# Balance and Gait Rehabilitation:

## Sensory Integration, Assessment, and Progressive Exercise

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# How to Use This Review

This comprehensive review addresses postural control physiology, balance assessment frameworks, gait rehabilitation strategies, and outcome measurement for vestibular patients. It integrates sensory integration principles, specific training progressions, and evidence-based outcome measures.

The document follows a structured clinical format with numbered sections, integrated callout boxes for rapid reference, summary tables, and a references section. It is designed both as a learning resource and a quick-reference tool for practising clinicians.

 **Key Point:** *Foundational concepts and summary statements that anchor the core scientific content of each section.*

 **Clinical Insight:** Clinically relevant observations derived directly from the evidence — for direct application in assessment and diagnosis.

 **Clinical Pearl:** High-yield, memorable clinical points — the take-home messages most likely to influence management or examination performance.

# Contents

**I. Introduction**

**II. Postural Control Physiology**
- Sensory integration model for balance
- Vestibular, visual, and proprioceptive contributions

**III. Balance Assessment Framework**
- Berg Balance Scale (BBS)
- Mini-BESTest and mCTSIB
- Sensory Organization Test (SOT)

**IV. Static Balance Training**
- Stance progressions
- Visual and proprioceptive modification

**V. Dynamic Balance Training**
- Perturbation training
- Weight shifting and stepping

**VI. Gait Assessment and Analysis**
- 10-Metre Walk Test
- 6-Minute Walk Test
- Dynamic Gait Index

**VII. Gait Retraining Principles**
- Visual feedback strategies
- Proprioceptive cueing

**VIII. Dual-Task Training**
- Cognitive-motor interference
- Real-world task integration

**IX. Sensory Reweighting**
- Vestibular to visual transitions
- Proprioceptive emphasis

**X. Falls Prevention and Risk Factors**
- Otago Exercise Program
- Identifying high-risk profiles

**XI. Outcome Measures and Minimal Clinically Important Difference**

**XII. Conclusions**

**XIII. References**

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### Version History

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# I. Introduction

Balance and gait dysfunction are cardinal features of vestibular disorders, significantly impacting functional independence, quality of life, and fall risk [10,11,18]. Rehabilitation specifically targets these impairments through assessment-driven, progressively challenging interventions that recruit residual vestibular function and engage compensatory sensory systems.

The vestibular contribution to balance and gait is often underestimated [6,11]. In dynamic environments or with degraded visual/proprioceptive information, the vestibular system becomes the dominant balance signal. Effective rehabilitation requires understanding the patient's sensory weighting profile and tailoring interventions accordingly [7,18].

 **Clinical Pearl:** Effective balance and gait rehabilitation integrates vestibular, visual, and proprioceptive systems rather than addressing each in isolation. Patients must learn to weight-shift between systems dynamically.

# II. Postural Control Physiology

## The Sensory Integration Model for Balance

Postural control integrates three sensory systems: vestibular (detecting head motion and gravity), visual (detecting environmental motion and self-motion relative to environment), and proprioceptive (detecting body segment position and movement) [6,7]. The central nervous system weights these inputs based on context, task demands, and individual sensory characteristics.

In normal vision with stable ground (ideal conditions), proprioception and vision dominate, with vestibular input providing redundancy [6,7]. In darkness or moving visual environments, vestibular input becomes critical for maintaining stability.

Vestibular hypofunction shifts the balance system's weighting toward increased visual and proprioceptive reliance [6,18]. Initially, this over-reliance on visual cues causes destabilisation in visually complex environments. As compensation develops, the brain re-establishes appropriate sensory weighting, though residual visual dependence may persist [18].

 **Key Point:** *The sensory integration model explains why vestibular patients may function normally in the clinic but struggle in real-world environments with poor lighting, complex visuals, or moving surfaces.*

## Vestibular, Visual, and Proprioceptive Contributions

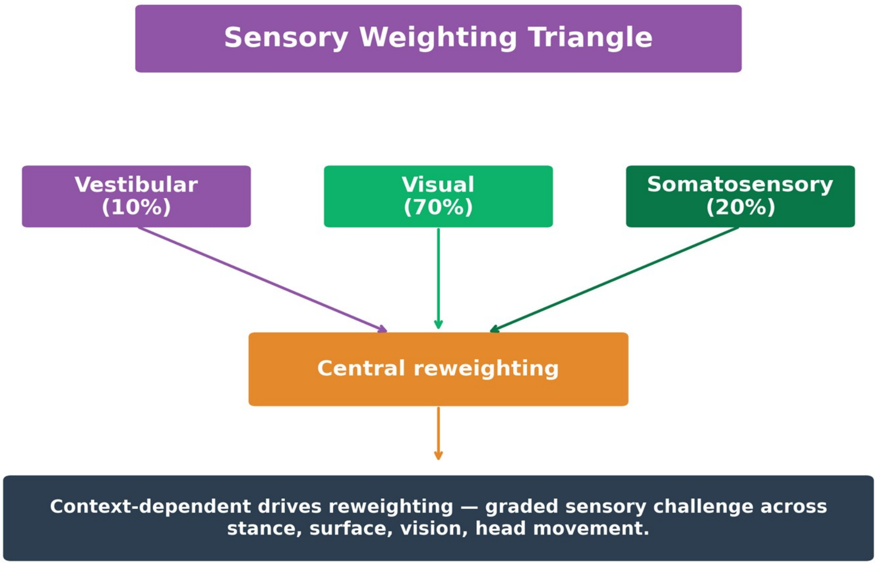
Vestibular system contribution: detects linear and angular head acceleration; drives reflexes (VOR, VSR) and contributes to postural orientation [6,8]. Loss of vestibular input degrades reflex-driven postural responses and dynamic balance, particularly during head movements.

Visual system contribution: provides orientation reference relative to environment; drives postural reflexes via optic flow [6]. Visual preference is task-dependent — tasks requiring stability over moving ground rely heavily on visual input.

Proprioceptive system contribution: detects body segment position and movement; critical for foot-floor interface feedback and lower limb control [6,7]. Proprioceptive loss (peripheral neuropathy, severe arthritis) significantly impairs balance and walking.

 **Clinical Insight:** Dual or triple sensory loss (e.g., vestibular loss + aging proprioceptive decline) produces dramatically worse balance outcomes than single system loss. Rehabilitation must address all affected systems.

*Figure 1. Sensory Weighting Triangle.*




*Source: Australian Dizziness Clinics, 2026.*

# III. Balance Assessment Framework

## Berg Balance Scale (BBS)

The Berg Balance Scale is a 14-item functional balance test assessing static and dynamic balance during various tasks: sitting, standing, reaching, turning, stepping, and stand-to-sit transitions [1]. Each item scored 0-4 based on quality of performance.

BBS scoring interpretation: 46-56 = low fall risk, 40-45 = medium risk, <40 = high fall risk [1,12]. A change of ≥4 points represents minimal clinically important difference (MCID) for vestibular populations [9].

Advantages: simple, quick (10-15 minutes), no special equipment, high reliability and validity [1]. Disadvantages: ceiling effect in younger patients without significant impairment; insensitive to subtle dynamic balance deficits.

 **Key Point:** *BBS is ideal for older vestibular patients and those with significant balance impairment. For younger or mildly impaired patients, more challenging tests are needed to detect improvements.*

## Mini-BESTest and Modified CTSIB

The Mini-Balance Evaluation Systems Test (Mini-BESTest) is a 14-item test focusing on dynamic balance, gait, and postural transitions [2]. It includes dynamic reach, turning, stepping over obstacles, and gait challenges, providing a more sensitive measure of dynamic balance than BBS.

The Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) systematically varies visual and proprioceptive inputs while maintaining stable stance [6,7]. Four conditions: (1) eyes open, firm surface, (2) eyes closed, firm surface, (3) eyes open, foam, (4) eyes closed, foam.

mCTSIB reveals sensory dependence patterns: disproportionate sway on foam (proprioceptive loss) versus eyes closed (visual dependence) indicates underlying systems contribution [7]. This information directly guides individualised treatment planning.

 **Clinical Insight:** mCTSIB is particularly valuable for identifying visual dependence in vestibular patients — patients who rely excessively on vision and destabilise quickly when visual input is degraded.

### Sensory Organization Test (SOT) and Force Plate Assessment

The Sensory Organization Test (SOT) uses a dynamic posturography platform where both visual surroundings and support surface move independently, isolating contributions of each system [7]. Six conditions systematically remove or distort sensory inputs.

SOT provides objective quantification of vestibular contribution to balance [7,8]. Disproportionate loss of balance when vision and proprioceptive inputs are compromised confirms vestibular involvement; the video head impulse test (vHIT) and other objective tests may complement SOT for comprehensive vestibular assessment [17].

Limitations: equipment expensive and not widely available; interpretive complexity for non-physiotherapists with a special interest in vestibular rehabilitation. The mCTSIB and Modified Romberg Test offer affordable alternatives that capture similar sensory-organisation information [6,7].

 **Key Point:** *SOT is the most specific assessment for vestibular balance contribution but clinically challenging. BBS and mCTSIB provide practical clinical alternatives that correlate with vestibular function.*

## IV. Static Balance Training

### Stance Progressions and Difficulty Hierarchy

Static balance training progresses through increasing difficulty: (1) double-leg stance on firm surface with visual support, (2) double-leg stance without visual support, (3) tandem stance, (4) single-leg stance, (5) single-leg stance with eyes closed [11,18]. Each progression removes a sensory compensatory mechanism.

Each progression removes a sensory compensatory mechanism, forcing the vestibular system to contribute more significantly [11]. The endpoint for most patients is maintaining single-leg stance with eyes closed for 30 seconds without falling.

Typical stance holding times: start at 30 seconds per position, progress to 60 seconds. Multiple repetitions (3-5) per session, 3-4× weekly. Progression occurs every 1-2 weeks based on stable performance at current level [11,18].

 **Clinical Pearl:** Never hold stance on foam with eyes closed initially; always precede with eyes open on foam. Jumping directly to highly challenging positions risks falls and loss of confidence.

### Visual and Proprioceptive Modification

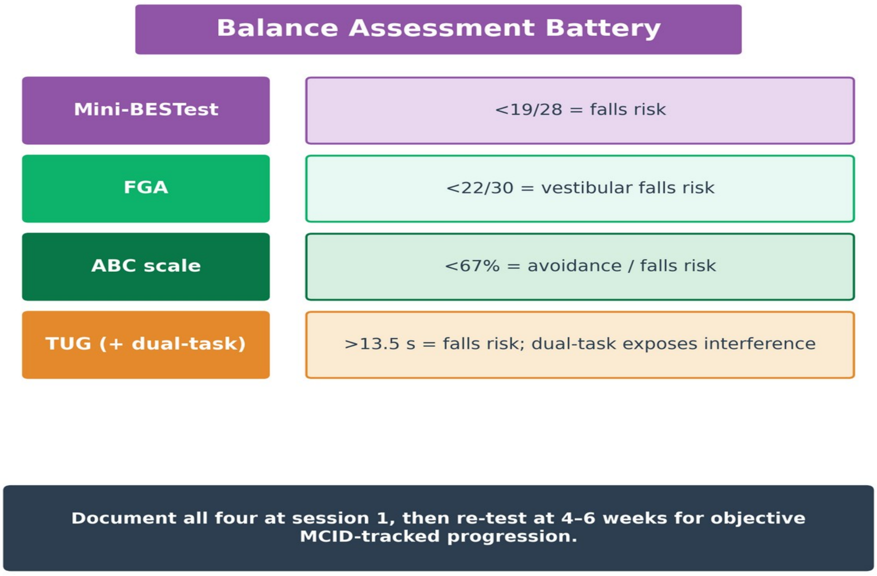
Visual modification techniques: (1) eyes closed, (2) reduced visual field (peripheral vision only), (3) moving visual background (optokinetic stimulus), (4) visual provocation (turning patterns) [11,18]. These specifically challenge visual dependence and force vestibular reweighting.

Proprioceptive modification: (1) firm surface → compliant (foam), (2) compliant → oscillating platform [11]. Proprioceptive challenge forces vestibular system to maintain stability without ground reference, accelerating compensation.

Individual tailoring: patients with visual dependence benefit from heavy visual degradation (eyes closed on foam) early; patients with proprioceptive loss benefit from progressive surface compliance [7,18]. Treatment plans should match the patient's specific weakness.

 **Key Point:** *Assessment-driven modification: mCTSIB results guide which sensory domain requires most aggressive challenge during balance training.*

*Figure 2. Balance Assessment Battery.*




*Source: Australian Dizziness Clinics, 2026.*

# V. Dynamic Balance Training

## Perturbation Training and Reactive Balance

Perturbation training involves applying unexpected external forces (pushes, platform disturbances) that displace the body, requiring reactive postural responses [6,11,18]. This trains automatic balance recovery mechanisms essential for real-world stability.

Clinician-applied perturbations: gentle pushes to shoulders from multiple directions (anterior, posterior, lateral) at unpredictable moments. Start gentle, gradually increase magnitude. Cue patients about postural strategies (ankle, hip, step) appropriate for the perturbation [11].

Platform perturbations: dynamic posturography platforms apply sudden surface translations or tilts, driving postural responses. While not available in most clinics, perturbation training principles can be adapted with simpler tools (Bosu balls, balance pads) [11,18].

 **Clinical Insight:** Perturbation training activates rapid brainstem mechanisms (VSR) rather than slower cortical balance mechanisms. This improves reactive balance — critical for fall prevention in real-world stumble scenarios.

## Weight Shifting and Stepping Exercises

Weight shifting progresses from: (1) comfortable side-to-side shifting, (2) directional shifting (forward/back, diagonal), (3) narrow base of support, (4) dual-task weight shifting [6,11]. Each iteration challenges the vestibular system more.

Stepping exercises progress from: (1) marching in place, (2) stepping over obstacles, (3) step-ups/step-downs, (4) tandem walking, (5) stepping with head turns, (6) stepping in unpredictable directions [11,18].

Each progression requires greater vestibular contribution. Stepping exercises particularly activate the dynamic vestibulo-spinal reflex and improve gait-related balance [11,19].

 **Key Point:** *Stepping exercises are essential for vestibular rehabilitation; static balance training alone* *does not fully restore gait-related balance or fall prevention.*

# VI. Gait Assessment and Analysis

## 10-Metre Walk Test and Gait Velocity

The 10-Metre Walk Test measures time to walk 10 metres at preferred pace [9]. It is simple, quick, and sensitive to gait dysfunction across vestibular and neurological conditions.

Normal gait velocity: 1.0-1.4 m/sec (healthy younger adults), 0.8-1.0 m/sec (healthy older adults). Vestibular dysfunction typically reduces velocity by 10-30% [9,12,13].

Gait velocity correlates with fall risk: slower walkers (<0.8 m/sec) have increased fall risk [12,13]. Improvement in gait velocity is a strong predictor of improved functional independence.

 **Clinical Pearl:** 10-Metre Walk Test is ideal for serial outcome tracking during vestibular rehabilitation. Consistent improvement in velocity demonstrates progress.

## 6-Minute Walk Test

The 6-Minute Walk Test measures total distance walked in 6 minutes. It assesses walking endurance, gait speed, and functional mobility simultaneously. Useful for tracking progressive change in vestibular rehabilitation [9].

Normal reference values: healthy younger adults 500-700 metres, older adults 350-500 metres. Vestibular dysfunction often reduces distance by 15-40%. MCID is approximately 30-50 metres for vestibular populations [9].

The 6-Minute Walk Test is particularly valuable for detecting vestibular fatigue: some patients maintain gait velocity for short distances but show velocity decay over 6 minutes [9]. This pattern indicates incomplete compensation.

 **Key Point:** *6-Minute Walk Test captures endurance and fatigue effects not detected by brief gait measures. Useful for vestibular patients who tire easily.*

## Dynamic Gait Index

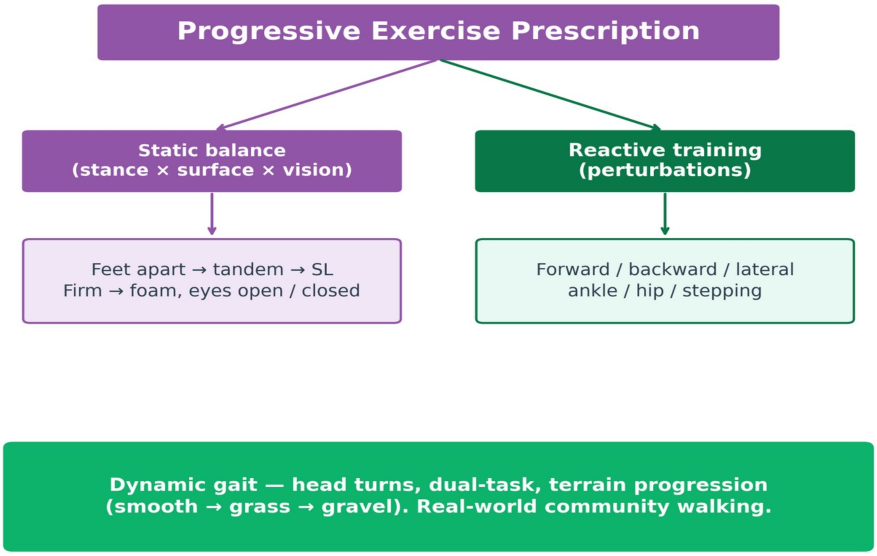
The Dynamic Gait Index assesses gait under challenging conditions: gait with head turns, gait with obstacles, gait with speed changes, gait with pivot turns [9]. Each condition is scored 0-3, total 0-24.

Dynamic Gait Index total score: 0-24, with higher scores indicating better performance. Score <19 indicates increased fall risk in older adults [9,12]. This test specifically captures dynamic vestibular gait stability.

Dynamic Gait Index is superior to simple gait velocity for detecting vestibular gait dysfunction [9]. Patients may walk normally straight but destabilise with head turns or obstacles, revealing vestibular involvement that velocity alone misses.

 **Clinical Insight:** Dynamic Gait Index reveals vestibular-specific gait deficits that straight-line gait measures miss. It is ideal for vestibular patient outcome tracking.

*Figure 3. Progressive Exercise Prescription.*




*Source: Australian Dizziness Clinics, 2026.*

# VII. Gait Retraining Principles

## Visual Feedback and Optokinetic Strategies

Visual feedback strategies include: (1) mirror practice (visual feedback of posture and movement), (2) video review (observing recorded gait), (3) real-time visual cues (lights, biofeedback) [11,18].

Patients with visual dependence benefit from visual feedback and guided walking along marked paths. As vestibular function recovers, reduce visual guidance and challenge the patient to maintain gait without visual cues [18].

Optokinetic training involves walking while exposed to moving visual backgrounds (treadmill with moving scenery, virtual reality environments) [11,18,20]. This challenges visual-vestibular integration and reduces visual dependence.

 **Key Point:** *Visual strategies are compensatory, not restorative. They are useful initially but should be gradually withdrawn as vestibular function recovers.*

## Proprioceptive Cueing and Haptic Feedback

Proprioceptive cueing includes: (1) wall/rail contact during walking, (2) light touch guidance (fingertip contact on wall), (3) haptic feedback devices (vibrating insoles, rhythmic tactile cues) [6,11]. These supplement reduced or impaired vestibular input.

Patients with proprioceptive loss (elderly, long-standing vestibular dysfunction) benefit from proprioceptive enhancement initially, gradually reducing reliance as vestibular function recovers [11,14].

Metronome training provides rhythmic auditory cuing that enhances gait consistency and stability, particularly in patients with vestibular-cerebellar coordination deficits [11].

 **Clinical Insight:** Proprioceptive and auditory cueing are particularly valuable for patients with coordination deficits. Systematic withdrawal of cues prevents dependence.

# VIII. Dual-Task Training

## Cognitive-Motor Interference in Vestibular Patients

Cognitive-motor interference refers to performance decrement when attention is divided between two tasks simultaneously [15,16]. Vestibular patients often show disproportionate dual-task interference compared to age-matched controls.

Mechanism: intact vestibular systems largely automate balance control, allowing cognitive resources to focus on secondary tasks [15]. Vestibular hypofunction requires conscious attention for balance, leaving fewer resources for secondary tasks.

Clinical significance: dual-task interference correlates strongly with fall risk in older vestibular patients [12,15,16]. Patients who slow dramatically during dual-task walking, or who lose balance under dual-task conditions, have higher fall risk.

 **Key Point:** *Dual-task testing (gait velocity while performing cognitive task) reveals cognitive load on balance — a sensitive marker of vestibular dysfunction and fall risk.*

## Task Integration and Real-World Complexity

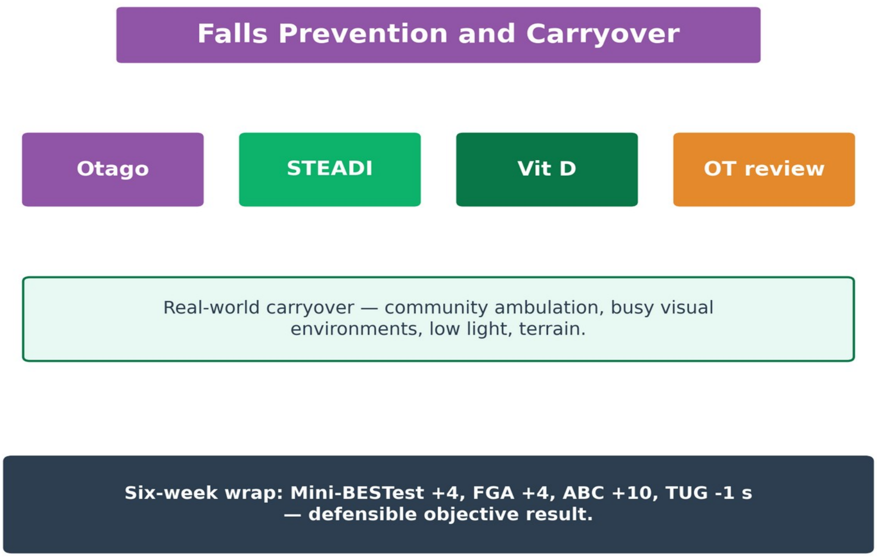
Dual-task training involves deliberate practice of simultaneous tasks: walking while counting backwards, walking while tracking targets, walking while reaching, walking while having conversations [11,15,18].

Real-world environments present substantial dual-task demands: navigating grocery stores (walking + visual search + decision-making), walking while talking, walking in crowded spaces. Training must include environments resembling real life [16].

Progression: simple dual-tasks (walking + easy cognition) → complex dual-tasks (walking + difficult cognition + navigation) → real-world environments [11,18].

 **Clinical Pearl:** Dual-task training improves real-world function more effectively than single-task balance training. Most falls occur during dual-task activities.

*Figure 4. Falls Prevention and Carryover.*




*Source: Australian Dizziness Clinics, 2026.*

# IX. Sensory Reweighting and System Integration

## Vestibular to Visual Transitions

As vestibular function recovers, the nervous system gradually reweights sensory inputs: vestibular input (initially providing most of the balance signal) becomes one of three balanced inputs again [6,7,18,19]. This natural reweighting can be facilitated through specific training.

Facilitation of reweighting involves: (1) environmental complexity progression (from blank walls to complex visuals), (2) gradually increasing visual degradation (eyes closed challenges), (3) progressive surface compliance challenges [6,11,18]. Each manipulation forces sensory reweighting.

Some patients show maladaptive reweighting: over-reliance on vision (visual dependence) develops, with patients destabilising inappropriately when visual input is degraded [18]. Treatment specifically addresses this through visual challenge progression.

 **Key Point:** *Optimal reweighting produces flexible sensory integration: patients weight inputs appropriately based on task and environment. Rigid over-reliance on any single system indicates incomplete rehabilitation.*

## Proprioceptive Emphasis and Interoceptive Integration

In bilateral vestibular loss where vestibular contribution cannot be restored, proprioceptive and visual systems must become primary balance mechanisms [11,14,18]. This requires sustained training to develop sufficient reliance on these alternative sensory inputs.

Proprioceptive emphasis involves: (1) feet-floor contact awareness (barefoot walking on varied surfaces), (2) weight distribution practice (feeling weight shift through feet), (3) joint position sense training [11,14]. These exercises develop proprioceptive sensitivity for balance.

Interoceptive integration involves conscious awareness of internal body signals (muscle tension, head orientation relative to body) to supplement external sensory input. This is particularly valuable in vestibular loss with visual degradation.

 **Clinical Insight:** Proprioceptive and interoceptive training represent the "last resort" sensory systems for balance when vestibular and visual inputs are significantly impaired. Explicit training and awareness development are essential.

# X. Falls Prevention and Risk Factors

## The Otago Exercise Program

The Otago Exercise Program is a home-based falls prevention program combining strength training (knee and ankle strengthening) and balance exercises [5,13]. It is designed for older adults at risk of falls.

Otago components: (1) five lower limb strength exercises, (2) three balance exercises, (3) walking program. Exercises are performed 3× weekly at home, with monthly clinician contact [5].

Otago efficacy: meta-analyses show 35% relative risk reduction in falls and 23% reduction in fall-related injuries [5,12,13]. NNT to prevent one fall is approximately 15 over one year for high-risk patients.

 **Clinical Pearl:** Otago is evidence-based, practical, and cost-effective. It is ideal for older vestibular patients with fall risk. Starting Otago early in vestibular rehabilitation prevents secondary deconditioning.

### Identifying High-Risk Profiles

High fall-risk vestibular patients share: (1) age >65 years, (2) bilateral vestibular loss or severe asymmetry, (3) concurrent proprioceptive or visual loss, (4) cognitive-motor interference, (5) prior falls [12,13].

Additional risk factors: prior fall history, reduced physical activity (deconditioning), home hazards (poor lighting, clutter), footwear inadequacy [12,13].

Risk stratification: patients with 3+ risk factors require intensive intervention including: early physiotherapy, home modification, medication review, potentially supervised exercise programs [13].

> **Key Point:** *Risk stratification guides intervention intensity and urgency. High-risk patients warrant expedited and intensive rehabilitation.*

## XI. Outcome Measures and Minimal Clinically Important Difference (MCID)

### Table 1. Balance and Gait Outcome Measures: MCID and Responsiveness

| Measure | Score Range | MCID | Responsiveness | Population |
|---|---|---|---|---|
| Berg Balance Scale | 0-56 | 4-6 points | High | Older adults, significant impairment |
| Mini-BESTest | 0-28 | 2-4 points | High | Dynamic balance deficits |
| 10-Metre Walk Test | m/sec | 0.1 m/sec | High | All populations |
| 6-Minute Walk Test | metres | 50 metres | Moderate | Endurance, fatigue |
| Dynamic Gait Index | 0-24 | 2-4 points | High | Vestibular populations |

*MCID guides interpretation of clinical change; changes below MCID may not represent meaningful improvement*

Interpreting outcome measures requires consideration of measurement error and minimal clinically important difference [9]. Patient-reported measures such as the Dizziness Handicap Inventory (DHI) [3] and Activities-Specific Balance Confidence (ABC) scale [4] capture perceived dizziness handicap and balance confidence respectively, complementing performance-based measures.

Serial assessment using same measures at baseline, mid-treatment, and discharge allows tracking of trajectory and predicting outcomes [9,11]. Rapid early improvement predicts good final outcome; absence of early improvement predicts persistent symptoms requiring treatment intensification.

## XII. Conclusions

Balance and gait rehabilitation represents a core component of vestibular physiotherapy [10,11,18]. Effective programs integrate assessment of sensory system contributions, individualised challenge progression, dual-task training, and falls prevention strategies.

Key principles: (1) individualised assessment guides specific training targets [6,7], (2) progressive challenge in multiple dimensions drives adaptation [11], (3) real-world simulation enhances functional carryover [18], (4) sustained practice produces lasting compensation [11,18].

Modern balance and gait rehabilitation moves beyond generic exercise toward mechanism-based, assessment-driven interventions [11,18,20]. This approach maximises efficacy and translates to meaningful real-world function.

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