

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Postural Imbalance in the Elderly: Main Aspects

*Natália Moya Rodrigues Pereira
and Marcos Eduardo Scheicher*

Abstract

The aging of the population is an unprecedented world phenomenon. Numerous physiological changes occur with aging, and one of the most common situations is postural imbalance and, consequently, the occurrence of falls. Balancing is the process of controlling the body's center of mass with respect to its base of support and depends on the integration of sensory systems (visual, vestibular, and somato-sensory) with the central nervous system (CNS). Each system is prone to deterioration with advancing age and is influenced by age-related diseases and use of some types of medications and polypharmacy. As with any good clinical evaluation, a detailed history and a thorough physical examination are essential to evaluate postural balance. The evaluation of balance must be done with tests that are quick and with relatively little equipment and training. The improvement of postural balance can be done in many ways, and exercises are a type of this treatment and can be done with video games or a treadmill, for example.

Keywords: aging, postural balance, sensory systems

1. Aging of population

The aging of the population is an unprecedented world phenomenon. The projections of the World Health Organization indicate that by 2050, all ages will increase by 35%, people aged 65–84 will increase by 164%, older people aged 85–99 will increase by 301% and centenarians will grow by 746% [1].

Increasing longevity also contributes to an aging population. Globally, life expectancy at birth is projected to increase from 69 years in 2005–2010 to 76 years in 2045–2050 and to 82 years in 2095–2100 [1] (**Figures 1** and **2**).

Physiological changes are observed with aging, increasing the risks of developing chronic diseases and dependence care. Auditory, visual, and movement problems may be present in people 60 years or older. In addition, some conditions such as dementia, heart disease, stroke, respiratory disorders, diabetes, and musculoskeletal conditions (osteoarthritis and back pain) are more frequent in this age group [2].

One of the most common situations for the elderly is postural imbalance and, consequently, the occurrence of falls, representing a significant health problem in older adults. Each year, approximately 30% of community-dwelling older people

fall at least once and 10–20% fall twice or more [3]. The incidence among institutionalized older people is even higher, with a mean percentage of residents who fall each year of over 40% [4].

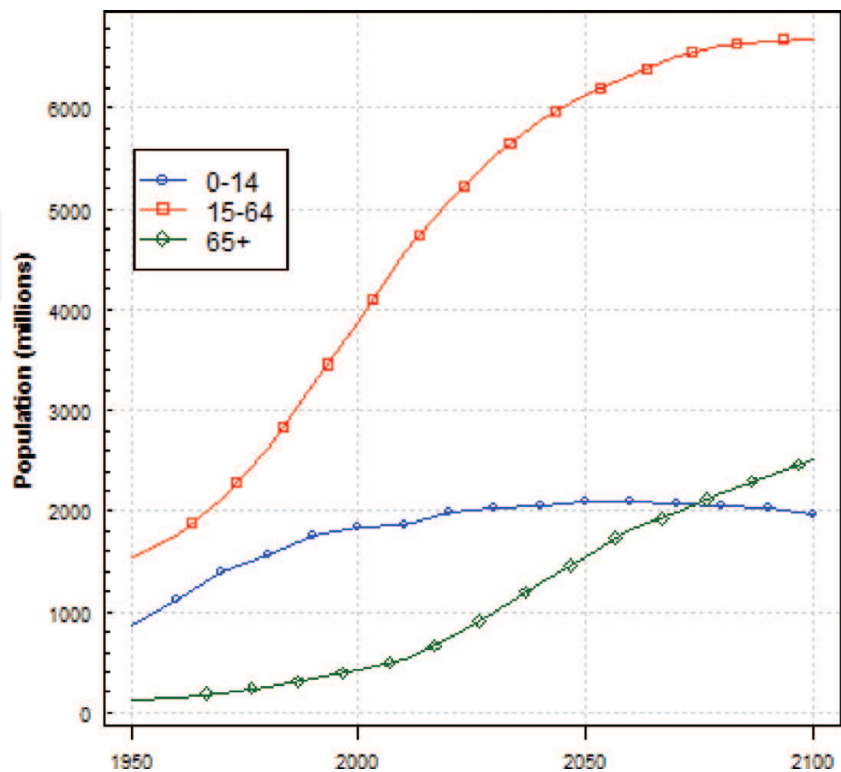


Figure 1.
Total population by broad age group. Courtesy: World Health Organization.

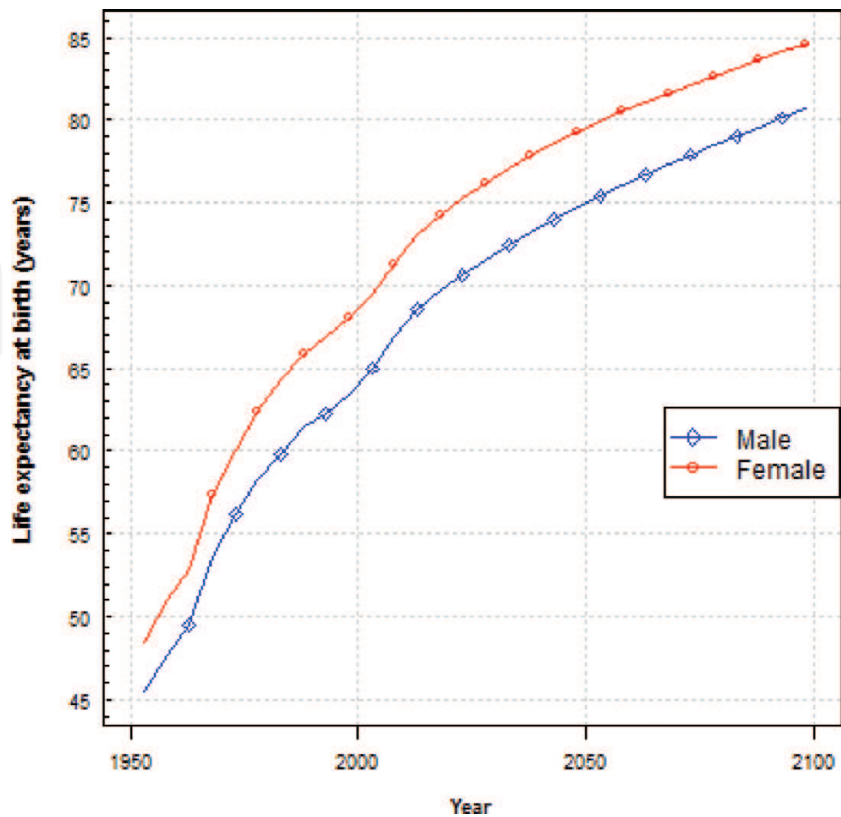


Figure 2.
Life expectancy at birth by sex. Courtesy: World Health Organization.

2. Postural balance

Balancing is the process of controlling the body's center of mass with respect to its base of support, whether in a static or dynamic situation. It depends on the integration of sensory systems with the CNS. Sensory information from somatosensory, visual, and vestibular systems must be integrated to interpret complex sensory environments. Each system interacts with each other to maintain balance in a closed loop, with an interrelation of cause and effect. When the sensory environment is changed, the CNS needs to re-weigh the contribution of each of the senses in postural balance. In an environment with good lighting and a firm surface, the contribution of somatosensory information is 70%, the visual information is 10%, and the vestibular information is 20% [5].

Each system is prone to deterioration with advancing age, and this is influenced by age-related diseases and use of some types of medications, in addition to polypharmacy [6]. Systems can partially compensate for each other's deterioration. Failing compensation strategies may eventually result in impaired balance, which may result in falls [7].

2.1 Vision and postural balance

The role of central and peripheral vision information in the control of movements and posture was examined in some studies [8, 9]. These authors suggested that peripheral vision is used for postural control and most particularly for stabilization of fore-aft sways, while the central vision is more often used for foot trajectory planning, targeting, obstacle avoidance, and stabilization of lateral sways.

Visual impairment is an important health problem and a major cause of injury in the elderly. Cataract, glaucoma, age-related macular degeneration, and diabetic retinopathy are the most common diseases related to the elderly and can interfere with the postural balance.

2.1.1 Cataract

Cataract, affecting mainly visual acuity and contrast sensitivity, contributes to about 50% of visual impairments in the elderly [10, 11]. The consequences include decreased ability to perform activities of daily living (such as reading, watching television, driving, and interacting socially), depression, increased number of falls, and increased mortality [10, 12]. The impact on patients is comparable with that of major systemic conditions including stroke, diabetes, and arthritis. In a study in patients with cataract, Pasma et al. found a higher proprioceptive weight compared with healthy elderly participants, which means that the elderly with cataract rely more on their proprioceptive information [7].

2.1.2 Glaucoma

Glaucoma is a progressive optic neuropathy characterized by degeneration of retinal ganglion cells and their axons with consequent vision loss and blindness. This condition leads to a characteristic reduction in the visual field (VF), with good central visual acuity. Previous studies have reported a higher risk of falling in patients with glaucoma compared to normal subjects [13–15]. In the study by Black et al., a cohort of glaucoma subjects was examined to assess body displacement of the trunk and the results showed that the worse the visual field defect, the greater the body sway [16].

2.1.3 Age-related macular degeneration

Age-related macular degeneration (AMD) is a disease that affects the macula (central vision), altering the accuracy of vision necessary for “direct” and fine activities, and may interfere with activities of daily living [17].

Wood et al. studied postural balance in older adults with AMD and showed that diminution of contrast sensitivity and visual field loss lead to postural instability and mobility difficulties in these patients [18]. Chatard et al., studying 10 elderly unilateral AMD subjects, 10 elderly bilateral AMD subjects, and 10 healthy age-matched control subjects, showed that bilateral AMD subjects had a surface area and an antero-posterior displacement of the CoP higher than healthy elderly. Unilateral AMD subjects had more antero-posterior displacement of the CoP than healthy elderly [19]. The authors conclude that because of aging, AMD subjects could have poor postural adaptive mechanisms which increase instability and risk of falls.

2.1.4 Diabetic retinopathy

Diabetic retinopathy (DR) is a common and potentially blinding microvascular complication of diabetes [20]. In a study, Gupta et al. found that diabetes per se was not a risk factor for falls. However, the authors found an association between diabetic patients with DR and risk of falling [20], suggesting a relation between DR and postural balance.

The greater tendency to fall in patients with mild-to-moderate DR can be explained by a reduction in the components of the visual function system, such as contrast, sensitivity, stereo acuity, and color perception [21, 22].

Figure 3 summarizes the normal vision and main eye disorders that can interfere with the postural balance described above.

Thus, it is important to evaluate visual function when we propose to work with postural balance in the elderly.

2.2 Vestibular system and postural balance

Through its sensory functions, the vestibular system detects the position and movement of the head in space relative to gravity, and helps to stabilize vision and balance [23].

The vestibular system has structures similar to miniaturized accelerometers, which report continuous information to the cerebral cortex, cerebellum, and somatic sensory cortices on the movements and position of the head and body. The vestibular nuclei make connections with structures of the brainstem and cerebellum and also innervate the motor neurons that control extraocular, cervical, and postural muscles [23] (**Figure 4**).

Impaired function of the vestibular system causes vertigo, loss of balance, and loss of gaze fixation during movement, often accompanied by dizziness and nausea [24].

Vestibular dysfunction is typically characterized by vertigo (i.e., an illusory sense of motion) and imbalance owing to disturbances in gaze and postural stability [25], which can culminate in falls [26].

So, the evaluation of the vestibular system is indispensable when the patients have a impaired balance control.

2.3 Somatosensory system and postural balance

People rely primarily on the proprioceptive and cutaneous input to maintain normal quiet stance and to safely accomplish the majority of activities of daily living [27].



Figure 3.
 The main vision impairments that interfere with balance. Courtesy: National Eye Institute, National Institutes of Health (NEI/NIH).

The proprioceptive information depends on muscle spindles, the Golgi tendon organ (GTO), and articular receptors. The first provide the nervous system with information about the muscle's length and velocity of contraction, thus contributing to the individual's ability to discern joint movement and position sense [28]. Besides, the muscle spindles provide afferent feedback that translates stimuli to appropriate reflexive and voluntary movements. The GTO relays information about tensile forces, and is sensitive to very slight changes [28], and when it is activated, the afferent neuron synapses in the spinal cord interneurons, which inhibit the muscle alpha motoneuron, resulting in decreased tension in muscle and tendon. Articular or joint proprioceptors respond to mechanical deformation of the joint capsule and ligaments.

On a slippery or dry floor surface, people show different gait parameters, including step length, required coefficient of friction, and heel contact velocity, evidencing the importance of the sensorimotor system in balance control [29].

Sensorimotor impairments occur with aging and are believed to contribute to the increased likelihood of imbalance and falling [30]. Damage to joint and muscular

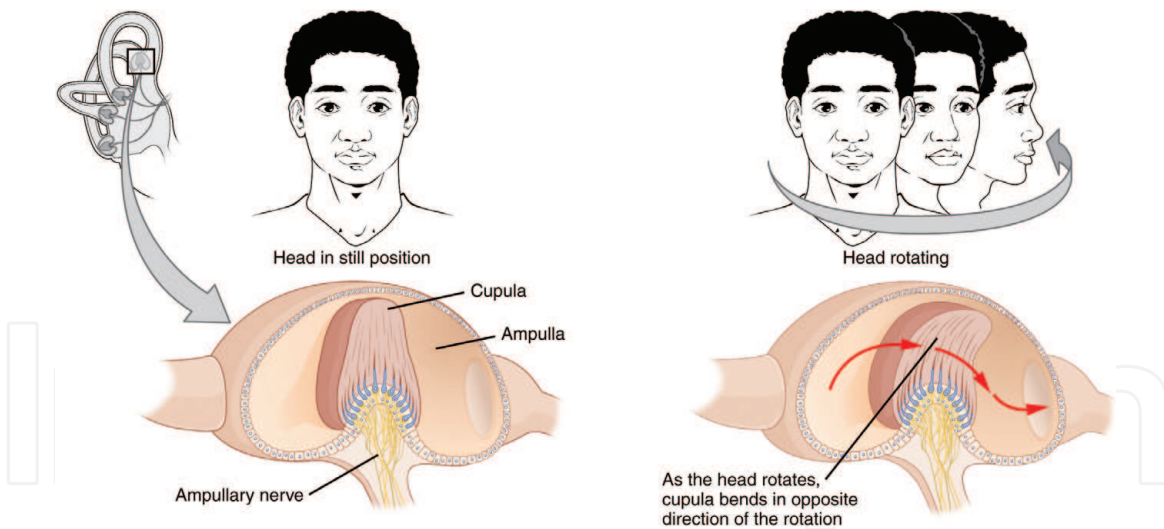


Figure 4.
Postural balance and the vestibular system responses. From Wikimedia Commons, https://commons.wikimedia.org/wiki/File:1410_Equilibrium_and_Semicircular_Canals.jpg.

proprioception, strength (capacity of muscle strength), and reaction time may contribute to the increase in the probability of fall [30].

Some diseases can affect muscles and joints. Studies have shown that, in patients with knee osteoarthritis (AO), postural balance is impaired due to reduced quadriceps function and decreased proprioception [31, 32]. Among elderly individuals, the prevalence of knee OA is approximately 12.2%, with a higher prevalence in women (14.9%) than in men (8.7%) [33].

Patients with neuromuscular diseases (NMDs), usually characterized by muscle weakness, appear to fall regularly. Aging causes a loss of muscle mass with a preferential decline in type II fibers [34], besides decrements in force production, power, specific tension, and fatigability [35], increasing the risk of falls.

Key points

- Elderly population is increasing.
- Postural imbalance and falling are serious problems faced by the older population.
- Postural control is based on the interpretation by central nervous system of convergent sensory information from somatosensory, vestibular, and visual systems.
- Impairments in these systems lead directly to functional loss, such as the inability to walk safely, to climb stairs, and dress independently, increasing the risk of falls.

3. Approach to the patient with a balance problem

3.1 Physical examination

As with any good clinical evaluation, a detailed history and a thorough physical examination are essential. As the postural balance depends on several systems, it is

essential to evaluate the visual system, the vestibular and auditory system, and the sensorimotor system.

3.2 Functional performance tests

A comprehensive assessment of balance is important for both diagnostic and therapeutic reasons in clinical practice.

The tests can be divided between single-task measures and multiple-task measures [36]. These tests often can be done very quickly and with relatively little equipment and training.

3.2.1 Single-task measures

3.2.1.1 Single-leg stance test

The single leg-stance test (SLS) is simple, has high reliability and low cost, and is widely used for diagnosis and follow-up of patients in research and clinical settings. In this test, the participant remains supported on one leg, with arms resting on the hips, and the time (in seconds) that the patient remains in the position without unbalance is verified [37]. Decreased eyes-open SLS time is associated with an increased risk for falls [38].

3.2.1.2 Functional reach test

The *functional reach test* (FRT) is an easy and inexpensive test in which the patient flexes the trunk, extending the arms horizontally and keeping the feet in contact with the ground. The score is obtained by measuring the distance between the initial and the final positions of the fingertip [39]. Displacements less than 15 cm indicate postural balance problems and increased risk of falls [40].

3.2.1.3 Gait speed test

The *gait speed test* gives an easy, inexpensive, reliable measure of functional capacity [41], with high interrater and test-retest reliability [42]; does not require laboratory equipment; is not limited to a specific health care discipline [43]; and may be done quickly in clinical settings. The test may vary according to the pace (usual or maximal speed), whether static or moving start, and the distance walked (ranging from 4 to 500 m) [44].

3.2.2 Multiple-task measures

3.2.2.1 Berg Balance Scale

The *Berg Balance Scale* (BBS) consists of a battery of 14 tasks common to the activities of daily living, which quantitatively evaluate the risk of falls, through observations undertaken by the examiner [45]. The score on the test ranges from 0 to 56 and the performance on each task is measured on a five-point scale ranging from 0 to 4 (0 = unable to perform, 4 = independent). Scores of 48 or less indicate

inability to walk independently and safely in activities of daily living and, consequently, increased risk of falls [46].

3.2.2.2 Short physical performance battery

The *short physical performance battery* (SPPB) is designed to measure functional status and physical performance, assessing walking speed, standing balance, and sit-to-stand performance [47]. The scores range from 0 (worst performance) to 12 (best performance). In a study, Veronese et al. demonstrated that SPPB scores ≤ 6 are associated with a higher fall rate in old people [48].

3.2.2.3 Timed up and go

The *Timed up and go* (TUG) test was developed in 1991 [49]. The test consists of finding the time the patient takes to get up from a chair (height about 46 cm), walk the distance of 3 m at a comfortable and safe step, turn around and go back to the chair, and sit down again. The subject wears his regular footwear and uses his customary walking aid (cane or walker) if necessary [49]. A faster time indicates a better functional performance [50].

Key points

- A good clinical evaluation, a detailed history, and a thorough physical examination are essential to evaluate postural balance.
- The tests can be divided between single-task and multiple-task measures.
- Assessment of balance is important for both diagnostic and therapeutic reasons in clinical practice.

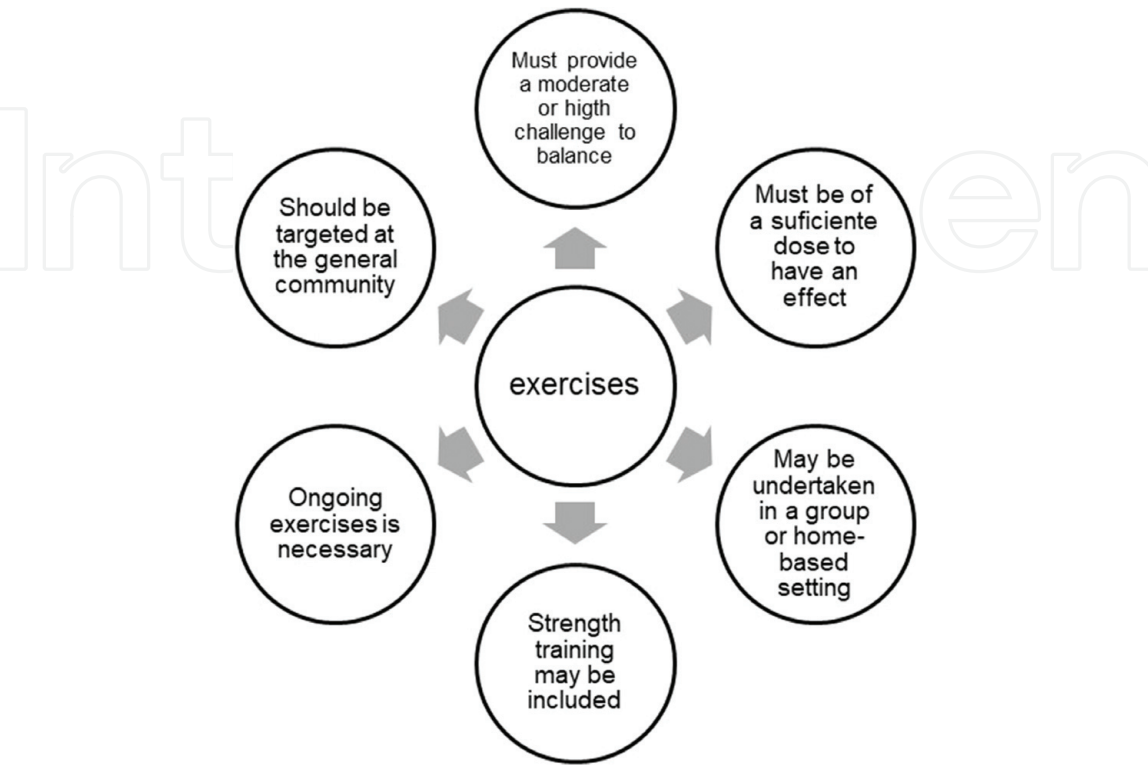


Figure 5.
Recommendations to guide the use of exercise for falls prevention.

4. Improvement of the postural balance

Falls are a public health problem. The risk of falling increases with age for many reasons, for example overall weakness and frailty, balance problems, cognitive problems, vision problems, some medications and polypharmacy, acute illness, and other environmental hazards. Because of this, multifactorial interventions should include an initial assessment of modifiable risk factors for falls and subsequent customized interventions for each patient based on issues identified in the initial assessment.

One type of treatment to improve balance is physical exercise. **Figure 5** presents a summary of best practice recommendations to use for improving postural balance and, consequently, fall prevention.

4.1 Types of exercises

Any physical exercise that overloads the balance systems without putting the patient at risk is recommended. It is possible, for example, to make a training circuit, with different stimuli for the elderly [51]. In the circuit, exercises such as one-legged support (both sides), gait on unstable surface, tandem gait, among others can be done, always increasing the level of difficulty.

Another possibility is to join two modalities of exercises: video games and muscle strengthening, for example. In a study, Prata and Scheicher found improvement in fear of falling and in mobility after 12 weeks of video game and muscle strength training in older women with a history of falls [52].

4.1.1 Video games

Postural balance training involving new technologies can promote more challenging situations for the elderly, increasing patient motivation and adherence to the program [53]. The use of video games provides immediate visual feedback, allowing users to make changes in motion according to the situations of the games and thus to develop strategies to restore and/or maintain postural balance, and may therefore be effective for the prevention of falls [54].

Carvalho et al. showed an increase in gait speed and a decrease in the TUG time in elderly female fallers after 12 weeks of training (two sessions per week) with commercialized games of Wii Fit by Nintendo® in sync with the Wii Balance Board® [55]. Three different games were used for postural balance training: *Penguin Slide*, where the participants had to catch fish while balanced on a piece of ice by shifting their weight from side to side; *Table Tilt*, where participants move their bodies in various directions to put balls into holes; and *Tightrope*, where participants walk on a tightrope with several vertical jumps to avoid obstacles.

4.1.2 Treadmill exercise

In the last decade, the use of the treadmill in the rehabilitation of gait in Parkinson's disease patients, stroke patients, and cerebral palsy (CP) patients has been studied. Some studies explain the reasons for improving postural balance patterns with treadmill training. One of them explains that treadmill training has the capacity to promote motor re-learning and, consequently, improve locomotor capacity during walking [56]. It has also been suggested that training, through repetitive movements generated by the treadmill, activates locomotor patterns of functional movements, sensory inputs, and circuits of the central nervous system [57]. In addition, it has been hypothesized that repetitive movements associated

with cutaneous and proprioceptive impulses may induce activation of central movement patterns and, in the long term, potentiate the motor cortex, facilitating motor learning [58].

Toole et al. and Frenkel-Toledo et al. showed an improvement in the gait and balance in Parkinson's patients that participated in a six-week treadmill walking program [59, 60]. Herman et al. showed an enhancement in the gait rhythmicity and several improvements in motor signs, the latter remaining significantly better 4 weeks after the training was stopped [61].

Training on a treadmill to fight the stroke-related disabilities resulted in valuable results: fatigue resistance [62], endurance performance improvement [63], and the development of motor function [64]. A study in chronic non-ambulatory hemiparetic subjects revealed that partial body weight-supported treadmill training was superior to conventional physiotherapy with regard to restoration of gait and improvement of ground walking velocity [65]. In this study, during one 30-min session of treadmill training, patients could practice up to 1000 gait cycles as compared with a median of less than 50 gait cycles during one regular physiotherapy session.

Bjornson et al. studied the effect of short-burst interval locomotor treadmill training on walking capacity and performance in cerebral palsy and concluded that this training may improve short-term walking capacity and performance [66]. In another study, Mattern-Baxter et al. concluded that home-based treadmill training accelerates the attainment of walking skills and decreases the amount of support used for walking in young children with CP [67].

In healthy elderly with falls history, there are few studies that evaluated the responses of the postural balance with the treadmill training. Dorfman et al. found that after 6 weeks of treadmill plus dual-task training program, elderly fallers demonstrated improved scores on tests of mobility, functional performance tasks, and cognition [68]. In another study, van Ooijen et al., using a treadmill training with visual context, found improvement in walking ability and reduced risk of falls and fear of falling in older adults with a recent fall-related hip fracture [69].

Key points

- Any physical exercise that overloads the balance systems without putting the patient at risk is recommended.
- Postural balance training involving new technologies can promote more challenging situations for the elderly, increasing patient motivation and adherence to the program.
- Treadmill training is another form of exercise to challenge the postural control system.

5. Conclusion

It is necessary to consider the various facets of the postural balance system when a patient presents a problem related to this. Evaluating these facets is important in prescribing the correct treatment for each situation. There are many types of training that can improve postural balance. Physical exercises, when performed with a moderate or high challenge to the balance system, are a type of treatment that can help reduce the risk of falls in the elderly.

Conflict of interest

The authors declare no conflicts of interest.

Author details


Natália Moya Rodrigues Pereira¹ and Marcos Eduardo Scheicher^{2*}

¹ Biosciences Institute, UNESP, Rio Claro, São Paulo, Brazil

² Physiotherapy and Occupational Therapy Department, UNESP, Marília, São Paulo, Brazil

*Address all correspondence to: marcos.scheicher@unesp.br

IntechOpen

© 2018 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] United Nations. World population prospects: The 2012 revision. Highlights and advance tables. Population and Development Review. 2013;**36**:775-801. Available from: <http://esa.un.org/unpd/wpp/Documentation/publications.htm>
- [2] World Health Organization. Integrated Care for Older People [Internet]. Geneva; 2017. 46 p. Available from: <http://apps.who.int/iris/bitstream/10665/258981/1/9789241550109-eng.pdf?ua=1>
- [3] Graafmans WC, Ooms ME, Hofstee HMA, Bezemer PD, Bouter LM, Lips P. Falls in the elderly: A prospective study of risk factors and risk profiles. American Journal of Epidemiology. 1996;**143**(11):1129-1136. Available from: <https://academic.oup.com/aje/article-lookup/doi/10.1093/oxfordjournals.aje.a008690>
- [4] Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. Clinics in Geriatric Medicine. 2002;**18**: 141-158
- [5] Peterka RJ. Sensorimotor integration in human postural control. Journal of Neurophysiology. 2002;**88**:1097-1118
- [6] Maki B, McIlroy W. Postural control in the older adult. Clinics in Geriatric Medicine. 1996;**12**(4):635-658
- [7] Pasma JH, Engelhart D, Maier AB, Schouten AC, van der Kooij H, Meskers CGM. Changes in sensory reweighting of proprioceptive information during standing balance with age and disease. Journal of Neurophysiology. 2015; **114**(6):3220-3233. Available from: <http://jn.physiology.org/lookup/doi/10.1152/jn.00414.2015>
- [8] Berencsi A, Ishihara M, Imanaka K. The functional role of central and peripheral vision in the control of posture. Human Movement Science. 2005;**24**(5-6):689-709
- [9] Marigold DS, Patla AE. Visual information from the lower visual field is important for walking across multi-surface terrain. Experimental Brain Research. 2008;**188**(1):23-31
- [10] Desapriya E, Subzwari S, Scime-Beltrano G, Samayawardhena LA, Pike I. Vision improvement and reduction in falls after expedited cataract surgery. Systematic review and metaanalysis. Journal of Cataract & Refractive Surgery. 2010;**36**(1):13-19. DOI: 10.1016/j.jcrs.2009.07.032
- [11] Chew M, Chiang PPC, Zheng Y, Lavanya R, Wu R, Saw SM, et al. The impact of cataract, cataract types, and cataract grades on vision-specific functioning using rasch analysis. American Journal of Ophthalmology. 2012;**154**(1):29-38
- [12] Polack S, Kuper H, Wadud Z, Fletcher A, Foster A. Quality of life and visual impairment from cataract in Satkhira district, Bangladesh. British Journal of Ophthalmology. 2008;**92**(8): 1026-1030
- [13] Wood JM, Lacherez P, Black AA, Cole MH, Boon MY, Kerr GK. Risk of falls, injurious falls, and other injuries resulting from visual impairment among older adults with age-related macular degeneration. Investigative Ophthalmology & Visual Science. 2018; **52**(8):5088-5092
- [14] Black AA, Wood JM, Lovie-Kitchin JE. Inferior field loss increases rate of falls in older adults with glaucoma. Optometry and Vision Science. 2011; **88**(11):1275-1282
- [15] Coleman AL, Stone K, Ewing SK, Nevitt M, Cummings S, Cauley JA, et al. Higher risk of multiple falls among

elderly women who lose visual acuity. *Ophthalmology*. 2004;**111**(5): 857-862

[16] Black AA, Wood JM, Lovie-Kitchin JE, Newman BM. Visual impairment and postural sway among older adults with glaucoma. *Optometry and Vision Science*. 2008;**85**(6):489-497

[17] National Eye Institute. Age-Related Macular Degeneration (AMD) [Internet]. [cited 2018 Jun 26]. Available from: <https://nei.nih.gov/health/maculardegen>

[18] Wood JM, Lacherez PF, Black AA, Cole MH, Boon MY, Kerr GK. Postural stability and gait among older adults with age-related maculopathy. *Investigative Ophthalmology and Visual Science*. 2009;**50**(1):482-487

[19] Chatard H, Tepenier L, Jankowski O, Aussems A, Allieta A, Beydoun T, et al. Effects of age-related macular degeneration on postural sway. *Frontiers in Human Neuroscience*. 2017; **11**(March):1-9. Available from: <http://journal.frontiersin.org/article/10.3389/fnhum.2017.00158/full>

[20] Gupta P, Aravindhan A, Gan ATL, Man REK, Fenwick EK, Mitchell P, et al. Association between the severity of diabetic retinopathy and falls in an Asian population with diabetes the Singapore epidemiology of eye diseases study. *JAMA Ophthalmology*. 2017; **135**(12):1410-1416

[21] Lord SR, Clark RD, Webster IW. Visual acuity and contrast sensitivity in relation to falls in an elderly population. *Age Ageing*. 1991;**20**(3):175-181. Available from: <https://academic.oup.com/ageing/article-lookup/doi/10.1093/ageing/20.3.175>

[22] Lord SR, Menz HB. Visual contributions to postural stability in older adults. *Gerontology*. 2000;**46**(6): 306-310

[23] Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia A-S, Mcnamara JO, et al. The Vestibular System. In: Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia A-S, Mcnamara JO, et al., editors. *Neuroscience*. 3rd ed. Sunderland: Sinauer Associates; 2004. p. 315-335

[24] Sedó-Cabezón L, Boadas-Vaello P, Soler-Martín C, Llorens J. Vestibular damage in chronic ototoxicity: A mini-review. *Neurotoxicology*. 2014;**43**:21-27

[25] Tian JR, Shubayev I, Baloh RW, Demer JL. Impairments in the initial horizontal vestibulo-ocular reflex of older humans. *Experimental Brain Research*. 2001;**137**(3-4):309-322

[26] Gazzola JM, Ganança FF, Aratani MC, Perracini MR, Ganança MM. Clinical evaluation of elderly people with chronic vestibular disorder. *Brazilian Journal of Otorhinolaryngology*. 2006;**72**(4): 515-522

[27] Grace Gaerlan M, Alpert PT, Cross C, Louis M, Kowalski S. Postural balance in young adults: The role of visual, vestibular and somatosensory systems. *Journal of the American Academy of Nurse Practitioners*. 2012;**24**(6):375-381

[28] Shaffer SW, Harrison AL. Aging of the somatosensory system: A translational perspective. *Physical Therapy*. 2007;**87**(2):193-207. Available from: <https://academic.oup.com/ptj/ptj/article/2742177/Aging>

[29] Lockhart TE, Spaulding JM, Park SH. Age-related slip avoidance strategy while walking over a known slippery floor surface. *Gait & Posture*. 2007; **26**(1):142-149

[30] Lord S, Ward J. Age-associated differences in sensori-motor function and balance in community dwelling women. *Age and Ageing*. 1994;**23**(6): 452-460

- [31] Turcot K, Sagawa Y, Hoffmeyer P, Suvà D, Armand S. Multi-joint postural behavior in patients with knee osteoarthritis. *Knee*. 2015;**22**(6):517-521. DOI: 10.1016/j.knee.2014.09.001
- [32] Walker CRC, Myles C, Nutton R, Rowe P. Movement of the knee in osteoarthritis. *Journal of Bone and Joint Surgery. British Volume*. 2001;**83**(2): 195-198
- [33] Quintana JM, Arostegui I, Escobar A, Azkarate J, Goenaga JI, Lafuente I. Prevalence of knee and hip osteoarthritis and the appropriateness of joint replacement in an older population. *Archives of Internal Medicine*. 2008;**168**(14):1576-1584
- [34] Barry BK, Carson RG. The consequences of resistance training for movement control in older adults. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*. 2004;**59**(7):730-754. Available from: papers://5a68cd75-9e27-4626-8d94-057f1df96060/Paper/p43
- [35] Orr R. Contribution of muscle weakness to postural instability in the elderly. A systematic review. *European Journal of Physical and Rehabilitation Medicine*. 2010;**46**(2):183-220
- [36] Persad C, Cook S, Giordani B. Assessing falls in the elderly: Should we use simple screening tests or a comprehensive fall risk evaluation? *European Journal of Physical and Rehabilitation Medicine*. 2010;**46**(2): 249-259
- [37] Hatton AL, Rome K, Dixon J, Martin DJ, McKeon PO. Footwear interventions: A review of their sensorimotor and mechanical effects on balance performance and gait in older adults. *Journal of the American Podiatric Medical Association*. 2013; **103**(6):516-533. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24297988>
- [38] Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. *Journal of Geriatric Physical Therapy* [Internet]. 2007;**30**(1):8-15. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/19839175>
- [39] de Waroquier-Leroy L, Bleuse S, Serafi R, Watelain E, Pardessus V, Tiffreau AV, et al. The Functional Reach Test: Strategies, performance and the influence of age. *Annals of Physical and Rehabilitation Medicine*. 2014; **57**(6):452-464. DOI: 10.1016/j.rehab.2014.03.003
- [40] Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: A new clinical measure of balance. *Journals of Gerontology*. 1990;**45**(6):M192-M197. Available from: <https://academic.oup.com/geronj/article-lookup/doi/10.1093/geronj/45.6.M192>
- [41] Cesari M, Kritchevsky SB, Penninx BWHJ, Nicklas BJ, Simonsick EM, Newman AB, et al. Prognostic value of usual gait speed in well-functioning older people—Results from the health, aging and body composition study. *Journal of the American Geriatrics Society*. 2005; **53**(10):1675-1680
- [42] Studenski S, Perera S, Wallace D, Chandler JM, Duncan PW, Rooney E, et al. Physical performance measures in the clinical setting. *Journal of the American Geriatrics Society*. 2003; **51**(3):314-322. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/12588574>
- [43] Graham J, Ostir G. Assessing walking speed in clinical research: A systematic review. *Journal of Evaluation in Clinical Practice*. 2008;**14**(4):552-562. Available from: <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2753.2007.00917.x/full>

- [44] Graham JE, Ostir GV, Kuo YF, Fisher SR, Ottenbacher KJ. Relationship between test methodology and mean velocity in timed walk tests: A review. *Archives of Physical Medicine and Rehabilitation*. 2008;**89**(5):865-872
- [45] Berg K. Measuring balance in the elderly: Preliminary development of an instrument. *Physiotherapy Canada*. 1989;**41**(6):304-311. Available from: <https://utpjournals.press/doi/10.3138/ptc.41.6.304>
- [46] Santos GM, Souza ACS, Virtuoso JF, Tavares GMS, Mazo GZ. Valores preditivos para o risco de queda em idosos praticantes e não praticantes de atividade física por meio do uso da escala de equilíbrio de berg. *Revista Brasileira de Fisioterapia*. 2011;**15**(2): 95-101
- [47] Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. *Journals of Gerontology*. 1994;**49**(2):M85-M94. Available from: <https://academic.oup.com/geronj/article-lookup/doi/10.1093/geronj/49.2.M85>
- [48] Veronese N, Bolzetta F, Toffanello ED, Zambon S, De Rui M, Perissinotto E, et al. Association between short physical performance battery and falls in older people: The Progetto Veneto Anziani Study. *Rejuvenation Research*. 2014;**17**(3):276-284. Available from: <http://online.liebertpub.com/doi/abs/10.1089/rej.2013.1491>
- [49] Podsiadlo D, Richardson S. The timed "Up and Go" test: A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*. 1991;**39**(2): 142-148
- [50] Rose D, Jones C, Lucchese N. Predicting the probability of falls in community-residing older adults using the 8-foot up- and-go: A new measure of functional mobility. *Journal of Aging and Physical Activity*. 2002;**10**(4): 466-475
- [51] Costa J, Gonçalves C, Rodrigues G, de Paula A, Pereira M, Safons M. Exercícios multisensoriais no equilíbrio e na prevenção de quedas em idosos [Internet]. 2009. Available from: <http://www.efdeportes.com/efd135/exercicios-multisensoriais-em-idosos.htm>
- [52] Prata MG, Scheicher ME. Effects of strength and balance training on the mobility, fear of falling and grip strength of elderly female fallers, *Journal of Bodywork and Movement Therapies*. 2015;**19**(4):646-650. DOI: 10.1016/j.jbmt.2014.11.013
- [53] Gil-Gómez JA, Lloréns R, Alcñiz M, Colomer C. Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: A pilot randomized clinical trial in patients with acquired brain injury. *Journal of NeuroEngineering and Rehabilitation*. 2011;**8**(1):30 Available from: <http://www.jneuroengrehab.com/content/8/1/30>
- [54] Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M. Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. *Gait Posture*. 2010; **31**(3):307-310. Available from: <https://www.sciencedirect.com/science/article/pii/S096663620900664X?via%3Dihub>
- [55] Carvalho IF, Leme GLM, Scheicher ME. The influence of video game training with and without subpatellar bandage in mobility and gait speed on elderly female fallers. *Journal of Aging Research [Internet]*. 2018;**2018**: 9415093. Published 2018 Mar 26. DOI: 10.1155/2018/9415093

- [56] Visintin M, Barbeau H. The effects of body weight support on the locomotor pattern of spastic paretic patients. *Canadian Journal of Neurological Sciences*. 1989;16(3): 315-325
- [57] Dietz V. Spinal cord pattern generators for locomotion. *Clinical Neurophysiology*. 2003;114(8): 1379-1389
- [58] Asanuma H, Keller A. Neuronal mechanisms of motor learning in mammals. *Neuroreport*. 1991;2:217-224
- [59] Toole T, Maitland C, Warren E, Hubmann M, Panton L. The effects of loading and unloading treadmill walking on balance, gait, fall risk, and daily function in Parkinsonism. *NeuroRehabilitation*. 2005;20(4): 302-322
- [60] Frenkel-Toledo S, Giladi N, Peretz C, Herman T, Gruendlinger L, Hausdorff JM. Treadmill walking as an external pacemaker to improve gait rhythm and stability in Parkinson's disease. *Movement Disorders*. 2005; 20(9):1109-1114
- [61] Herman T, Giladi N, Gruendlinger L, Hausdorff JM. Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: A pilot study. *Archives of Physical Medicine and Rehabilitation*. 2007;88(9):1154-1158
- [62] Abbasian S, Rastegar MMM. Is the intensity or duration of treadmill training important for stroke patients? A meta-analysis. *Journal of Stroke & Cerebrovascular Diseases*. 2018; 27(1):32-43. DOI: 10.1016/j.jstrokecerebrovasdis.2017.09.061
- [63] Sullivan KJ, Brown DA, Klassen T, Mulroy S, Ge T, Azen SP, et al. Effects of task-specific locomotor and strength training in adults who were ambulatory after stroke: Results of the STEPS randomized clinical trial. *Physical Therapy*. 2007;87(12):1580-1602. Available from: <https://academic.oup.com/ptj/article-lookup/doi/10.2522/ptj.20060310>
- [64] Barbeau H, Visintin M. Optimal outcomes obtained with body-weight support combined with treadmill training in stroke subjects. *Archives of Physical Medicine and Rehabilitation*. 2003;84(10):1458-1465
- [65] Hesse S. Treadmill training with partial body weight support after stroke: A review. *NeuroRehabilitation*. 2008; 23(1):55-65
- [66] Bjornson KF, Moreau N, Bodkin AW. Short-burst interval treadmill training walking capacity and performance in cerebral palsy: A pilot study. *Developmental Neurorehabilitation*. 2018;16:1-8. Available from: <https://www.tandfonline.com/doi/full/10.1080/17518423.2018.1462270>
- [67] Mattern-Baxter K, McNeil S, Mansoor JK. Effects of home-based locomotor treadmill training on Gross Motor Function in young children with cerebral palsy: A quasi-randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*. 2013;94(11):2061-2067. DOI: 10.1016/j.apmr.2013.05.012
- [68] Dorfman M, Herman T, Brozgol M, Shema S, Weiss A, Hausdorff J, et al. Dual-task training on a treadmill to improve gait and cognitive function in elderly idiopathic fallers. *Journal of Neurologic Physical Therapy*. 2014; 38(4):246-253
- [69] van Ooijen MW, Roerdink M, Trekop M, Visschedijk J, Janssen TW, Beek PJ. Functional gait rehabilitation in elderly people following a fall-related hip fracture using a treadmill with visual context: Design of a randomized controlled trial. *BMC Geriatrics*. 2013; 13:34