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الآيه(32) سوره البقره

EXAMINATION OF BALANCE AND EQUILIBRIUM

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BALANCE OR **EQUILIBRIUM**, SOMETIMES REFERRED TO AS **POSTURAL STABILITY**

the ability to maintain stability in an upright posture particularly keeping the body up against gravity.

- Balance is an essential component of all upright tasks involving both the ability to recover from episodes of instability and the ability to anticipate and move in ways to avoid instability and falling.

From the standpoint of physics, ***for any upright object to be stable the center of mass must be maintained over the base of support*.**

- **center of mass (COM)** is *the single point at which all the mass of the object can be considered to lie*.
- **The base of support (BOS)** includes *all points of body contact with the supporting surface* and can be described or visualized as the *area enclosed within the perimeter of all these points of contact*.

For example, in sitting, the BOS includes the ischial tuberosities and buttocks, probably part of the posterior thighs

INTRODUCTION

- **The statement relating COM to BOS** implies there must be *a system of sensory input to monitor the location of the COM in relation to the BOS* and *a system of motor output that can regulate these positional relationships.*

- The *maximum distance a person can intentionally move or displace his/her COM in each direction without losing balance* is known as the **limits of stability (LOS).**

- **Equilibrium or balance** is a complex body function/body structure that depends on normal operation of multiple sensory and motor systems.

- **Disequilibrium** or **balance impairment** is considered *a complex impairment because multiple body systems may be involved*.

Balance, in and of itself, is not an activity or functional task, but it is a required component in all specific upright functional tasks.

INTRODUCTION

- ✓ **Disequilibrium** can result from impairment of any of the related systems as described later.
- ✓ **Limitations in balance** may contribute to ***functional limitations*** in many specific tasks and activities. In adults, *limitations in standing & sitting*, for example, influence gait, transfers, activities of daily living (ADLs), and reaching activities. Balance also influences *function in other developmental positions* such as kneeling and quadruped,
- ✓ The decrease in functional abilities and avoidance of activities may negatively influence a person's societal roles and result in disability or **participation restrictions**. The examination of balance and equilibrium is a critical component of the neurological examination across the lifespan and in multiple neuromuscular diagnoses.

CATEGORIES OF BALANCE AND EQUILIBRIUM

- **Static balance**

maintaining upright posture, any posture, in the absence of self-initiated movement—that is, simply maintaining a posture while not trying to move or even *maintaining a posture against mild disturbance from an external source*.

- **Dynamic balance**

maintaining *upright posture or stability* during self-initiated body or body-segment active movement.

- A complex interaction of biomechanical components, sensory systems, motor systems, and CNS integration must occur to maintain balance during both static and dynamic activities.
- Cognition also plays an essential role.

THE PROCESS OF DYNAMIC EQUILIBRIUM

- Horak (1987) divides the postural control system into three basic functional components (**biomechanical**, **sensory**, and **motor**) that *provide a helpful framework to keep in mind for* **examination** and **intervention** *decisions regarding balance.*

- **The three elements should be kept in mind also as components that can be manipulated in the intervention plan (Fig. 9-1):**

I. **Biomechanically**, it is important to consider the forces applied and *the mechanical factors that contribute to body and joint/ segment stability*.

II. **Sensory components** include *all incoming information used to monitor the person's equilibrium status* as a basis upon which to determine appropriate adjustments to maintain an upright posture.

III. **The motor components** include *all parts of the neuromusculoskeletal systems that help to carry out the postural adjustments* and equilibrium reactions essential to maintain balance.

- **central processing** must take place in the CNS after receiving the sensory components and before implementing the motor components and for real-time adjustments and reactions during the balance reaction.

I- BIOMECHANICAL COMPONENTS

➢ **Force-platform studies** using computerized force-platforms have contributed to the understanding of the biomechanical properties of balance, including center of pressure and LOS.

✓ **center of pressure (COP)** or the **center of gravity** is the *single location on the supporting surface where the gravitational line, passing through the COM, would strike the floor or other supporting surface* as shown in Figure 9-2.

- When using a force platform, the COP can be displayed dynamically on a visual monitor or recorded as a string of data representing changes in the COP location(As a person's weight shifts, the COP moves in the direction of the weight shift).

FIGURE 9-2 An individual in standing, showing the approximate location of the Center of Pressure (COP) in relation to body position.

- ✓ **The LOS** are *the maximal distances an individual can safely lean in each direction without loss of balance* (Fig. 9-3).

- ○ or as *the circumferential extremes within which the COP can lean with the body remaining stable*.

- ▪ **In standing**, how far, without taking a step or repositioning your feet,

can you incline your body forward and how far backward (Fig. 9-3A), how far to the right, and how far to the left (Fig. 9-3A)?

The composite of all these movements circumferentially would create **a cone-shaped** representation of a person's ability to lean in each direction, the LOS (Fig. 9-3C).

Figure 9-3D illustrates the same concepts applied to a person in sitting position.

FIGURE 9-3 **A.** An individual in standing illustrating the anterior-posterior dimensions of the cone-shaped Limits of Stability (LOS) from a lateral view. **B.** An anterior view illustrating the lateral dimensions of the limits of stability. **C.** The projected cone-shaped Limits of Stability (LOS) in an adult. **D.** A possible anterior/posterior LOS for an adult in sitting position.

I- BIOMECHANICAL COMPONENTS

Using force-platform measures of movement of COP in subjects with hemiplegic stroke, dynamic balance measures using force-platform data are supported over static balance measures as valid indicators of functional balance performance (Liston, 1996).

- the **majority of functional skills or tasks** *involve movement toward the extremes of the LOS to accomplish a purposeful task rather than simply maintaining a static posture safely in midline*.
- Therefore, **during balance training**, *we should encourage our patients to regularly move toward the edge of their LOS while in a safe guarded environment.* ***Before this however we must observe and measure the patient's balance ability.***

I- BIOMECHANICAL COMPONENTS

Nashner (1990) reported In standing with four inches between the feet:

1. the LOS as 12 degrees in an anteroposterior direction and 16 degrees from side-to-side.
2. sway in a posterior direction is most limited as there is no extension of the BOS posteriorly.
3. The greater mediolateral sway is probably related to having two separated supports (the feet) in the frontal plane and the resulting stance width.
4. As balance abilities decline, logically ====the LOS decrease.

✓ It has been shown in **young healthy adults** that, *under more challenging stance conditions (eyes closed, narrow BOS, and movement of the support surface)*,

- the COP tends to move toward the center of the BOS and
- spends a greater time more centrally, away from the edge of the LOS

II- SENSORY SYSTEMS

- **The primary sensory (afferent) systems** involved in balance and equilibrium include the **visual system**, **somatosensory system** (both proprioception + superficial tactile), and the **vestibular system**.

- The **CNS** must integrate the information from these systems to appropriately regulate goal-directed actions and automatic postural responses to maintain balance.

A- The visual system

- **provides information regarding the environment**, in particular *a reference for determining "upright" to which the individual must accurately respond to maintain balance*.
- **Visual cues regarding the orientation of the environment** relative to the individual are obtained by ***scanning for horizontal + vertical cues*** such as the horizon, windows and doorframes, buildings, walls, room corners, and trees.

✓ These cues are then utilized to maintain an upright position during static tasks or dynamic movement.

A- The visual system

- **When standing on a ramp/incline,** *an individual must process information from the* ***somatosensory system*** *regarding the degree of the incline* and *integrate that information with* ***visual input*** *regarding what is upright against gravity*, **then** respond to maintain balance and equilibrium.

- **Visual processing:**

1) begins very early in development, and young children learn to *visually compare body position to vertical and horizontal images from the environment*.

2) Optical righting reactions, the orientation of the head in response to visual inputs, You may have experienced, as you were falling from your bicycle for example, awareness that your personal orientation was becoming less and less upright compared with the trees, bushes, and fence posts around you.

3) The visual system also provides information regarding obstacles to navigate and/or anticipate in the environment to maintain equilibrium.

4) the visual system provides dynamic information regarding the movement of objects. For example, when one approaches an **escalator**, the visual system provides information on the height and speed of the approaching step.

II- SOMATOSENSORY SYSTEM

information contributing to balance **includes:**
(1) cutaneous touch & pressure sensations from the body segments in contact with the supporting surface.

(e.g., differential pressure from the forefoot or heel while standing or from the ischial tuberosities, posterior thighs, and feet while sitting) provides the individual with

- ✓ *necessary information such as the shape, orientation, and stability of the support surface or environment and*
- ✓ *whether bodyweight in standing is mostly borne at the forefoot (leaning forward) or the heel (leaning backward).*

Tactile receptors in the skin, especially pressure receptors along the sole of the foot in standing or the buttocks/thigh in sitting, **help to self-monitor, in a general way, the location and movement of the COP.**

In the feet as you shift forward, you can feel most of your weight on the front of your foot, and as you **shift backward** most of the weight is felt at your heel. As your CNS detects extreme changes, you can use the motor system through the legs and trunk to adjust your body position accordingly.

information contributing to balance includes:

(2) proprioceptive & kinesthetic information from muscle receptors (muscle spindles) and joint receptors (Golgi tendon organs & joint capsule receptors).

- **subconscious position sense from muscle spindles carried by the spinocerebellar pathways**, *provides essential information about joint position at each body region but especially throughout the **legs** in standing.*

In standing, position sense from the ankles is *most important because this joint serves as the **primary pivot joint in quiet standing**.*

- ***For example,***

if excessive dorsiflexion is detected as an indication of excessive forward lean, *which would be accompanied by increased pressure sense from the forefoot,* → *the individual would use plantar flexor muscles to pull the tibia backward into plantar flexion,* → *and the body with it, back into a more upright position.*

Input from the joint & muscle receptors **provides the individual with** *information regarding joint position* **as well as** *the speed & direction of movement.*

- ✓ *This information is utilized to determine appropriate postural responses.*
- ✓ For example, **when running to kick a ball,** *the individual must anticipate and respond to the speed, direction, and magnitude of the lower extremity movement* by **activating postural responses** involving the **trunk** & **extremities**.

III- VESTIBULAR SYSTEM

- **it consisting** of the semicircular canals and the otolith organs in the inner ear **provides information about** the position of the head relative to gravity as well as the movement of the head in space.

Even with our eyes closed, we can sense position and movement of our head primarily using vestibular input. We tend to depend on this sense most when vision and somatosensation are limited.

- **The primary functions of this system for balance include:**

1) the awareness of upright in relation to gravity,
2) the stabilization of gaze during head movements **via** the *vestibulo-ocular reflex (VOR),*
3) the regulation of postural tone & muscle activation **via** the *vestibulospinal pathways.*

During any head movement, → **the VOR promotes gaze stability**

(the eyes to move at the same speed and magnitude but in the opposite direction from the head movement.)

maintenance of gaze → allows the visual system to transmit accurate information to the brain even during head movement, thus further assisting the individual in maintaining equilibrium.

CENTRAL PROCESSING

CNS integrates information from all of sensory systems as a basis for maintaining balance.

The relative importance of each system varies depending on:

1) the individual,

2) the task, and

3) the context of the task as each piece of information is interpreted in relation to others.

CENTRAL PROCESSING

Some types of sensory information are not valid in certain circumstances.

- **For example,** the **joint position at the ankle**, *very important sensory information while standing on a stable surface, is irrelevant if standing on an unstable surface with changing slant/incline.*
- **Under low light conditions**, *for instance, the somatosensory and vestibular systems would play a greater role than the visual system.*

➢ The redundancy of input from the three systems allows for increased flexibility in the system across diverse environments.

- For example, in an individual with somatosensory loss (e.g., a person with peripheral neuropathy related to diabetes), the roles of the visual and vestibular systems would increase.

CENTRAL PROCESSING

The interaction of these 3 sensory systems is essential in maintaining upright balance.

In quiet undisturbed standing

humans **depend most on the** *somatosensory* information from the ankle and foot, primarily position sense from the ankle, but some from pressure sensation from the sole of the foot (in sitting, the brain uses position sense from the hip joint and pressure sensation from the ischial tuberosities and buttocks).

standing on an unstable or moving surface (standing in a rocking boat on rough seas or walking across an inflatable mattress)

somatosensory input **is less reliable** in reflecting our relationship to upright and in fact can conflict with the other sensory systems.

CENTRAL PROCESSING

In fact, under such conditions,

if there were a hard and fast rule

that depended only on proprioception,

"always maintain the ankle at zero degrees,"

a fall would quickly result on unstable surfaces

*as this rule assumes that the support surface is always horizontal.*بافتراض

On unstable surfaces, people rely more on :

visual cues (e.g., *scanning the environment for the horizon*) and

(e.g., detecting whether the **vestibular information** is upright or not) to help maintain equilibrium.

CENTRAL PROCESSING

When standing on an unstable surface with limited vision
(e.g., standing in a fishing boat at night),

→ **the balance system depends primarily on** vestibular input **to** *help gauge position in relation to gravity* **as a prerequisite for** *making adjustments to maintain balance*.

with aging

→ **Declines in** somatosensory (Lia, 2002), visual (Kosnik, 1988), and anatomical and physiological aspects of vestibular system (Sloane, 1989) **function**

→ there is no particular pattern of loss in the elderly.

→ when more than one sensory modality is reduced, older adults are less able to maintain balance than younger individuals (Woolacott, 1986).

MOTOR RESPONSES

- The motor plans to maintain balance are complex and vary depending on the demands and context of the task and the individual.
- Each individual motor plan of the balance process in standing *is carried out by the neuromuscular system—specifically, motor pathways of the CNS acting upon specific muscle groups, primarily in the lower extremity*, to cause the desired coordinated actions that maintain equilibrium.
- **Righting**, **protective**, **and** **equilibrium reactions** are *postural responses that occur in a "reflexive" or stereotypic manner to certain sensory stimuli and are developed during childhood*

Righting reactions	○ **orient the head in space + the body in relation to the head and support surface** ○ can occur in response to **visual** (optical righting), **vestibular** (labyrinthine righting), or **somatosensory** (body on head righting) **cues.** ○ begin development at approximately ***3 months of age***.
Protective reactions,	○ **including protective extension which:** 1. prevent a fall after the *COM moves irreparably beyond the LOS*. 2. prevent injury *by one or more extremities reaching out* to prop on the surface or reset/*expand the BOS* in the direction of the disturbance to avert a fall. ○ In sitting, forward and sideways : ***6-9 month*** ○ backward protective reactions : ***10-12 month***
Equilibrium (balance) reactions	○ These movements generally shift the body in the direction opposite from the perturbing force to maintain balance. 1. Typically includes **trunk rotation** along with **extension** and **abduction of the extremities**. 2. occur in response to substantial displacement of the COM. ○ begin to develop at the ***end of the first year of life***.

MOTOR RESPONSES

Nashner has described and categorized the complex motor interactions of balance in standing as three levels or **three balance strategies**:

ankle strategy

- Most often, responses to such **mild perturbations.**
- tibial movement at the ankle joint to shift the body's COM toward the center of the BOS and enhance postural stability.
- **predominantly distal muscle activation of the lower extremity,** using muscles at the ankle as the primary pivot joint.
- In sitting, the analogous response would be movement at the hip joint for anterior/posterior sway and the lower trunk muscles for lateral sway.

hip strategy

- **At a more active level,** the bus or subway comes to a rapid stop while standing and facing forward.
- which involves flexion or extension of the hip to more extremely shift the COM within the bounds of the BOS.
- **A proximal to distal activation of muscles** has been described for this strategy, and knee flexion may also be incorporated to lower the COM, which also increases stability.
- The analogous response in sitting could be dramatic upper-trunk movements or upper extremity position changes to quickly reposition the COM over the BOS.

Stepping strategy

- **This most active balance strategy** occurs following sudden and forceful disturbances that **displace the COM well outside the BOS** even to such a degree that the person cannot recover stability using the ankle strategy or hip strategy.
- In standing, this "stepping strategy," which can be **considered a form of protective extension,** occurs by *quickly lifting and moving one foot in the same direction as the externally applied perturbation*

MOTOR RESPONSES

three balance strategies

- As part of the physical examination of balance, you should note the motor strategies utilized to maintain balance.
- In addition to the presence of the strategies, you should document

(1) whether the strategy utilized was effective and appropriate within the context of the task,

(2) whether the timing of the execution of the strategy was effective to meet the demand,

(3) whether the muscles were activated in the appropriate sequence.

These strategies should be tested across a variety of tasks involving both:

I. reactive postural control.

II. anticipatory postural control.

SAFETY CONCERNS

- During balance examination, the safety of the patient must be uppermost in the therapist's mind.
- As part of the initial examination, the balance test is performed because the therapist does not know the balance ability of the patient, and often before the examination, you already know the person has some known risk for falling related to the neuromuscular disorder or related system impairments such as weakness or range of motion restrictions.
- Also, most balance tests place the patient in a demanding or precarious position (e.g., narrow BOS, single-limb stance, etc.) that places the patient at further risk for falling.
- Therefore, you must **carefully observe**, **guard (including a gait belt),** and protect the patient from any risk of falling during the testing procedure.

PHYSIOLOGY AND NEUROSCIENCE OF BALANCE

WHERE IS IT? Figure 9-6

- The group of neuroanatomical structures that intercommunicate to maintain equilibrium is complex, including the ***integration of several sensory systems & the motor systems***.

- **several sensory systems :**

I. **The somatosensory system** utilizes mechanoreceptors **and somatosensory motor pathways**.

II. **The visual system** detects light via ***photoreceptors located in the retina***. Visual information is **transmitted via** ***both conscious and subconscious optic pathways*** **to** the ***primary visual cortex*** **to** ***allow the brain to perceive visual images of the environment***, including *horizontal + vertical cues to optimize upright position*.

III. **The vestibular apparatus,** located in the inner ear, consists of the **bony & membranous labyrinths** + the **hair cells** that are the ***vestibular sensory receptors***.

The bony labyrinth contains:

1) **three semicircular canals** that ***detect angular or rotary acceleration of the head in three different planes.***
2) **two otolith organs** that ***primarily monitor planar acceleration movements of the head.***

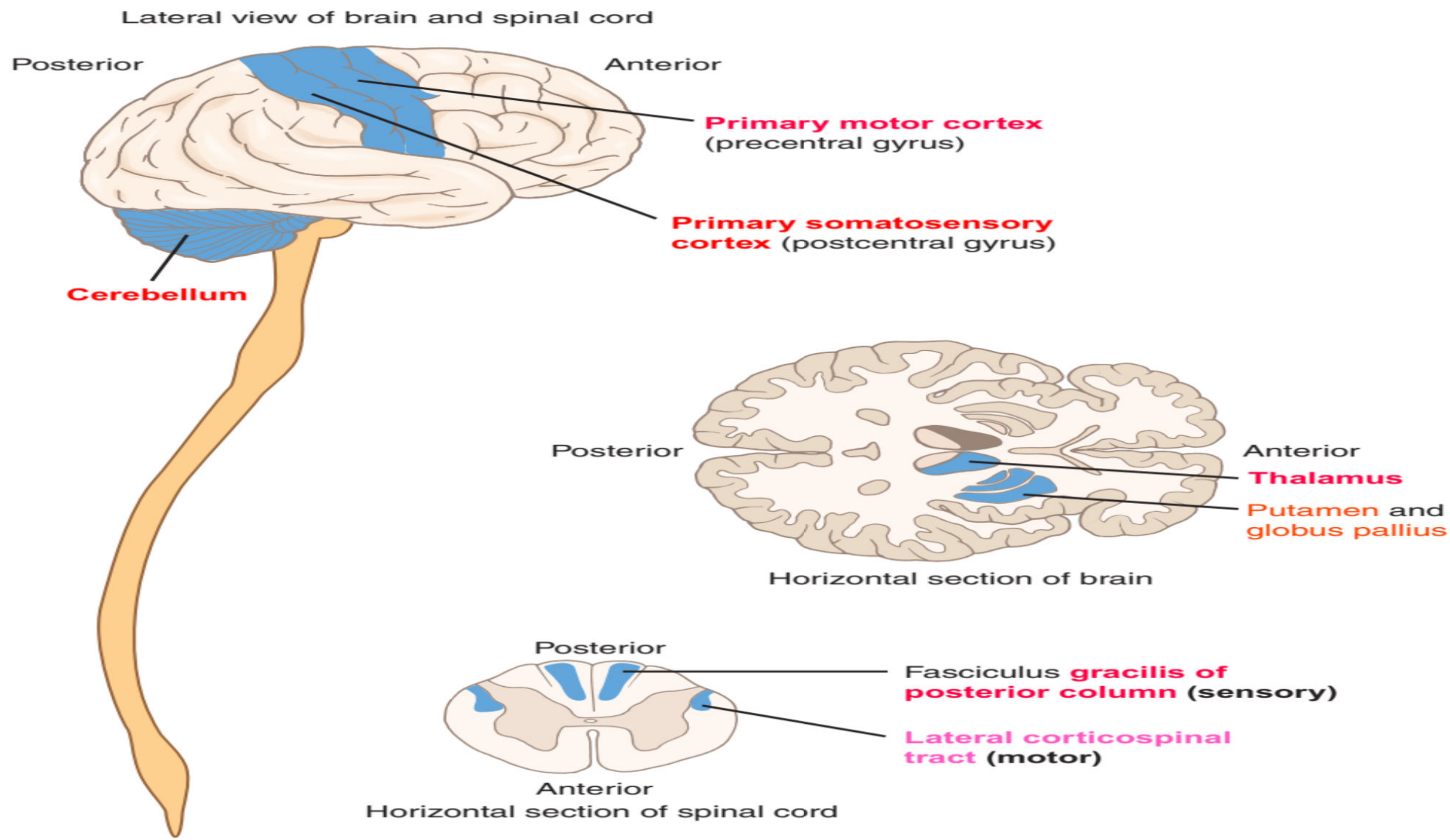


FIGURE 9-6 **Major CNS locations related to balance (within brain, brainstem, spinal cord)**. In the brain, **important areas** related to balance include the ***primary somatosensory cortex***(postcentral gyrus), ***primary and secondary motor cortex*** (precentral gyrus and posterior aspects of the superior frontal lobe), and **processing centers** in the ***cerebellum***, ***basal ganglia***,and ***thalamus.*** **Lesion locations are shown on only one side of the brain but damage to either side can impair balance.**

TABLE 9-1 Central Nervous System Sensory Structures and Their Roles in Maintaining Balance				
SENSATION	RECEPTORS/ LOCATION	PATHWAYS TO CNS	FUNCTIONAL ROLE IN BALANCE	PROJECTIONS/ DECUSSATION
Conscious proprioception	Muscle spindles, joint receptors, and Golgi tendon organs *in muscles, tendons, and joints*	**Dorsal Column**/Medial Lemniscus Fasciculus cuneatus and fasciculus gracilis in dorsal column of spinal cord, becomes ***medial lemniscal system in brainstem*** to parietal lobe of cerebral cortex	**Conscious knowledge** of position & movement of body relative to environment	Fibers cross in the ***low medulla*** through the internal arcuate fibers
Unconscious proprioception	Muscle spindles, joint receptors, and Golgi tendon organs in muscles, tendons, and joints	**Spinocerebellar pathways** to the cerebellum	**Subconscious feedback** regarding **accuracy** of movement & position	Most fibers end up in ipsilateral cerebellum (either as ***uncrossed*** fibers or tracts that cross in the spinal cord and then ***recross*** to the original side in the brainstem)

Visual	Photoreceptors (rods and cones) in retina of each eye	**Retinotectal** (Tectum)	Visual awareness of environment, including static and dynamic components **Feedforward anticipation** of environmental challenges **Feedback responses** to changes in environment and position of body relative to environment	Fibers from the medial half of each retina **cross *at the optic chiasm***
		Retinogeniculocalcarine (to visual cortex)	Conscious-movement **(dorsal-action stream)** *Visual identification of objects*	
Angular & linear acceleration	Hair cells, semicircular canals, and otolith organs of inner ear	**To the neocortex** via **oculomotor nuclei** via **medial longitudinal fasciculus** To the **spinal cord** via **vestibulospinal pathways**	- Perception of head movement - Coordination of eye movements - Postural control	

Tactile sensation	Mechanoreceptors	**Dorsal column/medial lemniscus** and **antero-lateral pathway** (ante-rior spinothalamic and lateral spinothalamic tracts) **to the somatosensory cortex**	Provide information regarding location & movement ***of center of pressure***	The fibers ***cross in low medulla*** (DCML)or ***in the spinal cord*** (spinothalamic) *before ascending to contralat-eral thalamus*

PHYSIOLOGY AND NEUROSCIENCE OF BALANCE

WHERE IS IT? Figure 9-6

- Several motor pathways are involved in the maintenance of equilibrium, including

I. **medial corticospinal**,

II. **vestibulospinal**, and

III. **tectospinal pathways.**

- Certainly, to maintain balance there must be precise coordination, motor control, and strength of muscle activity in the limbs and axial musculature.

the primary motor pathways considered in the maintenance of equilibrium are those pathways acting on the axial musculature.

- The motor system can be divided into:

A. **a dorsolateral system,** *controlling purposeful limb movement*.

B. **ventromedial system,** *controlling posture & balance*. The ventromedial system includes several pathways to the LMNs of axial & girdle musculature.

TABLE 9-2	Central Nervous System Motor Structures and Their Roles in Maintaining Balance			
MOTOR	STRUCTURE/ LOCATION	PATHWAYS FROM CNS	FUNCTIONAL ROLE IN BALANCE	PROJECTIONS/ DECUSSATION
Primary motor cortex	Cell bodies in **precen-tral gyrus of cerebral cortex** (head , neck,arms, and trunk cell bodies **on lateral sur-face**; lower extremity and foot cell bodies **on medial surface)**	Contribute to **corti-cospinal tracts**	**1) Voluntary contralateral motor control of *all skeletal muscle groups*;** **2)carries signals for *all reflexive motor responses of balance & equilibrium to skeletal muscles***	
Premotor cortex	Cell bodies in ***caudal portion of*** **lateral frontal lobe cortex, *just anterior to upper body portion of* precentral gyrus**	**Interconnects to primary motor cortex**	**Control of axial and proximal limb musculature + initial movements *to orient the body***	
Supplementary motor cortex	Cell bodies in ***supero-medial aspect of the*** **caudal frontal lobe** (*anterior to the* **para-central lobule lower extremity primary motor cortex**)	**Interconnects to primary motor cortex**	**Programming patterns + sequences of movements**	

Lateral corticospinal tract	**From cell bodies (pyramidal cells) of precentral gyrus**	Fibers pass sequentially through: - corona radiata - internal capsule -crus cerebri of cerebral peduncle - through pons - pyramids of medulla - pyramidal decussation to cross to contralat-eral side - then passes down through spinal cord as a tract in posterior aspect of lateral funiculus (lat-eral corticospinal tract) - terminates on target anterior horn cells (alpha motor neurons)	**Carries** ***motor signals*** **from** ***primary motor cortex*** **to** ***skeletal muscles***	Fibers cross in anterior aspects of **lower medulla** through pyramidal decussation
Final common pathway	**For each spinal level,** cell bodies of **AHC** of spinal cord **central gray matter**	Fibers pass sequentially through: - ventral root - spinal root - spinal nerve - peripheral nerve - terminates at neuro-muscular junction of specific target skeletal muscle	**All voluntary + re-flexive motor signals** ***must pass through final common pathway to activate muscles***	

FUNCTIONAL IMPLICATIONS OF BALANCE AND EQUILIBRIUM

- Impairment of balance in either sitting or standing → decrease independence in related specific functional tasks , → decrease efficiency in performance of those tasks.

→ decrease the individual's motivation to move → may result in a more sedentary lifestyle.

Limitations in balance & in mobility have been identified as **risk factors for falls**.

- Balance performance is a significant predictor of both gait speed and timed chair rise (Shubert, 2006).

- **In sitting, impaired balance can:**

✓ decrease a person's ability to sit unsupported.

✓ impair active sitting activities such as weight-shift, reaching, scooting in sitting, transfers, and sit-to-stand.

✓ **Functional tasks in standing** such as standing at a counter unsupported, standing in line, turning around to see someone, reaching for an object, walking, and stepping up ramps, curbs, or stairs, would also be negatively affected when balance is impaired.

PRINCIPLES OF EXAMINATION OF BALANCE

- **The history** should explore any **falls** or **near-falls** the patient has experienced.
- Then, assess whether the falls were the result of intrinsic or extrinsic factors.

I. **intrinsic factors :**

- ✓ **Sensory System impairments** including but not limited to dysfunction of the vestibular, proprioceptive, or visual sensory systems as well as
- ✓ **motor impairments** of weakness, incoordination, poor motorcontrol, and limited ROM.

II. **extrinsic factors**

- ✓ for example, ice that causes slipping, an indoor throw rug that causes slipping, poor lighting in a room or hallway, a pet or toddler who can interfere with safe stance or ambulation, or a raised threshold or environmental obstacle that causes tripping.

A detailed home assessment *should be included as part of the patient examination* so **the extrinsic risk factors** *can be addressed to minimize future falls*.

- A thorough examination of balance includes an evaluation of the multiple factors contributing to the maintenance of equilibrium as described earlier:

I. sensory reception and integration,

II. motor planning and execution,

III. musculoskeletal integrity,

IV. cognitive abilities and

V. allocation of attention,

VI. balance strategies, and

VII. balance-specific self-confidence.

- **measure balance in all the critical positions** *(at least sitting and standing).*
- **in static & dynamic tasks** focusing on the *functional skills that are limited by balance deficit*.

- **you must identify specific functional limitations** that result from balance impairment including how the task is specifically affected by impaired balance,
- Generally begin with an assessment of sitting balance, which has fewer risks, and proceed to standing balance.
- **The complexity of the tasks** selected in the examination of balance **begins with less complex static tasks** such as maintaining unsupported sitting or static standing during a conversation and **progresses to more challenging dynamic tasks** such as bending to put on a shoe while sitting or walking through a crowded cafeteria carrying a lunch tray.

- The clinical reasoning required during the evaluation of balance is complex.

✓ **The Taxonomy of Tasks by Gentile (1987)** will be particularly helpful in organizing your observations of the patient and their balance ability in a variety of settings and demand levels.

✓ **Tyson and Desouza (2003)** analyzed the clinical reasoning of therapists in the assessment of balance and suggested there are three overarching questions that must be addressed: (1) "What can the patient do?," (2) "How do they do it?," and (3) "Why do they do it that way?"

✓ **Essentially, you analyze task performance at the activity level with attention to** the functional abilities **and** level of independence.

✓ **Then, examine balance at the movement level**, studying the posture & movement strategies employed to maintain equilibrium.

✓ **Finally**, **identify the constraints and/or impairments underlying the performance** and whether these are primary problems **or** compensations.

- **Strength**, motor control, range of motion, and sensation should be assessed for their potential contribution to the patient's balance impairment, related functional activity limitations, and/or the compensatory strategies utilized.

TESTS AND MEASURES OF BALANCE

The complete examination of balance includes measures at

I. **the body structures and function level,**

(balance-related confidence, neuromuscular impairments, and postural impairments are considered.)

II. **activity limitation level,**

functional balance measures such as the Berg Balance Scale (Berg, 1992a, b) and the Performance-Oriented Mobility Assessment (Tinetti, 1986a) could be utilized

III. **at the participation restriction level, and balance tests at each level**

{**and quality of life indicators** can be assessed with tools such as the 36-Item Short Form Health Survey (SF-36) developed at RAND as part of the Medical Outcomes Study (2009).}

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

1) Balance-Related Confidence

- Psychological factors such as the fear of falling are significantly associated with changes in balance and gait, decreased activity level, and increased risk for falls.

- Balance-related confidence can be assessed with tools such as the Activities-specific Balance Confidence Scale **(ABC Scale)** (Filiatrault, 2007), Balance Efficacy Scale **(BES),** the Fear of Falling Avoidance Behavior Questionnaire **(FFABQ)** (Landers, 2011), and **the** Falls Efficacy Scale **(FES)** (Hellstrom, 2002)

✓ The ABC Scale (Fig. 9-7) and the BES (Fig. 9-8) are 16- and 18-item scales, respectively, based on patient self-report. Ask the patient to rate each item between 0% (reflecting no confidence) and 100% (reflecting complete confidence).

✓ Then, calculate the average percentage (Powell, 1995; Rose, 2003) and record the result in the patient record for current decision-making and for future comparison postintervention.

✓ There is some indication the ABC Scale is sensitive to change (Miller, 2003).

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

"How confident are you that you will not lose your balance or become unsteady when you ...

... walk around the house?	______%
... walk up or down stairs?	______%
... bend over and pick up a slipper from the front of a closet floor?	______%
... reach for a small can off a shelf at eye level?	______%
... stand on your tiptoes and reach for something above your head?	______%
... stand on a chair and reach for something?	______%
... sweep the floor?	______%
... walk outside the house to a car parked in the driveway?	______%
... get into or out of a car?	______%
... walk across a parking lot to the mall?	______%
... walk up or down a ramp?	______%
... walk in a crowded mall where people rapidly walk past you?	______%
... are bumped into by people as you walk through the mall?	______%
... step onto or off an escalator while you are holding onto a railing?	______%
... step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?	______%
... walk outside on icy sidewalks?	______%

FIGURE 9-7 The Activities-specific Balance Confidence (ABC) Scale. *(Reproduced from: Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale.* J Gerontol Med Sci. *1995;50(1):M28–34.)*

The Balance Efficacy Scale

Name: ____Date: _______________

Listed below are a series of tasks that you may encounter in daily life. Please indicate how confident you are, today, that you can complete each of these tasks without losing your balance. Your answers are confidential. Please answer as you feel, not how you think you should feel. (Circle one number from 0 to 100%)

1. How confident are you that you can get up out of chair (using your hands) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

2. How confident are you that you can get up out of a chair (not using your hands) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

3. How confident are you that you can walk up a flight of 10 stairs (using the handrail) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

4. How confident are you that you can walk up a flight of 10 stairs (not using a handrail) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

5. How confident are you that you can get out of bed without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

6. How confident are you that you can get into or out of a shower or bathtub (with the assistance of a handrail or support wall) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

7. How confident are you that you can get into or out of a shower or bathtub (with no assistance from a handrail or support wall) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

8. How confident are you that you can walk down a flight of 10 stairs (using the handrail) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

9. How confident are you that you can walk down a flight of 10 stairs (not using the handrail) without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

10. How confident are you that you can remove an object from a cupboard located at a height that is level with your shoulders without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

11. How confident are you that you can remove an object from a cupboard located above your head without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

12. How confident are you that you can walk across uneven ground (with assistance) when good lighting is available without losing your balance?
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident somewhat confident absolutely confident

FIGURE 9-8 Balance Efficacy Scale (BES). Reproduced from: Tinetti ME, Richman D, Powell L. Falls Efficacy as a Measure of Fear of Falling. *J Gerontol.* 1990;45(6):239–243.

13. How confident are you that you can walk across uneven ground (with no assistance) when good lighting is available without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

14. How confident are you that you can walk across uneven ground (with assistance) at night without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

15. How confident are you that you can walk across uneven ground (with no assistance) at night without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

16. How confident are you that you could stand on one leg (with support) while putting on a pair of trousers without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

17. How confident are you that you could stand on one leg (with no support) while putting on a pair of trousers without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

18. How confident are you that you could complete a daily task quickly without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
not at all confident — somewhat confident — absolutely confident

Last, we are interested in understanding what factors affect your confidence levels. On the lir below, please provide reasons for answering the way you did on questions 1 through 18. For example, if you answered that you were "not very" confident, why do you feel that way? If yoı were "not very" confident about an activity because you no longer do it very often (e.g. climb stairs, walk on uneven ground), we would like to know that also.

____

____

____

____

____

____

FIGURE 9-8—cont'd

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

2) Observe Postural Control

- Examine postural control through the **direct observation of trunk and limb activation and ankle, hip, and stepping strategies** as described earlier during a variety of tasks and in reaction to varying degrees of perturbation, always assuring patient safety.
- **Document :**

✓ presence and quality of righting and equilibrium reactions in sitting and standing.

✓ the timing, efficiency, and appropriateness of the reactions you observe.

✓ Static and dynamic posture.

✓ asymmetries and any deviations from midline using **visual observation**, perhaps with a *transparent posture grid*, or **force-platform** data (next section) to reflect the symmetry of stance or sitting.

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

3) Push and Release Test

- The Push and Release Test (Horak, 2004) was developed to improve standardization and sensitivity of the Pull Test, Item #30 on the Unified Parkinson Disease Rating Scale (UPDRS), as a measure of postural stability in static stance (Horak, 2004).
- To administer the test,

1) stand behind the patient and apply an isometric push at the upper trunk as patient leans back.
2) Ask the patient to continue to push back into your hands until his/her hips and shoulders are just behind his/her heels but without his/her heels lifting off the ground.

This extent of trunk excursion allows the COM to move outside his/her BOS.

3) Then, suddenly release your hands and visually observe the number, degree, and quality **of backward steps** and be prepared to assist the patient to prevent falling.
4) Then, score the patient on this five-point scale (Horak, 2004) :

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

3) Push and Release Test

0 – recovers independently with **one step** of normal length & width.

1 – **two to three small steps** backward, but recovers independently.

2 – **four or more steps** backward, but recovers independently.

3 – steps but needs to be assisted to prevent a fall

4 – falls without attempting a step or unable to stand without assistance

4) Posturography

- computerized balance assessment with objective data collected from a force platform.
- **The most commonly examined parameters:**

(1) **location of the COP** as a measure of symmetry (defined earlier),

(2) **postural sway measures** including *COP movement or excursion over a given time-period* and *speed of COP movement*,

(3) **LOS measures** to *reflect dynamic postural stability*.

- **For all posturography measures,:**

1) the patient, stands (posturography measures could also be completed in sitting position) on a force platform (Fig. 9-9A).
2) Enter age, gender, and anthropometric information regarding the patient, including weight and height into the computer to allow calculation of predicted values for the LOS.

3) **For static balance posturography testing** on the force platform, ask the patient to maintain quiet, unperturbed, upright stance while the computer measures the excursion/movement of the COP during a specified time period.

The patient's goal in static balance testing, using visual feedback through the computer monitor, is to *maintain the screen cursor within the central target box on the monitor*, sustaining a stable symmetrical position as much as possible.

4) **For dynamic balance posturography testing**, the patient is standing on the force platform. Ask the patient to sequentially shift the COP toward the periphery of the BOS in multiple directions following the visual cues/targets provided by the computer.

During this voluntary weight-shift, the patient visually observes feedback through the movement of the computer cursor on the monitor (representing the location of the COP) toward the targets at the periphery.

The cursor movement is a reflection of the patient's movement (see the three forward targets, left lateral target, right lateral target, and three posterior targets shown in the monitor screenshot: top left corner of Fig. 9-9B).

- During the movement, the computer measures the

1) actual length and path of active excursion of the COP (shown in the screen capture of Fig. 9-9B in the top left corner) and
2) the velocity of the sway excursion for comparison of results to the normative data for degree of intended excursion and the accuracy in reaching each target.
3) a rhythmic weight-shift test in which the patient actively and rhythmically shifts the body weight alternately between a right lateral target and a left lateral target (monitor view in Fig. 9-9C in the top left corner) following the timing and visual cues provided by the computer at slow, moderate, and fast speeds.
4) Force-platform velocity of sway excursion and mean sway in the anterior-posterior direction with eyes closed has been shown to be a valid balance measure with significant correlation to functional balance tests (Frandin, 1995).

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

- The **Balance Master by NeuroCom** and **Biodex Balance System SD** are *commercial computerized dynamic posturography* *<u>assessment</u>* *and* *<u>training syst.ems</u>*

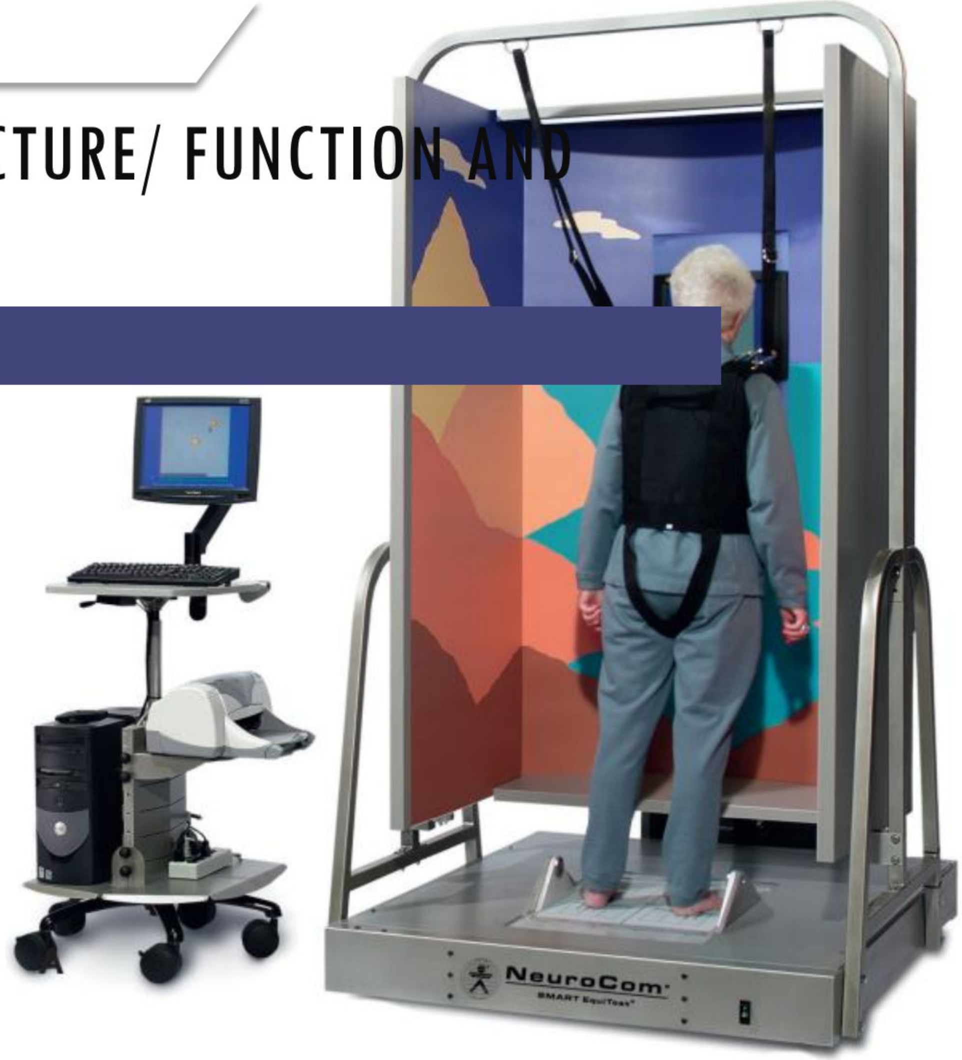


FIGURE 9-9 **A.** Patient standing on the Neurocom Balance Master SMART Equitest during dynamic posturography Limits of Stability (LOS) testing. The patient is voluntarily and actively shifting the weight toward their right side.

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

Examination of Sensory Systems Used in Balance

- The relative contributions of the various sensory systems (somatosensory, visual, and vestibular) to maintain balance can be examined with the **Clinical Test for Sensory Interaction in Balance (CTSIB).**
- The CTSIB, developed by Shumway-Cook (1986), originally **examined postural sway during quiet stance as influenced by six different test conditions** *(Fig. 9-10, the two conditions for visual conflict are not shown)* **for 30 seconds each with each condition** effecting a different aspect of sensory input to balance.
- Position the patient for each condition with feet together, side-by-side, and with hands at the hips.
- **Under each condition,** *the amount and direction of sway is documented for comparison.*

- Condition 1 provides full access to available visual, vestibular, and somatosensory information with eyes open while standing on a stable flat surface and provides a baseline for the other conditions.

- The six conditions are organized as two groups of three with

- **Conditions 1, 2, and 3** performed on a solid floor while

- **Conditions 4, 5, and 6** are performed standing on a 24″ × 24″ piece of medium-density Temper foam *to compromise the use of proprioceptive information from the ankle* (see Fig. 9-10C and 9-10D; Conditions 4 and 5).

- **Visual conditions** include "normal" for **Conditions 1 and 4** (Fig. 9-10A and 9-10C) and "blindfolded" for **Conditions 2 and 5** (Fig. 9-10B and 9-10D).

- Originally, **Conditions 3 and 6** utilized a large Japanese lantern cut in half and attached by a headband as a "dome" over the face to provide visual conflict, which allows visual input but inaccurate, unhelpful, visual input in regard to upright position.

- However, because results of visual conflict dome (Conditions 3 and 6) were not significantly different from vision eliminated (Conditions 2 and 4) (Cohen, 1993) the test was modified **(the modified CTSIB or mCTSIB)** to include only Conditions 1, 2, 4, and 5 (Whitney, 2004b).

- For each condition, it is recommended additional trials be allowed if a patient is unable to stand for 30 seconds (Horak, 1987), and an average of three trials should be calculated for each condition (Whitney,2004b).

- The test can be administered with the patient barefoot or wearing shoes, as no difference is seen in the results (Whitney, 2004b).

- The rationale behind the test is to systematically disadvantage the sensory systems involved. The **dense foam** is utilized to *interfere with accurate somatosensory information from the ankle* since a position of neutral ankle dorsiflexion while standing on foam does not mean the same thing as neutral ankle dorsiflexion while standing on a firm level surface.

- **The blindfold** is used to *eliminate vision completely*, and **the visual conflict dome** is placed over the head to *provide irrelevant visual information*.

- Each condition disadvantages one or more sensory systems forcing the patient to rely on the remaining system(s) to maintain balance.

- **Record and document :**

(1) time in balance (up to 30 seconds per condition) and

(2) increased sway or loss of balance for each condition.

(3) document strategies utilized and any subjective patient reports such as nausea or dizziness.

- An increase in instability in a particular condition or combination of conditions suggests dysfunction in the sensory system the patient is being forced to utilize.

- ✓ *if the patient exhibits increased instability when standing on the dense foam with a blindfold*, **dysfunction in the vestibular system is implicated**.

- **This information can then be used to guide intervention.** Specifically, you can develop a plan of care that challenges or stresses the system not adequately functioning to stimulate motor learning and recovery.

Shumway-Cook (2007) has proposed a model for interpreting results of this test,

I. categorizing patients with greater sway or loss of balance on **Conditions 2, 3, 5, and 6** as "visually dependent," depending on vision for postural control.

II. She categorizes patients with problems on **Conditions 4, 5, and 6** as "surface dependent," depending primarily on somatosensory information from the feet in contact with the surface for postural control.

This information has important implications for designing a customized therapeutic intervention plan.

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

The Sensory Organization Test (SOT)

- similar to the CTSIB but used with computerized dynamic posturography to assess an individual's ability to use visual, proprioceptive, and visual cues to maintain postural stability in stance.
- The individual stands on dual-force plates within a three-sided surround, and anterior-posterior sway is recorded under various conditions.

✓ **Conditions 1, 2, and 3** are performed on a flat stable force platform.

✓ **Conditions 4, 5, and 6** are performed on a force platform that is unstable and changes its orientation.

✓ **Conditions 1 and 4** are normal unrestricted vision with a fixed visual surround scene;

✓ **Conditions 2 and 5** are vision eliminated with a blindfold or by having the patient close their eyes;

✓ **Conditions 3 and 6** involve movement of the visual surround that corresponds to the patient's movement *to provide visual feedback unrelated to true upright*.

I. EXAMINATION OF BALANCE: BODY STRUCTURE/ FUNCTION AND BIOMECHANICS

Examination of Other Underlying Impairments

- Any other underlying impairments that could contribute to balance impairment detected on the neurological examination must be documented in the evaluation with major implications to guide interventions that will ultimately improve balance in each functional task.

For example, **a plantar flexion contracture** (examination techniques are covered in motor assesssment) *preventing the individual from optimally bringing the body weight forward over the feet must be addressed to optimize balance*.

- Other potential underlying impairments that must be evaluated and addressed to improve balance are lower extremity weakness, impaired coordination, impaired motor control, dystonia , and cognitive deficits.

Use of the HOAC is *highly recommended to help prioritize the examination as assessing every individual impairment* **may not be feasible in an appropriate clinical time frame**.

II. EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

A wide variety of functional balance tests exist to examine **static** & **dynamic balance** in individuals in the context of balance

as it supports functional activity.

Static Balance

Measures of static balance include:

1) double- and single-limb stance,
2) the Romberg test,
3) Sharpened Romberg.

- It is critical in all tests of static balance that you clearly establish the criteria for **stopping timed-measures** and the **position of the patient**, including **arm position**.

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

A. with eyes open **B.** with eyes closed)

Static Balance

Romberg test,

- ask the patient to stand unaided with feet together and arms crossed on the chest with each hand touching the opposite shoulder for up to 30 seconds (see Fig. 9-11A), first with eyes open (Fig. 9-11A), then with eyes closed (Fig. 9-11B) (Romberg, 1853).

✓ **Observe and record :**

1) the amount of sway
2) the duration the patient can maintain this position without stepping or losing balance.

✓**A positive test** is indicated when the patient demonstrates increased instability or stepping in the eyes-closed position, *indicating an excessive dependence on visual input*.

The **Romberg test** can be utilized to examine sensory ataxia *as a causal factor in postural imbalance* (Khasnis, 2003).

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Sharpened Romberg test

- the feet are placed in a tandem heel-to-toe position (see Fig. 9-11C and 9-11D) and the observation is repeated in both the eyes open (Fig. 9-11C) and eyes closed (Fig. 9-11D) conditions.

FIGURE 9-11 Testing position for the Romberg test (**A.** with eyes open, **B.** with eyes closed); and Sharpened Romberg test (**C.** with eyes open, **D.** with eyes closed).

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Balance Grading Scales

- Many therapists utilize an **ordinal rating scale** for first-round assessment of static and dynamic balance.
- Even though the scales are highly subjective, they can provide a general descriptor of the patient's balance ability.
- One example of such a grading scale is presented in **Table 9-5**.
- Although such scales provide a clinical "picture" of the patient and require little time or equipment, the psychometrics of such scales have not been well established, and the descriptive terms are usually poorly defined in any given facility.

TABLE 9-5 A Subjective Balance Scale to Rate Ability of the Patient

RATING	SITTING STATIC BALANCE	SITTING DYNAMIC BALANCE	STANDING STATIC BALANCE	STANDING DYNAMIC BALANCE
0	Needs MAX assist to maintain sitting without support	NA	Needs MAX assist to maintain without support	Unable to move voluntarily from midline
Poor	Needs MOD assist to maintain without support	NA	Needs MOD assist to maintain without support	Needs MOD assist during gait
Poor +	Needs MIN assist to maintain without support	NA	Needs MIN assist to maintain without support	Needs MIN assist during gait
Fair	Maintains without assist but unable to take challenges	Cannot move trunk without losing balance	Maintains without assist but unable to take challenges	Needs contact guard during gait
Fair +	Sustains balance during minimal challenges from all directions	Maintains balance through minimal excursions	Sustains balance during minimal challenges from all directions	Needs close supervision during gait and able to right self with minor loss of balance
Good	Sustains balance during moderate challenges from all directions	Maintains balance through moderate excursions	Sustains balance during moderate challenges from all directions	Needs supervision during gait and able to right self with moderate loss of balance
Good +	Sustains balance during maximal challenges from all directions	Maintains balance through maximal excursions	Sustains balance during maximal challenges from all directions	Independent gait with or without assistive device
Normal	No deviations seen in postures held statically	No deviations seen dynamically	No deviations seen in static standing posture	No deviation seen in any standing upright dynamic activity

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

The Functional Reach Test and Multidirectional Reach Test

- ❑ If your facility does not have a force platform, a patient's LOS can be approximated using tools such as the Functional Reach Test (FRT) (Duncan, 1990) or the Multidirectional Reach Test (MDRT) (Newton, 2001).
- ❑ **The FRT measures** *the maximal distance a standing patient can reach beyond arm's length while maintaining a fixed BOS*.
- ❑ **To perform the test,** tape a yardstick to the wall in a horizontal position at the level of the patient's acromion (two vertical strips of Velcro attached to the wall allow for easy adjustment of the ruler height to customize position for each specific patient's height).

✓ Have the patient stand adjacent to the wall, facing parallel to the wall but not touching the wall. In preparation for the test, ask the patient to move the shoulder adjacent to the wall, flexing to 90 degrees for the start position with the elbow extended and hand either fisted (interphalangeal joint flexion) or fingers fully extended as shown in Figure 9-12A.

✓

Static Balance

The Functional Reach Test

- Just make sure you use the same hand landmark, middle finger knuckle or tip of the middle phalynx, at the start and the end measurements.
- Note the starting position on the ruler at the end of the finger (Fig. 9-12A inset) and then have the patient reach forward as far as possible to the end position, keeping the feet in the initial position (Fig. 9-12B).
- The test result is the change in location from start to end, the mathematical difference between the start and end measurements.
- After a practice trial is given, measure and record three trials and calculate and document the average of the three trials with comparison to available norms.

Functional Reach Test FRT (Duncan, 1990)	**Age** (years)	**Mean Reach ± SD (inches) Males**	**Mean Reach Females (inches)**	• Unable to reach = 28x more likely to fall • 1–6" = 4x more likely to fall • 6–10" = 2x more likely to fall >10" = not likely to fall
	20–40 y	16.7 ± 1.9	14.6 ± 2.2	
	41–69 y	14.9 ± 2.2	13.8 ± 2.2	
	70–87 y	13.2 ± 1.6	10.5 ± 3.5	

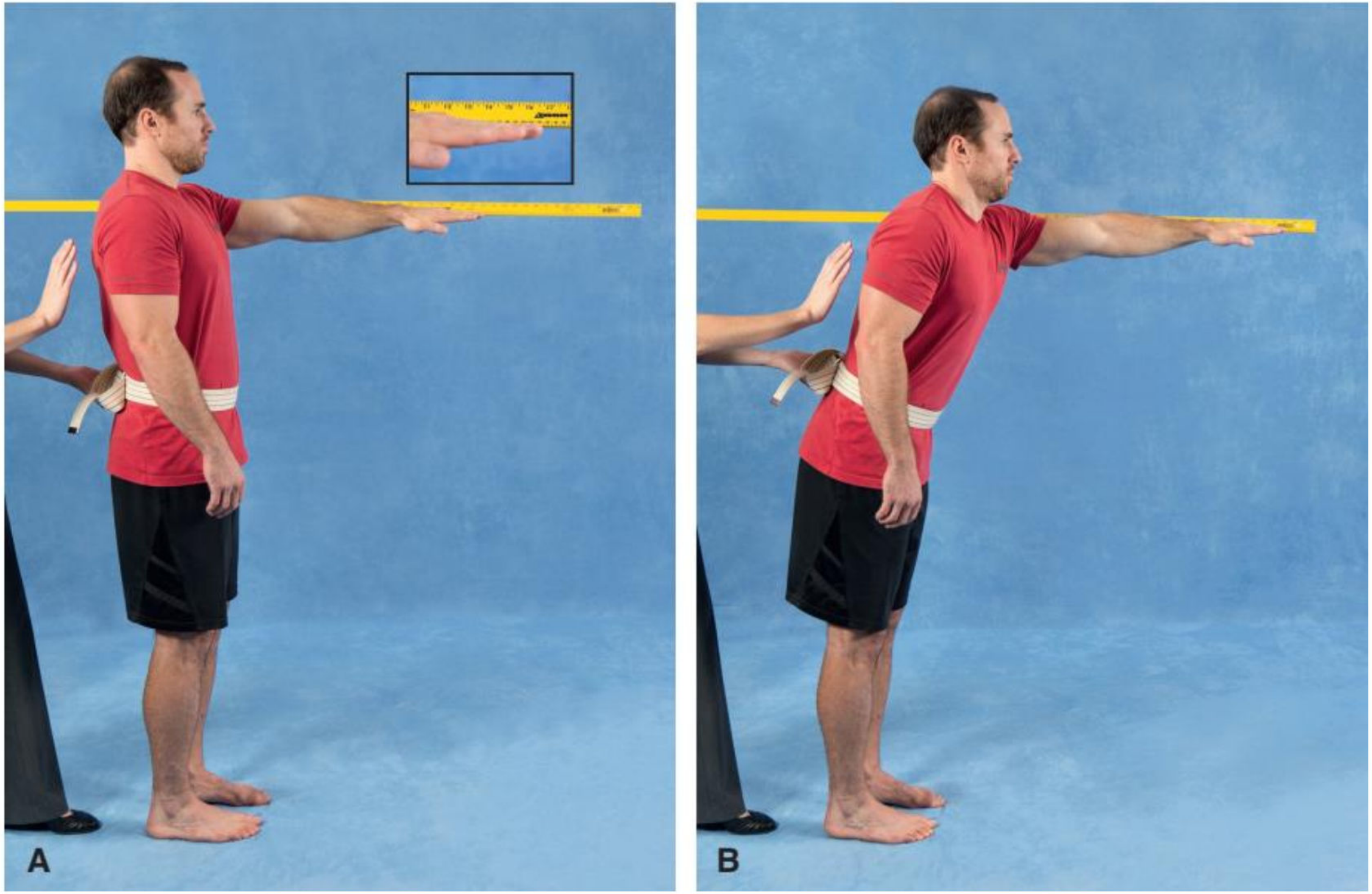


FIGURE 9-12 The Functional Reach Test is shown with **A.** start position (inset shows close-up of hand position at ruler) and **B.** end position. The difference between the start and end position (subtract one from the other) is recorded as the test result.

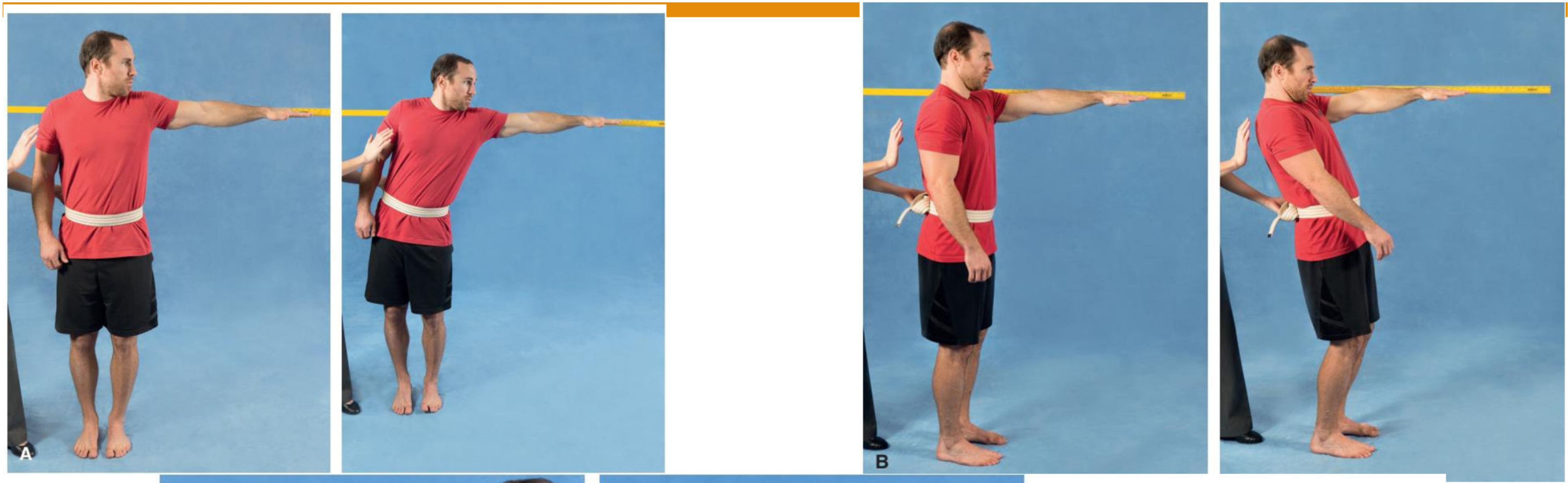
II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Multidirectional Reach Test

- the subject should reach forward as in the FRT but also test and record the magnitude of reach in the backward direction and lateral directions, right and left (Newton, 2001).
- **For the backward reach,** the position of the patient is the same as for the FRT but the yardstick is positioned for excursion of weight-shift in the backward direction (Fig. 9-13B). The measurement is again made the same, calculating the difference between start and end positions.
- **For the lateral reach,** ask the subject to face away from the wall and hold the test arm up in an abducted position with hand in front of the beginning of the yardstick. Then, ask the subject to reach as far as possible to the side without moving the feet (see Fig. 9-13A). Then, repeat the reach using the opposite arm in the opposite direction. Results can be compared with reference values.

When performing this assessment, you should also record the movement strategies you observe, in addition to the difference between start & end positions.



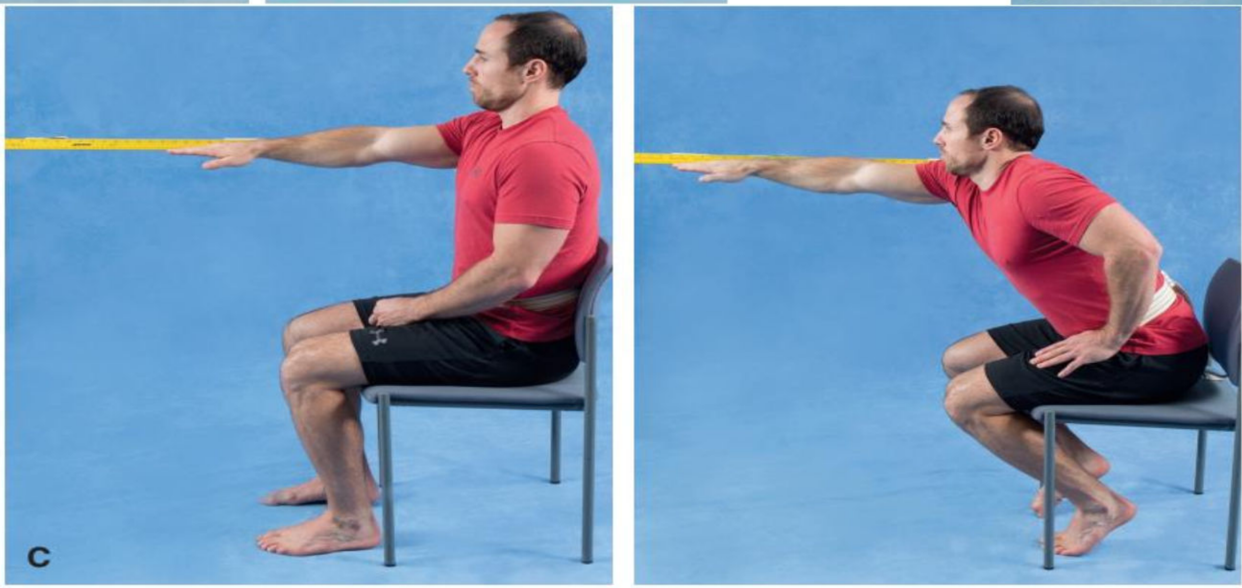


FIGURE 9-13 Standing Multidirectional Reach Test is shown with **A.** lateral reach start and end position and **B.** backward reach start and end position. An adaptation the Sitting Multidirectional Reach Test, is shown with **C.** forward reach start and end position and

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

The Functional Reach Test

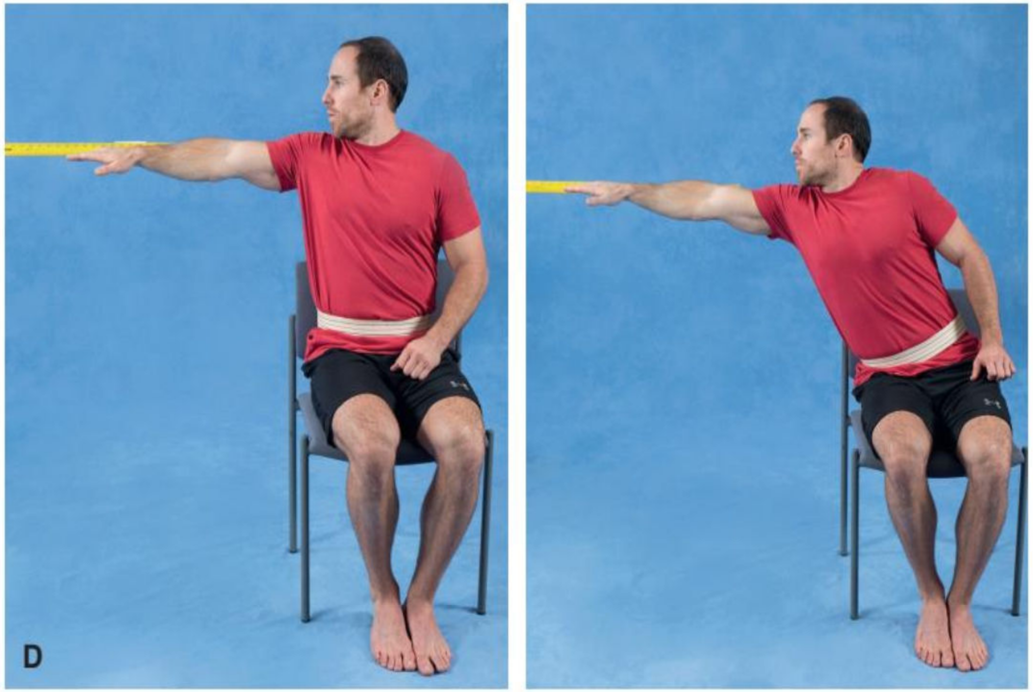


FIGURE 9-13—cont'd D. lateral reach start and end position.

Multidirectional Reach Test MDRT Reach in inches; older adults; mean age 74 (Newton, 2001)	**MDRT Direction**	**Mean ±SD (inch)**	**<Below Avg; >Above Avg**
	Forward	8.9 ± 3.4	<5.6; >12.2
	Backward	4.6 ± 3.1	<1.6; >7.6
	R Lateral	6.2 ± 3.0	<3.8; >9.4
	L Lateral	6.6 ± 2.8	<3.8; >9.4
Sitting Functional Reach measured in two directions among healthy adults (Thompson, 2007)	**Age group**	**Forward Reach (cm)**	**Lateral Reach (cm)**
	21–39 yo	44.9	29.5
	40–59 yo	42.3	26.7
	65–93 yo	32.9	20.3

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Berg Balance Scale

- consisting of 14 functional tasks, is a valid functional measure of static and dynamic balance in older adults and individuals with stroke (Berg, 1992a).
- These tasks, listed completely in Appendix 9-A, include activities such as retrieving an object from the floor and standing with feet together.
- The first five items are basic balance items and the remaining nine are considered more advanced balance tasks. A score is assigned for each task on a five-point ordinal scale and the scores are then summed for a maximal possible score of 56.
- This scale has been extensively studied in older adult and stroke populations. **Psychometric properties are very strong,** including the *prediction of falls in the elderly if the score is less than 45/56;* however, sensitivity at this cutoff is very low at 53% (Thorbahn, 1996).

Berg Balance Scale

APPENDIX 9-A

Berg Balance Scale
14-Item Long Form Original Version

Name: ______________________ Date: ______________________

Rater: ______________________

GENERAL INSTRUCTIONS: Please demonstrate each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if the time or distance requirements are not met, if the subject's performance warrants supervision, or if the subject touches an external support or receives assistance from the examiner. Subjects should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing are a stopwatch or watch with a second hand and a ruler or other indicator of 2, 5, and 10 inches (5, 12, and 25 cm). Chairs used during testing should be of reasonable height.

1. SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hands for support.
(4) able to stand without using hands and stabilize independently
(3) able to stand independently using hands
(2) able to stand using hands after several tries
(1) needs minimal aid to stand or to stabilize
(0) needs moderate or maximal assist to stand

2. STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for 2 minutes without holding.
(4) able to stand safely 2 minutes
(3) able to stand 2 minutes with supervision
(2) able to stand 30 seconds unsupported
(1) needs several tries to stand 30 seconds unsupported
(0) unable to stand 30 seconds unassisted. If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

3. SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
(4) able to sit safely and securely 2 minutes
(3) able to sit 2 minutes under supervision
(2) able to sit 30 seconds
(1) able to sit 10 seconds
(0) unable to sit without support 10 seconds

4. STANDING TO SITTING
INSTRUCTIONS: Please sit down.
(4) sits safely with minimal use of hands
(3) controls descent by using hands
(2) uses back of legs against chair to control descent
(1) sits independently but has uncontrolled descent
(0) needs assistance to sit

5. TRANSFERS
INSTRUCTIONS: Arrange chairs(s) for a pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chai
(4) able to transfer safely with minor use of hands
(3) able to transfer safely definite need of hands
(2) able to transfer with verbal cueing and/or supervision
(1) needs one person to assist
(0) needs two people to assist or supervise to be safe

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
(4) able to stand 10 seconds safely
(3) able to stand 10 seconds with supervision
(2) able to stand 3 seconds
(1) unable to keep eyes closed 3 seconds but stays steady
(0) needs help to keep from falling

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding.
(4) able to place feet together independently and stand 1 minute safely
(3) able to place feet together independently and stand for 1 minute with supervision
(2) able to place feet together independently but unable to hold for 30 seconds
(1) needs help to attain position but able to stand 15 seconds feet together
(0) needs help to attain position and unable to hold for 15 seconds

8. REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the finger reaches while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
(4) can reach forward confidently >25 cm (10 inches)
(3) can reach forward >12 cm safely (5 inches)
(2) can reach forward >5 cm safely (2 inches)
(1) reaches forward but needs supervision
(0) loses balance while trying/requires external support

9. PICK UP OBJECT FROM FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up shoe/slipper that is placed in front of your feet.
(4) able to pick up slipper safely and easily
(3) able to pick up slipper but needs supervision
(2) unable to pick up but reaches 2 to 5cm (1 to 2 inches) from slipper and keeps balance independently
(1) unable to pick up and needs supervision while trying
(0) unable to try/needs assist to keep from losing balance or falling

10. 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 twist turn.
(4) looks behind from both sides and weight shifts well
(3) looks behind one side only, other 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

11. TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
(4) able to turn 360 degrees safely in 4 seconds or less
(3) able to turn 360 degrees safely one side only in 4 seconds or less
(2) able to turn 360 degrees safely but slowly
(1) needs close supervision or verbal cueing
(0) needs assistance while turning

12. PLACING ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
(4) able to stand independently and safely and complete 8 steps in 20 seconds
(3) able to stand independently and complete 8 steps >20 seconds
(2) able to complete 4 steps without aid with supervision
(1) able to complete >2 steps, needs minimal assist
(0) needs assistance to keep from falling/unable to try

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 to 10 seconds
(2) able to lift leg independently and hold = or >3 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

(____) TOTAL SCORE (Maximum = 56)
A person under 45 is considered to be at risk for falling.

Adapted from: Berg K, Wood-Dauphinee S, Williams JI, Gayton D.: Measuring balance in the elderly: Preliminary development of an instrument. *Physiother Can.* 1989;41:304–311.

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Performance-Oriented Mobility Assessment (POMA)

- often referred to as the "Tinetti," is a measure of mobility with two subscales: (1) balance and (2) gait (Tinetti, 1986a). In a revised version, Tinetti and Ginter (1988b) eliminated step length, trunk stability, and walk stance items from the original gait subscale.

- To perform the test, only minimal equipment is needed: a hard armless chair, a stopwatch, and a 15-foot walkway.

- Consistent with the balance focus, **the balance subscale includes nine items:** **(1)** sitting balance, **(2)** sit-to-stand, **(3)** attempts to arise, **(4)** immediate standing balance, **(5)** standing balance, **(6)** balance when nudged or perturbed, (7) sustained standing with eyes closed, **(8)** standing when turning 360 degrees, and **(9)** stand-to-sit.

- **For each balance item,**

✓ typical/normal performance is awarded 1 or 2 points and

✓ 0 represents the most significant impairment

✓ a maximum balance subscale score of 16 points (Lewis, 1993).

Tinetti Performance Oriented Mobility Assessment (POMA)
Balance Tests

Initial instructions: Subject is seated in hard, armless chair. The following maneuvers are tested.

1. **Sitting balance**	Leans or slides in chair	= 0
	Steady, safe	= 1 ____
2. **Arises**	Unable without help	= 0
	Able, uses arms to help	= 1
	Able without using arms	= 2 ____
3. **Attempts to arise**	Unable without help	= 0
	Able, requires > 1 attempt	= 1
	Able to rise, 1 attempt	= 2 ____
4. **Immediate standing balance** (first 5 seconds)	Unsteady (swaggers, moves feet, trunk sway)	= 0
	Steady but uses walker or other support	= 1
	Steady without walker or other support	= 2 ____
5. **Standing balance**	Unsteady	= 0
	Steady but wide stance (medial heals > 4 inches apart) and uses cane or other support	= 1
	Narrow stance without support	= 2 ____
6. **Nudged** (subject at maximum position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)	Begins to fall	= 0
	Staggers, grabs, catches self	= 1
	Steady	= 2 ____
7. **Eyes closed** (at maximum position of item 6)	Unsteady	= 0
	Steady	= 1 ____
8. **Turing 360 degrees**	Discontinuous steps	= 0
	Continuous steps	= 1 ____
	Unsteady (grabs, staggers)	= 0
	Steady	= 1 ____
9. **Sitting down**	Unsafe (misjudged distance, falls into chair)	= 0
	Uses arms or not a smooth motion	= 1
	Safe, smooth motion	= 2 ____

Balance Score: ____ /16

FIGURE 9-14 The "Tinetti" Performance-Oriented Mobility Assessment (POMA) includes a balance subscale and a gait subscale. *(Reproduced from: Faber MJ, Bosscher RJ, Van Wieringen PCW. Clinimetric properties of the Performance-Oriented Mobility Assessment.* Phys Ther. *2006;86:944–954.)*

Continued

Tinetti Performance Oriented Mobility Assessment (POMA)
Gait tests

Initial Instructions: Subject stands with examiner, walks down hallway or across room, first at "usual" pace, then back at "rapid, but safe" pace (using usual walking aids)

10. **Initiation of gait** (immediately after told to "go")	Any hesitancy or multiple attempts to start	= 0
	No hesitancy	= 1 ____
11. **Step length and height**		
Right swing foot	Does not pass left stance foot with step	= 0
	Passes left stance foot	= 1 ____
	Right foot does not clear floor completely with step	= 0
	Right foot completely clears floor	= 1 ____
Left swing foot	Does not pass right stance foot with step	= 0
	Passes right stance foot	= 1 ____
	Left foot does not clear floor completely with step	= 0
	Left foot completely clears floor	= 1 ____
12. **Step symmetry**	Right and left step length not equal (estimate)	= 0
	Right and left step length appear equal	= 1 ____
13. **Step continuity**	Stopping or discontinuity between steps	= 0
	Steps appear continuous	= 1 ____
14. **Path** (estimated in relation to floor tiles, 12-inch diameter; observe excursion of 1 foot over about 10 ft. of the course)	Marked deviation	= 0
	Mild/moderate deviation or uses walking aid	= 1
	Straight without walking aid	= 2 ____
15. **Trunk**	Marked sway or uses walking aid	= 0
	No sway but flexion of knees or back or spreads arms out while walking	= 1
	No sway, no flexion, no use of arms, and no use of walking aid	= 2 ____
16. **Walking stance**	Heels apart	= 0
	Heels almost touching while walking	= 1 ____

Gait Score: ____ /12
Balance Score: ____ /16
Total Score (Gait + Balance): ____ /28

FIGURE 9-14—cont'd

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Static Balance

Performance-Oriented Mobility Assessment (POMA)

- ✓ **The gait subscale** incorporates balance components, with a focus on gait, and includes seven items: **(10)** initiating gait, **(11)** gait step length and height (foot clearance) with separate scores for right and left swing foot, **(12)** step symmetry, **(13)** step continuity while turning 360 degrees, **(14)** gait path, **(15)** trunk sway, and **(16)** walking stance width, each of which require balance, and are scored with 1 or 2 representing normal and 0 = abnormal for a total subscale score of 12 points.
- ✓ The test can be
- ✓ completed in 5 to 10 minutes (Nakamura, 1998).

Static Balance

The Timed Up and Go (TUG) Test

- The TUG test (Podsiadlo, 1991) is a timed modification of the earlier Get Up and Go test (Mathias, 1986) and is designed as a quick screen of balance that incorporates several functional activities.
- To perform the TUG, instruct the patient, starting from a seated position, to stand up from a chair, walk 3 meters to a mark on the floor, turn around, return to the original chair, and sit in the chair. Start timing with the stopwatch when the patient is instructed to “go” and end the timed measure when the patient returns to the seated position in the chair.
- Both young and older adults without deficits were able to perform the TUG in less than 10 seconds (Podsiadlo, 1991;

TABLE 9-3	Reference Values for Common Tests of Balance and Equilibrium in Adults—cont'd		
TOOL	**REFERENCE VALUES**		**FALL RISK**
TUG Mean times for various age groups (Wall, 2000)	**Group**	**TUG mean ± SD (sec)**	
	Young controls (19–29 y)	7.36 ± 0.945 s	
	Elderly controls (>65 y)	8.74 ± 0.851 s	
	Elderly at-risk: (>65 y) with history of falls or current treatment for gait or balance disorders	18.14 ± 4.604 s	
TUG Times in older adults >80 years of age; risk for falls (Huang, 2006)	**Group**	**TUG mean ± SD (sec)**	**95% CI**
	>80 y EO, Low Risk for Falls*	12.0 ± 3.4	(11.2–14.1)
	>80 y EO, Medium Risk for Falls*	28.3 ± 15.4	(22.4–34.2)
	>80 y EO, High Risk for Falls*	54.5 ± 39.1	(40.1–69.3)
TUG Dual Task Times in elderly without falls (Shumway-Cook, 2000)	**TUG (sec)**	**TUG-manual (sec)**	**TUG-cognitive**
	8.4	9.7	9.7

II- EXAMINATION AT THE ACTIVITY LEVEL: FUNCTIONAL BALANCE TESTS

Examination of the Allocation of Attention: Balance and Dual-task

- The role of cognition in function and movement the influence of dual-task performance on balance must be considered in the examination of balance.
- Difficulties with dual-task performance are associated with a history of falls and risk of future falls in institutionalized and community-dwelling older adults. (Shumway-Cook,1997;)

- Younger children demonstrate more difficulty with a dual-task paradigm than older children, related at least in part to increased attentional resources associated with greater maturity **(Boonyong, 2012**) and a gradual shift in reliance on visual versus proprioceptive cues to maintain postural control **(Peterson, 2006).**
- Gait velocity,, **has been shown to decrease under dual task conditions** **(Van Iersel, 2007),** *which may be a strategy used to maintain balance under more difficult conditions.*

Several procedures have been described to *assess the influence of the cognitive demand of attention (during talking or communication) on ambulation + balance*.

Clinically, there are several tools examine the influence of cognition and attention on balance and risk for falls:

1) Walkie Talkie,
2) The TUG-manual, the TUG-cognitive, and
3) the Walk While Talking (WWT) test.

- **The Walkie Talkie test** *assesses divided attention* (Rose, 2010) *by posing a question to the patient that requires more than a yes or no answer while walking alongside the patient and observing for the influence on walking.*

✓ *The test is considered positive if the patient has difficulty walking while talking*.

- An adaptation to the TUG test, described in the previous section, includes the addition of a manual or cognitive component and is called TUG-manual or TUG-cognitive, respectively.
- This adaptation can be used to assess the influence of dual task attention on balance in ambulation (Lundin-Olsson, 1998).
- **For the TUG-manual,** ask the patient to perform the TUG (stand, 3-meter walk, turn 180 degrees, walk 3 meters back, sit down) while simultaneously holding a glass full of water (Fig. 9-15).
- **For the TUG-cognitive,** the patient performs the TUG while counting backward by threes from a randomly selected number between 20 and 100.

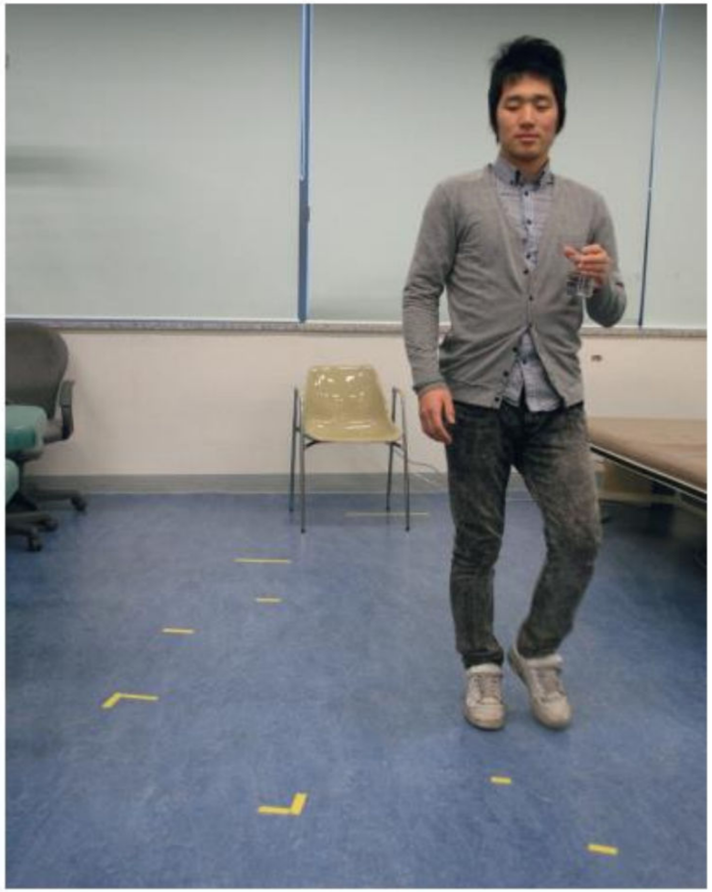


FIGURE 9-15 TUG-manual task as individual performs two simultaneous motor tasks: The TUG while carrying a glass of water.

In the WWT test, **you time the patient during a 40-foot walk** (a 20-foot path, turning & returning).

First, time the patient at a self-selected "normal" walking speed through the course, then repeat the test, *asking the patient to recite the letters of the alphabet aloud* **(WWTsimple)** or *alternate letters of the alphabet* **(WWT-complex).**

Comparing the time taken to ambulate 40 feet under the three conditions, it has been shown the **WWT-simple condition** *slows gait speed* and the **WWT-complex task** causes even *greater declines in gait velocity* (Verghese, 2002; Verghese, 2007).

Some specific test conditions to assess the influence of divided attention during walking:

(1) **asking a simple question** such as "What is your age?" (De Hoon, 2003),

(2) reciting the alphabet or alternate letters of the alphabet (skipping the letters in between) as described in the following text (Verghese, 2002; 2007),

(3) repeating random digits while walking (Sheridan, 2003), or

(4) reciting names while walking (Camicioli, 1997; Bootsma-van der Wiel, 2003).

- **The single question method** *was sufficient to identify the individuals who stop walking while talking* and these were the *same individuals who had slower walking speed and more unstable trunk control* (De Hoon, 2003).
- **Possible abnormal results** for which to observe include decreased speed with the added task or, in more severe cases, loss of balance or a patient who simply stops walking to respond to the question.

MEASUREMENT OF GAIT SPEED

Gait velocity

- it is a clinically useful outcome measure in the examination of balance & equilibrium.
- in fact, **slow velocity** has often been used as a criterion standard (goldstandard) for validity testing associated with decreased balance (Frandin, 1995; Liston, 1996; Judge, 1995; Hill, 1996).
- Specific methods for measuring gait velocity are described
- in general, the technique of **measuring temporal gait parameters** involves using **a stopwatch** to *measure the time to ambulate a given distance*, often measuring the time it takes to ambulate the central 6 meters of a 10-meter walkway (Fritz, 2009). The initial and final 2 meters are not included in the calculation as these are considered acceleration and deceleration areas. Alternatively, the central 10 meters can be measured in a 20-meter straight walkway (Steffen, 2002; Perera, 2006).

✓ For each trial, gait velocity is then easily calculated as **"distance divided by time,"** usually reported as meters/second (m/s).

✓ The result is most often reported as meters per second (m/s) and can be compared with norms

- In addition to gait velocity, you can **time other measures of specific functional upright mobility tasks** as a clinical indication of balance in function including crawling, transfers, sit-to-stand, and stair negotiation as long as you have clearly defined start and end points for the measurement.

Recommendations to improve validity include *having the patient ascend and descend at least 10 steps with the instruction to do so as quickly and safely as possible using a handrail only for balance as necessary* (Nightingale, 2014).

The task of *rising to stand from a starting position seated in a chair* can be easily timed (Anemaet, 1999; Salem, 2000). A protocol of completing 10 repetitions of standing and sitting down as quickly as possible require less than a minute to perform (Anemaet, 1999)

TOOL	REFERENCE VALUES			FALL RISK
Chapter 10) *++ data in this study was normalized as statures per second by dividing the velocity (m/s) by the person's height (m)*	Females with Idiopathic Gait Disorder of Elderly	0.19–0.41 statures/sec	Significantly slower than healthy groups; also very little difference between slow and fast self-selected pace	
	Subjects with stroke (Perry, 1995)	<0.4 m/s household ambulators 0.4–0.8 m/s limited community ambulators >0.8 m/s community ambulators		
Timed Measure of Standing from a Chair (10 repetitions) (Csuka, 1985)	**Age** (years)	**Mean for Women** (and upper limit) (seconds)	**Mean for Men** (and upper limit) (seconds)	
	60 y	16.6 (22.6)	16.6 (20.1)	
	65 y	18.4 (23.5)	17.6 (21.1)	
	70 y	19.2 (24.3)	18.5 (22.0)	
	75 y	20.1 (25.2)	19.5 (23.0)	
	80 y	20.9 (26.1)	20.5 (24.0)	
	85 y	21.8 (27.0)	21.5 (25.0)	
Five Times Sit to Stand Test Community dwelling adults (Bohannon, 2007)	**Age (years)**	**Mean ± SD (sec)**		
	19–49	6.2 ± 1.3		Cut off >15 sec recurrent fall risk community dwelling elderly (Buatois, 2010)
	50–59	7.1 ± 1.5		Cut off >16 sec fall risk for PD (Duncan, 2011)
	60–69	8.1 ± 3.1		
	70–79	10.0 ± 3.1		
	80–89	10.6 ± 3.4		

Gait Velocity measured as relative speed (velocity / height = statures per second) (Wall, 1991) *(see also Gait Velocity in*	**Group**	**Relative Gait Speed**: The range from self-selected slow pace to self-selected fast pace (statures/sec)++
	Healthy young females	0.57–1.23 statures/sec
	Healthy elderly females	0.50–1.05 statures/sec

Use of an Obstacle Course

- **Means (1996)** reported a course consisting of 12 simulated functional tasks with qualitative and quantitative individual tasks and overall scores.
- **Taylor and Gunther (1998)** developed a standardized walking obstacle course designed to quantify ambulation in an environmental context, which obviously requires balance. This course incorporates manipulation (i.e., carrying objects while walking), directional changes, negotiation past obstacles such as stepping over and around objects, changes in texture of the support surface, and response to ambulation in dimly lit conditions.
- **A Standardized Walking Obstacle Course (SWOC)** has also been described for the pediatric population (Kott, 2002).

Four Square Step Test ((Dite, 2002; Whitney, 2007)

- another method useful to examine dynamic standing balance in a functional setting because *it requires rapid stepping sequentially forward, sideways, and backward*.
- Four canes are placed on the floor in a "+" or cross pattern as shown in Figure 9-16A. The four squares formed by the canes are numbered one through four as shown in the figure.

✓ The subject stands in square number 1 facing square number 2.

✓ The aim is to step as quickly as possible from square 1 to the following **squares in this order: 2,3,4,1,4,3,2,1,** but always facing in the same direction (Fig. 9-16B).

✓ To do this, the subject steps over the canes in the following directional **sequence**: **forward, right, backward, left, right, forward, left,** and **backward** (see Fig. 9-16).

✓ Measure and record the time required to complete the sequence, returning to the starting square with both feet.

✓ The trial is not recorded if the subject touches a cane or does not complete the sequence.

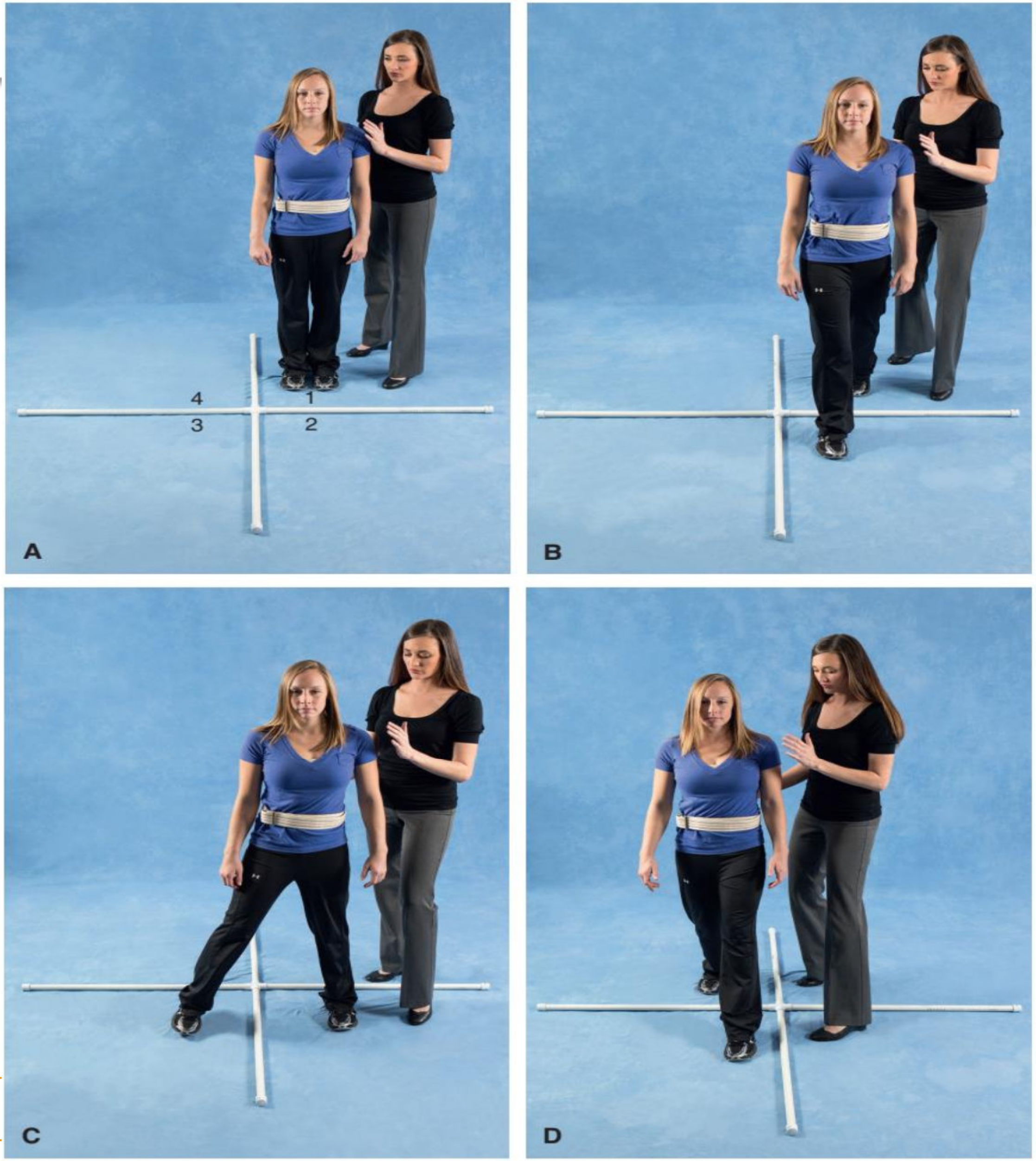


FIGURE 9-16 Four Square Step Test (FSST) **A.** showing the start position in block #1 and **B. through D.** showing the sequential steps through the first half of the test to block 2, 3, 4, respectively, and back to block #1. **Then the subject would reverse direction around the squares ultimately back to the original starting square.**

Balance Evaluation Systems Test (BESTest)

- Although all the balance assessments discussed previously provide clinicians with many options for evaluation and fall risk prediction, they are not able to identify the underlying postural control system which is contributing to a patient's balance dysfunction.
- To assist clinicians in evaluation of thesepostural control systems, Horak (2009) and colleagues have devised the Balance Evaluation Systems Test (BESTest). The score form can be downloaded at http://ptjournal.apta.org/content/89/5/484/suppl/DC1.
- This test has **integrated many elements** of the previously discussed balance tests such as functional reach, dynamic gait, TUG and TUG-cognitive, and mCTSIB.

Balance Evaluation Systems Test (BESTest)

The test includes six subsystems of balance (Fig. 9-17):

1. Biomechanical Constraints: Functional strength, foot evaluation (BOS)
2. Stability Limits/Verticality: Excursion of the body's COM over the stationary BOS
3. Anticipatory Postural Adjustments: Movements of the body's COM before activity in preparation of a destabilizing activity
4. Postural Responses: Postural control response to a destabilizing episode
5. Sensory Orientation: Ability to integrate and use afferent information about one's body position in space
6. Stability in Gait: Balance during walking

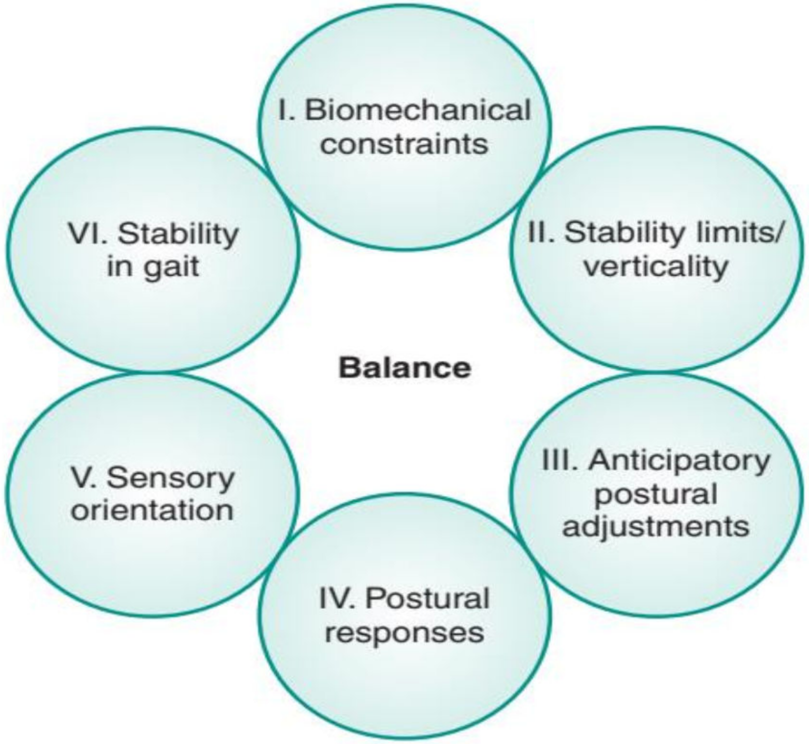


FIGURE 9-17 Model of Balance Systems: Model summarizing systems underlying postural control corresponding to sections of the Balance Evaluation Systems Test (BESTest). Used with

- It is important to note these balance systems work together rather than in isolation.
- Commonly, impairment in one subsystem will affect other subsystems.
- For example, if your patient has

decreased lower extremity strength (biomechanical constraints), the patient will have decreased LOS a*s lower extremity muscles will not be strong enough to hold the weight at the edge of the BOS*. The patient will also have limited anticipatory postural adjustments and postural responses *as force to create these movements will be limited* and *the resultant movements will be decreased in amplitude*.

- This test has also been shortened into two different versions: **Mini-BESTest** and **Brief BESTest** (Franchignoni, 2010; Padgett, 2012). While the shortened versions address

Summary of Balance Evaluation Systems Test (BESTest) Items Under Each System Category[a]

I. Biomechanical constraints	II. Stability limits/ verticality	III. Anticipatory postural adjustments	IV. Postural responses	V. Sensory orientation	VI. Stability in gait
1. Base of support	6. Sitting verticality (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
3. Ankle strength and ROM	8. Functional reach lateral (left and right)	11. Stand on one leg (left and right)	16. Compensatory stepping correction, forward		23. Walk with head turns, horizontal
4. Hip/trunk lateral strength		12. Alternate stair touching	17. Compensatory stepping correction, backward	20. Incline, EC	24. Walk with pivot turns
5. Sit on floor and stand up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)		25. Step over obstacles
					26. Timed "get up and go" test
					27. Timed "get up and go" test with dual task

[a] CoM = center of mass, ROM = range of motion, CTSIB = clinical test of sensory integration for balance, EO = eyes open, EC = eyes closed

FIGURE 9-18 Summary of BESTest Items Under Each System Category. Used with permission and reproduced from: Horak FB, Wrisley DM, Frank J. The balance evaluation systems test (BESTest) to differentiate balance deficits. *Phys Ther.* 2009;89:484–498.

EXAMINATION AT THE PARTICIPATION RESTRICTION LEVEL

- A complete examination of balance would also include the effect of any balance deficits on one's role in society and quality of life.
- Although not specific to balance, these tests include **ADL & Instrumental ADL (iADL) checklists** or scales, **Disability Rating Scale** (Rappaport, 1982), **Dizziness Handicap Inventory** (Jacobson, 1990), and **36-item Short Form Health Survey (SF-36)** (RAND Health, 1990).