The BESTest for Dynamic Balance
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Dept of Neurology
Biomechanical Engineering and Physiology

www.BESTest.us

Balance control involves many different neural circuits

Jacobs and Horak, 2007

The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits
Fay Horak, Diane Wrisley, James Frank, Physical Therapy 89(5), 2009

www.BESTest.us

What is wrong with balance in PD?

- 1/100 over 75 years old have PD
- 38% fall each year
- 18% of falls result in fractures

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Sensory Integration

**BESTest**

**Sensory Orientation**

**EO, EC, Foam, EC-Foam**

Stand on Incline EC

Shumway-Cook, Horak 1986

**Normal:**
- 50% more sway on foam with eyes closed (using vestibular function)

**Firm Surface**
- 70% Somatosensory
- 20% Vestibular
- 10% Vision

**Unstable Surface**
- 10% Somatosensory
- 60% Vestibular
- 30% Vision

Peterka et al, 2004

Sensory Weighting for Environmental Context

**Vestibular Weight**

**Surface Rotation Size**

**Vestibular Weight**

Controls
**BESTest**  Sensory Orientation

Kluzik, Hlavacka, and Horak, in preparation

**Vestibular Loss**

- Horizontal Surface
- Inclined Surface

Kluzik and Horak, in preparation

**Stability Limits**

- Sitting Verticality
- Sitting Lateral Lean
- Limits of stability – Forward
- Limits of stability – Backward
- Limits of stability - Lateral

**Stability Limits**: Area in which CoM can be safely moved without changing base of support

**ACTUAL VS PERCEIVED**

- Center of Mass (CoM)
  - Theoretical point about which an object pivots in equilibrium
  - Weighted average of the mass of your body projected down to surface

**Ankle Strategy**, **Hip Strategy**, **Stepping Strategy**
Mancini et al, 2008

PD show reduced forward, but not backward limits of stability

Functional Reach is not sufficient for evaluation of balance control

- Poor sensitivity for PD fallers (30%)
- Good specificity for PD fallers (92%)
  (Behrman, et al, 2002)

- Poor predictor of elderly future falls
  (Brauer et al, 2000)

- Doesn’t relate well to CoP
  (Jonsson et al, 2003)

Sitting: lateral limits of stability

Anticipatory postural adjustments prior to voluntary step initiation are smaller in the elderly and even smaller in participants with PD

Initial stance foot

Initial step foot
Automatic Postural Responses
- In place forward
- In place backward
- Step forward
- Step backward
- Step sideways

Slips and trips most common reason for falling!

Most falls in response to external perturbations are NOT due to ABSENT equilibrium responses.

DBS impairs Postural Responses

Horak and Nashner, 1986
DBS impairs Postural Responses
St. George et al, 2010

Compensatory Stepping
Control Participant
Participant with PD

Control Participant
Lateral step strategy
Cross over strategy

Participant with PD
Lateral step strategy
Cross over strategy
PD OFF state

PD ON state

Pull Test

New Push and Release Test

Tested 99 participants:
88 PD
11 Controls

More sensitive than Pull Test

Correlates better with ABC, UPDRS, Falls

3 Raters: Inter-rater = .98

Best Test
Reactive Postural Responses (In-place and stepping)

Jacobs, et al., 2006

Therapists need to evaluate and treat compensatory stepping responses to external perturbations.

Forward Push and Release Test

BEST TEST
Postural Responses

Lateral Push and Release Test

Push and Release Test

Elderly control but not PD subjects flexibly reduce size of Gastroc response to surface rotation when they hold onto a stable handle.


Elderly control but not PD subjects flexibly reduce size of Gastroc response to surface rotation when they hold onto a stable handle.

**BESTest**

**Anticipatory Postural Adjustments**

5. Sit to Stand
6. Rise to Toes
7. Stand on One Leg
8. Alternate Stair Touching
9. Standing Arm Raise

**VOLUNTARY STEPPING**

<table>
<thead>
<tr>
<th>control</th>
<th>PD narrow</th>
<th>PD wide</th>
</tr>
</thead>
</table>

Trial 1  Trial 2  Trial 3
Trial 4  Trial 5  Trial 6
Trial 7  Trial 8  Trial 9
Patients with Parkinson's Disease do not scale up the size of APAs for wide stance...

Difficulty changing postural set for initial conditions.

Rocchi et al., 2006

Freezing of postural stepping is associated with multiple anticipatory postural adjustments

Control Subject

PD Subject

Jacobs et al., 2006

Jacobs et al. Neuroscience 2007

PD with multiple APAs

Control with UNpredictable target = Multiple APA

APAs for Rise to Toes

Pre-DBS On

Post-DBS On/On
Stability in Gait
- Gait – Level Surfaces
- Change in Speed
- Walk with Head Turns
- Walk with Pivot Turns
- Step over Obstacle
- Timed “Get Up & Go”
- Timed “Get Up & Go” with Cognitive Task

Walking with head turns
No Cognitive Task
With Cognitive Task
The automaticity of postural control can be a good measure of successful rehabilitation.

Why is balance during gait dynamic?

- Falling CoM and catching with Base of Support
- Lateral trunk stability is major balance challenge for gait
- 2/3 of time spent on single foot stance in normal gait
- How to add balance challenge during gait?
- What is special about turning?
- Direction of falls give hints on balance problem!

Gait measures are sensitive to untreated PD, are stable across 12 months and some start to show progression.

Turning is more sensitive than clinical balance tests to early PD

Turning is sensitive to early disease (MS and PD)

Turning is slower by 25% When walking is slower by 10%--

King et al, submitted
Spain, et al, submitted
Effects of Vibrotactile Biofeedback in UVL Tandem gait

Dozza et al., 2007

Biofeedback improves gait performance, not learning

Effect of practicing tandem gait across trials. Each value represents the average among ten subjects of three consecutive trials.

How much attention is required for control of balance?

- Depends on difficulty of the task
- Attentional capacity can be reduced by aging and pathology
- As skilled tasks become more AUTOMATIC, they require less attention
- Therapists can use a secondary cognitive task to determine how well skills has been learned

Talking while walking slows people with early Parkinson’s disease more than controls

Zampieri, et al, in preparation
Biomechanical Constraints
- Base of Support
- Postural Alignment
- Ankle strength and range
- Hip/trunk lateral strength
- Transfer from floor
Stooped initial posture reduced postural stability margin in response to perturbations, especially backwards (like PD).

Stability Margin (peak CoP - peak CoM)  
Upright Control  
Stooped Control

Axial tone in PD

No change with L-dopa (although limb tone decreases)

Weight & HipTone
Corina Hoole

Different Postural Systems Affected:

<table>
<thead>
<tr>
<th>PD</th>
<th>Vestibular Loss</th>
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<tbody>
<tr>
<td>Sensory</td>
<td>OK?</td>
</tr>
<tr>
<td>Stability Limits</td>
<td>Reduced</td>
</tr>
<tr>
<td>Anticipatory</td>
<td>Hypometric</td>
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<tr>
<td>Responses</td>
<td>Hypometric</td>
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<tr>
<td>Gait</td>
<td>Turning</td>
</tr>
<tr>
<td>Biomechanical</td>
<td>Flexed</td>
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</tbody>
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What's next for BESTest?

- BESTest
- Fall Risk
- Normative Values
- Validate for other groups

- MiniBESTest
- Instrumented miniBESTest
Fall Risk with BESTest

Leddy, Crowner, and Earhart, PTJ
January 2011

- Retrospective Fall Risk
- 80 individuals with PD
- "BESTest is most sensitive for identifying fallers."

MiniBESTest for Dynamic Balance

Scores:
- 2 Normal
- 1 Abnormal
- 0 Absent

MiniBESTest

Franchignoni, Horak, Godi, Nardone, Giordano, J Rehab Med, 2010

Instrumented Balance Assessment System
OHSU and Dr. Horak have a significant financial interest in and/or are employees of ADPM, a company that may have a commercial interest in the results of this research and technology. This potential institutional and individual conflict has been reviewed and managed by OHSU.

In a clinic

Long Term Monitoring

Wireless Opals for iTUG

Measured iTUG parameters

<table>
<thead>
<tr>
<th>Gait</th>
<th>Turning</th>
<th>Transitions</th>
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</thead>
<tbody>
<tr>
<td>• Cadence</td>
<td>• Duration</td>
<td>• Duration</td>
</tr>
<tr>
<td>• Stride Velocity</td>
<td>• Speeds</td>
<td>• Speeds</td>
</tr>
<tr>
<td>• Stride length</td>
<td>• Number of steps</td>
<td>• Accelerations</td>
</tr>
<tr>
<td>• Arm Swing</td>
<td>• Step time</td>
<td>• Ranges of Motion</td>
</tr>
<tr>
<td>• Double Support</td>
<td>• 7 parameters</td>
<td>• First step time</td>
</tr>
<tr>
<td>• Ranges of Motion</td>
<td></td>
<td>• 7 parameters</td>
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<tr>
<td>• Asymmetry</td>
<td></td>
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</tr>
<tr>
<td>• 53 parameters</td>
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iSway: accelerometers on back is as good as force plates for sway in stance

Mancini et al, 2009
iPUSH

Instrumented Timed Up and Go (iTUG) is more sensitive than TUG for untreated PD

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