Assessment of Postural Control in the Geriatric Population

Salvador Bondoc, OTD, OTR/L, BCPR, CHT, FAOTA

Objectives

At the end of this presentation, participants should be able to:

1. Describe the Dynamic Model of Balance and Postural Control
2. State aging-related balance impairments associated with older adults
3. Apply evidence-based assessments and the Dynamic Model of Balance in evaluating balance and mobility impairments in older adults

Outline

- Overview of Balance and Postural Control
- Aging-related Issues in Balance and Postural Control
- Select Evidence-Based Assessments
Overview of Balance and Postural Control

Section 1

Prerequisite for all functional activities

Active or "online" process in all positions

Static balance is an oxymoron!
What is Postural Control?

Postural control
Control of the body’s position in relation to the task and environment

To do so, a person must be able to
1. Maintain balance or stability of posture (POSTURAL STABILITY)
2. Orient the body’s posture to the task and environment (POSTURAL ORIENTATION)

Balance Control

Postural Stability = Balance
Control of the center of mass (CoM) in relation to the base of support (BoS) or broadly, within the limits of stability (LoS)

Balance Control is Ongoing

During stance
Postural sway is normal in stationary position.

During task performance
Postural adjustments are ongoing to minimize shifts and control amplitude of body’s CoM
Have you played Wii Fit?

1. Maintain postural alignment while engaged in task
   Ex.: Standing or sitting balance
2. Facilitate voluntary movement
   Ex.: Transitions during transfers, shifts during reach
3. Recover equilibrium to external perturbations
   Ex.: Tripping or Slipping.

(Mancini & Horak, 2010)

Functional Goals of Balance Control

How could the environment and task influence your postural orientation?
How would a dynamic environment influence your use of postural strategies?

Multi-System Integration

- Nashner Model
  - Motor Systems
  - Postural evoked responses
  - Head-trunk-LE movements
  - Sensory Systems
  - Integration of visual, vestibular and somatosensory systems

- Systems Model
  - Musculoskeletal comps
  - Neuromuscular Synergies
  - Internal representations
  - Anticipatory Mechanisms
  - Adaptive Mechanisms
  - Individual Sensory Systems
  - Sensory Strategies

Nashner's Integrated Model of Balance and Postural Control

**Balance Control**

- **Sensory**
  - Sensory Organization and Integration
  - Sensory Processing
  - Environmental Stabilization

- **Motor**
  - Determination of Body Position
  - Determination of Force and Movement
  - Choice of Body Movement
  - Sensory-Motor Responses

**Neuromotor Musculo-Skeletal**


---

**Multi-System Integration**  
(Mancini & Horak, 2010)

**Functional Subsystems**
- Biomechanical Constraints
- Stability Limits
- Anticipatory Adjustments
- Reactive Postural Responses
- Sensory Orientation
- Stability in Gait

**Physiologic Subsystems**
- Vision
- Proprioception
- Reaction Time
- Postural Sway
- Strength

(BESTest: Horak, Wrisley, Frank, 2009)  
(PTA; Lord, 1989)

---

**Postural Control Systems**

- Neuro-Sensory
- Gaze Stabilization
- Neuro-Motor
- Postural Control Systems
- Cognitive System
- Musculo-Skeletal

For teaching purposes only - Do not copy without author's permission
Musculoskeletal System
- Joint integrity and muscle strength
- Muscle synergies

Neuro-Sensory System
- Organization, regulation and integration of sensory inputs (visual, vestibular, somatosensory)
- Use of sensory strategies

Neuro-Motor System
- Reflexive/ Automatic responses
- Adjustments against gravity, external forces (Adaptation)

Gaze Stabilization System
- Maintenance of gaze and visual acuity
- Vestibuloocular integration

Cognitive - Attentional System
- Dynamic Systems for Postural Control
  1. Postural Alignment
  2. Trunk and Hip/Pelvic Control
  3. Ankle Control
  4. Upper Body and Extremity Control

Musculoskeletal Issues Affecting Postural Control
3. Trunk and Hip-Pelvic Control
- Weak core stabilization
- Muscle tightness
- Limited trunk mobility

4. Ankle Control
- Limited mobility and weakness

Illustration retrieved from http://media.lanecc.edu/users/howardc/PTA204L/204LMusclesduringsway.jpg
Dynamic Systems for Postural Control

1. Reflexive/Automatic (Reactionary) control

2. Anticipatory (Feedforward) Control

3. Adaptive Control (Ongoing adjustment)

Things to Consider

- What attributes of balance control do we typically assess clinically?

- What range of responses do we consider as typical or normal?

Postural Control in Response to/in Anticipation of the Changing Environment

- Steadying balance/ Stance Control
  - Ongoing adjustments while engaged in stationary or moving tasks
  - Uses righting reactions (brainstem reflexes)

- Reactionary balance
  - rapid movement, protective
  - Uses spinal reflexes i.e., postural evoked responses and equilibrium responses

- Anticipatory balance
  - Slow adjustments because they are self-initiated and purposeful
  - Reflexes are in the "background" of conscious control
Neuromotor System for Postural Control

- CNS
- Limb movements
- Dynamic Task (Postural Instability)
- Feed Forward Control on Anticipated Task
- Feed Back on Unanticipated Instability
- Postural Adjustments

Adaptive Strategies to Control Postural Sway

- **Ankle Strategy**
  - Small perturbations on firm/stable surface
  - Key Synergies: Gastrocs → Hams and Tib Ant → Quads

- **Hip Strategy**
  - Large perturbations on less stable or narrow base surface
  - Key synergies: Abs + Quads and Paraspinals + Hams

- **Stepping Strategy**
  - Larger and rapid perturbations
  - Reflexive-mediated response
NeuroMotor Strategies are Adaptive
(Shumway-Cook & Woollacott, 2007)

- Depending on tasks, our body can shift quickly from one postural movement strategy to another.
- With frequent practice, postural responses improve and strategy use becomes more efficient

Common NeuroMotor-Related Problems with Postural Control

1. During Anticipatory Control
   - Problems sequencing and activation of proper postural synergies
2. During Reactive Control
   - Slow reaction time, delayed reflexive response
3. During ongoing Task Performance
   - Problems modifying or adapting postural control to changing environments or task demands

Dynamic Systems for Postural Control

Organization, regulation and integration of sensory inputs:
- Somatosensory
- Visual
- Vestibular

Selection of sensory strategies
**Somatosensory System**

- Golgi Tendon Organs
- Muscle Spindles
- Cutaneous Receptors

*Provides information about surface conditions and position of the limbs*


---

**Visual System**

- Retina
- Central visual system
  - What pathway
  - Where pathway

*Provides information about relationships between self and environment (e.g., depth, color, textures, location, spatial relations, movement of objects)*


---

**Vestibular System**

- Otoliths
- Semicircular Canals

*Works with visual and proprio-kinesthetic systems*

*Provides information about motion of the body in space*

Integration ➔ Motor plan
Adaptive response

**CTSIB Modified**

<table>
<thead>
<tr>
<th>FEET ON FIRM SURFACE</th>
<th>EYES OPEN</th>
<th>EYES CLOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Senses On-Line, “Balanced”</td>
<td>Vestibular, Somatosensory available</td>
<td></td>
</tr>
</tbody>
</table>

| FEET ON UNEVEN SURFACE | Somatosensory accurate; Vestibular + Visual available | Vestibular demands increased |

**Implications of Sensory Organization**

- Somatosensory
  - Used mainly on firm surfaces in absent/reduced vision

- Vestibular system
  - Mediates equilibrium
  - Heightened when somatosensation is inaccurate and vision is reduced or inaccurate

- Visual and visuomotor system
  - Default system
  - Override or compensate for conflicts or inaccuracy in somatosensation and vestibular sense
Dynamic Systems for Postural Control

1. Vestibulo-ocular reflex (VOR)
2. Optokinetic Reflex (OKR)

Maintenance of gaze stabilization of image for acuity

Dynamic Systems for Postural Control

Cognitive System
1. Attentional system
2. Dual task performance → Multi-tasking

Additional Factors that May Influence Balance and Postural Responses

- Emotional State/Motivation
- Cardiorespiratory Status
- Pain
Aging-Related Issues in Balance and Postural Control

Section 2

Heterogeneity of Aging
(Shumway-Cook & Woollacott, 2007)

Models of Aging

Genetics: Primary Aging Factors
- DNA damage due to oxidants
- Internal causes determine aging and its consequences

Environment: Secondary Aging Factors
- External causes damage the body systems
- Radiation, pollutants/toxins, micro-organisms, injury
Age-Related Factors Specific to Postural Control
(Bortz & Bortz, 1996)

- Health Behaviors
- Genetics
- Exercise

Secondary Aging Factors are Modifiable

- Nutrition (Lee et al, 1993)
- Exercises (Kramer et al, 2006)
- Improved cardiovascular health
- Manage/control obesity
- Improved muscle strength & flexibility adds longevity
- Lifestyle redesign (Clark et al, 1997)
- Falls Prevention Programs

The Problem with Falls
(Rubenstein 2006; Rubenstein & Johnson, 2001)

- 5th leading cause of death in the elderly
- 75% of deaths in falls occur with 65+ persons
- 33% of falls occur among community dwellers
- Multi-factorial cause of falls
  - Person factors
  - Environmental factors
Factors Associated with Falls in the Elderly

- Person Factors
  - Balance Dysfunctions
  - Visual Impairment
  - Fear of Falling
  - Depression
  - Poly-pharmacy
  - Incontinence
  - Cognitive Impairments

- Environment Factors
  - Accessibility
  - Lighting
  - Surface Conditions
  - Falls History

Predictive Risk Factors for Falls
(Oliver et al, 2004)

- Gait instability
- Muscle weakness
- Urinary incontinence
- Impaired cognition (e.g., agitation, confusion)
- History of falls

Age-Related Changes in the Systems of Postural Control

- What systems contribute to postural control?
  - Musculoskeletal
  - Neuromuscular
  - Sensory
  - Cognitive
Musculoskeletal System

- Muscle Strength
- Range of Motion
  - Loss of spinal flexibility
  - Loss of ankle joint flexibility
  - Increased muscle tightness

Neuromuscular System

- Increased postural instability (greater sway)
- Decreased adaptation to changes in task and environment (feedback mechanism)
- Decreased anticipatory control of posture in context (feedforward mechanism)

Sensory System

- Sensory changes contribute to decline in stability
  - Somatosensory
  - Vision
  - Vestibular
- Reduced accuracy of senses for postural control
Cognitive System

- Decreased attention to task
- Decreased problem solving
- Reduced dual task performance

Other Factors

- Cardiovascular Capacity
- Psychological / Emotional Status
  - Lowered sense of self-efficacy
  - Fear of falling
- Family-induced?
Evidence-Based Assessments

Part 3

Purposes of Assessment

1. Determine the presence of dysfunction

2. Determine the nature of dysfunction
   - Paints a clinical picture
   - Facilitates intervention planning

3. Prognosticate function/performance

Health condition
(disorder or disease)

- Impairments in Postural Systems
- Postural and Balance Difficulties Limiting Task Performance
- Decreased Participation and Life Roles

Environmental Factors
Personal Factors
Contextual Factors

(World Health Organization, 2002)
Considerations for Holistic Assessment

1. Consider Safety First!
2. Observe postural control in natural contexts (performance based assessments)
3. Understand underlying impairments (biomechanical, sensory, neuromotor, cognitive)
4. Understand the patient’s/client’s history
5. Understand the patient’s/client’s environment

1. Safety & Contextual Considerations

- Gait belt
- Guarding techniques
- Context or Environmental Conditions of Daily Life
  - Meal preparation
  - Bathing and Toileting
  - Dressing

2. Assess Conditions in Daily Life

1. Performance in self-initiated actions
2. Reactions or proactive measures to avoid a fall
3. Predict destabilizing situations
3a. Determine underlying impairments

- Structural Changes
- Range of Motion and Strength
- Cardiovascular
- Pain and Sensory Impairments
- Confounding Cognitive Impairments
- Psychosocial and Motivational Elements

3b. Determine strategy use

- Sensory strategies used to maintain postural control
  - Somatosensory
  - Visual – Visual Motor
  - Vestibular
- Motor strategies and maintaining balance during:
  - Stance (Hip and Ankle Strategies)
  - Anticipatory control
  - Reactive Balance (Stepping Strategy)

4. Understand the Client’s History

Starter Questions

- Do you have any troubles keeping your balance? Rising from the bed/chair? Standing? Walking?
- Which instances in your daily life routines do you find keeping your balance difficult?
- What activities have you given up because of difficulties keeping your balance?
5. Understand the Client’s Environment

- In addition to the "standard" questions…

- Are there areas in your home that you have not gone to in a while or have only gone to with help?

- How do you cook? Make a meal for yourself? Can you describe your kitchen set-up?

- How do you bathe?

5. Understand the Client’s Environment

- How about out in the community? Are there places have you avoided or stop going to?

- How is it like to go around your neighborhood? Walk by the sidewalk?

- How is it like for you to the grocery store?
6. Incorporate Objective Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

6. Incorporate Objective Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive

Outcome Measures

- Comprehensive:
  - Reflects impairments and dysfunctions
  - Distinguishes quality of strategies
- Psychometrically sound:
  - Reliable, valid and sensitive to change
  - Specific to balance and postural control
- Practical:
  - Easy to use/administer
  - Inexpensive
Timed “Up and Go” (TUG)
(Podsiadlo & Richardson, 1991)

Features:
- Easy to use
- Predicts fall risk (13.5 sec)
- Predicts frailty status (32.6 sec)
- Sensitive in moderate-severe cases

Norms:
- Up to 79 = 8-9 secs, 80+ = 10-11 secs
- With manual task = 14.5 sec
- With dual task = 15 sec

Five Times Sit-to-Stand Test
(Guralnik, 2000; Bohannon, 2006)

Features:
- Easy to use
- Measure of functional LE strength and movement transitions

Norms:
- 11.4 to 12.7 seconds
- Cut-off: 12 to 15 seconds

Functional Reach Test
(Weiner, Duncan, et al, 1990)

Features:
- Easy to use
- Predicts fall risk (17.5 cm) and frailty (18.5 cm)
- Moderate to high correlation with ADL and mobility dependence

Norms:
- Men = 13.2 (1.6)
- Women = 10.5 (3.5)
Berg Balance Scale

(Berg, 1992; Lusardi, 2004)

**Item Description**
- Sitting on stool
- Standing unsupported
- Lifting unsupported
- Standing on one foot
- Turning in midline
- Turning, 90 degrees
- Allowing anterior foot to stop
- Allowing one foot to pivot
- Allowing one foot to pivot
- Walking

**Scores**
- 56 = functional balance
- <45 = fall risk

**MDC = 5 points**

**Table 6. Berg Balance Scale Scores by Age, Gender, and Use of Assistive Device**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>86+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sample Items**

6. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING

**Instructions:** Turn to look directly behind you over toward left shoulder. Repeat to the right.

- Examiner may pick an object to look at directly behind the subject to encourage a better (swivel turn.)
  - 4 looks behind from both sides and weight shifts well
  - 3 looks behind one side only either side shows less weight shift
  - 2 turns sideways only but maintains balance
  - 1 needs supervision when turning
  - 0 needs assist to keep from losing balance or falling

**Figure:**

Berg score

(Shumway-Cook and Woollacott, 2007)
13. STANDING UNSUPPORTED ONE FOOT IN FRONT

INSTRUCTIONS: (DEMONSTRATE TO SUBJECT)
Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width)

( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead of other independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

14. STANDING ON ONE LEG

INSTRUCTIONS: Stand on one leg as long as you can without holding.

( ) 4 able to lift leg independently and hold >10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold 0-5 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently
( ) 0 unable to try or needs assist to prevent fall

Dynamic Gait Index

- 8 items, measured on a 4-point scale
- Assessment of gait mobility from steady state walking to stair climbing
- Interpretation:
  - 19 or less = falls risk
  - 22 to 24 = safe
- MDC for Elderly: 2.9 points

2. Change in gait speed

INSTRUCTIONS: Begin walking at your normal pace (for 5'), when I tell you "go," walk as fast as you can for 5'. When I tell you "slow," walk as slowly as you can for 5'.

(1) Normal: Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal, fast, and slow speeds.
(2) Mild Impairment: Able to change speed but demonstrates mild gait deviations, or not gait deviations but unable to achieve a significant change in velocity, or use an assistive device.
(3) Moderate Impairment: Makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, or changes speed but has significant gait deviations, or changes speed but loses balance but is able to recover and continue walking.
(4) Severe Impairment: Cannot change speeds, or loses balance and has to reach for wall or be caught.

3. Gait with horizontal head turns

INSTRUCTIONS: Begin walking at your normal pace. When I tell you to "look right," keep walking straight, but turn your head to the right. Keep looking to the right until I tell you "look left," then keep walking straight and turn your head to the left. Keep your head to the left until I tell you "look right," then keep walking straight, but return your head to the center.

(1) Normal: Performed head turns smoothly with no change in gait.
(2) Mild Impairment: Performed head turns smoothly with slight change in gait velocity, or minor disruption to smooth gait path or uses walking aid.
(3) Moderate Impairment: Performed head turns with moderate change in gait velocity, slows down, stumbles but remains on feet, can continue to walk.
(4) Severe Impairment: Performed task with severe disruption of gait, i.e., stutters outside 12" path, loses balance, stops, reaches for wall.
Self-Efficacy

The Activities-specific Balance Confidence (ABC) Scale

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%

no confidence completely confident

- 80% = high level of physical functioning
- 50-80% = moderate level of physical functioning
- < 50% = low level of physical functioning
  Myers AM (1998)
- < 67% = older adults at risk for falling; predictive of future fall
  LaRoie Y (2004)

BestTest

Balance Evaluation Systems Test (BestTest)

- Most comprehensive, aggregated items of evidence-based best measures of balance control systems
- Very lengthy = 36 items grouped into 6 categories
  - biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation, stability in gait
- Modified version, MiniBEST has 14 items, 3 times faster to administer
Compare with Berg

Mini-BESTest of DYNAMIC BALANCE: Balance Evaluation Systems Test: Copyright 2008

ANTICIPATORY

1. "STAND TO STAND" Simulate the one-legged stance. Try not to use your hands unless you must. Do not let your legs swing against the back of the chair when you stand. Please stand up. If you fall, score 0. If you stand up without use of hands or balance cues, score 2.

2. RISE TO TOES
   - Place your feet shoulder-width apart. Place your hands on your hips. Try to rise as high as you can without using your hands. If you have to use your hands, count -0.5 points for each hand used.

3. STAND ON ONE LEG
   - Place your foot sideways on the chair and your hand on your hip.

STANDING EQUILIBRIUM

1. STAND (FEET TOGETHER), EYES OPEN, FIRM SURFACE
   - Simulate the one-legged stance. Try not to use your hands unless you must. Do not let your legs swing against the back of the chair when you stand.

2. STAND (FEET TOGETHER), EYES CLOSED, FIRM SURFACE
   - Place your feet together and close your eyes.

3. INCLINE EYES CLOSED
   - Stand the incline chair. Place your hands on your hips. Place your head as close as possible and look straight when you close your eyes.

For teaching purposes only - Do not copy without author's permission
...only clinical balance test to include tests of postural responses to external perturbations..."

Balance is achieved by the complex integration and coordination of multiple body systems

Many of these body systems decline with aging

Balance assessments must consider holistically
- Presence and types impairments
- Nature of dysfunctions
- Impact on performance and participation

Review of Objectives

1. Describe the Dynamic Model of Balance and Postural Control
2. State aging-related balance impairments associated with older adults
3. Apply evidence-based assessments and the Dynamic Model of Balance in evaluating balance and mobility impairments in older adults
Questions?

Thank You!