FES CYCLING:

AN EVIDENCED BASED APPROACH TO UTILIZATION OF FUNCTIONAL ELECTRICAL STIMULATION BIKE IN THE INPATIENT REHAB SETTING

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Outline

- Objectives
- FES Overview
- FES Bike Overview
- Evidence for SCI
- Evidence for Brain Injury (TBI or Stroke)
- Evidence for Neuroprosthetic Use
- Questions

Objectives

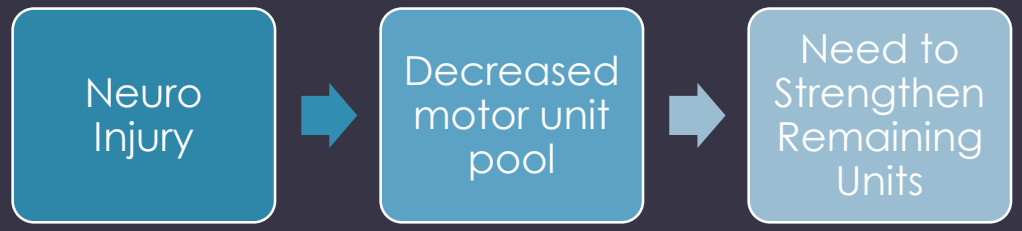
1. *Learners will become educated about Functional Electrical Stimulation, its general benefits, and parameters that can be altered for patient comfort/appropriate muscle contraction.*
2. *Learners will become educated about FES cycling, specifically the parameters and evidence supporting use in patient populations of SCI, Stroke, and TBI.*
3. *Learners will see a FES bike setup and patient demonstration on specific bike they will have access to in order to foster familiarity with device management.*
4. *Learners will be interested in taking the offered FES bike training at Carolinas Rehab so that the FES bike in the outpatient clinic bike can be utilized in their inpatient therapeutic interventions.*

FES[1]

- FES vs NMES
- Use of neuromuscular electrical stimulation to aid in function
- Used for numerous neurological diagnoses/conditions

Possible Mechanisms[1]

Peripheral



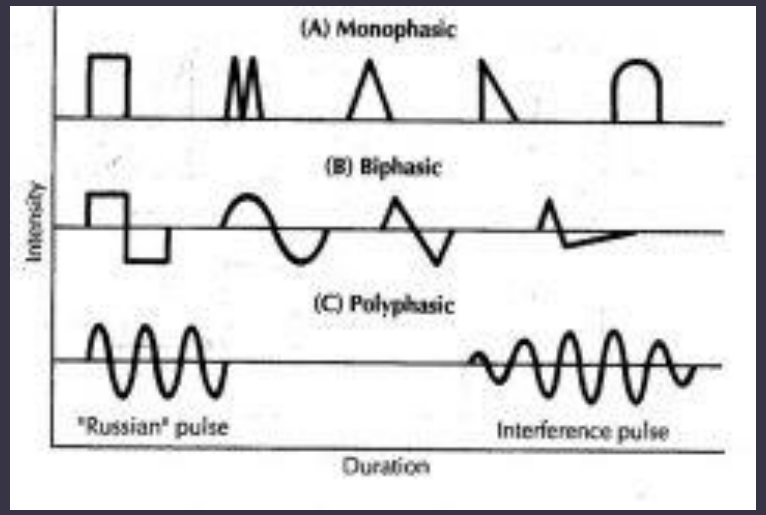
- Improve flexibility/ROM → voluntary muscle efforts more effective
- Decrease spasticity at interneuron level → improved function

Central

- Cortical Reorganization
- Activates Motor & Sensory fibers → activity in both directions
  - Antidromic firing alters anterior horn cells in SC
  - Anterior horn cells = Location motor units

Parameters[2]

- General:
  - Current Controlled
  - Rectangular
  - Alternating monophasic current

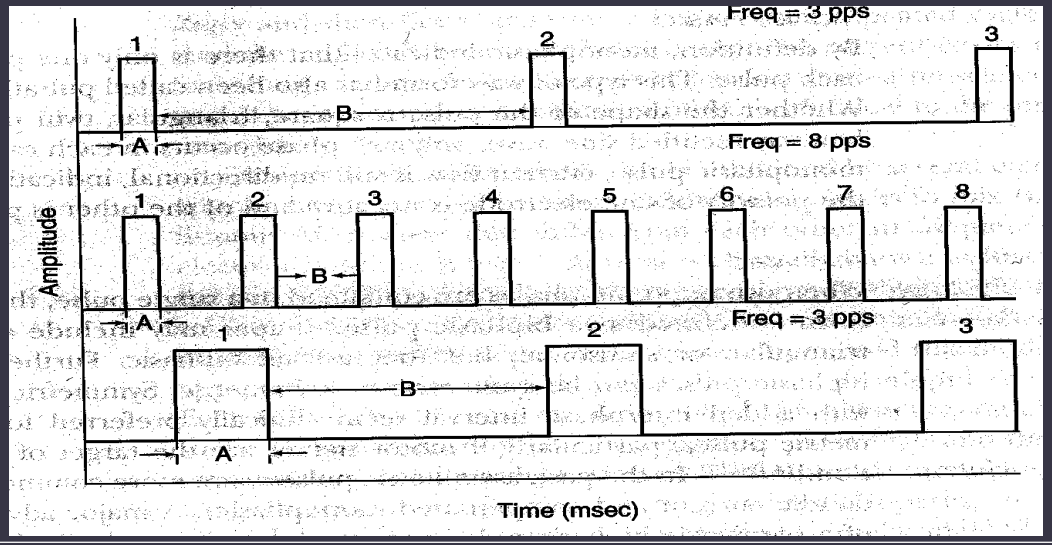


- Pulse Width:
  - Time current is "On"
  - 50-500 µsec
  - Increase pulse width → Increase depth of penetration → #/type N fiber excitation
  - Narrow: recruit greater proportion motor vs sensory neurons & decrease skin impedance
  - Wide pulse width + high freq + low amplitude : evoke H reflex

http://www.cram.com/flashcards/electrical-stimulation-5400262

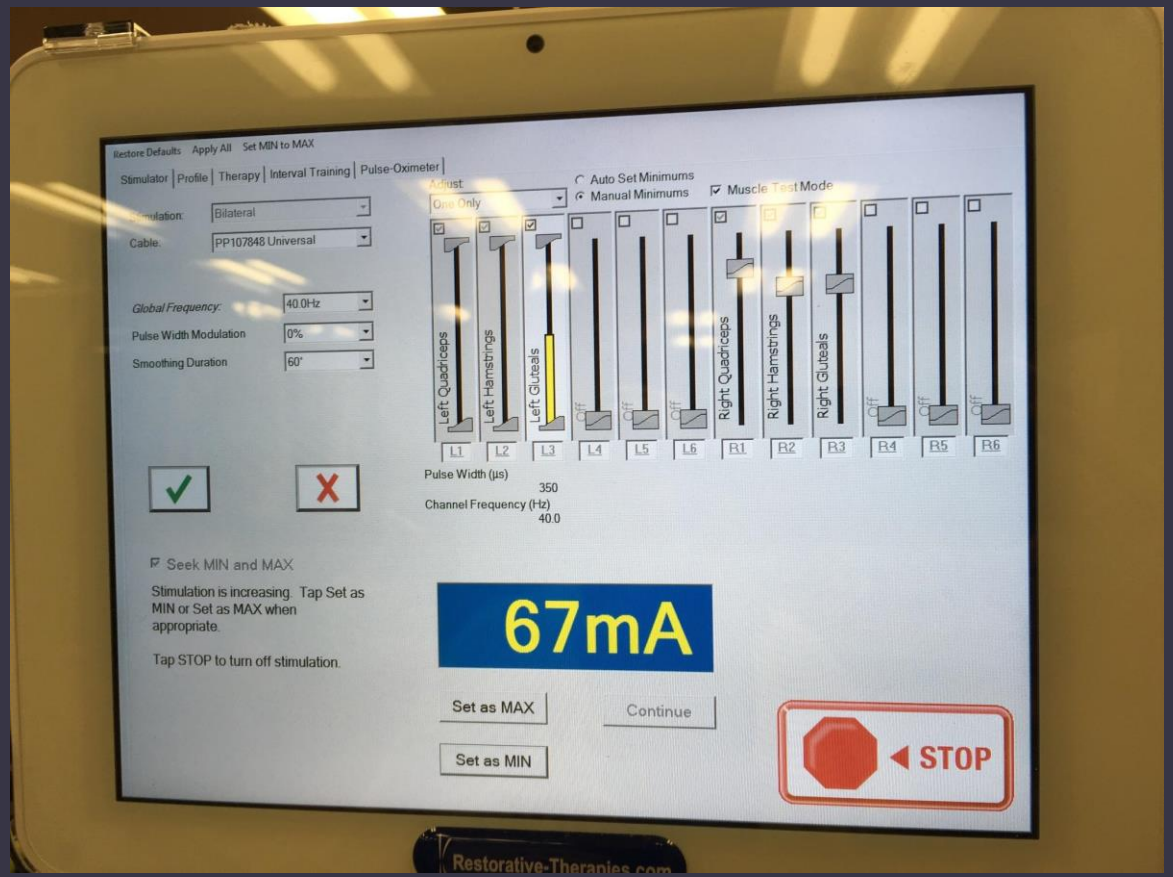
Parameters[2]

- Frequency:
  - Times per second stimulation pulses
  - 10 Hz – 100 Hz available
  - Common pre-set: 33Hz
  - Greater Frequency → More rapidly muscle fatigues



- Amplitude (Intensity):
  - Current strength
    - 10-40 mA – produces a muscle twitch
    - 60-80 mA - highest stimulation able bodied muscles can tolerate (20-40 mA in the UEs)
    - 140 mA – highest stimulation used in FES without skin burn

FES Bike^2


Restore Defaults
Apply All
Set MIN to MAX
Stimulator
Profile
Therapy
Interval Training
Pulse-Oximeter
Stimulation:
Bilateral
Cable:
PP107848 Universal
Global Frequency:
40.0Hz
Pulse Width Modulation
0%
Smoothing Duration
60"
Adjust
One Only
Auto Set Minimums
Manual Minimums
Muscle Test Mode
Left Quadriceps
Left Hamstrings
Left Gluteals
Right Quadriceps
Right Hamstrings
Right Gluteals
L1
L2
L3
L4
L5
L6
R1
R2
R3
R4
R5
R6
Pulse Width (µs)
350
Channel Frequency (Hz)
40.0
Seek MIN and MAX
Stimulation is increasing. Tap Set as MIN or Set as MAX when appropriate.
Tap STOP to turn off stimulation.
67mA
Set as MAX
Continue
Set as MIN
STOP
Restorative-Therapies.com


Resistance
(Nm)
0.50
Power
(W)
0.0
SPO2%
--
CONFIGURE
Passive therapy
Target Speed
(RPM)
40
40
Speed
(RPM)
Stimulation
Off
COOL DOWN
STOP
miles
01.85
0:44:22
Restorative-Therapies.com

FES Bike^2

- Video

Demonstration

(I had to remove video to upload ppt onto Sakai)

FES Bike^2

- Specific Cycle Parameters:
  - Power (W) = speed (rpms) x resistance (Nm)
  - MET (metabolic equivalent task) = Kcall per hour/weight (kg)
- Treatment Planning
- Treatment Rationale

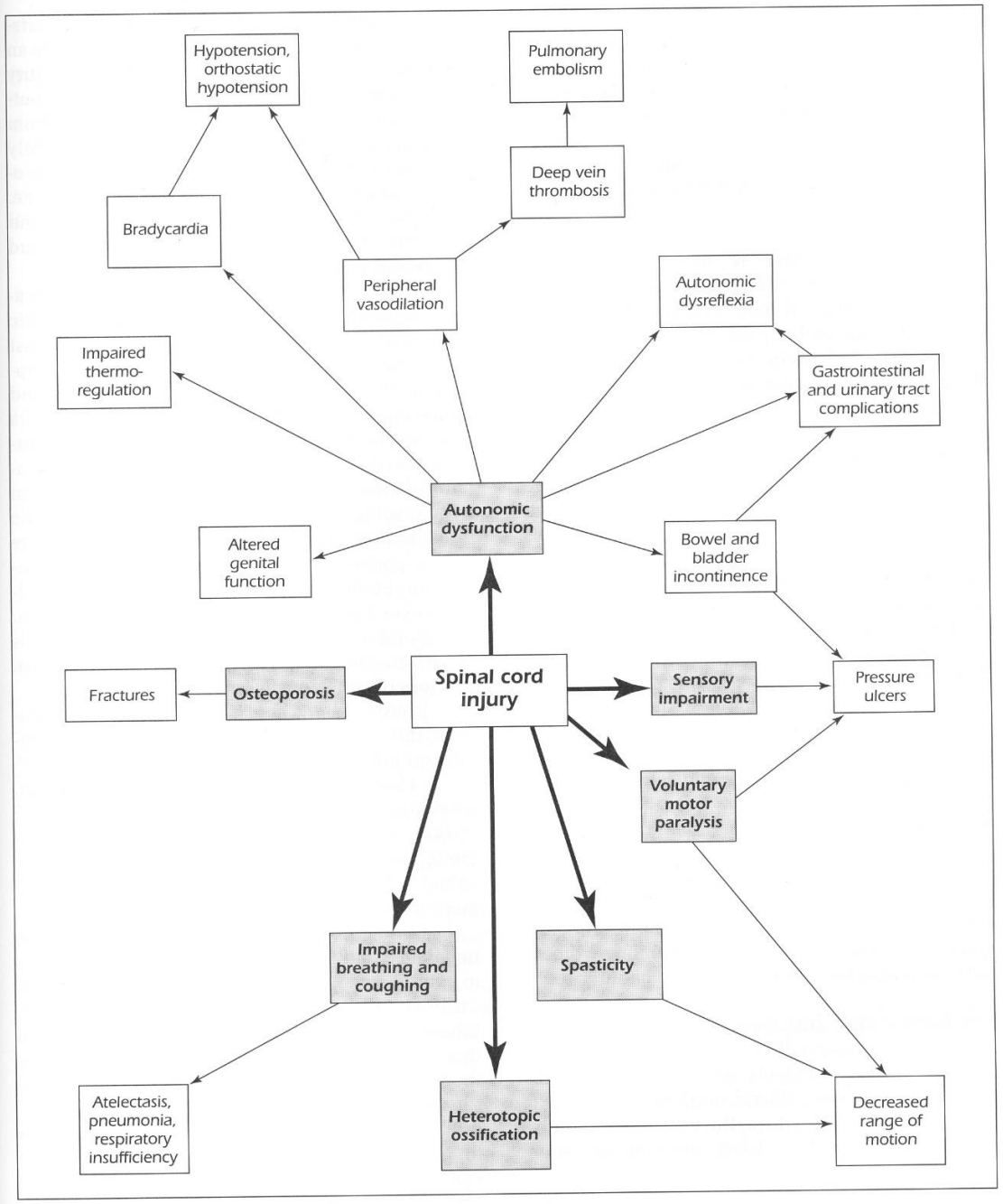


Figure 2–27. Schematic representation of the physical effects of spinal cord injury.

Evidence - SCI

Complications

Evidence – Subacute SCI[3]

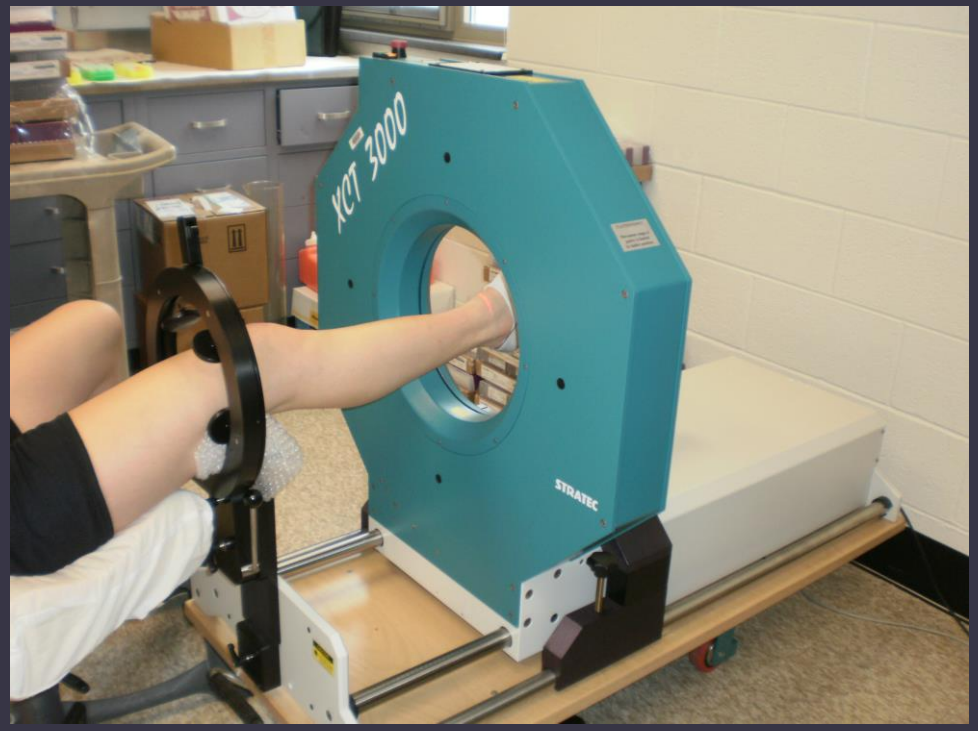
- Ralston et al, 2013
  - **Population:**
    - N = 14, > 6 months post SCI
    - ASIA A or B, C4-T10
  - **Parameters:**
    - Protocol: 4x/wk, 2 wks, 30-45 mins
    - Pads: Quads, hams, gluts
    - Freq: 33Hz
    - Wavelength: 350
    - Amplitude: 140mA
  - **Findings**:
    - No effect on urine output, lower limb swelling, spasticity
    - Perceived improvement of swelling, spasticity, circulation, urine output, bowel activity, well being

Evidence – Chronic SCI[4]

- Griffin et al, 2008
  - **Population:**
    - N = 18, Tetra or paraplegia , Average 11 years post injury
  - **Parameters:**
    - Protocol: 2-3x/wk, 10 wks, 30 mins limit
    - Pads: Quads, hams, gluts
    - Passive warmup with active cycle
    - Freq: 50Hz
    - Amplitude: not to exceed 140mA
    - Target Cadence: 49rpm
  - **Findings**:
    - Improved Power/Work Capacity, total body mass & lean muscle mass, ASIA LE & motor/sensory component scores, glucose & insulin levels, & inflammatory tags
    - No significant difference in adipose or bone tissue

Evidence – Chronic SCI[5]

- Frotzler et al, 2008
  - **Population:**
    - N = 11, Average 3 yrs post injury, ASIA A, T3-T12
  - **Parameters:**
    - Protocol:
      - Muscle conditioning
      - FES: up to 1 hr (10-60 mins), 3-4x/wk, 3 months
      - FES: 1 hr, 5x/wk, 9 months
      - Compliance: 79.3%
    - Pads: Quads, hams, gluts
    - Passive warmup with active cycle
    - Freq: 50Hz
    - Pulse Width: up to 500 µsec
    - Target Cadence: 45-50 rpm
  - **Findings**:
    - Improved bony density changes in femur
    - No bony density changes in tibia
    - Increased thigh muscle CSA, Decreased lower leg fat CSA



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Evidence – Chronic SCI[6]

- Sadowsky et al, 2013
  - **Population:**
    - N = 45 (20 "standard tx"; 25 FES cycle) Average 7.2 yrs post traumatic injury
  - **Parameters:**
    - Protocol: 3x/wk, 45-60 mins
    - Pads: Quads, hams, gluts
    - Freq: 100Hz
    - Pulse Width: 500 µsec
    - Amplitude: Max 140mA
    - Cadence: 50 rpm
  - **Findings**:
    - Improved motor function, motor score, pin prick, light touch, CMSS (composite motor-sensory score of ASIA)
    - Improved strength FES trained muscles and SF-36 scores
    - Decreased spasticity and need for anti-spastic medications
    - No improvement in ASIA grades, total thigh volume, or bone density

Evidence – Chronic SCI[7]

- Hasnan et al, 2012
  - **Population:**
    - N = 9 male, C6-T12 ASIA A, B, C; TSCI mean 6 year ago
  - **Parameters:**
    - Protocol: 8 sessions of testing for 7 days, all performed on separate days
    - Pads: Quads, hams, gluts
    - Freq: 35Hz
    - Pulse Width: 300 µsec
    - Amplitude: Max 140mA
  - **Findings**:
    - Better to perform ACE + FES-bike vs ACE or FES bike alone for submaximal CV responses

Evidence – Chronic SCI[8]

- Gorgery et al, 2014
  - **Population:**
    - N = 10, C5-T10 ASIA A or B; TSCI > 1 yr
  - **Parameters:**
    - Protocol: passive 5 min warmup → active cycle → 3 min passive cooldown → 5 min recovery
    - Pads: Quads, hams, gluts
    - Freq: 33.3 Hz
    - Resistance: 1Nm
    - Pulse Width: 200, 350, and 500 µsec
    - Cadence: 40-45 rpm
  - **Findings**:
    - Despite pulse duration administered, FES cycle caused DOM fatigue that persisted 48 and 72 hrs post cycling
    - P350 greatest effect on EE and VO2 during recovery
    - No significant difference with pulse duration on cycle time to fatigue
    - 6 out of 10 participants experienced autonomic dysreflexia at P500 vs 3 with other pulse widths

Take Home Points

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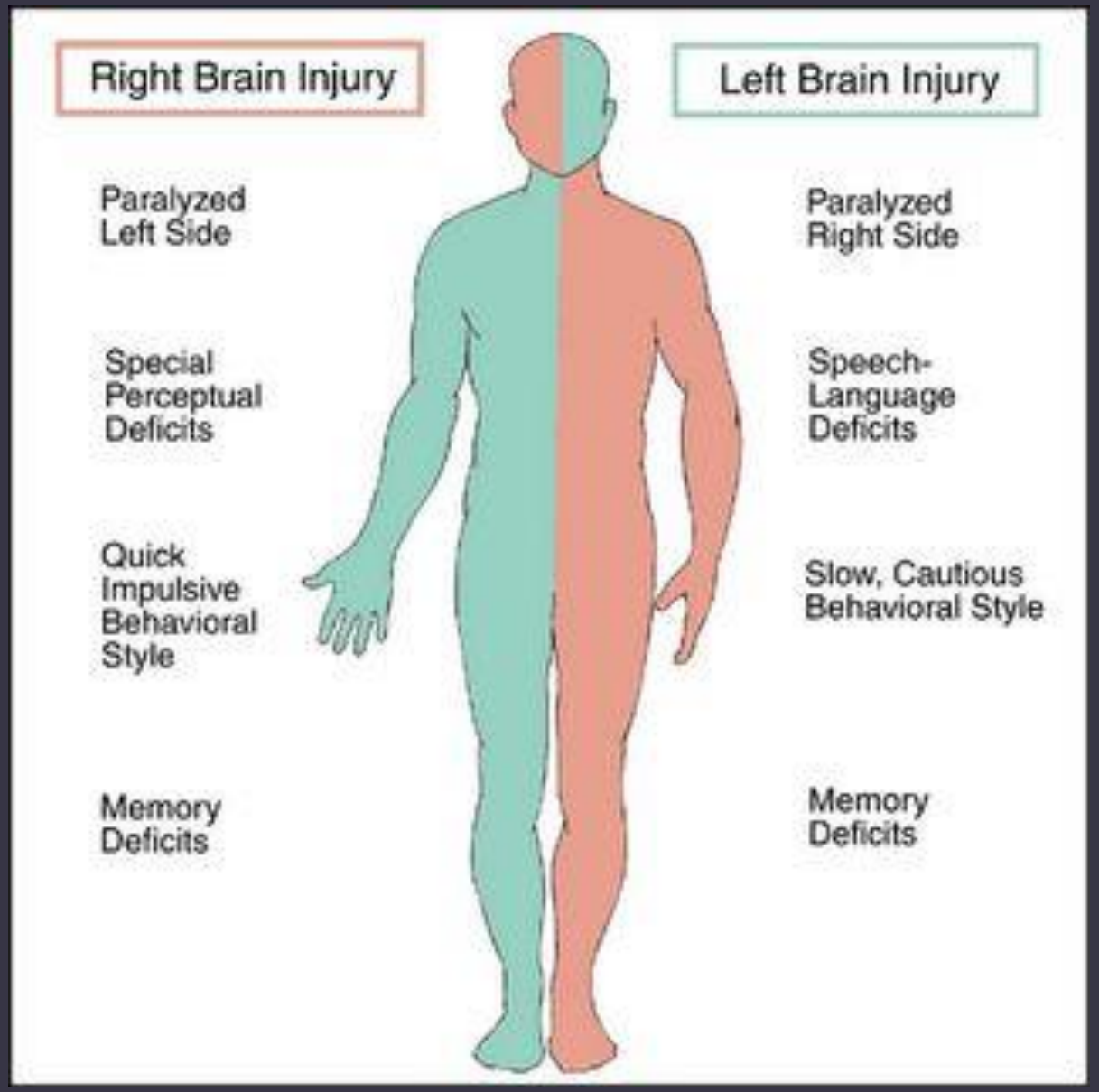
- Different protocols and parameters in the evidence
- ASIA A, B, C – C4-T12 levels
- FES cycle caused DOM fatigue that persisted 48 and 72 hrs post cycling
- Greater pulse duration → more pts experience autonomic dysreflexia
- Arm crank ergometer + FES Cycle = better for submaximal CV responses
- Perceived improvement: swelling, spasticity, circulation, urine output, bowel activity, wellbeing
- Improved:
  - Power/Work Capacity, total body mass & lean muscle mass, ASIA LE & motor/sensory component scores, glucose & insulin levels, & inflammatory tags
  - Motor function, motor score, pin prick, light touch, CMSS
- Bone density? Spasticity?



https://www.google.com/search?q=stroke+side+effects+on+function&espv=2&biw=1280&bih=595&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjFnJ_2uvbMAhXB4SYKHVIzCIMQ_AUIBigB#imgrc=4C0Td_qiVrZeTM%3A

Evidence – Brain Injury

Complications

Evidence – Brain Injury[9]

- Lee et al, 2013
  - **Population:**
    - N = 16 (8 FES group; 8 control ergometer), onset primary ischemic or hemorrhagic stroke within 6 months resulting in mild/moderate hemiparesis
  - **Parameters:**
    - Protocol: 5x/wk, 4 wks for 30 mins
    - Pads: ***Paretic*** Quads, hams, gluts, TA
    - Freq: 60 Hz
    - Pulse Width: 300 µsec
    - Amplitude: max 100mA (allowed on device)
    - Cadence: 30 rpm
    - Duty Cycle: 1:1
  - **Findings**:
    - Improved exercise capacity and functional ability (6MWT, BERG, Modified Barthel Index, $V0_{2peak,}$ MET and AT)
    - Control group: No improvement in exercise capacity; Improvements seen in BERG and Modified Barthel Index

Evidence – Brain Injury[10]

- Ambrosini et al, 2010
  - **Population:**
    - N = 30 (15 FES cycling; 15 placebo FES cycling), inpatient Stroke or TBI resulting in hemiparesis
  - **Parameters:**
    - Protocol: 5x/wk, 4 wks for 25 mins
    - Pads: ***Bilat*** Quads, hams, gluts, TA
    - Freq: 60 Hz
    - Pulse Width: 300 µsec
    - Cadence: 30 rpm
    - Duty Cycle: 1:1
  - **Findings**:
    - Improved Motricity Index and gait speed after treatment and at f/u
      - Main Effects Across Time: TCT, UMCT, and W_{pl}
    - No significant improvement after treatment in placebo group; Significance found at f/u for MI and gait speed

Evidence – Brain Injury[11]

- Bauer et al, 2015
  - **Population:**
    - N = 40 (20 active leg cycle w/ FES; 20 active leg cycle w/no FES); stroke with severe hemiparesis
  - **Parameters:**
    - Protocol: 3x/wk, 4 wks for 20 mins; 1 min warmup active cycle → 19 mins FES active cycle
      - Intervention provided as group therapy
    - Pads: ***Unilat*** Quads, hams
    - Freq: 25 Hz
    - Pulse Width: 250 µsec
    - Cadence: self selected-min: 20 rpm
    - Duty Cycle: 1:1
  - **Findings**:
    - 12 sessions cycling improved postural control and walking ability
      - FES cycle improved more than non FES group
      - FAC & POMA pre to post intervention significance (Not MI)
      - No significant changes in tone and force between intervention groups
      - 2x patients became self-ambulatory (improvement of FAC ≥ 3)

Take Home Points

https://www.google.com/search?q=check+mark+symbol&espv=2&biw=1280&bih=595&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjohpO-vvbMAhVD0oMKHUJACJIQ_AUIBigB#imgrc=LqD2zW5ShvUxyM%3A

- Assisted ergometer training → improvement in BERG and Modified Barthel Index
  - With FES stimulation → improvement in 6MWT, BERG, Modified Barthel Index, $V0_{2peak,}$ MET and AT
- Increased power paretic limb and gait speed after treatment and at 3-5 month f/u
- 12 sessions cycling improved postural control and walking ability

Evidence – Neuroprosthetics[12,13]

- **Lairamore et al, 2014**
  - Inpatient rehab: TBI or stroke causing hemiparesis and subsequent foot drop
  - Bioness during gait training to TA and peroneal; 45 mins, 3x/wk during inpatient stay
  - No significant difference with FES vs control for improvements in gait or TA activity
  - Clinical implications: use larger dose of FES or multi-channel

- **Page et al, 2016**
  - Chronic, moderate, stable UE impairment following chronic stroke
  - FES 3x/wk for 120 mins with estim neuroprosthesis to UE over 8 weeks
    - (60 min supervised clinic setting; 60 min at home)
  - Behavioral Supports: behavior contract, weekly reviews of UE use
  - Fugal-meyer impairment scale, box and block test, and motor activity log improved pre to post intervention and pre-intervention to 3 month f/u

Conclusions

- FES cycling has been shown to have positive effects on SCI and brain injuries
- Need for more research/evidence
- You have access to an FES cycle in Outpatient PT – Try it out!

Questions

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Survey Monkey

https://www.google.com/search?q=monkey+pic&espv=2&biw=1280&bih=595&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiC9IunxYXNAhVBcz4KHQ99CIcQ_AUIBigB#tbm=isch&q=happy+monkey+pic&imgrc=rUuFkbfBzD9SJM%3A

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