
ACRM
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PROGRESS IN REHABILITATION RESEARCH
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Functional Electrical Stimulation (FES) & Technology Task Force

Mission:

- Promote high quality FES research and evidence-based clinical applications of FES for people with SCI.
- Our target audience includes health professionals and consumers.

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Electrical Stimulation from Exercise to Locomotion after Spinal Cord Injury

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Disclosure Statement

I am currently the Chair of the FES and Technology Task Force Committee-ACRM

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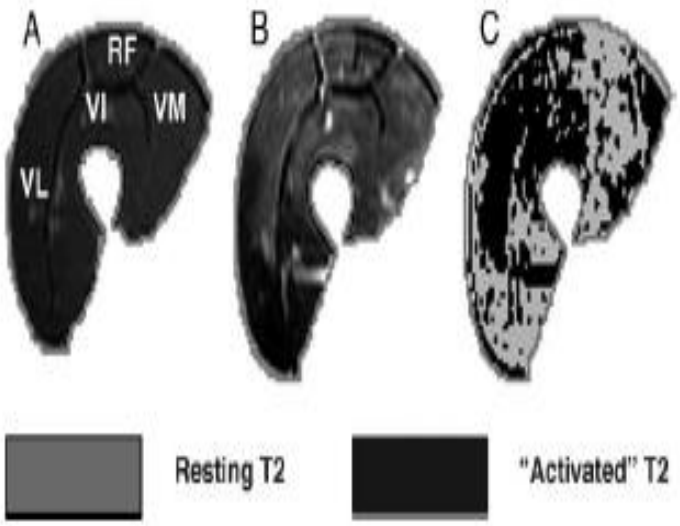
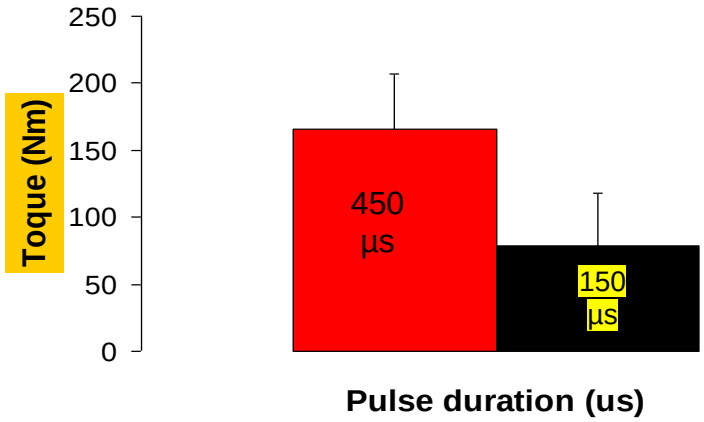
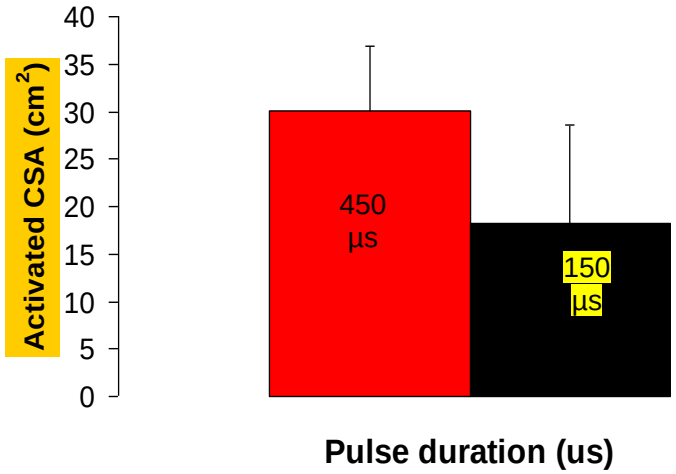
Learning Objectives

- Review previous/current knowledge about the use of electrical stimulation in training muscles after SCI.
- Introduce the concept of long pulse width stimulation (LPWS) to stimulate denervated muscles after SCI.
- Briefly summarize the current evidence about the use of trans-spinal/epidural stimulation in muscle activation and restoration of locomotion after SCI.

Pulse Durations (150 vs. 450 μs)

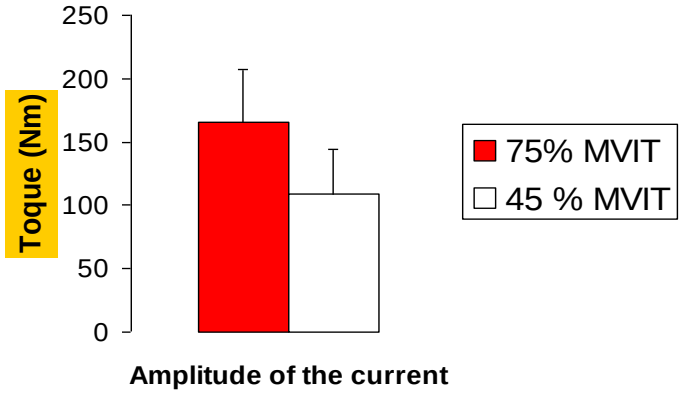


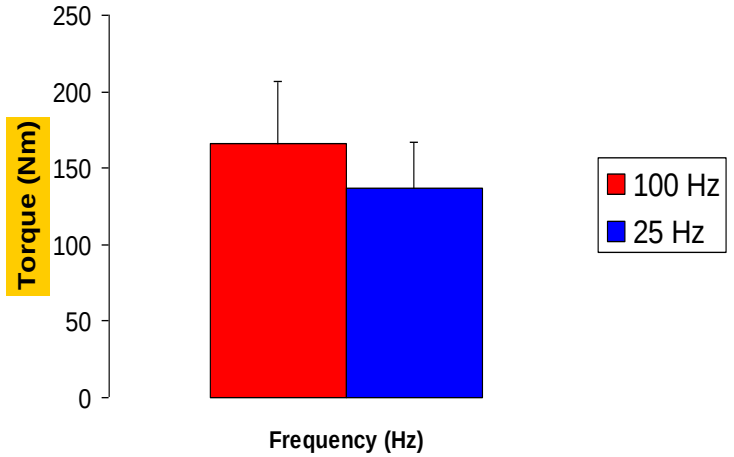


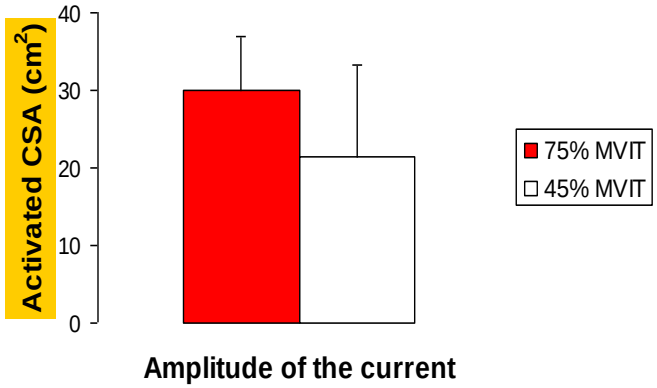


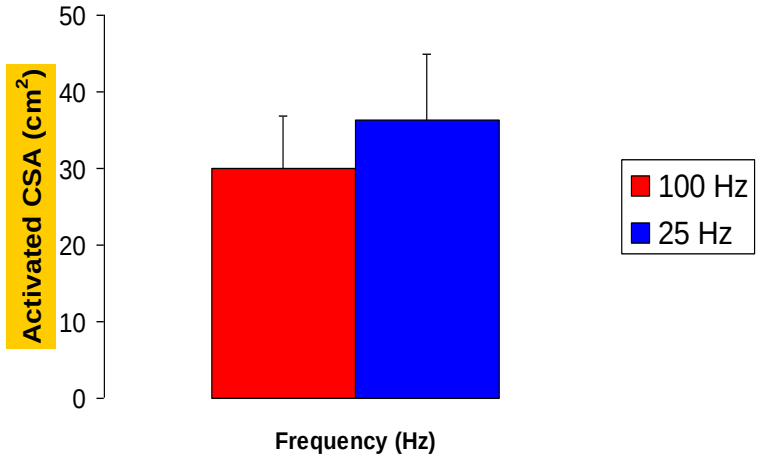
Gorgey et al. 2006; EJAP

Amplitude (mA) & Frequency (Hz)





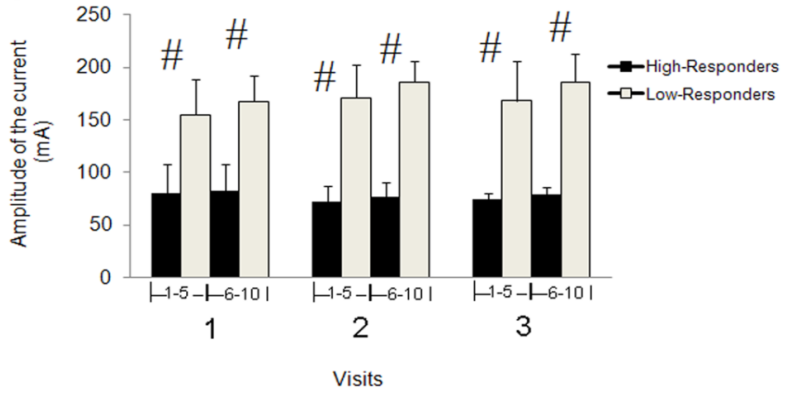


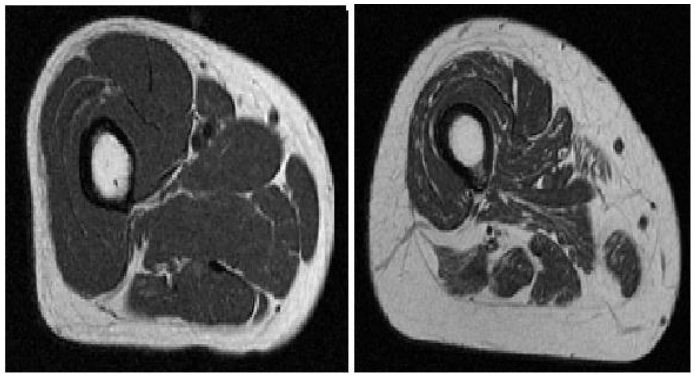


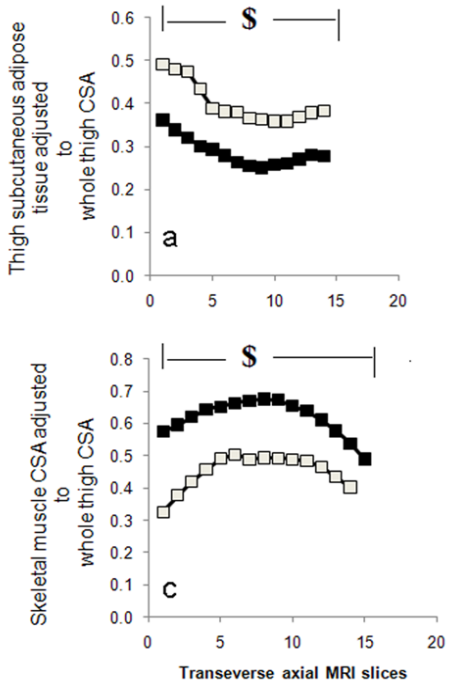
Gorgey et al. 2006; EJAP

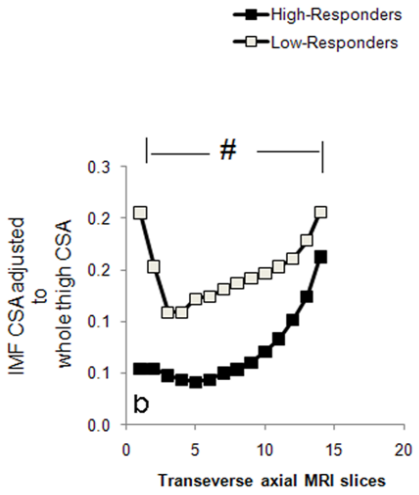
Amplitude of the current (mA) and SCI

Figure 2



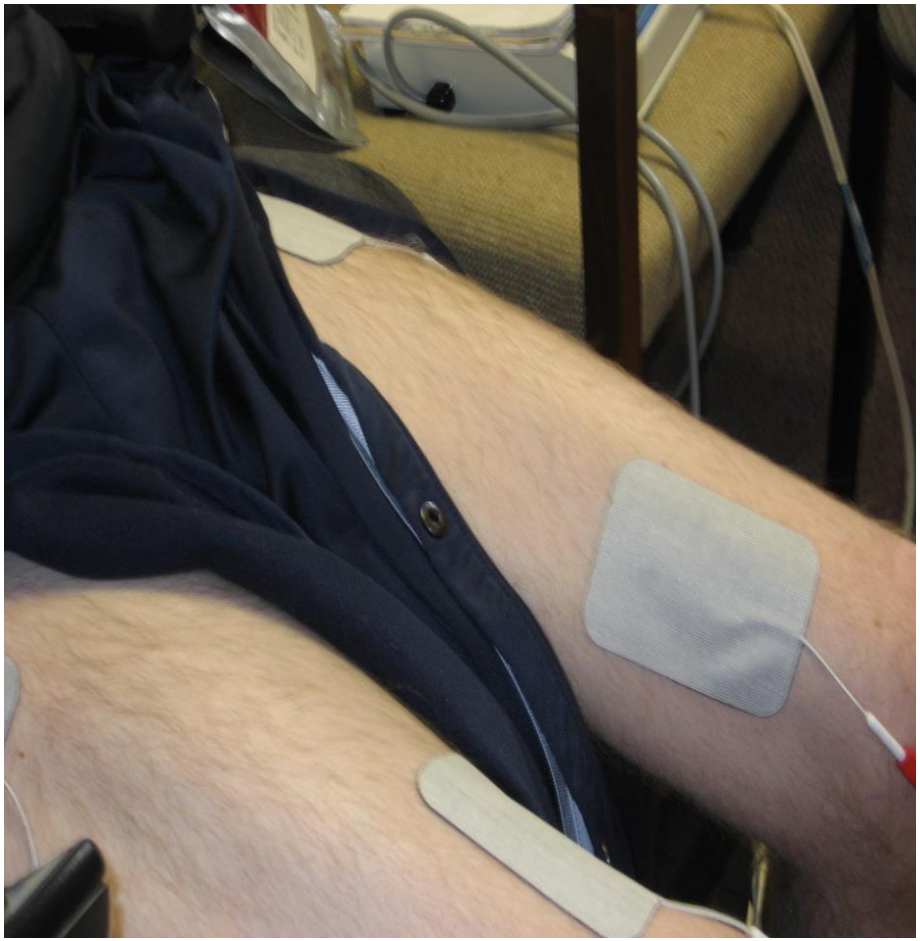






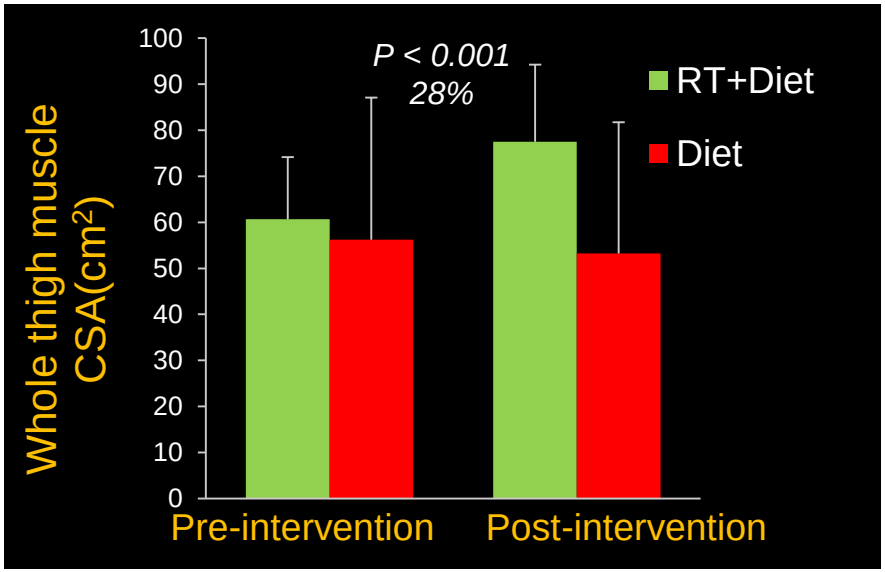
Gorgey et al. 2013; NeuroRehab.

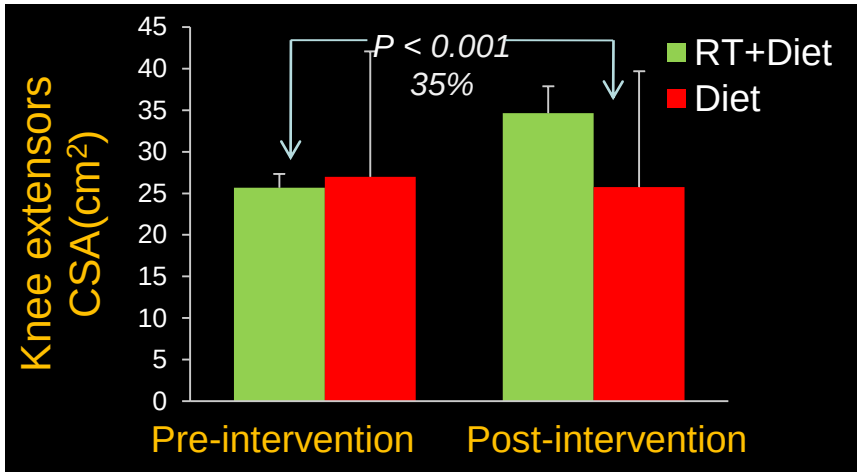
Evoked NMES Resistance Training (RT)
(12 weeks RT+ diet vs. diet control

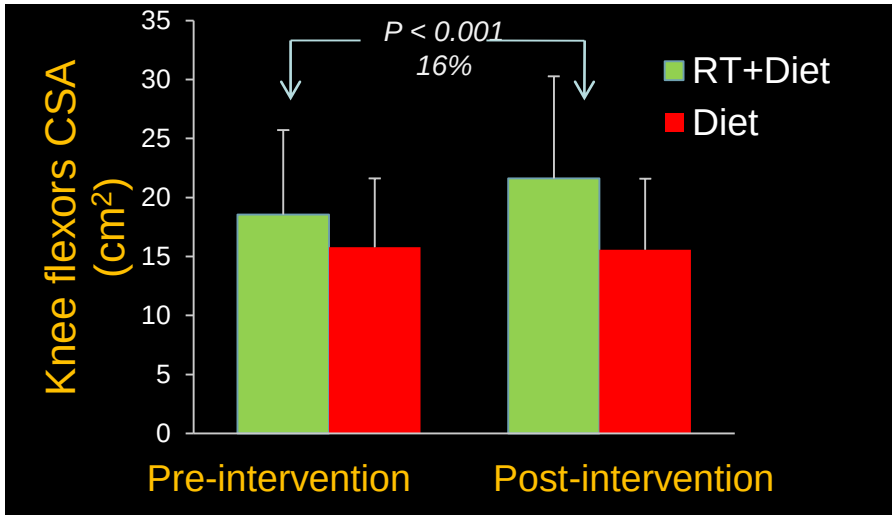


Gorgey A et al. 2012; MSSE

Skeletal muscle CSA

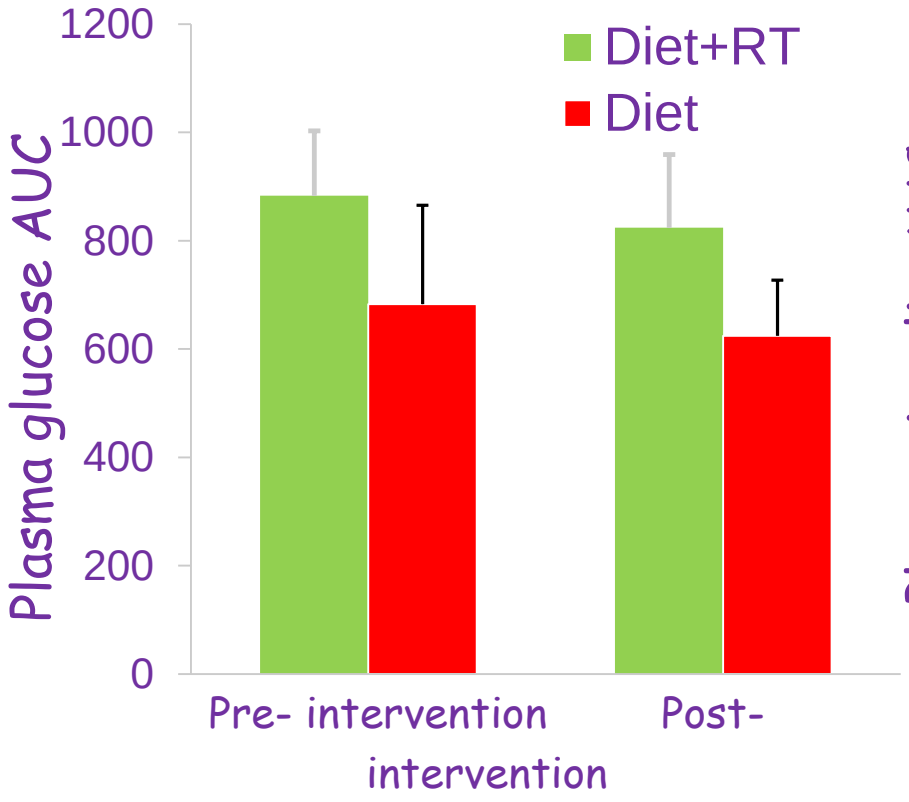


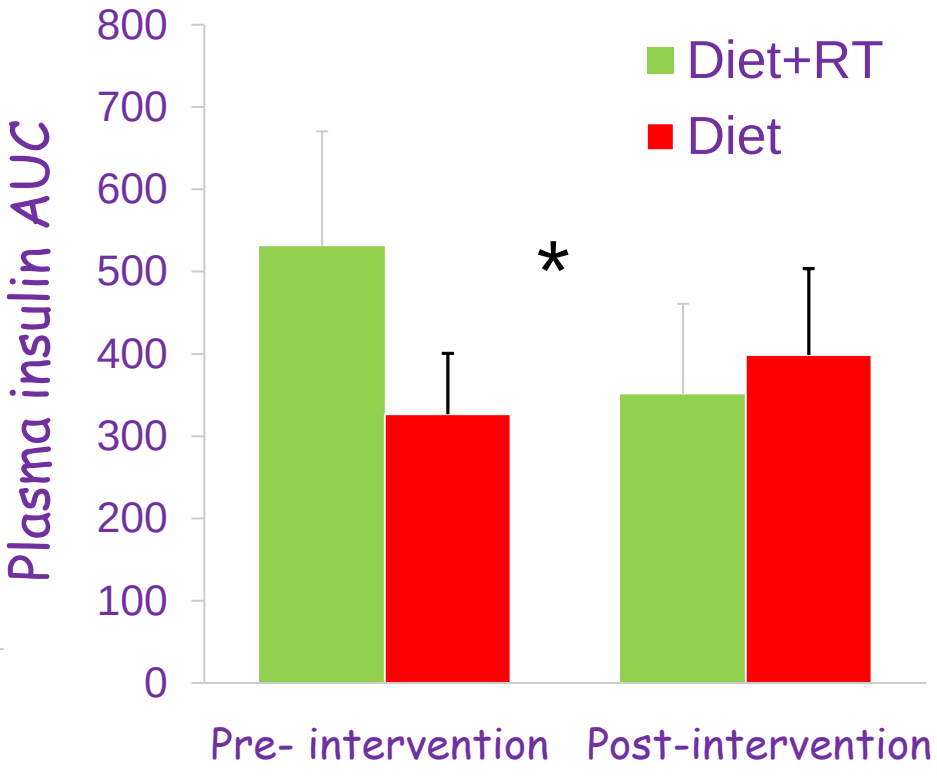




Gorgey A et al. 2012; MSSE

Carbohydrate Profile following 12 weeks NMES-RT



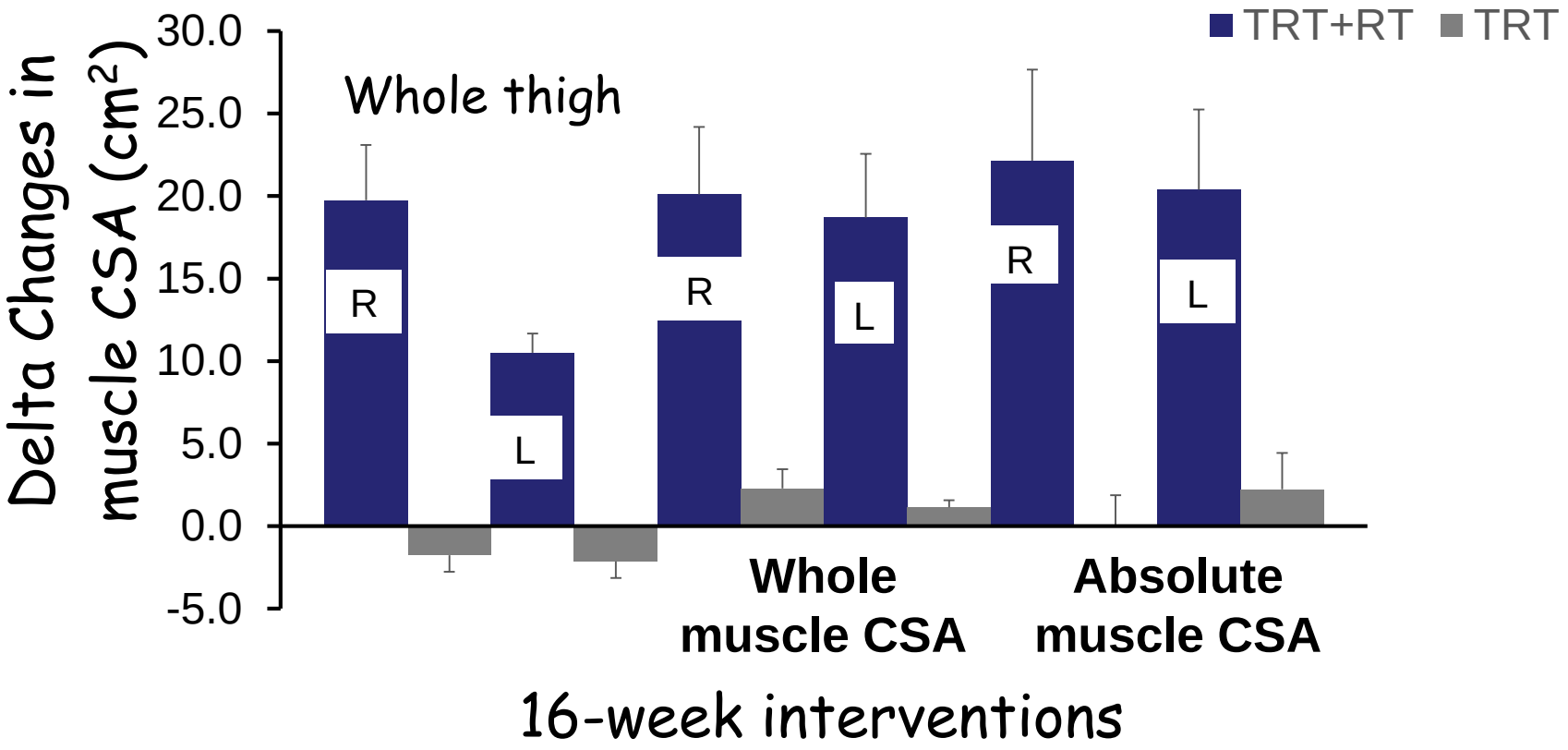


Gorgey et al. 2012

Resistance Training & TRT in motor complete SCI

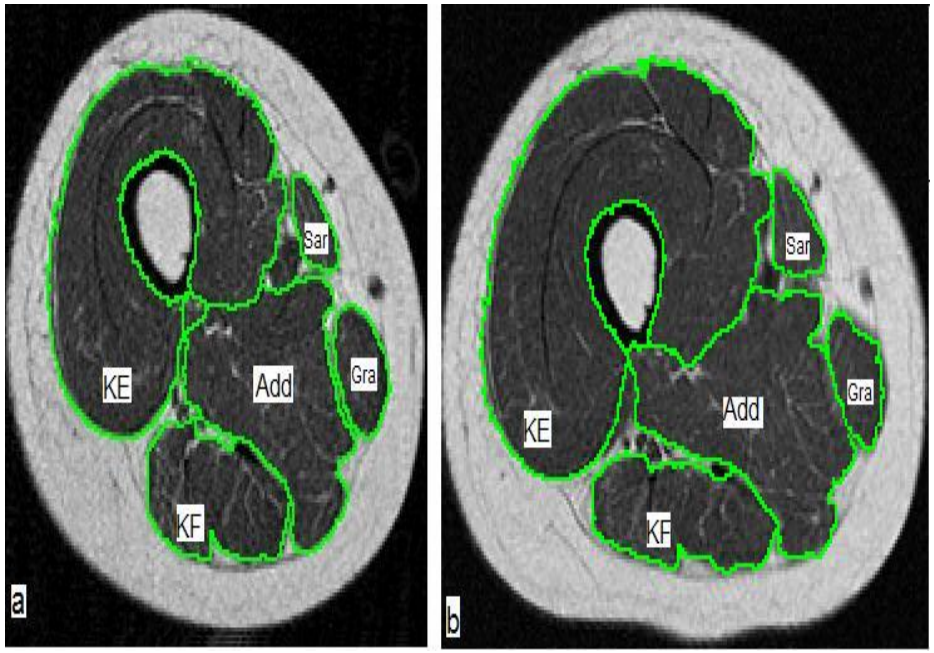
TRT+ Resistance Training for 16 weeks

Skeletal muscle CSA-measured by MRI (n=10/group)



Gorgey et al. In Press, NT

Home Based NMES-RT for 8 weeks



NMES-RT for 8 weeks

Figure 2

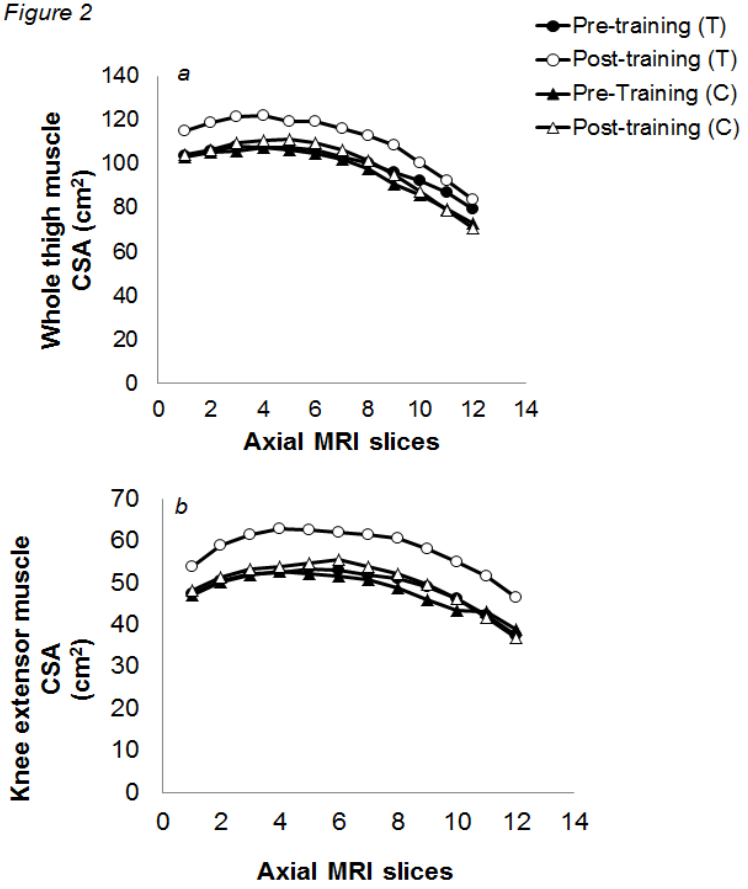
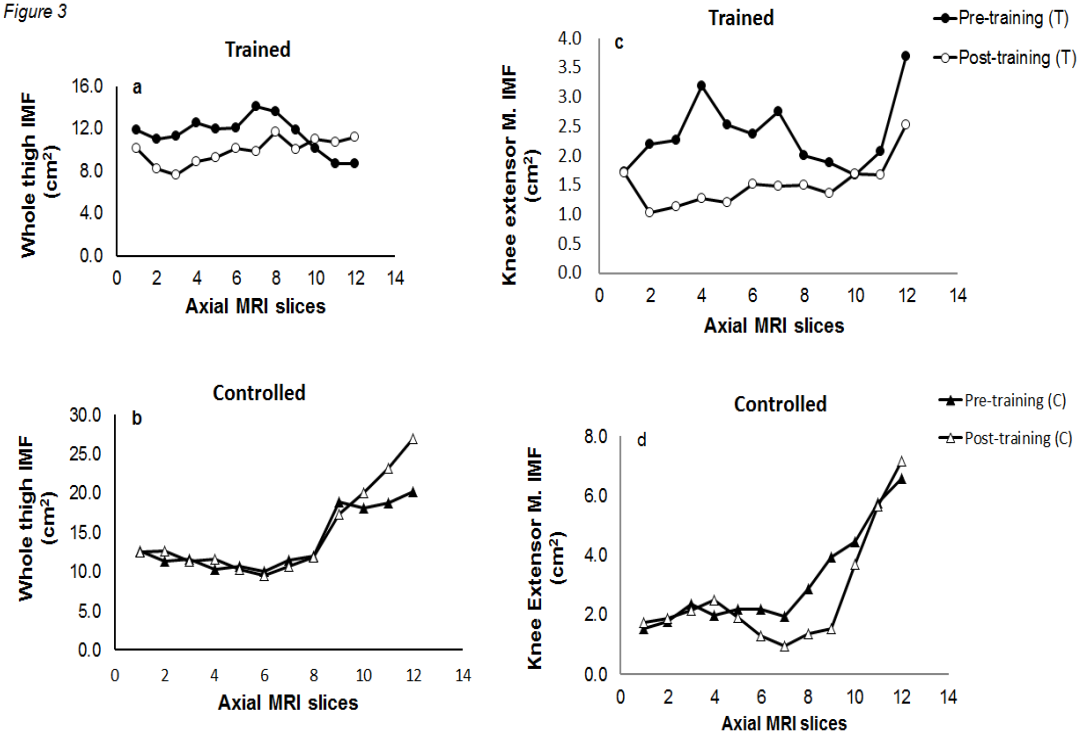


Figure 3

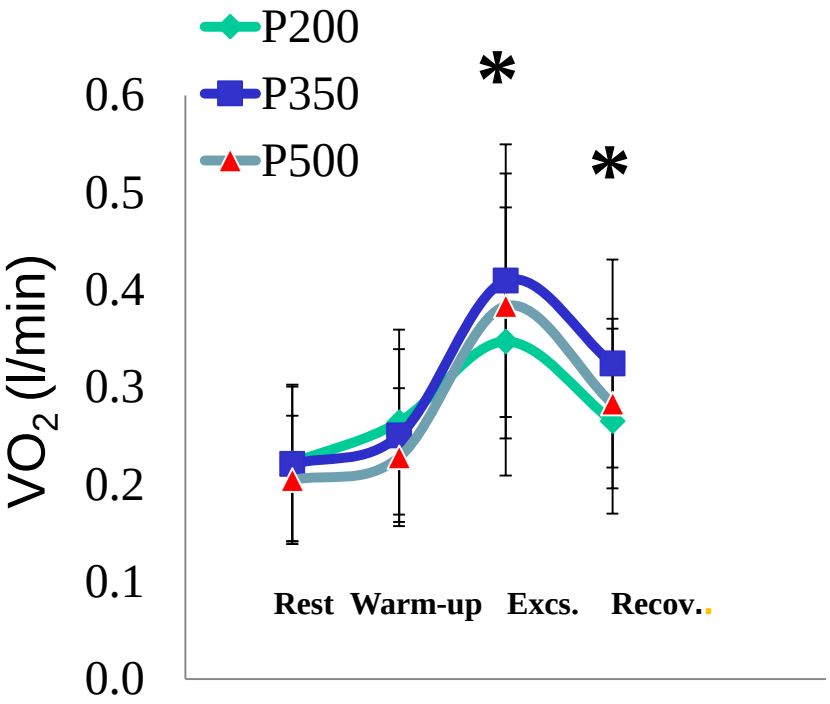


Gorgey et al. 2017; SCSC

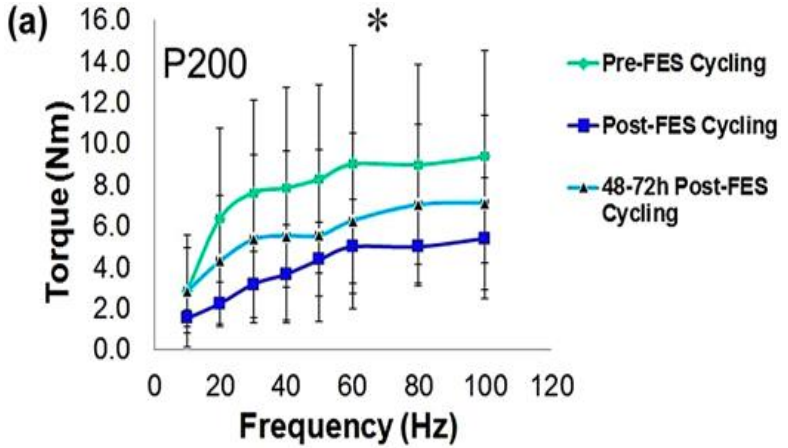
Functional Electrical Stimulation- Lower Extremity Cycling

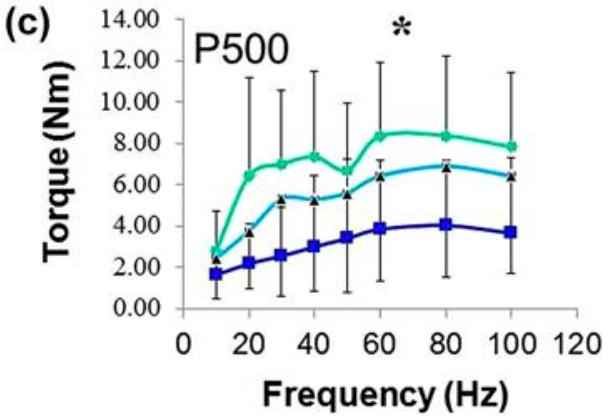
Gorgey et al. 2017; JoVE

Pulse Duration and SCI-tetra (n=10)



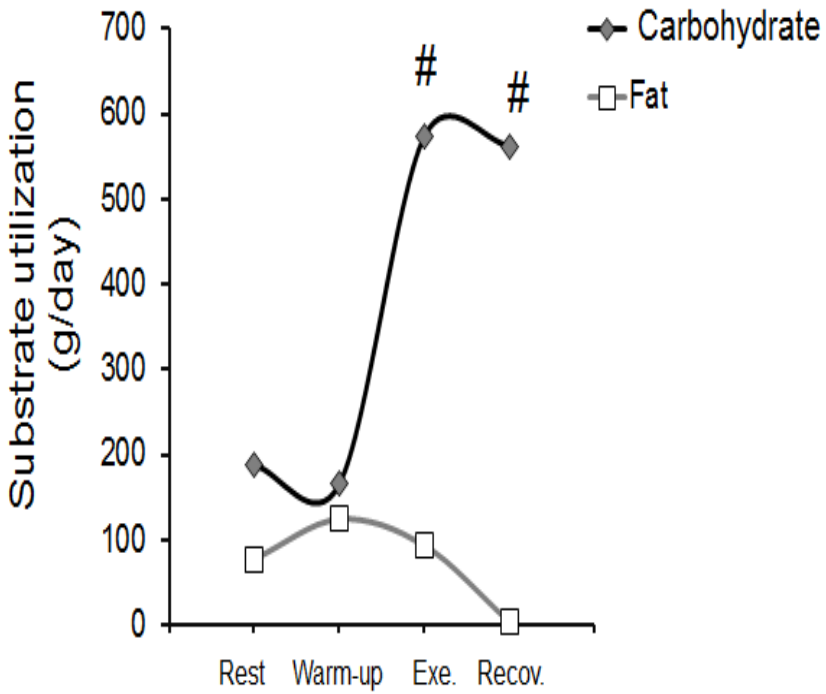
Gorgey et al. 2014; JRRD





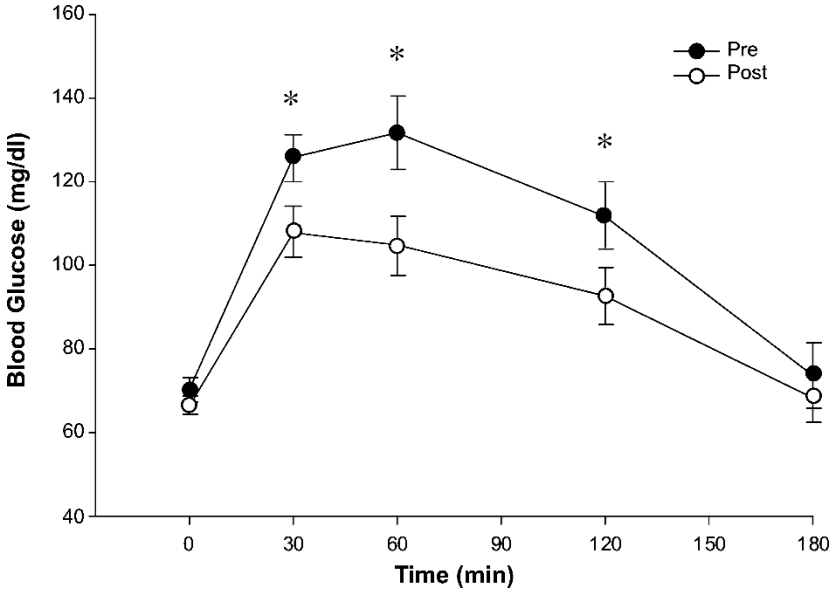
Functional Electrical Stimulation and Substrate Utilization (n=10)

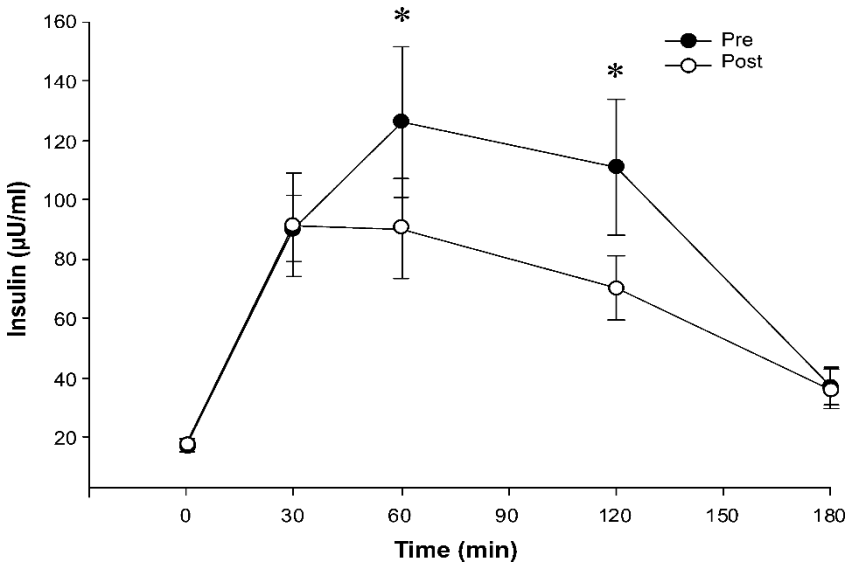
Figure 2



Gorgey AS & Lawrence J, 2016; PMR

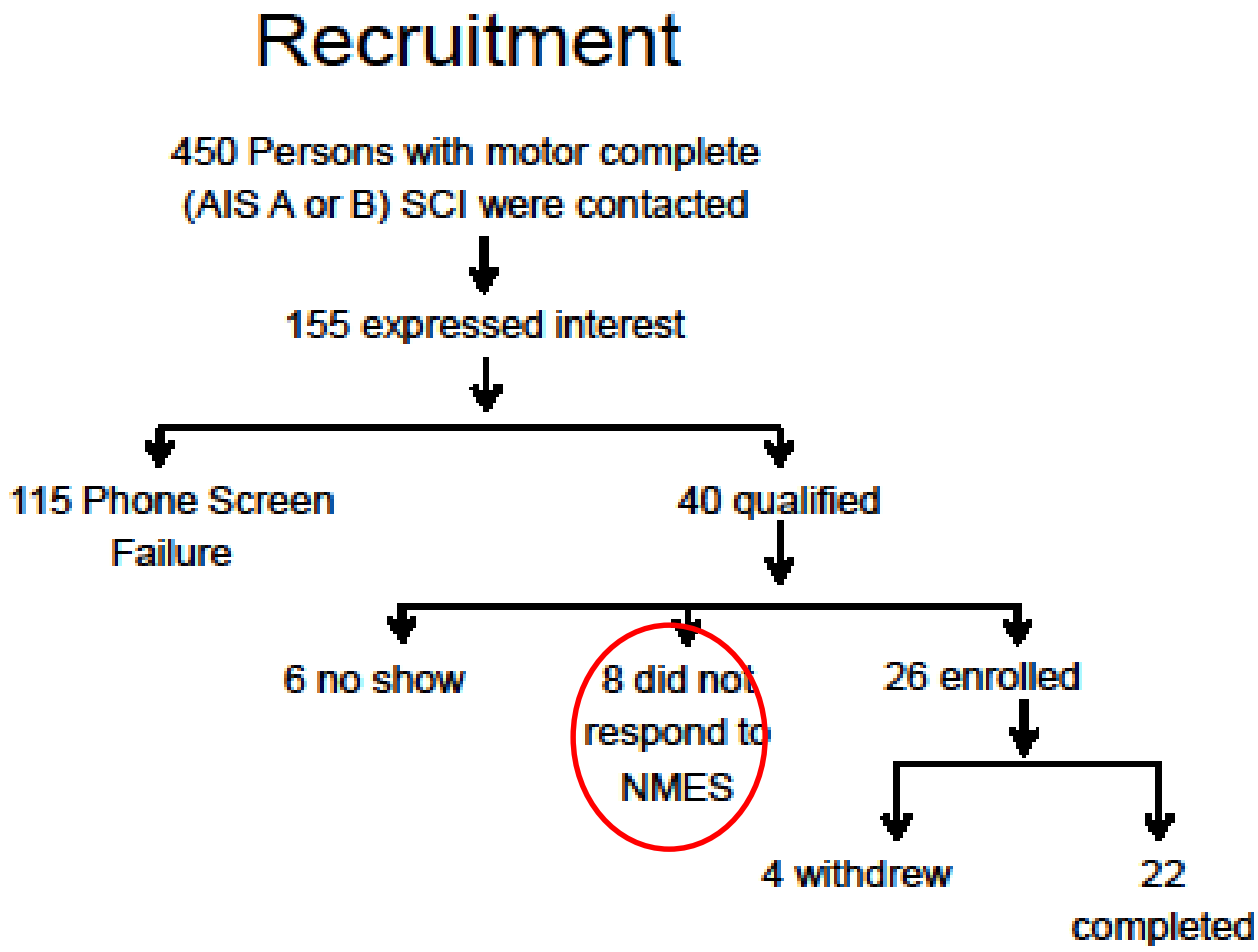
FES for 10 weeks on Metabolic Profile (n=18; Griffin et al. 2009)



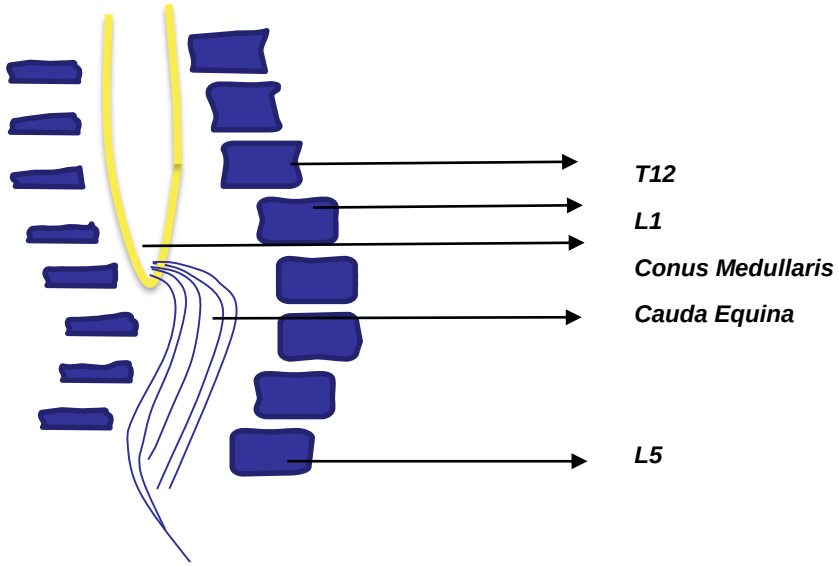


Metabolic factors		
CRP (mg/L)	15.92 ± 1.57	12.94 ± 0.78*
IL-6 (pg/ml)	4.91 ± 1.10	3.79 ± 0.52*
TNF-α (pg/ml)	11.82 ± 0.63	11.31 ± 0.62

SCI with Lower motor neuron injury

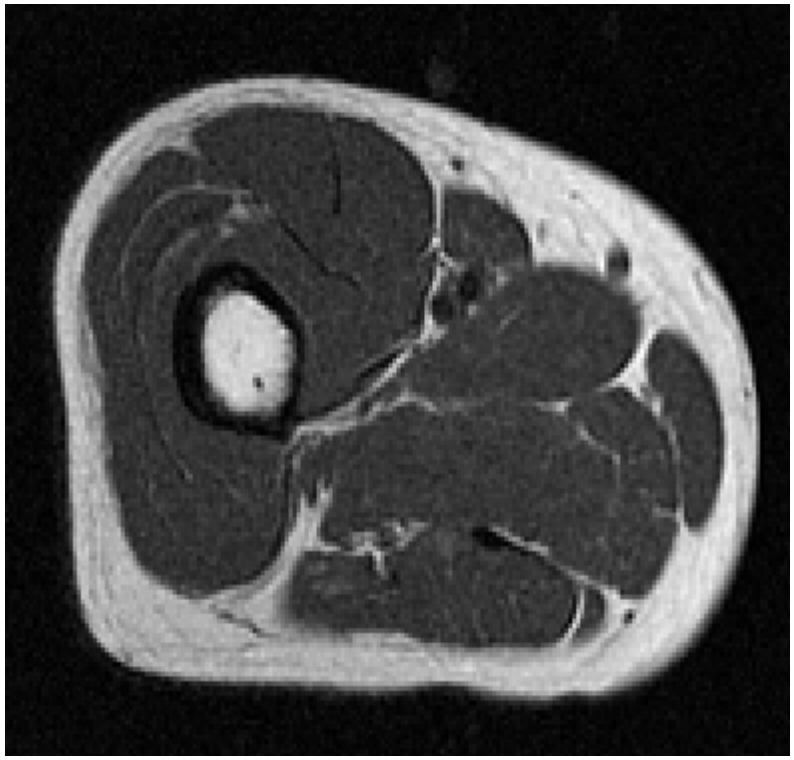


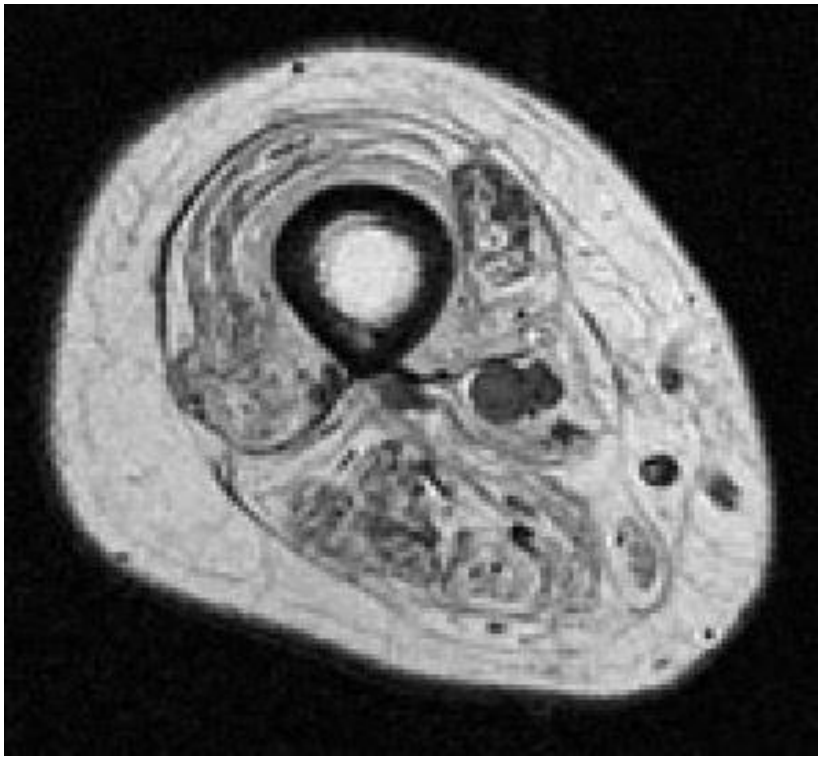
Stimulation of Denervated Muscle



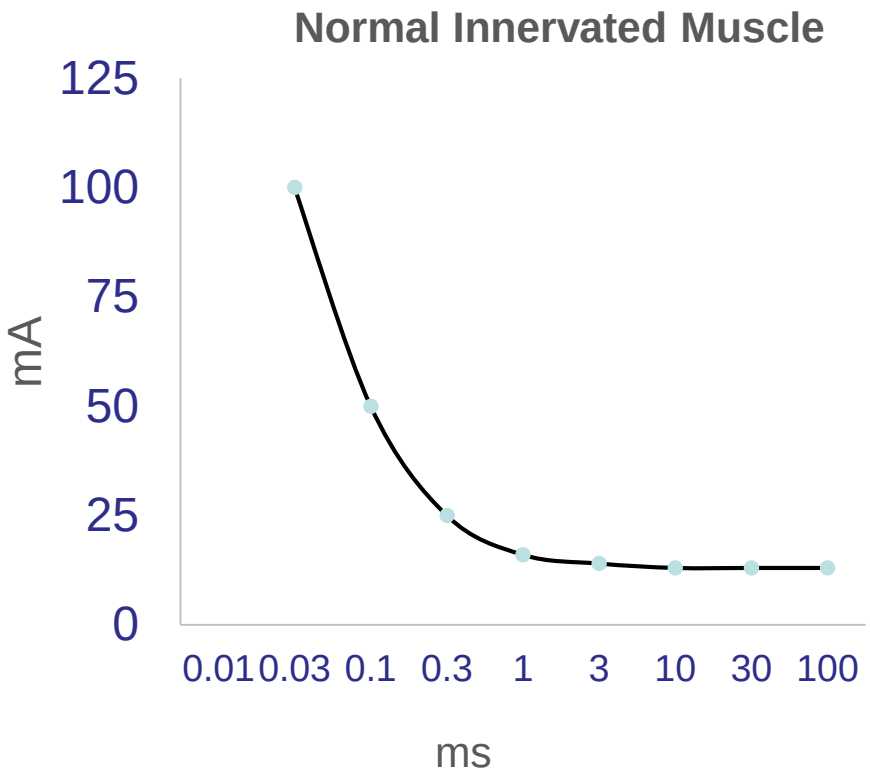
- Denervated muscle has lost its peripheral nerve supply
  - Results in a decrease in size, diameter, and weight of muscle fibers
  - Decrease in amount of tension which can be generated
  - Increase the time required for contraction
- Electrical currents may be used to produce a muscle contraction in denervated muscle to minimize atrophy

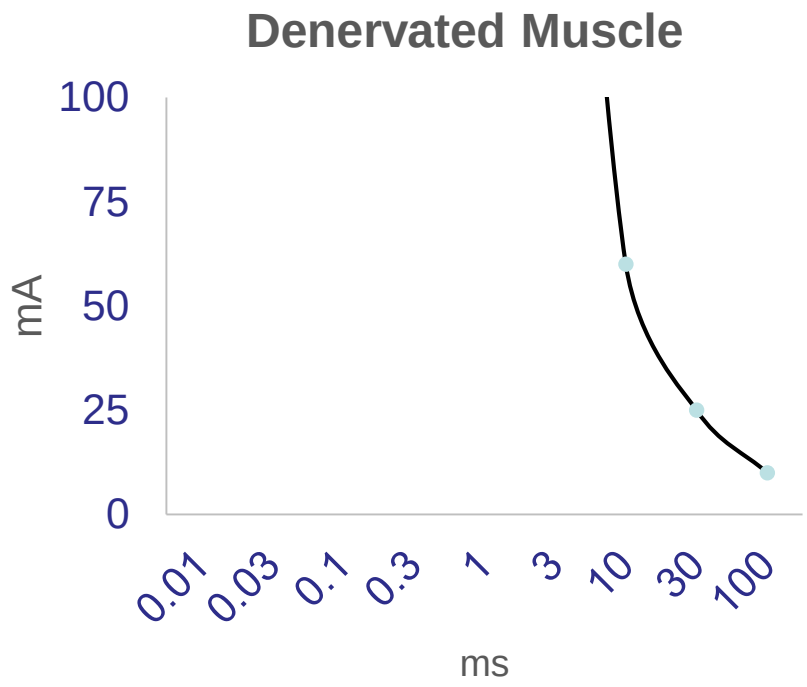
MRI of mid-thigh muscles following innervation and denervation in persons with SCI





Strength-Duration Curve of Denervated Muscle

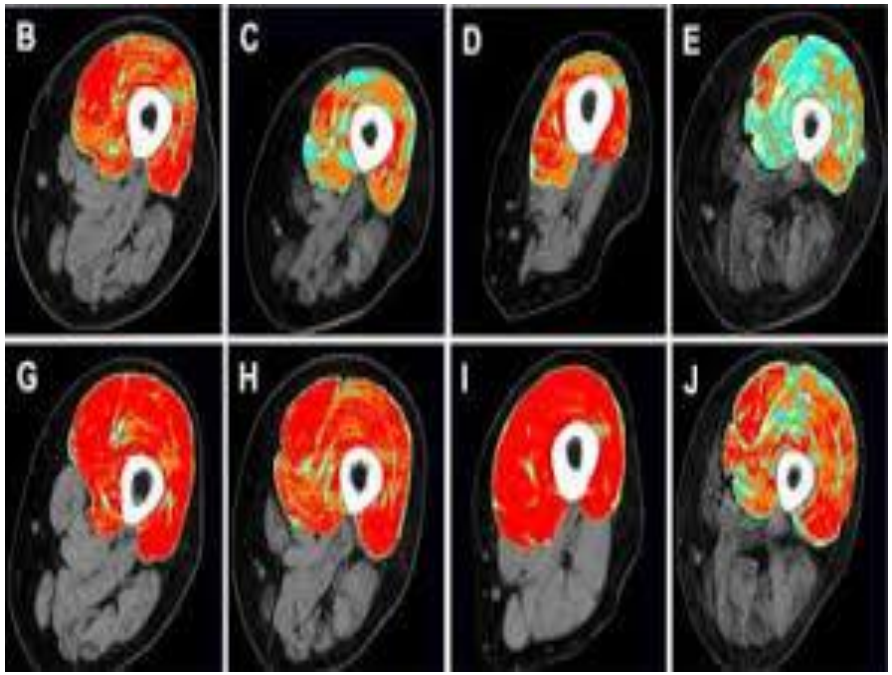




Long Pulse Width Stimulation & Denervated Muscle

Long Pulse Width Stimulation (LPWS)

Long Pulse Width Stimulation (LPWS)



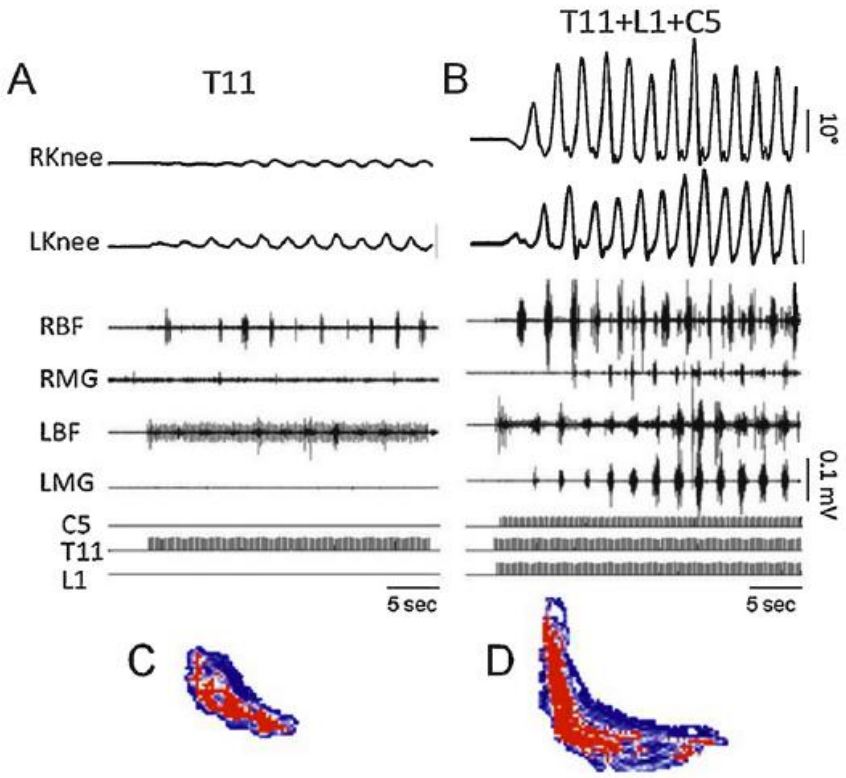
Denervated muscle following 1-2 years of training

- Home based functional electrical stimulation (FES) using a LPWS (120-150 ms) at an intensity of 250 mA for 5 days/week has been studied in 25 SCI persons with complete LMN denervation.
- There is an increase (24%) in knee extensor cross-sectional area (CSA) following the first year.

Automaticity of Spinal Cord Circuitry

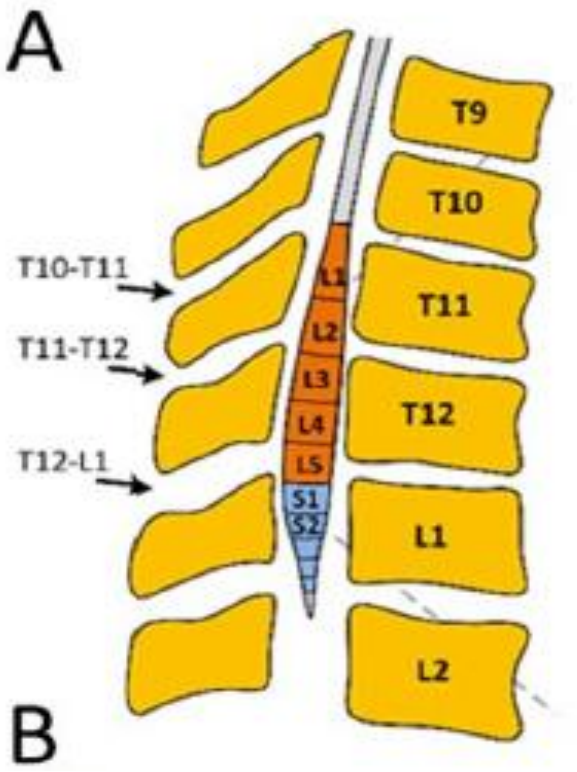
- Central Pattern Generator (Lumbar circuitry processing complex proprioceptive and cutaneous information to generate cyclic motor pattern).
- Central Pattern Generator is demonstrating the significance of automaticity in mammalian spinal cord.
- Fictive locomotion (stepping in the absence of supra-spinal control or peripheral afferent input).
- As a result, spinal cord can learn and modulate task specific by practice.

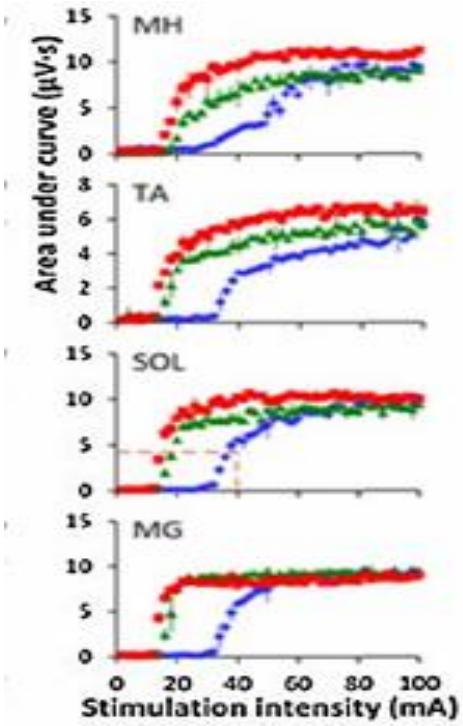
Transcutaneous electrical spinal cord stimulation (SCS)- Gerasimenko et al. 2015

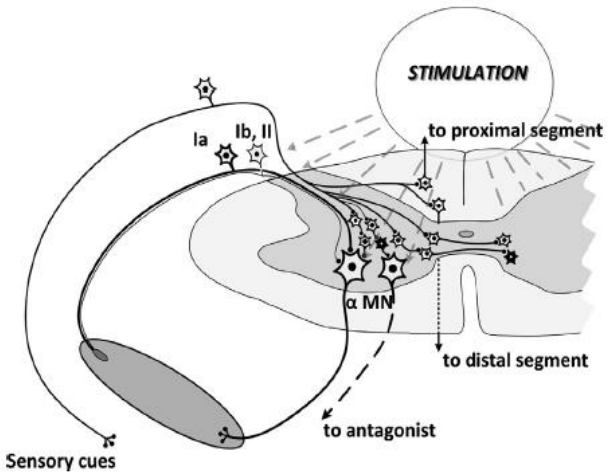


Carrier frequency at 10 KHz
Pulse duration: 0.3 ms -1.0 ms (300 μs-1000 μs)
Frequency: 5 to 40 Hz
Intensity: 30 to 200 mA

Stimulation intensity during Trans-spinal stimulation



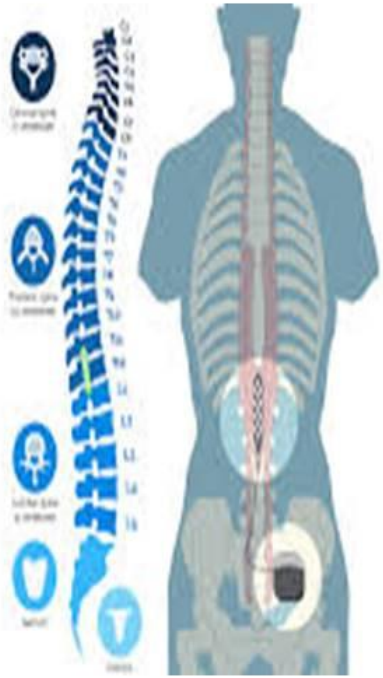


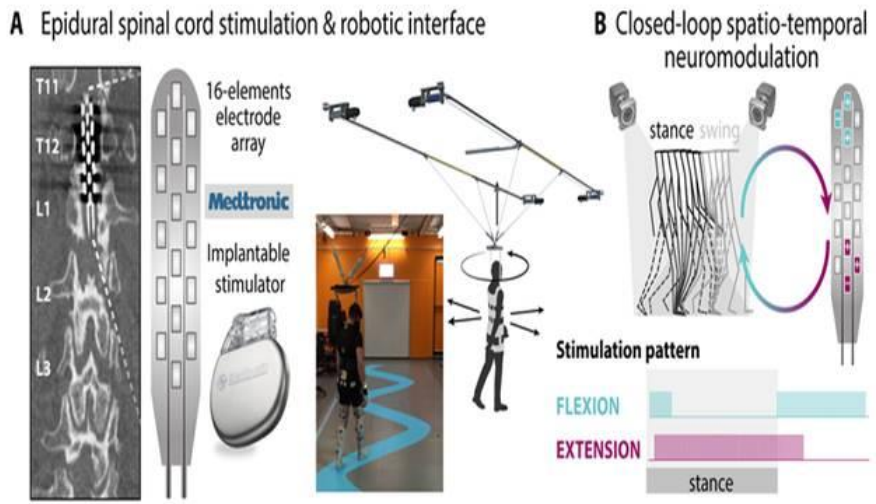


- Orthodromic excitation of motor axons
- Anti-dromic excitations of muscle spindles (Ia, II, Ib)

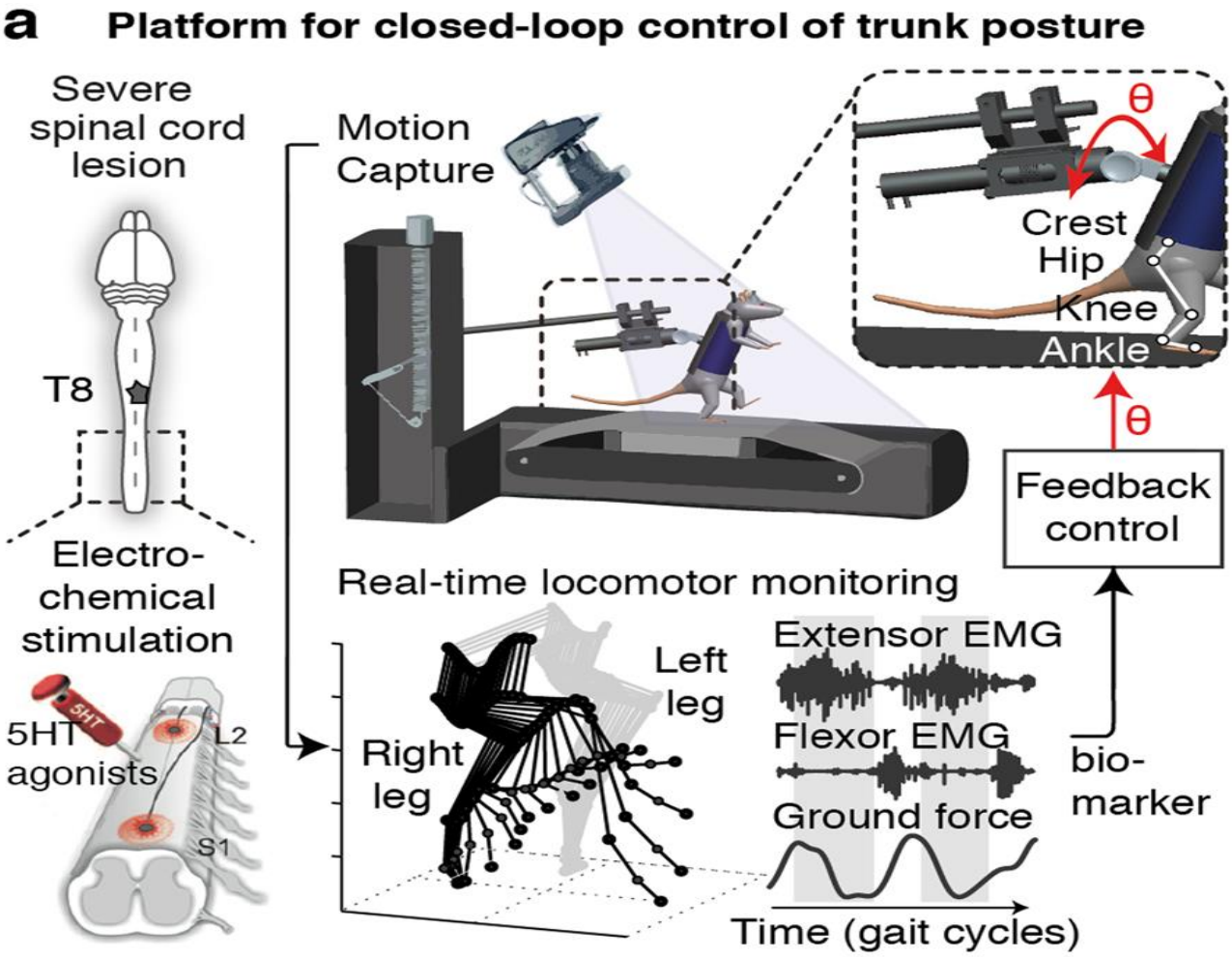
Epidural Stimulation

Epidural Stimulation in Rehabilitation after SCI

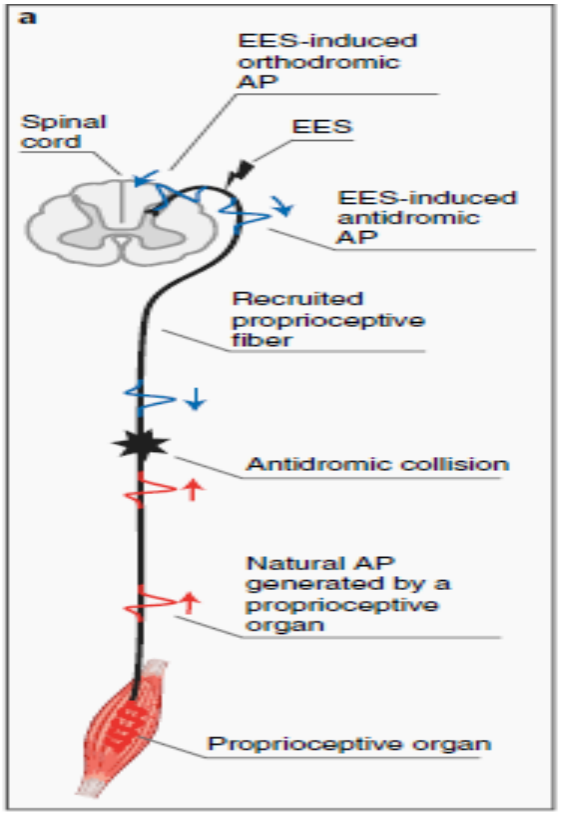


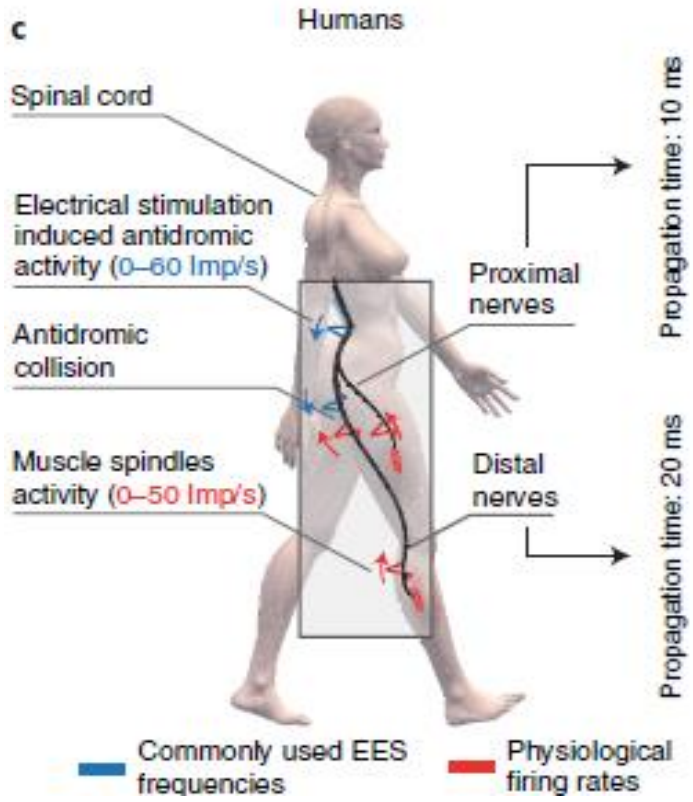


Moraud et al. 2018-Trunk Control During Locomotor training + EpiSCS



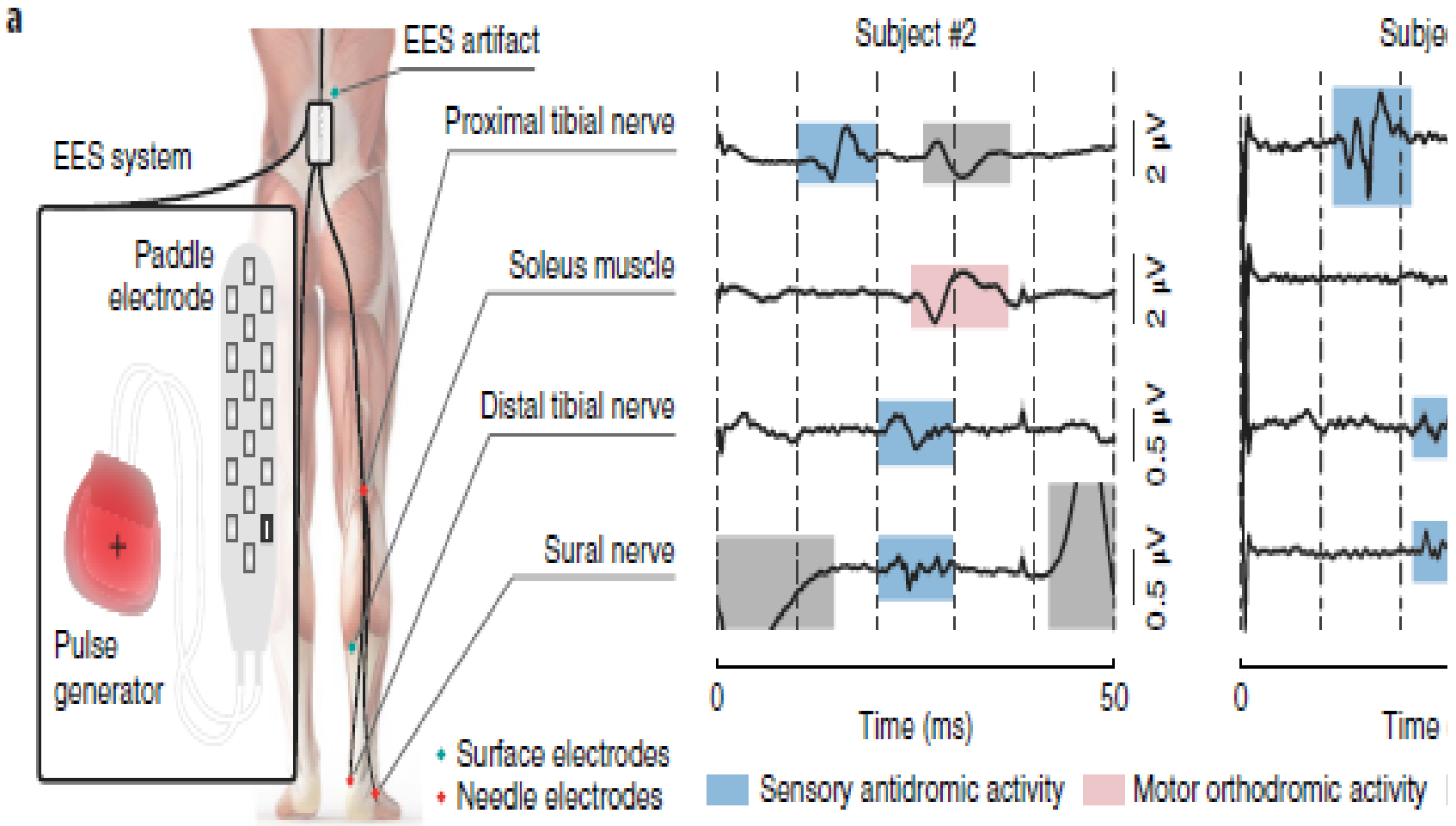
How does Epidural Stimulation Continuous vs. Pulsed Stimulation (to reduce antidromic collision) using high frequency and low stimulation amplitude



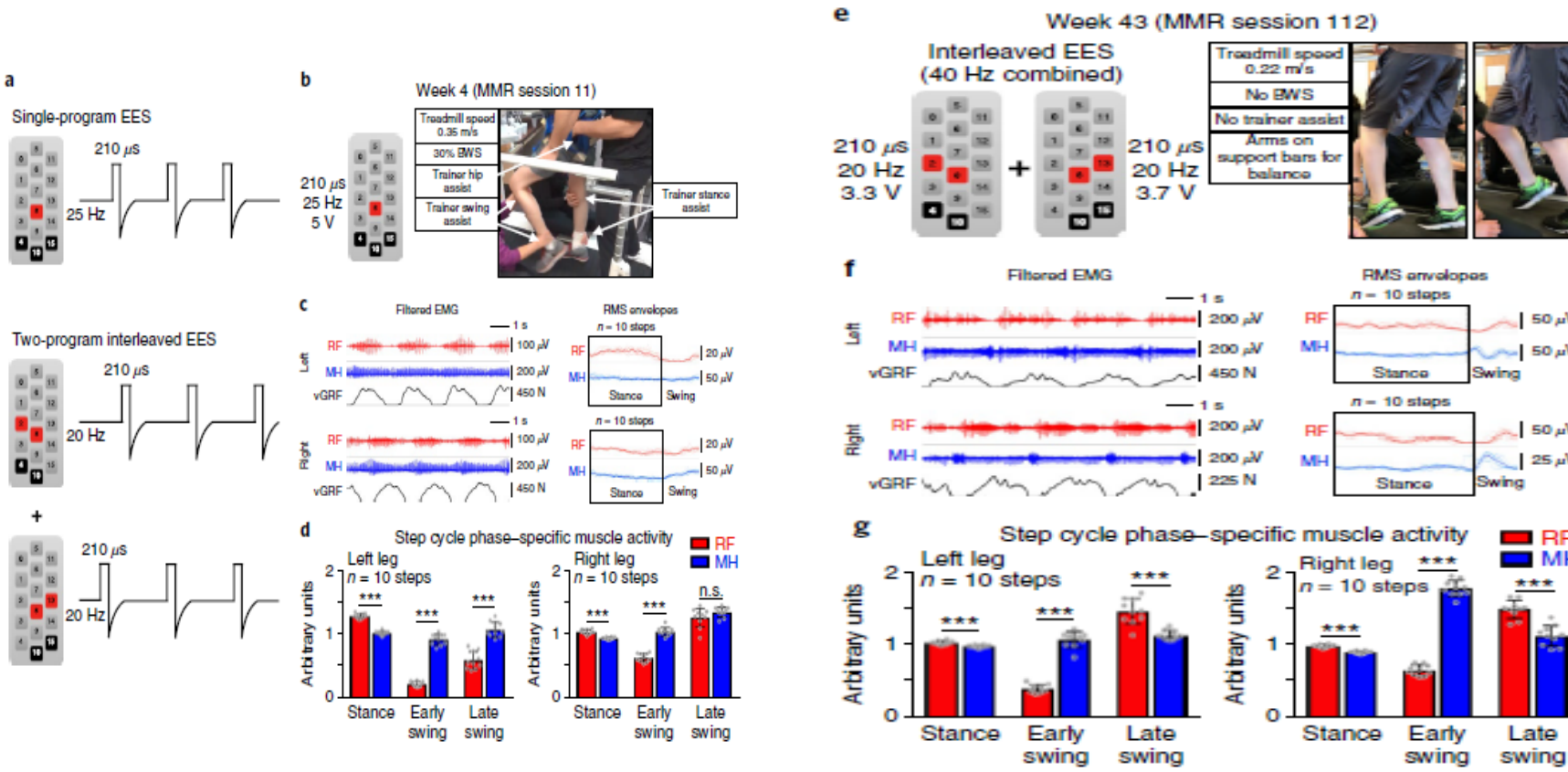


Formento et al. 2018

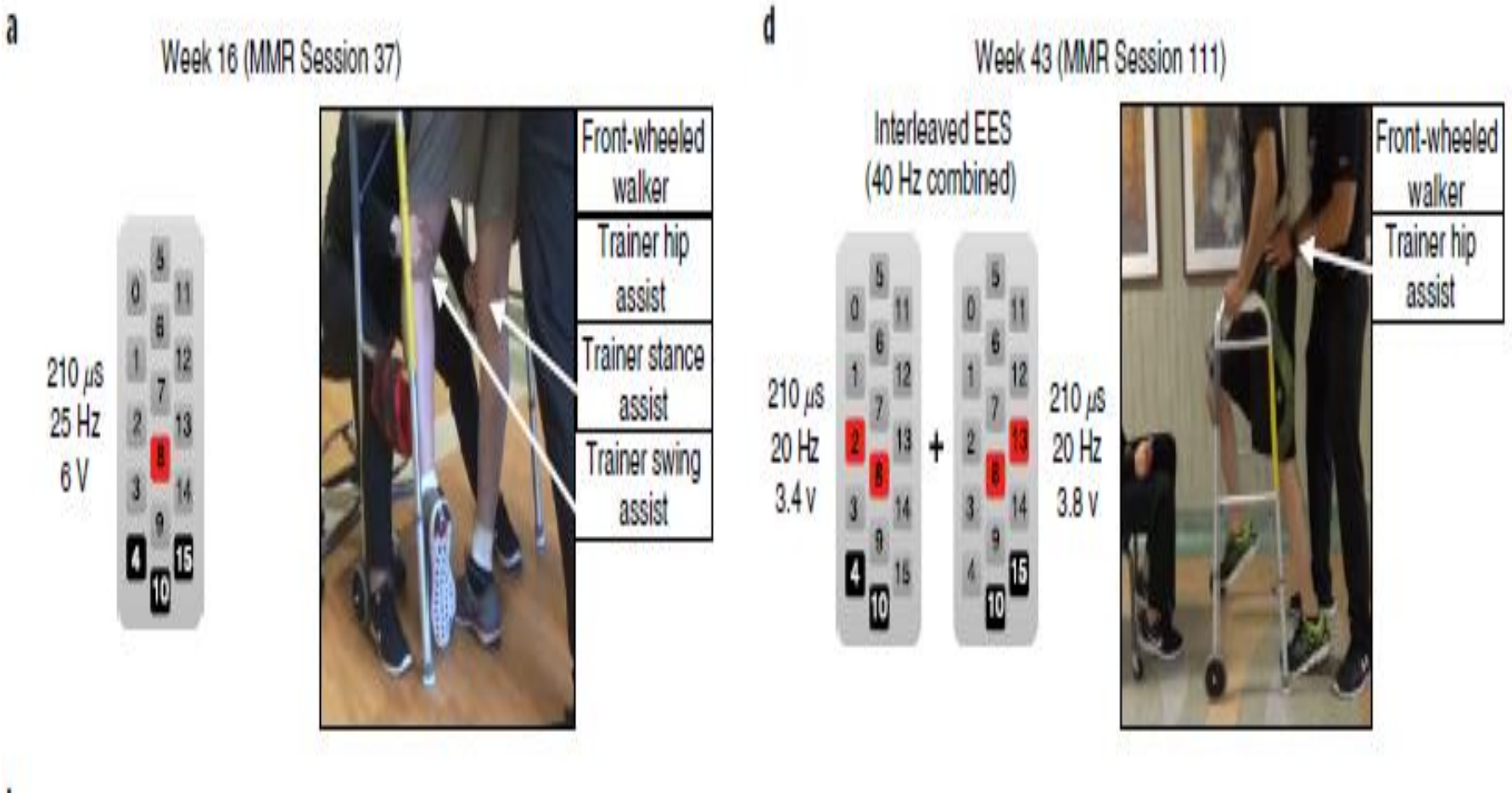
Epidural Stimulation pattern



Progression of SCS-enabled stepping performance on a treadmill (Gill et al. 2018)



Single vs. Interleaved SCES (Gill et al. 2018)



Summary/Conclusions

- NMES or FES training increases skeletal muscle size and soft tissue LM as well as helping carbohydrate metabolism.
  - Modest improvement in Body Composition parameters
  - Robust increase in Basal Metabolic Rate

- Long pulse width stimulation is a potential technique to stimulate denervated muscles and may help to restore muscle size in those with T10 or below level of injury or those with Quada equina injury.

- Trans-spinal/ Epidural stimulation may be potential rehabilitation tool to increase muscle activity, facilitate standing and stepping as well as over ground ambulation after SCI.

Research Team

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Thank You!