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**What do you want to know about your patient's balance?**

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**What We Need to Know?**

- Postural Response
- Muscle-skeletal
- Vestibular Function
- Postural Control
- Balance & Posture
- Cognition
- Vision
- Gait Stability

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**Postural Control**

- The ability to control our body’s position in space is fundamental to everything we do.

- We use postural control circuits in the nervous system to accomplish this.
To achieve Postural Control...

- A complex interaction of the musculoskeletal and nervous systems occurs.
- This interaction is referred to as the “Postural Control System.”

Shumway-Cook & Woolacott, 2012

Postural Control

“The successful accomplishment of ANY movement can only occur in conjunction with adequate postural control.”

Macpherson, Fung, and Jacobs (1997)
Two Main Goals of the Postural Control System:

<table>
<thead>
<tr>
<th>Orientation (Posture)</th>
<th>Stability (Balance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to maintain appropriate relationship between the body segments, and between the body and the environment.</td>
<td>Ability to control the center of mass (COM) in relationship to the base of support (BOS).</td>
</tr>
</tbody>
</table>

Two major requirements of Stability or Balance

1. Maintain the COM inside the BOS
   - Example: Standing

2. Controlled moving of the COM over the BOS
   - Example: Walking

Maintaining COM Inside BOS

The Location of the COM and BOS can change
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Controlling COM outside BOS

Location of COM and BOS can change

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“Stability and orientation requirements change with each task, and with demands of the environment.”

Stability and orientation requirements change with each task, and with demands of the environment.

(Shumway-Cook & Horak, 1996; Horak & Macpherson, 1996; Shumway-Cook & McCollum, 1990.)

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Systems Model:

Postural control emerges from interaction of the individual, the task, and the environment.

Postural Control

INDIVIDUAL

TASK

ENVIRONMENT

Shumway-Cook & Horak, 1996
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**What is a task?**

“If you can name it, it is probably a task.”

- Kathye Light, PhD

Walking, standing, turning, dancing, jogging, sitting, standing up, sitting down, rolling over, biking, swimming, reaching, pulling, pushing, grasping, nursing, jumping, lying down, climbing, juggling, scooting, pinching, lifting, hitting, driving, catching, throwing, rolling, hopping, skipping, kicking . . .

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**What picture is showing the task of WALKING?**

How do you know?

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**Why did Mrs. Smith Fall?**
Why does our postural control system sometimes fail us?

Constraints
- Boundaries that limit the movement capabilities of the individual (Newell, 1986).

Environmental Constraints
- Photographs of individuals in different settings.
Individual Constraints

- Many physiological systems underlie the ability to maintain orientation & stability
- Understanding of these systems can empower the PT to:
  - Identify specific balance deficits
  - Direct balance treatments that are appropriate for particular deficits

“Cone of Stability”:
Stability Limits/Verticality

- The area over which an individual can move their COM and maintain equilibrium without changing the base of support.
The brain has an internal representation of the cone of stability that it uses to maintain our equilibrium. 

Postural Motor systems:
- Postural motor mechanisms primarily engage involuntary motor pathways to maintain balance.

2 main goals of Postural Control System:
- Predict disturbances that occur during voluntary movement, and thus maintain balance during active or planned movement. Called Proactive Response
- React to outside or unplanned disturbances and recover balance. Called Reactive Response

Loss of Postural Control
Postural Reflex Responses:
Anticipatory Postural Adjustments

- are generated by CNS to predict and prevent disturbances in the body’s alignment and stability during planned, voluntary movements.
- are involuntary.
- occur just before, and during, a voluntary movement.

Reactive Postural Responses use:

- Movement Strategies to restore the COM over the BOS after a disturbance.
- 3 Main Strategies:
  - Ankle
  - Hip
  - Stepping

Ankle Strategy:
The body moves at the ankle

- Ankle Strategy is used when:
  - balance disturbance is small
  - standing surface is wide and firm
  - Head moves in unison with hips, like an inverted pendulum
  - Muscles are recruited from distal-to-proximal
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**Hip Strategy: The body moves at the hip**
- Hip Strategy used when:
  - balance disturbance is moderate or fast
  - surface is narrow or compliant
  - head movement is opposite in direction to hips
  - muscles are recruited proximal to distal

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**Stepping Strategy: One or more steps are taken**
- Stepping Strategy is used when:
  - balance disturbance is strong or fast
  - BOS needs to move quickly
  - commonly used during walking
  - BOS moves quickly to catch up with COM

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**4th Strategy: Suspensory**
- Trunk bends forward with hip and knee flexion \(\rightarrow\) squatting position
- Quickly lowers COM over BOS, immediately making you more stable
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When Postural Responses Fail

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Sensory Input is essential for the body to maintain its orientation and stability.

- Sensory Input
- Central Processing
- Motor Output

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3 Main Senses Used for Balance

- Vision
  - Horizontal orientation

- Vestibular
  - Vertical orientation

- Somatosensory
  - Support surface orientation

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Visual System

- Provides a picture of where things are in our environment
- Where we are in relation to our environment
- Works with the vestibular system:
  - to keep objects from blurring when our head moves and,
  - to keep us aware of our position when we move or are moved
Visual Function

- Visual acuity, contrast sensitivity, visual field, cataract, glaucoma and macular degeneration all contribute to risk of fall
- As do bifocal or multifocal lenses, which impair depth perception and edge-contrast sensitivity at critical distances for detecting obstacles

Somatosensory

- Sensory receptors in our joints and muscles help us maintain our balance when we stand still or move
- Brain receives, interprets and processes the information from these systems to control balance

Proprioceptive System

- Specialized cells in muscles, joints and tendons that help monitor body position
- Provide information about how much stress or force is on a muscle or joint
- Help the brain know what type of surface you are standing or sitting on
- Understand position of body
Structures in the inner ear provide information about head position and forces acting on the head.

- Like fluid filled levels
- Responsible for helping to maintain proper head position
- Works with the visual system to coordinate head and eye movement

Vestibular System

- Provides continuous input to the brain about rotational and translational head motion and orientation relative to gravity.
- Allows for keeping gaze and postural stability by way of the vestibulo-ocular reflex and vestibulospinal reflex.
- Dysfunction can be inferred from assessment of these reflexes (i.e. calorics, DVA test).

Vestibular Function is Integral to Balance Control

- The inner ear works with other sensorimotor systems in the body.
- To check and maintain the position of our body at rest or in motion.
- To maintain steady focus on objects even though the position of our body changes.
- By detecting mechanical forces, including gravity.
Imbalance can result from disturbances in gaze and postural stability.

Vestibular Function and Balance

- Generates compensatory eye movements in response to head movement
- Works with saccadic and smooth pursuits to maintain gaze stability independent of head position
- Deficit may indicate a unilateral or bilateral dysfunction

Vestibulo-Ocular Reflex

Healthy nervous system's automatically adjust the body's orientation in space, depending upon the task and the context:

<table>
<thead>
<tr>
<th>TASK</th>
<th>CONTEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>on flat, smooth surface on sunny day</td>
</tr>
<tr>
<td>Walking</td>
<td>on flat, smooth surface on dark night</td>
</tr>
<tr>
<td>Walking</td>
<td>on uneven gravel on sunny day</td>
</tr>
<tr>
<td>Walking very fast</td>
<td>on flat, smooth surface on sunny day</td>
</tr>
<tr>
<td>Walking very fast</td>
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</table>
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**Sensory Integration**

- Information from somatosensory, visual and vestibular systems are constantly integrated to interpret the environment.

- Depending upon the environment, one sense may play a stronger role than the other two.

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**Sensory Input → Integration → Output → Balance**

- **Vestibular**
  - Cerebellum coordinates and regulates posture, movement and balance.
  - Cerebral cortex contributes higher-level thinking and memory.
  - Brainstem integrates and sorts sensory information.

- **Visual**
  - Visual information is processed in the cerebral cortex.

- **Proprioceptive**
  - Proprioceptive input is processed in the brainstem.

**Motor Output**

- **Vestibulo-ocular Reflex**
  - Motor impulses to control eye movements.

- **Motor Impulses to Make Postural Adjustments**

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**For example**

- In a well-lit environment with a firm base of support, a healthy person rely on:
  - Somatosensory (70%)
  - Vision (10%)
  - Vestibular (20%)

...to maintain their balance.
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Sensory Re-weighting

- The ability to re-weight the balance senses as an individual moves from one context to another is essential for maintaining balance.
- Examples:
  - Standing with eyes open, then with eyes closed
  - Walking from sidewalk onto grass
- Example: Moving from well-lit to very dimly-lit area (movie theatre)

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Sometimes the brain misinterprets sensory input!
The Vestibular System resolves inter-sensory conflicts

- Example: All cars are stopped. Cars on the left start to move, cars on the right remain stopped. Driver in the car on the right thinks he is rolling backwards!

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Stability in Gait

- Diagram showing different stages of the gait cycle.
**Control of COM during Walking**

- Balance during walking requires many levels of postural control around a constantly moving COM.
- Unlike quiet stance, the COM is not kept within the BOS support when walking.
- The COM must be controlled as it repeatedly moves outside of the BOS.

**3 Essential Requirements for Successful Walking**

- Reciprocal Stepping
- Maintaining upright posture during walking
- Adaptation to demands of Task and/or Environment

Forssberg, 1982, Adapted by Patla, 1991

**Looking at the 3 Requirements of Gait in terms of postural control mechanisms**

- Stepping
- Maintaining Upright
- Adaptation

- Orientation
- Balance
- Reactive
- Proactive
P.T. often stops here

- Restore stepping and upright posture with assistive device
- Is there more to functional walking that we could assess, and possibly treat and restore?

Feedback Mechanisms
Strategies & Synergies

- Feedback control refers to postural control that occurs in response to sensory feedback (visual, vestibular, & somatosensory) from an external perturbation
- Support surface moves
- Trips and slips
- Reactive Control

Neuromuscular Synergies:
Automatic Postural Responses (APRs)

- Ankle Strategy
- Hip Strategy

Muscle Synergy:
- Backward Perturbation
- Forward Perturbation
Feed forward Mechanisms

- Feed forward control refers to postural responses that are made in anticipation of a voluntary movement that is potentially destabilizing in order to maintain stability during the movement
- Proactive Control

Anticipatory Mechanisms: Central Set

- CNS “readiness” for anticipated movement.
- Predictive pre-set prior to force requirement

If we accept the assumption that postural control is the co-requisite for all coordinated movement, then...

- To restore movement after injury or disease,
- We must consider not only re-training the specific motor task,
- but we must also consider re-training the postural control system because it is an essential component for the successful performance of that task.
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For example:

Compensation Approach  
Recovery Approach

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Basic Requirements of Gait

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Musculoskeletal Contributions

• Muscle function may play a role in the ability to maintain balance
• Likely muscle group specific
• Relation between balance performance measures and hip muscle performance (Lesback, 1996)
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**Muscle Strength and Motion**

- Hip muscle weakness may be a single best predictor of falls in elderly (Tinetti, 1988)
- Plantar flexor strength of the hallux and ankle inversion-eversion range of motion, are important to balance and functional ability in older people (Spink, et al 2011)

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**Muscle Stength and Gait Speed**

- Falls occur primarily during ambulation
- Relation shown between gait speed (dynamic steady state balance) and measures of strength and power, especially in frail elderly (Granacher, et al 2012)
- Older adults showed deficits in compensation of perturbations during stance and gait
- Slower onset latencies
- Decreased reflex activity
- Increased co-agonist activity

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**Cognition**

- Though much of postural control activity is without conscious effort, cognitive systems are still required
- **Attention**
  - The more difficult the postural task, the more cognitive processing is required
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**Cognition**
- Cognitive deficit is clearly associated with increased risk of fall
- Example: 5+ errors on MMSE is associated with increased risk of fall
- 3 item recall has been demonstrated to be an independent risk factor for those over 75

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**What do we want to know to treat...?**
- Postural Responses
- Musculo-skeletal
- Postural Control
- Balance & Posture
- Vision
- Peripheral Sensory
- Age

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**So what are these tests testing?**
- Romberg
- Tandem/Single Leg Stance
- Modified Combined Test for Sensory Interaction and Balance (CTSIB)
- Timed Up and Go Test
- Berg Balance Test
- Tinnetti Balance Assessment Tool
- Dynamic Gait Index
- Balance Evaluation Systems Test (BESTest)