Taking the patient to the next level: High intensity exercise in neurological rehabilitation’

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Terminology

• Physical activity
  – body movements resulting in increased energy expenditure

• Exercise
  – Planned, structured, repetitive activity

• Fitness
  – A set of attributes relating to one’s ability to perform physical activity
Are we active?

• 6 out of 10 men are not active enough to benefit their health
• 7 out of 10 women are not active enough to benefit their health
• Older people are less active/ exercise less
• People with disabilities are less active/exercise
• People from certain ethnic/cultural backgrounds are less active/exercise less
• Activity levels in more developed countries are lower than in less developed countries
FIGURE 2—Prevalence of U.S. men and women meeting the CDC/ACSM physical activity recommendations by age, 2005.
Prevalence of physical inactivity (%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Least developed</th>
<th>Most developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countries according to the quartiles of Human Development Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18.7</td>
<td>27.8</td>
</tr>
<tr>
<td></td>
<td>20.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19.2</td>
<td></td>
</tr>
</tbody>
</table>
How active should we be?

• ACSM/AHA 2007 update:
  • Aerobic activity:
    • 30 min x 5/week (moderate) or
    • 20 min x 3/week (vigorous) or combinations
  • Strength
    • 8-10 exercises; 8-10 repetitions x 2/week
  • More provides for additional benefits
• Older people should also include flexibility and balance exercises and tailor intensity
<table>
<thead>
<tr>
<th>Light &lt;3.0 METs</th>
<th>Moderate 3.0 – 6.0 METs</th>
<th>Vigorous &gt;6.0 METs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>Walking 3.0 mph = 3.3*</td>
<td>Walking, jogging &amp; running</td>
</tr>
<tr>
<td>Walking slowly around home, store or office = 2.0*</td>
<td>Walking at very brisk pace (4 mph) = 5.0*</td>
<td>Walking at very very brisk pace (4.5 mph) = 6.3*</td>
</tr>
<tr>
<td>Household &amp; occupation</td>
<td>Cleaning — heavy: washing windows, car, clean garage = 3.0</td>
<td>Walking/hiking at moderate pace and grade with no or light pack (&lt;10 lb) = 7.0</td>
</tr>
<tr>
<td>Sitting — using computer work at desk using light hand tools = 1.5</td>
<td>Sweeping floors or carpet, vacuuming, mopping = 3.0–3.5</td>
<td>Hiking at steep grades and pack 10–42 lb = 7.5–9.0</td>
</tr>
<tr>
<td>Standing performing light work such as making bed, washing dishes, ironing, preparing food or store clerk = 2.0–2.5</td>
<td>Carpentry — general = 3.6</td>
<td>Jogging at 5 mph = 8.0*</td>
</tr>
<tr>
<td></td>
<td>Carrying — stacking wood = 5.5</td>
<td>Jogging at 6 mph = 10.0*</td>
</tr>
<tr>
<td></td>
<td>Mowing lawn — walk power mower = 5.5</td>
<td>Running at 7 mph = 11.5*</td>
</tr>
<tr>
<td>Leisure time &amp; sports</td>
<td>Badminton — recreational = 4.5</td>
<td>Basketball game = 8.0</td>
</tr>
<tr>
<td>Arts &amp; crafts, playing cards = 1.5</td>
<td>Basketball — shooting around = 4.5</td>
<td>Bicycling — on flat: moderate effort (12–14 mph) = 8.0; fast (14–16 mph) = 10</td>
</tr>
<tr>
<td>Billiards = 2.5</td>
<td>Bicycling — on flat: light effort (10–12 mph) = 6.0</td>
<td>Skiing cross country — slow (2.5 mph) = 7.0; fast (5.0–7.9 mph) = 9.0</td>
</tr>
<tr>
<td>Boating — power = 2.5</td>
<td>Dancing — ballroom slow = 3.0; ballroom fast = 4.5</td>
<td>Soccer — casual = 7.0; competitive = 10.0</td>
</tr>
<tr>
<td>Croquet = 2.5</td>
<td>Fishing from river bank &amp; walking = 4.0</td>
<td>Swimming — moderate/hard = 8–11†</td>
</tr>
<tr>
<td>Darts = 2.5</td>
<td>Golf — walking pulling clubs = 4.3</td>
<td>Tennis singles = 8.0</td>
</tr>
<tr>
<td>Fishing — sitting = 2.5</td>
<td>Sailing boat, wind surfing = 3.0</td>
<td>Volleyball — competitive at gym or beach = 8.0</td>
</tr>
<tr>
<td>Playing most musical instruments = 2.0–2.5</td>
<td>Swimming leisurely = 6.0†</td>
<td>Table tennis = 4.0</td>
</tr>
<tr>
<td></td>
<td>Table tennis = 4.0</td>
<td>Tennis doubles = 5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Volleyball — noncompetitive = 3.0–4.0</td>
</tr>
</tbody>
</table>

Ainsworth, et al. 2000 (1). * On flat, hard surface. † MET values can vary substantially from person to person during swimming as a result of different strokes and skill levels.
Pedometers for all?

Receiving a pedometer increases walking time in older individuals; Petersen 2012

Fig. 3. Total walking (min/week) at 3-month follow-up by age groups in the control group and the pedometer group. (Denmark, 2008).
Health Related benefits of exercise

• Exercise participation reduces health costs in the over 45’s (Nicholl et al. 1994)

• Activity and fitness reduces disease rates in
  • Hypertension
  • Obesity
  • Stroke
  • Coronary artery disease
  • Some cancers
  • Diabetes
  • Osteoporosis (Blair, 1993, 2007; Hooker 2008)

• Physical activity is positively related to Health Related Quality of Life (Klavestrand 2009)
Exercise and brain function

Exercising can help maintain cognitive functions into older age (Colcombe & Kramer 2003)

Fig. 1. Effect sizes for the different process-task types reflecting the four theoretical hypotheses concerning the process-based specificity of the benefits of fitness training. Parenthetical notations on the x-axis indicate the number of effect sizes contributing to the point estimates for each task type in the exercise (E) and nonexercise (C) groups. Error bars show standard errors.
Effects of neurological pathology (Ivey 2006)

- Decreased Aerobic Capacity
  - Inactivity & Functional Decline

- Body Composition
  - Gross muscle atrophy
  - Increased intramuscular fat
  - Obesity

- Muscle Molecular Phenotype
  - Increased fast MHC isoform
  - Altered muscle metabolism

- Inflammatory Markers
  - Increased inflammatory markers in muscle and plasma

- Peripheral Hemodynamics
  - Decreased resting blood flow in paretic leg
  - Decreased peak hyperemic blood flow in paretic leg

- Insulin Resistance
  - Worsening CVD and Stroke Risk

G. 4. Proposed conceptual model of tissue-level changes after stroke, with related functional and metabolic implications. CVD
Weakness in Parkinson’s disease; Folland, Haas and Castle 2011

Fig. 2. Maximum activation of the knee extensors, assessed with the interpolated twitch technique, of Parkinson’s patients On and Off Medication [Mean ± SEM, n = 10]. *P < 0.01.
Circuit class therapy for improving mobility after stroke; English 2010 Cochrane review

N.B. no adverse effects
Improved strength, walking and QL in Parkinson's disease

Improved balance, reduced falls in Parkinson’s disease

Improved mobility after stroke

Reduced fatigue in MS

Improved walking ability in MS

Improved walking performance after stroke

exercise
Aerobic exercise training improves aerobic capacity and mobility in individuals with stroke; Pang 2006

Figure 1 Meta-analysis: aerobic capacity. (a) Peak $\text{VO}_2$. (b) Peak workload. Each set of dot (●) and error bars represent the standardized effect size (SES) and its 95% confidence interval (CI), respectively, for each study. The first author, the number of subjects involved, the SES value and its 95% CI of each study were also indicated beside each respective set of dot and error bars. The pooled SES was indicated by ◆ (all studies) and □ (without Bateman et al.⁶⁸).

Figure 2 Meta-analysis: walking performance. (a) Walking velocity. (b) Walking endurance. The same figure convention was used as in Figure 1.
Exercise Training improves Motor Performance and Corticomotor Excitability in People With Early Parkinson's Disease; Fisher 2008

Fig 2: Pre- and postexercise measures of maximal CSP duration (in milliseconds) for subjects in the (A) zero-intensity, (B) low-intensity, and (C) high-intensity groups. Four subjects within the zero-intensity group participated in the TMS studies compared with 6 subjects in the low-intensity and 5 subjects in the high-intensity exercise groups. The thick black lines represent the average pre-CSP and post-CSP for each group.
Barriers and facilitators

- Built and natural environment
- Resources
- Perceptions and attitudes
- Cost/economic
- Information
- Equipment
- Guidelines, codes, regulations & laws, policies and procedures
- Knowledge, education, training

Rimmer, 2004
Do we support our patients to be sufficiently active?

- ACSM/AHA 2007 update:
  - Aerobic activity:
    - 30 min x 5/week (moderate) or
    - 20 min x 3/week (vigorous) or combinations
  - Strength
    - 8-10 exercises; 8-10 repetitions x 2/week
  - More provides for additional benefits
  - Older people should also include flexibility and balance exercises and tailor intensity
### Guidelines (ACSM, 2003)

<table>
<thead>
<tr>
<th></th>
<th>Stroke/Brain Injury</th>
<th>SCI</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>aerobic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intensity</strong></td>
<td>40-70% VO2peak</td>
<td>50-80% HRpeak</td>
<td>50-70% VO2peak 60-85% HRpeak</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>3-5 x/week</td>
<td>3-5 x/week</td>
<td>3 x/week</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>20-60 min</td>
<td>20-60 min</td>
<td>30 min</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intensity</strong></td>
<td>3 sets/8-12 reps</td>
<td>2-3 sets/8-12 reps</td>
<td>?</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>2x week</td>
<td>2-4x week</td>
<td>Not on same day as aerobic</td>
</tr>
</tbody>
</table>
Do we include intensity of exercise in our treatment plans/goals?

Current ‘work in progress’ at Plymouth University, analysing and coding rehabilitation goals of patients with ‘spinal injuries’ suggests that patient goals do not normally include exercise intensity as a goal component. (unpublished data)
Routine physiotherapy does not induce a cardiorespiratory training effect post-stroke, regardless of walking ability. Kuys et al 2006
Forced exercise Improves Motor Function in Parkinson's Disease; Riddell 2009

Forced exercise: 8 weeks of 1 hr exercise/week of pedalling 30% above their VE cycle pedalling rate
Gait improvements following stroke are speed dependent; Pohl, 2002

**TABLE 2. Training Programs**

<table>
<thead>
<tr>
<th>Component 1</th>
<th>CGT Group (n=20)</th>
<th>LTT Group (n=20)</th>
<th>STT Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12×45 minutes of CGT</td>
<td>12×30 minutes of LTT</td>
<td>12×30 minutes of STT</td>
<td></td>
</tr>
<tr>
<td>8×45 minutes of conventional physiotherapy, gait training allowed</td>
<td>8×45 minutes of conventional physiotherapy, gait training allowed</td>
<td>8×45 minutes of conventional physiotherapy, gait training allowed</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15 hours of treatment</td>
<td>12 hours of treatment</td>
<td>12 hours of treatment</td>
</tr>
</tbody>
</table>

**TABLE 3. Gait Parameters**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CGT Group (n=20)</th>
<th>LTT Group (n=20)</th>
<th>STT Group (n=20)</th>
<th>Overall Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastest comfortable overground walking speed, m/s</td>
<td>0.66±0.42</td>
<td>0.66±0.39</td>
<td>0.61±0.32</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>At baseline</td>
<td>0.84±0.60</td>
<td>0.86±0.57</td>
<td>1.13±0.59</td>
<td></td>
</tr>
<tr>
<td>After 2 weeks</td>
<td>0.97±0.64</td>
<td>1.22±0.74</td>
<td>1.63±0.80</td>
<td></td>
</tr>
<tr>
<td>At end of study</td>
<td>0.66±0.42</td>
<td>0.66±0.39</td>
<td>0.61±0.32</td>
<td></td>
</tr>
<tr>
<td>Cadence, steps/min</td>
<td>79.9±29.7</td>
<td>82.8±33.2</td>
<td>81.6±22.8</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>At baseline</td>
<td>91.4±40.3</td>
<td>89.0±35.5</td>
<td>113.5±28.4</td>
<td></td>
</tr>
<tr>
<td>After 2 weeks</td>
<td>96.8±39.0</td>
<td>115.4±51.9</td>
<td>128.8±30.1</td>
<td></td>
</tr>
<tr>
<td>At end of study</td>
<td>0.46±0.15</td>
<td>0.45±0.13</td>
<td>0.42±0.13</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Stride length, m</td>
<td>0.51±0.18</td>
<td>0.52±0.17</td>
<td>0.57±0.16</td>
<td></td>
</tr>
<tr>
<td>At baseline</td>
<td>0.56±0.17</td>
<td>0.60±0.16</td>
<td>0.72±0.21</td>
<td></td>
</tr>
<tr>
<td>FAC score</td>
<td>3.9±0.7</td>
<td>3.7±0.8</td>
<td>3.7±0.8</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>At baseline</td>
<td>4.3±0.7</td>
<td>4.6±0.6</td>
<td>5.0±0.0</td>
<td></td>
</tr>
<tr>
<td>At end of study</td>
<td>0.46±0.15</td>
<td>0.45±0.13</td>
<td>0.42±0.13</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean±SD.
*Interaction between factors order (STT, LTT, and CGT) and treatment (values at baseline, after 2 weeks, and at end of study) revealed by ANCOVA.
Faster treadmill training improves gait velocity post stroke; Sullivan 2002

Fig 3. Self-selected velocity for each training group (group means) for the training phase and 1-month follow-up (N=24). All groups improved performance over training ($P<.001$) and continued to make improvement between the end of training and the 1-month follow-up ($P<.01$).
High intensity treadmill training improves fitness, gait and balance after stroke; Globas 2012

TAEX: 60-80% HRR

Figure 2. Effects of 3 months TAEX compared with conventional physiotherapy. Effects of 3 months TAEX compared with conventional physiotherapy (control) on cardiovascular fitness (A: VO₂ peak), walking parameters (B: 6 minute walk, C: maximum walking speed in 10-m timed walks), and balance (D: Berg Balance scale). Within-group comparison (paired t): *P < .05, **P < .01, ***P < .001. Between-group comparison (time × group): †P < .05, ††P < .01, †††P < .001.
High intensity strength training improves muscle strength and functional performance after stroke; Ouelette 2004; Weiss 2000

**TABLE 3**

<table>
<thead>
<tr>
<th>Functional performance measures (mean ± SE)</th>
<th>Baseline</th>
<th>Week 4</th>
<th>Week 8</th>
<th>Week 12</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stair climb (8 steps) (sec)</td>
<td>10.3 ± 2.0</td>
<td>10.5 ± 2.2</td>
<td>9.5 ± 1.8</td>
<td>9.2 ± 1.8</td>
<td>0.97</td>
</tr>
<tr>
<td>Repeated chair stand time (5×) (sec)</td>
<td>19.3 ± 2.4</td>
<td>18.9 ± 2.0</td>
<td>18.5 ± 2.1</td>
<td>15.2 ± 2.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Habitual gait velocity (m/sec)</td>
<td>0.70 ± 0.15</td>
<td>0.64 ± 0.17</td>
<td>0.62 ± 0.17</td>
<td>0.67 ± 0.15</td>
<td>0.73</td>
</tr>
<tr>
<td>Unilateral leg stance affected (sec)</td>
<td>4.2 ± 3.2</td>
<td>4.5 ± 2.2</td>
<td>4.8 ± 3.1</td>
<td>5.7 ± 4.0</td>
<td>0.69</td>
</tr>
<tr>
<td>Unilateral leg stance intact (sec)</td>
<td>5.1 ± 1.9</td>
<td>6.5 ± 1.6</td>
<td>7.0 ± 1.8</td>
<td>9.2 ± 2.3</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**TABLE 4**

<table>
<thead>
<tr>
<th>Functional assessment measures (mean ± SE)</th>
<th>Baseline</th>
<th>Week 12</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Assessment Scale</td>
<td>25.8 ± 1.3</td>
<td>28.0 ± 0.6</td>
<td>0.02</td>
</tr>
<tr>
<td>Walking subscale (MAS)</td>
<td>3.7 ± 0.5</td>
<td>4.3 ± 0.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Fugl-Meyer Balance Scale</td>
<td>46.9 ± 1.9</td>
<td>52.6 ± 0.8</td>
<td>0.003</td>
</tr>
</tbody>
</table>

**Figure 2.** Plot of mean paretic and nonparetic knee extensor strength ±SE for the PRT □, n=13, n=21, respectively) and control □, n=11, n=20, respectively) groups at baseline and week 12.

70% 1RM
High intensity eccentric resistance training decreases bradykinesia and improves quality of life in persons with Parkinson's disease; Dibble 2006, 2009

Fig. 3. Bradykinesia changes. Graphs of mean (Standard deviation) for both the a) 10 meter walk and the b) Timed Up and Go are presented. In the 10 meter walk, the experimental group (light bars) demonstrated a 12% increase, while the control group (dark bars) demonstrated a 2% decline. In the Timed Up and Go, the experimental group demonstrated a 17% increase, while the control group demonstrated a 2% decline.

PDQ-39 summary index improved significantly
Safe, no adverse effects
good for everyone

Plasticity

Consumer viewpoint

Positive effects on strength, fitness, mobility and QoL

Higher intensity shows added benefits

Current guidance on exercise in neurological conditions not dissimilar from guidance for healthy

Current research limited to 60-80% of capacity

Evidence based Practice

Frequency - **Intensity** - Type - Time
References and reading


