# Postural Balance and Peripheral Neuropathy

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## 1. Introduction

### 1.1. Control of posture

Postural control can be defined as the control of the body's position in space for the purposes of balance and orientation [1]. A definition of balance is the ability to maintain or return the body's centre of gravity within the limits of stability that are determined by the base of support (i.e., the area of the feet) [2]; while spatial orientation defines our natural ability to maintain our body orientation in relation to the surrounding environment, in static and dynamic conditions.

Maintaining balance encompasses the acts of preserving, achieving or restoring the body centre of mass relative to the limits of stability that are given by the base of support [3], which implies the control of posture in preventing falling. Then, in order to modify motor responses on the basis of sensory input, the appropriate responses to any external or internal perturbation have to be chosen [4]. Nevertheless, to maintain stability, all movements that affect the static and dynamic position of the center of mass of the body must be preceded or accompanied by adjustments of other segments.

During upright stance, balance corrections appear to be triggered by signals presumably located within the lower trunk or pelvis [5], and sensory feedback is required from vestibular, visual and somatosensory origin. A bipedal stance position that provides good stability is maintained mainly by efferent ankle mechanisms; to minimize the effect of perturbations when segmental oscillation is allowed, hip mechanisms are used. Locations of the centre of gravity at the borders of the limits of stability correspond to the region where balance cannot be maintained without moving the feet [6].

In order to orient the body, while keeping balance, visual, vestibular and somatosensory modalities are also involved. Every directed activity implies that the body was previously oriented [7]. Although, any part of the body surface can influence the control and perception of body orientation [8], evidence suggest that the representation of the body's static and dynamic geometry may be largely based on muscle proprioceptive inputs that continuously inform the central nervous system about the position of each part of the body in relation to the others [9-11]. The muscle innervation patterns necessary to produce particular body relative movements depend on body orientation to gravity [12]. To oppose the acceleration of gravity, there are contact forces of support on the body surface, the otolith organs provide information about head orientation with respect to the gravitoinertial force. If the head or both the head and the trunk are aligned with the vertical, the gravitational or egocentric reference associated with vertical gravity provide a strong spatial invariant used to control balance [13].

The attentional demands of postural control vary according to the postural task [14], the age of individuals and their balance abilities [15-17]. Teasdale et al. (1993) [18], examined the extent to which reduction in available sensory inputs may increase the attentional demands of postural control in healthy aduls; both young and old adults showed delays in reaction time as the postural task complexity increased, with an increase on attentional demands when sensory inputs were reduced. Studies using dual task paradigms to examine attention requirements of balance control when performing a secondary task, in both healthy and older adults with balance impairment, suggest that these are important contributions to instability, depending on the complexity of the task as well as the type of the second task being performed [15,17].

## 2. Afferent contributions to control posture

The maintenance of bipedal stance is characterized by continuous, small deviations around the actual upright. Depending on sensory context and neuromuscular constraints, the nervous system can adjust the relative afferent contributions to maintain stability. Evidence supports that, as we move about a changing environment, the nervous system continually integrates multisensory information, with the need for continual online updating of estimates of the centre of mass [19].

Balance corrections imply the interaction among several sensory inputs. Somatosensory systems respond early to motion and muscle stretch at the ankle, knee and trunk, as does the vestibular system, which senses head accelerations [20]. Visual inputs mainly influence later stabilizing reactions to the initial balance corrections [20-21]. Each sensory modality makes a unique contribution to control posture. However, the information sent by discrete receptors is not as relevant as the integrated information sent by receptors distributed throughout the body. Descending postural commands are multivariate in nature, and the motion at each joint is affected uniquely by input from multiple sensors. In different sensory environments, the nervous system is able to re-weight its available afferents in order to optimize stance control. For example, with increasing stance width, lateral body motion is detected more easily by proprioceptors and less readily by vision or the vestibular system [22].

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Allum et al. have suggested that a confluence of knee, trunk and vestibulo-spinal inputs triggers human balance corrections depending on the mode of movement the body is forced into by a perturbation, and on the differential weighting of proprioceptive and vestibulo-spinal inputs in the triggered muscle's balance correcting response [5]. A combined deficit of vestibular and somatosensory input may preclude adjustments to postural control [23].

Normal postural coordination of the trunk and legs also requires both somatosensory and visual information [24]; older adults may be less stable under conditions in which peripheral vision is occluded and ankle somatosensation is limited, only remaining foveal vision and vestibular input [25]. However, evidence suggest different selection of sensory orientation references depending on the personal experience of the subjects, leading to a more or less heavy dependence on vision [26].

### 2.1. Somatosensory systems

When healthy subjects stand on a solid base of support, in a lightened environment, they rely on their somatosensory systems, the proprioceptive and the tactile systems. For this purpose, the proprioceptive system provides information on joint angles, changes in joint angles, joint position and muscle length and tension; while the tactile system is associated mainly with sensations of touch, pressure and vibration. In children, studies on the development of sensory organization to control posture according to each sensory component in relation to age suggests that the proprioceptive function seems to mature at 3 to 4 years of age [27].

During upright stance, somatosensory information from the legs may be utilized for both, direct sensory feedback and use of prior experience in scaling the magnitude of automatic postural responses [28]. Reduced somatosensory information from the lower limbs alters the ability to trigger postural responses and to scale the magnitude of these responses [29-31]. Even if the input from skin, pressure and joint receptors of the foot may be of minor importance for the compensation of rapid displacements, it may play a major role at low frequencies [32].

In patients with diabetic neuropathy, sensory conduction in the lower legs results in the late onset of an otherwise intact, centrally programmed response; along with this finding, a different relationship between the severity of the neuropathy and the quality of amplitude and velocity scaling suggests that the role of this peripheral sensory information may differ depending both, on the postural control task and on the quality of the sensory information available [28].

The foot sole and ankle muscle inputs contribute jointly to posture regulation [33]. Foot sole sensation is an important component of the balance system [34]. Cutaneous afferent messages from the main supporting zones of the feet may have sufficient spatial relevance to induce adapted regulative postural responses [35]. After perceptual training for hardness discrimination of the support surface, the ability of healthy subjects to regulate their standing posture may improve with improvement of the perceptive ability of the soles [36].

In healthy subjects, increased severity of experimentally induced loss of plantar cutaneous sensitivity may be associated with greater postural sway; such an association could be affected by the availability of visual input and the size of the support surface [37]. Additionally, subthreshold mechanical noise may enhance the detection of pressure changes on the sole of the feet [38].

Clinical studies have shown that patients with large-fibre neuropathy do not show abnormal body sway during stance [39-40]. Studies in patients with Charcot-Marie-Tooth type 1A disease suggest that functional integrity of the largest afferent fibres may not be necessary for appropriate equilibrium control during quiet stance [39]; also, in this group of patients, postural instability correlates significantly with decreased vibration [41].

Contact of the index finger with a stationary surface can greatly attenuate postural instability during upright stance, even when the level of force applied is far below that necessary to provide mechanical support [42]. In healthy subjects, standing in the dark, spatial information about body posture derived from fingertip contact with a stationary surface greatly improves stability [42]. However, haptic information about postural sway derived from contact with other parts of the body can also increase stability [43].

### 2.2. Visual system

Visual influence on postural control results from a complex synergy that receives multimodal inputs, and may have similar effects on the leg and trunk segments [44]. In order to stabilize the head in space, visual information of the environment must be definite [45]. Healthy subjects show decreased stability in the dark [46], and to compensate for large postural instabilities, visual information is required.

In infants, a cephalo-caudal developmental gradient may be observed as children develope from 3 to 14 months of age, while a wide variety of response patterns may be seen in the 3- to 5-month-olds, indicating that postural responses are not functional prior to experience with stabilizing the center of mass [47]. In children, the peripheral visual contribution to dynamic balance control increase from 3 to 6 years of age, with a maximum in 6-year-old children.; then it decreases in the 7-year-old children and increase again from 8–9 years of age to adulthood [48]. Evidence on the development of sensory organization to control posture, according to each sensory component, in relation to age suggests that the visual afferent system reach adult level at 15 to 16 years of age [27].

Epidemiological studies have shown that visual impairment is strongly associated with falls in the elderly [49-50]. Among older adults with glaucoma, greater visual field loss or thinner retinal nerve fiber layer thickness is associated with reduced postural stability [51]. These findings could be explained by several factors, including poor visual acuity, reduced visual field, impaired contrast sensitivity, and the presence of cataract [49, 52]. However, the role of vision in posture control may be evident even in subjects between 40 and 60 years old [53].

Visual inputs distinguish between translation and rotation of the head. Static visual cues may slowly control re-orientation or displacement, whereas dynamic visual cues may contribute to fast stabilization of the body [54]. Optical motions, like those produced when an observer moves through an environment, have an effect on postural stability [55}. However, flow structure apparently interacts with the exposed retinal area in controlling stance [56].

### 2.3. Vestibular system

Vestibular inputs tonically activate the anti-gravity leg muscles during normal standing

During dynamic tasks, vestibular information contributes to head stabilization to enable successful gaze control [57] and, during active tasks, it provides a stable reference frame from which to generate postural responses [13]. In children, evidence on the development of sensory organization to control posture, according to each sensory component in relation to age suggests that the vestibular afferent system reach adult level at 15 to 16 years of age [27].

Since loss of vestibular information may lead to deficits in trunk control but had less effect on the legs, vestibulo-spinal control may act primarily to stabilize the trunk in space and to facilitate intersegmental dynamics [58]. Vestibular influences are earlier for the sagittal plane and are directed to leg muscles, whereas roll control, in the frontal plane, is later and focused on trunk muscles [59]. Vestibular reflexes and perceptual signals appear to have a specific role in the maintenance of upright stance, under conditions in which other sources of postural information are attenuated or absent [60].

Patients with chronic unilateral peripheral loss may vary widely in the amount they could use their remaining vestibular function and show an increased reliance on proprioceptive information [61]. In patients with bilateral loss of vestibular function, postural compensation depends upon the ability to increase reliance on the remaining sensory systems for postural orientation [62]. During visually induced sway, patients with loss of vestibular function may not utilize somatosensory cues to a greater extent than normal subjects; that is, changes in somatosensory system gain may not be used to compensate for their vestibular deficit [63}. However, precision contact of the index finger at mechanically non-supportive force levels may serve as a substitute in subjects with vestibular loss, when they are attempting to maintain quiet stance [64].

## 3. Motor contribution to control posture

According to the review by Massion (1984) [65], posture is built up by the sum of several basic mechanisms. First the tone of the muscles gives them a rigidity that helps to maintain the joints in a defined position; the postural tone is added to this basic tonus, mainly in the extensor muscles. Postural fixation maintains the position of one or several joints against an internal force (eg. body weight), by co-contraction of the antagonistic muscles around the joints. Coordination between movement and posture is observed with the voluntary movements of body segments. Postural adjustments accompanying voluntary movements show three main characteristics [65]: they are anticipatory with respect to movement, they are adaptable to the condition in which the movement is executed and they are influenced by instructions given to the subjects concerning the task to be performed

During upright stance, compensatory torques must be generated to oppose the destabilizing torque due to gravity. Then, spontaneous sway is generated by the continuous body deviations countered by corrective torques. During movement of one segment of the body, other segments are disturbed, producing instability. Thus the precise movement of distal segments can be realized only by stabilizing more proximal segments [66]. Just before a voluntary movement, the stretch reflex response in agonist muscles is enhanced [67], consistent with a stabilizing effect. In healthy subjects, axial tone is modulated sensitively and dynamically, this control originates, at least in part, from tonic lengthening and shortening reactions, and a similar type of control appears to exist for postural tone in the proximal muscles of the arm [68].

To preserve balance, postural adjustments are made through flexible synergies, in which the activity of the participating muscles is set to task-specific conditions [5]. The most rapid postural reactions are a class of motor activities mediated primarily by inputs derived from the forces and motions of the feet upon the surface of support [69]; the supporting reactions and placing reactions (tactile, visual and vestibular) adapt the activity of the postural muscles of the limbs to their function of body support. Perturbations to balance imply that the central nervous system select patterns of muscle activation that are appropriate for a variety of perturbations [70], in agreement with biomechanical constraints such as those imposed by inter-segmental dynamics and musculoskeletal geometry [71]. A confluence of proprioceptive and vestibular modulation to the basic centrally initiated template of activity may establish the amplitude pattern of the muscle response synergy [70, 72-73]. The confluence of sensory inputs presumably permits the proprioceptive and vestibular inputs to reinforce each other righting effects, and prevent to fall.

It has been suggested that postural adjustments can be described as a single feedback control scheme, with scalable heterogenic gains that are adjusted according to biomechanical constraints [74]. In addition, muscle weakness and muscle fatigue have to be considered. Clinical evidence have shown that patients with polyneuropathy who have ankle weakness are more likely to experience multiple and injurious falls than are those without specific muscle weakness [75]. Also, an altered posture, which is common in patients with muscle weakness, may interfere with the position of the centre of mass, and there by also cause balance problems [76].

In healthy subjects, inducing localized muscle fatigue at various musculatures has been shown to adversely affect postural control. Plantar-flexor muscle fatigue may impair the effectiveness of postural control and increase the amount of postural regulatory activity required to control unperturbed bipedal posture when the quality of the postural support surface information is altered (by standing on a foam support surface) to a greater extent than when it is not [77]. In healthy subjects who perform fatiguing exercises, acute effects of fatigue may differ between joints, with the most substantial effects evident at the lower back, followed by the ankle and recovery of postural control [78]. Also, during quiet standing, fatigue of trunk muscles may increase reliance on somatosensory inputs from the foot soles and ankles for controlling posture [79], while lumbar fatigue impairs the ability to sense a change in lumbar position [80].

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## 4. Clinical assessment of balance

In order to assess instability or walking difficulty, it is essential to identify the affected movements and circumstances in which they occur (i.e. uneven surfaces, environmental light, activity) as well as any other associated clinical manifestation that could be related to balance, postural control, motor control, muscular force, movement limitations or sensory deficiency.

The clinical evaluation should include a detailed assessment of long tracts, cranial nerves, motor control, motor strength, the eyes and the ears. To evaluate the vestibular system and its relationships with other sensory inputs and the oculo-motor system, specific tests have to be performed, including eye movement recordings and vestibular reflexes.

Standardized scales and questionnaires may be helpful to evaluate and to follow-up deficits that may be evident on daily life activities (e.i. Berg's Balance Scale [81]; Tinetti scale [82]; balance symptoms questionnaire by Jáuregui-Renaud et al.[83]), as well as falls [84]. Some clinical test include the "Get up and go test" [85], the five-step test and the Functional Reach [86], the Mobility Fall Chart [87] and the evidence based risk assessment tool [88], among others. However, before choosing a tool the clinician should consider the purpose of its design and the purpose for which the tool is to be applied, as well as its reliability.

To evaluate balance, a neurological examination should be performed, including an examination of motor and sensory function; care should be taken to assess static and dynamic postural control and gait, as well as to identify visual and vestibular disorders. During static upright stance, it is important to observe the width of the stance, the symmetry of the stance, the balance at the level of the joints as well as the trunk posture, while changing the sensory conditions (i.e. visual input and the surface of support). The sensory conditions may include at least: standing with the eyes open and closed, on a hard and a compliant surface, standing with the feet together and balancing on the two legs. To clinically asses the response to simple perturbations, the clinician may observe the reaction to push gently the patient while standing.

To measure balance, different aspects may be analysed: electric potentials due to muscle activation, kinematics that is concerned with movement itself and kinetics, concerned with the forces and the moments of forces that are developed during movements. To record kinetics, force platforms are used. The centre of pressure is recorded over a period of time, while standing on the force platform (wearing a safety harness) under different sensory conditions. Several moving force platforms have been designed in order to create dynamic conditions, while maintaining a constant angle between the foot and lower leg and moving the visual enclosure of the platform, which can be coupled to the body sway. Regardless of the technique of measurement used, to interpret any recording of body sway, several factors have to be considered, including the fact that body sway increase with age, with an increased dependence on vision [53, 89-90], and may be affected by body weight and gender [90-91]. In patients with polyneuropathy, special care should be taken in considering adaptive compensation to changes in biomechanical factors as well as sensory deficits.

To evaluate gait, a sensory-motor evaluation should be performed, as well as a postural and skeletal examination [92]. To asses walking it is necessary to analyse the initiation, the stepping, the termination and the associated movements. During stepping, it is important to evaluate at least the speed of walking, the rhythm and the length of each stride.

The analysis of gait may include measurements of joint kinematics and kinetics, other measurements include electromyography, oxygen consumption and foot pressures. Using electromyography, specific muscles or muscle groups during movement can be studied. A kinematic evaluation (e.i. joint angles, stride length, walking velocity) may be performed by optoelectric methods as well as by tracking the position of the body segments using light-emitting markers. Power is a kinetic variable, to assess the rate of work performed at a given joint [93], which allows to identify when the muscle is generating or absorbing mechanical energy (concentric or eccentric contraction).

## 5. Balance in patients with peripheral neuropathy

Patients with polyneuropathy, which reduces sensation and often strength in the lower extremities, may have decreased stability while standing and when subjected to dynamic balance conditions [28, 94-97]. In patients with severe peripheral neuropathy of unknown origin, compared to healthy age and sex matched controls, visual and vestibular input cannot fully compensate for the impairment in proprioception, with progressive deterioration of balance [31].

The ability to re-weight sensory information depending on the sensory context is important for maintaining stability, when an individual moves from one sensory context to another, such as a flat walking surface to an uneven surface or a well-lit sidewalk to a dimly lit garden. Individuals with peripheral vestibular loss or somatosensory loss from neuropathy are limited in their ability to re-weight postural sensory dependence [31, 98].

In patients with peripheral neuropathy, including Charcot-Marie-Tooth disease type 1A and type 2 and diabetic neuropathy, the effects of impaired proprioceptive input in balance control under static and dynamic conditions [99] showed that, during static conditions, across all patients, instability increased as a function of the slowing of conduction velocity. In contrast, during dynamic conditions head displacement was only slightly increased, compared to healthy subjects, despite the increased delay at which the head followed displacement of the feet.

Charcot–Marie–Tooth disease is a genetically heterogeneous group of hereditary neuropathies characterized by slowly progressive weakness and atrophy, primarily in the distal leg muscles. The clinical disability has been shown to best correlate with the degree of axonal loss [100]. However, evidence suggest that functional integrity of the largest afferent fibres is not necessary for appropriate equilibrium control during quiet stance, and unsteadiness is related to additional functional alterations in smaller fibres, most likely group II spindle afferent fibres [39].

In adult patients with Charcot–Marie-Tooth type 1A, the decline in axonal function and in muscle strength may reflect, to a considerable extent, a process of normal ageing, and physical disability in adulthood may well be explained by decreased reserves and compensatory mechanisms together with progression of skeletal deformations due to muscle weakness [101]. On the other hand, during static conditions, patients with Charcot-Marie-Tooth type 2 may show less postural stability than patients with Charcot-Marie-Tooth type 1A disease, but similar than the postural stability shown by diabetic patients with peripheral neuropathy [99]; while in patients with diabetic peripheral neuropathy, unsteadiness relates to alterations in medium-size myelinated afferent fibres, possibly originating from spindle secondary terminations [40].

A frequent source of polyneuropathy is diabetes mellitus. Diabetic peripheral neuropathy is initially characterized by a reduction in somesthesic sensitivity due to the sensitive nerve damage, and with progression motor nerves are damaged. During upright stance, compared to healthy subjects, recordings of the centre of pressure in patients with diabetic neuropathty have shown larger sway [95-96, 102], as well as increased oscillation at 0.5-1 Hz [103]. However, in this group of patients, in addition to postural instability caused by neuropathy, balance deterioration may also result from the bio-mechanical impairment caused by progression of foot complications [104], as well as from the compromise of other sensory inputs such as vision [105-106]. Compared to healthy subjects, diabetic patients may have poorer balance during standing in diminished light compared to full light and no light conditions [105].

Balance and gait difficulties are the most frequently cited cause of falling in all age and gender groups [107] A fall is often defined as inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects [108]. Cavanagh et al. (1992) [109] have shown that, compared to patients with diabetes but no peripheral neuropathy, patients with diabetic peripheral neuropathy are more likely to report an injury during walking or standing, which may be more frequent when walking on irregular surfaces [110].

Epidemiological surveys have established that a reduction of leg proprioception is a risk factor for falls in the elderly [111-112]. Symptoms and signs of peripheral neuropathy are frequently found during physical examination of older subjects. These clinical manifestations may be related to diabetes mellitus, alcoholism, nutritional deficiencies, autoimmune diseases, among other causes. In this group of patients, loss of plantar sensation may be an important contributor to the dynamic balance deficits and increased risk of falls [34, 109].

Falls occur as a result of complex interactions among demographic, physical and behavioural factors. Risk factors may be intrinsic or extrinsic: intrinsic factors include demographic and biological factors, while extrinsic factors encompass environmental and behavioural factors [108]. Among other risk factors, the occurrence of falls may be significantly associated with lower extremity weakness, which can be measured by knee extension, ankle dorsiflexion, and chair stands [113], visual acuity of less than 6/12 [114], lower extremity impairments [108-109] and poly-pharmacy [115-116].

Apart from sensorymotor compromise, fear of falling may relate to restriction and avoidance of activities, which results in loss of strength especially in the lower extremities, and may also be predictive for future falls [117-119].

## 6. Interventions to improve balance in patients with peripheral neuropathy

Richardson et al. (2004) [120], in patients with various forms of peripheral neuropathy, found that the use of a cane, ankle orthoses or touching a wall improved spatial and temporal measures of gait regularity while walking under challenging conditions. Evidence support that, additional hand contact of external objects may reduce postural instability caused by a deficiency of one or more senses. Contact with support of varying stability may reduce the destabilizing effect of a moving visual scene [121]. In patients with moderate to severe diabetic neuropathy, mechanical noise stimulation may improve vibration and tactile perception [122].

To improve stability in patients with decreased somatosensation, footwear may represent a modifiable factor. The efficacy of certain types of stabilizing reactions may be improved whether incorporating a pressure plantar-based biofeedback system in footwear [123], vibrating shoe insoles [38], or by mechanical facilitation of sensation from the boundaries of the plantar surface of the foot [124]. In patients with Charcot-Marie-Tooth, considering individual sensory and muscular deficits, ankle-foot orthosis prescription, appears relevant for improving balance and gait performance [125].

Exercise that improves lower-extremity balance and strength (force-generating capacity) has been shown to be effective in reducing falls in older adults [126]. In patients with clinically defined sensory ataxia due to bilateral chronic neuropathy compared to patients with unilateral loss-related to multiple sclerosis, after a rehabilitation program including foot sensory stimulation, balance and gait training with limited vision, balance assessed on a static force platform remained similar in the open-eyes condition and improved in the closed-eyes condition only in patients with unilateral sensory loss, while dynamic balance improved in the two groups, suggesting that the relative contribution of proprioceptive and visual inputs may depend on the extent of somatosensory loss [127].

Guidelines for diabetes management recommend that patients perform at least 30 min of physical activity a day six times a week. Few studies on prevention of diabetic neuropathy through exercise have been reported, even if moderate intensity exercise in patients with type 2 diabetes mellitus has been associated with a decrease in blood glucose [128]. A preliminary controlled study has shown that a 12 week program of *tai chi chuan* exercises may improve peripheral nerve conduction velocities and fasting glucose levels [129].

Studies evaluating treatment strategies that could improve balance in diabetic patients with polyneuropathy are also scarce. Although, some interventions including leg strengthening and balance exercises to promote ambulatory physical activity may not decrease fall rates, but neither they increase them; suggesting that physical activity interventions that increase activity probably do not increase the risk of falling in patients with diabetic peripheral neuropathy [130]. In this group of patients, specific training may improve gait speed, balance, muscle strength and joint mobility [131].

To determine the effect of a specific exercise regimen on clinical measures of postural stability and confidence in a population with peripheral neuropathy, compared to a control group, ten patients with diabetic peripheral neuropathy underwent a 3-week intervention to increase rapidly available distal strength and balance, showing improvement on unipedal stance time, functional reach, tandem stance time, but the score on the activities-specific balance and confidence scale [132]. To further increase physical activity and protocol adherence, a supervised centre-based exercise program rather than a self-administered program may be recommended [130]. However, there is a need of studies examining the effect of physical training on the incidence of foot breakdown and fall risk in people with diabetes mellitus and peripheral neuropathy.

## 7. Conclusions

Postural control can be defined as the control of the body's position in space for the purposes of balance and orientation. Balance is the ability to maintain or return the body's centre of gravity within the limits of stability that are determined by the base of support. Spatial orientation defines our natural ability to maintain our body orientation in relation to the surrounding environment, in static and dynamic conditions.

The representation of the body's static and dynamic geometry may be largely based on muscle proprioceptive inputs that continuously inform the central nervous system about the position of each part of the body in relation to the others. Posture is built up by the sum of several basic mechanisms. First the tone of the muscles gives them a rigidity that helps to maintain the joints in a defined position; the postural tone is added to this basic tonus. Postural fixation maintains the position of one or several joints against an internal force. During movement of one segment of the body, other segments are disturbed, producing instability. Thus the precise movement of distal segments can be realized only by stabilizing more proximal segments.

Postural balance is dependent upon integration of signals from the somatosensory, visual and vestibular systems, to generate motor responses, with cognitive demands that vary according to the task, the age of the individuals and their ability to balance. Descending postural commands are multivariate in nature, and the motion at each joint is affected uniquely by input from multiple sensors.

The proprioceptive system provides information on joint angles, changes in joint angles, joint position and muscle length and tension; while the tactile system is associated mainly with sensations of touch, pressure and vibration.

Visual influence on postural control results from a complex synergy that receives multimodal inputs. Vestibular inputs tonically activate the anti-gravity leg muscles and, during dynamic tasks, vestibular information contributes to head stabilization to enable successful gaze control, providing a stable reference frame from which to generate postural responses.

In order to assess instability or walking difficulty, it is essential to identify the affected movements and circumstances in which they occur (i.e. uneven surfaces, environmental light, activity) as well as any other associated clinical manifestation that could be related to balance, postural control, motor control, muscular force, movement limitations or sensory deficiency. The clinical evaluation should include neurological examination; special care should be taken to identify visual and vestibular disorders, and to assess static and dynamic postural control and gait. Standardized scales and questionnaires may be helpful to evaluate and to follow-up deficits that may be evident on daily life activities.

The simplest method to record postural sway uses a force plate to measure the feet centre of pressure on the platform. To modify the somatosensory and visual inputs, moving force platforms and visual surroundings have been designed. Gait analysis may include the measurement of joint kinematics and kinetics, electromyography, oxygen consumption and foot pressures.

Polyneuropathy modify the amount and the quality of the sensorial information that is necessary for motor control, with increased instability during both, upright stance and gait.

Patients with peripheral neuropathy may have decreased stability while standing and when subjected to dynamic balance conditions. During upright stance, compared to healthy subjects, recordings of the centre of pressure in patients with diabetic neuropathy have shown larger sway, as well as increased oscillation at 0.5-1 Hz.

Balance and gait difficulties are the most frequently cited cause of falling in all age and gender groups Epidemiological surveys have established that a reduction of leg proprioception is a risk factor for falls.

Patients with polyneuropathy who have ankle weakness are more likely to experience multiple and injurious falls than are those without specific muscle weakness.

Elderly patients with diabetic peripheral neuropathy are more likely to report an injury during walking or standing, which may be more frequent when walking on irregular surfaces. Among other risk factors, the occurrence of falls may be significantly associated with lower extremity weakness, which can be measured by knee extension, ankle dorsiflexion, and chair stands, visual acuity of less than 6/12, lower extremity impairments and poly-pharmacy, among other factors.

In patients with various forms of peripheral neuropathy, the use of a cane, ankle orthoses or touching a wall improved spatial and temporal measures of gait regularity while walking under challenging conditions. Additional hand contact of external objects may reduce postural instability caused by a deficiency of one or more senses.

Studies evaluating preventive and treatment strategies through excercise that could improve balance in patients with polyneuropathy are scarce. However, evidence support that physical activity interventions that increase activity probably do not increase the risk of falling in patients with diabetic peripheral neuropathy, and in this group of patients, specific training may improve gait speed, balance, muscle strength and joint mobility.

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