Return to Running in Patients with Acquired Brain Injury

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Katie Ann Sheeran, PT, DPT

APTA Combined Sections Meeting
February 19, 2016
Objectives

1. Understand the importance of running for appropriate patients after acquired brain injury

2. Understand the normal biomechanics of running

3. Describe running abnormalities after acquired brain injury

4. Utilize the recommended examination techniques and outcome measures for return to running

5. Identify objective criteria to guide initiation of running

6. Utilize the recommended intervention to retrain running
Outline

1. Introduction
2. Normal Biomechanics of running
3. Running abnormalities after Acquired Brain Injury
4. Examination
5. Criteria to initiate training
6. Intervention
7. Case studies
8. Questions
Importance of running for patients after acquired brain injury

The rehabilitation process after an acquired brain injury has traditionally focused on improving a patient’s independence with ambulation, without considering return to higher level activities such as running.
Running can improve..

Quality of life and return to work

(Lindstrom et al., 2009)

Balance and gait

(Hornby et al., 2011)

Cardiovascular health

(Boyne P., 2015)
Patient Goals

Patients with an acquired brain injury who live an active lifestyle, often have a goal to run.

Patient goals may be:

- Return to leisure activity
- Keeping up with children or grandchildren
- Running for public transportation
Traumatic Brain Injury and Running

79% of physically well-recovered men diagnosed with TBI changed their sporting activities

27% did not exercise weekly

58% did not participate in leisure activities > 1 x week

25% reported that difficulty running prevented them from returning to sporting activities

(Rinne et al, 2006)
Stroke and Running

After stroke, people who considered it important to return to work, who retained the ability to run a short distance, and who had support concerning their working situation, had the greatest chance of return to work.

(Lindstrom et al., 2009)
Safety Concerns

- Higher risk for head injury
- Orthopedic injuries
- Safety awareness
- Cardiovascular fitness
- May need clearance from MD
Normal Biomechanics of Running
Running compared to walking

Increased ROM

The greatest amount of work in running is through eccentric contractions

Increased stresses on soft tissues

Increased velocity

Decreased BOS

Increased ground reaction forces

(Dugan and Bhat, 2005)
Gait cycle: A = Walking, B = Running

(Dugan and Bhat, 2005)
Range of Motion

(Novacheck, 1998)
Muscle activation when running

(Novacheck, 1998)
Power Generators

Walk
(1.2 m/sec)

Run
(3.2 m/sec)

Sprint
(3.9 m/sec)

(Novacheck, 1998)
Running abnormalities after Acquired Brain Injury
Factors that may affect running after Acquired Brain Injury

- Safety awareness / judgment
- Spasticity / tone
- Impaired motor control
- ROM restrictions
- Visual deficits
- Poor endurance
- Motivation

(Sache et. al, 2014)
Running abnormalities after Traumatic Brain Injury

- Higher cadence and shorter stride length to attain a similar speed
- Reduced stance and flight phases
- Increased width of BOS and lateral COM displacement, indicating postural instability
- Greater amplitude of pelvic axial rotation

(Morris, Schache and Williams, 2013)
Running abnormalities after Traumatic Brain Injury

Significantly reduced knee power absorption in early stance phase

Excessive knee flexion at toe off and initial contact

Excessive knee extension at mid stance

Reduced ankle power generation at push-off

Increased hip extensor power generation in early stance

(Morris, Schache and Williams, 2013)
Video 1
Video 2
Examination
Evaluation
Examination

• Interview

• Body Functions and Structures / Impairments Level

• Activity Level and Skills Performance

• Participation Level
Subjective Data and Interview

• History of Present Condition
  – Occurrence of relevant incident
  – Care received acutely and rehabilitation course

• Relevant and Recent Surgeries
  – Contraindications such as patients with craniectomies awaiting cranioplasty procedures

• Past Medical History
  – Concurrent Morbidities
Subjective Data and Interview

- Current Medication List
  - Seizures, hyper- / hypo-tension
- Diagnostic Tests
- Fall History
- Social History / Home Environment
  - Home Access
    - Assistance Required / Receiving
  - Work Status
  - Primary Language Spoken
  - Evidence of Abuse / Neglect
- Precautions List
Subjective Data and Interview

- Prior Level of Function
- Previous Outpatient Therapy Course Prior to Current Evaluation
- Current Level of Function
International Classification of Functioning, Disability, and Health

Box 1: The ICF Model: Interaction between ICF components

![Diagram showing the interaction between Health condition (disorder or disease), Body Functions and Structures, Activities, Participation, Environmental Factors, and Personal Factors.]

*WHO 2001, 18*

(Word Health Organization, 2001)
Systems Review

- **Cardiovascular / Pulmonary**
  - Blood Pressure
  - SpO2 %
  - Heart Rate

- **Integumentary**

- **Musculoskeletal**

- **Neuromuscular**

- **Cognitive Component**
  - Communication / Affect
    - Language
    - Ability to make needs known
    - Learning preferences and style
  - Cognition
    - Consciousness
    - Orientation (Person, Place, Time)
  - Expected Emotional / Behavioral Responses
Body Functions and Structures: Impairment Level

Musculoskeletal

• Extremity AROM / PROM
  – UE involvement*
  – Knee FLEX*Ankle Dorsi- / Plantar-flexion, Hip FLEX / EXT,
• Muscle Length / Flexibility Testing
  – Hip flexors, Plantar flexors

Neuromuscular

• Motor Control / Spasticity / Tone
  – (STREAM / Modified Ashworth Scale)
• MMT
  – Hip Flexors*
  – Ankle Plantar-flexors*
  – Hip Extensors*
• Proprioception / Spatial Awareness / Sensation
• Balance
  – SLS, Romberg, EO / EC
Gait Assessment

(Dugan and Bhat, 2005)
(Requiao, 2005)
(Mann, 1980)
## Spasticity

### Initial

<table>
<thead>
<tr>
<th></th>
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<tbody>
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<td>Participants, n</td>
<td>34</td>
<td>41</td>
<td>3</td>
<td>15</td>
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<tr>
<td>Age, y</td>
<td>29.2 +/- 12.9</td>
<td>29.9 +/- 9.9</td>
<td>25.0 +/- 2.7</td>
<td>26.8 +/- 8.9</td>
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<tr>
<td>Gait Velocity, m/s</td>
<td>1.21 +/- 0.35</td>
<td>0.96 +/- 0.33</td>
<td>0.67 +/- 0.09</td>
<td>0.91 +/- 0.47</td>
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<tr>
<td>HiMAT score, (/54)</td>
<td>24.4 +/- 12.2</td>
<td>20.0 +/- 11.1</td>
<td>9.0 +/- 8.5</td>
<td>18.2 +/- 12.4</td>
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</table>

### 6-month follow-up

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<tbody>
<tr>
<td>Participants, n</td>
<td>9</td>
<td>14</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Gait Velocity, m/s</td>
<td>1.29 +/- 0.23</td>
<td>1.34 +/- 0.17</td>
<td>0.83 +/- 0.05</td>
<td>0.88 +/- 0.48</td>
</tr>
<tr>
<td>HiMAT score, (/54)</td>
<td>33.7 +/- 14.5</td>
<td>33.5 +/- 9.3</td>
<td>18.0 +/- 0.05</td>
<td>16.4 +/- 8.4</td>
</tr>
<tr>
<td>Mean HiMAT change</td>
<td>14.8 +/- 12.5</td>
<td>14.3 +/- 7.7</td>
<td>9.0 +/- 8.2</td>
<td>8.0 +/- 5.9</td>
</tr>
</tbody>
</table>
APTA EDGE Task Force (Evaluation Database to Guide Effectiveness)
StrokEDGE

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

Recommended measures:
- 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
- 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

Task force Co-chairs: Jane Sullivan, PT, DHS, Genevieve Pinto-Zipp, PT, EdD; Members: Beth Crownner, PT, DPT, NCS, Patty Kluding, PT, PhD, Diane Nichols, PT, NCS, Dorian Rose, PT, PhD, Rie Yoshida, PT, DPT

(Sullivan, et al. 2011)
**TBI EDGE**

**Recommendations for patients with traumatic brain injury:**

**Highly recommended measures**

**Inpatient only:** Coma Recovery Scale-Revised  
Moss Attention Rating Scale  

**Outpatient only:** High Level Mobility Assessment

**Recommended measures (both in- and outpatient):**

- 6 minute walk
- 10 meter walk
- Berg Balance Scale
- Community Balance and Mobility Scale
- Disability Rating Scale
- Functional Assessment Measure
- Modified Ashworth Scale
- Patient Health Questionnaire
- Quality of Life after Brain Injury
- Rancho Levels of Cognitive Function

**Recommended measures (inpatient only):**

- Agitated Behavioral Scale
- Barthel Index
- Cog-Log and O(rientation)-Log
- Disorders of Consciousness Scale
- FIM

**Recommended measures (outpatient only):**

- Action Research Arm Test
- Apathy Evaluation Scale
- Balance Error Scoring Scale
- Community Integration Questionnaire
- Dizziness Handicap Inventory
- Global Fatigue Index
- Sydney Psychosocial Reintegration Scale

**Task force members:** Karen McCulloch, PT, PhD, NCS and Anna de Joya, PT, DSc, NCS (co-chairs); Erin Donnelly, PT, NCS, Kaitlin Hays, PT, DPT, Tammie Keller Johnson, PT, DPT, MS, Coby Nirider, PT, DPT, Heidi Roth, PT, DHS, NCS, Sue Saliga, PT, MS, DHSc, Irene Ward, PT, DPT, NCS

(APTA, 2015)
ICF– Activity Domain

Activities-Specific Balance Confidence Scale (ABC)

- SEM: 5.05 – 6.1
- Cutoff Score: 81.1% (non-fallers)
  - <67% (captures 84% healthy population)
- Normative: 68.3% (79.89% healthy)
- Test-Retest:
  - Total Score: ICC Excellent (0.85)

6MWT

- MDC: 34 – 61 m (112 – 200 ft)
- MCID: 50 m (164 ft)
- Normative: 408 – 422 m (1339 – 1385 ft)
- Test-Retest: ICC Excellent (0.80 – 0.99 distance and VO2)
- Intra-rater Reliability: ICC Adequate (0.74 – 0.76)

(Rehab Measures)
## Motor Skills Assessment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounding onto a single leg</td>
<td>Partial tandem, non-affected -&gt; affected with NSP, toe of to IC</td>
</tr>
<tr>
<td>Toe walking</td>
<td>Forefoot walking without heel strike, flat surface, as long as possible</td>
</tr>
<tr>
<td>Backward step up</td>
<td>8-10” away, step up with affected side, without UE support, ½” increments</td>
</tr>
<tr>
<td>Time standing on one leg</td>
<td>Timed standing on “weaker” leg, ended with non-support foot contact or stabilizing with stance leg</td>
</tr>
</tbody>
</table>

(Williams and Goldies, 2001)
Timed Standing on One Leg

Single Leg Stance (SLS) (Williams, 2011)
Affected versus Non-affected
Eyes Open / Closed
  Maximum of 30 seconds
Average of 3 trials each scenario
Summed to create “Total SLS Score” maximum is 120 seconds

(Williams and Goldies, 2001)
Motor Skills Assessment –

• (Video)

• Bounding

• Toe Walking

• Retro-Step Up

• SLS
ICF – Activity Domain
10 Meter Walk Test / Gait Speed

**Stroke**
- MCID: 0.16 m / sec
- Cutoff Scores:
  - < 0.4 m / sec
  - 0.4 – 0.8 m / sec
  - > 0.8 m / sec
- Normative: 0.84 +/- 0.3 m / sec
- Test-Retest: ICC Excellent (0.94 – 0.99)
- Intra-rater Reliability: ICC Excellent (0.87 – 0.99)

**TBI**
- MDC: > 0.05 m / sec
- MCID SS: 0.15 m / sec
- MCID Fast: 0.25 m / sec
- Test-Retest: ICC Excellent (0.95 – 0.99)
- Intra-rater Reliability: ICC Excellent (0.99)

(Rehab Measures)
Gait Speed and Quality

**TABLE 2** Relationship between predictor variables and ability to run (n = 97)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Range</th>
<th>$r_{pb}$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral center of mass displacement</td>
<td>93.2 (40.9)</td>
<td>38.9-246.2</td>
<td>−0.50</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Ankle power generation push-off</td>
<td>1.25 (0.77)</td>
<td>0.01-3.40</td>
<td>0.48</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Gait Profile Score</td>
<td>11.3 (2.2)</td>
<td>7.4-21.2</td>
<td>−0.36</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Self-selected walking speed</td>
<td>0.99 (.37)</td>
<td>0.05-1.80</td>
<td>0.64</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

**TABLE 3** Logistic regression modeling the ability to run (n = 97)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>$P$</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-selected walking speed</td>
<td>6.42</td>
<td>1.94</td>
<td>10.99</td>
<td>1</td>
<td>.001</td>
<td>615.78</td>
<td>13.82-27439.21</td>
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<tr>
<td>Lateral center of mass displacement</td>
<td>−.01</td>
<td>0.01</td>
<td>0.14</td>
<td>1</td>
<td>.709</td>
<td>1.00</td>
<td>0.97-1.02</td>
</tr>
<tr>
<td>Ankle power generation push-off</td>
<td>−.21</td>
<td>0.55</td>
<td>0.15</td>
<td>1</td>
<td>.700</td>
<td>0.81</td>
<td>0.28-2.37</td>
</tr>
<tr>
<td>Gait Profile Score</td>
<td>−.25</td>
<td>0.17</td>
<td>2.11</td>
<td>1</td>
<td>.147</td>
<td>0.78</td>
<td>0.56-1.09</td>
</tr>
<tr>
<td>Constant</td>
<td>−3.42</td>
<td>2.63</td>
<td>1.69</td>
<td>1</td>
<td>.193</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

(Williams, 2013)
## Gait Speed and Quality

<table>
<thead>
<tr>
<th>Self-selected walking speed, m/s</th>
<th>10-m walk time, s</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>0.1</td>
<td>100.0</td>
<td>1.901</td>
</tr>
<tr>
<td>0.2</td>
<td>50.0</td>
<td>3.614</td>
</tr>
<tr>
<td>0.3</td>
<td>33.3</td>
<td>6.870</td>
</tr>
<tr>
<td>0.4</td>
<td>25.0</td>
<td>13.061</td>
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<td>0.5</td>
<td>20.0</td>
<td>24.830</td>
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<td>0.6</td>
<td>16.7</td>
<td>47.204</td>
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<td>0.7</td>
<td>14.3</td>
<td>89.737</td>
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<td>0.8</td>
<td>12.5</td>
<td>170.596</td>
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<tr>
<td>0.9</td>
<td>11.1</td>
<td>324.314</td>
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<tr>
<td>1.0</td>
<td>10.0</td>
<td>616.540</td>
</tr>
<tr>
<td>&gt;1.1</td>
<td>&lt;9.1</td>
<td>999.999</td>
</tr>
</tbody>
</table>

(Williams, 2013)
Summarizing Gait Speed and Quality

- Gait speed
  - Characteristics
    - Decreased lateral COM displacement (improved postural stability)
    - Ankle power generation push-off

- Gait profile score via 3-dimensional analysis
  - More “normal” walking, indicates higher likelihood of running
Gait Speed and Quality Assessment

Figure 1. Distribution of runners and nonrunners by gait speed and high-level mobility assessment tool (HiMAT) Scores. The graph shows the relationship between self-selected walking speed, HiMAT scores, and the ability to run. Runners are represented by the circles and nonrunners by the dots. The vertical dashed reference line represents the 1.06 m/s threshold for running.

(Williams, 2013)
# HIMAT: HIGH LEVEL MOBILITY ASSESSMENT TOOL

**DATE**

**DATE OF ACCIDENT**

**DIAGNOSIS**

**AFFECTED SIDE** LEFT / RIGHT

<table>
<thead>
<tr>
<th>ITEM</th>
<th>PERFORMANCE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>SCORE</th>
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<tbody>
<tr>
<td>WALK</td>
<td>sec</td>
<td>X</td>
<td>&gt;6.6</td>
<td>5.4-6.6</td>
<td>4.3-5.3</td>
<td>&lt;4.3</td>
<td>X</td>
<td></td>
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<tr>
<td>WALK BACKWARD</td>
<td>sec</td>
<td>&gt;13.3</td>
<td>8.1-13.3</td>
<td>5.8-8.0</td>
<td>&lt;5.8</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WALK ON TOES</td>
<td>sec</td>
<td>&gt;8.9</td>
<td>7.0-8.9</td>
<td>5.4-6.9</td>
<td>&lt;5.4</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WALK OVER OBSTACLE</td>
<td>sec</td>
<td>&gt;7.1</td>
<td>5.4-7.1</td>
<td>4.5-5.3</td>
<td>&lt;4.5</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN</td>
<td>sec</td>
<td>&gt;2.7</td>
<td>2.0-2.7</td>
<td>1.7-1.9</td>
<td>&lt;1.7</td>
<td>X</td>
<td></td>
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<tr>
<td>SKIP</td>
<td>sec</td>
<td>&gt;4.0</td>
<td>3.5-4.0</td>
<td>3.0-3.4</td>
<td>&lt;3.0</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOP FORWARD (AFFECTED)</td>
<td>sec</td>
<td>&gt;7.0</td>
<td>5.3-7.0</td>
<td>4.1-5.2</td>
<td>&lt;4.1</td>
<td>X</td>
<td></td>
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<tr>
<td>BOUND (AFFECTED)</td>
<td>cm</td>
<td>&lt;80</td>
<td>80-103</td>
<td>104-132</td>
<td>132</td>
<td>X</td>
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<tr>
<td>BOUND (LESS-AFFECTED)</td>
<td>cm</td>
<td>&lt;82</td>
<td>82-105</td>
<td>106-129</td>
<td>129</td>
<td>X</td>
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<tr>
<td>UP STAIRS DEPENDENT (Rail OR not reciprocal: if not score 5 and rate below)</td>
<td>sec</td>
<td>&gt;22.8</td>
<td>14.6-22.8</td>
<td>12.3-14.5</td>
<td>&lt;12.3</td>
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<tr>
<td>UP STAIRS INDEPENDENT (No rail AND reciprocal: if not score 0 and rate above)</td>
<td>sec</td>
<td>&gt;9.1</td>
<td>7.6-9.1</td>
<td>6.8-7.5</td>
<td>&lt;6.8</td>
<td>X</td>
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<tr>
<td>DOWN STAIRS DEPENDENT (Rail OR not reciprocal: if not score 5 and rate below)</td>
<td>sec</td>
<td>&gt;24.3</td>
<td>17.6-24.3</td>
<td>12.8-17.5</td>
<td>&lt;12.8</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DOWN STAIRS INDEPENDENT (No rail AND reciprocal: if not score 0 and rate above)</td>
<td>sec</td>
<td>&gt;8.4</td>
<td>6.6-8.4</td>
<td>5.8-6.5</td>
<td>&lt;5.8</td>
<td>X</td>
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<td></td>
</tr>
</tbody>
</table>

**TOTAL Himat Score** /54

Please notify Gavin Williams at gavin@neuro-solutions.net or gavin.williams@epworth.org.au so that the use of the Himat can be tracked.

(Williams, 2005)
HiMAT: High-level Mobility Assessment Tool

Instructions

**Subject suitability:** The HiMAT is appropriate for assessing people with high-level balance and mobility problems. The minimal mobility requirement for testing is independent walking over 20m without gait aids. Orthoses are permitted.

**Item testing:** Testing takes 5-10 minutes. Patients are allowed 1 practice trial for each item.

**Instructions:** Patients are instructed to perform at their maximum safe speed except for the bounding and stair items.

- **Walking:** The middle 10m of a 20m trial is timed.
- **Walk backward:** As for walking.
- **Walk on toes:** As for walking. Any heel contact during the middle 10m is recorded as a fail.
- **Walk over obstacle:** As for walking. A house brick is placed across the walkway at the mid-point. Patients must step over the brick without contacting it. A fail is recorded if patients step around the brick or make contact with the brick.
- **Run:** The middle 10m of a 20m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
- **Skipping:** The middle 10m of a 20m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
- **Hop forward:** Patients stand on their more affected leg and hop forward. The time to hop 10m meters is recorded.
- **Bound (affected):** A bound is a jump from one leg to the other with a flight phase. Patients stand behind a line on their less affected leg, hands on hips, and jump forward **landing on their more affected leg.** Each bound is measured from the line to the heel of the landing leg. The average of three trials is recorded.
- **Bound (less-affected):** Patients stand behind a line on their more affected leg, hands on hips, and jump forward **landing on their less affected leg.** The average of three trials is recorded.
- **Up stairs:** Patients are asked to walk up a flight of 14 stairs as they normally would and at their normal speed. The trial is recorded from when the patient starts until both feet are at the top. Patients who use a rail or a non-reciprocal pattern are scored as **Up Stairs Dependent.** Patients who ascend the stairs reciprocally without a rail are scored as **Up Stairs Independent** and get an additional 5 points in the last column of Up Stairs Dependent.
- **Down stairs:** As for Up stairs.

**Scoring:** All times and distances are recorded in the “performance” column. The corresponding score for each item is then circled and each column is then subtotaled. Subtotals are then added to calculate the HiMAT score.

(Williams, 2005)
HiMAT Prerequisites

HiMAT: High-level Mobility Assessment Tool

Instructions

Subject suitability: The HiMAT is appropriate for assessing people with high-level balance and mobility problems. The minimal mobility requirement for testing is independent walking over 20m without gait aids. Orthoses are permitted.

Item testing: Testing takes 5-10 minutes. Patients are allowed 1 practice trial for each item.

Instructions: Patients are instructed to perform at their maximum safe speed except for the bounding and stair items.

(Williams, 2005)

20 m = 65.62 ft
10 m = 32.81 ft
HiMAT – Acquired / Traumatic BI Population

Original Version
- SEM: 1.36 points
- MDC:
  - Increase of 4 points
  - Decrease of 2 points
- Test-Retest: ICC Excellent (0.99)
- Inter / Intra-Rater Reliability: ICC Excellent (0.99)
- Internal Consistency: ICC Excellent (0.99)

Revised 8-Item Version
- SEM: 0.79
- MDC:
  - Increase of 2 points
  - Decrease of 1 point
- Test-Retest: ICC Excellent (0.99)
- Internal Consistency: ICC Excellent (0.99)
## HiMAT

<table>
<thead>
<tr>
<th>ITEM</th>
<th>PERFORMANCE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALK</td>
<td>sec</td>
<td>X</td>
<td>&gt; 6.6</td>
<td>5.4-6.6</td>
<td>4.3-5.3</td>
<td>&lt; 4.3</td>
<td>X</td>
</tr>
<tr>
<td>WALK BACKWARD</td>
<td>sec</td>
<td></td>
<td>&gt;13.3</td>
<td>8.1-13.3</td>
<td>5.8-8.0</td>
<td>&lt; 5.8</td>
<td>X</td>
</tr>
<tr>
<td>WALK ON TOES</td>
<td>sec</td>
<td></td>
<td>&gt; 8.9</td>
<td>7.0-8.9</td>
<td>5.4-6.9</td>
<td>&lt; 5.4</td>
<td>X</td>
</tr>
<tr>
<td>WALK OVER OBSTACLE</td>
<td>sec</td>
<td></td>
<td>&gt; 7.1</td>
<td>5.4-7.1</td>
<td>4.5-5.3</td>
<td>&lt; 4.5</td>
<td>X</td>
</tr>
<tr>
<td>RUN</td>
<td>sec</td>
<td></td>
<td>&gt; 2.7</td>
<td>2.0-2.7</td>
<td>1.7-1.9</td>
<td>&lt; 1.7</td>
<td>X</td>
</tr>
<tr>
<td>SKIP</td>
<td>sec</td>
<td></td>
<td>&gt; 4.0</td>
<td>3.5-4.0</td>
<td>3.0-3.4</td>
<td>&lt; 3.0</td>
<td>X</td>
</tr>
<tr>
<td>HOP FORWARD (AFFECTED)</td>
<td>sec</td>
<td></td>
<td>&gt; 7.0</td>
<td>5.3-7.0</td>
<td>4.1-5.2</td>
<td>&lt; 4.1</td>
<td>X</td>
</tr>
<tr>
<td>BOUND (AFFECTED)</td>
<td>cm</td>
<td></td>
<td>&lt; 80</td>
<td>80-103</td>
<td>104-132</td>
<td>&gt; 132</td>
<td>X</td>
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<tr>
<td>BOUND (LESS-AFFECTED)</td>
<td>cm</td>
<td></td>
<td>&lt; 82</td>
<td>82-105</td>
<td>106-129</td>
<td>&gt; 129</td>
<td>X</td>
</tr>
<tr>
<td>UP STAIRS DEPENDENT</td>
<td>sec</td>
<td></td>
<td>&gt;22.8</td>
<td>14.6-22.8</td>
<td>12.3-14.5</td>
<td>&lt; 12.3</td>
<td></td>
</tr>
<tr>
<td>(Rail OR not reciprocal: if not, score 5 and rate below)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UP STAIRS INDEPENDENT</td>
<td>sec</td>
<td></td>
<td>&gt; 9.1</td>
<td>7.6-9.1</td>
<td>6.8-7.5</td>
<td>&lt; 6.8</td>
<td>X</td>
</tr>
<tr>
<td>(No rail AND reciprocal: if not score 0 and rate above)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOWN STAIRS DEPENDENT</td>
<td>sec</td>
<td></td>
<td>&gt;24.3</td>
<td>17.6-24.3</td>
<td>12.8-17.5</td>
<td>&lt; 12.8</td>
<td></td>
</tr>
<tr>
<td>(Rail OR not reciprocal: if not score 5 and rate below)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOWN STAIRS INDEPENDENT</td>
<td>sec</td>
<td></td>
<td>&gt; 8.4</td>
<td>6.6-8.4</td>
<td>5.8-6.5</td>
<td>&lt; 5.8</td>
<td>X</td>
</tr>
<tr>
<td>(No rail AND reciprocal: if not score 0 and rate above)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Williams, 2005)
HiMAT - < 14 stairs

<table>
<thead>
<tr>
<th>14</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Time X</td>
<td>-------------------------------</td>
</tr>
<tr>
<td># of Steps</td>
<td></td>
</tr>
</tbody>
</table>

= Adjusted HiMAT Time

- Tested with 6 / 8 / 11 / 14 steps
  - Average inflation of 0.5 points with 6 vs. 14 steps
- Correlation
  - 0.80 – 0.98 up stairs
  - 0.92 – 0.95 down stairs

The Center for Outcome Measurement in Brain Injury (COMBI)
Walk

• (Video)

Walking: The middle 10m of a 20m trial is timed.
Walk Backward

• (Video)
Walk on Toes

- (Video)

Walk on toes: As for walking. Any heel contact during the middle 10m is recorded as a fail.
Walk Over Obstacle

- (Video)

- Walk over obstacle: As for walking. A house brick is placed across the walkway at the mid-point. Patients must step over the brick without contacting it. A fail is recorded if patients step around the brick or make contact with the brick.
Run: The middle 10m of a 20m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Skipping: The middle 10m of a 20m trial is timed. A fail is recorded if patients fail to have a consistent flight phase during the trial.
Hop Forward (Affected)

• (Video)

Hop forward: Patients stand on their more affected leg and hop forward. The time to hop 10 meters is recorded.
Bound (Affected / Less-Affected)

- (Video)

Bound (affected). A bound is a jump from one leg to the other with a flight phase. Patients stand behind a line on their less affected leg, hands on hips, and jump forward **landing on their more affected leg**. Each bound is measured from the line to the heel of the landing leg. The average of three trials is recorded.

Bound (less-affected). Patients stand behind a line on their more affected leg, hands on hips, and jump forward **landing on their less affected leg**. The average of three trials is recorded.
Up Stairs Dependent / Independent

• (Video)

Up stairs: Patients are asked to walk up a flight of 14 stairs as they normally would and at their normal speed. The trial is recorded from when the patient starts until both feet are at the top. Patients who use a rail or a non-reciprocal pattern are scored on Up Stairs Dependent. Patients who ascend the stairs reciprocally without a rail are scored on Up Stairs Independent and get an additional 5 points in the last column of Up Stairs Dependent.
Down Stairs Dependent / Independent

- (Video)

Down stairs: As for Up stairs.

Up stairs: Patients are asked to walk up a flight of 14 stairs as they normally would and at their normal speed. The trial is recorded from when the patient starts until both feet are at the top. Patients who use a rail or a non-reciprocal pattern are scored on Up Stairs Dependent. Patients who ascend the stairs reciprocally without a rail are scored on Up Stairs Independent and get an additional 5 points in the last column of Up Stairs Dependent.
## Mobility Hierarchy

### TABLE 1: Mobility hierarchy

<table>
<thead>
<tr>
<th>Logit score</th>
<th>Items</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>HiMAT—Hop</td>
</tr>
<tr>
<td>4</td>
<td>HiMAT—Skip</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Run</td>
</tr>
<tr>
<td>3</td>
<td>HiMAT—Descend stairs—independent</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Bounding</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Ascend stairs—independent</td>
</tr>
<tr>
<td>2</td>
<td>HiMAT—Walk on toes</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Walk over obstacle</td>
</tr>
<tr>
<td>1</td>
<td>HiMAT—Walk backward</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Walk</td>
</tr>
<tr>
<td>-1</td>
<td>HiMAT—Descend stairs—dependent</td>
</tr>
<tr>
<td></td>
<td>HiMAT—Ascend stairs—dependent</td>
</tr>
</tbody>
</table>

(Williams, 2010)
Impressions…

• Motor Skills Assessment (Bound, Toe-Walk, Retro-Step, SLS)
• Gait Speed: 1.0 m / sec or greater recommended to initiate HLM
  – 2.0 to 2.7 transition speed from walking to running in healthy population – Unknown in this population (Schache, 2014; Hreljac, 1993; Neptune, 2005; Pandy, 2010)
• Gait Quality
• HiMAT scores… inconclusive
  – NSP
    • Ankle plantarflexion motor control
      – Compensatory mobility
• Ceiling Effect on Other Outcome Measures
Interventions
Preliminary Considerations

• Many impairments interfering with running
  – Tone
  – Impaired motor control
  – Weakness
  – Limited PROM
  – Impaired balance
  – Impaired coordination
  – Impaired cognition

• Safety consideration
  – Fall
  – Musculoskeletal injuries

(Moriello et. al, 2009)
Interventions

Impairments

Skill acquisition
Impairments

- Core strengthening
- Balance
- Functional strengthening
- Endurance
Core strengthening

• A stable trunk is important for running

• Can be included in balance training

• Can incorporate UE movement

• Examples of exercises:
  – Plank
  – Alternate arm and leg movement
    • Quad, prone, supine
    • Physioball, foam roll

(Williams G et. al, 2013; Wilk B et. al, 2008)
Balance

• Being able to stand on one leg predict return to running

• Running is a single support to no support mobility

• Challenge different sensory system

• Examples:
  – Static: romberg
  – Dynamic:
    • slow: tandem walk, squat on foam
    • fast dynamic: DGI type activities, throwing/catching while walking

(Williams and Goldie, 2001; Williams and Schache, 2010; Wilk et. al, 2008)
Functional strengthening

• Running requires increase LE strength – especially PF and hip flex

• Closed chain exercises:
  – Decrease shear force
  – Increase proprioception
  – Increase muscle group coordination (timing)
  – Improve functional performance
  – Strengthen hip/knee/ankle muscles

• Open chain exercises:
  – Emphasis on hip and knee flex

(Wilk et. al, 2008; Williams and Morris, 2009; Miller et. Al, 2008; Williams and Schache, 2010; Schache et. al, 2014; Moriello et. al, 2009, Williams et al, 2013)
Examples

LT step up
• video

RT step up
• video
Example

• video
Example

• video
Functional strengthening

• Plyometrics
  – Build eccentric strength
  – Develop muscle power - force with speed

(Wilk et. al, 2008; Williams and Morris, 2009; Miller et. Al, 2008; Williams and Schache, 2010; Schache et. al, 2014; Moriello et. al, 2009)
Examples

Double Hopping

• video

Alternate Bounding

• video
Endurance

• Running is a vigorous intensity physical activity – greater than 6 MET (WHO) and 17-19 RPE (AHA)

• Aerobic exercise recommendations for stroke survivors from AHA
  – Intensity: 11-14 RPE
  – Duration: 10-60 min or multiple of 10 min
  – Frequency: 3 to 7 days a week

• Interval training – alternate walking and running (Boyne 2015)
  – Mix neuromuscular intensity and aerobic intensity
Guideline for safe exercise prescriptions:

– Discontinue if ↓ SBP with ↑ workload w/ signs and symptoms
– Discontinue if ↓ SBP less than resting SBP
– Discontinue if hypertensive – SBP > 260 mm Hg, DBP > 115 mm Hg
– Discontinue if signs of poor perfusion – pallor, cyanosis, cold, clammy
– Discontinue if unusual/severe fatigue, severe SOB
– Discontinue if increased chest pain
– Discontinue if patient request

(ACSM)
Example

UE support

• Video

No UE support

• Video
Skill Acquisition
Skill Acquisition

• The content of next slides is primarily based on the work done by Williams and Schache presented in 2 articles:

• Evaluation of a conceptual framework for Retraining High Level Mobility following TBI: 2 case report. J Head Trauma Rehabilitation 2010.
  – Offer a hierarchical structure and progression to higher mobility skills following the development of HiMat presented earlier by Mike
  – Apply biomechanical parameter of running to guide intervention
  – Breakdown running into different components/skills

• Lower Limb Muscle Strategies for Increasing Running Speed. JOSPT, 2014.
  – Breakdown running into different components/skills
Skill Acquisition

- Pre-running mobility skill acquisition
- Running skills acquisition
- Post running mobility skill acquisition

(Williams and Schache, 2010; Williams et. al, 2013)
Pre-Running Mobility Skill Acquisition

- Walking
  - Achieving a speed of 1 m/s

- Stairs
  - Ascending/descending using hand rail

- Walking backward

- Walking over obstacles

- Walking on toes

- Stairs
  - Ascending without hand rail
  - Descending without hand rail

- Bounding

(Williams and Schache, 2010; Williams et. al, 2013)
Running skill acquisition

• Simulate the biomechanical demands of running

• How running is different from walking:
  – Single support
  – Floating phase
  – Narrow BOS
  – Forward velocity
  – Greater force
  – Greater angular velocity

• 2 strategies to run:
  – Increase generation force in stance
  – Increase frequency of step in swing

(Schache et. al, 2014; Williams and Schache, 2010)
Running Skill Acquisition

• Stance Phase
  – Force production part I
  – Force production part II

• Swing phase
  – Frequency of steps
Force Generation in Stance phase – Part I

- Retraining loading/unloading of Lower Extremity
  - Deceleration/Acceleration
  - Initiate training in **vertical plane**
  - Progression:
    - Gravity minimized
    - Trampoline
    - Ground
  - Increase frequency of step
    - Goal decrease stance time
  - Increase knee lift
    - Goals increase hip flexion

(Schache et. al, 2014; Williams and Schache, 2010)
Loading/Unloading gravity minimized

RT single hop
• video

LT single hop
• video
Fast feet gravity minimized

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>• video</td>
<td>• video</td>
</tr>
</tbody>
</table>
Fast feet trampoline

• video
Fast feet on ground

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>• video</td>
<td>• video</td>
</tr>
</tbody>
</table>
Force Generation in Stance Phase – Part II

• Introduce horizontal plane movement

• Retrain the limb to move COM in the vertical and horizontal plane

• Bounding

• Series of Bounding

(Schache et. al, 2014; Williams and Schache, 2010)
LT Bounding

video

video
RT Bounding

• video

• video
Alternate Bounding

- video

- video
Frequency of Steps - Swing phase

• Practice swing phase movement in standing
  
  – Hip/knee flex at 90 degrees → hip/knee extension → hip/knee flexion (knee flex > 90 degrees → resume starting position)
  
  – Increase precision of movement
  
  – Increase speed of movement

(Schache et. al, 2014)
Swing phase

speed

• video

precision

• video
Running - Bring everything together

- From running in place to series of bounding
- Introduce running forward by increasing stride length
- Body weight supported system

(Schache et. al, 2014; Moriello et. al, 2009; Miller et. al, 2008; Williams and Schache, 2010)
Running

• video

• video
Post Running Skill Acquisition

• Agility drills
  – Running fwd/bwd
  – Running sideways rt/lt

• Skipping

• Hopping

(Williams and Morris, 2009; Wilk et. al, 2008)
Dosage of Therapy

• Literature:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Frequency</th>
<th>Duration</th>
<th>Volume</th>
<th>Setting</th>
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</thead>
<tbody>
<tr>
<td>Williams 2010</td>
<td>2x per week</td>
<td>1 hr for 3 months</td>
<td>24 hours</td>
<td>group</td>
</tr>
<tr>
<td>Moriello 2009</td>
<td>1x per week</td>
<td>1.5 hrs for 9 months</td>
<td>57 hours</td>
<td>individual</td>
</tr>
<tr>
<td>Williams 2009</td>
<td>2x per week</td>
<td>1 hr for 3 months</td>
<td>24 hours</td>
<td>group</td>
</tr>
<tr>
<td>Miller 2008</td>
<td>3x per week</td>
<td>0.5 hr for 2 months</td>
<td>12 hours</td>
<td>individual</td>
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</table>

• In our clinic

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Duration</th>
<th>Volume</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x per week</td>
<td>.5 to 1 hr for 2 to 6 month</td>
<td>8 to 48 hours</td>
<td>individual</td>
</tr>
</tbody>
</table>
Case Studies
Case Studies

1 – Traumatic Brain Injury

2 – Cerebral Vascular
Case Study #1

HPI: 35 yo TBI – hit by a bus on 9/2014, s/p craniectomy, coma x 1 month. IE on 02/2015, pending cranioplasty

PMH/PSH: insignificant

SH: Prior to injury: Independent; worked full time as an accountant

    Post injury: long term disability, now lives with family

PLOF: Independent with all activities; travelled frequently

CLOF: SC to walk indoor, limited community ambulation w/ assistance

Medication: none
Case Study #1

System reviews

CV: 110/68, HR: 78 bpm
Integumentary: skin intact – patient wears a helmet
Cognition: patient follows 2-3 steps command w/o difficulty

Impairments – musculoskeletal and neuromuscular system

– Motor control: isolated movement throughout
– Spasticity: clonus to right ankle 3-4 beats
– Strength: pf: unable to perform u/l heel raises, b/l heel raises through 50% of the range
– Sensation: intact
– Balance
Case Study # 1

Goal(s):

“I would like to get back to how I was before, or even better”

“I want to get back to my job again”

“I want to restore my balance”

- 60 minute 1:1 PT sessions (36 sessions) twice per week
- Initial sessions focused on balance & core strengthening
- Transitioned to pre-running activities, dynamic balance, and dual task activities.
Case Study #1

Activity limitations

Gait

- Speed: 2.22 ft/sec = 0.67 m/s  
  WBOS, small steps

Stairs

- Requires handrail and sc, step to pattern

<table>
<thead>
<tr>
<th>HiMat – some components</th>
<th>Score / time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>(1) 10.1 sec</td>
</tr>
<tr>
<td>Walk backward</td>
<td>(1) 1.1 min</td>
</tr>
<tr>
<td>Walk on toes</td>
<td>Unable – multiple errors</td>
</tr>
<tr>
<td>Walk over obstacle</td>
<td>(1) 45.6 sec, 18.38 sec</td>
</tr>
<tr>
<td>Upstairs dependent</td>
<td>(3) 12.31 sec</td>
</tr>
<tr>
<td>Downstairs dependent</td>
<td>(1) 25.09 sec</td>
</tr>
</tbody>
</table>
## Case Study #1

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG</td>
<td>19 sec</td>
</tr>
<tr>
<td>FTSTS</td>
<td>14.8 sec</td>
</tr>
<tr>
<td>HiMat</td>
<td>7/54</td>
</tr>
<tr>
<td>RT SLS</td>
<td>2 sec</td>
</tr>
<tr>
<td>LT SLS</td>
<td>12 sec</td>
</tr>
<tr>
<td>Gait speed / 50 foot</td>
<td>2.2 ft/sec = 0.67 m/s</td>
</tr>
<tr>
<td>ABC</td>
<td>45.6%</td>
</tr>
</tbody>
</table>

*01/29/2015*
Case Study #1

• VIDEO
Case Study # 1

Interventions 1-10 visits

Impairments:
- Balance – static/dynamic
- Strength – sit <> stand, step up fwd and bwd, heel raises; core strengthening (quadruped)

• Skills
  - High marching – hip/knee flex 90 degrees
  - Introduce plyometric ex on reformer (visit 7)

  • DL squat jump
  • SL squat jump
  • Fast feet
### Case Study # 1

<table>
<thead>
<tr>
<th>Test</th>
<th>03/24/2015</th>
<th>01/29/2015</th>
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<tbody>
<tr>
<td>TUG</td>
<td>10.3 sec</td>
<td>19 sec</td>
</tr>
<tr>
<td>FTSTS</td>
<td>9 sec</td>
<td>14.8 sec</td>
</tr>
<tr>
<td>HiMat</td>
<td>17/54</td>
<td>7/54</td>
</tr>
<tr>
<td>RT SLS</td>
<td>N/A</td>
<td>2 sec</td>
</tr>
<tr>
<td>LT SLS</td>
<td>N/A</td>
<td>12 sec</td>
</tr>
<tr>
<td>Gait speed / 50 foot</td>
<td>3.3 ft / sec = 1.0 m/s</td>
<td>2.2 ft/sec = 0.67 m/s</td>
</tr>
<tr>
<td>ABC</td>
<td>80.63%</td>
<td>45.6%</td>
</tr>
</tbody>
</table>
Case Study # 1

Intervention 10-20

Progress balance and strengthening exercises

Skill acquisition

- Progress to trampoline
- Progress to ground – at visit 18 after cranioplasty was done
  - Bounding
  - b/l jumps
  - Fast feet
  - Attempt to run visit 19 – using ceiling track harness
# Case Study # 1

## Re-examination visit 20

<table>
<thead>
<tr>
<th></th>
<th>05/05/2015</th>
<th>03/24/2015</th>
<th>01/29/2015</th>
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</thead>
<tbody>
<tr>
<td><strong>TUG</strong></td>
<td>N/A</td>
<td>10.3 sec</td>
<td>19 sec</td>
</tr>
<tr>
<td><strong>FTSTS</strong></td>
<td>N/A</td>
<td>9 sec</td>
<td>14.8 sec</td>
</tr>
<tr>
<td><strong>HiMat</strong></td>
<td>26/54</td>
<td>17/54</td>
<td>7/54</td>
</tr>
<tr>
<td><strong>RT SLS</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>2 sec</td>
</tr>
<tr>
<td><strong>LT SLS</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>12 sec</td>
</tr>
<tr>
<td><strong>Gait speed / 50 foot</strong></td>
<td>3.74 ft/sec</td>
<td>3.3 ft / sec = 1.0 m/s</td>
<td>2.2 ft/sec = 0.67 m/s</td>
</tr>
<tr>
<td><strong>ABC</strong></td>
<td>94%</td>
<td>80.63%</td>
<td>45.6%</td>
</tr>
</tbody>
</table>
Case Study # 1

Intervention 20-30

Advance balance/strengthening ex

Skill acquisition

– Bounding
– Running
– Single leg hop
– Skipping

Outdoor ambulation training
## Case Study # 1

### Re-examination visit 30

<table>
<thead>
<tr>
<th></th>
<th>06/30/2015</th>
<th>05/05/2015</th>
<th>03/24/2015</th>
<th>01/29/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG</td>
<td>9.9 sec</td>
<td>N/A</td>
<td>10.3 sec</td>
<td>19 sec</td>
</tr>
<tr>
<td>FTSTS</td>
<td>N/A</td>
<td>N/A</td>
<td>9 sec</td>
<td>14.8 sec</td>
</tr>
<tr>
<td>HiMat</td>
<td>29/54</td>
<td>26/54</td>
<td>17/54</td>
<td>7/54</td>
</tr>
<tr>
<td>RT SLS</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>2 sec</td>
</tr>
<tr>
<td>LT SLS</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>12 sec</td>
</tr>
<tr>
<td>Gait speed / 50 foot</td>
<td>4.42 ft/sec</td>
<td>3.74 ft/sec</td>
<td>3.3 ft / sec = 1.0 m/s</td>
<td>2.2 ft/sec = 0.67 m/s</td>
</tr>
<tr>
<td>ABC</td>
<td>N/A</td>
<td>94%</td>
<td>80.63%</td>
<td>45.6%</td>
</tr>
</tbody>
</table>

RUSK REHABILITATION
Case Study #1

- Video
Case Study #1

• Video
Case Study # 1

• Video
Case Study # 2

HPI: 27 yo, right hand dominant, male with rupture of AVM and CVA during recoiling on 3/28/2013.

PMH/PSH: AVMs, removal of right temporal lobe, VP shunt


PLOF: Independent with all activities. Active in the gym.

CLOF: Min A to negotiation the environment while using straight and without lower extremity orthosis. Unable to participate in recreational activities, such as baseball, which includes jumping and running.

Medications: none.
Case Study # 2

Systems Review

CV: BP 114/72, HR 76 bpm
Cognition: A&O x 3. Long term memory affected – unable to recall events that occurred in the last 2 years. Short term memory also affected but compensates.

Impairments:
• Decreased motor control and spasticity : left upper & lower extremities
• Repeated falls due drop foot
• Homonymous hemianopsia
• Decreased coordination
• Poor endurance
Case Study # 2

- 60 minutes 1:1 individual PT session once to twice a week
- 30 minute supervised therapeutic exercise class to focus on cardiovascular and progressive resistive exercises
- Extensive home exercise program.
- Incorporated the use of a toe-off brace for everyday use and FES during treatment sessions.
- Treatment sessions included task-specific training, treadmill training with use of the Lite Gait for safety, and intensive mobility exercises
- GOAL: “I want to get back to my gym routine and possibly run”.

RUSK REHABILITATION
## Case Study # 2

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time/Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTSTS</td>
<td>13.50 sec</td>
</tr>
<tr>
<td>SLS</td>
<td>RLE 11.12 sec, LLE 3.53 sec</td>
</tr>
<tr>
<td>Gait Speed / 50 ft with SC</td>
<td>3.44 ft / sec = 1.0 m/s</td>
</tr>
<tr>
<td>Ascends 10 steps</td>
<td>7.07 sec with HR &amp; reciprocal step</td>
</tr>
<tr>
<td>Wall sit (quad endurance)</td>
<td>45.66 sec</td>
</tr>
</tbody>
</table>

8/27/2013

RUSK REHABILITATION
Case Study # 2

Interventions 1-7

Impairments
  – Tone
  – Motor Control / Strength
  – Balance

Skills
  – Use of FES (Bioness ®)
  – Jumping: in place, hip abd/add
  – Treadmill
  – Stairs with reciprocal step pattern with/without handrail
## Case Study # 2

<table>
<thead>
<tr>
<th></th>
<th>9/27/2013</th>
<th>8/27/2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTSTS</td>
<td>9.38 sec</td>
<td>13.50 sec</td>
</tr>
<tr>
<td>SLS</td>
<td>RLE 7.36 sec, LLE 1.97 sec</td>
<td>RLE 11.12 sec, LLE 3.53 sec</td>
</tr>
<tr>
<td>Gait Speed / 50 ft</td>
<td>3.29 ft/sec</td>
<td>3.44 ft / sec</td>
</tr>
<tr>
<td>Ascends 10 steps</td>
<td>6.65 sec</td>
<td>7.07 sec with HR &amp; reciprocal step</td>
</tr>
<tr>
<td>Wall sit</td>
<td>76 sec</td>
<td>45.66 sec</td>
</tr>
</tbody>
</table>
Case Study # 2

Interventions #8 – 12

Impairment
  – Endurance
  – Motor Control / Strength
  – Quality of gait

Skills
  – Use of Bioness ®
  – Treadmill
  – Jumping forward 2-4”
# Case Study #2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FTSTS</td>
<td>9 sec</td>
<td>9.38 sec</td>
<td>13.50 sec</td>
</tr>
<tr>
<td>SLS</td>
<td>N/A</td>
<td>RLE 7.36 sec, LLE 1.97 sec</td>
<td>RLE 11.12 sec, LLE 3.53 sec</td>
</tr>
<tr>
<td>Gait Speed / 50 ft</td>
<td>N/A</td>
<td>3.29 ft/sec</td>
<td>3.44 ft/sec</td>
</tr>
<tr>
<td>Ascends 10 steps</td>
<td>N/A</td>
<td>6.65 sec</td>
<td>7.07 sec with HR &amp; reciprocal step</td>
</tr>
<tr>
<td>Wall sit</td>
<td>120 sec</td>
<td>76 sec</td>
<td>45.66 sec</td>
</tr>
<tr>
<td>6 MWT</td>
<td>1,218 ft TOE OFF &amp; SC</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Case Study # 2

Interventions #13 – 15

Impairments
  – Balance
  – Gait

Skills
Toe off brace
  – Treadmill
  – Step ups
  – Jumping forward 2-4”
  – Jogging over ground
# Case Study # 2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FTSTS</strong></td>
<td>8.22 sec</td>
<td>9 sec</td>
<td>9.38 sec</td>
<td>13.50 sec</td>
</tr>
</tbody>
</table>
| **SLS**              | RLE: 34.38 sec  
LLE: 3.22 sec     | N/A        | RLE 7.36 sec, LLE 1.97 sec  
RLE 11.12 sec,  
LLE 3.53 sec   |
| **Gait Speed / 50 ft** | 3.79 ft/sec TOE OFF | N/A        | 3.29 ft/sec | 3.44 ft / sec |
| **Ascends 10 steps** | 6.36 sec with TOE OFF | N/A        | 6.65 sec | 7.07 sec with HR & reciprocal step |
| **Wall sit**         | 140 sec    | 120 sec    | 76 sec    | 45.66 sec |
| **6 MWT**            | 1,204 ft TOE OFF | 1,218 ft TOE OFF & SC | 9/27/2013 | 7/28/2013 |
Case Study # 2

Interventions 16-25

– Treadmill training (session 17)
– Treadmill with FES and harness (session 19)

Interventions 26-36

– Treadmill training with FES at higher speed
– Plyometrics – Jumping on trampoline
– Core strengthening
Case Study #2

• Video
### Case Study #2

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait / 50 feet (Normal Pace) w/Bioness</td>
<td>4.62 ft/sec</td>
</tr>
<tr>
<td>Run / 50 feet w/Bioness</td>
<td>8.30 ft/sec</td>
</tr>
<tr>
<td>Ascend stairs without HR</td>
<td>6.10 sec</td>
</tr>
<tr>
<td>Descend stairs without HR</td>
<td>6.78 sec</td>
</tr>
</tbody>
</table>

02/18/2014

RUSK REHABILITATION
Case Study #2

• Video
# Case Study #2

<table>
<thead>
<tr>
<th></th>
<th>5/14/2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Speed / 50 feet (Normal pace)</td>
<td>4.10 ft/sec</td>
</tr>
<tr>
<td>Run / 50 feet</td>
<td>9.45 ft/sec = 2.9 m/s</td>
</tr>
<tr>
<td>Walk Backwards / 50 feet</td>
<td>9.37 sec</td>
</tr>
<tr>
<td>Walk on Toes / 50 feet</td>
<td>15.60 sec</td>
</tr>
<tr>
<td>6 MWT</td>
<td>1440 feet</td>
</tr>
<tr>
<td>Ascend 10 stairs without HR</td>
<td>5.75 sec</td>
</tr>
<tr>
<td>Descend 10 stairs without HR</td>
<td>5.98 sec</td>
</tr>
</tbody>
</table>
Case Study #2

• Video
Case Study #2

<table>
<thead>
<tr>
<th>HiMat</th>
<th>5/20/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking forward</td>
<td>6.2 sec</td>
</tr>
<tr>
<td>Walking backward</td>
<td>9.6 sec</td>
</tr>
<tr>
<td>Walk on toes</td>
<td>8.87 sec</td>
</tr>
<tr>
<td>Walk over obstacle</td>
<td>6.8 sec</td>
</tr>
<tr>
<td>Run</td>
<td>3.43 sec</td>
</tr>
<tr>
<td>Skip</td>
<td>n/a</td>
</tr>
<tr>
<td>Hop forward</td>
<td>n/a</td>
</tr>
<tr>
<td>Bound (landing on more affected leg)</td>
<td>115 cm</td>
</tr>
<tr>
<td>Bound (landing on less affected leg)</td>
<td>115 cm</td>
</tr>
<tr>
<td>Up stairs</td>
<td>5.8 sec</td>
</tr>
<tr>
<td>Down stairs</td>
<td>4.43 sec</td>
</tr>
</tbody>
</table>
Case Study #2

• Video
Case Study #2

• Video
Case Study #2

• Video
Case Study #2

• Video
Case Study #2

• Video
Case Study #2

- Video
Case Study #2

• Video
Conclusion
Conclusion

Running and return to high level activity is a goal for many people with acquired brain injury.
Improvements are possible in young, middle aged and older adults acute and chronic acquired brain injury.
High level mobility training including running is both safe and feasible in the appropriate candidates with acquired brain injury.
May improve ability to return to work: Young stroke survivors are nearly 3 x more likely to return to work if they regain the ability to run, even if only for a few steps (Lindstrom, Roding and Sundelin, 2009)
Questions to be answered

• Further research: beyond case studies and series
• Does the acquisition of running skill improve ability to walk?
• Does the acquisition of running skill improve return to work for this patient population?
• Does the acquisition of running skill improve quality of life in this patient population?
Questions to be answered

• What orthopedic injuries, if any, will arise in the future?

• Are there better bracing options for neurologically impaired people with high level mobility goals?
Thank you!
References


References


References


