38

Balance Assessment

Sathya Guruprasad, Feba Roy, Sai Bhavani

LEARNING OBJECTIVES

After the completion of the chapter, the readers will be able to:

- Explain the concept of balance.
- Discuss the components of static and dynamic balance.
- Perform the assessment for static and dynamic balance and interpret the test results.
- Explain the clinical indications and relevance of the balance tests.

CHAPTER OUTLINE

- Introduction
- Mechanism of Balance
- Techniques for Assessment
- Scoring and Interpretation
- Clinical Indications
- Clinical Applications
- Clinical Relevance

INTRODUCTION

Balance is the capability to manage the center of gravity (COG) over the base of support. It is fundamental to human movement and function to maintain independence.

Balance can be categorized into three main components:

1. **Static balance**: The ability to maintain a steady position while the body is at rest, such as standing or sitting.
2. **Dynamic balance**: The ability to maintain stability while moving or transitioning between positions, such as walking or transferring from a chair.
3. **Reactive balance**: The ability to respond to unexpected perturbations, such as tripping or being pushed.

Balance requires the intricate interplay of the vestibular, visual, and proprioceptive systems. A disruption in any of these systems can result in balance impairments and a heightened risk of falls. As physiotherapists, evaluating and managing balance issues are essential for enhancing our patients' quality of life. This chapter delves into the different methods and tools utilized in balance assessments and the interpretation of their results.

MECHANISM OF BALANCE

The neurophysiology of balance involves a complex interaction between sensory input, central processing, and motor output, all coordinated to maintain postural stability and orientation (Fig. 38.1). Balance is maintained through the integration of sensory information from the vestibular, proprioceptive, visual, and somatosensory systems, processed by the brainstem, cerebellum, and cerebral cortex, which then coordinate motor outputs to stabilize the body. This system allows humans to maintain posture, navigate their environment, and perform complex movements with stability.

Sensory Input

- **Visual system:** Vision provides information about the environment and helps the brain interpret body orientation and movement. Visual cues are essential for maintaining balance, especially when other sensory inputs are compromised.
- **Proprioception:** Proprioceptors in muscles, tendons, and joints send information to the brain about body position and movement. This feedback helps the brain understand where the limbs and body parts are in space.
- **Vestibular system:** Located in the inner ear, the vestibular apparatus (including the semicircular canals and otolith organs) detects head movements and orientation relative to gravity. It provides critical information about acceleration, deceleration, and rotational movements.

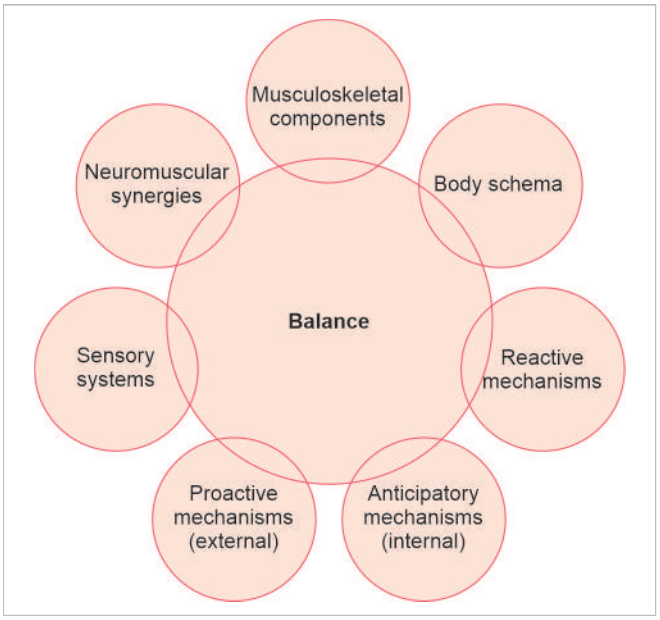


Fig. 38.1: Neurophysiology of balance

- **Somatosensory system:** This system gathers tactile information from the skin and deeper tissues, contributing to the awareness of pressure, touch, and vibration, which are essential for detecting shifts in the body's position.

Central Processing

- **Brainstem:** The brainstem integrates sensory inputs, particularly from the vestibular system, and coordinates reflexes that maintain balance. It plays a critical role in automatic postural adjustments.
- **Cerebellum:** The cerebellum fine-tunes motor commands and ensures smooth, coordinated movements. It helps in adjusting muscle activity to maintain balance, especially during dynamic activities like walking or running.
- **Cerebral cortex:** The cerebral cortex processes higher-level information and contributes to voluntary control of posture and balance. It integrates sensory inputs and plans complex movements that require balance, such as reaching or avoiding obstacles.

Motor Output

- **Muscle activation:** The brain sends signals to the muscles to adjust posture and stabilize the body. Postural muscles, particularly those in the legs, back, and neck, are continuously active to counteract gravity and maintain balance.
- **Postural reflexes:** Reflexive responses, such as the stretch reflex, are crucial for quick adjustments to maintain balance. For example, if you start to fall, the muscles will reflexively contract to restore balance.

- **Coordination of movement:** The motor cortex and cerebellum work together to coordinate voluntary movements that involve shifts in balance, ensuring that movements are smooth and do not destabilize the body.

Feedback and Adaptation

- **Feedback loops:** Continuous feedback from the sensory systems allows the brain to make rapid adjustments to maintain balance. This process is dynamic, with constant updates as the body moves and interacts with the environment.
- **Adaptation:** The balance system can adapt to new conditions, such as changes in the environment or after injury. The brain can learn to rely more on certain sensory inputs if others are compromised, a process known as sensory reweighting.

TECHNIQUES FOR ASSESSMENT

Balance assessment involves evaluating an individual's ability to maintain postural stability under various conditions. These tests are typically categorized into static, dynamic, and functional formats, each targeting different components of balance control (Fig 38.2). These tests help physiotherapists identify impairments and guide rehabilitation strategies. Assessment includes the following aspects:

- **Subjective assessment:** A comprehensive subjective assessment is the initial step in evaluating a patient's balance. Key components include:
  - **Medical history:** Examining the patient's medical history for neurological, musculoskeletal or cardiovascular conditions that could impact balance.
  - **Fall history:** Asking about past falls, the circumstances surrounding them, and any injuries sustained.
  - **Medication review:** Identifying medications that might affect balance, such as sedatives or antihypertensives.

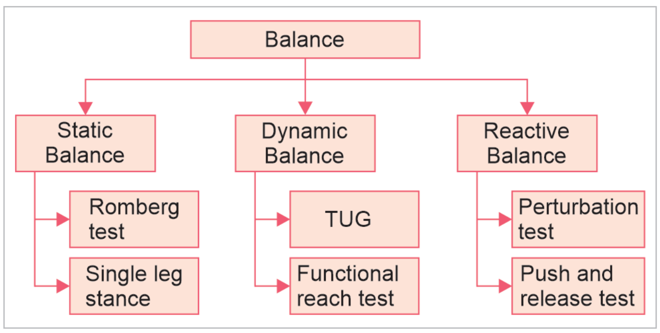


Fig. 38.2: Types of test used to assess balance

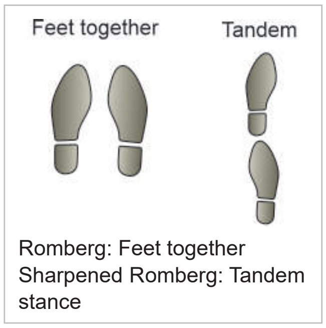


Fig. 38.3: Foot placement for Romberg and Sharpened Romberg test

  - **Lifestyle factors:** Evaluating physical activity levels, use of assistive devices, and potential environmental hazards at home or work.
- **Objective assessment:** It involves a series of standardized tests and measures to evaluate different aspects of balance.

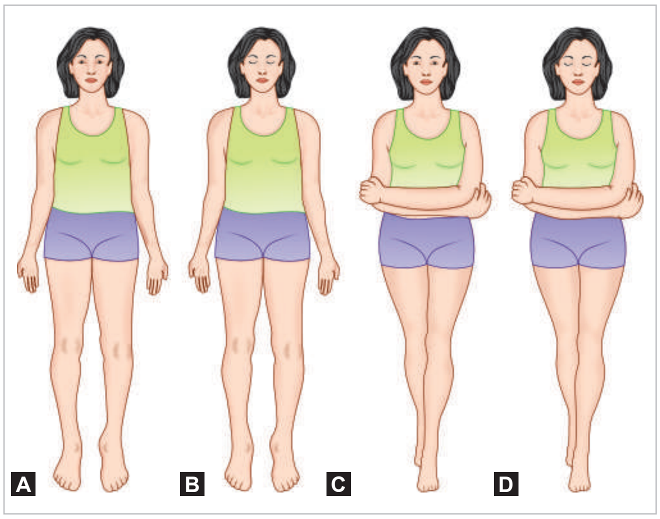
Static Balance Tests

Romberg Test and Sharpened Romberg Test

The Romberg Test was first described by Moritz Heinrich Romberg in the 19th century. Romberg test involves the individual standing with feet together, arms at their sides, and eyes closed for about 30 seconds, observing for any swaying or loss of balance. The Sharpened or tandem Romberg test, a more challenging variant, requires the individual to stand in a tandem position (heel-to-toe) with eyes closed (Fig. 38.3). Both tests primarily assess proprioception and vestibular function. These tests are simple and require minimal materials, typically just a stopwatch and a safe environment. They are considered valid and reliable for detecting sensory ataxia and balance impairments, particularly in older adults. However, their limitations include reduced sensitivity in detecting minor balance deficits and the inability to assess dynamic or reactive balance (Figs 38.4A to D).

Single Leg Stance Test

To perform the test, an individual stands on one leg while the other leg is lifted and not touching the ground, with arms crossed over their chest or on their hips, maintaining the position for as long as possible (Fig. 38.5). The duration they can hold this stance is recorded, typically up to a maximum of 30 seconds. The test requires minimal materials, generally just a stopwatch. The Single Leg Stance Test (SLST) has demonstrated good validity and reliability for identifying balance impairments and fall risk, particularly in elderly populations. However, its limitations include potential variability due to fatigue, strength or proprioceptive issues, and it may not fully capture balance challenges experienced



Figs 38.4A to D: **A.** Romberg test position with eyes open. **B.** Romberg test position with eyes closed. **C.** Sharpened Romberg test with eyes open. **D.** Sharpened Romberg test with eyes closed

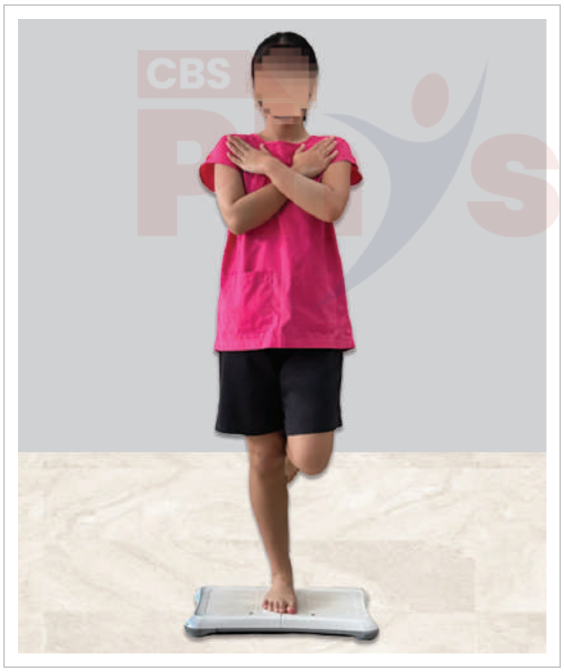


Fig. 38.5: Single leg stance test

Adapted from: Sangkarit, N., Tapanya, W., Amput, P., Muangchuen, C., Seeta, P., & Paleeta, W. (2025). Assessment of balance in overweight and obese young adults: utilizing centre of pressure displacement variables in the single leg sit-to-stand test. International Journal of Adolescence and Youth, 30(1).

during dynamic activities. Additionally, individuals with severe balance impairments may not be able to perform the test safely without support.

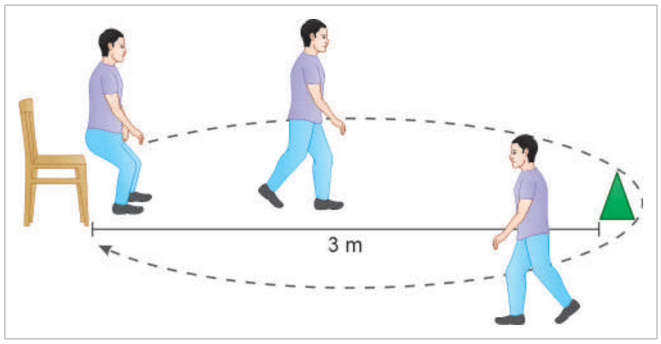


Fig. 38.6: Setup for timed up and go test

Adapted from: Martín-Díaz, P., Carratalá-Tejada, M., Molina-Rueda, F. et al. Reliability and agreement of the timed up and go test in children and teenagers with autism spectrum disorder. Eur J Pediatr 182, 3577–3585 (2023).

Dynamic Balance Tests

Timed Up and Go Test

The Timed Up and Go (TUG) test is a simple and widely used assessment of a person's mobility and balance. It was developed by Podsiadlo and Richardson in 1991. The materials needed for the test include a standard armchair, a stopwatch, and a marked line on the floor 3 m (10 feet) away from the chair. The method involves having the patient start seated in the chair, stand up on command, walk to the line, turn around, walk back to the chair, and sit down. The time taken to complete is recorded (Fig. 38.6).

The TUG test has been shown to have good reliability and validity for assessing balance and functional mobility in various populations, including older adults and individuals with neurological conditions. Its ease of administration and minimal equipment requirements, make it a practical tool for clinical and research settings. Time of 10 seconds or less are considered normal for healthy older adults, while times over 12 seconds can indicate a higher risk of falling.

Limitation: It measures basic mobility tasks and does not assess the ability to recover from unexpected perturbations. Additionally, it may not capture the full range of balance issues in individuals with specific conditions, such as vestibular disorders or those requiring more dynamic or multitasking capabilities. Despite these limitations, the TUG test remains a valuable, quick, and easy-to-administer tool for screening mobility and fall risk in various populations.

Functional Reach Test

The Functional Reach Test (FRT) was introduced by Duncan et al. in 1990. The FRT is a clinical assessment used to evaluate

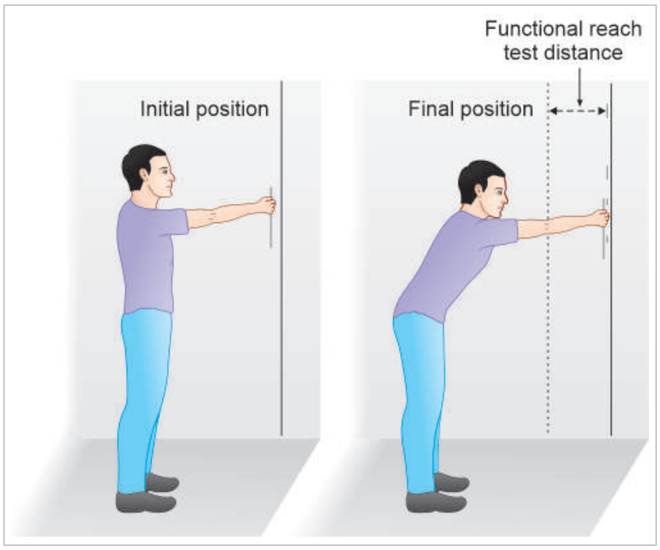


Fig. 38.7: Functional reach test

Adapted from: Pires IM, Garcia NM, Zdravevski E. Measurement of Results of Functional Reach Test with Sensors: A Systematic Review. Electronics. 2020; 9(7):1078.

dynamic balance and the risk of falling. To perform the FRT, an individual stands next to a wall with their feet shoulder-width apart and reaches forward as far as possible without taking a step or losing balance, while keeping their arm parallel to the measuring device, typically a yardstick or tape measure affixed to the wall. The distance reached is recorded (Fig. 38.7). The FRT is considered both valid and reliable for predicting fall risk, particularly in elderly and neurologically impaired populations. The test is easy to administer and requires minimal equipment, making it practical for various settings.

Limitations: It includes potential inaccuracies for individuals with severe balance or cognitive impairments, and it primarily assesses forward reach, not capturing multidirectional stability or balance during more dynamic activities.

Reactive Balance Test

Pertubation Test

Perturbation tests are commonly used to assess reactive balance by introducing unexpected disturbances that challenge postural stability. During the test, the participant stands in a stable position—typically with feet shoulder-width apart—while the examiner applies sudden, controlled pushes or pulls to the body, often at the shoulders or trunk, in different directions (forward, backward, or lateral). These externally generated forces disrupt the participant's center of mass, potentially shifting it outside the base of support. The participant is then required to respond with appropriate balance-correcting reactions, such as ankle strategies, hip adjustments or compensatory stepping, depending on the intensity of the perturbation. These responses are observed and assessed to evaluate the integrity and adaptability of the individual's postural control system.

Push and Release Test

Push and release test (PRT) is a sensitive tool for evaluating postural responses to manual perturbation. In this test, the participant leans backward against the examiner's palms, allowing the trunk to tilt backward. Once the participant's trunk and hips reach a stable position with an inclination of approximately 10°, causing the center of pressure to move outside their base of support, the examiner abruptly removes their hands. This action requires the participant to take a compensatory step backward to regain balance.

Functional Scales

Berg Balance Scale

Berg balance scale (BBS) is an objective scale with 14 items that assesses static and dynamic balance. It was developed by Katherine Berg in 1989. Each item is scored on a scale of 0–4, with a maximum score of 56. Higher scores indicate better balance. For a comprehensive understanding of the scale, refer to Chapter 42, which provides detailed descriptions of its components, administration procedures, and clinical applications.

Performance-Oriented Assessment of Balance

The Performance-Oriented Mobility Assessment (Tinetti Test) was developed by Mary Tinetti in 1986. Performance Oriented Mobility Assessment (POMA), thus also called Tinetti Test (TT), is a widely used tool to evaluate an individual's gait and balance. The method involves a series of tasks divided into two main sections: Balance tests (sitting, rising, standing, turning, etc.) and gait tests (initiation, step length, step symmetry, etc.). Each task is scored on a scale, with higher scores indicating better performance. The patient will begin seated in a hard, armless, stable chair. They will be instructed to stand up from the seated position without using their arms or hands for support. Once standing, the patient will be asked to place their feet as close together as possible. The examiner will then apply pressure to the patient's sternum with the palm of their hand three times—first with the patient's eyes open, and then with their eyes closed. Finally, the patient will be asked to complete a full 360-degree turn and sit back down in the chair. The scoring for this assessment is divided into ten standardized subsets, with a maximum total score of sixteen.

The POMA has demonstrated strong validity and reliability for assessing fall risk, particularly in older adults. The limitations include potential variability in scoring due to subjective judgments and the possibility that it may not fully capture balance issues during more complex or real-world activities.[12]

SCORING AND INTERPRETATION

Grading and interpreting balance assessment results necessitates a thorough understanding of the patient's overall health, functional capabilities, and specific impairments. Key considerations include:

- **Comparing scores to normative data:** Many balance assessments have established normative values based on age and sex. Comparing a patient's scores to these benchmarks helps identify deviations and assess the severity of balance impairments.
- **Identifying patterns of impairment:** Different balance tests evaluate various aspects of balance. Recognizing specific deficits, such as issues with dynamic balance or reduced reactive responses, helps to direct targeted interventions.
- **Contextual factors:** Taking into account the patient's living environment, daily activities, and personal goals is crucial for developing a meaningful and effective intervention plan. Here is the grading and interpretation for the balance tests mentioned above:

Romberg Test

Purpose: To assess proprioceptive and vestibular function for postural control.

Scoring

- **0 = Negative (normal):** Minimal sway, maintains position ≥30 seconds with eyes closed.
- **1 = Mildly positive:** Noticeable sway, able to hold for 30 seconds.
- **2 = Positive (abnormal):** Loss of balance or stepping/falling before 30 seconds.

Grading

- **Negative Romberg:** The patient maintains balance with minimal sway with eyes open and closed. It indicates normal proprioception and vestibular function.
- **Positive Romberg:** The patient loses balance or sways significantly after closing their eyes. It indicates impaired proprioception or vestibular dysfunction.

Interpretation

- Negative = normal proprioception
- Positive = sensory or vestibular impairment.

Sharpened Romberg Test

Purpose: A more challenging version of the Romberg, used to detect mild balance deficits.

Scoring

- **30 seconds = Normal (score 3):** Maintains position with minimal sway.
- **10–30 seconds = Borderline (score 2):** Some sway, able to recover.
- **<10 seconds = Abnormal (score 1):** Unable to hold, large sway or step.
- 0 = Unable to maintain position >5 seconds.

Interpretation

- When vision is removed and the base of support is narrowed, patients with subtle postural control impairments will show increased sway or loss of balance.
- Difficulty maintaining tandem stance with eyes closed indicates reduced postural stability or sensory integration deficits.
- A positive test indicates impaired proprioceptive or vestibular control.

Single Leg Stance Test

Purpose: To assess static balance and lower extremity strength.

Grading

- **Normal:** Can hold the position for ≥30 seconds without assistance or significant sway.
- **Mild impairment:** Can hold for 10–29 seconds with mild sway.
- **Moderate impairment:** Can hold for <10 seconds with significant sway or assistance.
- **Severe impairment:** Cannot hold the position or requires immediate assistance.

Age-Related Norms

- **Younger adults:** ≥30 seconds.
- **Older adults (65+):** 10–15 seconds may be normal.

Timed Up and Go Test

Purpose: To assess dynamic balance and mobility.

Grading

- **<10 seconds:** Normal mobility for healthy adults.
- **10–19 seconds:** Normal for older adults or mildly impaired mobility.

TABLE 38.1: Timed up and go (TUG) test: Interpretation

Time taken (seconds)	Interpretation of mobility/ fall risk	Clinical implication
≤10	Indicates good functional mobility with minimal risk of major mobility limitation.	Normal mobility; monitor routinely.
10–12	Mildly slowed mobility; may indicate emerging limitation or slightly increased fall risk.	Further evaluation of gait, balance, and strength recommended.
12–13.5 and above	Increased risk of mobility limitation and falls; ≥12.6 s associated with approximately fourfold odds of future falls.	Initiate fall prevention strategies and balance training.
>15–20	Significant mobility impairment and high fall risk; may require assistive device or supervision.	Comprehensive rehabilitation or physiotherapy assessment advised.

- **20–29 seconds:** Moderate mobility impairment, may need assistive devices.
- **≥30 seconds:** Severe mobility impairment, high fall risk.

Interpretation

Table 38.1 discusses the interpretation for TUG.

Functional Reach Test

Purpose: To measure dynamic balance and limit of stability.

Grading

- **≥10 inches (25 cm):** Normal functional balance.
- **6–10 inches (15–25 cm):** Moderate balance impairment.
- **<6 inches (15 cm):** Severe balance impairment, high fall risk.
- **Unable to reach:** Indicates very poor balance and mobility.

Interpretation

Table 38.2 discusses the interpretation of the functional reach test.

Age-Related Norms

- **Adults 20–40 years:** 14–16 inches (35–40 cm).
- **Adults 41–69 years:** 13–15 inches (33–38 cm).
- **Adults 70+:** 10–13 inches (25–33 cm).

Push and Release Test

Purpose: To assess postural control and reactive balance by evaluating the ability to recover from an external perturbation.

TABLE 38.2: Interpretation for functional reach test

Reach distance	Balance and fall risk	What it means
>25 cm (≈10 inches)	Good balance—low risk of falls	Normal forward reach; person can maintain balance easily.
15 – 25 cm (≈6 – 10 inches)	Moderate risk—some reduction in balance	Indicates mild difficulty maintaining balance; may benefit from balance training.
<15 cm (≈6 inches)	High fall risk—poor balance control	Suggests limited ability to reach or recover balance; needs immediate intervention or supervision.

Grading (Based on Patient Response)

- **0:** Recovers independently with no steps.
- **1:** Recovers independently with 1 step.
- **2:** Recovers independently with 2–3 small steps.
- **3:** Recovers but requires 4 or more steps to stabilize.
- **4:** Unable to recover and requires assistance to prevent a fall.

Interpretations

- **Grades 0–1:** Normal or mild impairment of balance.
- **Grades 2–3:** Moderate impairment, indicating higher fall risk.
- **Grade 4:** Severe impairment, suggesting very high fall risk and the need for close supervision or interventions.

Performance-Oriented Mobility Assessment

Purpose: To assess balance and gait, especially in older adults, for fall risk evaluation.

Scoring

- Each item is scored on a 3-point scale (0–2):
  - **0:** Severe impairment.
  - **1:** Moderate impairment.
  - **2:** Normal performance.
- **Total score range: 0–28**.
  - Balance section: 9 items, **16 points** maximum.
  - Gait section: 7 items, **12 points** maximum.

Interpretations

- Higher scores indicate better functional mobility.
- **25–28:** Low fall risk.
- **19–24:** Moderate fall risk.
- **<19:** High fall risk.

These scales are widely used in clinical and rehabilitation settings to evaluate balance capabilities, plan interventions, and track progress over time.

HIGH-YIELD POINT

Instrumented Assessments
For a more precise and detailed analysis, instrumented assessments utilizing technology, such as force plates, inertial measurement units (IMUs), and motion capture systems can be used. These tools offer quantitative data on postural sway, gait parameters, and balance reactions.

CLINICAL INDICATIONS

Balance assessment is a critical component of neurological evaluation, aimed at understanding a patient's ability to maintain postural control and stability. It provides insights into the coordination of sensory, motor, and central nervous system functions.

- **Vestibular dysfunctions:** These conditions often lead to dizziness, vertigo, and impaired spatial orientation, necessitating evaluation of balance (e.g., labyrinthitis, Meniere's disease, vestibular neuritis).
- **Cerebellar disorders:** Disorders affecting the cerebellum often result in poor coordination, unsteady gait, and difficulty maintaining equilibrium, warranting comprehensive balance testing (e.g., ataxia, cerebellar stroke).
- **Sensory deficits:** Impairments in proprioception, tactile sensation, or visual input can compromise the body's ability to detect and respond to changes in position, increasing the risk of instability and falls (e.g., peripheral neuropathy, multiple sclerosis).
- **CNS lesions:**
  - Poststroke balance impairments or ataxia.
  - Traumatic brain injury with dizziness, vertigo or instability.
- **Movement disorders:**
  - Conditions like Parkinson's disease, may cause postural instability or gait abnormalities.
  - Dystonia or chorea affecting movement control.
- **Age-related or degenerative conditions:**
  - Elderly patients with fall risk due to reduced proprioception or vestibular function.
  - Neurodegenerative disorders like Huntington's disease and Amyotrophic Lateral Sclerosis (ALS).
- **Developmental and congenital disorders:**
  - Balance issues in cerebral palsy or spina bifida.
  - Developmental coordination disorders affecting postural control.

CLINICAL APPLICATIONS

- **Diagnosis and localization:**
  - Differentiate between sensory, vestibular, and cerebellar causes of imbalance.
  - Identify central nervous system lesions affecting balance pathways.
- **Fall risk assessment:**
  - Screen for fall risk in elderly patients or those with neurological impairments.
  - Guide interventions to prevent falls and improve safety.
- **Rehabilitation and therapy planning:**
  - Provide baseline data to design targeted balance rehabilitation programs.
  - Assess progress in patients recovering from stroke, trauma or surgery.
- **Monitoring disease progression:**
  - Track worsening of balance in progressive conditions like multiple sclerosis or Parkinson's disease.
  - Evaluate the effectiveness of medications or therapies aimed at improving balance.
- **Sports medicine and performance:** Identify balance deficits in athletes recovering from concussions or vestibular injuries.

CLINICAL RELEVANCE

Balance assessment tests are clinically relevant because they provide critical information about a patient's ability to maintain stability and posture, which is essential for performing daily activities and preventing falls. Here is why these tests are important:

- **Fall risk evaluation:** These tests help to identify individuals at risk of falling, especially in older adults or those with neurological conditions. Early detection allows for timely intervention to reduce fall risk and associated injuries.
- **Diagnosis of underlying conditions:** Poor balance may indicate underlying health issues, such as vestibular disorders, neurological diseases (e.g., Parkinson's, multiple sclerosis), musculoskeletal problems or even cognitive impairments. Balance tests assist in diagnosing these conditions by revealing specific deficits.
- **Monitoring disease progression:** In patients with chronic conditions like Parkinson's disease or stroke, balance assessments are used to monitor disease progression and the effectiveness of treatments or rehabilitation programs.
- **Rehabilitation planning:** The results of balance tests guide the development of personalized rehabilitation plans. They help clinicians tailor interventions to improve specific aspects of balance, such as strengthening, coordination or sensory integration.

- **Postsurgical evaluation:** After surgeries, especially those involving the lower limbs or spine, balance tests assess recovery and guide the progression of physical therapy, ensuring patients regain stability and functional independence.
- **Sports and occupational screening:** In athletes or individuals in physically demanding jobs, balance assessments are used to evaluate readiness for return to activity and prevent injuries by identifying and addressing balance deficits.

Overall, balance assessment tests are a vital tool in clinical practice, aiding in diagnosis, treatment planning, and improving patient outcomes across various medical fields.

SUMMARY

- Balance, the ability to control the center of gravity over the base of support, is essential for human movement and function. It involves the vestibular, visual, and proprioceptive systems, and impairments can lead to falls. Physiotherapists use various methods to assess balance, which is crucial for improving patients' quality of life.
- Balance is divided into static, dynamic, and reactive components. Static balance is maintaining a steady position at rest, dynamic balance is stability while moving, and reactive balance is responding to unexpected perturbations.
- Subjective assessments consider medical history, fall history, medication review, and lifestyle factors. Objective assessments use standardized tests to evaluate balance aspects.
- Static balance tests include the Romberg test, which assesses proprioception and vestibular function, and the single leg stance test, which identifies balance impairments and fall risk. Dynamic balance tests, such as the timed up and go test (TUG) and the functional reach test (FRT), assess mobility and balance, predicting fall risk. Reactive balance tests, like the push and release test, evaluate postural responses to perturbations.
- Functional scales like the Berg Balance Scale and the Performance-Oriented Assessment of Balance (POMA) provide comprehensive evaluation of balance and gait, respectively. Instrumented assessments using technology offer detailed quantitative data on balance.
- Interpreting balance assessment results requires understanding the patient's health, functional capabilities, and specific impairments. Scores are compared to normative data, and patterns of impairment are identified to guide interventions.
- Balance assessment is a multifaceted process involving subjective and objective tools to identify balance impairments and develop targeted interventions aimed at enhancing functional independence, reducing fall risk, and improving quality of life. Assessing balance is a complex process that necessitates a deep understanding of the underlying systems and contributing factors. By employing a mix of subjective and objective assessment tools, physiotherapists can precisely pinpoint balance impairments and formulate effective intervention strategies. The primary aim is to boost the patient's functional independence, minimize fall risk, and enhance their overall quality of life.

FURTHER READINGS

- Bergland A, Jorgensen L, Emaus N, Strand BH. Timed Up and Go: Reference values for community-dwelling older people (the Tromsø Study). J Geriatr Phys Ther. 2020;43(4):153–60.
- Bohannon RW, Wolfson LI, White WB. Functional reach of older adults: normative reference values based on new and published data. Physiotherapy. 2017 Dec;103(4):387-391. doi:10.1016/j.physio.2017.03.006.
- Cassidy B, Pelo R, Fino NF, Presson AP, Cushman DM, Monson NE, Dibble LE, Fino PC. Reactive Postural Responses After Mild Traumatic Brain Injury and Their Association with Musculoskeletal Injury Risk in Collegiate Athletes: A Study Protocol. Front Sports Act Living. 2020 Oct 29;2:574848. doi:10.3389/fspor.2020.574848.
- Choo PL, Tou NX, Jun Pang BW, Lau LK, Jabbar KA, Seah WT, Chen KK, Ng TP, Wee SL. Timed Up and Go (TUG) Reference Values and Predictive Cutoffs for Fall Risk and Disability in Singaporean Community-Dwelling Adults: Yishun Cross-Sectional Study and Singapore Longitudinal Aging Study. J Am Med Dir Assoc. 2021 Aug;22(8):1640-1645.
- Cleveland Clinic. Romberg test: purpose, procedure & results [Internet]. Cleveland Clinic; 2023 [cited 2026 Jan 20]. Available from: https://my.clevelandclinic.org/health/diagnostics/romberg-test.
- Davies J, Louwagie N, Power S, Santin S, Hunter SW. Functional Reach Test, Single-Leg Stance Test, and Tinetti Performance-Oriented Mobility Assessment for the Prediction of Falls in Older Adults: A Systematic Review. Phys Ther. 2021 Oct 1;101(10):pzab173. Available at: https://academic.oup.com/ptj/article/101/10/pzab173/6317705
- De Jesus Gil Rodrigues AM, de Cássia Domingues de Freitas R, et al. Usefulness, assessment and normative data of the Functional Reach Test: a systematic review and meta-analysis. Gait Posture. 2018;61:236-44.

- De Waroquier-Leroy L, Bleuse S, Serafi R, Watelain E, Pardessus V, Tiffreau AV, Thevenon A. The Functional Reach Test: strategies, performance and the influence of age. Ann Phys Rehabil Med. 2014 Aug-Sep;57(6-7):452-64. doi:10.1016/j.rehab.2014.03.003.
- El-Gohary M, Peterson D, Gera G, Horak FB, Huisinga JM. Validity of the Instrumented Push and Release Test to Quantify Postural Responses in Persons With Multiple Sclerosis. Arch Phys Med Rehabil. 2017 Jul;98(7):1325-1331. doi:10.1016/j.apmr.2017.01.030.
- Forbes J, Munakomi S, Cronovich H. Romberg Test. [Updated 2023 Aug 13]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK563187/
- Greene BR, Doheny EP, O'Halloran A, Kenny RA. Does the Timed Up and Go test predict future falls among British community-dwelling older people? BMC Geriatr. 2015;15:87.
- Juniper Publishers. Sharpened Romberg test for balance assessment [Internet]. Juniper Publishers; 2018 [cited 2026 Jan 20]. Available from: https://juniperpublishers.com/gjo/GJO.MS.ID.555782.php.
- Kear BM, Guck TP, McGaha AL. Timed Up and Go (TUG) Test: Normative Reference Values for Ages 20 to 59 Years and Relationships With Physical and Mental Health Risk Factors. J Prim Care Community Health. 2017 Jan;8(1):9-13. doi:10.1177/2150131916659282.
- Lee JE, Chun H, Kim YS, Jung HW, Jang IY, Cha HM, Son KY, Cho B, Kwon IS, Yoon JL. Association between Timed Up and Go Test and Subsequent Functional Dependency. J Korean Med Sci. 2020 Jan 20;35(3):e25.
- Lee SP, Dufek J, Hickman R, Schuerman S. Influence of procedural factors on the reliability and performance of the timed up-and-go test in older adults. Int J Gerontol. 2016 Mar;10(1):37-42. doi:10.1016/j.ijge.2015.10.003.
- Miranda N, Tiu TK. Berg Balance Testing. 2023 Feb 17. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available from: https://www.ncbi.nlm.nih.gov/books/NBK574518/
- O'Sullivan SB, Schmitz TJ, Fulk GD. Physical rehabilitation: assessment and treatment. 7th ed. Philadelphia: F.A. Davis; 2019.
- Ortega-Bastidas P, Gómez B, Aqueveque P, Luarte-Martínez S, Cano-de-la-Cuerda R. Instrumented Timed Up and Go Test (iTUG)-More Than Assessing Time to Predict Falls: A Systematic Review. Sensors (Basel). 2023 Mar 24;23(7):3426. doi:10.3390/s23073426
- Scura D, Munakomi S. Tinetti Gait and Balance Test. [Updated 2022 Nov 20]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available at: https://www.ncbi.nlm.nih.gov/books/NBK578181/
- Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2017.
- Sibley KM, Straus SE, Inness EL, Salbach NM, Jaglal SB. Balance assessment practices and use of standardized balance measures among Ontario physical therapists. Phys Ther. 2011 Nov;91(11):1583-91. doi:10.2522/ptj.20110063.
- Umphred DA, Lazaro RT, Roller M, Burton GU, editors. Umphred's Neurological Rehabilitation. 6th ed. St. Louis: Mosby, Elsevier; 2013.
- Yang YR, Lee YC, Chen YC, et al. Timed Up and Go (TUG) reference values and predictive cutoffs for identifying individuals with high probability of falling and predicting disability. Arch Gerontol Geriatr. 2021;94:104346.
- Yokoyama H, Kitano Y. Real-Time Fall Risk Assessment Using Functional Reach Test. Sensors (Basel). 2024;24(4):1301.
- Zasadzka E, Borowicz AM, Roszak M, Pawlaczyk M. Assessment of the risk of falling with the use of Timed Up and Go test in the elderly with lower extremity osteoarthritis. Clin Interv Aging. 2015;10:1289–96.

STUDENT ASSIGNMENT

ANSWER THE FOLLOWING QUESTIONS

1. What are the primary components of balance that are assessed during a balance evaluation?
2. How does the Romberg test help in assessing an individual's balance?
3. What is the role of vestibular system in maintaining balance?

MULTIPLE CHOICE QUESTIONS

1. **Which of the following systems is not directly involved in maintaining balance?**
   a. Vestibular system
   b. Musculoskeletal system
   c. Digestive system
   d. Visual system
2. **What is the main purpose of the Timed Up and Go (TUG) test?**
   a. To assess vision
   b. To evaluate balance and mobility
   c. To check for hearing impairment
   d. To test muscle strength in the upper limbs
3. **During the Romberg test, a person is asked to:**
   a. Walk in a straight-line heel to toe
   b. Stand with their feet together and eyes closed
   c. Stand on one leg for 30 seconds
   d. Perform rapid alternating hand movements
4. **Which of the following is an example of a dynamic balance assessment?**
   a. Standing on one leg
   b. Walking on a treadmill
   c. The Berg Balance Scale
   d. The Sit and Reach Test
5. **The inability to maintain balance with eyes closed during the Romberg test suggests an issue with:**
   a. Visual feedback
   b. Vestibular or proprioceptive input
   c. Cardiovascular system
   d. Cognitive processing

ANSWER KEY

1. c **2.** b **3.** b **4.** c **5.** b