Curr Neurol Neurosci Rep (2010) 10:407–412
DOI 10.1007/s11910-010-0128-0

Postural Control in Multiple Sclerosis: Implications for Fall Prevention

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Published online: 22 June 2010

Abstract People with multiple sclerosis (MS) often have poor postural control, which likely underlies their increased risk of falls. Based on several studies of balance and gait in MS, it appears that the primary mechanisms underlying the observed changes are slowed somatosensory conduction and impaired central integration. This review of the published research on balance, gait, and falls in people with MS demonstrates that people with MS have balance impairments characterized by increased sway in quiet stance, delayed responses to postural perturbations, and a reduced ability to move toward their limits of stability. These impairments are likely causes of falls in people with MS and are consistent with the reduced gait speed, as well as decreased stride length, cadence, and joint movement, observed in most studies of gait in MS. Based on these findings, we identify several factors that may be amenable to intervention to prevent falls in people with MS.

Keywords Accidental falls · Gait · Multiple sclerosis · Postural balance · Walking

Introduction

Multiple sclerosis (MS) is a chronic progressive disease of the central nervous system (CNS) that affects a wide range of neurologic functions, including cognition, vision, muscle strength and tone, coordination, sensation, and balance. Many people with MS have abnormal balance and gait control, and many also fall frequently [1–6]. Imbalance is also often the initial symptom of MS. Because MS may affect all areas of the CNS and may cause such a wide range of impairments, it was initially thought that changes in postural control in people with MS had multifactorial cumulative causes that differed from one person to the next [4]. Another popular theory, given the ataxic gait and frequency of cerebellar lesions in people with MS, was that cerebellar lesions are the primary cause of impaired postural control in MS [7]. However, in this review, we demonstrate, based on studies examining the mechanisms underlying imbalance in MS, that changes in postural control in most people with MS are likely primarily the result of slowed somatosensory conduction and impaired central integration [1, 6, 8, 9, 10•].

The literature reviewed in this article includes all studies on postural control in MS published to date. These papers were found by searching Medline, Embase, the Cochrane Database of Systematic Reviews, the Database of Abstracts of Reviews of Effectiveness (DARE), and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) through November 2009. Related journals, reference lists, and conference proceedings also were hand searched for relevant articles. Searches were performed using the Medical Subject Heading (MESH) keywords *multiple sclerosis and postural balance*, *accidental falls*, *gait*, or *walking*, as well as similar terms in other databases. We included all published, peer-reviewed articles with an abstract available in English and a description of the study that included the number of subjects, the methods of assessment, and a quantitative summary of results. We excluded papers that evaluated only the effects of interventions in those with MS and imbalance or at high risk for

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falls, papers only validating measures of balance or falls, and case reports. The reviewed papers fall broadly into three categories: balance control in MS, gait in MS, and falls in MS.

Balance Control in MS

Several systematic studies demonstrated that balance abnormalities are common in people with MS, including those with significant impairments [1, 2] as well as those with minimal [3–5, 11] or even no clinically assessable impairments [6]. Overall, these studies demonstrate that people with MS have three related abnormalities of balance control: first, they have decreased ability to maintain position; second, they have limited and slow movement toward their limits of stability; and third, they have delayed responses to postural displacements or perturbations.

Decreased Ability to Maintain Position

When trying to stand still, people with MS sway more than healthy controls [2, 4, 6, 12–16]. Their postural sway increases even more than in controls when they close their eyes [4, 12, 13], and postural sway in quiet stance is greater in those with MS who are more impaired (higher vs lower Expanded Disability Status Scale [EDSS] score) and in those with progressive rather than relapsing forms of MS [12]. People with MS also are less able to maintain standing with a reduced base of support, such as on one leg or in tandem stance, compared with healthy controls [17].

Limited and Slowed Movement Toward Limits of Stability

When trying to reach or step, people with MS move less far and less quickly than healthy controls [2, 5, 11, 17, 18]. Martin et al. [11] found that people with MS had significantly reduced functional reach distance when standing compared with controls. Frzovic et al. [17], as well as Soyuer et al. [2], found that besides reduced functional reach, people with MS could reach upward fewer times in 15 s and complete fewer steps up onto a step in 15 s versus healthy controls. In addition, Karst et al. [5] found that people with MS had a significantly reduced center of pressure displacement during voluntary leaning and reaching. Consistent with the finding that people with MS can lean less far when standing, it was reported recently that during gait initiation, when one needs to lean forward to displace one's center of mass anteriorly, people with MS displace their center of mass less far and less quickly and get less close to their stability boundaries [18].

Delayed Responses to Postural Displacements and Perturbations

In addition to increased sway in quiet stance and reduced ability to move toward their limits of stability, people with MS have poorer trunk control and delayed postural responses when the support surface moves [1, 9, 10•, 19]. In 1984, Diener et al. [9] reported that 17 of 21 tested subjects with MS had delayed postural responses to toe-up postural perturbations while standing and that these delays correlated with prolongation of somatosensory evoked potential (SSEP) latencies. Shortly after this publication, Jackson et al. [1] reported that 26 of their 27 subjects with mild MS had slowed automatic postural responses to forward and backward displacements while standing, as well as reduced ability to control anterior–posterior sway in response to these perturbations, and Williams et al. [19] reported that 5 of their 10 subjects with MS who could walk independently without an assistive device had increased latency of postural responses to forward perturbations. Similarly, our recently published study found that 8 of 10 independently ambulatory subjects with MS had delayed postural responses to backward translations in standing, that these delays correlated with prolongation of spinal SSEP latency, and that these subjects had unimpaired predictive scaling of their postural responses [10•]. These findings are in contrast to those in people with cerebellar disorders, who typically have normal postural response latencies but severely impaired predictive scaling of these responses [20]. People with MS have also been found to have poorer trunk control than healthy people when sitting on an unstable surface [21].

Overall, the studies of postural responses indicate that people with MS have delayed automatic postural responses to postural perturbations, that there is a relationship between these postural response delays and delays in spinal somatosensory conduction, and that imbalance in people with MS is unlike imbalance from cerebellar disorders. In addition, the finding of impaired postural control in sitting indicates that, beyond slowed somatosensory conduction from the lower extremities, deficits in central integration likely also contribute to imbalance in people with MS.

Gait in MS

Gait disturbance is common in MS, and walking tolerance, gait speed, and gait quality are components of measures of MS-related disability and disease progression. Many studies have also found that people with MS walk more slowly [11, 15, 18, 22–28], take shorter steps (decreased step length) [11, 22, 23, 25, 28], step more slowly (decreased cadence) [23, 25, 26, 28], have less joint motion during gait [11, 22,

25, 27], and demonstrate more variability in most gait parameters [27] than healthy controls. In addition, people with MS slow down more and demonstrate more swing time variability when they walk while performing a cognitive task than do healthy controls, suggesting that they need to devote greater cognitive reserve to walking than do people without MS [29•].

There is conflicting evidence regarding differences in gait between people with MS and healthy controls when walking at the same speed. Although one study with 48 subjects (24 with MS, 24 healthy controls) found that, on average, people with MS expend more energy than do healthy controls even when walking at the same speed [30], another recent small study (three MS patients, four controls) did not find a difference in stride length and dual support time between people with MS and controls when walking at the same slow, medium, or fast speeds [31].

The changes in gait reported in people with MS are consistent with their reported changes in balance control. Walking may be seen as a sequence of standing still, leaning forward, and then catching oneself with one foot (Fig. 1), and, as discussed previously, people with MS have impaired ability to stand still, to lean, and to respond to the perturbation produced by leaning. Thus, the changes in gait observed in people with MS are likely largely the result of changes in postural control.

Falls in MS

Several studies indicate that many people with MS fall frequently [32–36•], that they fear falling [34], that they are at increased risk for fall-related injuries [35], and that they have an elevated risk of fatal falls [37]. The first published study concerning falls in people with MS evaluated falls in 50 people with MS in Italy and found that 54% reported falling once or more in the prior 2 months and that 32% reported falling twice or more in the same period [32]. Three other published reports on falls in people with MS are based on more than 1000 older people (aged 45–90 years) with MS in the midwestern United States [33–35]. More than 50% of these people reported falling at least once in the previous 6 months, and more than 50% reported a history of at least one injurious fall at some time, with 12% reporting injurious falls in the previous 6 months [35] and 63.5% reporting a fear of falling [34]. More than 80% of those who feared falling curtailed their activity because of this fear [34].

All the studies of falls in MS relied on retrospective recall of falls to estimate fall frequency until Nilsagard et al. [36•] recently published a report of their prospective count of falls in people with MS, the method currently recommended to accurately assess fall frequency [38]. They found that 48 of 76 subjects with MS (63%) registered a total of 270 falls over 3 months.

Although the cause of falls in people with MS is uncertain, fall status has been associated with impaired balance [32, 33, 36•], reduced ability to walk [32, 33, 36•, 39], and use of a cane [32] or other walking aid [36•]. In addition, studies have identified disturbed proprioception [36•], spasticity [36•, 39], and more severe MS (higher EDSS score) [36•] as risk factors for falls in people with MS; people with MS also identify divided attention, reduced muscular endurance, fatigue, and heat sensitivity as causes of falls [39].

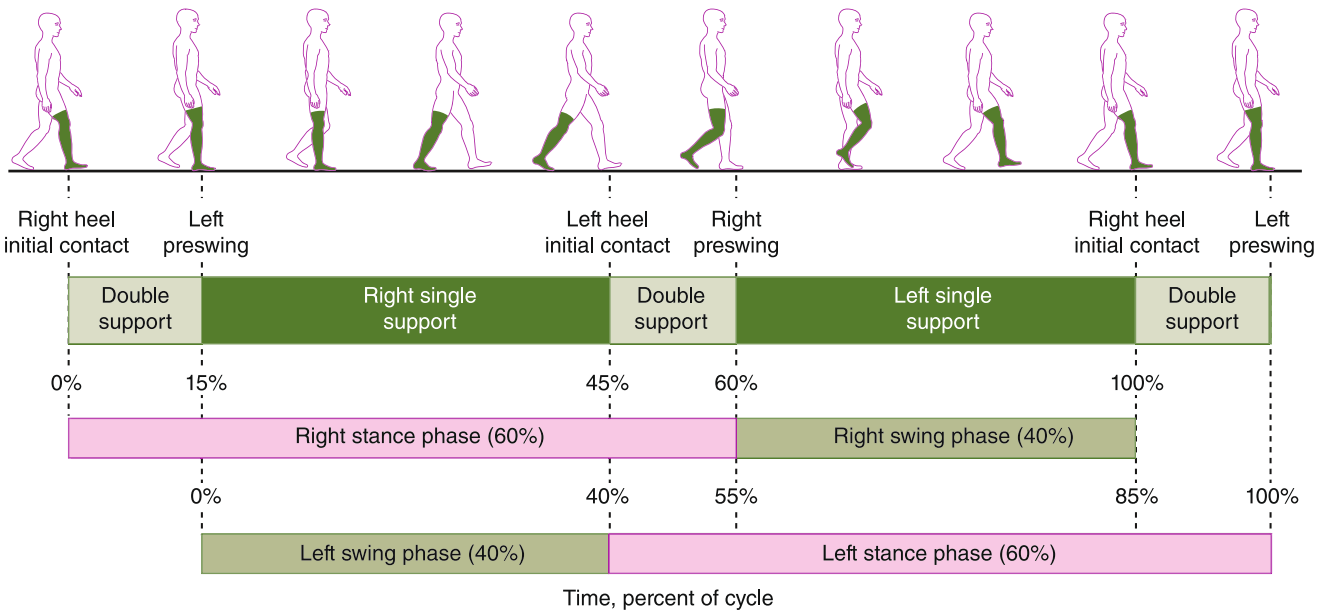

Fig. 1 Gait as a sequence of standing still, leaning forward, and then catching oneself with one foot. (*Adapted from* Magee [51])

Discussion and Recommendations for Fall Prevention

Although no studies clearly elucidate how imbalance, gait impairment, and falls are associated in MS, and there has been no systematic study of the mechanisms underlying imbalance and falls in people with MS, the evidence to date indicates that people with MS have changes in postural control and gait that likely contribute significantly to their risk of falling. MS is associated with increased postural sway in standing, decreased ability to move toward one's limits of stability, slowed responses to postural perturbations, slow walking, and frequent falls. Walking can be understood as a repeated sequence of balance challenges, starting with standing (double-limb support), reducing the base of support (single-limb support), leaning forward (a perturbation), and responding to the perturbation with a step to catch oneself with the forward leg (swing phase of the other leg followed by initial contact) (Fig. 1). Performance of all these balance tasks appears to be impaired in people with MS, resulting in a gait that is slowed and unsafe. Evidence suggests that these impairments most likely are the result of sensory and particularly proprioceptive impairments and/or central processing deficits rather than deficits in strength, vision, or other neurologic functions affected by MS. It is possible that proprioceptive deficits predominate in those with more spinal lesions and central processing deficits predominate in those with more brain lesions.

Currently, interventions used to improve balance and prevent falls in the elderly and others with imbalance and increased fall risk are also used in people with MS. Interventions used in older people are appealing because older people have impaired functioning of physiologic systems that contribute to balance control, including vision, sensation, strength, reaction time, and coordination, as do people with MS. Older people also fall frequently, and based on more than 111 randomized controlled trials, we know that exercises promoting strength and balance and environmental modifications to promote safety in the home can prevent falls in community-living older people [40].

Small uncontrolled studies in people with MS also suggest that exercise in standing [41], static and dynamic ankle foot orthoses [42], and physical therapy with a neurodevelopmental training approach [43] may improve balance in people with MS, but none of these approaches specifically addresses the postural control deficits unique to this population. Consistent with our expectations that interventions that specifically address proprioceptive or central processing deficits are likely to be particularly effective in people with MS, Cattaneo et al. [44••] recently found that balance rehabilitation to improve sensory as well as motor strategies improved balance and reduced fall frequency more effectively than balance rehabilitation aimed only at improving motor strategies or than nonspecific rehabilitation treatments. We believe that interventions that specifically address the proprioceptive and central processing deficits that probably underlie imbalance and falls in people with MS are likely to most effectively improve balance and prevent falls most in this population.

Balance impairment caused by proprioceptive deficits may be addressed with approaches that enhance sensory input, including sensory facilitation techniques using supplementary tactile input and supportive devices that provide additional proprioceptive input. Supplementary tactile input provided by light touch of the fingertips on a metal bar [45], rubbing on the skin of the leg or shoulder [46], or rubbing with Velcro on the skin of the leg [47] has been found to reduce standing postural sway in healthy people and in those with lower-extremity sensory impairment, indicating improved postural control. Supplementary tactile input also may be provided by elastic bandages, ankle braces, or shoes with high heel collars.

Supportive footwear and canes, which traditionally have been thought to improve balance by providing additional support, also likely contribute to improved balance by enhancing sensory input. For example, wearing lace-up boots rather than shoes is associated with better balance in older women [48], and wearing insoles with a raised projection outlining the periphery of the foot improves the stepping response to unexpected platform perturbations in both young and older adults [49]. Similarly, light touch provided by a cane improves stability in people with diabetic peripheral neuropathy [50]. These interventions provide additional sensory input to the lower or upper extremities and provide additional proprioceptive information about the position of the body in space in addition to providing mechanical support of the foot, ankle, or body weight. A cane or walking stick held in the hand also has the advantage of inputting proprioceptive information to the CNS via the cervical cord, bypassing dysfunction in more caudal areas of the spinal cord.

Dual-task training also is recommended to help address the central processing deficits that contribute to imbalance and falls in people with MS. Dual-task training involves walking while performing a cognitive task and then gradually increasing the difficulty of both tasks. For example, practice might start with walking in a quiet straight hallway and counting aloud forward by 1 s, then progress to walking in a straight hallway with music playing and counting aloud forward by 1 s, and then progress to walking on the sidewalk of a quiet street or to walking on the sidewalk of a noisy and busy street. In addition, until dual-tasking is mastered, patients may benefit from counseling to avoid situations with many distractions and to select safer situations, such as going to the supermarket only at nonbusy times, walking where there is low foot and vehicle traffic, and undertaking

demanding cognitive tasks when seated or in quiet places with few distractions.

Conclusions

Several studies show that people with MS fall frequently and have poor balance, as indicated by increased sway in quiet stance, delayed responses to postural perturbations, and reduced ability to move toward their limits of stability. Increased fall risk also is reflected in assessments of gait, which have consistently found that people with MS have reduced gait speed and decreased stride length, cadence, and joint movement. It appears that the primary mechanisms underlying the impaired balance and gait in MS are slowed somatosensory conduction and impaired central integration. Preliminary studies evaluated the efficacy of exercise, physical therapy, and various technologies for improving balance in people with MS, but the interventions most likely to be effective are those related to sensory facilitation and dual-task practice, as these specifically address the proprioceptive and central integration deficits that underlie imbalance and falls in people with MS.

Acknowledgment Dr. Cameron was supported in this work by a Sylvia Lawry Fellowship from the National Multiple Sclerosis Society and by a Jacqueline Du Pré award from the Multiple Sclerosis International Federation.

Disclosure No potential conflicts of interest relevant to this article were reported.

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