Assessing changes in postural and manual control following spaceflight: Implications for managing clinical status evaluations

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Towards Integrated Countermeasures
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Objectives

- Postural recovery after space flight
  - Multisensory aspects
  - ISS countermeasures
- Evidence gap for manual control risk
  - Shuttle ZAG experiment – Clément
  - ISS Manual Control – Moore
- Implications for clinical status evaluations
Resolving sensory ambiguity

- Our ability to sense motion and orientation depends on a learned ability to interpret the continuous input of multiple sensory signals.

- Redundancy means that one system can compensate for limitations in another.

- Redundancy also sets up potential for sensory conflict through aging, pathology or environmental change.
Mechanisms of Adaptation

- Multisensory integration
  - Different patterns of sensory cues, e.g., otolith cues during head tilt
  - Interaction with support surfaces for locomotion and orientation

- Gravitational unloading
  - Altered proprioception for mass discrimination and force control
  - Fluid shifts, deconditioning

- Adaptive for microgravity ... maladaptive for transition to new gravitoinertial state
## Post-flight neurological exam

<table>
<thead>
<tr>
<th>Rank Order</th>
<th>Neurological Function Test</th>
<th>% with positive signs on Landing Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tandem/Heel to Toe Walk (eyes open)</td>
<td>57.0%</td>
</tr>
<tr>
<td>2</td>
<td>Gaze/Ocular Movements</td>
<td>55.0%</td>
</tr>
<tr>
<td>3</td>
<td>Dynamic Equilibrium</td>
<td>47.2%</td>
</tr>
<tr>
<td>4</td>
<td>Leg lift-Hop</td>
<td>39.6%</td>
</tr>
<tr>
<td>5</td>
<td>Standing/ Romberg</td>
<td>22.2%</td>
</tr>
<tr>
<td>6</td>
<td>Finger to Nose</td>
<td>19.4%</td>
</tr>
<tr>
<td>7</td>
<td>Dizziness/Faintness</td>
<td>16.5%</td>
</tr>
<tr>
<td>8</td>
<td>Rising from Chair</td>
<td>13.8%</td>
</tr>
<tr>
<td>9</td>
<td>Vertigo/Spinning</td>
<td>11.9%</td>
</tr>
<tr>
<td>10</td>
<td>Drift</td>
<td>10.2%</td>
</tr>
<tr>
<td>11</td>
<td>Headache</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

Sensory Organization Tests

<table>
<thead>
<tr>
<th></th>
<th>Eyes Open</th>
<th>Eyes Closed</th>
<th>Head-Fixed Surround</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Support</td>
<td><img src="image1" alt="Image 1" /></td>
<td><img src="image2" alt="Image 2" /></td>
<td><img src="image3" alt="Image 3" /></td>
</tr>
<tr>
<td>Unstable Support</td>
<td><img src="image4" alt="Image 4" /></td>
<td><img src="image5" alt="Image 5" /></td>
<td><img src="image6" alt="Image 6" /></td>
</tr>
</tbody>
</table>

Altered Vision

References:
Nashner et al., J Neurosci (1982) 2:536-544
Post Shuttle (EDOMP)

Adapted from Paloski et.al. 1995
Supplement to Post-Shuttle Neuro Exam

Less stable

Fall

Eyes Closed, Fixed Support

Eyes Closed, Unstable Support
% Change R+0 Post-ISS (Exp 1-29)

1. Eyes Open
   - Fixed Support: -4.6%
   - Unstable Support: -22.3%

2. Eyes Closed
   - Fixed Support: -8.1%
   - Unstable Support: -82.4%

3. Head-Fixed Surround
   - Unstable Support: -7.0%

Wood et al., Aviat Space Environ Med (2013)
Sharpen tests with head tilts

**Head Erect**

**Head Moving**

**Pitch**

0.33 Hz  
±20°

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Wood et al., Aviat Space Environ Med (2013)
ISS Countermeasures

Head Erect, Eyes Closed, Fixed Support

Wood et al., Aviat Space Environ Med (2013)
ISS Countermeasures

Head Erect, Eyes Closed, **Unstable Support**

![Graph showing median cEQ score over pre-flight and post-flight (days) for Exp 1-9, Exp 10-18, and Exp 20-26.](image)

Wood et al., Aviat Space Environ Med (2013)
ISS Countermeasures

Head Moving, Eyes Closed, Unstable Support

Wood et al., Aviat Space Environ Med (2013)
# Post-flight Reconditioning Program

## Exercise

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dynamic Stretch &amp; Warm-up</td>
<td>Every day: R+1-45</td>
</tr>
<tr>
<td>2 Aerobic Conditioning</td>
<td>Every day: R+1-45</td>
</tr>
<tr>
<td>3 Resistance Exercise</td>
<td>Every other day: R+1-45</td>
</tr>
<tr>
<td>4 Mobility, Balance &amp; Proprioception Drills</td>
<td>Every other day: R+1–45</td>
</tr>
<tr>
<td>5 Medicine Ball Drills</td>
<td>Every other day, R+1-45</td>
</tr>
<tr>
<td>6 Cone and Agility Ladder Drills</td>
<td>Every other day: R+6-45</td>
</tr>
<tr>
<td>7 Jumping Drills</td>
<td>Every other day: R+21-45</td>
</tr>
<tr>
<td>8 Core Exercise</td>
<td>Every day: R+1-45</td>
</tr>
<tr>
<td>9 Static Stretching</td>
<td>Every day: R+1-45</td>
</tr>
</tbody>
</table>

Wood Loehr & Guilliams. NeuroRehab (2011) 29:185-95
Posturography vs Self-Rating

Wood et al. NeuroRehab (2011) 29:185-95
Manual control risk?

Risk of impaired control of spacecraft, associated systems and immediate vehicle egress due to vestibular/sensorimotor alterations associated with space flight

SM6: Addresses vehicular control after six months in microgravity
Shuttle data mining

Vertical Velocity at Touchdown
STS Landing versus STA

STS 43 - 108
STS
STA *

Cum Dist Fx

> -5 fps acceptable
> -3.5 fps desired

* Note: STA data from same CDRs within 1 month of launch

Paloski et al., J Gravit Physiol (2008) 15:1-29
Shuttle ZAG experiment – Clément
Shuttle ZAG experiment – Clément

- On R+0 nulling gain reduced by >30%
- Recovery within 2 days after return

ISS Manual Control – Moore

Operator proficiency tests (motion simulations)
- driving a car
- landing an aircraft
- operating a Mars rover

Sensorimotor Test Battery
- Reaction time
- Perspective taking
- Manual tracking
- Dual tasking and manual tracking
- Manual dexterity
- Visual acuity
- Sleepiness rating
- Motion perception
ISS Manual Control – Moore

Operator Proficiency Tests

Driving

Flight

Mars Rover
Implications: Clinical Status Eval

- Large inter-subject variability! Self-assessment will be important during more autonomous missions
- Functional tests requiring more complex tasks sharpen diagnostic performance
- Both inflight countermeasures and post-flight reconditioning (e.g., systematically increasing crew activities) can enhance adaptation and reduce risk
- Post-ISS reconditioning may represent “better case” scenario – some self-administered reconditioning capability should be expected