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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
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
Changes in synaptic efficacy underlie retention of practice effects

“Practice puts brains in your muscles”
*Sam Snead*
Stimulation can mimic practice

Field-Fote. Exerc Sport Sci Rev, 2004

...and in spinal humans

Similar case in: Calancie et al. Brain, 1994
Vibration elicits involuntary step-like movement in ND individuals

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


Vibration elicits involuntary stepping in individuals with SCI
ND Individual: Involuntary Stepping with Muscle Vibration

Motor-incomplete SCI: Involuntary Stepping with Muscle Vibration
Motor-complete SCI: Involuntary Stepping with Muscle Vibration

Activation-dependent Plasticity in Lower Extremity Function
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*

Improved walking following 12-session course of WBV
WBV is associated with improved gait speed and quality

Biomechanical quantification of stretch reflex excitability

Low spasticity

Pendulum Test

High spasticity
When spinal reflexes are problematic is it more effective to focus on *decreasing* involuntary activity ~or~ *increasing* voluntary activity?
Should we train to ↓ reflexes or to ↑ voluntary control?

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


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

Sample SOL ↓ Outcome

- H-reflex
- M-wave

Outcomes reflexes, strength, walking, EMG

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<tr>
<th></th>
<th>TA ↑</th>
<th>SOL ↓</th>
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<tr>
<td>TA %MVC amplitude</td>
<td>✓</td>
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<tr>
<td>Stretch reflex threshold</td>
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<td>Active dorsiflexor ROM</td>
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<td>Step height in walking</td>
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<td>TA/SOL co-activation</td>
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**significant between-group diff
…but if we really want to improve walking, then we should probably practice walking…

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)

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

Groupwise changes in Walking Speed & Distance

Locomotor practice modulates reflex excitability
EMG Timing and Amplitude

Limb Coordination is the Hallmark of Motor Control
Intralimb Coordination
Subject with SCI - pre & post training

Activation-dependent Plasticity in Upper Extremity Function
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.**
Can sensory stimulation augment motor training?

Beekhuizen & Field-Fote. *Arch Phys Med Rehabil, 2008*
Change in hand function is associated with change in cortical excitability

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

Reorganization of cortical map

Hoffman & Field-Fote. Phys Ther, 2006
Is all that training worth the effort?

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

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)
rTMS is associated with improved functional scores in persons with SCI

Dashed line indicates threshold for moderate effect size


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tDCS represents a clinically accessible approach to direct cortical stimulation

Anodal = EXCITATION
Cathodal = INHIBITION

(Fregni & Pascual-Leone, 2007)
Bihemispheric anodal tDCS

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

Bimanual finger-sequencing scores

Gomes-Osman & Field-Fote. *J Motor Behav*, 2013
Is direct cortical activation more effective than indirect (somatosensory) activation?

Assessment of clinically available approaches

$t\text{D}CS$  

Vibration

$T\text{EN}S$

$t\text{D}CS$ is associated with most effect. $T\text{EN}S$ also influenced function.

Dashed line = moderate effect size

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

- 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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Thank You