Clinical Interventions in Aging

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REVIEW

# Balance and Gait Disorders in the Aged Population. Causes, Assessment and Management: A Literature Review

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**Abstract:** With aging, compensatory mechanisms and physiological reserve may become insufficient to maintain balance and gait (BG), particularly when associated with stroke, Alzheimer's disease, diabetes, osteoarticular diease, vestibular disorders, orthostatic hypotension (OH), heart rhythm disorders, or drug side effects. This leads to poorer postural-motor function and increased risk of falling (RoF). This review aims to highlight recent scientific advancements relative to BG disorders (BGDs) for gerontology professionals. When assessing older adults (OAs) with BGDs, a thorough assessment of patient history is needed to identify the origins. This should include the history of falls, an inventory of medications, and an analysis of the home environment. A comprehensive clinical examination is also required to guide etiological diagnoses. A clinical suspicion of cardiac arrhythmia/conduction disorders, for example, will be confirmed by electrocardiogram (ECG)/Holter ECG, whereas suspected OH (on questioning) will be confirmed by an OH test, and, in the presence of confusion, epilepsy will be confirmed by the electroencephalogram. Several tools, ranging from simple and quick to more complex and thorough, have been validated to evaluate BGDs in OAs. These tests involve activities of daily living tasks required to preserve independence. Emerging technologies for RoF assessment (ie, surface electromyography, force platforms, three-dimensional motion capture systems) while not yet used in routine geriatric practice, can improve early detection, monitoring, and rehabilitation. Optimal BGD management requires the implication of several health professionals. Rehabilitation programs such as the "Otago exercise programme" and "falls management exercise" have been validated. Assistive technologies (canes, walkers, grab bars, and orthopedic footwear or automated alert systems), and new technologies (virtual reality) can also be used. Additional steps include medication review and deprescribing, occupational therapy and home environment adaptations. Understanding and managing BGDs in OAs remains a major public health issue, and is vital for preserving independence in later life.

**Keywords:** balance, gait, posture, older adult, central nervous system

## Introduction

Although with aging, balance and gait (BG) may become less efficient,[1,2] older adults (OAs) can maintain adequate BG thanks to compensatory mechanisms and physiological reserve in the absence of chronic or acute disease. However, when aging is combined with illness, these reserves may become insufficient, leading to a breakdown of postural and locomotor functions and increasing the risk of falling (RoF). This concept, in which functional decompensation occurs once a threshold of insufficiency is surpassed, is known as the Bouchon model.[3]

Considering the importance of BG for maintaining independence, we propose a focused and updated overview of these disorders in OAs.[1] Beyond summarizing established knowledge, we have highlighted recent advances in clinical assessment and multidisciplinary management. This includes both well-established clinical tests and recent digital tools such as sensor-based systems and wearable technologies that enhance diagnostic precision and RoF prediction.

Received: 29 March 2025
Accepted: 26 August 2025
Published: 11 November 2025

This study aims to provide gerontology professionals with the latest scientific advances, particularly in the assessment and management of balance and gait disorders (BGDs). This includes both well-established clinical tests and more recent digital tools such as sensor-based systems and algorithmic approaches aimed at improving diagnostic accuracy and prediction of falls.

## Methods

In this narrative review, we draw on foundational texts in geriatric practice and supplement our discussion with recent literature (<5 years) in English or French. In order to do so, we performed a targeted search using PubMed, ScienceDirect and Google Scholar. However, when specific clinical tools or interventions had not been robustly studied within this timeframe, key references published before 2020 were also included. Particular attention was given to major international guidelines.

## Physiology of Balance and Gait

The simultaneous and coordinated action of afferents, the central nervous system (CNS) and effectors is essential for maintaining balance and walking.

As shown in Figure 1, the afferents provide individuals with information about their environment and position therein. They are also involved in perception and regulation of balance. They comprise the following three types of receptors:[4]

- Proprioceptive receptors, present in the muscles, joint capsules, skin and trunk,[5,6] inform the CNS of the position and movements in space of body parts.[6,7]
- Vestibular receptors, located in the inner ear, which include the semicircular canals, informing the CNS of angular movements of the head and body, as well as the otoliths (utricle and saccule) providing information on linear accelerations and verticality (of the head and body).[5–7] As with the proprioceptive system, this information allows balance to be controlled at multiple hierarchical levels of the CNS.[4] Unlike the otoliths which affect balance and postural control, the semicircular canals are not involved in postural control.[5]

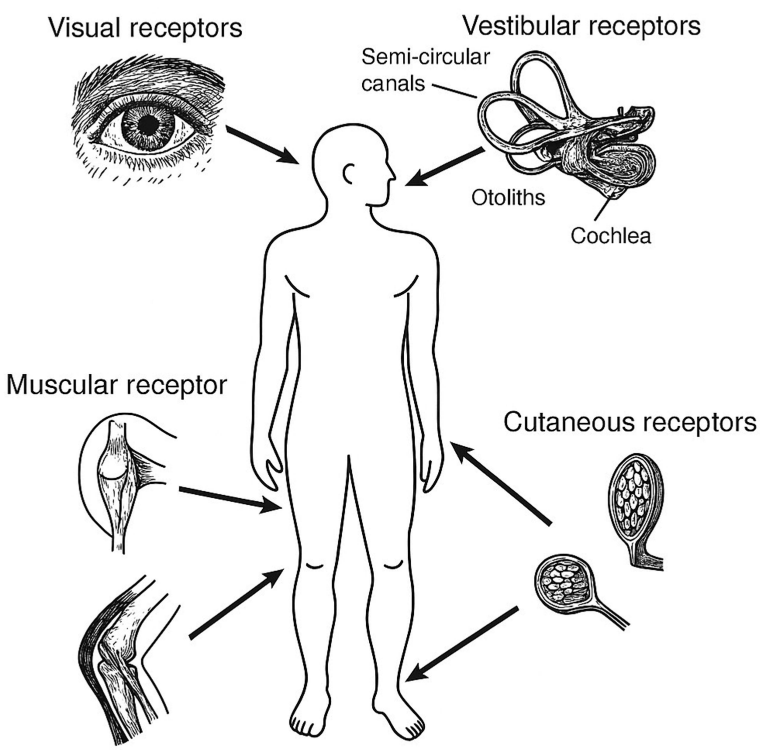


**Figure 1** Sensory receptor involved in kinesthesia. From Berthoz A., *Le Sens du Mouvement* © Odile Jacob, 1997.[8]

**Table 1** Involvement of Different Components of the Central Nervous System in Maintaining or Adapting Posture, Balance and Walking

| Nervous System Area | Programming | Organization | Coordination | Control | Learning | Automations | PA |
|---|---|---|---|---|---|---|---|
| **Cerebral cortex** | X | X | X (VMC) | | | | |
| **Cerebellum** | X | | | X | X | | |
| **Spinal cord** | | | X (MC & PC) | | | | |
| **Brainstem (with VN)** | | | X (MC & PC) | | | | |
| **Basal ganglia** | X | | | | | X | X |
| **Subcortex** | X | | | | | X | X |

**Abbreviations**: PA, postural adaptation; VMC, visual motor coordination; MC, muscular coordination; PC, propulsion coordination; VN, vestibular nuclei.

- Visual receptors, located in the retina, inform the CNS of the individual's position in space and the environment.[6] In addition to sophisticated analysis of the image generated (exteroceptive function), the central retina also controls the position of body segments during fine movements, while the peripheral retina analyzes the movement.[5,6] Ultimately, due to its unique property as a telereceptor, the visual system allows for various actions including anticipation, obstacle avoidance and navigation, informing the CNS about body movements and postural oscillations.[7]

The CNS receives messages from the afferents, which it processes.[7] It then orders the effectors to perform various actions to maintain or adapt a posture, balance or walking by inducing, through the pyramidal and extrapyramidal pathways, motor reflexes stabilizing the gaze (visio-oculomotor and vestibulo-oculomotor reflexes) and posture (vestibulospinal reflexes). In addition to these reflexes, there are voluntary cognitive responses that allow the body to be sheathed and stabilized in a normal position.[6,9] Each part of the CNS has a specific role within this organization (Table 1).

The effectors are the third element of the system, comprising the muscles and skeleton (including the joints). They receive instructions from the CNS by the nerve impulse transiting through the somatic efferent pathways.[6]

The integrity of afferents, the CNS and effectors, essential for the precise and fine organization of BG, can decline with aging and be affected more or less severely by various pathological conditions.

## Aging of Balance and Gait Functions

Even in the absence of associated pathologies, aging can have a negative impact on BG. Although the functional reserve diminishes, the threshold of insufficiency is never reached by aging alone.[3]

### Afferent Nervous System Aging

With age, proprioceptive acuity decreases. Muscle spindles and joint mechanoreceptors, particularly Pacinian corpuscles, show marked reductions in density and conduction speed. Quantitative histological studies report that the number of Pacinian corpuscles may decrease by more than 30% at age 80, whereas the reduction of Ruffini endings is limited to approximately 10–15%.[9] This relatively good preservation may explain why some low-threshold tactile feedback is maintained in advanced age, although integration at the cortical level remains impaired.[10] Similar age-related degradation is observed in other proprioceptors, such as Golgi tendon organs located in the musculotendinous junction and sensitive to muscle contractions, and which show an estimated 30% decline in sensitivity. These organs are also found in muscle spindles, which are sensitive to muscle lengthening and exhibit a reduction of up to 30% in stretch reflex response with aging.[9] Cutaneous receptors also exhibit a measurable decrease in both the size and functional efficiency of Pacinian and Meissner corpuscles over time, while Ruffini endings are less affected. These alterations degrade afferent encoding, resulting in delayed, low-amplitude or noisy sensory nerve signals, which become increasingly insufficient for accurate postural regulation in complex environments.[11]


https://doi.org/10.2147/CIA.S531235

Even without a vestibular condition, aging leads to a progressive loss of vestibular function. Vestibular hair cells are reduced by 20% to 40% after age 70, and there is a decrease in the number of nerve fibers and a decline in vestibular reflex efficiency.[11,12] These changes impair the ability to stabilize the body during head movements or postural transitions.

In addition to presbyopia, aging induces anatomical and functional changes in the retina and visual pathways, increasing susceptibility to age-related eye diseases. Cataracts affect more than 70% of individuals over 75, while age-related macular degeneration affects 11–13% and glaucoma 7%.[11] These conditions contribute to impaired visual acuity and field, damaged motion perception, reduced accommodation capacity, and decreased contrast sensitivity.[5,6,13,14] Half of OAs experience decreased contrast sensitivity, which doubles the risk of recurring falls.[15] These visual deficits interfere with anticipatory adjustments, obstacle detection, spatial navigation, and the CNS's integration of body movement and postural sway, thereby promoting balance disorders.

## Aging of the Central Nervous System

With age, the CNS undergoes structural and functional changes that profoundly affect postural control and gait regulation. Neuroimaging studies have shown progressive brain atrophy, particularly in the prefrontal cortex, basal ganglia, cerebellum and supplementary motor areas, which are all essential for motor planning, sensorimotor integration and postural adaptation.[11] White matter hyperintensity, observed in up to 90% of OAs, impairs the transmission of signals between motor and sensory regions, contributing to slower reaction times and less efficient balance correction strategies.[16] Functionally, aging leads to reduced neural plasticity, decreased motor unit recruitment and less automatic gait control, resulting in a higher reliance on attentional and executive resources for walking.[17] This contributes to the "cognitive-motor interference" phenomenon, in which OAs exhibit disproportionate gait slowing or instability during dual-task conditions.[11] In addition, there is evidence of impaired central sensory integration, with the CNS showing decreased ability to reweight sensory input in response to changing environmental demands.[9] This reduced adaptability contributes to increased postural sway, delayed compensatory steps, and decreased ability to recover from perturbations.[6]

## Impact of Aging on Effectors

Changes in muscle quality, including increased fat and decreased myocytes, associated with sarcopenia, all worsened by aging, are harmful for BG, especially as they can be exacerbated by a sedentary lifestyle and malnutrition.[18] Osteoporosis, which increases in prevalence with age, exerts an indirect impact on BG primarily through structural and neuromuscular mechanisms. Vertebral compression fractures and associated hyperkyphosis are associated with a doubled RoF in OAs [odds ratio (OR)=2.1].[19] These postural alterations shift the body's center of mass forward and limit joint range, impairing anticipatory and reactive postural responses. Controlled trials show that women with osteoporosis-related kyphosis exhibit significantly greater mediolateral sway, reduced anteroposterior displacement, and slower gait velocities compared to controls.[20] Furthermore, osteoporosis frequently coexists with sarcopenia ("osteosarcopenia") which amplifies deficits in muscle strength and balance. Osteosarcopenic OAs have a 1.5 fold increased the RoF and fractures compared to those without.[21] Muscle weakness associated with sarcopenia compromises postural stability and corrective muscle responses, particularly after destabilization. Lastly, fear of falling and concern over possible fractures often lead to reduced physical activity, resulting in deconditioning and reduced functional reserve, which further impairs gait and balance.[10,22]

# Causes of Balance and Gait Disorders in Older Adults

BGDs reflect a dysfunction in the postural and motor regulation system secondary to certain pathological conditions, which have more pronounced effects in aging organisms. The main causes of BGDs are:

- Neurological pathologies that may be:
  - Central: Stroke can lead to postural asymmetry, ataxia, and executive dysfunction, all of which limit adaptive responses. Alzheimer's disease and related disorders cause executive, attentional, and visuospatial deficits, impairing navigation and postural anticipation. Cerebellar syndromes disrupt motor coordination and gait

regularity. Normal-pressure hydrocephalus typically results in a magnetic gait, reduced postural adjustments, and frontal lobe dysfunction. Parkinsonian syndromes interfere with movement and postural adjustments through akinesia, axial rigidity, and delayed motor responses.[1,6,23–26]

  - Or peripheral: The leading cause is diabetes, which induces a length-dependent sensory neuropathy that impairs plantar proprioception and delays postural corrections. Amyloidosis can cause a severe mixed axonal neuropathy, often with autonomic involvement. Both hypothyroidism and hyperthyroidism are associated with sensory or sensorimotor neuropathies through metabolic or immune-mediated mechanisms. Osteomalacia, particularly when related to severe vitamin D deficiency, leads to proximal muscle weakness and pain, impairing motor control. Deficiencies in vitamins $B_1$, $B_6$, or $B_{12}$ can cause painful or proprioceptive sensory neuropathies, altering gait. Chronic exposure to alcohol or toxins (lead, solvents) is also implicated. Finally, lumbar stenosis causes neurogenic claudication, intermittent leg weakness and sensory loss, worsened by walking and relieved by rest.[27–33]

- (Neuro)muscular disorders, including myopathies and myositis, may result from dysthyroidism, osteomalacia or medication use.[29,30,32–34] These conditions typically degrade gait through proximal weakness, reduced endurance, and impaired postural control. Malnutrition contributes to muscle wasting and worsens sarcopenia. Myasthenia gravis affects gait through muscle fatigability, while polymyalgia rheumatica causes pain, stiffness and fatigue in the pelvic girdle, limiting walking capacity.[35,36]

- Osteoarticular pathologies, including osteoarthritis, kyphosis, laxity of the lower limbs, osteoporosis, stiffness of the ankles or deformation of the feet (hallux valgus, hallux rigidus, claw toe, quintus varus, rheumatoid arthritis), degrade proprioception and cause chronic pain altering postural adaptation reflexes and modifying motor patterns.[1,6,22]
- Eye pathologies including cataracts, age-related macular degeneration or glaucoma (promoted by aging), particularly when there is a decrease in visual acuity and field.[14]
- Vestibular disorders such as toxic vestibular neuritis, Meniere's disease or benign paroxysmal positional vertigo.[23,37]
- Cardiovascular pathologies, which promote a decrease in cerebral blood flow with or without discomfort, including arterial hypotension, particularly orthostatic hypotension (OH), cardiac arrhythmia, conduction disorders, sequelae of myocardial infarction or pulmonary embolism.[1,6,38]
- Deconditioning due to reduced physical activity may be secondary to various pathological conditions including depression, malnutrition, thyroid dysfunction, heart failure, respiratory failure and anemia.[1,6]
- Drugs that cause 1) low cerebral blood flow due to hypotension, bradycardia or cardiac rhythm disturbances, including antihypertensives, psychotropic medications, antiarrhythmics, acetylcholinesterase inhibitors or memantine,[38–40] 2) hypovigilance, including psychotropic medications,[38] or 3) neuropathies or (neuro)muscular disorders, including corticosteroids, chloroquine/hydroxychloroquine, cimetidine, fibrates, statins, colchicine, D-penicillamine, certain antibiotics, beta-blockers, cyclosporine, certain anticonvulsants, certain chemotherapies or other molecules.[30,34]
- Toxins, including from alcohol use disorders.[30]

In OAs with motoric cognitive risk syndrome, although there are no objective cognitive or BG disorders, except gait speed decrease, there is an increased RoF.[41]

## Assessment of Balance and Gait Disorders

BGDs affect independence and are associated with RoF, and the physical, psychological and social consequences of these disorders can have a functional or even vital effect. While BGDs can be relatively easy to diagnose thanks to the physical examination, the etiological diagnosis is more complex and requires a careful investigation including questioning the patient, a meticulous clinical examination, and relevant paraclinical examinations.

## Detailed Interview

The anamnesis of OAs with BGDs and their close entourage aims to reconstruct as best as possible the chronology of events by specifying potential triggering factor(s) (illness, medication, stress, etc) and the context, which is often neglected but can make a valuable contribution. In addition to the age and onset (sudden or progressive) of the disorders, the personal and family history, especially neurological, osteoarticular, cardiovascular, ophthalmological, otolaryngological and BG, will be collected. The review of medications must be thorough, including treatments consumed through self-medication and any recent changes. Particular attention should be paid to well-recognized fall-risk–increasing drugs (FRIDs), such as benzodiazepines, antipsychotics, antidepressants, opioids, anticholinergics, antiepileptics, diuretics, alpha-blockers, and beta-blockers. These drugs may contribute to falls by inducing sedation, OH, balance disorders, slowed reaction time, and cognitive dysfunction.[16,42,43] The use of at least one FRIDs has been shown to increase the incidence of falls by 13%, and by up to 22–33% for individuals taking multiple FRIDs.[43] Several tools are available to assist clinicians in identifying potentially inappropriate medications, such as the STOPP/START criteria, the Beers criteria, or the REMEDI[e]S list.[44–46] An history of falls (number and circumstances over the past 12 months) should be systematically obtained.[47] Particular attention should be paid to so-called "near-falls", defined as a loss of balance that does not result in a fall, which are increasingly recognized as strong predictors of future injurious falls. They often reflect declining postural reserves and subclinical gait impairment. Identifying near-falls allows for early detection of instability and therefore prevention of full-blown falls. The individual will be asked about their ability to rise from the floor. The interview will investigate the symptoms associated with BGDs, such as feelings of dizziness, nausea, lower limb weakness or postural instability.[11] Footwear should be examined, as inappropriate/worn shoes may contribute to instability.[15] In addition, an assessment of cognitive state and mood is crucial to detect even subtle depressive symptoms or cognitive impairment, which may exacerbate gait or balance difficulties.[41] Broader functional status should be evaluated using activities of daily living (ADLs) and instrumental ADLs (IADLs). The use of a walking aid (cane, walker) or fall monitoring (alarm system, connected watch, videosurveillance) should be recorded,[48] as should the presence of family/caregivers.[47]

## Clinical Exam

The clinical examination is essential and should be as exhaustive as possible, emphasizing certain aspects described in Table 2.

**Table 2** Clinical Examination of Older Adult with Balance and/or Gait Disorders

| System Examined | What to Look For? | Examinations or Tests to Perform During Clinical Investigation |
|---|---|---|
| **Cardiovascular** | – Cardiac arrhythmia<br>– Conduction disorders<br>– OH | – ECG<br>– OH test: after 10 min of bed rest, measure blood pressure in the supine position and then in the standing position at 1 min and 3 min. Measure heart rate at the same time. |
| **Neurological** | – Pyramidal signs<br>– Extrapyramidal signs<br>– Cerebellar signs<br>– Sensitivity disorders<br>– Sensory disorders or motor deficits: hemiparesis, mowing, stepping, etc.<br>– Other disorders: lameness, ataxia, astasia, abasia, etc. | |
| **Ear-nose-throat** | – Tinnitus<br>– Deafness<br>– Nystagmus | Romberg sign[49] |

(*Continued*)

**Table 2** (Continued).

| System Examined | What to Look For? | Examinations or Tests to Perform During Clinical Investigation |
|---|---|---|
| **Ocular** | – Visual acuity<br>– Visual field<br>– Ocular motility | |
| **Musculoskeletal and articular** | – Sarcopenia<br>– Dorsal and lumbar statics<br>– Knee stability<br>– Ankle flexion<br>– Morphology and motor skills of the feet | Measuring grip strength (hand) with a dynamometer |

**Abbreviations**: OH, orthostatic hypotension; ECG, electrocardiogram; min, minute(s).

According to the results of the interview and clinical examination, additional paraclinical examinations may be relevant, including imaging. In case of a fall accompanied by prodromes, a cardiac cause (rhythm disorder, conduction disorder, etc) should be ruled out first with an electrocardiogram (ECG), supplemented by a Holter ECG (≥24 hours). An OH test can then be performed, OH being frequent and the cause of repeated falls. Repeated falls with abnormal movements or confusion indicate the need to perform an electroencephalogram to rule out epilepsy, which can be non-convulsive in OAs. A lesion of the CNS may also be suspected in case of confusion, requiring a brain computed tomography scan.

## Posture and Motor Skills Assessment

Numerous clinical tests have been developed to assess balance, gait, and RoF in OAs. These tools, presented in Table 3 and Table 4 (for the mini motor test (MMT)) differ in their clinical objectives, time constraints, and diagnostic value.[6,26,41,48–80]

## Emerging Technologies for Risk of Falling Assessment

Many technological tools have been developed to complement the clinical assessment of gait and balance disorders. These devices provide objective, reproducible, and sensitive measurements, capable of detecting subtle alterations in postural control or motor coordination that may be invisible during standard clinical evaluation.

- Surface electromyography (EMG) is used to analyze the timing and coordination of muscle group activation, particularly during anticipatory postural adjustments, gait initiation, and balance recovery strategies. Altered EMG patterns, such as delayed activation of ankle stabilizing muscles, have been observed in older adults compared to younger individuals, with average delays ranging from 30 to 120 ms depending on the muscle group involved.[81] However, its use in routine clinical practice appears of limited practical value.
- Force platforms, either static or dynamic, measure center-of-pressure (CoP) displacement. Metrics such as total path length (>400 mm) or CoP velocity are robust predictors of RoF: a longer path length is associated with a 75% increase in the RoF, with an 8% rise per additional 10 mm.[82] More recently, Liang et al demonstrated that combining CoP data with machine learning algorithms allows RoF classification based on the timed-up and go (TUG) test with an accuracy of 80–90% in older adults.[83] However, predictive models remain difficult to generalize due to heterogeneous testing protocols.[82]
- Three-dimensional motion capture systems (eg, Vicon®) provide precise spatiotemporal and kinematic gait parameters under a variety of conditions. In a 2025 study involving 18 older adults, Vicon analysis showed that obstacle crossing significantly reduced gait speed (+15%) and increased head motion (+20%), negatively affecting postural stability.[84] Visual search tasks were also shown to reduce speed, shorten step length (–8%), and decrease hip extension.[84] These technologies can identify some of the fine markers of RoF that often elude traditional clinical examination.

https://doi.org/10.2147/CIA.S531235


**Table 3** Tests That Can Be Used to Assess Balance and Gait in Older Adults

| Test | Background/Support | Description/What is Assessed? | Interpretation | Other Benefits | Runtime | Key Strengths | Observations | Limits |
|---|---|---|---|---|---|---|---|---|
| Standing position | Everyday situation<br>Essential for functional independence | It provides key clinical information on:<br>– PC and compensatory mechanisms such as knee flexion,<br>– trunk, knees and head alignment with detection of BD, frequently observed in frail OAs and in over 40% of Parkinsonian syndrome patients.[26]<br>– body sway amplitude | The test is abnormal if there is an immediate RoF when the OA tries to maintain a standing position without human or material assistance. | | < 1 min | Very fast and simple to execute.<br>It can detect signs that often precede overt instability or falls, hence its value in geriatrics. | Knee flexion, adopted by a number of OAs with BD, is a common compensatory strategy to stabilize the center of gravity when PC is impaired.[6] This adaptation may reflect loss of strength, impaired verticality perception, or an early sign of PC degradation.<br>A subtle posterior sway in quiet standing is associated with a 2- to 3-fold increase in the RoF in institutionalized OAs.[50] | Need to be able to stand. |
| Five times sit-to-stand test[49,51] | Everyday situation | It evaluates the:<br>– time required to perform the sit-to-stand and back-to-sit transitions five times.<br>– ability to rise from a chair repeatedly without using the arms.<br>– lower-limb strength<br>– dynamic balance | Several abnormality thresholds have been established. A score:<br>– > 12 sec is associated with an increased RoF in OAs.[52]<br>– > 23.8 sec induces a RoF within 6 months in OAs.[53]<br>– > 15 sec is associated with a risk of recurrent falls.[54] | Predictive of the RoF and sarcopenia. | < 1 min | Fast and simple to execute.<br>No specific equipment is required One of the most widely used functional tests in clinical practice.<br>Recommended by the EWGSOP2 in the screening process for sarcopenia. | | Being able to stand up and sit down again without using your arms |
| Anticipatory postural adjustments[55]<br>Pull test[56] | Assess the ability to adapt to impromptu situations requiring balance. | Anticipatory postural adjustments include:[55]<br>– Several reactive postural responses: automatic corrective movements triggered by unexpected perturbations, involving ankle or hip strategies, or compensatory stepping (this corresponds to the Pull test)<br>– and protective reactions, 3 protective reactions: 1 of the upper limbs (arm opposition in the event of an imbalance caused by an obstacle), and 2 of the lower limbs in front (moving the upper limbs forward to protect the body in the event of a forward fall to the ground) and back (in the event of a backward fall). | The ineffectiveness of reactive postural responses exposes to a RoF, while that of protective reactions exposes to a risk of serious injury in the event of a fall. | | A few min | Fast and simple to execute.<br><br>The Pull test is a simple yet robust tool. | They are assessed in the MMT.[55]<br>The Pull test is particularly effective in detecting early postural instability in neurodegenerative diseases (progressive supranuclear palsy, Parkinson's disease, etc), in which BD can appear as an early and predictive sign. Additionally, modern sensor-based systems allow for the precise quantification of stepping latency and BD angle, improving measurement reliability and enabling more objective assessment.[56] | Need to be able to stand.<br>Increased RoF. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| One-leg stance test[57] | It is part of walking which includes, among other things, a series of one-leg supports. | Evaluation of static postural stability. | Abnormal when standing on one leg lasts < 5 sec. | | < 1 min | Very fast and simple to execute. | Observes also postural quality including trunk sway, tremor, or compensatory movements of the upper limbs, for the early detection of balance control deficits.<br>Each additional sec. of single-leg stance is associated with a 5% reduction in the RoF. Each centimeter of displacement during mediolateral sway increases RoF by 1.5.[58] | Being able to stand on one leg.<br>Increased RoF |
| Gait speed[57] | A reduced gait speed is an important predictor of disability. | Measures speed when walking in a straight line for 10, 6 or 4 meters.[59] | Abnormal when gait speed is < 1 m/sec. | | < 1 min | Fast and very simple to execute. | A gait speed between 0.65 and 1 m/s indicates postural or motor frailty.<br>A gait speed below 0.65 m/s is an overall frailty marker and is associated with a high risk of hospitalisation.<br>The threshold of 1.0 ms-1 has been used to predict mortality. However, that of 0.8 ms-1 would be more relevant and more frequently used to predict adverse health effects.[59]<br>OAs with slower gait are at higher risk for cognitive or functional decline (including falls), institutionalization and mortality.[59] | |
| Rise from the floor test[60,61] | Biomechanically and functionally demanding task. | It assesses/analyses the:<br>– ability to perform the task independently,<br>– time required for execution<br>– compensatory strategies used, hesitation or instability | The most important thing is to be able to rise from the floor, no matter how long it takes (1, 5, 10, 15 or 20 minutes). | It provides key information on lower limb strength, motor planning, functional independence, and RoF. | < 5 min | | The inability to rise independently from the floor is associated with a significant increase of the risk of serious fall.<br>Community-dwelling women > 75 unable to get up with assistance after a fall had an OR=2.1 for serious injuries and an OR=3.7 for fracture.[61] | Test may require several changes of position on the floor and is therefore complex to perform. |
| Timed-up and go test[62] | Everyday situation | Analysis of the mobility related to an individual's functional capacity, including lower limb muscle strength, aerobic capacity and walking endurance.<br>Evaluation of the RoF. | A duration ≥ 12 sec is commonly accepted the RoF threshold. However, this must be nuanced. | | < 1 min | | A time ≥12.6 sec is associated with a fourfold increase in RoF [OR=3.94], and each additional sec increases the risk by 9%.[63] | Being able to stand up and sit down again. |
| Dual-task test[64,65] | It highlights the competition for attentional resources between 2 tasks, revealing vulnerabilities not observed in a single-task.<br>The additional task impairs execution of the main task. | Balance and gait assessment<br>The main task is static standing or gait, while the interfering task is often cognitive. | Appearance of balance or gait disorders when adding a cognitive task | In addition to fall prediction, dual-task including gait is increasingly used to early identify executive dysfunction, frontal gait disorders or incipient neurodegenerative disorders such as motoric cognitive risk syndrome.[41] | < 5 min | Valuable tool in the functional assessment of OA whose gait appears normal under standard conditions. | Impaired dual-task performance, reflected by reduced gait speed or increased gait variability, is associated with high risk of future falls, particularly in cognitively frail OAs. | |

(*Continued*)

https://doi.org/10.2147/CIA.S531235

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**Table 3** (Continued).

| Test | Background/Support | Description/What is Assessed? | Interpretation | Other Benefits | Runtime | Key Strengths | Observations | Limits |
|---|---|---|---|---|---|---|---|---|
| MMT[55,66] | Developed to evaluate the psychomotor disadaptation syndrome.<br>It provides a comprehensive overview of motor adaptability and balance responses.<br>It includes a set of situations to which an OA may be exposed. | 20 items including 5 simple tasks evaluating postural transitions, anticipatory postural adjustments and reactive/protective responses. | A score < 17/20 is abnormal | Beyond screening, MMT also allows the monitoring progress in rehabilitation, by repeated posturo-motor assessments. Addressing the essential components of balance and PC, MMT is also useful in guiding targeted interventions. | < 15 min | | It includes the assessment of certain tasks not assessed in any other test, although they are daily including the ability to turn over in bed or on a clinical examination table and to move from a lying to a sitting position. In addition, the history of falls over the last 6 months is mentioned. | Quite long and can be tedious. |
| Performance Oriented Mobility Assessment or Tinetti test[67] | It includes a set of tasks that can be used daily. | Assessment of static and dynamic balance, and gait while sitting, sit-stand transition, standing, and walking.<br>2 versions depending on the number of items: the initial one with 16 items (score from 0 to 28) and the simplified one with 7 items (score from 0 to 7). | A score < 25 (out of 28) is considered to be with RoF.[68] | | 5 to 20 min depending on the version | | Tinetti test has a 69.5% sensitivity and 89.8% specificity in identifying OAs with prior falls.[69]<br>A cutoff score of ≤19 (/28) is associated with a 68% sensitivity and 88% specificity for predicting the risk of future falls.[70]<br>Tinetti test is mainly used in rehabilitation by physiotherapists. | More or less long depending on the version and can be tedious. |
| Short physical performance battery[71] | The 3 tests that constitute it include everyday life situations | A brief, standardized and widely validated tool combining the assessment of balance in 3 different foot poses, a 4-m gait speed and lower limb strength during 5 repetitions of sit-to-stand.<br>Scored from 0 to 12.<br>RoF assessment. | A score ≤ 9 is associated with a significant increase in RoF.[48,49] | Considered a core tool for sarcopenia screening and frailty evaluation.[49] | 5 min | Its predictive validity is robust.[49] | Recommended in major clinical guidelines for the RoF assessment.[49] | This tool is more or less complex due to the combination of 3 tests. |
| Berg balance scale[72,73] | It integrates 14 daily living tasks. | It assesses static and dynamic balance evaluated through 14 tests rated from 0 to 4. | A score (out of 56):<br>– ≥ 41 corresponds to a low RoF and independent walking<br>– of 21 to 40 is associated with a moderate RoF and the need for walking aid,<br>– ≤ 20 reflects a high RoF and the need to use a wheelchair | | 10 to 15 min | | Its sensitivity, of 53%, is relatively low to identify OAs at RoF.[74] | This tool is more or less complex due to the combination of 3 tests.<br>Quite long. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Perception of postural vertical[75] | Postural vertical perception comes from the somatosensory graviceptive information delivered by the proprioceptive and cutaneous pressure mechanoreceptors, as well as by the perirenal visceral graviceptors and around the large vessels.[75] An individual's sense of verticality is their ability to explicitly perceive the direction of the vertical, to develop a mental representation of verticality and to use this representation to orient themselves or a part of their spatial environment.[78] | To measure postural vertical, the individual sits on a chair, in complete safety. In order to determine the postural vertical, the wheel is inclined in the sagittal plane to a defined angle of which the subject is not aware. It is then brought back in the opposite direction until the individual indicates having reached the postural vertical.[76] | The normal value of the angle (after 50 years), varying around 0°, is between −3.95° and 1.65°.[77] | | 10 min | | Needs a mechanical device consisting of a seat fixed in a wheel. The alteration of postural vertical perception in the sagittal plane is associated with BD.[76] | Fairly long preparation phase. |
| FRT[79] | When leaning forward, in a standing position, the center of mass can be moved safely without changing the base of support, up to a certain limit depending on each individual. | During FRT, the individual stands up along a wall, arms extended forward, and advances his/her trunk as far as possible away from the wall without losing balance. FRT assesses the balance and the limits of anteroposterior stability of an individual during a pointing task, while reaching forward in a standing position. | A forward displacement of < 25.4 cm puts individuals over 70 years to a risk of recurrent falls.[79] A forward displacement of < 17.78 cm is a physical frailty marker.[80] | | < 1 min | FRT implicates several joints, including the ankle, knee, hip, and trunk, all involved in performing daily tasks. | | Increased RoF. |

**Abbreviations**: PC, postural control; BD, backward disequilibrium; ROF, risk of falling; OA, older adult; sec, seconds; MMT, mini motor test; min, minutes; EWGSOP2, European Working Group on Sarcopenia in Older People 2; FRT, functional reach test.

https://doi.org/10.2147/CIA.S531235

**Table 4** The Mini Motor Test

| Score Each Item 1 If the Answer is "Yes" or 0 if the Answer is "No" | | | |
|---|---|---|---|
| | **Item** | | **Score** |
| **In bed** | Able to roll onto one side | | |
| | Able to rise from lying to sitting position | | |
| **The sitting position** | No retropulsion of the trunk | | |
| | Able to bend trunk forward | | |
| | Able to rise from a chair | | |
| **The standing position** | Possible | | |
| | Without assistance (material or human) | | |
| | Able to stand on two legs with closed eyes | | |
| | Able to stand on one leg | | |
| | No backward disequilibrium | | |
| | Reactive postural responses | | |
| | Protective reactions | Protective reactions of upper limbs | |
| | | Stepping reactions forwards | |
| | | Stepping reactions backwards | |
| **Gait** | Possible | | |
| | Without assistance (material or human) | | |
| | Normal heelstrike | | |
| | No knee flexion | | |
| | No backward disequilibrium | | |
| | Harmonious turn round | | |
| **TOTAL … / 20** | | | |
| **For the two questions below answer yes or no** | | | |
| Has the patient had one or more falls in the previous six months? | | | |
| Is it possible to rise from the floor? | | | |

- Wearable sensors (inertial measurement units, accelerometers, gyroscopes, or portable equivalents of Vicon®) can now be integrated into accessible devices such as smartphones and smartwatches. These systems provide objective gait data under real-life and extended conditions. One study showed that a single IMU sensor worn for one minute of walking could predict RoF with an accuracy of 81.6% in older adults.[85] Smartphone-integrated systems also demonstrated good correlation with clinical reference standards for gait speed, stride regularity, and postural transitions.[86] These tools enable remote, autonomous, and repeated assessments over time, helping to monitor subtle motor changes and support early intervention.

Although not yet widely adopted in routine geriatric practice, these tools are a major advance in the early detection of RoF, long-term monitoring, and personalized rehabilitation.

 https://doi.org/10.2147/CIA.S531235 

## Management of Balance and Gait Disorders in Older Adults

The management of BGDs in OAs requires a coordinated multidisciplinary approach involving physicians, nurses, physiotherapists, occupational therapists, psychomotor therapists, and psychologists. Physicians evaluate underlying medical causes, prescribe appropriate interventions, and coordinate care programs. Nurses and nursing assistants contribute to clinical monitoring (including treatment) and daily support of OAs, as well as the prevention of risks related to BGDs (including patient education). Physiotherapists lead physical exercises and train gait, posture and balance. Occupational therapists assess functional capacities and adapt the home environment. Psychomotor therapists work on coordination, body schema, and movement safety. Psychologists are involved in the management of associated cognitive disorders and post-fall anxiety. This integrated model is built on targeted, evidence-based, and personalized strategies adapted to the patient's needs and capacities.[47] The key message here is the importance of multifactorial interventions, as no isolated approach has proven effective in preventing falls and their consequences.[47]

Important aspects of management are:

- Medication review and deprescribing: reducing FRIDs is a priority. A structured deprescribing approach has been shown to reduce RoF by 14% when included in a comprehensive management program.[11,16] A collaborative process involving the patient, pharmacist, general practitioner, and geriatrician improves adherence: a recent study reported, for the first time, a 3-month maintenance rate of 86% for treatment changes following a joint discussion.[87]
- Physical exercise remains the most effective intervention for preventing falls. A meta-analysis reports a 20% relative reduction in falls (RR = 0.80) with programs combining muscle strengthening, balance training, and gait practice. The Otago Exercise Programme and Falls Management Exercise are the two commonly used validated models.[88,89] The first is an individualized, home-based program led by a physiotherapist. The programme includes lower-limb strengthening, balance exercises, and active walking. It starts with an initial session and continues with monthly follow-up over 12 months. The second is a group-based program conducted in a dedicated setting, supervised by trained professionals. It focuses on progressive strengthening, dynamic balance, anticipatory postural reactions, and fall prevention strategies. An adapted physical activity professional may also be involved in delivering these sessions. These programs show optimal effectiveness at two to three sessions per week for at least six months, provided participants have sufficient physical and cognitive capacity.[11,15]
- Gait rehabilitation and targeted physiotherapy: physiotherapists play a central role in motor rehabilitation. However, isolated interventions focusing solely on gait retraining, posture or strength when not part of a structured and comprehensive program have not demonstrated significant benefit: the difference in fall rates is less than 5% compared to no intervention in trials included in current recommendations.[15,47]
- Sensory assessment: sensory deficits, particularly reduced visual acuity and age-related hearing loss (presbycusis), are frequently involved in the onset of falls in OAs. Systematic screening is essential, especially in cases of disorientation, complaints of instability, or unexplained falls. However, isolated interventions such as prescribing new glasses or cataract surgery have not shown significant benefit in reducing falls, and in some cases (eg, rapid and major changes in visual correction), may even temporarily worsen postural instability.[11,15] With regard to hearing, presbycusis is associated with increased RoF and cognitive decline risk. Uncorrected hearing loss nearly doubles RoF, and exacerbates social isolation and cognitive impairment.[90] Hearing aids may help to prevent functional decline and falls, provided the process is gradual, supported, and adapted to cognitive abilities. Their benefit is limited in longstanding or severe cases due to cochlear cell atrophy and a threshold beyond which recovery is no longer possible.
- Occupational therapy and home environment adaptation: assessing the home environment including stairs, lighting, obstacles, bedroom, toilet and bathroom allows for personalized fall prevention strategies. Although the effectiveness of environmental modifications alone is difficult to quantify, their value is widely acknowledged in secondary prevention, particularly after the first fall. Simple and low-cost interventions such as installing grab bars, removing rugs, or improving lighting are strongly recommended.[9]

 https://doi.org/10.2147/CIA.S531235 

- Assistive technologies: they play an increasingly important role in fall prevention, particularly among OAs living at home. Conventional tools such as canes, walkers, grab bars, and orthopedic footwear help improve stability and confidence during daily movement. Their effectiveness depends on appropriate indication, proper adjustment, and supervised use. In parallel, embedded technologies have rapidly evolved. Automated alert systems (eg, bracelets or pendants that detect prolonged inactivity or falls), smart mats, and motion sensors allow for early fall detection and reduce response time, thereby improving functional outcomes. Devices such as smartwatches now integrate accelerometers and gyroscopes capable of analyzing gait patterns, assessing stability, and even anticipating imbalance. Further innovations include instrumented insoles, smart clothing, and intelligent hearing devices with alert and geolocation features. While most of these technologies are well accepted by patients, their clinical effectiveness in reducing falls has yet to be confirmed in large-scale randomized trials. Nonetheless, they already offer undeniable added value in terms of perceived safety, autonomy, and home-based aging.[91] These devices are also a means of implementing personalized digital monitoring of RoF, opening the prospect of predictive fall medicine combining biometric sensors, artificial intelligence, and adaptive rehabilitation programs. Virtual reality is an emerging rehabilitation tool, enabling users to perform or simulate motor tasks in a fully virtual environment. It can be used to analyze motor behavior and brain activity in a safe and controlled setting. While a habituation stage is essential due to the disorienting effects of immersive environments, several studies report significant benefits for balance and RoF and less dizziness, as measured by the one-leg stance test, TUG, Tinetti test, Berg balance scale, and functional reach test (FRT).[24,92,93]

## Conclusion

BGDs are common in frail OAs and considering the increase in life expectancy thanks to medical progress and improved hygiene conditions, their prevalence will continue to rise. Once fatal medical situations can now be stabilized, leading to chronic conditions. It is thus necessary for health professionals managing OAs to fully understand BGDs, to thoroughly analyze each situation, and tailor care.

After interviewing to gather the OA's history, including any previous falls, a medication inventory, in particular FRIDs, and the analysis of the home environment, a thorough clinical examination, possibly supplemented by para-clinical examinations, should be performed. These first steps are needed to obtain a clear picture of the situation and identify potential causes of BGDs. For example, a clinical suspicion of cardiac arrhythmia or conduction disorders requires an ECG or a Holter ECG. A suspicion of OH during interview will be confirmed by the OH test. In case of confusion, a lesion of the CNS may be suspected, requiring a brain computed tomography scan, or epilepsy, which must be confirmed by an electroencephalogram.

Among the many validated tools for assessing BGDs in OAs, some are easy and quick to administer (standing position, Five times sit-to-stand test, One-leg stance test, Gait speed, TUG, Dual-task test), while others are more complex and informative but take longer to complete (MMT, Tinetti test, Berg balance scale). All these tests involve tasks related to the daily activities necessary to preserve independent living. Emerging technologies such as surface electromyography, force platforms, and three-dimensional motion capture systems, although not yet used in routine geriatric practice, have considerably improved the early detection of RoF, monitoring, and rehabilitation of older adults with BGDs.

Regarding the management of BGDs, classic and validated and proven approaches such as motor rehabilitation must be associated with new technologies such as virtual reality. Automated alert systems such as fall detector bracelets or video surveillance can also be used.

Overall, the objective is to prevent falls and to limit or ideally avoid the loss of independence in OAs.

## Abbreviations

ADLs, activities of daily living; BG, balance and gait; BGDs, balance and gait disorders, CNS, central nervous system; FRT, functional reach test; IADLs, instrumental activities of daily living; MMT, mini motor test; OA, older adult; OH, orthostatic hypotension; OR, odds ratio; RoF, risk of falling; SPPB, short physical performance battery; TUG, timed-up and go test.

## Acknowledgments

The authors are grateful to Mrs. Suzanne RANKIN, a native English speaker, for editing and proofreading this article.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

## Funding

There is no funding to report.

## Disclosure

The authors report no conflicts of interest in this work.

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