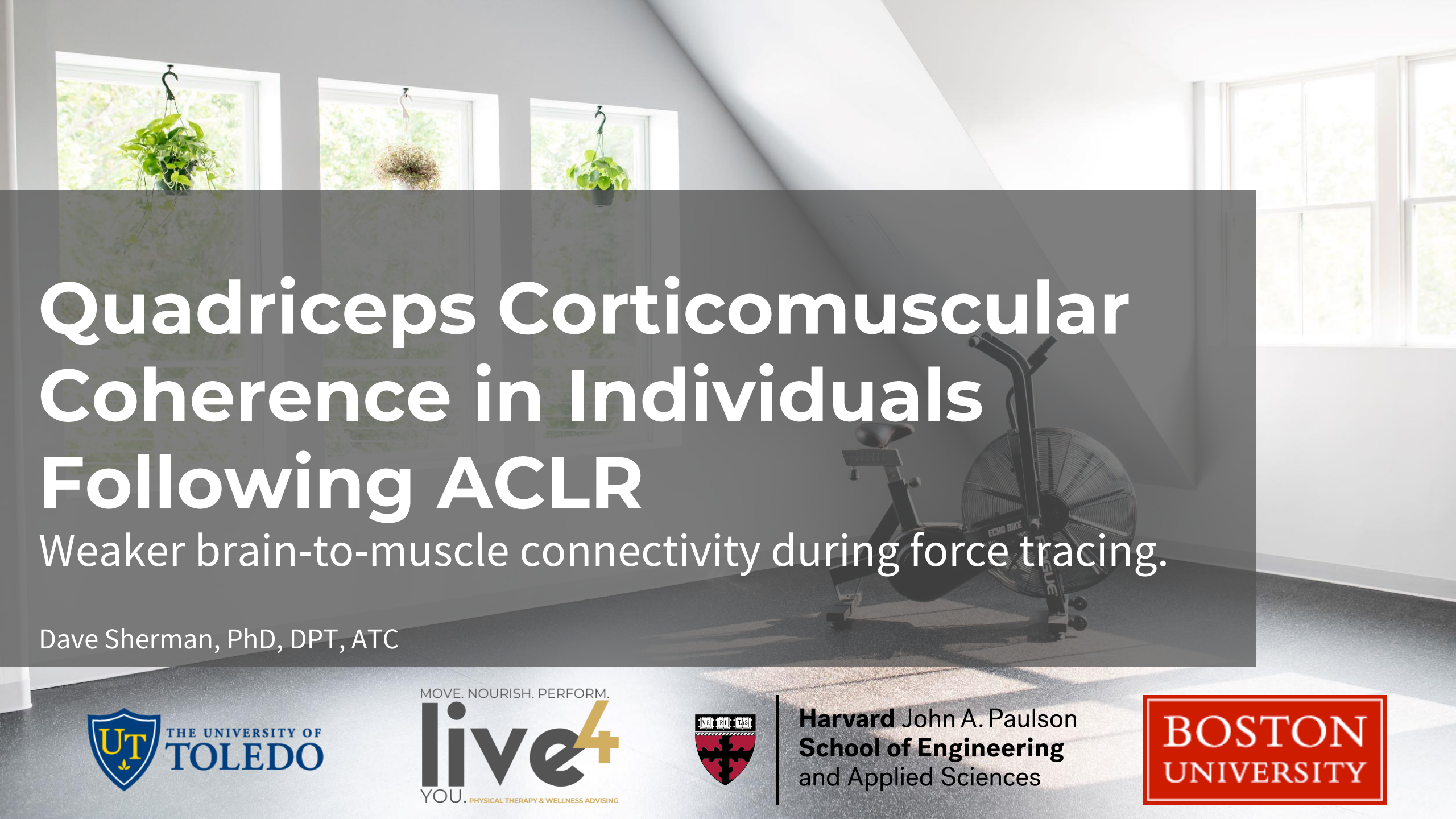

Quadriceps Corticomuscular Coherence in Individuals Following ACLR

Weaker brain-to-muscle connectivity during force tracing.

Dave Sherman, PhD, DPT, ATC

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Disclosures

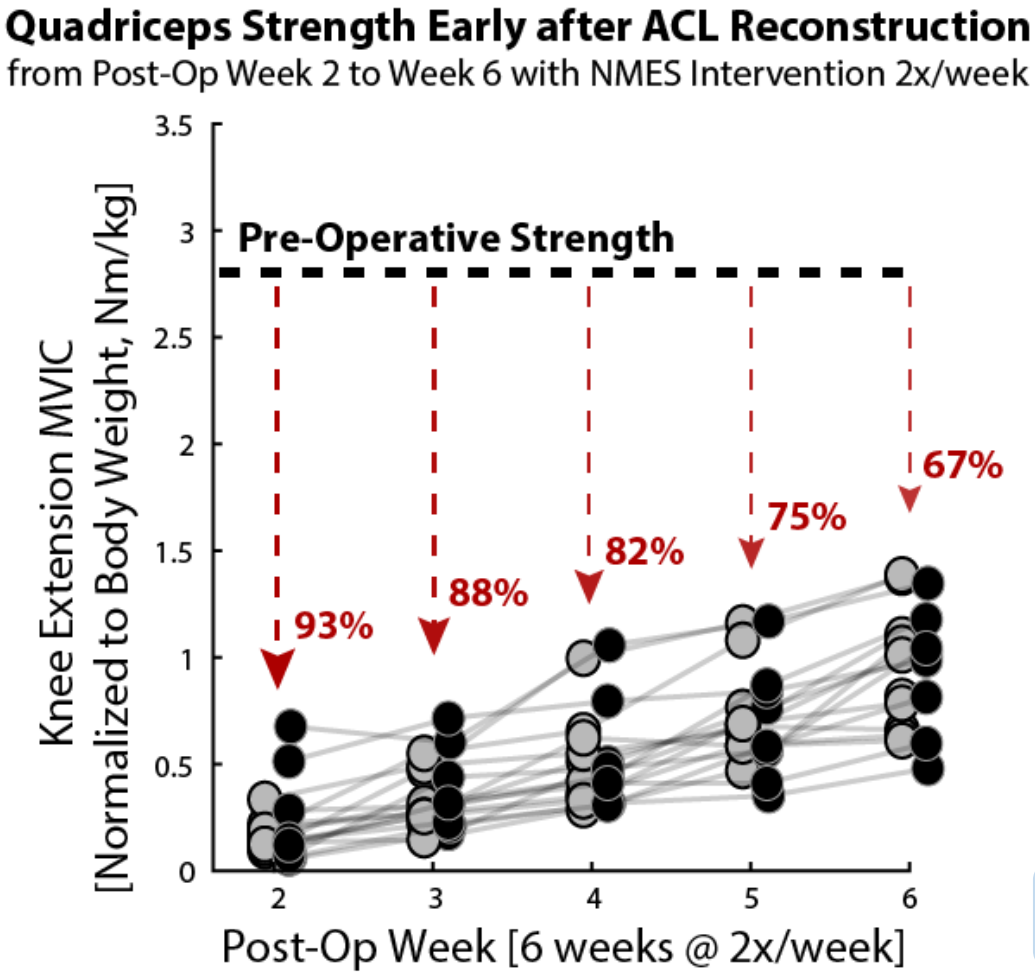
- I thank those who supported this work.

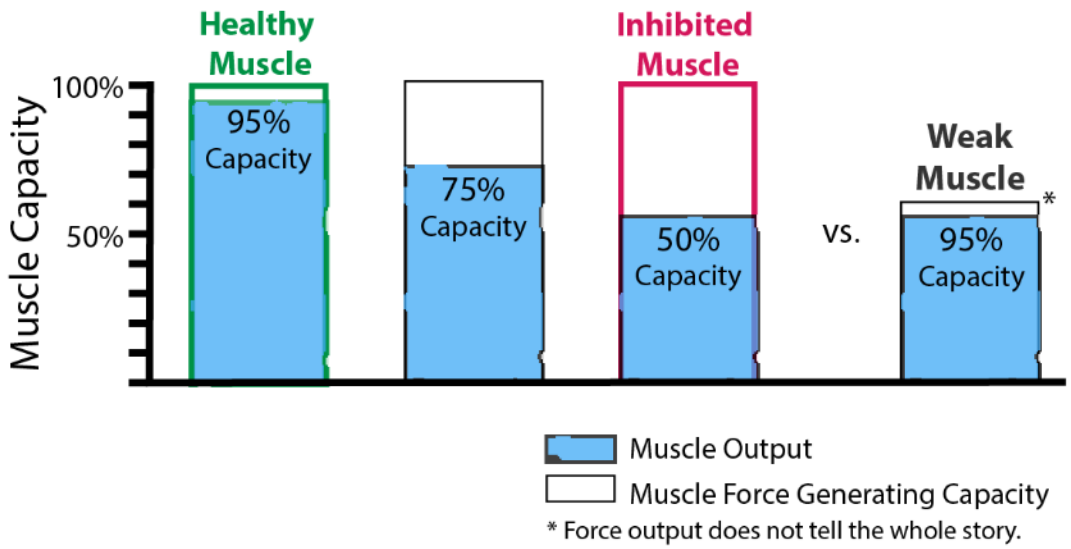
- Presentation includes published data.

- I have no other conflicts of interest to disclose.


Muscle function is dependent upon
neural input.

The Quadriceps Problem



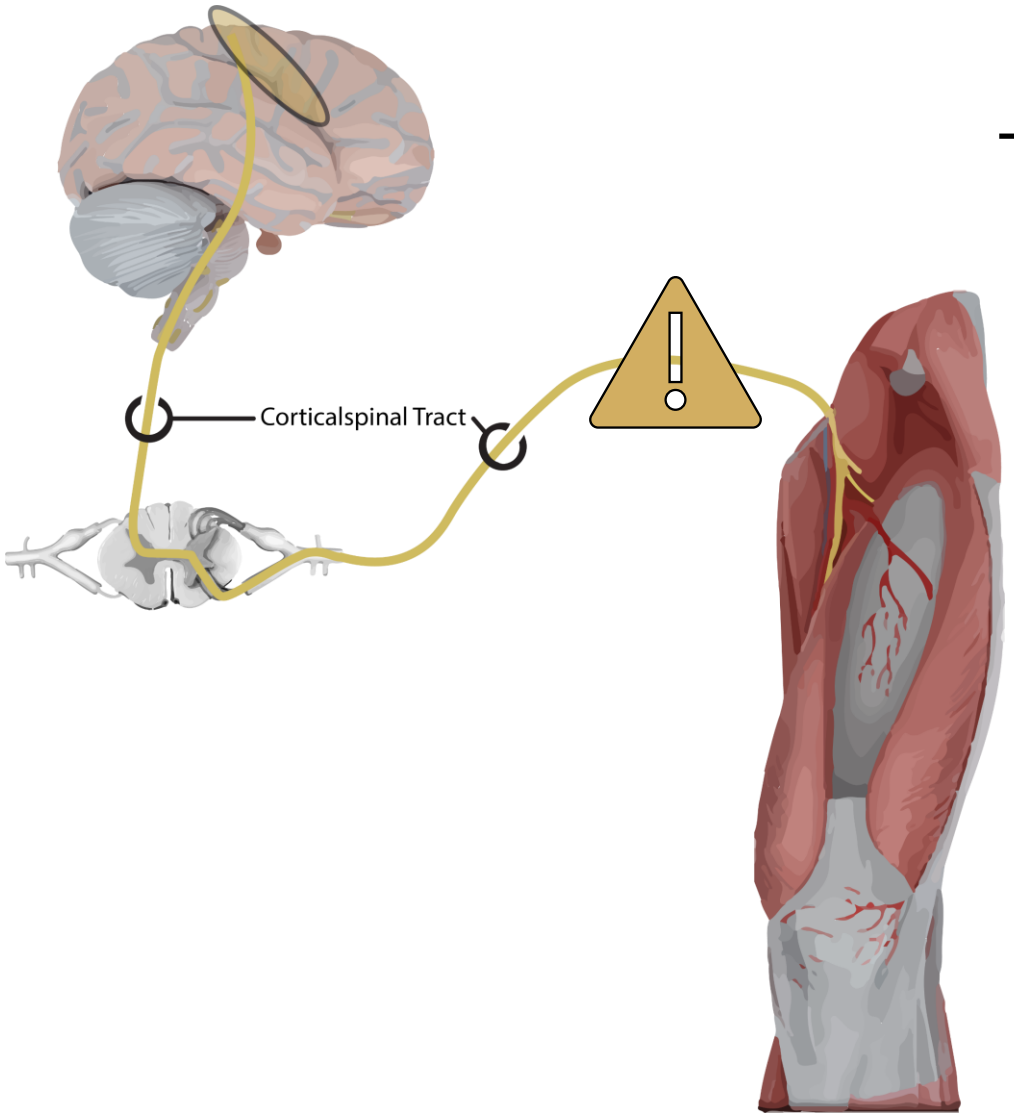


Post-op strength loss is **NOT** muscle weakness*

*At least not early on.

Activation Failure in Quadriceps is the most prominent neural impairment after ACLR

Cortical Motor Pathway

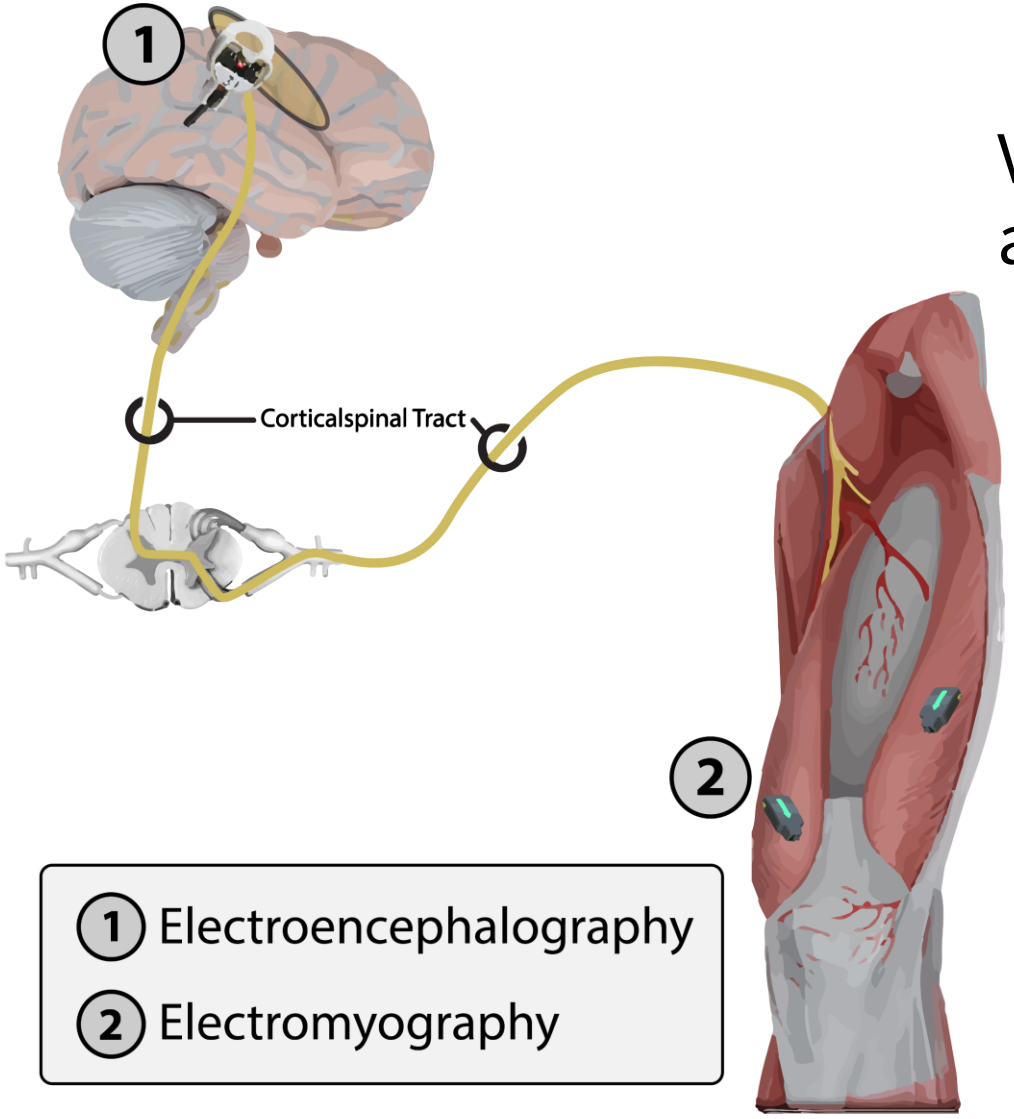


Those with ACLR exhibit

- ↑↑ motor cortex inhibition
  (Scheurer, 2020; Rush, 2021; Sherman 2022)
- ↓↓ corticospinal tract volume
  (Lepley, 2020)
- ↑↑ motor cortex activation during:
  - Rhythmic flex/ext tasks (fMRI) (Grooms, 2017)
  - Force control tasks (EEG) (Baumeister, 2011)
- ↓↓ motor cortex activation during:
  - Single Limb Balance (Sherman, 2023)
  - Reaction Time (Sherman, 2022)

Impairments in the corticospinal tract coincide with quadriceps weakness after ACLR

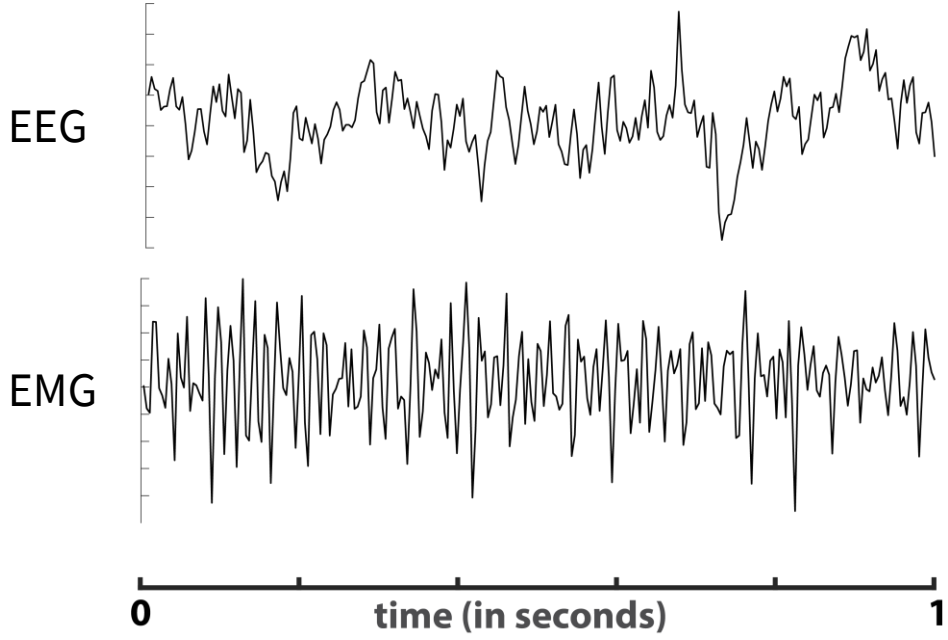
Corticomuscular Connectivity



Volitional control requires coupling of neural activity

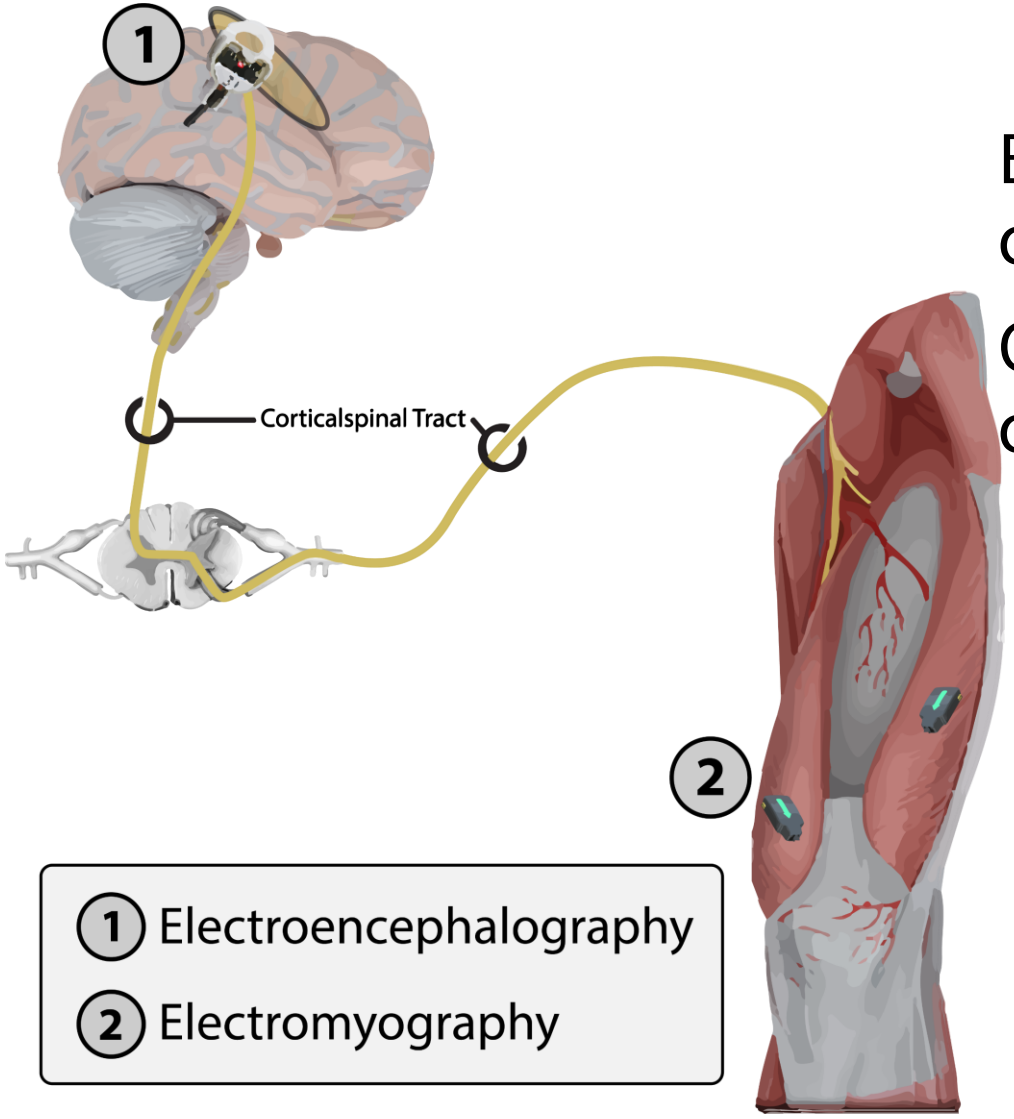
EEG and **EMG** are coupled systems (Yang, Eur J Neurosci, 2018)

"Predict signal Y from signal X"



The Quality of Brain-to-Muscle connectivity can be measured with corticomuscular coherence.

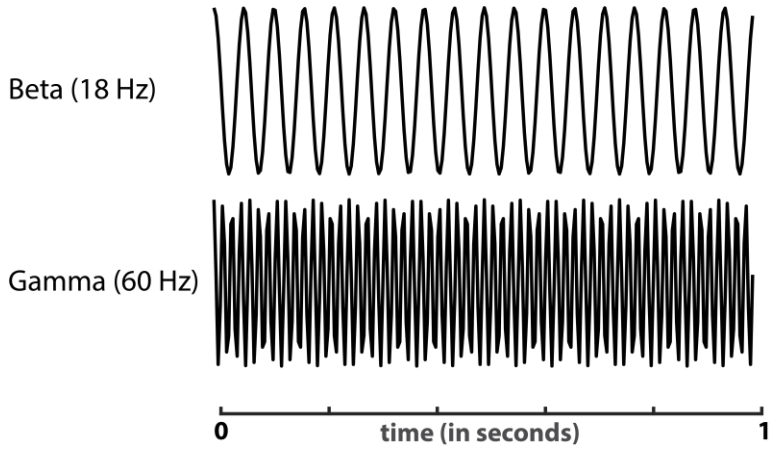
Corticomuscular Connectivity



Beta [13-30 Hz] dominant in **isometric** contractions

Gamma [31-80 Hz] dominant in **dynamic** contractions

Requirement of more visual/somatosensory information (Gwin & Ferris, Front Hum Neuro, 2012)



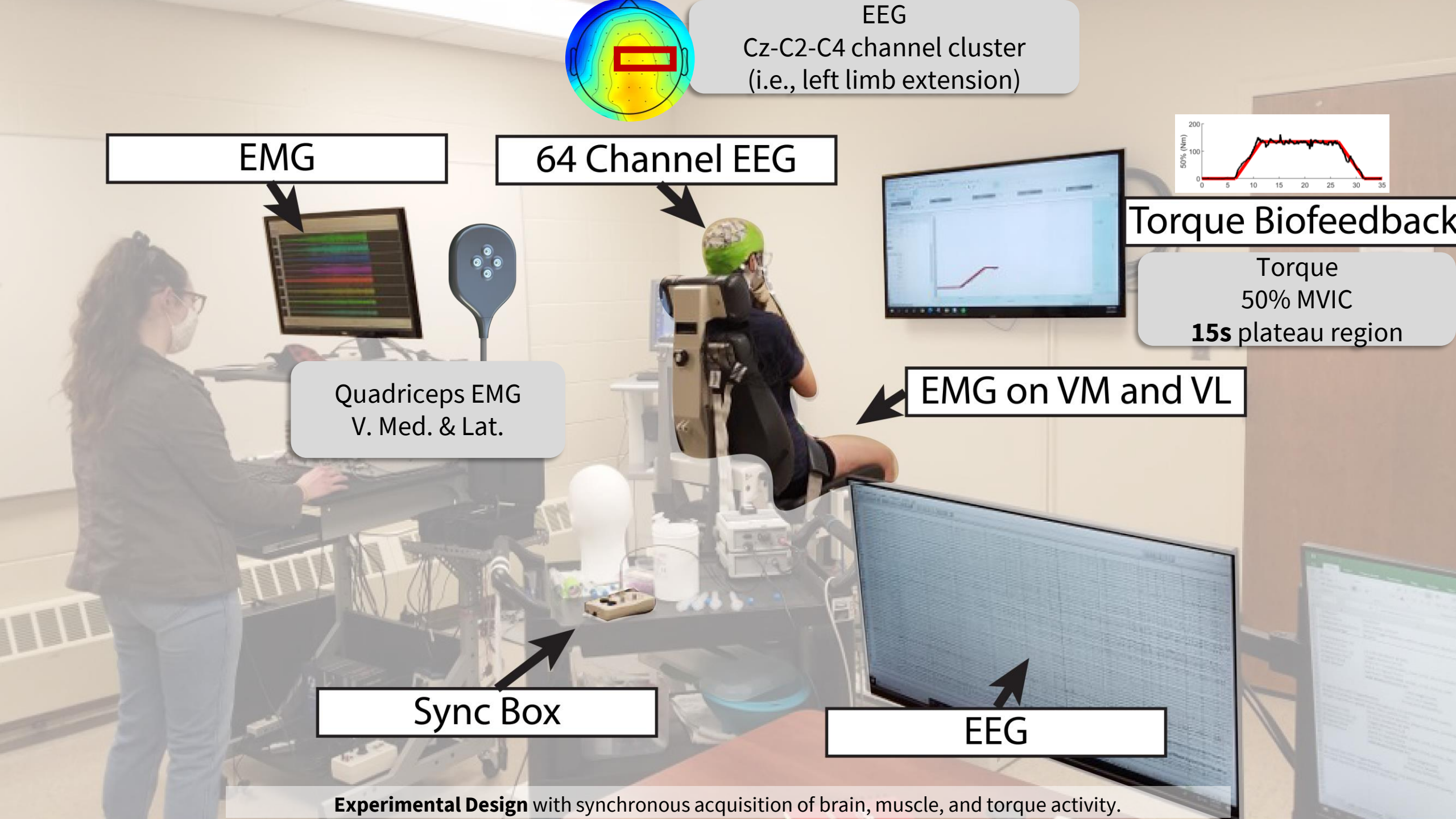
The Quality of Brain-to-Muscle connectivity can be measured with corticomuscular coherence.

Hypotheses

1. Individuals with ACLR would demonstrate **lower quadriceps CMC amplitude bilaterally** (beta and gamma frequency bands) compared to matched controls.

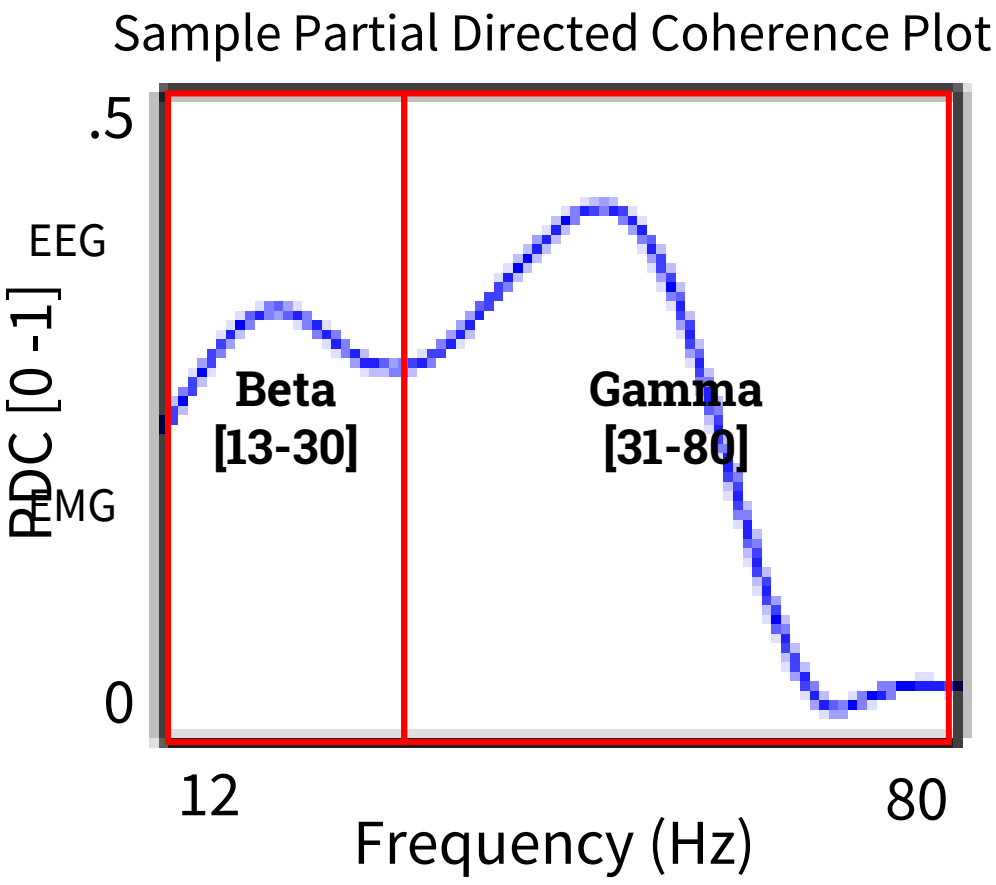
2. Individuals with ACLR would demonstrate worse force control than controls.

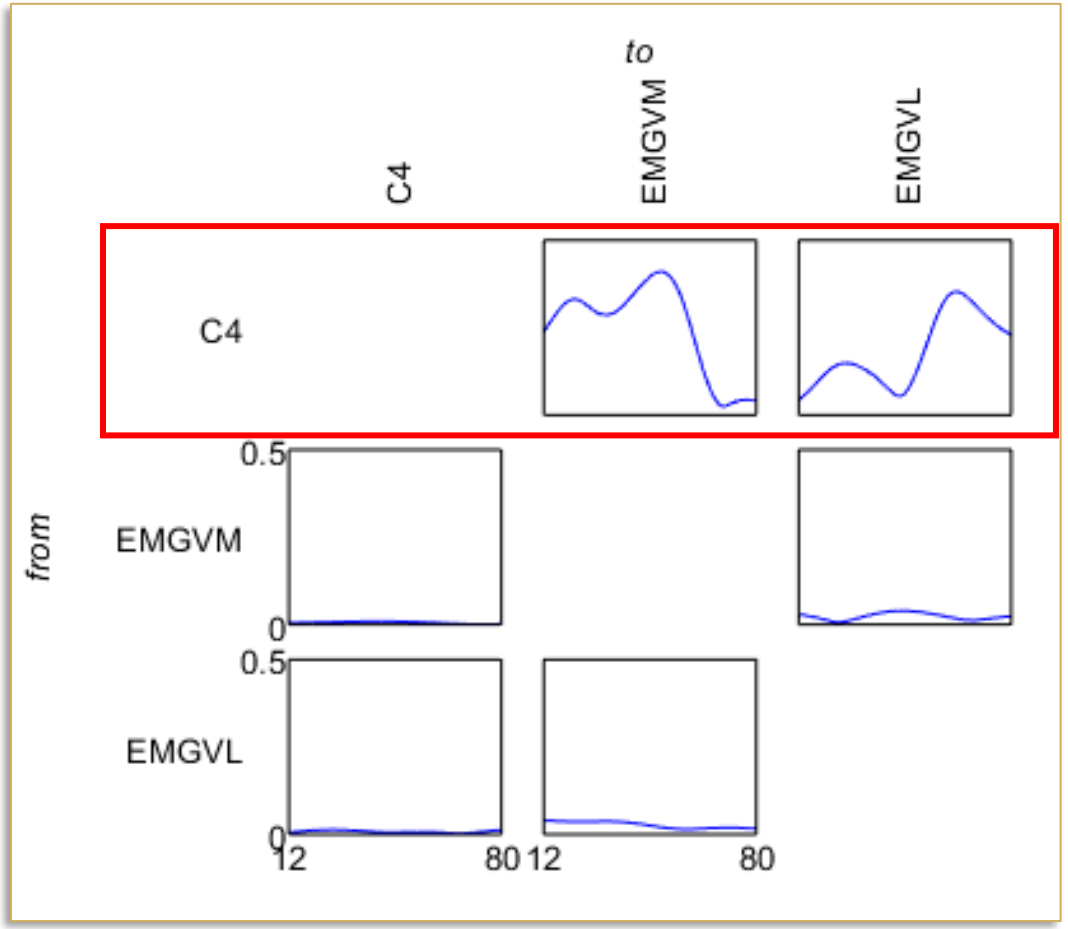
Hypotheses detailing negative motor plasticity after ACLR during knee extension



Experimental Design with synchronous acquisition of brain, muscle, and torque activity.

Data Processing - Partial directed coherence





Directed Connectivity was computed for brain to muscle, and muscle to brain relationships.

Statistical analysis

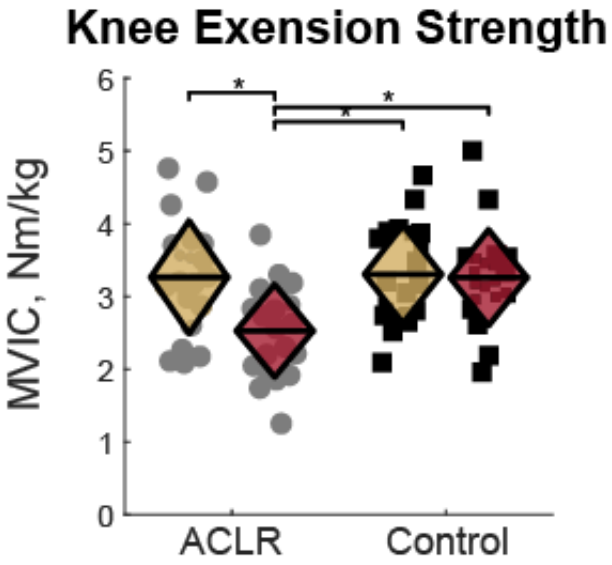
Differences in corticomuscular coherence & force control between groups and limbs

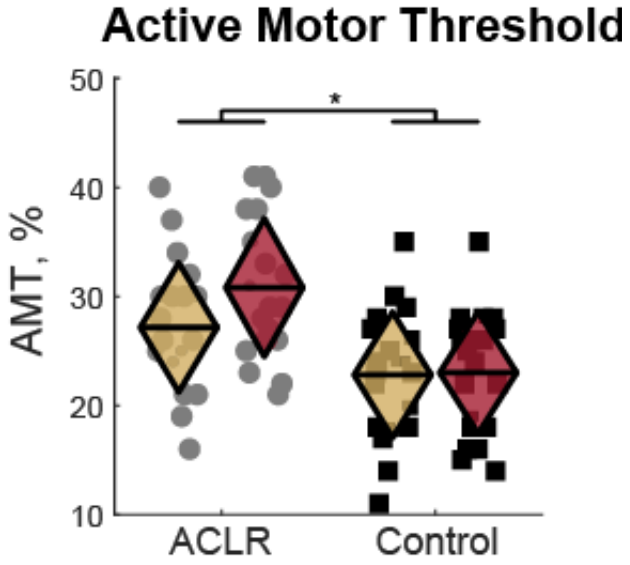
- 2x2 factorial ANCOVA*/ANOVA
  - Alpha < 0.05
  - *post hoc* Bonferroni-corrected paired-sample t tests
  - Cohen's *d* effect sizes with 95% confidence intervals
    - ≥ 0.2 small / ≥ 0.5 medium / ≥ 0.8 large (Cohen, 1988)

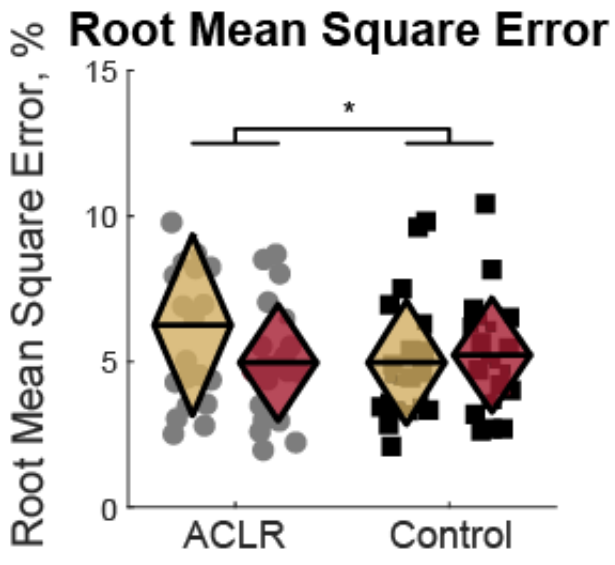
*CMC is likely to be influenced by torque output and motor threshold, thus MVIC and AMT were *a priori* co-variates for ANCOVA

Analysis included quadriceps strength and TMS-derived active motor threshold as covariates.

Strength, Motor Threshold, + Force Steadiness Performance







ACLR$_{INV}$ > All (Large Effects)

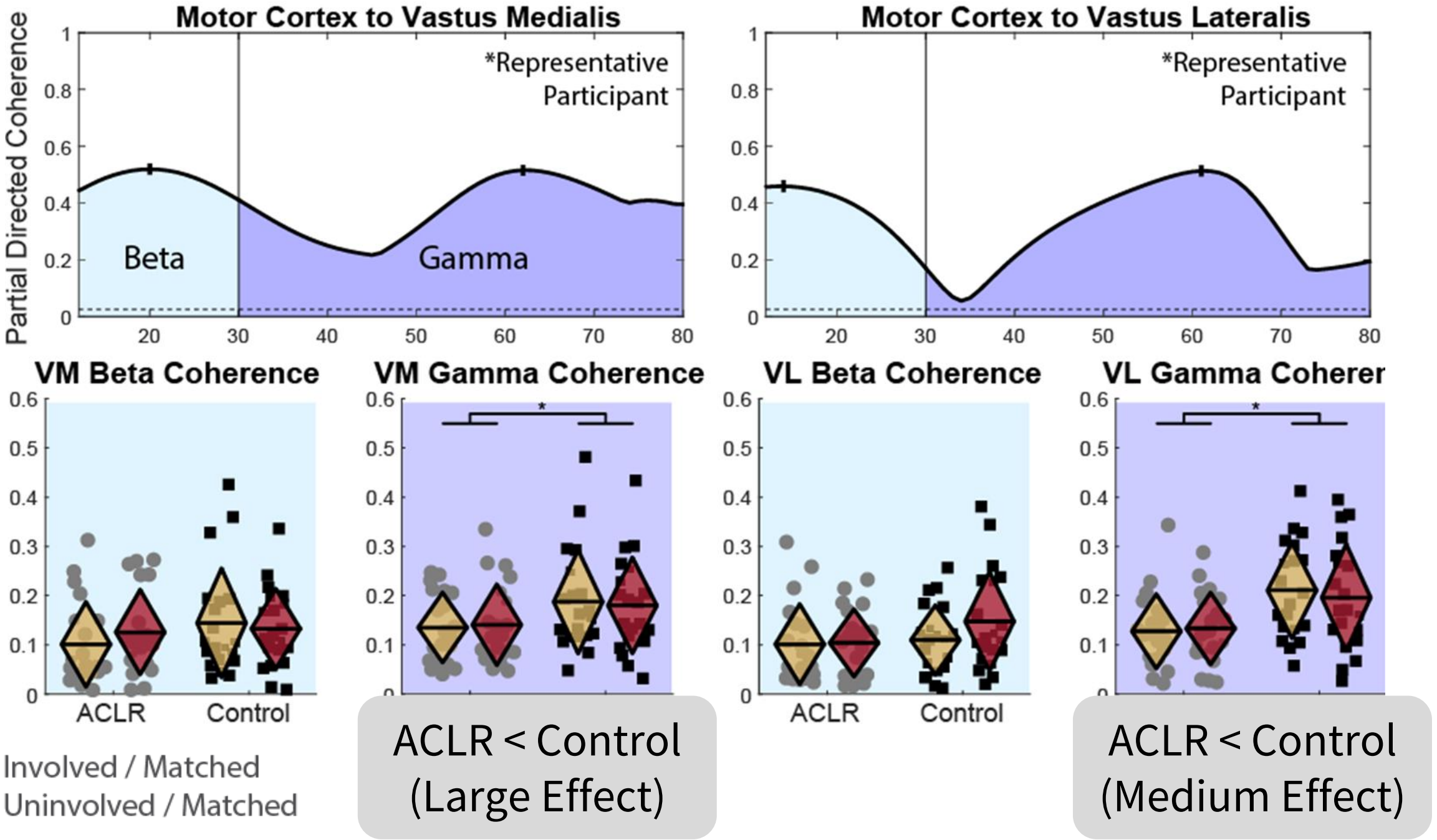
ACLR > Control (Large Effect)

ACLR > Control (Medium Effect)

◆ Involved / Matched

◆ Uninvolved / Matched

Strength, Motor Threshold, and Force Control results detailing limb and group impairments in the ACLR group



Functional connectivity results detailing weaker gamma band connectivity in the ACLR group

Reduced Neural Drive to Quadriceps after ACLR

Bilateral motor inhibition extends to:

- structural **atrophy of cortical spinal tract** (Lepley, Neuroimage Clin. 2020)
- ↑ **inhibitory afferent inputs** to spinal motor neurons (Nuccio, J Phys, 2021)

NEW: ↓ **cortical excitatory input** (i.e., lower cortical drive)

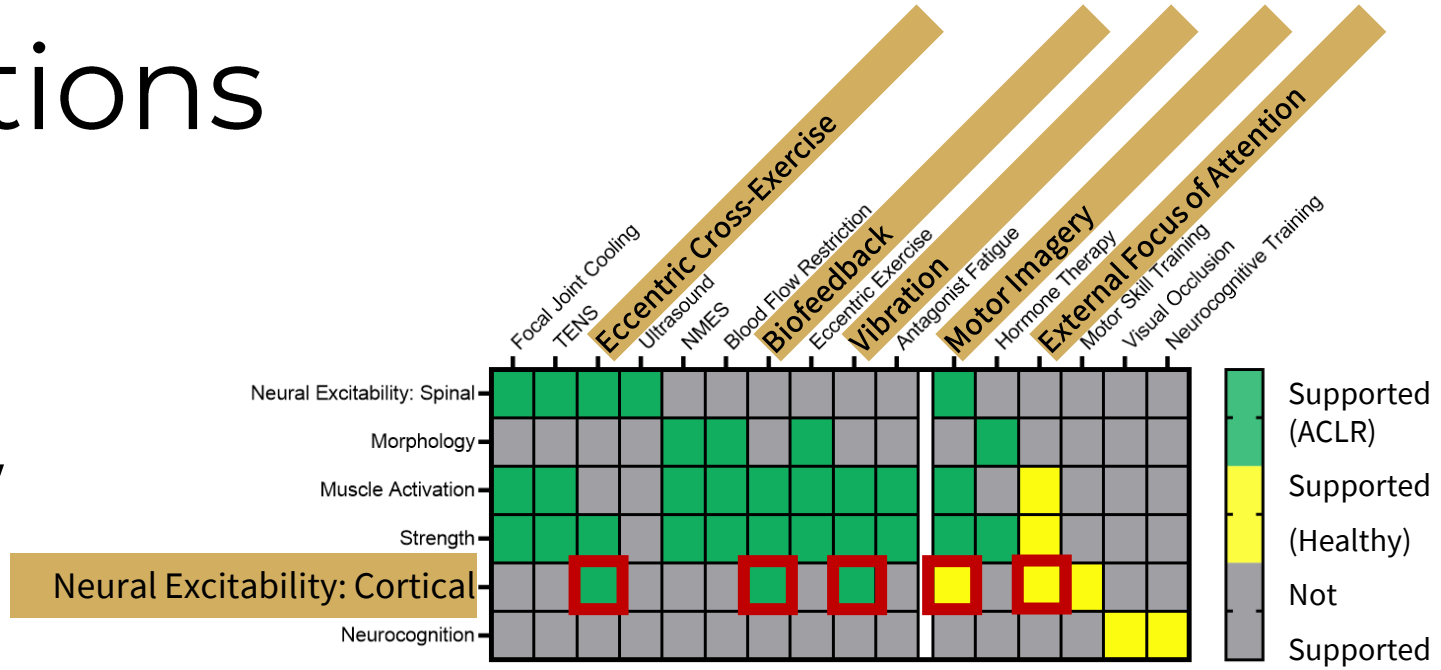
NEW: Gamma band coherence points to faults in sensorimotor integration

- Gamma reflects complex integration of visual and somatosensory information
  - ↓ coherence may signal impairments in force modulation in response to visual biofeedback
- Suggests more errant behavior results from multisensory integration & motor planning impairments

Clinical Implications

Consistent findings:

- **Reduced Cortical Excitability**
  - Single limb balance
  - Force steadiness
- **Motor planning impairments**
  - Multisensory integration
  - Modulation / Adjustments to performance
- **Not specific to limb**



Neurocognitive interventions:

- Visuo-motor reaction time (Wilkerson, 2017)
- Motor learning principles
- Control-Chaos Continuum

Interventions that align with these impairments already exist. **Use them!**

Thank you.

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More of Our Research

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