High Intensity Aerobic Exercise to Enhance Plasticity Post-Stroke

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Disclosure

• JLA has authored intellectual property related to the forced exercise control algorithm.
Course Objectives

At the end of the presentation, the participants will be able to:

- Describe the potential role of BDNF in neuroplasticity after stroke.
- Describe an evidence based approach to implementing aerobic exercise in individuals after stroke.
- Discuss the impact of a FE paradigm on the future of stroke rehabilitation.
Course Outline

I. Rationale for our research

II. Cellular response to forced exercise

III. Forced exercise and Parkinson’s disease

IV. Methodology for implementing forced exercise paradigm in individuals with stroke

V. Motor and non-motor results

VI. Clinical translation and future directions
Effects of aerobic exercise on brain health

• Enhances acquisition and retention of information
• Improves memory and executive function
• May protect against age related brain atrophy
• Evidence of increased brain volume in older adults (white and gray matter)
• Treatment for depression
Neurotrophic Factors

• Neurotrophins signal neurons to survive, differentiate, and grow

• Brain derived neurotrophic factor (BDNF)
  — Of particular interest in rehabilitation
Upregulation of BDNF via Aerobic Exercise Training

• Dependent on
  – Exercise Type
  – Exercise Intensity
  – Exercise Duration
  – Genetics

• Increased levels tend to be transient
What can animal models tell us about exercise and neuroplasticity?
Forced-exercise and neuroprotection in rodent models of PD

**Experimental design**

- **Ex**
  - Day 0
  - 7
  - 14
  - 21
  - 28

- **Non-Ex**
  - BrdU injection
  - 6-OHDA lesion
  - Behavioral test
  - Behavioral test
  - Behavioral test
  - Behavioral test
  - Euthanasia

**Exercise**

(30 minutes each day, consecutive 5 days/week for 4 weeks)
Effects of Forced Exercise (FE) in Animal Models of PD

• Increased release of dopamine
• Decreased synaptic clearance of dopamine
• Increase in dopamine D2 receptor
• Increase in neurotrophic factors (BDNF, GDNF, IGF-1)
  – Greater intensity (forced-exercise) results in higher levels of neurotrophic factors and more extensive the anatomical regions involved
From the Cornfields to a Clinical Trial to Community Outreach
Closing the gap between animal and human studies
What is FE in a patient population?

• Voluntary efforts of the patient are augmented
  – Exercise rate increased by approximately 30-35%
  – Consistent pedaling rate at high RPMs
  – Consistent pedaling pattern

• Aerobic
  – 60-80% target HR zone

• FE is not passive
Forced-Exercise Mechanisms(?) of Action

It Is Not About the Bike, It Is About the Pedaling: Forced Exercise and Parkinson’s Disease

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1Department of Biomedical Engineering, 2Center for Neurological Restoration, 3The Imaging Institute, Cleveland Clinic Foundation; and 4Cleveland FES Center, L. Stokes Cleveland VA Medical Center, Cleveland, OH
Design of bike
Forced vs. Voluntary Exercise

Intervention:
- Randomly assigned to forced- or voluntary exercise groups
- Three 1 hr. sessions/wk for 8 weeks
- 10 min. warm up, 40 min. main set, 10 min cool down
- 60-80% ACSM target HR
- Forced-exercise group pedaled 30% faster and produced 42% less work compared to the voluntary exercise group.

Forced-exercise

Voluntary exercise

Ridgel et al., 2010
Aerobic exercise improves fitness, only FE improves clinical ratings
Study enrollment

1996

1999

2003

2006

EOT

Post EOT
Forced-exercise Improves UE Motor Function
Reduced Anosmia with Increased Cadence

Change in UPSIT Score from Baseline to EOT+4 weeks

Average RPM during trial

Change in UPSIT Score

-12 -9 -6 -3 0 3 6 9 12

Assisted
Voluntary

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Exercise Induced Changes Measured with fMRI
Aerobic Exercise improves Cardiovascular fitness in Patients with Stroke

• At 1 month s/p stroke, peak VO$_2$ limited

• In subacute (as early as 15 days) and chronic stroke, a CV exercise program has been shown to be feasible

• Stoller (2012) systematic review: favorable results with improving peak VO$_2$ and 6MWT, but not gait speed

• CV training is a safe intervention for well-screened patients
Challenges in using aerobic exercise to drive motor recovery

• Varied exercise interventions
  – Dose
  – Intensity
  – Timing in disease process
  – Duration
  – Reliance on clinical assessments

• Small sample sizes

• Mixed patient characteristics

• Physical limitations in a diseased population
How can aerobic exercise promote neuroplasticity?

- Upregulation of brain-derived neurotrophic factor (BDNF)
  - Enhance long term potentiation
  - Promote neurogenesis
  - Promote angiogenesis
  - Suppress oxidative stress
- Increase insulin-like growth factor
- Increase neurotransmitters

Mang, 2013
What can animal models in stroke tell us about exercise and neuroplasticity?

- Mixed Results

- Intensive FE (aerobic and forced use) applied immediately post-lesioning may result in increased lesion size & worse behavioral outcomes

- An enriched environment is beneficial to long-term behavioral recovery

- FE improves motor outcomes, but optimal dose and timing are unknown
Timing of Exercise and RTP Intervention impact Outcomes

• Aerobic exercise
  – As early as 11-15 days, but lower intensity (≤60% of HHR)
  – Majority of research done in subacute to chronic stroke

• RTP
  – EXCITE trial → 3-9 months post stroke
  – VECTORS trial → 10 days post stroke
    1) Traditional therapy
    2) Standard CIMT: 2 hrs of shaping/day, constraint mitten x 6hrs
    3) High Intensity CIMT: 3hrs of shaping/day, constraint mitten x 90% of waking hours
What is Forced Exercise In Stroke Rehabilitation?

• Animal models – forced motor practice
• Animal models – forced aerobic exercise
• Human models – forced motor practice
• Human models – forced aerobic exercise
Can FE be used to enhance Recovery of Function after Stroke?
Motor and Sensory Representation

Motor cortex (precentral gyrus)

Somatic sensory cortex (postcentral gyrus)

Region of decreased blood flow

Interruption of blood supply (blood clot)
Functional Outcomes for Stroke Patients

- 35% do not regain full function of the leg
- 65% cannot use their affected upper extremity for daily tasks
- 18% experience residual aphasia
- ~30% live with severe, permanent disability
Barriers to Optimizing Functional Recovery

Difficult to Rehabilitate the Damaged Brain

Time-Consuming & Expensive

Cuts in Reimbursement & Caps on Therapy Visits
Current Approaches to Stroke Rehabilitation

• Exercises/Activities to Increase Active Movement
• Teach compensatory strategies
• Retrain Functional Tasks Using Motor Learning Approach
The Challenge in Applying Aerobic Exercise to Individuals with Stroke to Facilitate Neuroplasticity

• Hemiplegia / Hemiparesis – Decreased motor output
• Changes in skeletal muscle physiology
• Sensory loss
• Spasticity
• Severe deconditioning
Call for Novel Approaches to Stroke Rehabilitation: Our Solution

Prime the CNS via AE

Intensive Motor Practice
Study Aims

• To determine the differential effects of forced and voluntary exercise on motor function, non-motor function, and cardiovascular fitness in individuals with chronic stroke
**Hypothesis:** Aerobic exercise will influence motor recovery and non-motor function in individuals with stroke

**Anticipated Outcome:** Those in the FE intervention group will have a greater recovery of motor and non-motor function than RTP alone
Proposed Mechanism of FE after Stroke

Forced Exercise
- Extrinsic Feedback
  - Visual
  - Auditory
- Intrinsic Feedback
  - GTO
  - Muscles spindles
  - CV response

Structure
- Cognition
  - Hippocampus & cortex
- Executive Function
  - Prefrontal & cingulate cortex
- Emotion
  - Amygdala
  - Prefrontal cortex
- Motivation
  - Hypothalamus
  - Accumbens
  - VTA
- Motor Control
  - Motor cortex
  - Striatum
  - Brainstem
  - Cerebellum
  - Spinal cord
- Metabolism
  - ANS
  - Endocrine system
  - Hypothalamus

CNS
- Proposed Mechanism
  - BDNF
  - GDNF
  - IGF3
  - Dopamine
- Change
  - Repair
  - Plasticity
  - Neurogenesis

Function
- Motor Control
- Mood

Neuro-physiologic Response

Repetitive Task Practice

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Study Overview

- Screening & Consent
- Baseline Biking Stress Test
- Baseline Testing
- 3x/wk for 8 wks
- FE + RTP
- VE + RTP
- RTP Only
- End of Treatment (EOT) Testing
- EOT Biking Stress Test
- EOT + 4 weeks

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Inclusion/Exclusion Criteria

Inclusion

• 18-85 years old
• 6-12 months post ischemic stroke
• Approval from physician to participate in stress test
• 19-55 on Fugl-Meyer upper extremity motor assessment
• Ability to follow 1-2 step commands

Exclusion

• Hospitalization for MI, CHF, heart surgery within the past 3 months
• Serious cardiac or pulmonary contraindication to exercise (cardiomyopathy, PE, afib, etc.)
• Other musculoskeletal contraindications to exercise
• Major psychiatric disorder
• Anti-spasticity injections (botox) within the past 3 months
• Resting SBP>200mmHg or DBP>110mmHg
• Fall in SBP>20mmHg with exercise
Time-Matched Interventions

- **Group 1 (FE)**
  - Forced Exercise (45 min)
  - RTP (45 min)

- **Group 2 (VE)**
  - Voluntary Exercise (45 min)
  - RTP (45 min)

- **Group 3 (RTP)**
  - RTP (45 min)
Outcome measures

• Motor outcomes
  ― Fugl-Meyer Assessment (FMA)
  ― Wolf Motor Function Test (WMFT)

• Non motor outcomes
  ― Center for Epidemiologic Studies Depression Scale (CES-D)
  ― Stroke Impact Scale (SIS)

• Cardiovascular
  ― Peak VO2
  ― 6 Minute Walk Test (6MWT)

• Intervention-Related outcomes
  ― Cycling: HR, cadence, power
  ― RTP: # of reps, HR
Screening for Safety

• Review of Medical History

• Cardiopulmonary Exercise Stress Test
  — Physiologic response to intensive exercise
  — Baseline data
    — Heart rate (resting, maximal)
    — Blood pressure
    — Oxygen uptake
    — Cadence
    — Pedaling symmetry
Cardiopulmonary Stress Test (CPX)

• Continuous, incremental metabolic stress test employed on a stationary bike
• Beginning with a workload of 20W and increasing by 20W every two minutes
• A 12-lead EKG and gas analysis to determine peak VO2 were continuously monitored
• RPE every 2 min
Cardiovascular Targets and Monitoring

• Karvonen Formula:

  THR: (HRmax-HRrest) * 60-80% + HRrest

• Beta Blockers

• Use of RPE
Applying 2 modes of Aerobic Exercise training to individuals with stroke

Forced Exercise
- Patient’s voluntary efforts are augmented
- Rate (cadence) is increased & constant
- Exercise at 60-80% of HR reserve

Voluntary Exercise
- Efforts toward exercise are not augmented
- Rate is self-selected
- Exercise at 60-80% of HR reserve
Repetitive Task Practice (RTP)

- Focus on maximizing reps
  - Typically between 75-100+ reps of 1 task
- Type of practice
  - Blocked, whole part
  - Patient goal setting with reps or time
- Standing vs. Sitting
- Minimize rest time
- Incorporate ROM into functional activity
- Grading of activities
Screened (n=147)

Randomization (n=20)

BASELINE

FE + RTP (n=6)

VE + RTP (n=8)

RTP (n=6)

N=1 Recurrent Stroke N=1 Dropout

N=1 Dropout

EOT

FE + RTP (n=6)

VE + RTP (n=6)

RTP (n=5)

N=1 Received Botox

EOT + 4

FE + RTP (n=5)

VE + RTP (n=6)

RTP (n=5)
Top Reasons for Exclusion

• Too low/high functioning UE
• Cardiac co-morbidities
• Lack of Transportation
Study compliance and outcomes

• Transportation

• Attendance

• Dropouts (N = 3)
  1) Disappointed about randomization
  2) Non-compliant with attendance
  3) Medical complication unrelated to intervention

• Unusable data (N = 1)
  1) Botox before EOT+4
# Study Demographics

<table>
<thead>
<tr>
<th></th>
<th>RTP</th>
<th>VE</th>
<th>FE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>61.6</td>
<td>60.7</td>
<td>44.8</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>5/5</td>
<td>5/6</td>
<td>5/6</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td>4 white</td>
<td>5 white</td>
<td>3 white</td>
</tr>
<tr>
<td></td>
<td>1 African-American</td>
<td>1 African-American</td>
<td>2 African-American</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Asian</td>
</tr>
<tr>
<td><strong>Avg Time Since</strong></td>
<td>9.1 months</td>
<td>9.9 months</td>
<td>8.7 months</td>
</tr>
<tr>
<td><strong>CVA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Avg Baseline FM</strong></td>
<td>25.4</td>
<td>30.5</td>
<td>36.1</td>
</tr>
<tr>
<td><strong>Score (out of 66)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Safe Delivery of AE and Improvements in Function
Results of CPX for screening

- 41 uneventful stress tests
- 2 abnormal stress tests at baseline
  1) ST segment depression
     - Pharmacological stress test with nuclear imaging → no ischemia and he was cleared to exercise
  2) ST segment depression
     - Decided not to obtain follow up care
     - Did not continue with study
### Patients with Stroke are Deconditioned

<table>
<thead>
<tr>
<th>Subject</th>
<th>Peak VO2 (mL/kg/min)</th>
<th>Percent of predicted peak VO2</th>
<th>Subject</th>
<th>Peak VO2 (mL/kg/min)</th>
<th>Percent of predicted peak VO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-01</td>
<td>20.3</td>
<td>66%</td>
<td>H-11</td>
<td>17.2</td>
<td>70%</td>
</tr>
<tr>
<td>H-02</td>
<td>17.3</td>
<td>52%</td>
<td>H-13</td>
<td>13.7</td>
<td>33%</td>
</tr>
<tr>
<td>H-03</td>
<td>33.0</td>
<td>78%</td>
<td>H-14</td>
<td>16.1</td>
<td>55%</td>
</tr>
<tr>
<td>H-04</td>
<td>17.1</td>
<td>54%</td>
<td>H-16</td>
<td>12.6</td>
<td>35%</td>
</tr>
<tr>
<td>H-05</td>
<td>28.9</td>
<td>69%</td>
<td>H-17</td>
<td>22.4</td>
<td>53%</td>
</tr>
<tr>
<td>H-06</td>
<td>14.1</td>
<td>79%</td>
<td>H-18</td>
<td>20.5</td>
<td>56%</td>
</tr>
<tr>
<td>H-07</td>
<td>11.9</td>
<td>44%</td>
<td>H-21</td>
<td>16.0</td>
<td>45%</td>
</tr>
<tr>
<td>H-08</td>
<td>19.1</td>
<td>54%</td>
<td>H-22</td>
<td>16.0</td>
<td>45%</td>
</tr>
<tr>
<td>H-09</td>
<td>12.8</td>
<td>35%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Representative Day of HR Data

- Forced Exercise
- Rest
- Repetitive Task Practice
AE Groups Received Half the Dosage of RTP

![Bar chart showing the number of repetitions and minutes engaged in RTP for different groups. The chart indicates that AE groups received half the dosage of RTP compared to other groups.](chart_image)
Participants were able to exercise at recommended aerobic levels.
Cardiovascular Outcomes
Aerobic exercise improves cardiovascular function

![Graph showing the improvement in Peak VO2 (mL/kg/min) over time. The graph displays three lines representing different conditions: RTP (black), VE (red), and FE (blue). The x-axis represents time (Baseline to EOT), and the y-axis represents Peak VO2 (mL/kg/min). The graph shows an increase in Peak VO2 for both RTP and VE, while FE shows a decrease.](image-url)
Motor Outcomes
FE produces greater change in Fugl-Meyer Scores
Greater Improvements in Motor Recovery with Fewer Repetitions of UE Task Practice

For EOT - Baseline

- RTP
- VE
- FE

FMA difference vs. Avg. # of reps during UE practice
Higher Cadence May Improve Motor Outcomes
Relationship Between Baseline FMA and Motor Recovery
Age did not correlate with motor recovery

R-squared: 0.08, Adjusted R-squared: 0.01
All groups improve number of task completed on the WMFT

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>EOT</th>
<th>EOT + 4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg. Time in Seconds (# of items unable to complete)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE</td>
<td>1.148 (0)</td>
<td>1.884 (0)</td>
<td>2.173 (0)</td>
</tr>
<tr>
<td>FE</td>
<td>6.831 (0)</td>
<td>3.701 (0)</td>
<td>3.738 (0)</td>
</tr>
<tr>
<td>FE</td>
<td>9.192 (2)</td>
<td>14.732 (0)</td>
<td>NA - Botox</td>
</tr>
<tr>
<td>FE</td>
<td>1.836 (0)</td>
<td>1.693 (0)</td>
<td>1.547 (0)</td>
</tr>
<tr>
<td>FE</td>
<td>2.311 (0)</td>
<td>2.191 (0)</td>
<td>1.614 (0)</td>
</tr>
<tr>
<td>FE</td>
<td>2.093 (0)</td>
<td>1.922 (0)</td>
<td>1.717 (0)</td>
</tr>
<tr>
<td>VE</td>
<td>1.865 (0)</td>
<td>1.726 (0)</td>
<td>1.979 (0)</td>
</tr>
<tr>
<td>VE</td>
<td>3.712 (0)</td>
<td>4.419 (0)</td>
<td>3.912 (0)</td>
</tr>
<tr>
<td>VE</td>
<td>9.543 (11)</td>
<td>16.735 (11)</td>
<td>43.301 (8)</td>
</tr>
<tr>
<td>VE</td>
<td>6.993 (0)</td>
<td>6.028 (0)</td>
<td>6.150 (0)</td>
</tr>
<tr>
<td>VE</td>
<td>35.977 (5)</td>
<td>30.346 (4)</td>
<td>33.495 (3)</td>
</tr>
<tr>
<td>VE</td>
<td>23.647 (7)</td>
<td>23.070 (5)</td>
<td>20.679 (5)</td>
</tr>
<tr>
<td>RTP</td>
<td>19.984 (0)</td>
<td>13.619 (0)</td>
<td>9.274 (0)</td>
</tr>
<tr>
<td>RTP</td>
<td>12.848 (9)</td>
<td>23.810 (7)</td>
<td>10.258 (9)</td>
</tr>
<tr>
<td>RTP</td>
<td>8.458 (0)</td>
<td>10.205 (0)</td>
<td>7.521 (0)</td>
</tr>
<tr>
<td>RTP</td>
<td>3.109 (0)</td>
<td>2.360 (0)</td>
<td>2.254 (0)</td>
</tr>
<tr>
<td>RTP</td>
<td>28.939 (8)</td>
<td>35.673 (7)</td>
<td>34.151 (7)</td>
</tr>
</tbody>
</table>
Non-Motor Outcomes
FE group with significant improvements in depression scale

Score on CES-D (points)

Time
- Baseline
- EOT
- EOT+4

- RTP
- VE
- FE

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All groups improve on motor domains of Stroke Impact Scale (SIS) QOL Measure
Clinical Implications: Barriers and Possibilities
# Aerobic Exercise Recommendations for Stroke Survivors

<table>
<thead>
<tr>
<th>Mode</th>
<th>Intensity</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
</table>
| Large-muscle activities (i.e. walking, stationary cycle, combined arm-leg ergometry, seated stepper) | - 40-70% peak O2 uptake  
- 40-70% HRR  
- 50-80% max HR  
- RPE 11-14 (6-20 scale) or 1.5-3 (0-10 scale) | 3-7 days/wk | 20-60 min/session  
- multiple 10 min sessions |
Subjects’ HR Responses to RTP

Time Spent >40% of Target HR Range during RTP

<table>
<thead>
<tr>
<th>Subject</th>
<th>Time in Target HR Range (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>87%</td>
</tr>
<tr>
<td>2</td>
<td>12%</td>
</tr>
<tr>
<td>3</td>
<td>27%</td>
</tr>
<tr>
<td>4</td>
<td>31%</td>
</tr>
<tr>
<td>5</td>
<td>27%</td>
</tr>
<tr>
<td>6</td>
<td>70%</td>
</tr>
<tr>
<td>7</td>
<td>11%</td>
</tr>
</tbody>
</table>
Mixed Results regarding Aerobic Response during PT/OT

Observational studies during PT/OT sessions

*MacKay-Lyons, 2002*
- ≥ 40% of HR reserve (HRR)
  - PT: 5% of the session (2.8 ± 0.9 minutes)
  - OT: 2% (0.7 ± 0.2 minutes)

*Kuys, 2006*
- Average HR intensity during PT session was 24.2% of HHR

*Koopman, 2013*
- ~ 2hrs of a patient’s day in a was spent >40% HRR
- Attributed standing time in PT/OT to eliciting this strain
Understanding what is done in research setting to guide clinical utilization

• Constraint Induced Movement Therapy (CIMT) → 6hrs/day
• Modified CIMT → 3 hrs/day
• What can be done in 45-60 min?

Birkenmeier et al., 2010
- >300 reps in 1 hour OP setting

Waddell et al., 2014
- >280 reps in 1 hour IP rehabilitation session
What is occurring in the clinic

How many reps are patients actually performing?

• Lang, et al. (2009)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean Number of Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE passive exercise</td>
<td>33</td>
</tr>
<tr>
<td>UE active exercise</td>
<td>54</td>
</tr>
<tr>
<td>UE functional task</td>
<td>32</td>
</tr>
<tr>
<td>LE active exercise</td>
<td>75</td>
</tr>
<tr>
<td>Gait</td>
<td>357</td>
</tr>
<tr>
<td>Transfers</td>
<td>11</td>
</tr>
</tbody>
</table>
## Implementing RTP with Patients of various levels of UE function

<table>
<thead>
<tr>
<th>Impairment/Functional Limitation</th>
<th>Task</th>
<th>Grading of Task</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower functioning UE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decreased shoulder AROM and strength making donning a coat difficult</td>
<td>Using gross motor shoulder flex/abd to knock down dominos dispersed on tray table</td>
<td>Move domino location on table</td>
</tr>
<tr>
<td><strong>Higher functioning UE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impaired intrinsic hand coordination limiting writing legibility</td>
<td>Writing practice on a lined white board</td>
<td>Changing the size of the lines to vary letter size requirements</td>
</tr>
<tr>
<td>Decreased shoulder ER resulting in difficulty washing hair</td>
<td>Overhead throwing to target with emphasis on external rotation during ‘wind-up’</td>
<td>Varying the distance of the target</td>
</tr>
</tbody>
</table>
Number of reps does not impact HR Range

During 45 minute RTP Session

Pearson's r 0.03683
Number of reps show weak correlation with baseline level of UE function

![Graph showing the relationship between Number of Reps in 45 Min. Session and Baseline FMA Score. The Pearson's r coefficient is 0.32446.](image-url)
Do all patients need a formal stress test?

• AHA/ASA recommend that individuals with stroke undergo a graded exercise test with EKG.
• “If the physician overseeing the patient’s care determines an exercise test is not indicated or such an assessment in a given facility is not possible, the initiation of an exercise training program, individually tailored to a patient’s physical capabilities, should not be delayed.”
• “In lieu of graded maximal exercise tests, submaximal tests may be considered for stroke survivors.” —6MWT

Eliminating barriers to cycling intervention

• Keeping feet on pedals
  – Hypertonic, hypontonic, altered sensation and proprioception
  – Clip in biking shoe
  – Theraband for pedals, hip abduction
  – Warm up time

• Baseline deconditioning
  – 10 min increments with seated rest breaks if needed
Clinical Translation
Summary of Motor, Non-motor, & CV Results

• **Motor**
  – All 3 groups improved overall in motor function
  – VE and FE groups improved ≥ RTP group despite receiving only ~half the RTP reps

• **Non motor**
  – Significant improvement in depression for FE group
  – Global improvements in QOL for all 3 groups

• **Cardiovascular**
  – VE and FE groups displayed improved cardiovascular fitness as measured by peak VO2
Conclusions

• With proper screening, aerobic exercise training (forced & voluntary) is a safe and feasible intervention for individuals with chronic stroke.

• Aerobic exercise (forced & voluntary) when paired with half of an RTP dosage is efficacious in improving:
  — Motor function
  — Mood and Quality of Life
  — Cardiovascular fitness

• FE appears to be superior to VE & time-matched RTP in improving motor impairment
Future Directions

• Larger clinical trial
  — Stratified randomization

• Refining motor outcomes
  — Arm Motor Ability Test
  — Biomechanical Assessment of Bimanual Dexterity

• Further investigate HR response to RTP

• Facilitate the cost-effective implementation of this approach into clinical practice

• Investigate potential mechanism for neuroplasticity
Is Exercise Medicine?

Yes

No
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References


• MacKay-Lyons M. Cardiovascular stress during a contemporary stroke rehabilitation program: Is the intensity adequate to induce a training effect? Arch Phys Med Rehabil. 2002;83:1378-1383


• Stinear CM, Barber PA, Coxon JP, Fleming MK, Byblow WD. Priming the motor system enhances the effects of upper limb therapy in chronic stroke. Brain. 2008;131:1381-1390


• Alberts JL, Linder S, Penko AL, Lowe MJ, Phillips M. It is not about the bike, it is about the pedaling: Forced exercise and parkinson's disease. Exercise Sports Science Reviews. 2011;37:177-186


• Luft A, Macko R, Forrester L, Goldberg A, Hanley DF. Post-stroke exercise rehabilitation: What we know about retraining the motor system and how it may apply to retraining the heart. Cleveland Clinic Journal of Medicine. 2008;75:S83-S86
References

References

• Frick EM, Alberts JL. Combined use of repetitive task practice and an assistive robotic device in a patient with subacute stroke. *Phys Ther*. 2006;86:1378-1386
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