Reliability of a Test Battery Designed for Quickly and Safely Assessing Diverse Indices of Neuromuscular Function

Barry A. Spiering\textsuperscript{1,2}, Stuart M.C. Lee\textsuperscript{1}, Ajitkumar P. Mulavara\textsuperscript{3}, Jason R. Bentley\textsuperscript{1}, Roxanne E. Buxton\textsuperscript{4}, Emily L. Lawrence\textsuperscript{1}, Joseph Sinka\textsuperscript{1}, Mark E. Guilliams\textsuperscript{1}, Lori L. Ploutz-Snyder\textsuperscript{3}, Jacob J. Bloomberg\textsuperscript{5}

\textsuperscript{1}Wyle Integrated Science and Engineering Group, Houston, TX; \textsuperscript{2}California State University, Fullerton, CA; \textsuperscript{3}Universities Space Research Association, Houston, TX; \textsuperscript{4}University of Houston, Houston, TX; \textsuperscript{5}National Aeronautics and Space Administration Lyndon B. Johnson Space Center, Houston, TX
Introduction

- Spaceflight affects nearly every physiological system
- Spaceflight-induced alterations in physiological function translate to decrements in functional performance
Introduction

• **Challenge:**
  – How do we develop countermeasures to offset the plethora of physiological decrements?

• **Solution:**
  – Identify the physiological factors most critical for functional outcomes
  – Develop countermeasures targeted toward the most critical factors
Introduction

**Functional Performance**
- Seat Egress and Walk
- Ladder Climb
- Rock Translation
- Construction Activity
- Torque Generation
- Jump Down
- Recovery from Fall/Stand

**Physiological Measures**

**Muscle**
- Strength
- Power
- Endurance
- Control
- Neuromuscular Drive

**Sensorimotor**
- Posture
- Gait
- Dynamic Visual Acuity
- Fine Motor

**Cardiovascular**
- Plasma Volume
What “Neuromuscular Performance Variables” Do We Assess?

• Reduced **strength** is a hallmark consequence of spaceflight
  – Strength is strongly associated with functional performance (Visser et al. 2000)
  – “Neural factors” (e.g., central activation) clearly contribute to unloading-induced strength loss (Clark et al. 2006)

• **Power** is perhaps the strongest predictor of functional performance (Puthoff et al. 2008)

• **Force steadiness** might relate to functional performance (Seynnes et al. 2005; Manini et al. 2005)
Purpose

- To develop a test battery for **quickly** and **safely** assessing **diverse indices** of neuromuscular performance
  - **Quickly:**
    - Battery of tests must be completed in ~30 min
  - **Safely:**
    - Increased susceptibility to muscle damage after spaceflight
    - Impaired postural stability post-spaceflight
  - **Diverse indices:**
    - Strength
    - Central activation
    - Power
    - Endurance
    - Force steadiness
Methods

• Subjects
  – 10 healthy volunteers (5 women, 5 men)
  – Age: 31 ± 5 y
  – Height: 173 ± 11 cm
  – Weight: 73 ± 14 kg

• Procedures
  – Completed a battery of neuromuscular performance tests on 3 occasions separated by at least 48 h
Knee Extension Tests

**Test #1: Interpolated Twitch Test**
- Central Activation

**Test #2: Force Steadiness Test**
- With and without Visual Feedback
Leg Press Tests

**Test #3: Maximal Isometric Force Test**
- Maximal Strength
- Rate of Force Development

**Test #4: Power Endurance Test**
- Maximal Power
- Fatigue Index
- Total Work
Bench Press Tests

**Test #5:** Maximal Isometric Force Test
- Maximal Strength
- Rate of Force Development

**Test #6:** Force Steadiness Test
- With and without Visual Feedback

**Test #7:** Power Endurance Test
- Maximal Power
- Fatigue Index
- Total Work
Statistical Analyses

• Reliability of each test was assessed via
  – Standard error of the measurement (SEM)
    • SEM reported as percent of the mean
  – Intraclass correlation coefficient (ICC)

• Time required to set up and conduct each test is reported as mean ± SD
Results: Knee Extension Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Dependent Variable</th>
<th>SEM</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpolated Twitch</td>
<td>Central Activation Capacity (%)</td>
<td>3%</td>
<td>0.87</td>
</tr>
<tr>
<td>Force Steadiness</td>
<td>Force Steadiness with Visual Feedback (CV)</td>
<td>35%</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Force Steadiness without Visual Feedback (CV)</td>
<td>35%</td>
<td>0.28</td>
</tr>
</tbody>
</table>
## Results: Leg Press Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Dependent Variable</th>
<th>SEM</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal Isometric Force</td>
<td>Maximal Isometric Force (N)</td>
<td>4%</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Rate of Force Development (N/ms)</td>
<td>9%</td>
<td>0.94</td>
</tr>
<tr>
<td>Power Endurance</td>
<td>Maximal Power (W)</td>
<td>3%</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Fatigue Index (%)</td>
<td>18%</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Total Work (J)</td>
<td>4%</td>
<td>0.99</td>
</tr>
</tbody>
</table>
## Results: Bench Press Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Dependent Variable</th>
<th>SEM</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal Isometric Force</td>
<td>Maximal Isometric Force (N)</td>
<td>3%</td>
<td>0.99</td>
</tr>
<tr>
<td>Rate of Force Development</td>
<td>Rate of Force Development (N/ms)</td>
<td>14%</td>
<td>0.93</td>
</tr>
<tr>
<td>Force Steadiness</td>
<td>Force Steadiness with Visual Feedback (CV)</td>
<td>20%</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>Force Steadiness without Visual Feedback (CV)</td>
<td>33%</td>
<td>0.26</td>
</tr>
<tr>
<td>Power Endurance</td>
<td>Maximal Power (W)</td>
<td>9%</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Fatigue Index (%)</td>
<td>16%</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Total Work (J)</td>
<td>4%</td>
<td>0.99</td>
</tr>
</tbody>
</table>
## Results: Time Requirements

<table>
<thead>
<tr>
<th>Testing Device</th>
<th>Test</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Extension</td>
<td>ITT Current Optimization</td>
<td>11</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Interpolated Twitch</td>
<td>7</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Force Steadiness</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Leg Press</td>
<td>Maximal Isometric Force</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Power Endurance</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bench Press</td>
<td>Maximal Isometric Force</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Force Steadiness</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Power Endurance</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>46</strong></td>
<td><strong>39</strong></td>
<td><strong>40</strong></td>
</tr>
</tbody>
</table>
Conclusions

• Purpose: To develop a test battery for **quickly** and **safely** assessing **diverse indices** of neuromuscular performance
  
  – Quickly:
  
  • Battery of tests can be completed in ~30-40 min

  – Safely:
  
  • No eccentric muscle actions or impact forces
  
  • Tests present little challenge to postural stability

  – Diverse indices:
  
  • Strength: Excellent reliability (ICC = 0.99)
  
  • Central activation: Very good reliability (ICC = 0.87)
  
  • Power: Excellent reliability (ICC = 0.99)
  
  • Endurance: Total work has excellent reliability (ICC = 0.99)
  
  • Force steadiness: Poor reliability (ICC = 0.20 – 0.60)
Acknowledgments

• This work was supported by the Exercise Physiology and Countermeasures Project of the National Aeronautics and Space Administration

• We thank Brent Crowell, Kirk English, Jamie Guined, Mark Leach, Peggy Lynn, and Leah Stroud for invaluable assistance during data collection