High Intensity Locomotor Training Post Stroke

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Outline

Block 1:
• Traditional approaches
• Neuroplasticity concepts
• Motor learning concepts

Block 2:
• Propose a new direction
• High intensity locomotor training
• Supporting evidence

Block 3:
• Outcome measures
• Moving forward
• Case studies
• Questions

Walking After Stroke

• #1 goal of stroke rehab
• 85% regain some ability to walk
• But weakness, imbalance, and poor activity tolerance limit walking function
• Increased sedentary behavior reinforces walking limitations

Eng 2007

Walking After Stroke

• Walking endurance related to cardiovascular fitness and community reintegration
• Improving walking function likely has protective effects against secondary complications (osteoporosis, heart disease, etc.)

Eng 2007

Perhaps surprisingly...

• Walking not significantly impacted by
  – Quad or PF spasticity
  – LE sensory deficits

Eng 2007

What does matter?

• Strength
• Motor control
• Balance
• Cardiovascular fitness & walking endurance
• Walking speed

Eng 2007
What have we done traditionally?

Neurofacilitory Methods
- Focus on attempting to retrain motor control by facilitating desired and inhibiting less desired movement patterns
- Lots of verbal and manual feedback
- Emphasis on “normal” gait patterns, avoiding compensatory strategies

Neurofacilitory Methods
- Bobath/NDT
  - Normal automatic postural reflex mechanism is foundation for normal motion patterns
  - Work to limit stereotyped synergy patterns
  - Widely used but limited evidence on gait
- Walking patterns not “more normal” after outpatient NDT
- Equivalent or inferior to other training approaches

Neurofacilitory Methods
- Bobath
  - Avoid strength exercises
  - Concern of worsening spasticity
- Not supported by research
  - Neither strength training nor moderate-high aerobic exercise worsens spasticity after stroke

Neurofacilitory Methods
- Brunnstrom
  - Use of resistance, associated reactions, and primitive postural reactions to facilitate synergistic movements and return of muscle tone
  - Little evidence to support for poststroke gait training

Neurofacilitory Methods
- Proprioceptive Neuromuscular Facilitation (PNF)
  - Use resistance (not too much) to facilitate movement
  - Has not been shown to improve walking performance after stroke

References:
- Kollen 2009
- Eng 2007
- Bobath 1977
- Bogey 2007
- Eng 2007
- Holleran 2014
- Bogey 2007
Traditional Approaches

• Neurofacilitation approaches still widely presented in DPT curriculums for stroke rehab
• But they don’t appear to have a substantial impact on walking recovery
• Can we do better?

What’s the Problem?

• Traditional approaches appear to conflict with modern concepts of neuroplasticity, motor learning, and exercise physiology

So how can we apply neuroplasticity?

Neuroplasticity

• Defined: the adaptive capacity of the CNS
• Neurons have the ability to alter their structure and function in response to internal and external demands
• “The mechanism by which the damaged brain relearns lost behaviors in response to rehabilitation”

10 Neuroplasticity Principles

#1: Use It or Lose It

• Neural circuits not actively engaged in task performance for an extended period of time begin to degrade
  – Cortex real estate gets reallocated
• Potential downside of neuroplasticity
Learned Non-Use

#2: **Use It and Improve It**
- Extended training can induce plasticity in specific brain regions with resulting improved performance
  - Increased
  - Dendritic growth
  - Synaptogenesis
  - Synaptic responses
  - Cortical reorganization

Kleim 2008

#3: **Specificity**
- The nature of the training experience dictates the nature of plasticity
  - Training in dysphagia does not automatically carry over to voice production
  - Impact on gait training?
  - Does part task training work for gait retraining?
  - Does static balance training transfer to walking?

Kleim 2008

#4: **Repetition Matters**
- Induction of plasticity requires sufficient repetition
- A sufficient level of rehab is likely required to obtain a level of improvement and brain reorganization sufficient to maintain and progress
- Do we provide sufficient practice for our patients?

Kleim 2008

#5: **Intensity Matters**
- Induction of plasticity requires sufficient intensity
  - Repetition and effort
  - Are we sufficiently challenging our patients?
#6: **Time Matters**
- Different forms of plasticity occur at different times during training
  - Gene expression \(\rightarrow\) synaptogenesis \(\rightarrow\) functional change
- Generally, the earlier therapy is initiated, the more effective

#7: **Salience Matters**
- The training experience must be sufficiently meaningful to induce plasticity
- Cholinergic neural system appears to mediate saliency
  - ACh agonist drugs promote cortical plasticity
- Motivation to promote engagement in training
  - Emotions modulate memory consolidation
- Patient’s goal is to walk - *does what we do seem meaningful to them?*

#8: **Age Matters**
- Training-induced plasticity occurs more readily in younger brains
- Normal aging associated with widespread neuronal and synaptic atrophy
- Delayed re-sprouting of new connections as we age

#9: **Transference**
- Plasticity in response to one training experience can enhance the acquisition of similar behaviors
- Electrical stim of the pharynx enlarges its cortical representation and improves swallowing function post stroke
- Walking, stairs, transfers
- *Is there a single task we can focus our training on that can result in improvements in other domains?*

#10: **Interference**
- Plasticity in response to one experience can interfere with the acquisition of others
- Development of compensatory strategies
  - Easier, end up being used more than what is taught in therapy
- Learned non-use in UE and LE with transfers and gait
- What do our HEP’s look like?

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**What about motor learning?**
Motor Learning

- Defined: process of improving a motor task
- Guided by
  - Instruction
  - Reward
  - Error

External Focus of Attention

- Best for patient to place attention on task results in environment, rather than internally on body movements
  - Promotes automaticity of movement
    - More effective
    - More efficient (reduced muscle activity, HR, O2 consumption)
  - Internal actually slows and inhibits automaticity

Wulf 2010
Wulf 2016

Focus of Attention in the Clinic

- “Feel your weight shift onto your leg”
  VS
- “Place your foot onto the step”

Focus of Attention in the Clinic

- “Take a bigger step”
  VS
- “Reach for the target”

Focus of Attention in the Clinic

- “Pick your foot up”
  VS
- “Don’t step on my hand” or “Step over obstacle”

Explicit Information Interferes with Implicit Motor Learning

- Explicit information (verbal instructions) is not as useful as discovering the solution to the motor task through practice alone
- Actually slows implicit motor learning
- Constant feedback about what patient needs to do to accomplish a task is not as helpful as letting them struggle after being set up appropriately

Boyd 2006
Importance of **Self Efficacy**

- Raises learner’s expectancies and confidence
- Promotes automaticity of movement
- Simply telling people they should do well on a perceived challenging task promotes self efficacy and superior learning

*Wulf 2016*

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**Challenge with Success**

- “Challenge, in the context of prevailing success, elicits a potentiating dopaminergic response that contributes to learning beyond success or challenging alone.”
  - Need to balance challenge while allowing pt to be successful
  - Allows further self efficacy and higher expectancies

*Wulf 2016*

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**Areas Traditional Rehab Misses**

- Lacking **Specificity** of practice
- Lacking **Repetition**
- Lacking **Intensity** in challenge
- Excessively frequent *explicit* instructions
- **Often stress internal** instead of external focus of attention

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**Lacking Specificity of Practice**

- Much time spent practicing multiple tasks
  - Bed mobility
  - Transfers
  - Seated/supine leg strengthening & stretching
  - Sitting balance
  - Standing balance
  - Pre-gait activities - weight shifts, step to and back
- And THEN maybe we get to walk
  - Results in less walking practice

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**Motivation**

- Autonomy

**Enhanced expectancies**

- Goal-action coupling

**Self-focus**

**Focus on task goal**

- Motor performance
- Motor learning
Lacking Specificity

• Common practice assumes transfer of strengthening and pre-gait activities into walking
• Don’t actually see that borne out in the evidence
  – Strengthening improves strength
  – Static balance training improves static balance
  – Transfer training improves transfers
• We need to actually walk to improve walking

Winston 1989
Eng 2007
Straube 2014

“Leap Frog” Phenomenon

• Idea of practicing more challenging tasks right away, instead of slowly progressing tasks
  – Go right into locomotor training instead of starting with transfers, standing balance, weight shifting, etc.
• Much data suggests more time working on walking translates to improvements in toilet transfers without explicitly practicing them
• Concept of skill transference

Horn 2005

Effects of Dynamic Stepping Training on Nonlocomotor Tasks in Individuals Poststroke

Don D. Straube, Carey L. Holleran, Catherine R. Kinnaird, Abigail L. Leddy, Patrick W. Hennessy, T. George Hornby

• Subacute and chronic stroke survivors
• High intensity dynamic stepping practice only
• Effects on nonlocomotor tasks - Berg & 5xSTS

Straube 2014
"Reverse Transfer"

- Perhaps we’ve been training in the wrong direction
- Instead of targeting strength and balance to improve walking, it appears we can improve those PLUS walking capacity with a single targeted intervention

Lacking Repetition

- Average number of steps practiced during PT sessions in inpatient rehab = **292**
- Sufficient to effectively drive neuroplasticity?
- How can we address this in the clinic?

<table>
<thead>
<tr>
<th>Category or subcategory</th>
<th>% (n) of sessions observed (n)</th>
<th>Repetitions/ session</th>
<th>SD</th>
<th>SE</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>Upper extremity</td>
<td></td>
<td></td>
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<tr>
<td>Active exercise</td>
<td>36 (13)</td>
<td>38.8 ±30.9 ±8.6</td>
<td>20.1-57.5</td>
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<td>Passive exercise</td>
<td>47 (17)</td>
<td>33.9 ±20.6 ±8.5</td>
<td>20.2-47.6</td>
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<tr>
<td>Purposeful</td>
<td>44 (16)</td>
<td>12.0 ±12.3 ±3.1</td>
<td>5.4-18.6</td>
<td></td>
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<tr>
<td>Sensory</td>
<td>17 (6)</td>
<td>2.5 ±1.6 ±0.7</td>
<td>0.7-4.2</td>
<td></td>
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<tr>
<td>Lower extremity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active exercise</td>
<td>14 (5)</td>
<td>33.4 ±33.4 ±14.8</td>
<td>8.0-74.8</td>
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</tr>
<tr>
<td>Passive exercise</td>
<td>17 (6)</td>
<td>6.3 ±5.0 ±2.0</td>
<td>1.1-11.5</td>
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</tr>
<tr>
<td>Purposeful</td>
<td>19 (7)</td>
<td>8.0 ±12.3 ±4.6</td>
<td>3.4 to 19.4</td>
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</tr>
<tr>
<td>Sensory</td>
<td>3 (1)</td>
<td>7  ±9.0</td>
<td>--</td>
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<tr>
<td>C2t: episodes</td>
<td>50 (18)</td>
<td>3.8 ±3.3 ±0.8</td>
<td>2.2-5.5</td>
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<tr>
<td>C2t: steps</td>
<td>50 (18)</td>
<td>291.4 ±121.2 ±117.456</td>
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<tr>
<td>Stairc: steps</td>
<td>14 (5)</td>
<td>4.2 ±4.5 ±2.0</td>
<td>1.4 to 9.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stairc: steps</td>
<td>14 (5)</td>
<td>21 ±20.1 ±11.7</td>
<td>11.4 to 53.4</td>
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<tr>
<td>Transfers</td>
<td>75 (27)</td>
<td>10.5 ±9.4 ±1.8</td>
<td>6.8-14.2</td>
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<tr>
<td>Balance</td>
<td>14 (5)</td>
<td>5.0 ±2.1</td>
<td>1.0</td>
<td>4.0-9.0</td>
<td></td>
</tr>
</tbody>
</table>

* Total sessions = 36, 16 were PT and 20 were OT sessions.

Lang 2007
Stepping Activity

- Average person = ~10,000 steps/day
- Sedentary = 5,000 to 6,000 steps/day
- Chronic stroke = 2,500 to 3,500 steps/day

Moore 2010

Finally! 2011 rolls around and we get a 400+ person study looking at body weight support treadmill training

The NEw ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Body-Weight–Supported Treadmill Rehabilitation after Stroke

LEAPS trial should address specificity and repetition concerns of traditional approaches

• BWS treadmill training (initiated at 2 or 6 mo post) vs. Progressive HEP
• 36 sessions, 90 minutes over 12-16 weeks

What went wrong?
What are we missing?

Table 1. Functional Status and Quality of Life at Baseline (2 Months) and Change from Baseline at 6 Months and 12 Months

<table>
<thead>
<tr>
<th>Variable</th>
<th>Early LT (N=329)</th>
<th>Late LT (N=143)</th>
<th>HE (N=126)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean comfortable or usual walking speed — m/sec</td>
<td>0.57±0.22</td>
<td>0.38±0.23</td>
<td>0.19±0.22</td>
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<tr>
<td>Change from baseline</td>
<td>0.25±0.21</td>
<td>0.13±0.14</td>
<td>0.23±0.20</td>
</tr>
<tr>
<td>Mean distance walked at 6 mo — meters</td>
<td>124.3±77.5</td>
<td>125.7±81.8</td>
<td>126.3±75.0</td>
</tr>
<tr>
<td>Change from baseline</td>
<td>81.8±62.3</td>
<td>41.7±47.4</td>
<td>75.6±59.5</td>
</tr>
<tr>
<td>12 mo</td>
<td>103.2±68.4</td>
<td>79.7±73.1</td>
<td>85.2±72.8</td>
</tr>
<tr>
<td>Step Activity Monitor — median no. steps per day (25th and 75th percentiles)</td>
<td>1468 (607, 3589)</td>
<td>1666 (847, 3354)</td>
<td>1813 (925, 3354)</td>
</tr>
<tr>
<td>Change from baseline</td>
<td>1017 (-102, 2209)</td>
<td>565 (-342, 2045)</td>
<td>1357 (84, 3382)</td>
</tr>
<tr>
<td>12 mo</td>
<td>838 (-253, 2422)</td>
<td>1022 (-111, 3009)</td>
<td>1471 (449, 1481)</td>
</tr>
</tbody>
</table>

● Early vs. Late
● Early vs. HEP
**Likely Limitations**

- BWSTT groups:
  - All had treadmill speed at 2.0 mph (0.89 m/s), 20-30 minutes with manual assist as needed
  - Then 15 minutes overground
- BWSTT groups had mean HR of 90 bpm
- Lacking intensity piece

**Why consider INTENSITY?**

**Lacking Intensity of Challenge**

- Patients are deconditioned
  - Bed rest
  - Hospital environment
  - Neuro insult
- Patients post stroke move less efficiently with higher energy costs compared to healthy

So,

- Does their poor aerobic fitness limit their ability to participate in walking practice?

**Lacking Intensity of Challenge**

- **Does their poor aerobic fitness limit their ability to participate in walking practice?**
  - **NO**

  - Aerobic deconditioning is NOT the cause of lack of walking practice in therapy
    - We don’t even challenge our patients aerobically
    - We choose to not spend more time walking

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**Ave of 24% HRR achieved in standing PT activities**

**Max of 30% HRR for non-walkers**

**Max of 35% HRR for walkers**

Kuys 2006

Prajapati 2013

Duncan 2011
Lacking Intensity of Challenge

• Averaging less than 3 minutes of hour long PT sessions during IP-R spent in target HR range (>70% HRR)
• Overwhelming majority of therapists do not monitor heart rate and blood pressure in stroke rehab
• Lack of attention to cardiorespiratory status

MacKay-Lyons 2002

Benefits of Higher Aerobic Intensity

• Greater muscular and CV demand
  – Mediated by increased neural drive
  – Potential to strengthen neural connections
• Benefits of CV exercise
• Release serotonin and norepinephrine which facilitate excitability of force generation and locomotor function spinal circuitry
• Ultimately improve walking function

So...

Is there an intervention that addresses the needs of specificity, repetition, and intensity - AND actually improves walking function?

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Break #1
What’s Important?

- Specificity
- Repetition
- Intensity
- External focus of attention on task completion
- It improves walking function

High Intensity Variable Stepping Practice

Feasibility and Potential Efficacy of High-Intensity Stepping Training in Variable Contexts in Subacute and Chronic Stroke

Carey L. Holleran, MPT\textsuperscript{1}, Don D. Straube, PT, PhD\textsuperscript{2}, Catherine R. Kinney\textsuperscript{3}, Abigail L. Leddy, DPT, MS\textsuperscript{4}, and T. George Hornby, MPT, PhD\textsuperscript{1,2}

- Subacute and chronic stroke survivors
- Supratentorial stroke
- Able to walk 10 m with mod A but <0.9 m/s
- Intensive variable stepping practice
- Up to 40 one-hour sessions over 10 weeks (4-5 days/week)

Intervention

- Maximize stepping practice
  - Forward, backward, sideways, stairs, obstacles, etc.

- Stepping variability
  - Recruit more expansive neural circuitries while focusing on fundamentals of walking
  - Improve walking adaptability

Calculating Target Exercise Intensity

- **Karvonen formula**
  - Max HR = 208-(0.7 x age)
  - 70% HRR = Rest HR + [(Max HR - Rest HR) x 0.7]
  - 80% HRR = Rest HR + [(Max HR - Rest HR) x 0.8]

- Decrease HRR by 15 bpm if on beta blockers
- RPE >14/20
Interventions

• Minimal focus on “normal” patterns, but did ensure:
  – Positive step length
  – Foot clearance
  – Absence of limb collapse
  – AFO’s okay

Intervention

• Increase task demands and errors by challenging biomechanical subcomponents of upright walking (error augmentation)
  – Limb swing
  – Weight bearing during stance
  – Forward propulsion
  – Upright stability (balance)

Limb Swing

• Increase assistance
  – Manual or elastic assistance

• Increase challenge
  – Ankle weights
  – Posterior-directed elastic resistance
  – Stepping over obstacles

Weight Acceptance During Stance

• Increase assistance
  – Body weight support via harness systems

• Increase challenge
  – Weighted vest
  – Reduced UE use on handrails / assistive devices

Propulsion

• Increase assistance
  – Manual or elastic assistance at pelvis

• Increase challenge
  – Decrease UE support
  – Increase stepping speeds
  – Inclined surfaces
  – Elastic resistance at pelvis

Upright Stability (Balance)

• Increase assistance
  – Manual assistance at pelvis
  – Use of handrails or assistive device

• Increased challenge
  – Decreased UE support
  – Progress to backward or sidestepping
  – Stepping over/around obstacles
  – Uneven, compliant, narrow surfaces
  – Dual physical tasks
Principles of High Intensity Variable Stepping Practice

- Specificity
- Repetition
- Intensity
- Self efficacy
- External focus of attention
- Variable practice
- Error augmentation

*But does it work?*

What would be meaningful results?

- Gait speed (10MWT)
  - MCID = 0.16 m/s

- 6 Minute Walk Test
  - MDC = 61 m for subacute
  - MDC/MCID = 35 m for chronic

- Berg Balance Scale
  - MDC = 6-8 points for subacute
  - MDC = 4 points for chronic

Feasibility of Focused Stepping Practice During Inpatient Rehabilitation Poststroke and Potential Contributions to Mobility Outcomes

T. George Hornby, PhD,1,2, Casey L. Holleran1, Abigail L. Leddy1, Patrick Hennessy1, Kristan A. Leech1,2, Mark Connolly1, Jennifer L. Moore1, Donald Straube, PhD1, Linda Lovell1,3, and Elliot Roth, MD1,3

- Subacute stroke
- Same intervention as previous study
- Implemented in inpatient rehab unit
- All levels of mobility included
Walking improvements
Non-walking tasks also improved - reverse transfer

Variable Intensive Early Walking Poststroke (VIEWS): A Randomized Controlled Trial

T. George Hornby, PhD1,2,3, Carey L. Holleran, DHS1, Patrick W. Henry1, Abigail L. Leddy, DPT1,2, Mark Connolly1, Jaclyn Camardo1, Jane W woods1, Jordan Mahtani, MS1, Linda Lovell2, and Elliot J. Roth, MD1,3

Subacute stroke survivors
- Mod A to walk 10 m -> 0.9 m/s unassisted
- Intensive stepping vs. Conventional PT at RIC
- Both groups up to 40 sessions over 10 weeks

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>Admission</th>
<th>Discharge</th>
<th>n (%)</th>
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</thead>
<tbody>
<tr>
<td>6-Minute walk test (m)</td>
<td>15 (3.0-67)</td>
<td>146 (44-281)</td>
<td>166 (83)</td>
</tr>
<tr>
<td>6-Minute level of assistance</td>
<td>3 (2-4)</td>
<td>5 (4-5)</td>
<td>166 (83)</td>
</tr>
<tr>
<td>Berg Balance Scale</td>
<td>5 (4-22)</td>
<td>34 (13-46)</td>
<td>173 (86)</td>
</tr>
<tr>
<td>FIM-Bed mobility</td>
<td>2 (1-3)</td>
<td>5 (3-5)</td>
<td>201 (100)</td>
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<tr>
<td>FIM-Toilet transfers</td>
<td>2 (1-3)</td>
<td>4 (3-5)</td>
<td>201 (100)</td>
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<tr>
<td>FIM-Walk</td>
<td>1 (1-2)</td>
<td>4 (3-5)</td>
<td>201 (100)</td>
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Demographics

<table>
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<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
<th>P Value</th>
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<tbody>
<tr>
<td>Age, years</td>
<td>57 ± 12</td>
<td>60 ± 9.2</td>
<td>.31</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>12/3</td>
<td>12/5</td>
<td>.54</td>
</tr>
<tr>
<td>Race, white/other</td>
<td>9/6</td>
<td>8/9</td>
<td>.46</td>
</tr>
<tr>
<td>Side of paresis, left/right</td>
<td>9/6</td>
<td>12/5</td>
<td>.53</td>
</tr>
<tr>
<td>Ischemic/hemorrhagic, n</td>
<td>9/5</td>
<td>15/2</td>
<td>.07</td>
</tr>
<tr>
<td>Duration poststroke, days</td>
<td>114 ± 56</td>
<td>89 ± 44</td>
<td>.16</td>
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<tr>
<td>Ankle foot orthosis, n</td>
<td>11</td>
<td>14</td>
<td>.54</td>
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<td>Assistive device, n</td>
<td>13</td>
<td>14</td>
<td>.74</td>
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<td>Baseline impairments</td>
<td></td>
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<tr>
<td>Fugl-Meyer: lower limb</td>
<td>20 ± 5.8</td>
<td>21 ± 6.2</td>
<td>.63</td>
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<tr>
<td>PHQ-9</td>
<td>4.3 ± 3.5</td>
<td>3.2 ± 3.3</td>
<td>.74</td>
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<table>
<thead>
<tr>
<th>Training parameters</th>
<th>Experimental</th>
<th>Control</th>
<th>P Value</th>
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<tr>
<td>Sessions, n</td>
<td>34 ± 8.9</td>
<td>33 ± 8.9</td>
<td>.314</td>
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<tr>
<td>Steps/session</td>
<td>2358 ± 860</td>
<td>948 ± 489</td>
<td>&lt;.001</td>
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<td>Steps/day</td>
<td>4046 ± 2596</td>
<td>2572 ± 1689</td>
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<td>Average peak RPE</td>
<td>18 ± 1.2</td>
<td>15 ± 1.8</td>
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<tr>
<td>Average peak HR reserve (%)</td>
<td>74 ± 8.7</td>
<td>40 ± 5.4</td>
<td>&lt;.001</td>
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</table>

Activities (percentage of sessions)

<table>
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<th>Control</th>
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<tbody>
<tr>
<td>Gait</td>
<td>100 ± 0.0</td>
<td>99 ± 1.8</td>
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<tr>
<td>Stairs</td>
<td>49 ± 9.9</td>
<td>44 ± 13</td>
<td></td>
</tr>
<tr>
<td>Transfers</td>
<td>79 ± 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance exercise</td>
<td>93 ± 8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-limb active exercise</td>
<td>87 ± 26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-limb passive exercise</td>
<td>71 ± 22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to improving mobility...

- Moderate-high aerobic exercise in stroke survivors produces significant improvements in cardiopulmonary fitness - VO2max (Globas 2012, MacKay-Lyons 2013, Moore 2010)

The current evidence suggests....

- High intensity variable stepping practice is **BETTER** than conventional therapy for improving
  - Gait speed
  - 6-Minute Walk Test
- **At least as good** as conventional therapy for improving
  - Berg
  - Five Time Sit-Stand
  - Transfer assist
- And provides missing **aerobic exercise** in stroke rehab
Outline

Block 1:
- Traditional approaches
- Neuroplasticity principles
- Motor learning concepts

Block 2:
- Propose a new direction
- High intensity locomotor training
- Supporting evidence

Block 3:
- Outcome measures
- Moving forward
- Case studies
- Questions

Functional Outcome Measures Related to Walking for Patients Post Stroke

Why use outcome measures?

- Assess baseline performance
- Goal setting
- Help inform treatment
- Monitor progress
- Patient motivation
- 3rd party payer communication

StrokEDGE Recommendations

Recommendations for patients with stroke:

Highly recommended measures:

- 6 minute walk
- 10 meter walk
- Berg Balance Scale
- FIM
- Functional Reach
- Goal Attainment Scale
- Motor Activity Log
- Postural Assessment Scale for Stroke Patients
- Stroke Impact Scale
- Timed Up and Go
- 5 time sit to stand
- 9 hole peg test
- Action Research Arm Test Activities-Specific Balance
- Confidence Scale
- Arm Motor Ability Test
- Assessment of Life Habits
- Box & Blocks test
- Chedoke-McMaster Stroke Assessment
- Dynamic Gait Index
- Dynamometry
- EuroQOL
- Falls Efficacy Scale
- Fugl–Meyer Assessment of Motor Performance

Recommended measures:

- Functional Ambulation Categories
- Modified Rankin Scale
- NIH Stroke Scale
- Rivermead Motor Assessment
- Stroke Adapted SIP-30
- Stroke Rehabilitation Assessment of Movement
- Tardieu Spasticity Scale (Modified Tardieu)
- Trunk Impairment Scale
- Wolf Motor Function Test

*=inpatient rehab only
†=outpatient rehab only
StrokEDGE Recommendations

**10MWT / Gait Speed**
- Measure time to walk 10 m
- Calculate speed, to get units in m/s
- **Self-selected** vs. fast
- Contact guard or better
- Assistive devices OK, but consider consistency

**6 Minute Walk Test**
- Measure distance covered in 6 minutes
- Sub-max test of aerobic capacity / walking tolerance
- Physical assist and/or assistive device okay
- Consistent course
- **MDC/MCID** = 35 m subacute
  = 50-60 m chronic

**Highly recommended measures:**

- 6 minute walk
- 10 meter walk
- Berg Balance Scale
- FIM
- Functional Reach
- Goal Attainment Scale
- Motor Activity Log
- Postural Assessment Scale for Stroke Patients
- Stroke Impact Scale+
- Timed Up and Go

**10MWT / Gait Speed**
- **MCID** = 0.16 m/s
- May predict community access
  - <0.4 m/s household ambulator
  - 0.4 to 0.8 m/s limited community
  - >0.8 m/s full community
- Improvements tied to improved function and quality of life

**6 Minute Walk Test**
- Excellent correlation with **community reintegration** and an excellent predictor of steps/day
- May see gait changes and safety issues emerge as pt fatigues
- Pre and post vitals may be appropriate, especially on eval
**Berg Balance Scale**

- 14-item test of **static and dynamic balance**
- Max of 56 points
- No assistive device
- MDC in Subacute
  - Walks with SBA or better = 6 points
  - Walks with assist = 8 points
- MDC in Chronic = 4-5 points

**Fall risk <45/56**

- Potential floor and ceiling effects
  - For higher level, consider
    - Functional Gait Assessment or
    - High-level Mobility Assessment Tool
  - For lower level, consider
    - Postural Assessment Scale for Stroke Patients (PASS)

**RehabMeasures.org**

- Database of outcome measures, instructions, handouts, psychometrics specific to diagnosis
- Google: rehab measures + Berg / 6MWT / etc.

**Patient Safety**

**Contraindications for Exercise Or Physical Activity**

<table>
<thead>
<tr>
<th>Signs</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting HR</td>
<td>&gt; 100 bpm or &lt; 50 bpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting SBP</td>
<td>&gt; 200 mmHg or &lt; 90 mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting DBP</td>
<td>&gt; 110 mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen Saturation</td>
<td>&lt; 90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>cyanosis, diaphoresis, bilateral edema in a patient with CHF, pallor, fever, weight gain &gt; 4-6 lbs/day, abnormal change in breath sounds or heart sounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptoms</td>
<td>SOB, angina, dizziness, severe headache, sudden onset of numbness or weakness, painful calf suggestive of DVT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Indications to Terminate Exercise Or Physical Activity**

<table>
<thead>
<tr>
<th>Signs</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>cyanosis, diaphoresis, bilateral edema in a patient with CHF, pallor, abnormal change in breath sounds or heart sounds, ataxia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptoms</td>
<td>SOB, angina, dizziness, severe headache, sudden onset of numbness or weakness</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case Study: SB

- 52 yo M with CVA with R hemiplegia 2 mo ago
- PMH: HTN, DM2
- PLOF: indep with all mobility, worked in foundry
- No inpatient rehab due to insurance issues
- Referred to our outpatient day program

SB Initial Evaluation

- R hemiplegia including
  - 0/5 ankle DF
  - 2-/5 knee flex
  - 3+/5 knee ext
  - 2-/5 hip flex
  - 2-/5 hip ext
  - 1/5 hip abd
  - ~Flaccid UE
- Poor fractionation of movement

SB Initial Evaluation

- Transfers: Min A without RLE weight bearing
- Gait: Min A, 50 ft, LBQC
  - Intermittent R knee buckling
  - AFO to assist with foot clearance, constant drag
  - Significantly fatigue limiting distance
- Berg: 11/56
- PASS: 23/36
- 6MWT: 50 ft with LBQC, min A

SB Interventions

- 2x/week, 60 minute sessions
- Variable intensive stepping practice
  - Started forward on treadmill with 20% BWS due to R knee collapse and poor advancement x 2 sessions
  - Progressed to overground activities
- Progressed to single point cane from LBQC
- HEP: supine therex, caregiver assisted PROM, home walking program
SB Variable Stepping + Error Augmentation + Balance Challenges

SB Results

<table>
<thead>
<tr>
<th>Eval</th>
<th>3 weeks tx**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berg</td>
<td>11/56</td>
</tr>
<tr>
<td>PASS</td>
<td>23/36</td>
</tr>
<tr>
<td>6MWT</td>
<td>50 ft, LBQC, min A</td>
</tr>
<tr>
<td></td>
<td>182 ft, SPC, CGA, 3 standing breaks</td>
</tr>
</tbody>
</table>

SB Results

- No longer with R knee collapse
- Progressing RLE advancement
- Persisting hip and knee flexion weakness
- Progressing but severely impaired act tolerance
- Wife now comfortable guarding during home walking practice
- Modified Indep transfers
- To continue with other therapist...

Case #2

Case Study: KM

- 50 yo F with hx of RR-MS, stroke 6 mo ago
- Prior to stroke: indep with all mobility, runner
- Underwent inpatient rehab, discharged to group home
- Falling several times/week, tripping frequently
- Delayed referral to our OP clinic due to mental health needs

Initial Evaluation

- R hemiparesis (distal > proximal)
- Gait observations: variable and shortened step length, poor R toe clearance, slow speed
- Goals: stop falling, walk independently without a device, maybe return to running
Initial Evaluation

- **Gait speed:** 1.13 m/s
- **Berg:** 52/56
- **Functional Gait Assessment:** 20/30
- **6MWT:** 1249 ft
- **Timed Up & Go:**
  - Normal: 10.47 sec
  - Cog (2’s): 15.63 sec
  - Manual: 21.50 sec

Interventions

- 2x/week, 60 minute sessions
- Variable intensive stepping practice
  - Treadmill
  - Overground
- Cognitive and manual dual tasking
- HEP: stretching for spasticity management, LE strength, dynamic balance

### KM Results

<table>
<thead>
<tr>
<th></th>
<th>Eval</th>
<th>2 mo tx</th>
<th>3 mo tx</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gait speed</strong></td>
<td>1.13 m/s</td>
<td>1.22 m/s</td>
<td>1.47 m/s</td>
</tr>
<tr>
<td><strong>FGA</strong></td>
<td>20/30</td>
<td>28/30</td>
<td>30/30</td>
</tr>
<tr>
<td><strong>6MWT</strong></td>
<td>1249 ft</td>
<td>1298 ft</td>
<td>1525 ft</td>
</tr>
<tr>
<td><strong>TUG - normal</strong></td>
<td>10.47 sec</td>
<td>9.45 sec</td>
<td>NT</td>
</tr>
<tr>
<td>- cog</td>
<td>15.63 sec</td>
<td>11.70 sec</td>
<td>NT</td>
</tr>
<tr>
<td>- man</td>
<td>21.50 sec</td>
<td>13.50 sec</td>
<td>NT</td>
</tr>
</tbody>
</table>
KM Results

• No longer falling
• Was able to move back home from group home
• Working on short distance jogging intervals
• Now regularly accessing community with SO and family

What about other diagnoses?

Case Study: MH

• 19 yo M with hx of MVA with resultant severe TBI, multiple BLE fractures with surgical fixation
• Coma x 2 months
• Inpatient brain injury rehab once emerged
• Referred to our outpatient brain injury day program

Case #3

Initial OP Evaluation - 5 mo post injury

• Rancho level 5 (confused, appropriate)
• R hemiparesis
• Hyperentive R plantar foot
• Decreased R ankle DF and hamstring ROM
• RLE spasticity grossly MAS 2
• Poor insight to deficits, unsure why in therapy

Initial Mobility

• **Bed mobility**: supervision for safety
• **Transfers**: mod A, reaching for caregiver
• **Sit-stand**: max A, reaching for caregiver, posterior lean, avoids R foot touching ground
• **Ambulation**: total A x 2 with eva walker 20 ft, minimal toe touch RLE, poor trunk control
• **Wheelchair mobility**: supervision, slow, using BUE
**Early Interventions**

- HEP: family assisted BLE PROM, standing program
- POC 2x/week, 60 min sessions
- Seated scooting and UE pushing activities
- Convince pt to wear shoe on R foot
- Standing RLE stomping activities (external focus)
- Amb practice with 2WW to initiate reciprocal stepping pattern (vs. hopping)

---

**Early Progress**

<table>
<thead>
<tr>
<th>Initial OP Eval</th>
<th>2 months later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>Mod-max A</td>
<td>-CGA squat</td>
</tr>
<tr>
<td>- Min A stand pivot</td>
<td></td>
</tr>
<tr>
<td>Ambulation</td>
<td>Total A x 2, Eva, 20 ft</td>
</tr>
</tbody>
</table>

---

**Progressing Interventions**

- Ambulation practice with varying UE assist
- Promote emerging balance reactions
- R AFO with additional ankle wrapping to allow heel contact
- Recumbent stepper intervals for aerobic conditioning and promoting RLE weight acceptance

---

**Continuing Progress**

<table>
<thead>
<tr>
<th>2 months Tx</th>
<th>6 months Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>- CGA squat;</td>
<td>-Indep squat pivot</td>
</tr>
<tr>
<td>- Min A stand pivot</td>
<td></td>
</tr>
<tr>
<td>Ambulation</td>
<td>Mod A, 2WW, 150 ft</td>
</tr>
<tr>
<td></td>
<td>Mod A, B canes, 50 ft</td>
</tr>
<tr>
<td>Stairs</td>
<td>Unable</td>
</tr>
</tbody>
</table>

---

**Now able to complete:**

- **Timed Up & Go:** 43 seconds with 2WW
- **Gait speed:** 0.123 m/s with 2WW
- **6 Minute Walk Test:** 175 ft with 2WW
2 month therapy hiatus for hardware removal due to infection

- Re-eval showed maintained gains, but no spontaneous recovery

Now

- **Timed Up & Go:** 47 seconds with 2WW
- **Gait speed:** 0.188 m/s with 2WW
- **6MWT:** 282 ft with 2WW

**Progressing Interventions**

- Limited UE assist
- High intensity variable stepping practice
  - Forward, backward, lateral stepping
  - Stairs
  - Obstacle negotiation
  - Inclines
- Utilization of external focus of attention
  - Basketball
  - Timed challenges
Significant Improvements

<table>
<thead>
<tr>
<th></th>
<th>Post Surgery</th>
<th>3 months tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit-stand</td>
<td>Min A</td>
<td>Stand by</td>
</tr>
<tr>
<td>TUG</td>
<td>47 sec 2WW</td>
<td>13.6 sec, no device</td>
</tr>
<tr>
<td>Gait speed</td>
<td>0.188 m/s 2WW</td>
<td>0.726 m/s, no device</td>
</tr>
<tr>
<td>6MWT</td>
<td>282 ft 2WW</td>
<td>573 ft, no device</td>
</tr>
</tbody>
</table>

MH Participation
- Now able to walk with friends standing by, negotiate home environment

Evidence in Other Populations
- Pre-frail and frail elderly (mean age ~83 yo)
  - Decreased frailty
  - Improved:
    - Gait speed
    - Walking tolerance (6MWT)
    - Balance (Berg)

Evidence in Other Populations
- Persons with incomplete spinal cord injury
  - Improved fast gait speed
  - Improved stride length & cadence
  - Improved muscle recruitment during walking
  - Does not worsen spasticity or aberrant muscle activity during walking

Upcoming Clinical Practice Guideline
- Combined Sections Meeting 2018
- Preliminary recommendations for improving walking function after stroke, TBI, i-SCI
- Encourages:
  - Higher intensity aerobic exercise (70-85% HRR)
  - Walking practice; BWSTT not to replace overground
- Discourages:
  - Pre-gait/weight shifting activities
  - Static balance exercises
  - Robotics

Implementing in Your Clinic
- Use outcome measures
- Monitor resting and exercise vital signs
- Reflect on your current practice
  - Are you maximizing neuroplasticity and motor learning principles?
Implementing in Your Clinic

• Remember the principles
  – Specificity
  – Repetition
  – Intensity
  – Variable practice
  – Error augmentation
  – Salience
  – External focus of attention

• Don't be afraid to start!

References


References


References


Questions?

Thank you!