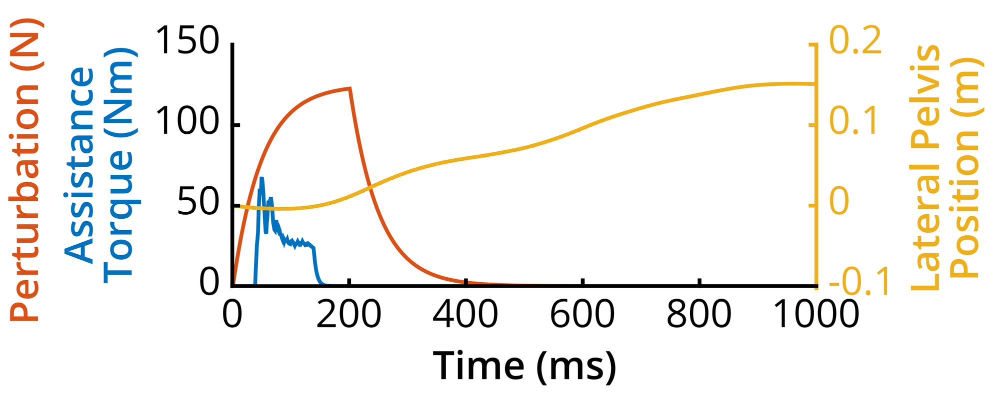
ASSISTANCE

- Perturbation detected by pelvis acceleration crossing threshold
- 200 ms hip abduction torque applied
- Torque decay to limit interaction energy



PROTOCOL

- *Familiarization:* 2–3 minutes treadmill walking no perturbations.
- *Baseline:* 40 perturbations. No assistance
- *Assistance:* 70 perturbations. Assistance applied
- *Catch:* 10 perturbations. No assistance
  Randomly inserted in last 30 Assistance perturbations



ACKNOWLEDGMENTS

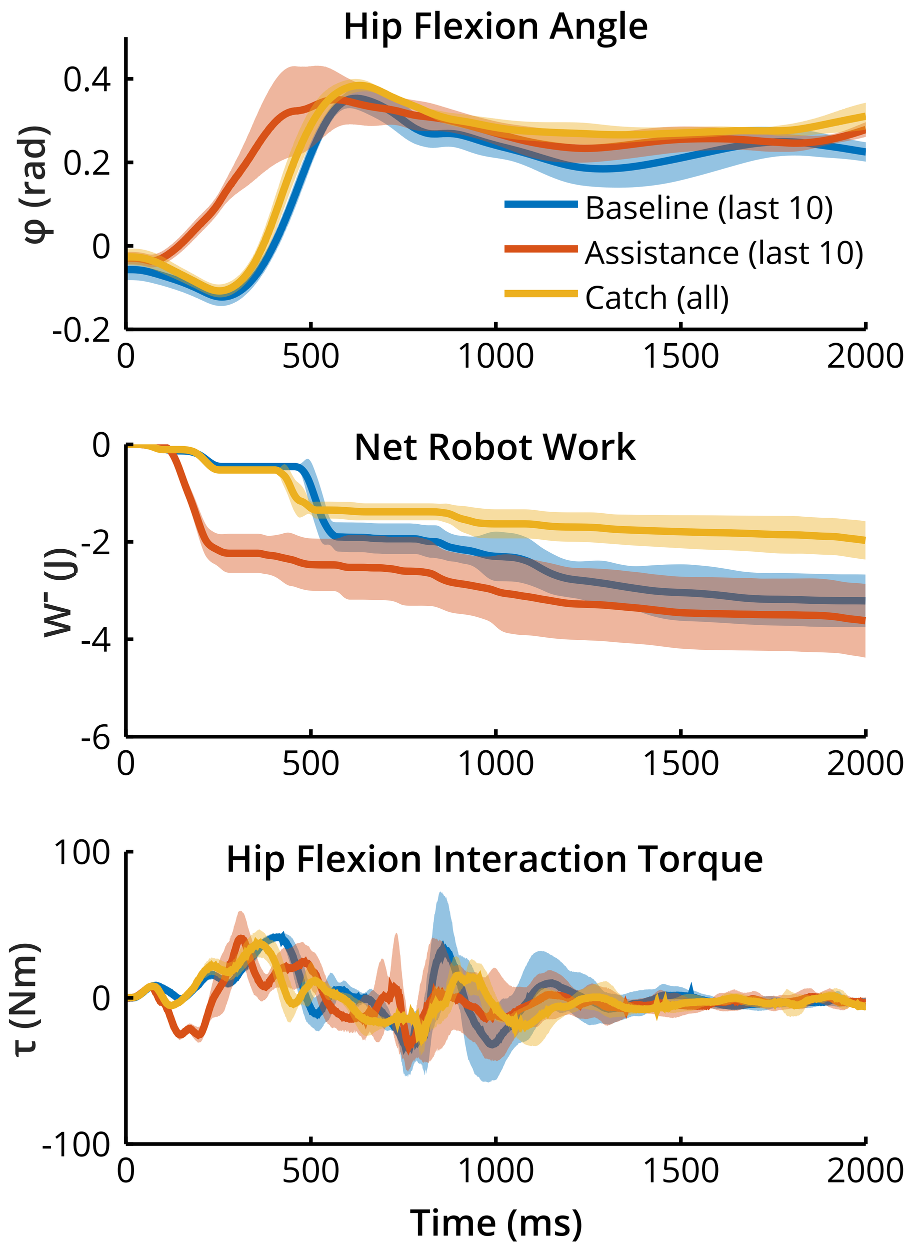
This work was supported by the EU FP7 grant BALANCE ICT-601003
Julia Ebert is supported by a Marshall Scholarship

SEVENTH FRAMEWORK PROGRAMME BALANCE MARSHALL SCHOLARSHIPS

RESULTS

STANDING EXPERIMENT

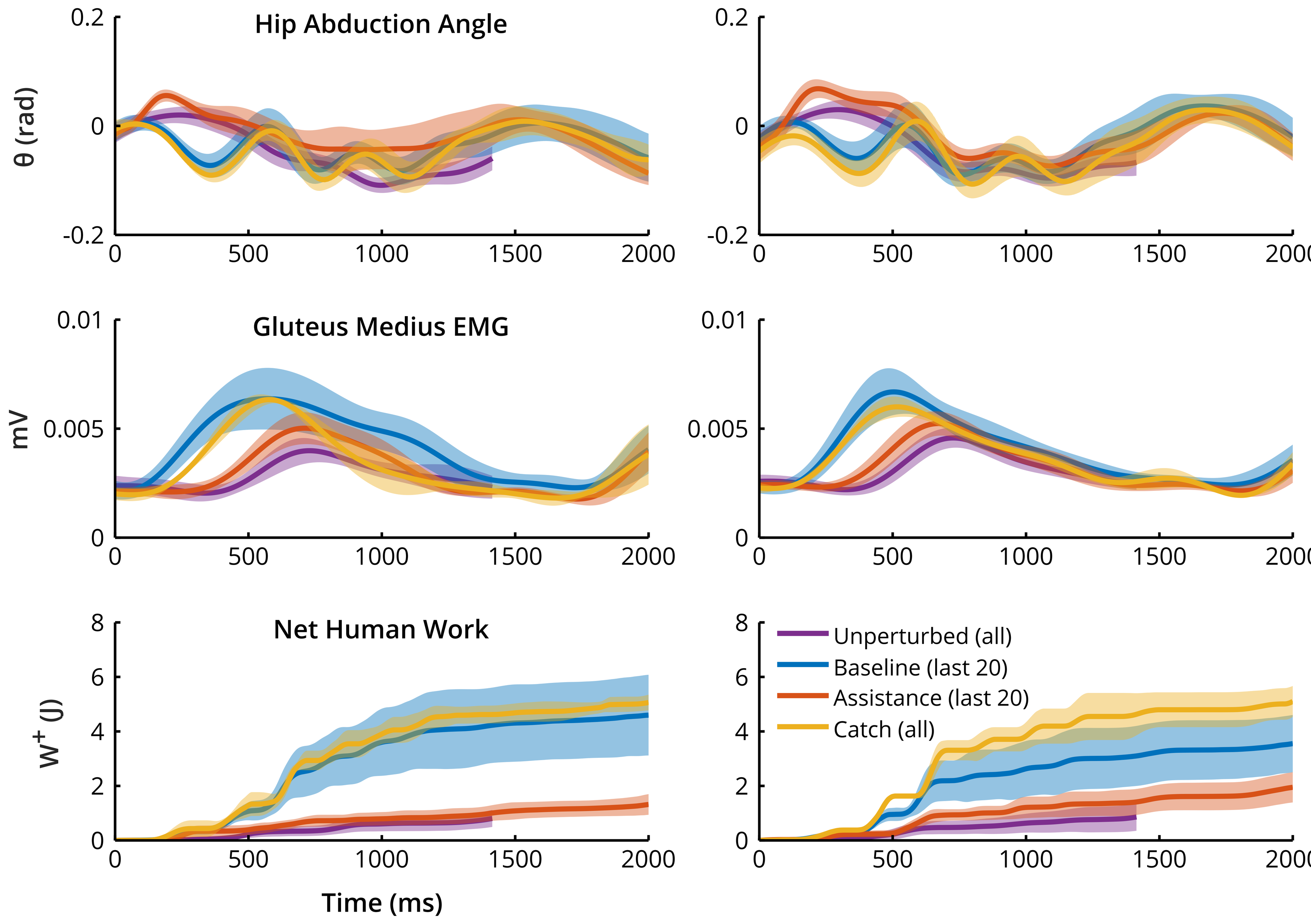
- Work (mechanical energy) is divided into positive (net power from human) and negative (net power from robot)
- Peak hip flexion angular velocity occurs at 200 ms only in *Assistance*
- Net robot work dropped sharply early in *Assistance*
- Interaction torque has local minimum at 250 ms in *Assistance*
- Interaction torque did not change from early to late *Assistance*
- 3/5 subjects showed an increase in peak angular velocity from early to late *Assistance*



Plots show mean and standard deviation for a single subject, aligned at perturbation onset

WALKING EXPERIMENT

- Hip abduction angle in *Assistance* more closely matches unperturbed trajectory
- Swing leg EMG is reduced for all subjects in *Assistance*
- Net human work is lower with assistance
- Net robot work has sharp drop following the perturbation in *Assistance,* as in standing experiment



DISCUSSION

STANDING EXPERIMENT

- Robot work and interaction torque differences are result of assistance
- No differences between baseline and catch implies no change to subject movement strategy necessary (or caused)
- Lack dependent measure to quantify whether observed changes resulted in improved balance recovery

WALKING EXPERIMENT

- Assistance caused hip abduction similar to unperturbed walking
- Design of assistance decay successfully reduced interaction torques, resulting in net lower human work
- Lower EMG implies assistance successfully limited muscular effort to achieve stable walking