RECHARGING USE OF FUNCTIONAL ELECTRICAL STIMULATION IN YOUR CLINIC: A REVIEW & HANDS-ON PRACTICE SESSION

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INTRODUCTION & ACKNOWLEDGEMENT

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Acknowledgement to Amy Berryman, OTR, MSHSA for collaboration on prior presentations re: FES

LEARNING OBJECTIVES

1. Discuss purpose and parameters for use of FES for neuromuscular rehabilitation.
2. Summarize current literature for use of FES for management of impairments.
3. Practice use of Electrical Stimulation Unite with clinical case examples.

Neuromuscular Electrical Stimulation (NMES)

vs.

Functional Electrical Stimulation (FES)

- **NMES:** uses a device to send electrical impulses to nerves. This input causes muscles to contract. The electrical stimulation can increase strength and range of motion, and offset the effects of disuse. It is often used to "re-train" or "re-educate" a muscle to function and **to build strength** after a surgery or period of disuse but is more truly routine exercise and strengthening.
- **FES:** refers to the use of (NMES) or **electrical stimulation during a task**. This can include walking or using an arm to reach. Foot drop is a common problem following a neurological injury which may result in decreased walking speed, decreased step length, and tripping. When FES is applied to the muscles that lift the foot at the correct time during the walking cycle it may not only impact the ability to clear the foot and improve safety when walking but may result in increased strength of those muscles and increased range of motion at the ankle joint. FES can also improve safety, ease, and efficiency with walking.

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E STIM BASICS: CONTRAINDICATIONS/PRECAUTIONS

- Cardiac Demand Pacemaker-need MD permission
- Hx of Congestive Heart Failure-need MD permission
- Recent Myocardial Infarction-need MD permission
- De-conditioned elderly patients- need MD permission
- Pregnancy (esp. 1st and 3rd trimesters)
- Protruding metal (staples or external fixation)
- Incision sites
- Skin abrasions
- Do not shave the skin sooner than two days before Estim is applied. Use scissors to cut hair.

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E STIM BASICS: PARAMETERS

Clinical Neurophysiology Systematic Review – 19 studies

[Peripheral electrical stimulation to induce cortical plasticity: A systematic review of stimulus parameters]

Mar2011, Volume 122, Issue 3, *Pages 456-463*

L.S. Chipchase, S.M. Schabrun, P.W. Hodges

- This review provides an overview of the electrical stimulation parameters needed to induce cortical plasticity in human subjects.
- Current data indicate that stimulation intensity may be an important factor in determining the direction of rapid plastic change. In particular, there was a trend for stimulation above motor threshold to increase excitability of the corticomotor pathway.
- Electrical stimulation in the clinical setting is a feasible and inexpensive application. It has been widely used although its potential for inducing plastic change has been realized only recently.
- How ES can be used to induce clinically meaningful plastic change in movement related disorders needs to be addressed

E STIM BASICS: PARAMETER ADJUSTMENT

Goal of Adjusting Parameters:

- To achieve the most beneficial and appropriate muscular contraction and in the case of our presentation to achieve function
- To maintain maximum patient comfort

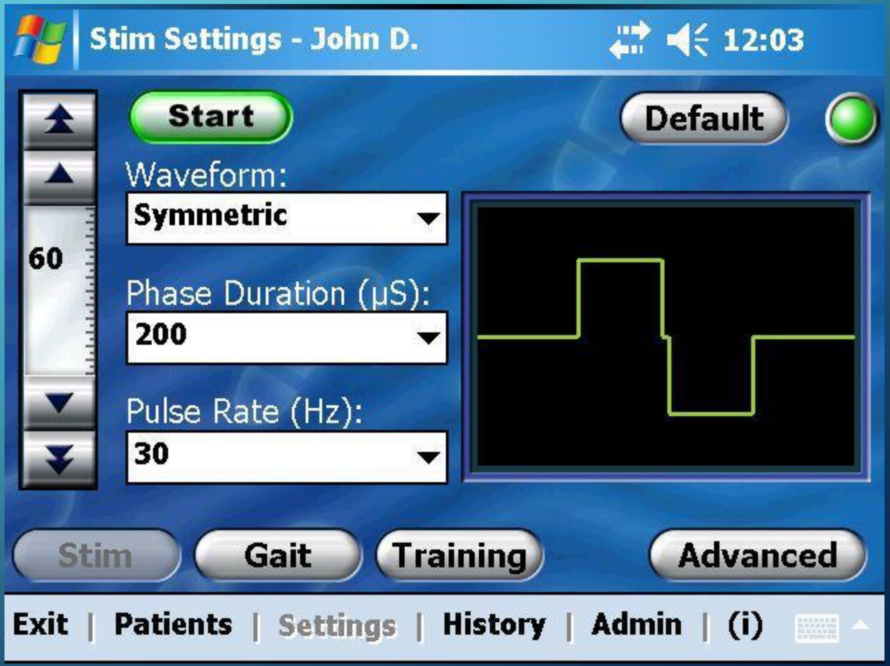
E STIM BASICS: PARAMETERS

Pulse Amplitude (Intensity)

Duration

Pulse Rate (Frequency)

Waveform



E STIM BASICS: PULSE AMPLITUDE

UNITS: milliamps, mA

- Increasing amplitude (intensity) increases muscle recruitment until a threshold contraction is achieved.
- When increasing amplitude, should not exceed patient's tolerance.
- Is not consistent from one session to another,

  impacted by electrodes / skin impedence

E STIM BASICS: DURATION

Phase/pulse Duration UNITS: microseconds, uS:

- Affects current intensity required to generate a motor response
- **If duration is short <40uS** will require a very high amplitude to stimulate.
- If **duration is between 200-400uS,** a lower amplitude can be used to achieve a quality muscle contraction. This range has also been found to be safer for skin.
- Higher duration may have greater overflow if working with smaller muscle groups
- Collins DF; 2007 suggests 500us or larger for encouraging central contributions

E STIM BASICS: PULSE RATE / FREQUENCY

Pulse Rate or Frequency UNITS: pulses per second / Hz

- Plays a significant role in patient comfort
- Pulse Rates between 30-35pps are usually sufficient to achieve tetany (fused contractions) in most muscles of UE and LE.
- Pulse rates < tetany= Tremorous contractions; > tetany = Fatigue
- For long tx session use min pulse rate to produce tetany. Start high and lower pulse rate to where still maintain tetany.

E STIM BASICS: PULSE RATE / FREQUENCY

- Maneski et al 2013 Muscle / Nerve suggest rates 10 Hz (low frequency) to minimize fatigue
- It affects the quality of muscle contraction and also the rate of muscle fatigue.
- First time NMES patients may prefer higher pulse rate for comfort. OK to train at higher rates to achieve comfort, but sessions should be shorter, or increase off times.

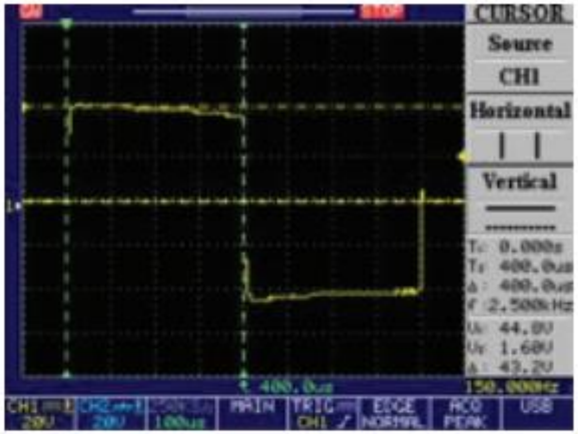
E STIM BASICS: WAVEFORM

- Waveform affects both the **effectiveness** of the neuromuscular activation and the **comfort** of the application.
- **Square**(rectangular) **Waveforms**:

–abrupt onset and offset and are typical in NMES

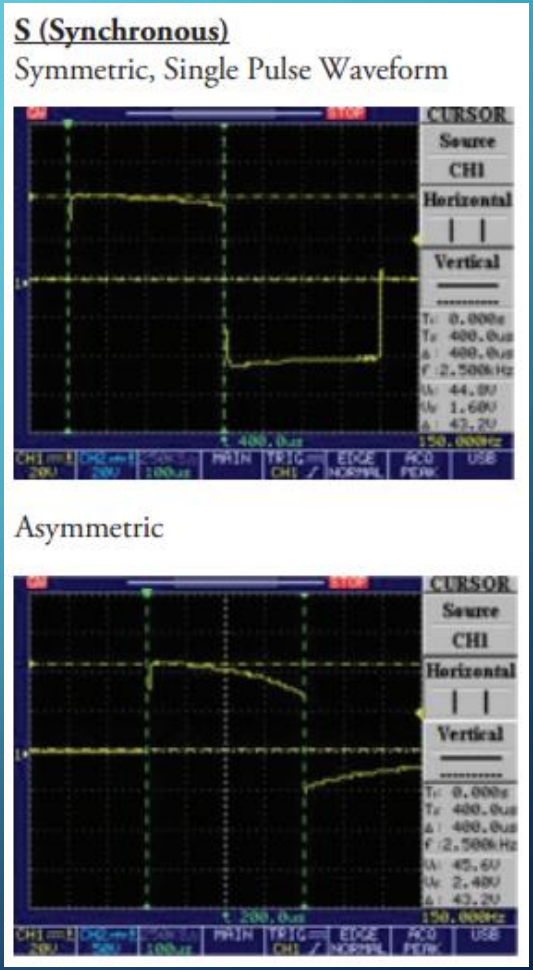
–Due to the abrupt onset of the pulse, nerve accommodation does not occur, **and** minimal stimulation amplitudes are used.

Single Pulse Waveform (Channel 2)



E STIM BASICS: WAVEFORM

- Symmetrical (equal) and Asymmetrical Biphasic Waveform
- Bidirectional flow of ions
- Can be balanced (equal current flow in both directions) with one or more of the waveform attributes (amplitude or duration) being unequal.
- Can be unbalanced (unequal current flow) with one or more of the waveform attributes (amplitude or duration) being unequal.
- Spiked Waveform- it reaches its peak momentarily and therefore not as comfortable



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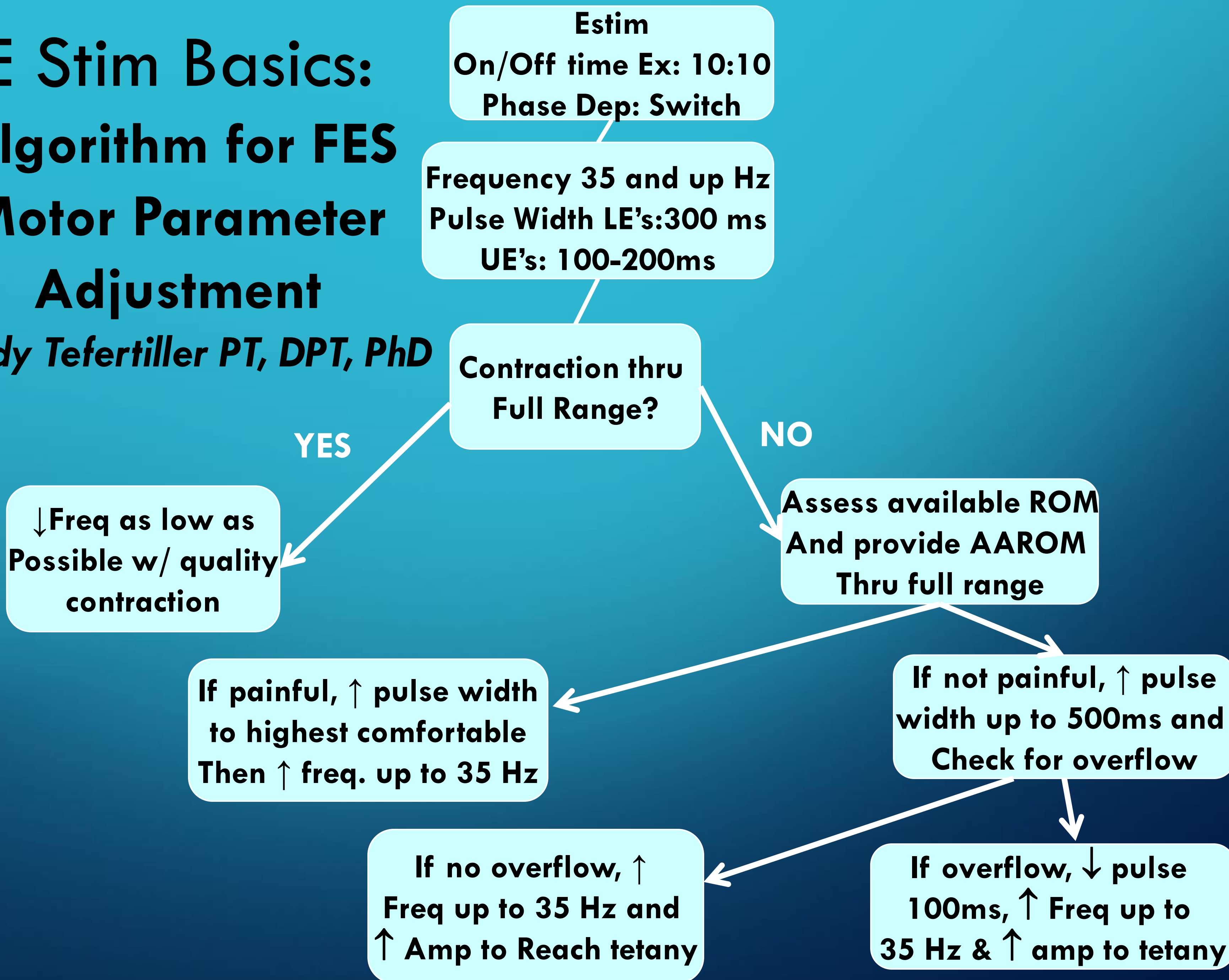
E STIM BASICS: CURRENT DENSITY

- **Smaller electrode**: Greater current density (may be less comfortable, but able to achieve more "robust" contraction if over motor point).
- **Larger electrode**: Lesser current density (may be more comfortable, but will get more "spreading" out of the charge and may not be able to isolate particular muscle group as well).

E Stim Basics:
Algorithm for FES Motor Parameter Adjustment

Candy Tefertiller PT, DPT, PhD



E-STIM BASICS: DOSAGE

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PRINCIPLES TO ENHANCE NEURAL PLASTICITY

- Use it or Lose it
- Use it and Improve it
- Specificity Matters
- Repetition Matters
- Intensity Matters

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- Time Matters
- Salience Matters
- Age Matters
- Transference
- Interference

Kleim & Jones 2008; Hornby et al 2011

E-STIM BASICS: PREPARATORY METHODS

Overall Treatment Planning to optimize quality of Practice

- ***Evaluate and adjust for/treat:***

  ROM, Spasticity, Sensation

- ***Manage spasticity***
  - Tone reduction techniques, meds, splinting/casting
- ***Postural interventions***
- ***Assess Learning needs/best environment for practice***

E-STIM BASICS: PREPARATORY METHODS

Immediately before FES Practice

- ***Prepare ROM***
  - Stretching, PROM/AROM activities
- ***Reduce Spasticity***
  - Weightbearing, closed chain/modified closed chain, heat/ice
- ***Adjust posture to match the task***
  - Consider props or other tools
- ***Adjust to learning needs of patient***

SPECIFIC FOCUS FOR FES INTERVENTIONS:

1. Muscle activation
2. Sensory awareness

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REFERENCES FOR MUSCLE ACTIVATION

- Howlett O. et al. Electrical stimulation improves activity after stroke: A systematic review with meta-analysis. Arch. Phys. Med. Rehab. 2015;96:934-43.
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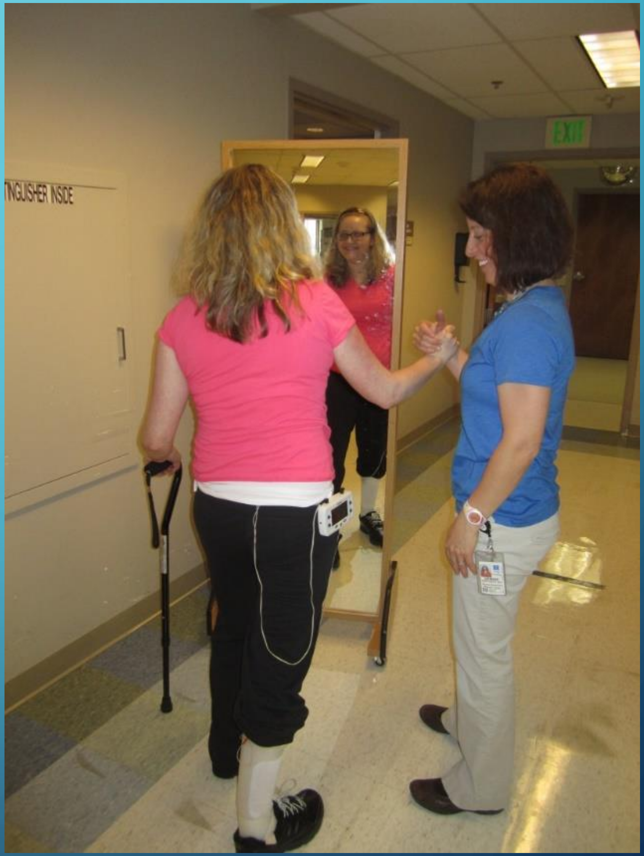
FACILITATING WEIGHT SHIFT

- Case example:
- 22 yo female, s/p motor vehicle accident
- 2 years post injury (outpatient)
- Severe spasticity in bilateral UE and LE

FACILITATING WEIGHT SHIFT



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PARAMETERS USED

- **Placement:** right glutes
- **Pulse Rate:** 35 pps
- **Pulse Width:** 350 microseconds
- **Waveform:** Symmetrical
- **Cycle:** N/A: Single Channel
- **Amplitude:** To motor contraction
- **Timing Characteristics:** Left heel switch

FACILITATING WEIGHT SHIFT

- Case Example
- 45 yo female, s/p CVA with right hemiparesis, severe inattention and proprioceptive loss, 1 yr post injury (outpatient)
- (Photo Included)

PARAMETERS USED

- **Placement:** right triceps and right wrist extensors
- **Pulse Rate:** 35 pps
- **Pulse Width:** 350 microseconds
- **Waveform:** Symmetrical
- **Cycle:** Simultateous
- **Amplitude:** To muscle contraction
- **Timing Characteristics:** Heel switch under left (uninvolved) foot, when pt shifts weight to involved side, estim is triggered to the right triceps and wrist extensors to stabilize lettuce while cutting

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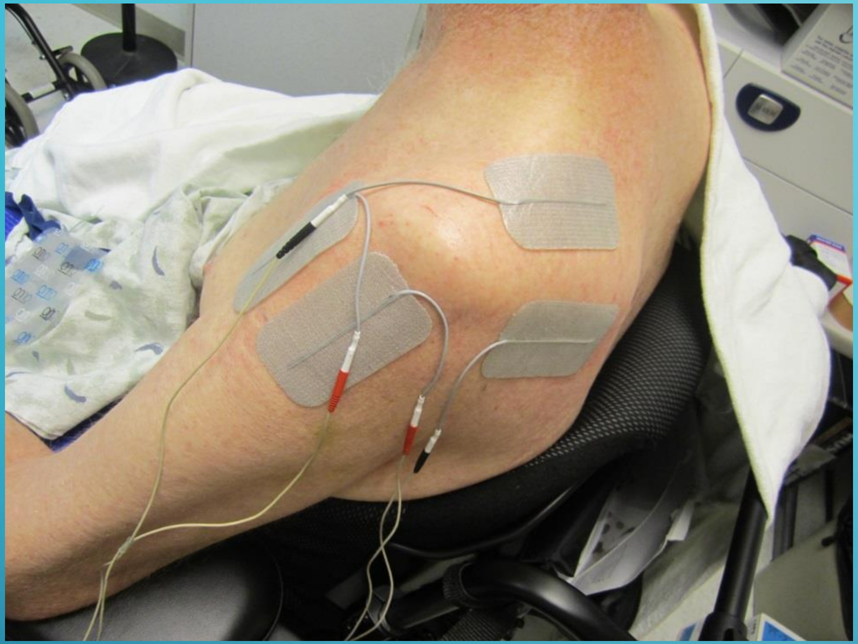
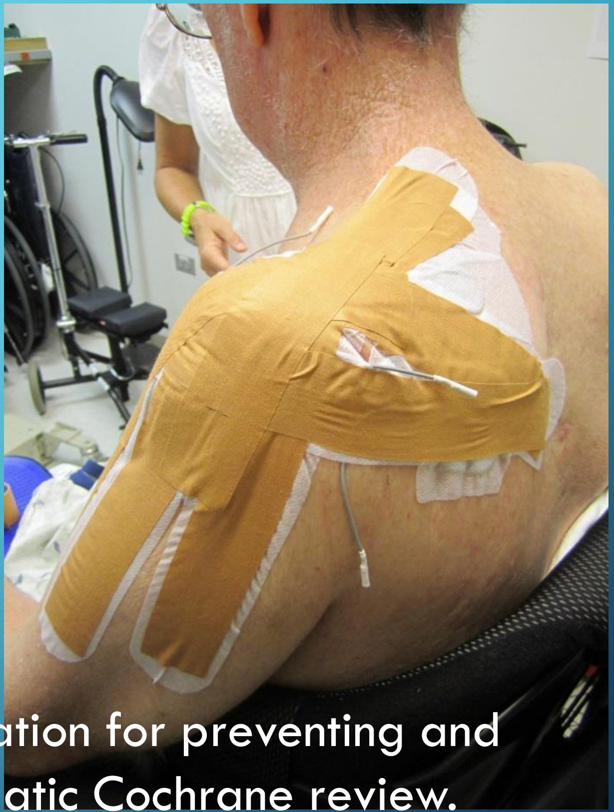
SHOULDER SUBLUXATION





Price, C.I.M.; Pandyan, A.D. Electrical stimulation for preventing and treating post-stroke shoulder pain: a systematic Cochrane review. Clin. Rehab.2001.15(1):5-19.

PARAMETERS USED

- **Placement:** right supraspinatus, anterior deltoid, infraspinatus, and middle deltoid
- **Pulse Rate:** 35 pps
- **Pulse Width:** 350 microseconds
- **Waveform:** Symmetrical
- **Cycle:** Simultaneous
- **Amplitude:** To muscle contraction
- **Timing Characteristics:** Used either 1:1 or 1:2 ratio, example 10 on, 10 off or 10 on, 20 off

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FUNCTIONAL ACTIVITY: WHEELCHAIR PROPULSION

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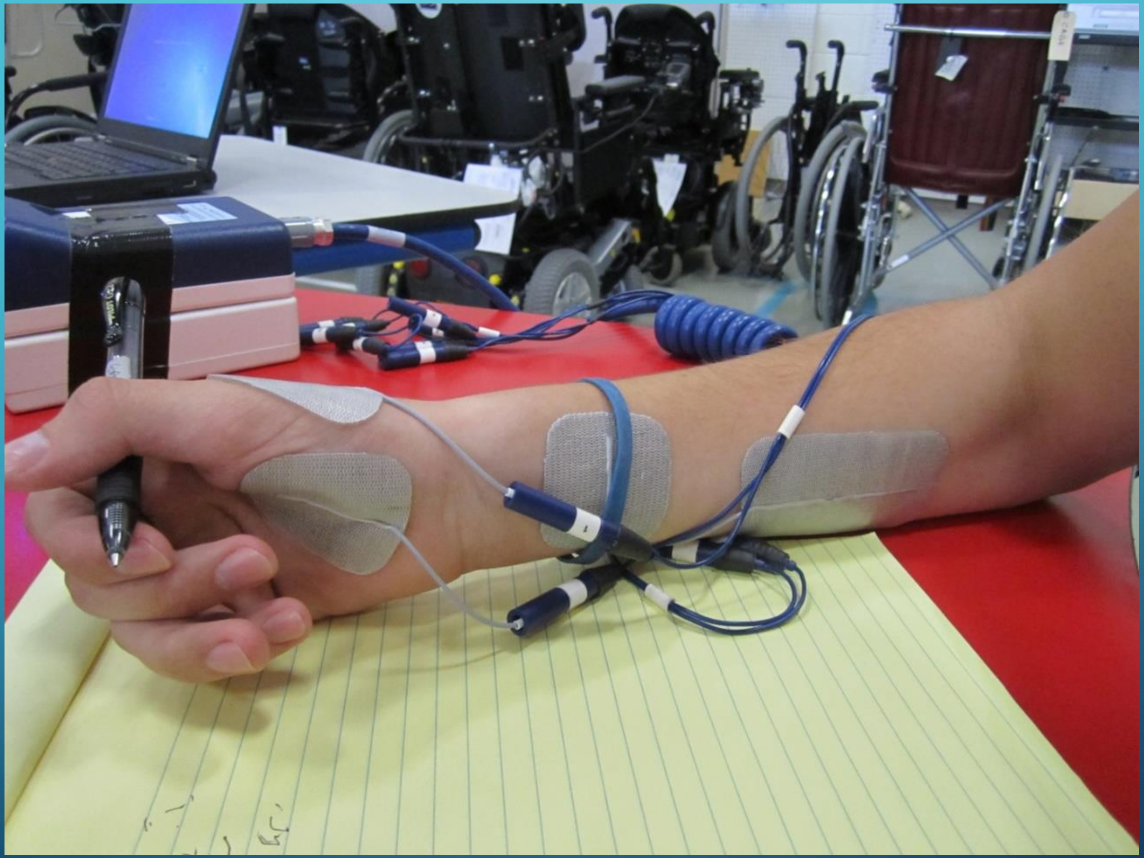
PARAMETERS USED

- **Placement:** left wrist extensors and triceps
- **Pulse Rate:** 50 pps (for comfort)
- **Pulse Width:** 300 microseconds
- **Waveform:** Asymmetrical
- **Cycle:** Simultaneous
- **Amplitude:** To muscle contraction
- **Timing Characteristics:** Hand switch to time with activity

FUNCTIONAL ACTIVITY: HANDWRITING



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LIP CLOSURE FOR SWALLOWING

- 30s male, s/p TBI, 1 yr post injury (outpatient)
- Goal is to close lips while swallowing, stop drooling
- (Photo included)

PARAMETERS USED

- **Placement:** Orbicularis oris
- **Pulse Rate:** *
- **Pulse Width:** *
- **Waveform:** *
- **Cycle:** Simultaneous
- **Amplitude:** To muscle contraction
- **Timing Characteristics:** 12 seconds on, 8 seconds off

***Used parameters in the Vital Stim manual, co-tx with speech therapist to set up home estim unit**

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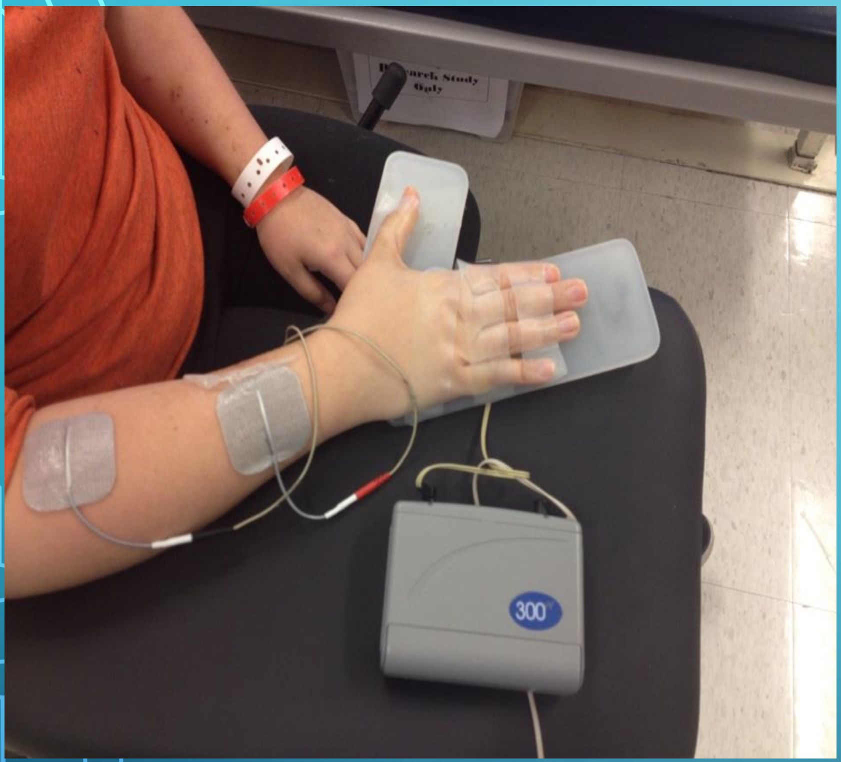
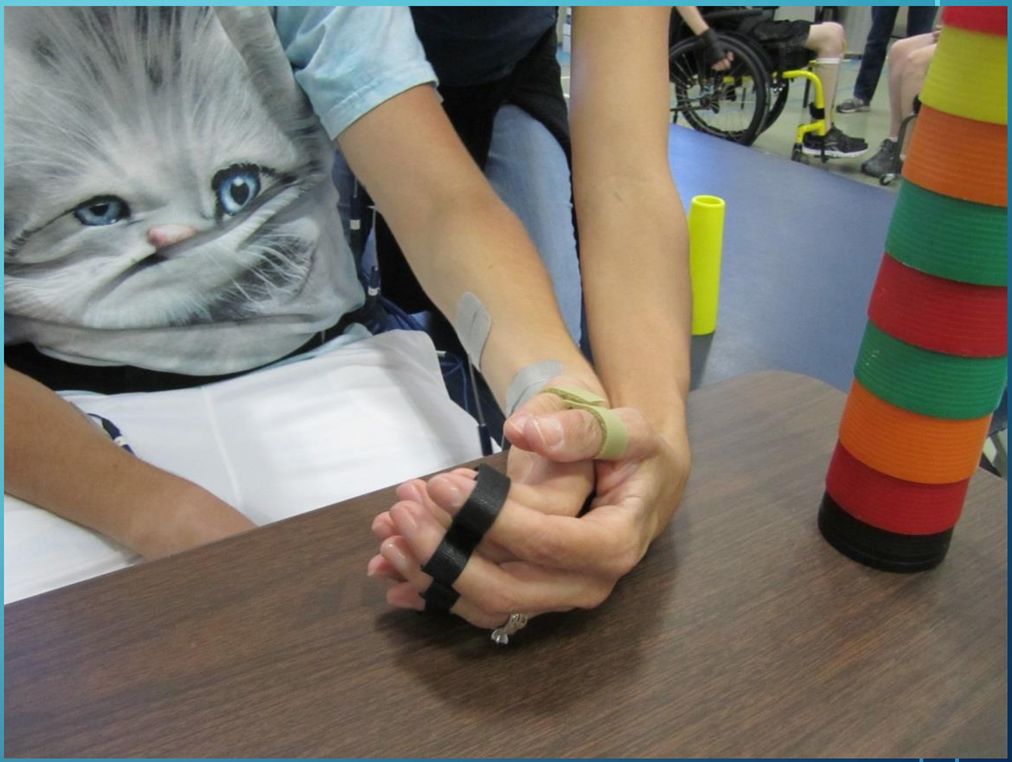
USING OTHER TOOLS TO SUPPLEMENT





Using orthosis to keep fingers straight while working on wrist extension (pts fingers were curling, negatively reinforcing a "tenodesis" effect, which could increase flexor tightness)

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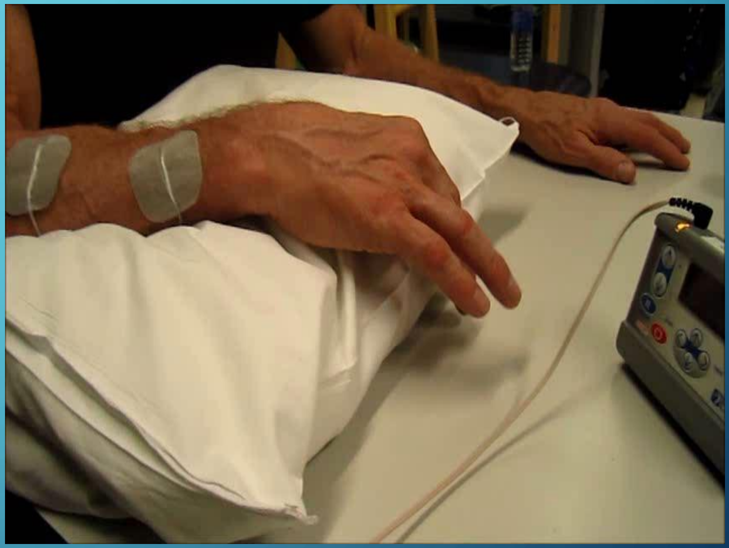
Using buddy strapping to positively reinforce appropriate grasp pattern with e-stim on wrist/finger flexors

OPTIMIZING PRACTICE

Wrist/finger extension practice, note the bending of middle finger



Wrist/finger extension practice, taping to middle finger to assist with full extension

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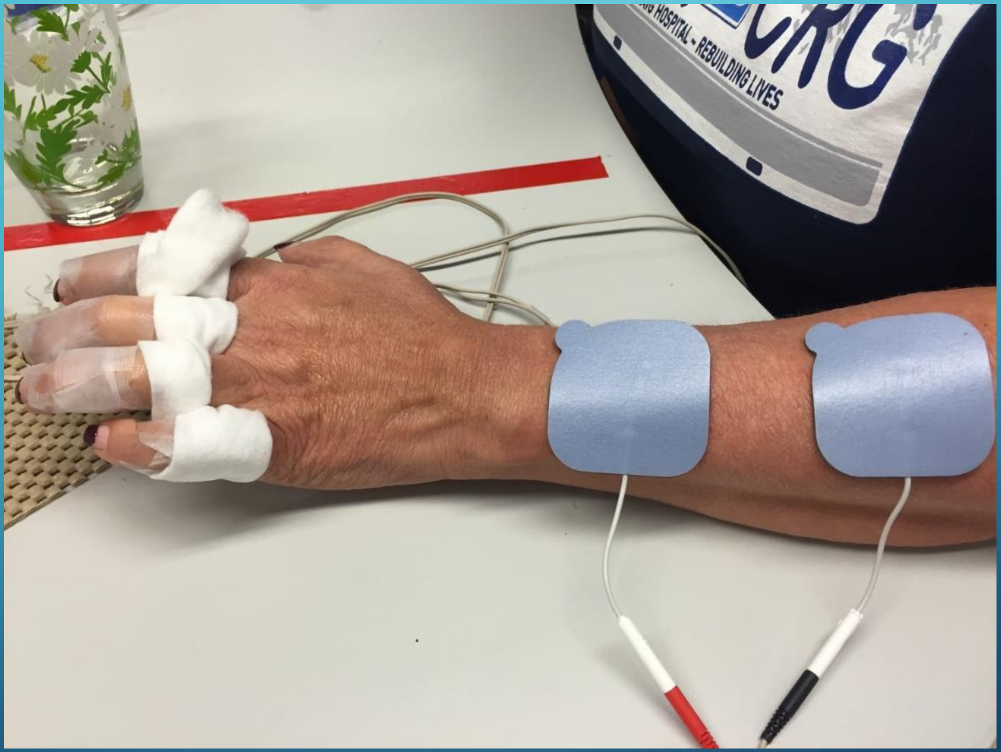
OPTIMIZING PRACTICE



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DISCUSSION

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PRACTICE OPPORTUNITIES

- 3 Different Units to trial today
- Thank you to Regis University for allowing me to bring EMPI units, electrodes, switches
- Zynex – Ewave and electrodes

  Ariane Mullen amullen@zynex.com
- EMSI – FlexMTplus-

  Ryan Belsher - rbelsher@wecontrolpain.com

SENSORY AWARENESS

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SENSORY LEVEL STIMULATION

- **Sensory level stim can improve hand/arm kinematics**
  - Koesler IBM et al. Electrical somatosensory stimulation improves movement kinematics of the affected hand following stroke. *Journal of Neurology, Neurosurgery, and Psychiatry 2008.*
- **Mirror Therapy as Sensory Input with FES**
  - Kim H, Lee G, Song C. Effect of functional electrical stimulation with mirror therapy on UE motor function in post-stroke patients. J Stroke Cerebrovascular Diseases, 2014, 23 (4):655-661.

MIRROR THERAPY EXAMPLE

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Does Sensory Electrical Stimulation During Task-based Exercise Affect Balance and Gait in Chronic Stroke?: Preliminary results of a pilot study

Northwestern University Feinberg School of Medicine
Physical Therapy and Human Movement Science

Almdale K, SPT[1], Bednarczyk M, SPT[1], Clement C, SPT[1], DelMonaco J, SPT[1], Druktenis N, SPT[1], Eid S, SPT[1], Kimalat A, PT, MS, DPT, NCS[2], Lopez-Rosado R, PT, DPT, MSPT, MA[1], Sullivan JE, PT, DHS, MS[1]
[1]Department of Physical Therapy & Human Movement Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL
[2]Schwab Rehabilitation Hospital, Chicago, IL

Schwab Rehabilitation Hospital
A proud member of Sinai Health System

PURPOSE:

This study examined the effect of sensory electrical stimulation (SES) delivered via sock electrode during task-specific leg exercise on balance, balance confidence, walking speed, motor function, sensation and quality of life in individuals with chronic stroke.

METHODS:

Inclusion Criteria: >6 months post stroke, community ambulator, no Botox to involved LE within 6 months prior to participation, no contraindications to SES, no coexisting neurological disorder other than Diabetes

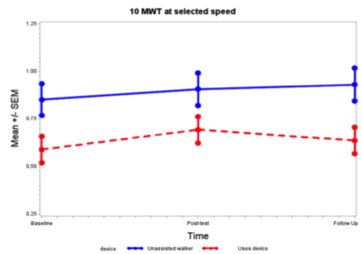
Subjects:
- n = 15 enrolled, 13 completed the study (2 Female; 11 Male)
- Age: 56.5 ± 7.84 years
- Time Since Stroke: 8.21 ± 4.36 years
- Involved Side: 7 Right; 6 Left

Design: Experimental, pre-test, post-test, 3 month follow-up

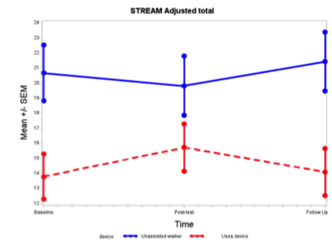
Outcome Measures and Subject Baseline Scores:
- Berg Balance Scale (BBS)
  - $\bar{x}$: 50/56 (32-56/56)
- Activities-Specific Balance Confidence Scale (ABC)
  - $\bar{x}$: 75.4/100% (46.5-95/100)
- Stroke Impact Scale (SIS)
  - Recovery $\bar{x}$: 65%(50-85%)
- Stroke Rehabilitation Assessment of Movement (STREAM) – LE Subscale: $\bar{x}$: 9.67/20 (7-14/20)
- Monofilament Testing
- 10-Meter Walk Test (10MWT) with Self-Selected (SSP) and Fast Pace (FP)
  - $\bar{x}$: SSP: .7 m/sec (.28-1.12); FP: 1.02 m/sec (.46-1.81)

RESULTS:

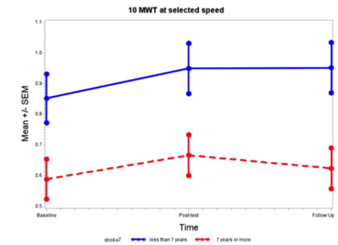
10 MWT- The only significant effect over time was 10MWT m/s under self-selected speed condition (Slow), p=0.030 for total time difference; non-adjusted p-values compared to baseline were 0.011 and 0.064 for post treatment and follow up, respectively (graph 1)
Community ambulators without assistive devices perform better at self-selected gait speed; STREAM scores may also be higher in the same individuals, both at f/u (graphs 1 & 2)
Survivors of more recent stroke onset (less chronic) significantly improved their self selected gait speed (graph 3)



Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
time	2	22	3.61	0.0442
device	1	13	6.12	0.0280
time*device	2	22	0.85	0.4403



Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
time	2	22	0.16	0.8524
device	1	13	8.34	0.0127
time*device	2	22	1.24	0.3078



Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
time	2	22	4.19	0.0286
stroke7	1	13	8.88	0.0106
time*stroke7	2	22	0.54	0.5917

*Fig 1. 300PV Stimulator, Empi Inc, St. Paul, MN, Silver-Thera Sock electrode, Prizm Medical, Oakwood, GA

Intervention:

- 6 Week Intervention Period:
  - Individualized task-based leg exercise with SES
  - 30 minutes twice daily for 5 days
  - Subjects returned for a minimum of 2 visits to monitor progress
- Stimulator* Parameters: Sensory threshold amplitude, 50Hz frequency, 1:2 duty cycle, 250μsec phase duration, 2s ramp/fall

LIMITATIONS:

- Pilot study - small subject number limits generalizability
- No control group for comparison
- Largely home-based intervention - subject reported compliance
- Potential ceiling effect on balance outcome measures due to high baseline scores

CONCLUSIONS:

The use of home-based SES via sock electrode combined with leg exercises may improve gait speed in chronic stroke. Subject age and baseline sensory capacity may affect outcome.

FACILITATING WEIGHT SHIFT WHILE WALKING

- Case example:
- 26 yo male, s/p brain tumor rupture, 6 mos post injury (outpatient)
- L hemiparesis with severe loss of sensation/proprioception

FACILITATING WEIGHT SHIFT WHILE WALKING

PARAMETERS USED

- **Placement:** left tricep, left lower trapezius
- **Pulse Rate:** 35 pps
- **Pulse Width:** 350 microseconds
- **Waveform:** Asymmetrical
- **Cycle:** Simultaneous
- **Amplitude:** To motor contraction
- **Timing Characteristics:** 20 seconds on, 2 seconds off with 2 second ramp time

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SENSORY AWARENESS

- Case example:
  - 33 yo male s/p TBI, 1 year post injury, at Craig for 1 week re-evaluation, resolving right hemiparesis
  - Has full active range of motion and can reach in all planes against gravity, abnormal proprioception in right hand
  - Goal: increase right UE coordination

SENSORY AWARENESS

- Videos Included

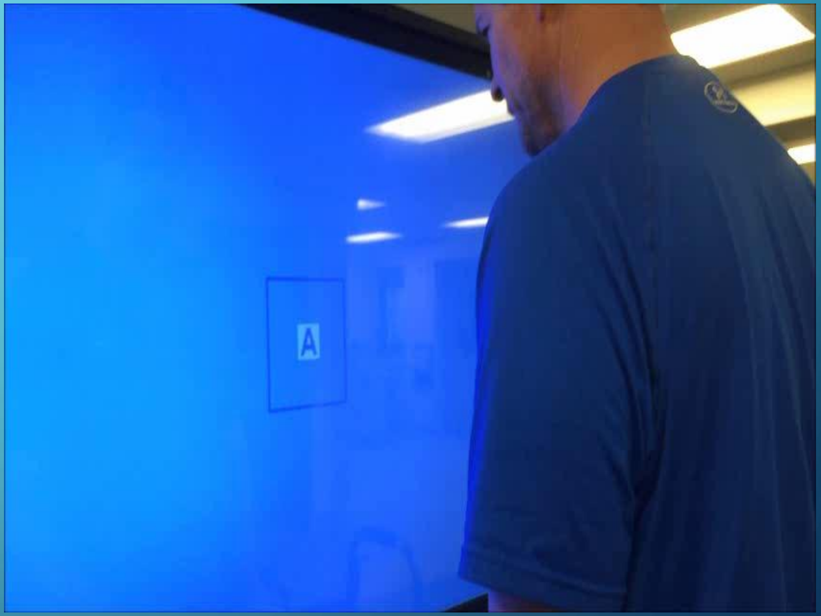
PARAMETERS USED

- **Placement:** Channel 1: Posterior forearm and back of hand, Channel 2: Anterior forearm
- **Pulse Rate:** 65 pps
- **Pulse Width:** 250 microseconds
- **Waveform:** asymmetrical
- **Cycle:** simultaneous
- **Amplitude:** sensory level only
- **Timing Characteristics:** 20 seconds on, 2 seconds off, with 2 second ramp

SENSORY AWARENESS

- Case example:
  - 48 yo male s/p spinal cord infarct, outpatient 4 months post onset resolving left hemiparesis
  - Has full passive shoulder range of motion and better distal movements than proximal.
  - absent light touch and proprioception in left elbow and hand or left LE.

SENSORY AWARENESS



No electrical stimulation

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With sensory electrical stimulation

SENSORY AWARENESS

No UE electrical stimulation

With UE sensory electrical stimulation

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SENSORY AWARENESS

- Video Included

PARAMETERS USED

- **Placement:** left forearm (2 channels) OR left wrist extensors and left scapula stabilizers
- **Pulse Rate:** 50 pps
- **Pulse Width:** 300 microseconds
- **Waveform:** symmetrical
- **Cycle:** simultaneous
- **Amplitude:** sensory level only, pt unable to feel so took it to motor and went right below motor threshold
- **Timing Characteristics:** Continuous for the task

COMPARING SENSORY PARAMETERS

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DISCUSSION

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TRANSLATION INTO YOUR PRACTICE

Hands on Practice - Switch units

Trial wrist extensor

Tibialis anterior

TRANSLATION INTO YOUR PRACTICE

- Low cost options for home and clinic use
- Patient and family independent in use to maximize neuroplasticity
- Remember to integrate neuroplasticity principles and appropriate preparatory methods

QUESTIONS/DISCUSSION

THANK YOU!

- dodell001@regis.edu

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