WEBER STATE UNIVERSITY

Quad Blue: Reviving the Quadriceps in Early ACL Rehab

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Uninvolved Limb

Pre-ACLR (2 weeks post-injury)

1 week post-ACLr

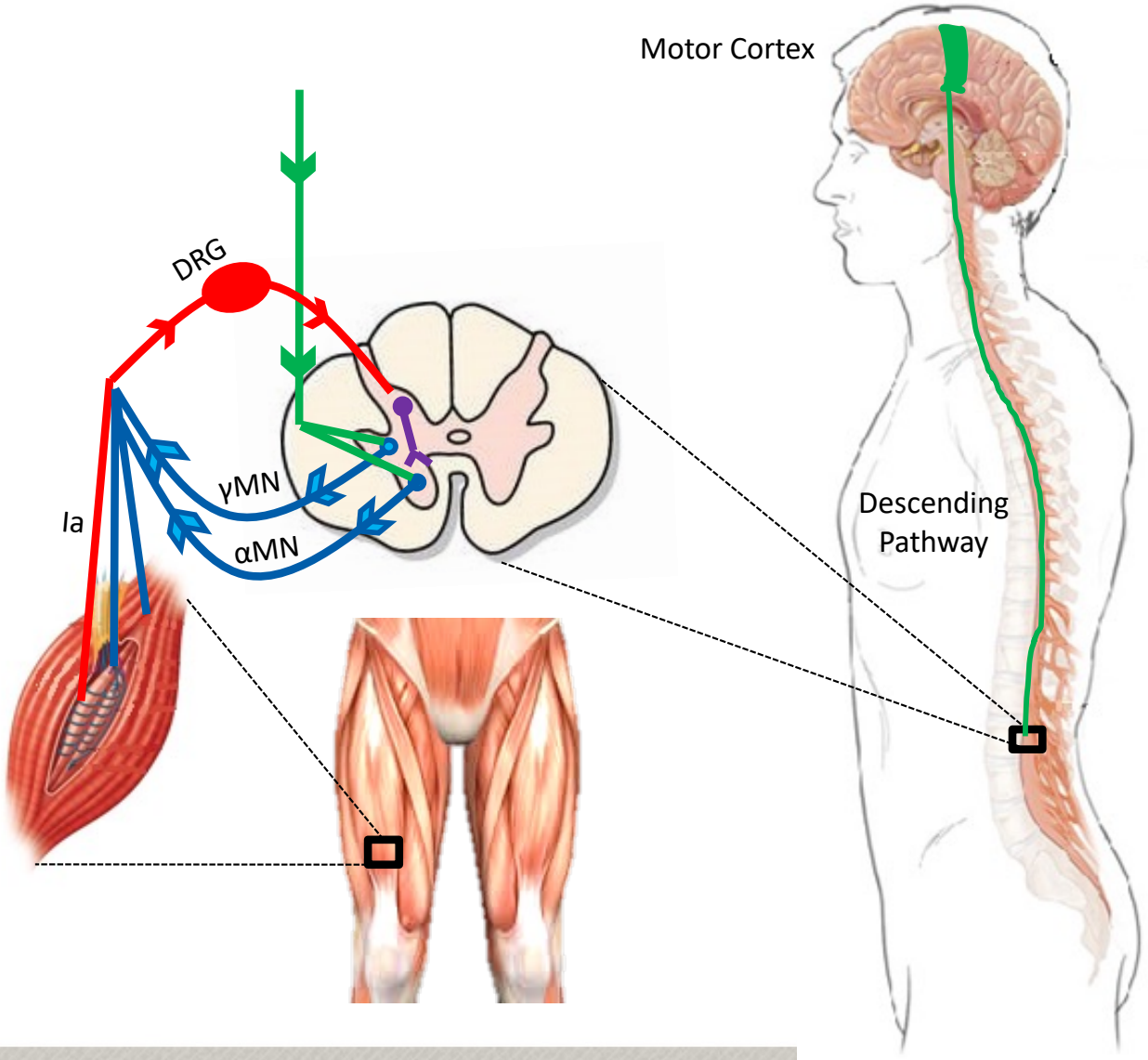
Objectives

1) What is arthrogenic muscle inhibition?

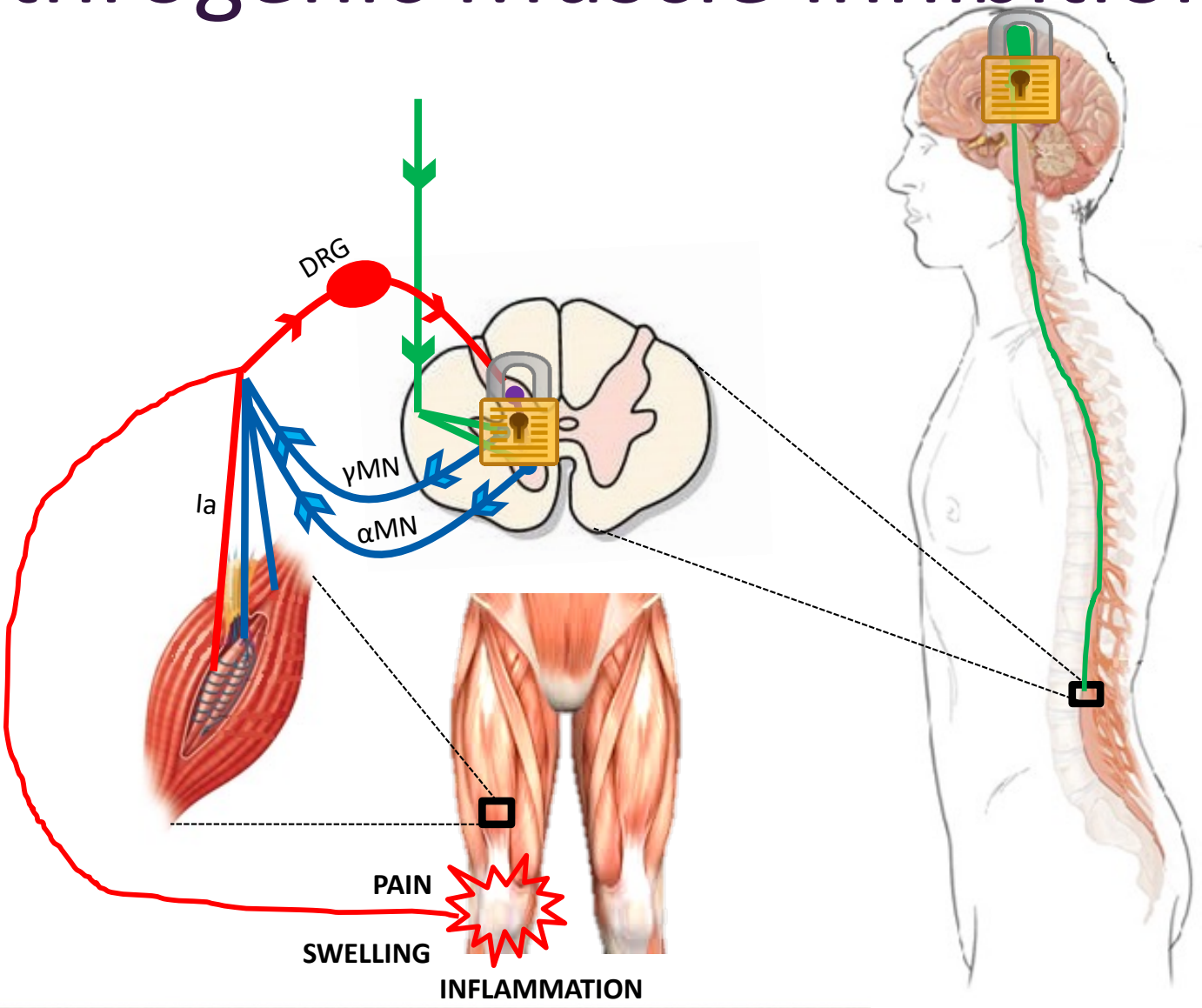
2) What are its consequences?

3) How to treat it?

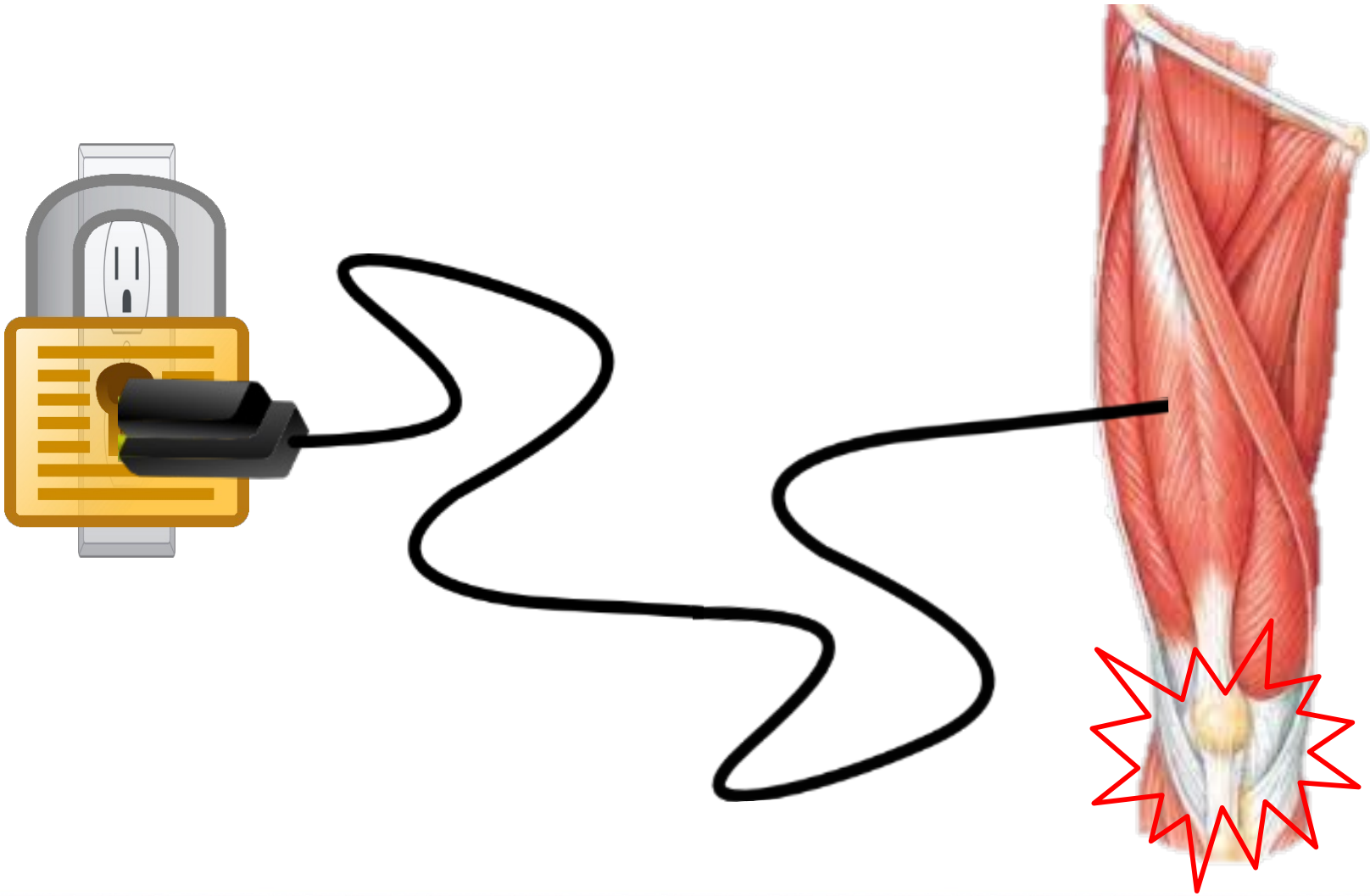
Quadriceps Activation



Arthrogenic Muscle Inhibition



The Problem



Immediate Consequences

1. Quadriceps atrophy (Sheenam BSSMR 2025, De la Fuente JBM 2025, Johnston, MSSE 2023, Tourville JOR 2021)
2. Quadriceps weakness (Ishida OJSM 2025, Cobian OJSM 2024, Johnson JSMS 2023, Pietrosimone JAT 2021)
3. Decreased performance (He OJSM 2022, Palmieri-Smith SH 2021, Hunnicutt JAT 2020, Birchmeier JSCR 2019)
4. Decreased self-reported knee function (Ishida OJSM 2025, Pottkotter IJSPT 2020, Pottkotter OJSM 2018, Lepley JAT 2018)

Long-term Consequences

4. Altered lower extremity biomechanics (Pietrosimone JAT 2021, Palmieri-Smith SH 2021, Spencer CB 2019, Shi GP 2019, Garrison OJSM 2019)
   - Decreased knee loading
5. Weakness = WeaKNEES (Brunst JOR 2021, Pietrosimone KSSTA 2018, Takagi KSSTA 2017)
   - **65%** higher odds of developing knee OA (Oiestad, OC 2015)

The Solution?

OPEN & EXPLOIT

JOURNAL OF ATHLETIC TRAINING

J Athl Train. 2014 Nov-Dec;49(6):733–739. doi: 10.4085/1062-6050-49.3.39

Quadriceps Muscle Function After Rehabilitation With Cryotherapy in Patients With Anterior Cruciate Ligament Reconstruction

Joseph M Hart *, Christopher M Kuenze *, David R Diduch *, Christopher D Ingersoll †

JOURNAL OF ATHLETIC TRAINING

J Athl Train. 2014 May-Jun;49(3):411–421. doi: 10.4085/1062-6050-49.1.04

Disinhibitory Interventions and Voluntary Quadriceps Activation: A Systematic Review

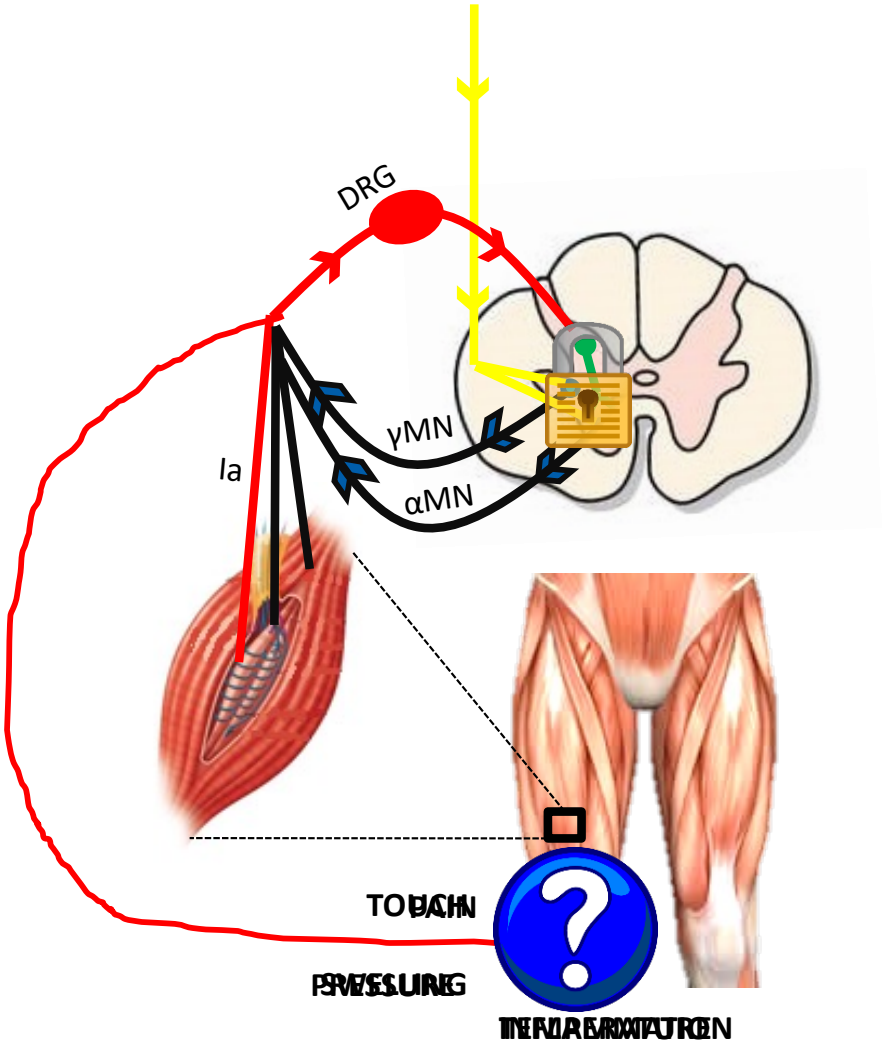
Matthew S Harkey [1], Phillip A Gribble [1], Brian G Pietrosimone [1]

Review > J Sport Rehabil. 2022 Feb 14;31(6):694-706. doi: 10.1123/jsr.2021-0128. Print 2022 Aug 1.

Arthrogenic Muscle Inhibition Following Anterior Cruciate Ligament Injury

Brian Pietrosimone, Adam S Lepley, Christopher Kuenze, Matthew S Harkey, Joseph M Hart, J Troy Blackburn, Grant Norte

OPEN



Sensory-Based (Open)

Cryotherapy

- One of the most effective dual-purpose modalities
- Demonstrates lasting disinhibitory effects after removal (Hopkins et al., 2002; Rice et al., 2009; Kuenze et al., 2017; Loro et al., 2019)

Sensory-Based (Open)

TENS

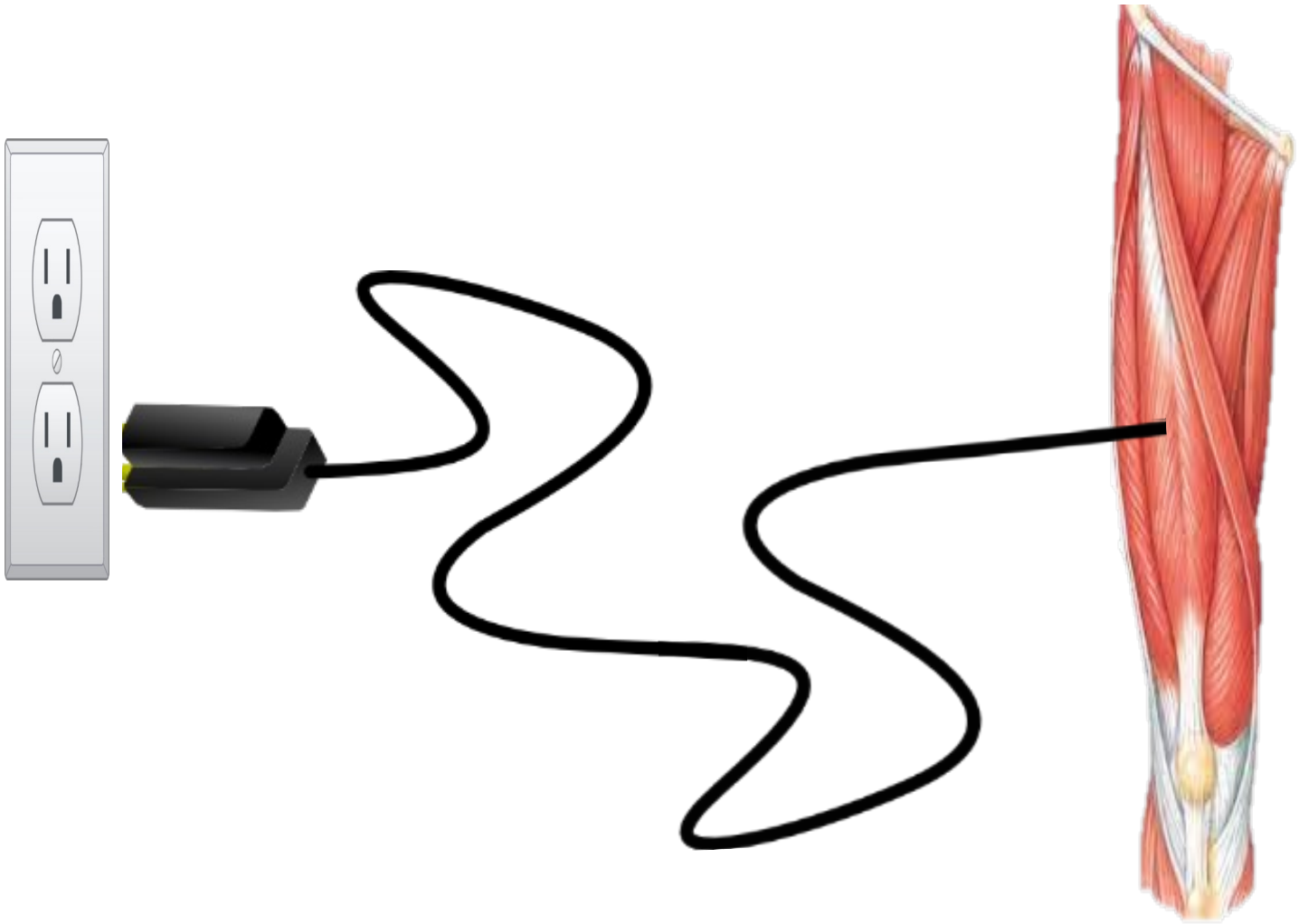
- Oldest modality shown to disinhibit the quads after knee surgery (Stokes et al., 1985)
- May offer the most versatility in rehabilitation (Pietrosimone et al., 2011; Hart et al., 2012; Gabler et al., 2015)

Sensory-Based (Open)

Muscle Vibration

- Novel method for improving quadriceps function (Fu et al., 2013; Berschin et al., 2014; Pistone et al., 2016; Costantino et al., 2017; Sogut et al. 2021; Blackburn et al., 2021)
- Thought to ”prime” the CNS
  - Corticomotor excitability (Pamukoff et al., 2016)
- Tendon vibration → hamstring fatigue?
  - Reciprocally disinhibits the quadriceps (Yu et al., 2020)
  - Decreases joint compressive forces (Lowe et al., 2023)

EXPLOIT



Motor-Based (Exploit)

Eccentrics

- The most effective exercise for improving quad activation (Lepley et al., 2015, Lepley et al., 2017)
- Demonstrates cross-education capabilities (Lepley et al., 2014)

Motor-Based (Exploit)

EMG Biofeedback

- Provides patients immediate feedback of their voluntary muscle activity
- Targets the cortical aspect of quadriceps inhibition (Gabler et al., 2013; Pietrosimone et al., 2015; Bodkin et al. 2021)

Motor-Based (Exploit)

NMES

- Well known for its muscle strengthening and re-education capabilities (Kim et al., 2010; Maffiuletti et al., 2010; Imoto et al., 2011)
- Mixed evidence as a disinhibitory modality (Palmieiri-Smith et al., 2010; Marmon & Snyder-Mackler et al., 2011; Stevens-Lapsley et al., 2012; Elboim-Gabyzon et al., 2013)
- Best in early ACL rehab (Hauger et al., 2018; Toth et al. 2020)

Motor-Based (Exploit)

Blood Flow Restriction

- Low-load resistance training in a vascularly occluded state
- Best for increasing quadricep strength and hypertrophy in early rehab
  - High-load resistance training > low-load BFR training > low-load resistance training (Lin et al., 2024; Garcia-Rodriguez et al. 2023; Curran et al., 2020)

Take Home Points

1. Treat AMI ASAP
   - Don't wait for surgery
2. "Open" the muscle thru sensory-based modalities
   - TENS, cryo, muscle vibration, etc.
3. "Exploit" the muscle thru motor-based modalities
   - Eccentrics, BFR, biofeedback, etc.

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Questions?