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CONTINUED

Neuroplasticity: Putting principles into practice

Guest Editor: Mike Studer, PT, MHS, NCS, CEEAA, CWT

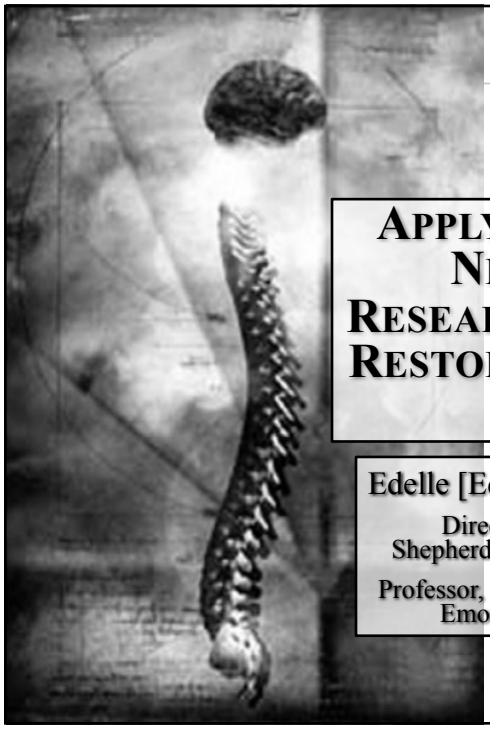
Apr 23: Neuroplasticity and Rehabilitation
Jim Lynskey, PT, PhD

Apr 24: Applying Cutting-edge Neuroplasticity Research for Functional Restoration after Spinal Cord Injury
Edelle Field-Fote, PT, PhD, FAPTA

Apr 25: Neuroplasticity in Stroke Across the Spectrum
Kelsi Smith, PT, DPT, NCS, and Erin McMullen, PT, DPT, NCS

Apr 26: Neuroplasticity in Vestibular Impairment: The Foundation and Facilitatory Techniques for Optimizing Healing
Janene M. Holmberg, PT, DPT, NCS

Apr 27: Neuroplasticity in Degenerative Diseases
Diane Huss, PT, DPT, NCS, and Herb Karpatkin, PT, DSc, NCS, MSCS



Applying Cutting-edge Neuroplasticity Research for Functional Restoration after Spinal Cord Injury

Edelle [Edee] Field-Fote, PT, PhD, FAPTA
Director, Spinal Cord Injury Research
Shepherd Center – Crawford Research Institute
Professor, Department of Rehabilitation Medicine
Emory University School of Medicine

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Objectives

- Explain the mechanisms underlying neuroplasticity and summarize the neuroplastic changes that occur in the brain and spinal cord after injury to the CNS
- Discuss spinal contributions to reflexive and complex motor output
- Describe interventions that affect spinal mechanisms related to reflex activity and walking function
- Describe cutting edge interventions to address hand/arm impairment in individuals with CNS injury

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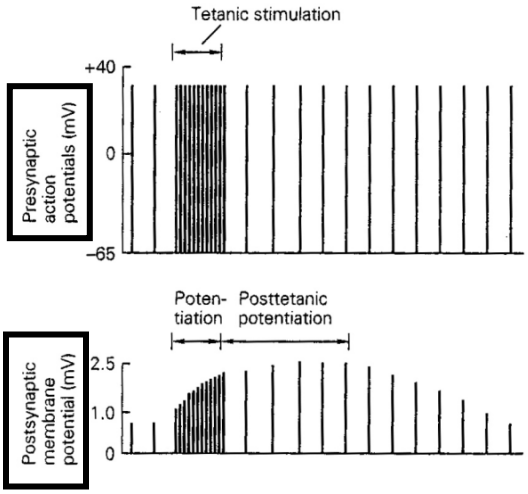
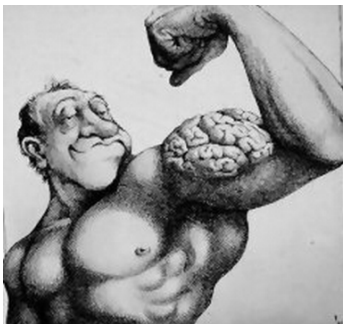
Changes in synaptic efficacy underlie retention of practice effects



Kandel, Schwartz & Jessell, *Principles of Neural Science*, 2000

"Practice puts brains in your muscles"

Sam Snead



8

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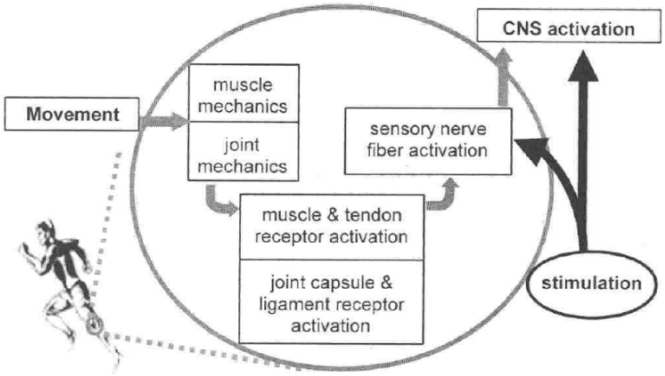
Stimulation can mimic practice



Field-Fote. *Exerc Sport Sci Rev*, 2004

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CONTINUED

…and in spinal humans

Similar case in: Calancie et al. *Brain,* 1994

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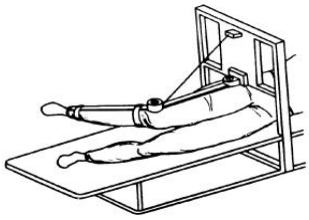
Vibration elicits involuntary step-like movement in ND individuals

- **Vibration elicits locomotor-like movements**
- **Single muscle or contralateral leg**
- **Cyclic behavior suggesting CPG origin**



Gurfinkel et al. *Eur J Neurosci,* 10:1608-1612, 1998

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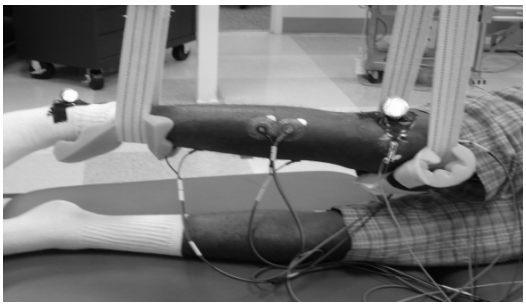
Vibration elicits involuntary stepping in individuals with SCI



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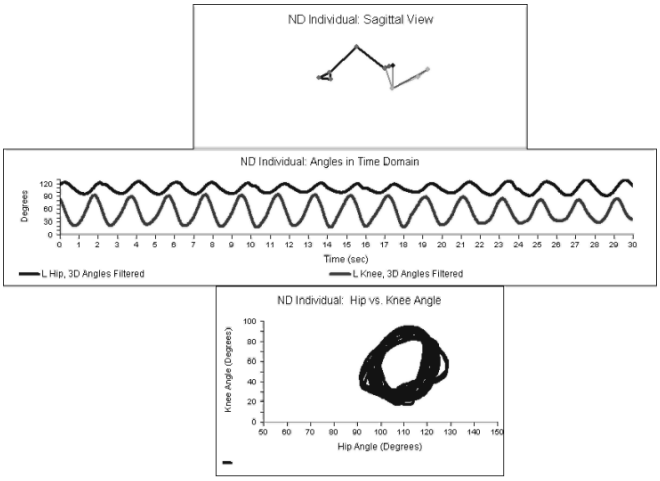
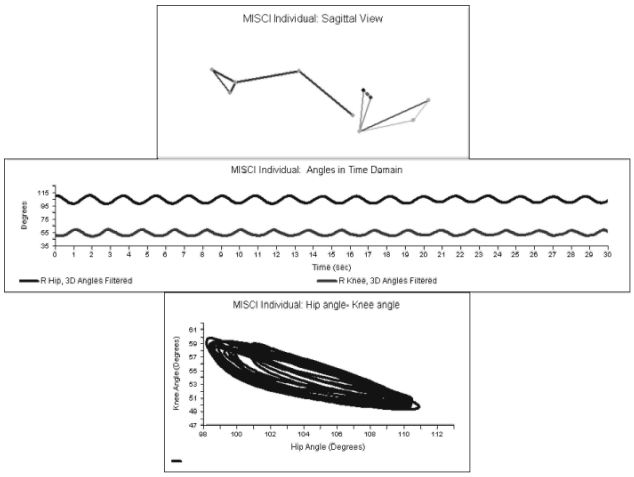
ND Individual: Involuntary Stepping with Muscle Vibration



13

Motor-incomplete SCI: Involuntary Stepping with Muscle Vibration



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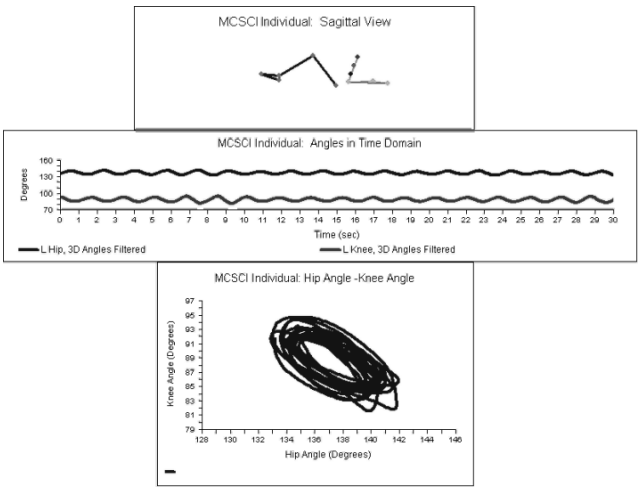
Motor-complete SCI: Involuntary Stepping with Muscle Vibration



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Activation-dependent Plasticity in Lower Extremity Function

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CONTINUED

Whole-body Vibration (WBV) improves walking and decreases spasticity in SCI

- Subjects: 17 individuals with chronic SCI
- 50 Hz, low amplitude (2-4 mm)
- 3 days/week x 4 wks

- Outcomes:
  - increased walking speed
  - decreased quad spasticity

Walking function: Ness & Field-Fote. *Gait & Posture,* 2009
Spasticity: Ness & Field-Fote. *Restor Neurol Neurosci,* 2009

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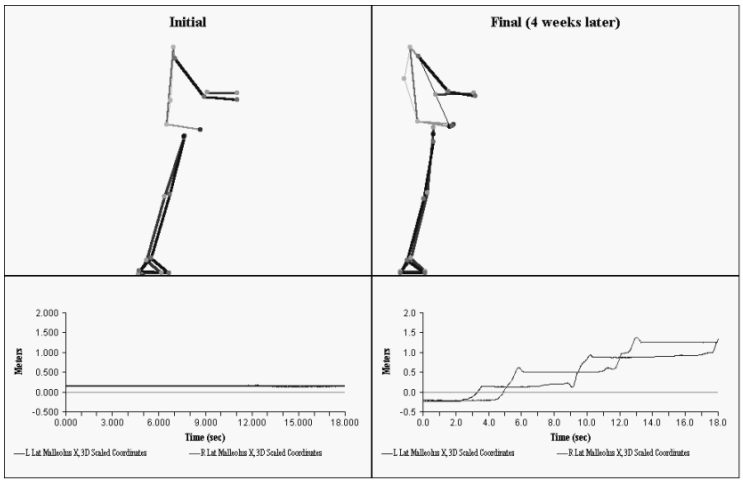
Improved walking following 12-session course of WBV



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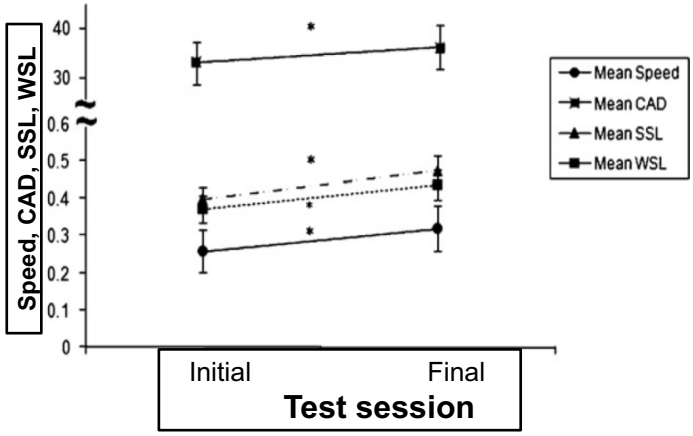
WBV is associated with improved gait speed and quality



Ness & Field-Fote. *Gait & Posture,* 2009

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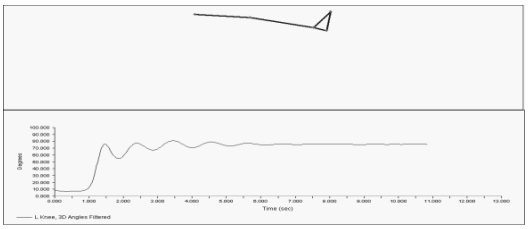
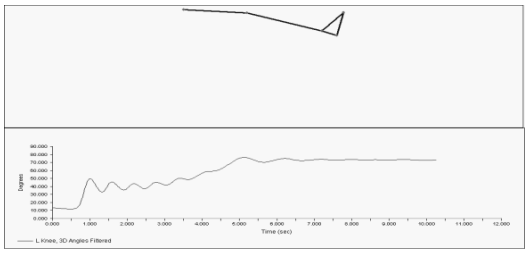
Biomechanical quantification of stretch reflex excitability

Low spasticity



Pendulum Test
High spasticity



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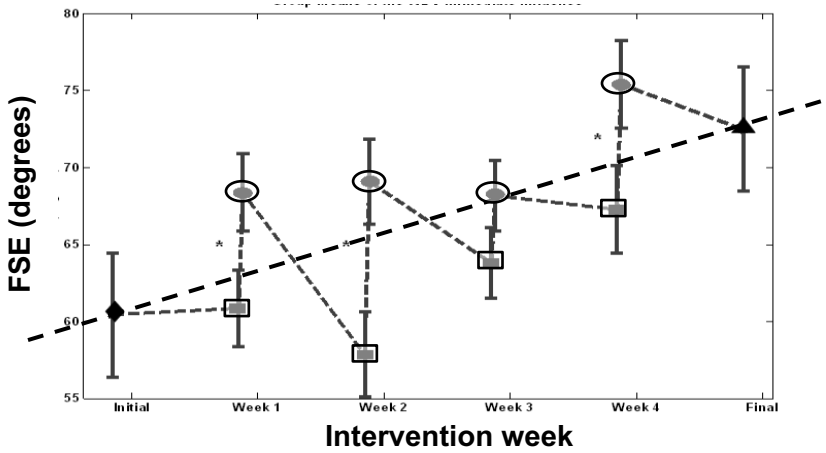
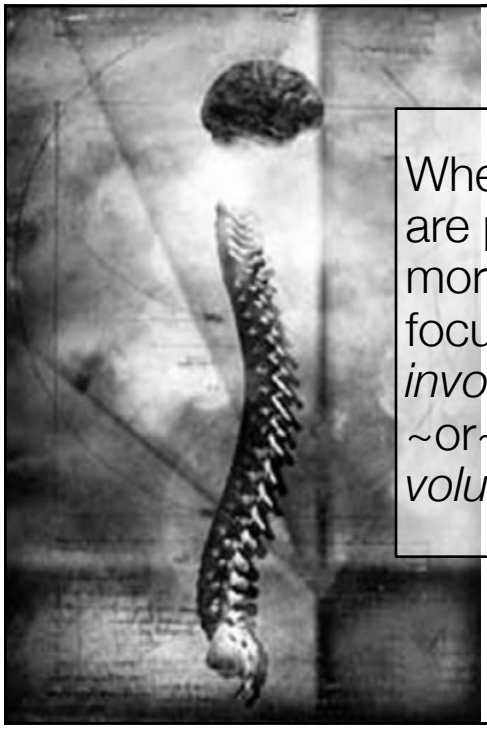
WBV influences on spasticity

- cumulative multi-session effects
- early within-session effects
- late within-session effects



Ness & Field-Fote. *Restor Neurol Neurosci,* 2009

21



When spinal reflexes are problematic is it more effective to focus on *decreasing involuntary* activity ~or~ *increasing voluntary* activity?

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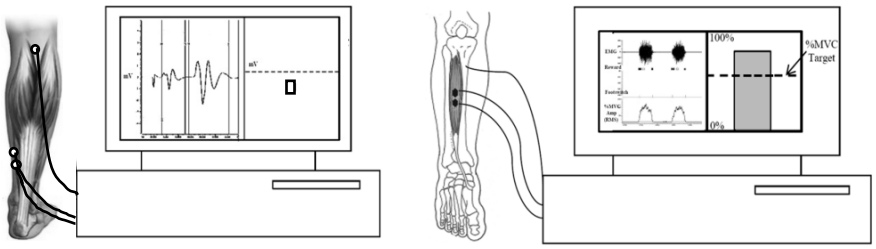
Should we train to ↓ reflexes or to ↑ voluntary control?

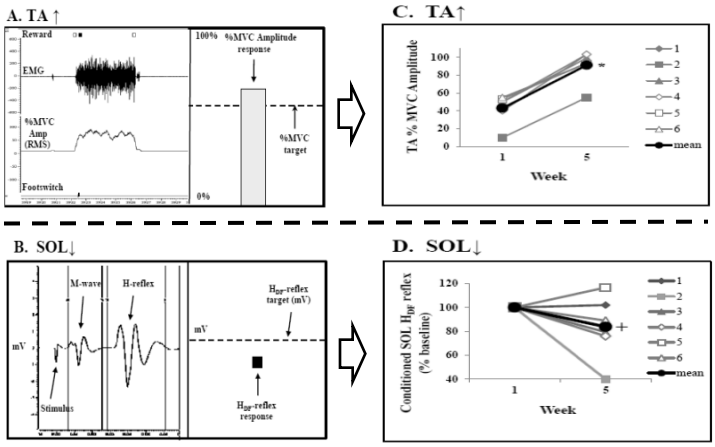


3 baseline sessions
300 repetitions/session ► 12 training sessions
(3/wk x 4 wks)

Manella, Roach, Field-Fote. *J Neurophys*, 2013

23

Training to ↑ voluntary control vs. to ↓ reflexes – which is associated with greater benefit?



Manella, Roach, Field-Fote. *J Neurophys*, 2013

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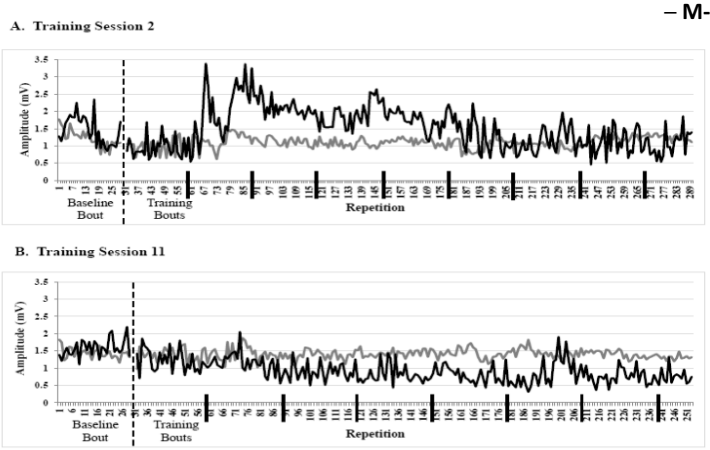
Sample SOL ↓ Outcome

– H-reflex
– M-wave



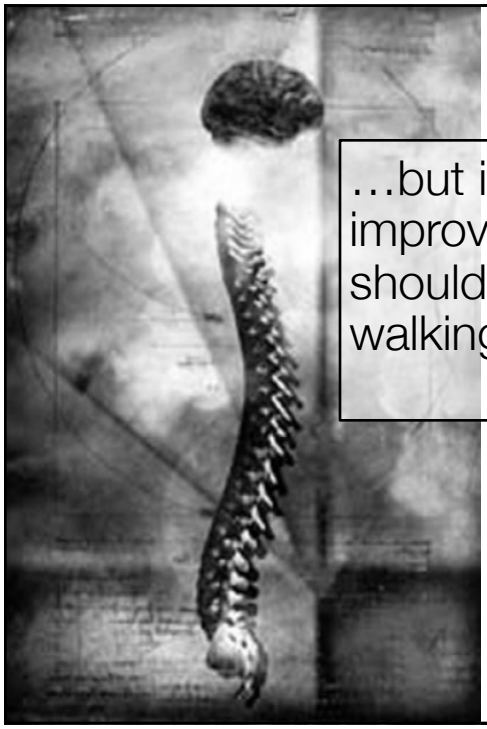
Manella & Field-Fote. *J Neurophys*, 2013

Outcomes
reflexes, strength, walking, EMG

	TA ↑	SOL ↓
TA %MVC amplitude	✓**	
Stretch reflex threshold ↑	✓	
Active dorsiflexor ROM	✓	
Dorsiflexor strength	✓	
Step height in walking	✓	
2MinWT distance	✓	✓
TA/SOL co-activation		✓

**significant between-group diff

Manella, Roach, Field-Fote. *J Neurophys*, 2013



…but if we really want to improve walking, then we should probably practice walking…

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Is there a "best" approach to locomotor practice?

Treadmill training with manual assistance (TM)

Treadmill training with CPN stimulation assist (TS)

Overground training with CPN stimulation assist (Walkaide II stimulator; OG)

Treadmill training with robotic assistance (Lokomat robotic orthosis; LR)

TM

TS

OG

LR

N = 74 enrolled, 64 completed (across 4 groups)

Field-Fote & Roach. *Phys Ther,* 91:48-60, 2011

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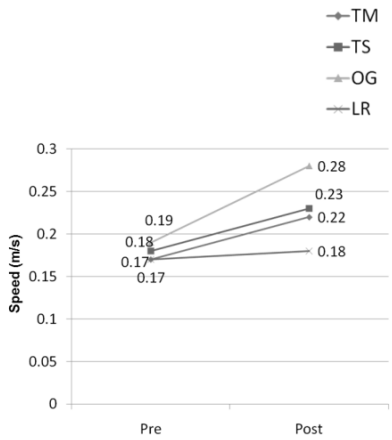
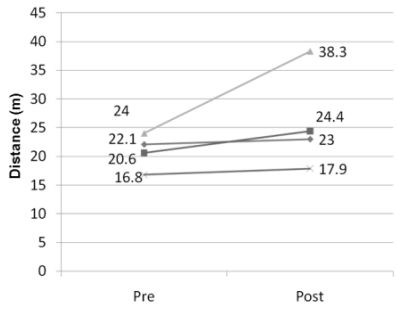
Groupwise changes in Walking Speed & Distance





Field-Fote & Roach. *Phys Ther,* 91:48-60, 2011

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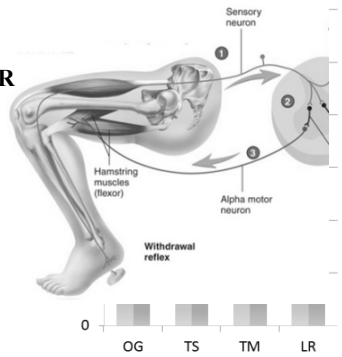
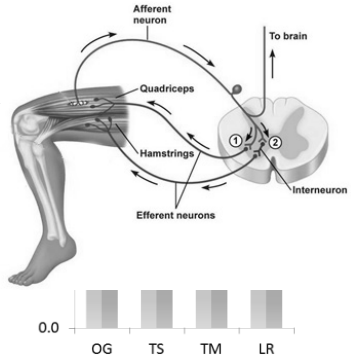
Locomotor practice modulates reflex excitability

FRR



R 1



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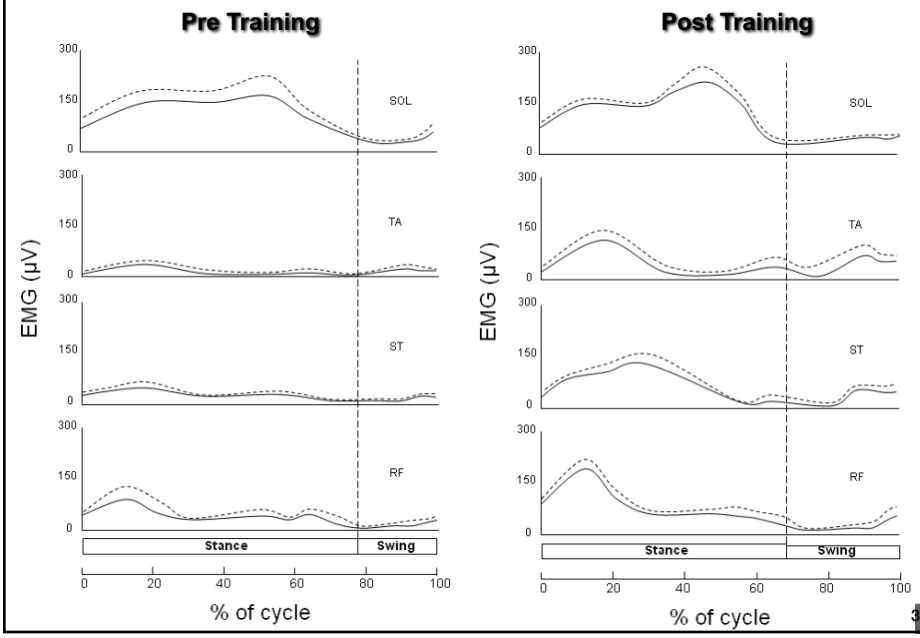
EMG Timing and Amplitude



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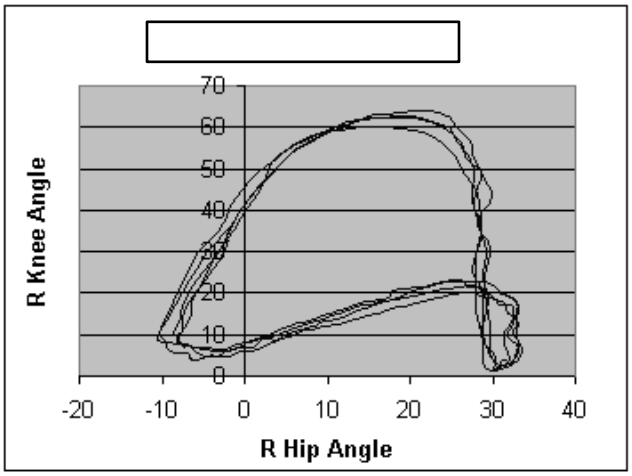
Limb Coordination is the Hallmark of Motor Control



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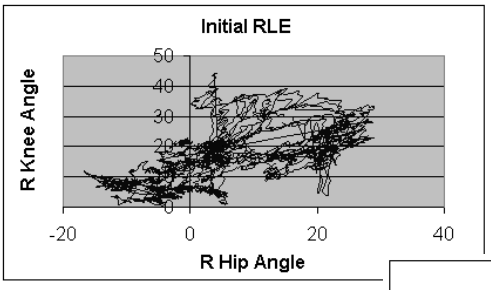
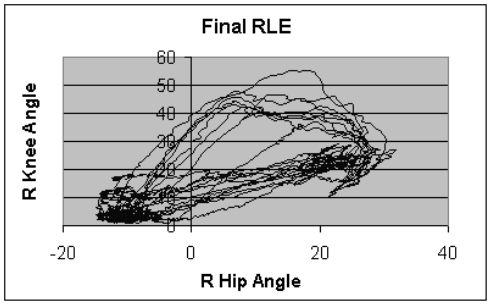
Intralimb Coordination

Subject with SCI - pre & post training





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Activation-dependent Plasticity in Upper Extremity Function

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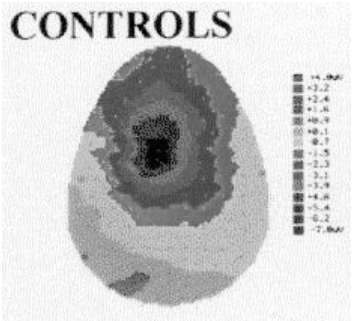
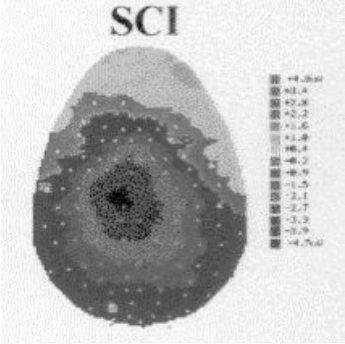
The cortex reorganizes after SCI…

…does this contribute to functional deficits?





Green et al. *Neurology,* 1998

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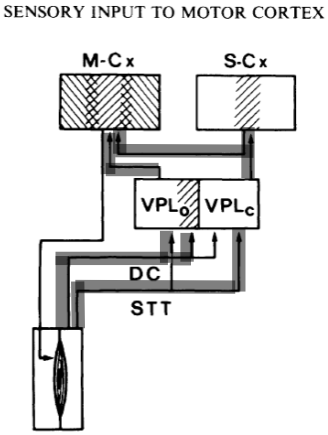
Sensory input influences corticomotor excitability



Asanuma & Mackel *Jpn J Physiol*, 1989.

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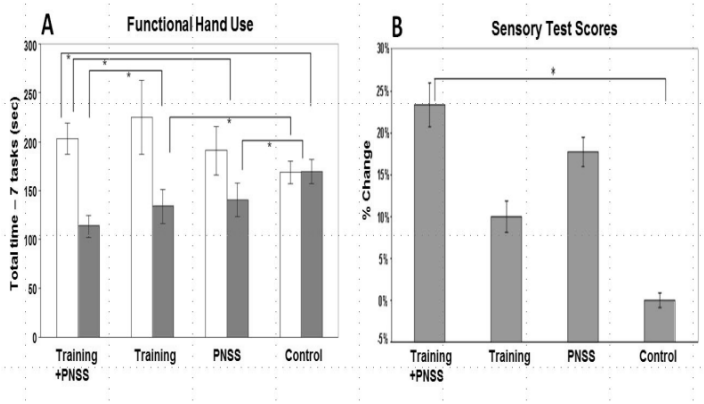
Can sensory stimulation augment motor training?



Beekhuizen &Field-Fote . *Arch Phys Med Rehabil,* 2008

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Neurorehabilitation and Neural Repair 19(1); 2005

Massed Practice versus Massed Practice with Stimulation: Effects on Upper Extremity Function and Cortical Plasticity in Individuals with Incomplete Cervical Spinal Cord Injury

Kristina S. Beekhuizen and Edelle C. Field-Fote

Physical Therapy Volume 87 Number 2 February 2007

Cortical Reorganization Following Bimanual Training and Somatosensory Stimulation in Cervical Spinal Cord Injury: A Case Report

Larisa R Hoffman, Edelle C Field-Fote

JNPT • Volume 34, December 2010

Functional and Corticomotor Changes in Individuals With Tetraplegia Following Unimanual or Bimanual Massed Practice Training With Somatosensory Stimulation:

Larisa R. Hoffman, PT, PhD, and Edelle C. Field-Fote, PT, PhD

Arch Phys Med Rehabil Vol 89, April 2008

Sensory Stimulation Augments the Effects of Massed Practice Training in Persons With Tetraplegia

Kristina S. Beekhuizen, PhD, PT, Edelle C. Field-Fote, PhD, PT

Topics in Spinal Cord Injury Rehabilitation/Fall 2013

Effects of Practice Combined with Somatosensory or Motor Stimulation on Hand Function in Persons with Spinal Cord Injury

Larisa Hoffman, PT, PhD,[1] and Edelle Field-Fote, PT, PhD[2]

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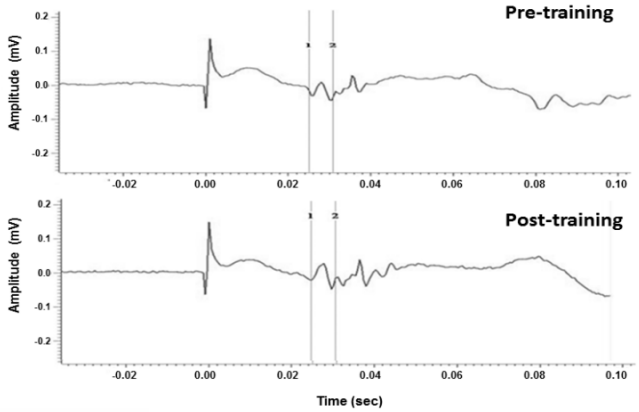
Change in hand function is associated with change in cortical excitability



Sample thenar MEPs at 80% MSO (avg of 5 traces)

Beekhuizen &Field-Fote . *Arch Phys Med Rehabil*, 2008

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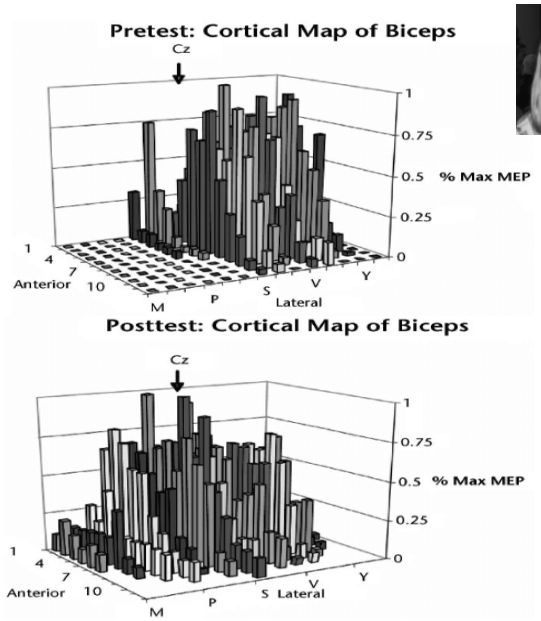
Reorganization of cortical map



Hoffman & Field-Fote. *Phys Ther*, 2007

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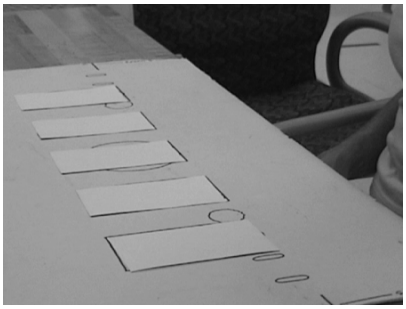
Is all that training worth the effort?



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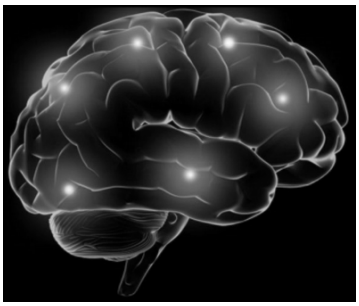
Is (direct) cortical stimulation
more beneficial than
(indirect) somatosensory stimulation?



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Approaches for direct cortical stimulation

- Repetitive transcranial magnetic stimulation
  - Activates neurons
  - Studies in persons with stroke
    - High frequency

- Transcranial direct current stimulation (tDCS)
  - Modulates neuronal excitability
  - Studies in persons with stroke
    - anodal vs cathodal

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CONTINUED

rTMS in SCI and ND

High frequency rTMS
- 10Hz [excitatory])
- 80% biceps RMT

(Pascual-Leone, 1994; Beradelli et al, 1998; Butefish et al, 2004; Kim et al, 2006; Tallelli & Rothwell, 2006)

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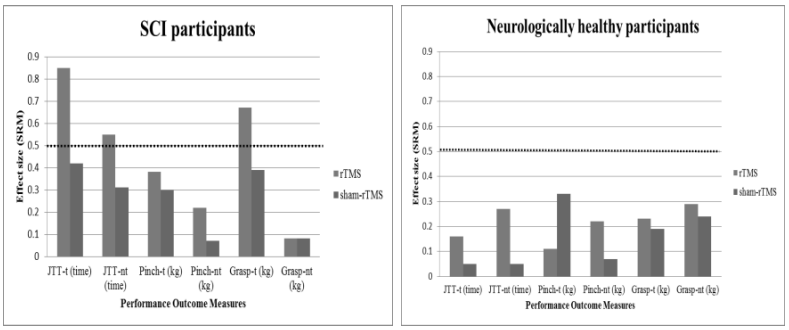
rTMS is associated with improved functional scores in persons with SCI



Dashed line indicates threshold for moderate effect size

Gomes-Osman & Field-Fote. *Clin Rehabil,* 2014

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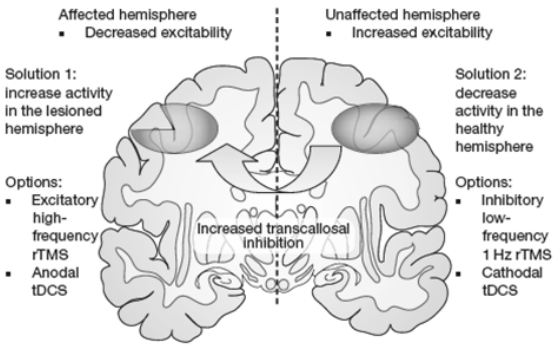
tDCS represents a clinically accessible approach to direct cortical stimulation

Anodal= EXCITATION
Cathodal= INHIBITION

ANODE CATHODE



(Fregni & Pascual-Leone, 2007)

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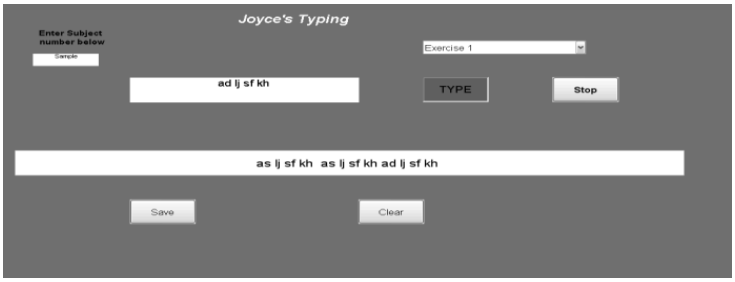
Bihemispheric anodal tDCS

- **Bilateral anodal corticomotor tDCS (1 mA, 20 min) or sham**
- **Outcome Measures: BT and STM tasks**



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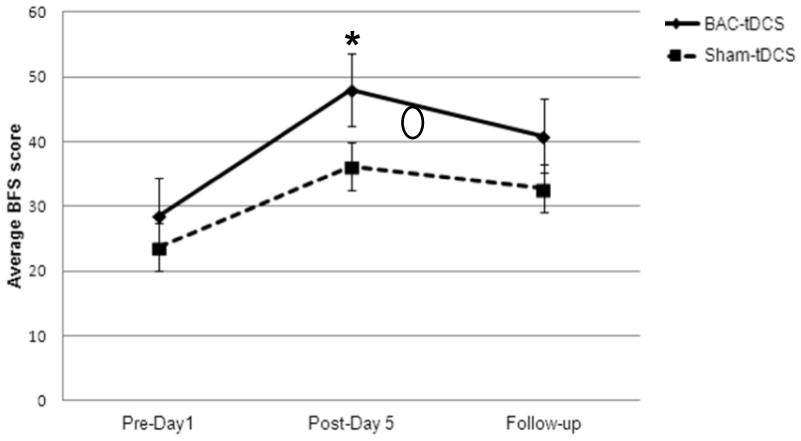
Bimanual finger-sequencing scores



Gomes-Osman & Field-Fote. *J Motor Behav*, 2013

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Is direct cortical activation more effective than indirect (somatosensory) activation ?

Assessment of clinically available approaches

tDCS

Vibration

TENS

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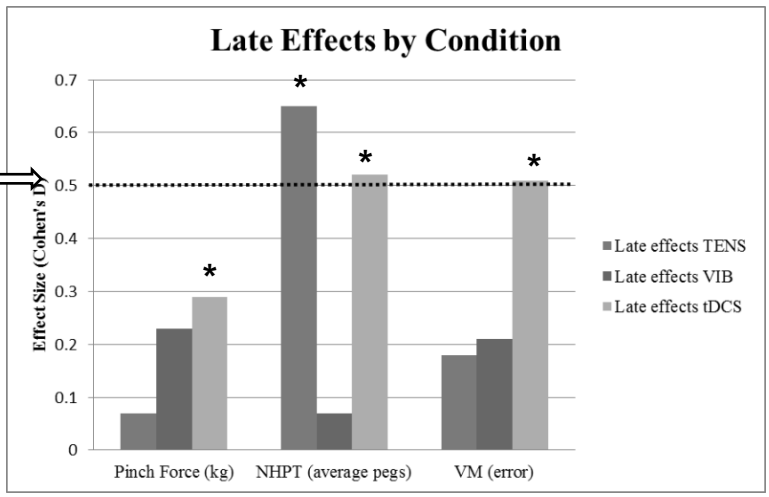
tDCS is associated with most effect
TENS also influenced function

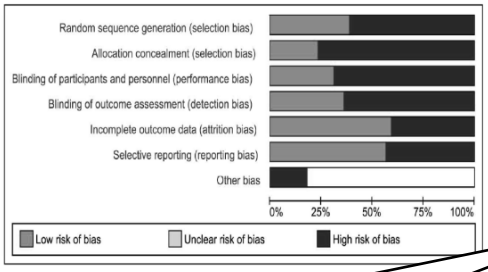
Dashed line = moderate effect size

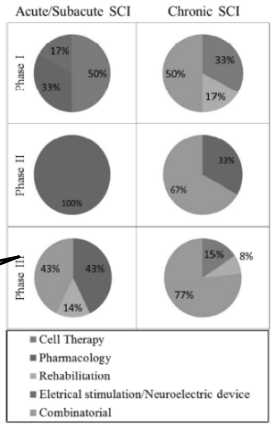


Gomes-Osman & Field-Fote. *J Neurol Phys Ther,* 2015

50

A Systematic Review of Experimental Strategies Aimed at Improving Motor Function After Acute and Chronic SCI.
Gomes-Osman J, Cortes M, Guest J, Pascual-Leone A.
J Neurotrauma. 2016; 33:425-38





"The highest evidence level was for Phase III studies supporting the role of multi-intervention approaches that contained a rehabilitation component…"

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The Caudal End

- Stimulation (electric & vibration) activates much the same circuitry as training
- In people with SCI, training promotes adaptive neuroplasticity of cortical and spinal circuits
- Clinically accessible stimulation can be a valuable adjuvant to training
- Continued training at a sufficient dose is necessary to maintain gains

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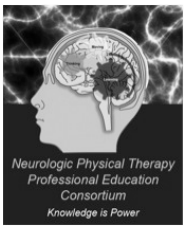
CONTINUED

Please be sure to complete the webinar evaluation.

The link will be sent to you in an email.



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Thank You
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