ORIGINAL ARTICLE

Balance-Based Torso-Weighting May Enhance Balance in Persons With Multiple Sclerosis: Preliminary Evidence

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Objective: To determine whether weight placed on the trunk in response to directional balance loss would enhance function and stability in people with multiple sclerosis (MS).

Design: Quasi-experimental study in which subjects served as their own controls.

Setting: Research laboratory.

Participants: Subjects (N=16) age 20 to 65 years with MS recruited through the Northern California Chapter of the National Multiple Sclerosis Society.

Interventions: Balance-based torso-weighting where up to 1.5% body weight was placed in a garment on the trunk. Subjects were tested at baseline and then in randomly ordered balance-based torso-weighting and nonweighted garment conditions.

Main Outcome Measures: Sharpened Romberg, eyes open (SREO) and Sharpened Romberg, eyes closed, computerized dynamic platform posturography (CDPP), Timed Up & Go (TUG), and 25-foot timed walk.

Results: Significant improvement ($P<.014$) was found with SREO in the balance-based torso-weighting compared with nonweighted conditions. CDPP eyes open and TUG showed improvements ($P<.03$) from baseline to balance-based torso-weighting and nonweighted conditions.

Conclusions: Improved performance in a group of adults with MS was seen when light weights were placed on the torso to counteract balance loss. Placement of weights may have the potential to produce immediate improvements in balance in this population.

Key Words: Multiple sclerosis; Rehabilitation.

BALANCE REQUIRES THE function and interaction of multiple neurologic processes. The intact CNS controls upright positioning by detecting and selecting sensory input, choosing the correct postural response based on the sensory information and the task to be performed, and then generating neural signals to execute an appropriate motor response. Problems in any of these systems, often seen in people with MS, can lead to decreased balance with subsequent activity restrictions. Managing balance problems in people with MS is complicated by the variability of lesions affecting multiple neurologic processes.

Deficits in somatosensation, vision, vestibular function, central processing, or activation of motor output are common in people with MS, but the variability in lesion location and severity means that no typical patterns of gait or balance dysfunction exist. The presence of abnormal motor tone and ataxia can further complicate the clinical picture. Cerebellar ataxia, a significant cause of balance and gait problems, is present in up to one third of people with MS.[1] Although presentation of functional limitation is highly variable, balance problems and falling seem to be common. In a survey of 364 middle-aged and older adults with MS, 97.3% reported that they had problems with balance[2]; other authors report that over 50% of people with MS have fallen at least once in the prior 2 to 6 months.[3,4] Falls were more common in people reporting balance and mobility impairments or use of a cane.[4] Peterson et al[2] found that 50% of fallers with MS experienced an injurious fall.

Despite the frequency and significance of balance impairments in this population, rehabilitative solutions remain challenging. Clinicians have used several strategies to address balance and gait dysfunction in persons with MS, including aerobic exercise,[5] resistance training,[6-9] balance and gait retraining,[10] and neurodevelopmental techniques.[10,11] One strategy applied to people with MS has arisen from interventions for people with ataxia: that of adding weights to the torso or extremities to assist in coordinated movement for function or gait.[12-17] Morgan[15] reported that placing weight on the waist or distal extremities of 14 subjects with cerebellar ataxia (of unspecified origin) improved gait velocity in 68% of subjects. Lucy and Hayes[17] showed that shoulder weighting reduced lateral sway in 10 persons with cerebellar ataxia (3 had MS). Clopton et al[16] studied the effects on gait characteristics of placing weight on the shoulders or around the waist of 5 subjects with cerebellar ataxia (none with MS). Although 2 of

List of Abbreviations

ANOVA	analysis of variance
CDPP	computerized dynamic platform posturography
CNS	central nervous system
COP	center of pressure
EC	eyes closed
EO	eyes open
MS	multiple sclerosis
RR	relapsing remitting
SP	secondary progressive
SREC	Sharpened Romberg, eyes closed
SREO	Sharpened Romberg, eyes open
TUG	Timed Up & Go

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the 5 participants increased gait velocity, the authors concluded that their variable results failed to support weighting of the torso as an effective intervention. Gibson-Horn[18] reported good success in the case of a patient with MS and ataxia that showed immediate improvement in balance, gait, and function when small weights were placed on the torso. The author noted the patient's tendency to lose balance posteriorly, and placed 1 and 0.68kg (1.5lb) in small weights to counter this loss. Videography recorded visible differences in gait stability with the weights applied.[18] Although these results are mixed, adding weights could have a potential benefit. Adding weight can change the sensory input from the torso or limbs, add resistance or joint compression, or change the biomechanics of coordinated movement, all possible mechanisms for this intervention that may affect its influence particularly on the balance and gait of people with MS.

To study the effects of weighting more specifically in people with MS, we investigated whether adding a small amount of weight to the trunk of individuals with MS could improve their balance and function. We used the balance-based torso-weighting protocol described by Gibson-Horn[18] to determine weight placement. Our hypothesis was that using the balance-based torso-weighting protocol would improve measures of gait and balance in subjects with MS. For this study, gait and balance were assessed by subjects' performance during a timed 25-foot (7.62m) walk, Timed Up & Go, Sharpened Romberg tests, and computerized dynamic platform posturography.

METHODS

Subjects

A sample of convenience was recruited through the local chapter of the National MS Society and through a local neurologist's office. Potential participants contacted the researchers by phone, had a diagnosis of MS, could walk at least 35 feet with or without a cane or walker, could stand at least 10 seconds without support, and could speak English. Because this was a preliminary study and the balance-based torso-weighting method had been observed in only a few patients in the clinic, the inclusion criteria were kept very broad. Participants were excluded if they had problems that would limit their ability to undergo and tolerate the testing and treatment: complete blindness, current back pain, osteoporosis, or steroid treatment for longer than 1 year. Such problems were identified through a medical screening questionnaire given on day 1. All subjects provided informed consent as approved by the Institutional Review Board of Samuel Merritt University.

Experimental Design

Subjects served as their own controls in this quasi-experimental study. Each subject performed the same set of tasks 3 times, 1 set under each of 3 conditions, a baseline condition, and 2 intervention conditions: (1) wearing a balance-based torso-weighting vest, and (2) wearing a nonweighted vest weighing 0.23kg (.5lb). The latter 2 conditions were performed in randomized order with the testing researcher blind to test condition.

Procedures

The first 4 subjects completed testing in 1 visit, but because of the extreme fatigue experienced by 1 of the subjects, the investigators split up the initial screening and tested the remaining subjects over 2 visits. For the last 12 subjects, initial screening and baseline testing occurred on day 1, while balance-based torso-weighting and nonweighted testing occurred on day 2 and was generally conducted within 1 week of day 1. For initial screening, subjects completed a questionnaire consisting of detailed questions about comorbidities, balance, falls, fatigue, injuries, sensory changes, age, and weight. Expanded disability scale scores were determined on day 1.[19] Objective tests were performed at the knee and ankle according to previously published standardized protocols in the following order: tone,[20] position sense,[21] and range of motion.[22] For testing under each condition (baseline, balance-based torso-weighting, and nonweighted), subjects performed a set of 6 tasks in the following order: SREO[23,24] and SREC, static standing using CDPP EO and closed, TUG test,[25] and a timed 25-foot walk. These tests were chosen because they represent static (Sharpened Romberg and CDPP) and dynamic (TUG and 25-foot walk) balance. SREC was included because the inclusion criteria were very broad and we wanted to ensure that all subjects would be challenged during balance testing. Throughout testing, subjects were guarded against falls.

The procedure for assuming the tandem position for the Sharpened Romberg test consisted of the subject placing 1 foot on a line, folding the arms across the chest, and placing the heel of the opposite foot at the toe of the first foot, also on the line. The test was repeated with the opposite foot in back. If subjects were able to score in the EO condition, they were tested with the eyes closed. Subjects were allowed to obtain each Sharpened Romberg position while their eyes were open. Timing began when their eyes closed. Timing ended if the subject stepped out of position or required assistance from the guarding investigator to avoid a fall. Maximal scores were 30 seconds in each condition. Subjects were allowed at least 1 practice trial with all Sharpened Romberg tests.

CDPP was performed using a Basic Balance Master[a] according to the manufacturer's recommendations. The Balance Master recorded subjects' body sway in a standing position via changes in the center of pressure on the forceplate for 3 consecutive 10-second trials with EO and 3 more with EC. Subjects were positioned according to the recommended foot placement for their height. Tape was placed on the forceplate to ensure consistent foot placement across trials and conditions.

The TUG[25] was timed as subjects rose from a chair, walked 3m to a line on the floor, turned around, walked back to the chair, and sat down with their back against the back of the chair. Subjects were allowed 1 practice trial before timing.

For the 25-foot walk, subjects were instructed to walk as quickly as they comfortably could to a line about 3 feet beyond the 25-foot mark. Time began when the subject started walking at the 0-foot line and ended when a foot crossed the 25-foot line. Subjects had 1 trial of the 25-foot walk in each condition.

For both the balance-based torso-weighting and nonweighted conditions, a modified neoprene vest[b] was snugly fit around the participant's trunk (fig 1). The vest was modified to allow consistent placement on subjects' bodies. In addition, pockets with hook and loop fasteners were added to the vest to increase the number of potential weight placements, and it was numbered to allow accurate documentation of where the weights were placed. For the balance-based torso-weighting condition, the vest had weights already placed according to the balance-based torso-weighting method described below. For the nonweighted condition, the vest had no additional weight. Subjects wore an oversized black t-shirt over the vest to blind the recording investigator to test condition. Test condition was not explicitly revealed to the subjects, although several reported feeling the additional weight in the balance-based torso-weighting condition.

Fig 1. Vest with adjustable shoulder attachments and Velcro closure at the waist.

Determination of weight placement for the balance-based torso-weighting condition involved several steps. The first step was to observe the subject's body sway while the subject stood with feet together, EO then EC, without the vest. The second step was to observe the subject's reaction to perturbation with nudges to the upper torso in 4 directions. Posterior perturbation involved gently applying a posterior force at the sternum, anterior perturbation involved an anterior force applied to the back at about thoracic levels 4 and 5, and lateral perturbation involved a force from each side at the shoulder. If the upper torso was stable, perturbations were performed at the hips in a similar manner. The next step was to observe the trunk rotation elicited by manually applied resistance to the shoulders in a diagonal direction (right anterior, left posterior and left anterior, right posterior). The direction of the sway and instability observed in these steps determined the initial weight placement (described below). Once the direction of balance dysfunction was identified, the vest was placed snugly around the subject's torso. Small weights in 0.11kg (.25lb) to 0.23kg (.5lb) increments (up to a maximum of 1.13kg [2.5lb] for any 1 subject) were strategically placed on the torso in the vest to counteract the identified direction(s) of instability. Weights could be placed in pockets or attached with Velcro on the neoprene vest, medial to lateral from the shoulders to the waist. Generally, 2 types of weighting were employed: opposite to the direction of balance loss or the same direction as the balance loss. A test - weight - retest approach was used to determine weight placement. The therapist confirmed final weighting by asking subjects to walk, turn, and get up and down from a chair while the therapist looked for qualitative changes in their movements. When a subject showed greater stability with perturbations, improved function and ability to resist rotation, the therapist documented the weight amount and location to ensure that the balance-based torso-weighting for that subject remained identical for all tasks.

Sharpened Romberg tests were scored by the time the position was held summed over the right and left foot tandem positions. Longer times indicate greater postural stability. The TUG and timed walk tests were scored by the time it took subjects to complete the task. Less time indicated greater postural stability or improved function. The CDPP tests indicated changes in the center of pressure recorded at the forceplate. Reduced centimeters/second measurements indicated less body sway while standing on the forceplate. The 3 trials were averaged to determine each score.

Dependent variables were analyzed based on data from the 3 conditions (baseline, nonweighted, and balance-based torso-weighting) using repeated measures ANOVA for the TUG, timed walk, and CDPP tests. For these variables, Mauchly's Test of Sphericity was performed when the ANOVA was significant, to determine whether the assumption of equal variances was met across conditions. If the test of sphericity was significant, the degrees of freedom were adjusted according to the Greenhouse-Geisser correction.[26,c] The Sharpened Romberg tests had an upper time limit of 30 seconds per tandem position (60 seconds for the summed right and left tandem positions) so data were not expected to have a normal distribution. The nonparametric Friedman 2-way ANOVA by ranks was used for the Sharpened Romberg tests. The familywise alpha was set at 0.10 for each set of comparisons. The more liberal alpha was set because the consequences of a type I error, advocating a potentially ineffective (but low risk) treatment, are less of a loss to the clinical community than missing a potentially useful treatment when few treatments have documented effectiveness in this population. Post hoc analyses used paired *t* tests, 1-tailed, with the α set at 0.033 to correct for the fact that we examined 3 comparisons for each dependent variable.

RESULTS

Twenty-eight people between the ages of 20 and 65 years contacted the researchers. Eighteen subjects met the inclusion and exclusion criteria. Two of the 18 did not return for the second visit and their data were eliminated. One subject completed all but the last 2 tests because of severe fatigue; all data obtained from this subject were included. A summary of the subjects' characteristics appears in table 1. Thirteen (81.3%) of the 16 subjects were women. The mean age of the subjects was 44.5 years and the mean time since MS diagnosis was 11.8 years with expanded disability status scale[19] scores between 2 and 6.5. Eight subjects had relapsing remitting MS, 3 secondary progressive, 6 primary progressive, and 1 unknown. Fourteen (87.5%) of the subjects complained of MS-related fatigue and thirteen (81.3%) had fallen at least once in the past 6 months. One subject with fatigue who had not fallen reported that she "almost fell" frequently. A near fall was operationally defined as imbalance leading to bumping into the wall or landing on a chair or bed more quickly than expected, whereas a fall was defined as losing balance and unexpectedly landing on the floor. During walking tests, subjects 3 and 7 used a cane, while subject 16 required a walker. During 1 walking test, subject 16 stopped and started talking. The test was not repeated because of patient fatigue. This score was removed from data analysis.

Table 1: Subject Characteristics

Subject	Age	Sex	Years Since Dx	Type of MS	MS Fatigue	Falls*	EDSS Score
1	50	F	7	SP	Yes	>1	6.0
2	63	M	7	PP	No	0	3.0
3	37	F	6	RR	Yes	>1	6.0
4	55	F	37	RR	Yes	1	2.0
6	55	F	11	PP	Yes	1	6.0
7	45	F	3	RR	Yes	1	6.0
8	48	M	12	PP	Yes	1	6.0
9	47	F	10	RR	Yes	>1	6.0
10	47	F	7	RR	Yes	0[†]	3.0
11	62	F	11	SP	Yes	>1	4.0
12	43	F	12	RR	Yes	>1	4.0
13	51	F	4	PP	Yes	>1	6.0
15	46	F	16	SP	No	0	4.0
16	46	M	9	PP	Yes	>1	6.5
17	52	F	3	PP	Yes	1	3.0
18	61	F	35	Un	Yes	>1	6.5
Mean	44.5		11.8				

Abbreviations: DX, diagnosis; EDSS, Expanded Disability Scale score; F, female; M, male; Un, unknown.
*Number of falls self-reported in the past 6 months.
[†]Several near falls.

Weighting Characteristics

Subjects were weighted anywhere from 0.23kg (.5lb) to 0.91kg (2lb) above the weight of the vest. Average weight used was 1.5% body weight. Weighting was individualized as data showed no 2 subjects were weighted in the same location and with the same amount.

Static Balance

Table 2 contains the scores for SREO and SREC for the baseline, nonweighted, and balance-based torso-weighting conditions. At baseline, 11 out of 16 subjects were able to attain and hold the SREO position; only 8 subjects were able to do so in SREC. In the nonweighted condition 12 of 16 subjects were able to attain and hold the SREO, while 9 out of 16 were able to do so with the SREC. In the balance-based torso-weighting condition, 13 of 16 subjects were able to hold SREO while 10 subjects could perform the SREC. At baseline, the mean for the SREO was 14.6 seconds (range, 0–60s), whereas the mean for the SREC was 3.0 seconds (range, 0–18s). The Friedman ANOVA was significant across conditions for the SREO test ($\chi^2_r=8.55$, $df=2$, $P=.014$) but not the SREC test ($\chi^2_r=1.76$, $df=2$, $P=.41$). The planned post hoc analysis for SREO revealed a significant pair-wise difference between nonweighted and balance-based torso-weighting conditions (but not between baseline and nonweighted conditions) with the mean for the nonweighted vest condition at 15 seconds compared with 20 seconds under the balance-based torso-weighting condition (n=15).

The mean CDPP EO score was 0.3±0.1cm/s with a range of 0.1 to 0.6cm/s at baseline, compared with a mean of 0.5±0.6 and range of 0.2 to 2.5cm/s with the EC. Repeated measures ANOVA across conditions for the CDPP showed a statistically significant difference for EO ($P<.04$) but not EC ($P=.31$). The assumption of equal variances across conditions for CDPP eyes open was met. Post hoc analysis of CDPP eyes open showed pair-wise improvements from baseline to the nonweighted vest condition ($P<.02$) and from baseline to the balance-based torso-weighting vest condition ($P<.03$) (fig 2). Inspection of the CDPP eyes closed data at baseline revealed that 5 subjects demonstrated abnormal sway (≥0.5cm/s, according to Balance Master age-matched norms) and all of these had decreased sway with balance-based torso-weighting. A post hoc sign test indicated that having all 5 subjects decreasing and none increasing in sway is statistically significant ($P=.03$). Only 3 of these 5 subjects showed decreased sway in the nonweighted condition ($P=.50$). Of particular interest, 1 subject (number 9) who had abnormal sway scores in both baseline and nonweighted conditions with eyes closed (2.5 and 2.7cm/s, respectively), lost her balance enough to require the guarding investigator to catch her. However, during the balance-based torso-weighting condition this subject both decreased her sway (to 1.0cm/s) and required no assistance to remain upright. Compared with the data gathered for CDPP eyes closed, only 2 subjects exhibited

Table 2: Static Balance Scores—Sharpened Romberg

	EO (s)			EC (s)		
Subjects	BL	NW	BBTW	BL	NW	BBTW
1	39.9	33.9	60.0	4.7	3.4	3.6
2	3.3	2.5	4.4	0.0	1.0	2.7
3	0.0	0.0	0.0	0.0	0.0	0.0
4	60.0	60.0	60.0	17.9	10.3	23.2
5	4.7	4.5	8.8	1.7	0.5	2.9
6	25.6	31.1	33.0	4.5	3.4	3.0
7	0.0	0.0	0.8	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	6.2	5.1	8.3	0.0	0.0	1.5
10	3.1	0.8	3.1	0.0	0.0	0.0
11	2.2	0.8	3.3	1.7	0.0	0.0
12	0.0	24.7	35.3	0.0	1.5	3.1
13	10.6	26.8	25.7	3.7	8.3	6.6
14	2.7	3.9	3.1	0.8	2.2	2.7
15	60.0	37.4	49.3	9.5	10.8	7.5
16	0.0	0.0	0.0	0.0	0.0	0.0
Mean ± SD	14.6±21.1	14.5±18.6	18.4±22.2*	3.0±4.8	2.6±3.8	3.6±5.7

Abbreviations: BBTW, balance-based torso-weighting condition; BL, baseline; NW, nonweighted condition.
*Significant difference across SREO conditions, ($\chi^2_r=8.55$, $df=2$, $P=.014$) using Friedman's ANOVA.

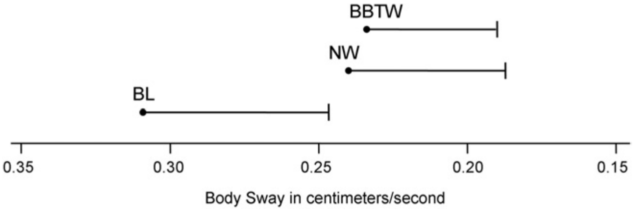

Fig 2. Mean body sway and 1-tailed confidence intervals (α=.033) in the CDPP test with the EO, performed under the balance-based torso-weighting (BBTW), nonweighted (NW), and baseline (BL) conditions.

abnormal sway with eyes open at baseline, and both demonstrated decreased sway with both the nonweighted and the balance-based torso-weighting vest.

Dynamic Balance, Incorporating Gait

The TUG and 25-foot walk scores are shown in table 3. Repeated measures ANOVA for the TUG demonstrated statistically significant differences across conditions ($P<.03$). The assumption of equal variances across conditions was not met (Mauchly's test, $P=.019$), but with the correction in the degrees of freedom, the significance was minimally changed ($P=.04$). Pairwise comparisons revealed that baseline TUG times were longer than those in both of the other conditions ($P<.02$ for both). There was no difference between the balance-based torso-weighting and nonweighted vest conditions ($P=.12$).

No significant differences among conditions were found with the repeated measures ANOVA for the 25-foot walk test ($P=.49$).

While the numbers were too low to compare statistically, the results of the 5 tests based on the type of MS, primary progressive, RR, and SP are of interest. Five of the 6 subjects with primary progressive (83.3%) improved their SR scores with balance-based torso-weighting. Four (66.7%) showed improvements in their TUG scores, and seemed more centered as measured by CDPP with EO and EC. Three showed improvement in their timed walk scores. In comparison, of the 6 subjects with RR MS, 4 (66.7%) improved in their TUG scores, timed walk, SREO and the CDPP while weighted. All 3 SP subjects showed improvements in the timed walk, TUG and CDPP; 2 (66.7%) of 3 exhibited improved SREO.

DISCUSSION

This study investigated the immediate effects of balance-based torso-weighting in a cohort of 16 participants with different types of MS. Data support a positive effect with the addition of torso weight and improved balance. Applying small amounts of weight to the torso is a promising intervention that produced immediate improvements in measures of static and dynamic balance. Although long-term effects were not recorded, observation of immediate changes in function may indicate increased short-term potential for activities and participation in people with progressive disorders such as MS.

In this study, subjects' static balance generally showed improvement with balance-based torso-weighting. CDPP testing indicated that balance-based torso-weighting reduced sway in all subjects with abnormal baseline scores. When reducing the base of support with the Sharpened Romberg test and increasing the challenge to lateral balance, subjects with balance-based torso-weighting were more easily able to get into and hold the position than in either the baseline or nonweighted conditions. This is similar to the effects Lucy[17] found in subjects with cerebellar ataxia: improved lateral balance but little effect on anterior-posterior sway. However, the balance-based torso-weighting method we used resulted in a much smaller amount of weight added to subjects compared with that used by Lucy[17]; a potentially important consideration for individuals with MS because of the prevalence of fatigue issues.

Improvement in the TUG test demonstrated increased functional ability (gait plus sit-to-stand transfers and turns) and dynamic balance in both the balance-based torso-weighting and the nonweighted conditions compared with baseline. However, there was no difference between balance-based torso-weighting and nonweighted conditions. Perhaps the 0.23kg (.5lb) of weight or the snug fit of the nonweighted vest was sufficient to

Table 3: Dynamic Balance Scores—TUG and Timed Walk

Subject	TUG (s)			Timed Walk (s)		
	BL	NW	BBTW	BL	NW	BBTW
1	10.6	9.1	9.7	7.1	6.0	6.9
2	10.1	8.9	8.0	6.5	6.2	6.2
3	23.1	26.1	25.5	10.4	12.7	13.9
4	6.9	6.5	7.1	4.9	5.3	5.3
5	10.5	8.1	7.7	4.9	4.9	4.2
6	12.1	11.2	10.8	9.3	7.7	8.2
7	11.9	12.3	12.1	5.1	6.0	6.1
8	11.3	9.9	8.8	6.4	6.2	5.7
9	14.6	13.3	11.6	7.9	6.5	7.0
10	10.9	11.3	10.1	8.6	7.0	7.5
11	8.9	8.9	8.4	5.8	5.4	5.3
12	12.7	11.0	10.2	6.1	5.8	6.4
13	10.6	9.3	10.7	6.0	5.5	5.7
14	12.3	9.6	12.4	6.3	6.3	6.2
15	10.3	9.1	8.6	6.1	5.6	5.9
16	66.4	63.8	56.2			
Mean ± SD	15.2±14.1	14.3±13.9*	13.6±12.1*	6.7±1.6	6.5±1.9	6.7±2.3

Abbreviations: BBTW, balance-based torso-weighting condition; BL, baseline; NW, nonweighted condition.
*BL significantly different from NW and BBTW ($P<.03$) using repeated measures ANOVA and post hoc pairwise comparisons.

change the sensory conditions for participants in this study so that no difference was apparent between balance-based torso-weighting and nonweighted conditions on this measure. To provide perspective on the scores obtained here, Brotherton et al[27] reported mean TUG test times of 5.5 seconds for young adults, 8.1 seconds for healthy older adults, 14.5 seconds for people with Parkinson disease, and 11.6 seconds for adults with peripheral neuropathy. In our study the mean baseline TUG time at baseline, minus 1 exceptionally slowly moving subject, was 11.8 seconds, similar to the scores of people with peripheral neuropathy. However, in the current study only subject 13 had impaired lower extremity proprioception as indicated in gross testing suggesting that this is not the reason for the slowed TUG scores. Shumway-Cook et al[28] found that TUG scores greater than or equal to 13.5 seconds predicted falls (80% sensitivity for fallers, 100% specificity for nonfallers) in a cohort of community-dwelling elders with a mean age of 86.2 years and a variety of comorbidities. We found that a score of 13.5 seconds on the TUG would have predicted only 12% of fallers in this study. However, the participants in our study were younger than those in the Shumway-Cook study[28] (mean age, 44.5y) although they had MS associated neurologic impairments. Cattaneo et al[29] reported that the TUG test was not predictive of fallers in people with MS.

The other measure of dynamic balance was gait velocity as measured by the 25-foot walk test in which no differences were found among the 3 conditions. However, qualitative differences such as improved ease of movement were often observed by the investigators and reported by subjects. Of interest, the blinded investigator correctly identified the balance-based torso-weighting condition in all but one subject based on observations of qualitative changes in movement fluency seen during walking, turning, sway with static stance, and the ease of obtaining the SR position. These subtle movement changes observed would likely be detectable and quantifiable using motion analysis and electromyography in future research.

The amount of weight used in this study (0.45 to 1.13kg [1 to 2.5lb], inclusive of vest weight) was considerably less than what has been previously reported for trunk weighting. Morgan[15] used 1 to 2kg (2.2–4.4lb) on the waist and an additional 600 to 900g (1.32–1.98lb) on the thighs and 400 to 600g (1.06–1.32lb) around the ankles. Lucy and Hayes[17] applied 2.76kg of weight (6lbs) on the shoulders while Clopton et al[16] added 10% body weight in 2 conditions, shoulders, and waist. In this study we show that much lower amounts of weight can be effective; even the .23kg (0.5lb) nonweighted condition resulted in improvement over baseline for some subjects.

In addition to the amount of weight, the strategic placement of weight in the balance-based torso-weighting condition made it different from the nonweighted condition and from other studies of weighting. Strategic placement included both (1) weight placement determined by the direction of postural instability, and (2) weight strategically placed at various locations on the trunk (not just the waist or shoulders). No previous studies have reported use of the direction of postural instability to guide weight placement. The ability to vary placement of weight on the trunk may be critical to the success of this weighting method. Humans can perceive a change in trunk rotation as small as 0.9°[30] and lateral flexion of less than 3°.[31] Perhaps weight application provides a small amount of change in participants' trunk awareness during upright positioning or movement.

The actual mechanism behind improvement in function with weighting is not yet understood. In addition to affecting balance in people with ataxia, added weights have been reported to improve motor control in people who have intention tremor. Smaller amounts of weight have been employed when weighting an upper extremity to control tremor. Hewer et al[13] determined that 480 to 600g (1.06–1.32lb) of weight were needed to dampen intention tremors at the wrist for adults, but an 8-year-old child only required 240g (0.5lb). Morgan[14] added weights of 600 to 840g (1.32–1.85lb) to the wrists of people with intention tremor and found that each subject required an optimal amount in order to produce a reduction. Morgan[15] reported the optimal amount of weight required to dampen upper extremity tremor varied between 480 and 720g (1.06–1.59lb). He found that in general, the more severe the tremor, the greater the amount of weight needed to produce an effect. Holmes,[32] in his study of subjects with cerebellar tremor, suggested that adding weight to dampen tremor increased patients' awareness of the problem that may have led to improved performance. In our study, many subjects reported knowing in which condition the weight was present. However, other subjects were unaware of test condition; the latter state suggests that increased conscious awareness of the body is an unlikely mechanism for improved control.

The immediacy of the effects observed with weighting lends credence to awareness as the mechanism for therapeutic effect. Our study examined only immediate effects, with the weight present.[14,16,17] Morgan[14] reported an instantaneous decrease in intention tremor with application of weight to the wrists. Hewer[13] found that weighting the wrists of people with intention tremor improved the immediate performance of function in 36% of cases. Morgan[15] reported that weighting the waist or lower extremities had to be done over the course of days or weeks to allow the subjects to make slow adjustments, even though immediate gait improvements were initially observed. Another possible mechanism for balance-based torso-weighting-associated postural improvement is that weighting changes the body's center of gravity. We attempted to examine this by checking the COP recorded with CDPP testing. While centering of the COP was noted with balance-based torso-weighting for several subjects, not all subjects' COP became more centered when weighted. Subject nine's COP did not become more centered from the baseline to the weighted condition, but the subject still showed marked improvement in her sway scores. This was the subject who required assistance to avoid falling, however no assistance was needed when weighted. This subject did not need to place the COP over the center of the base of stability to show improved stability.

A third possible mechanism for improvement is that torso weighting changes sensory inputs to the CNS with resultant improved balance. Results of 2 tests support this hypothesis. TUG and CDPP EO test scores improved in both the nonweighted and balance-based torso-weighting conditions compared with baseline. However, because of testing order, these effects may be the result of a learning effect. The compression of the vest alone or the small weight of the empty vest may have provided additional sensory input that facilitated improved motor responses. However, the significant differences between nonweighted and balance-based torso-weighting scores with the SR test suggest that exteroceptive sensation alone might not explain the differences seen. Further studies may provide insight into the reasons why weighting seems to affect balance and may give additional guidance as to the most effective positioning of that weight for different individuals. Lastly, there may have been a placebo effect with subjects wanting to improve and therefore trying harder in the nonweighted and balance-based torso-weighting conditions.

Study Limitations

There are several limitations of this pilot study. Because of the small number of participants, the results cannot be generalized to the larger population of people with MS. This sample targeted people with balance problems and therefore represents only a subset of the overall MS population. The initial design of the study was too strenuous (fatiguing) so the study design had to be changed after the first 4 subjects. The subjects in this study were heterogeneous leaving us to wonder if the intervention might show more marked changes on a more homogeneous group of people. In addition, because baseline testing was performed before nonweighted or balance-based torso-weighting, there is the potential that the differences found between baseline and either the nonweighted or balance-based torso-weighting conditions were because of a learning effect. Finally, subjects noted the neoprene vest was too warm. In future testing alternative ways to weight the body should be considered.

While the immediate impact of weighting was evaluated in this study, further research should include a sham condition (standard weight amount and location) versus balance-based torso-weighting, and either larger more diversified groups or more homogeneous groups of people with MS. A more thorough examination of the characteristics of people who are helped by balance-based torso-weighting must be completed so that this intervention can be directed specifically to those for whom it will be beneficial. This is important because other studies suggest weighting is not helpful while failing to address the positive changes seen in some subjects. Previous studies have also failed to explore differences with different weight placement, or the potential importance of a rational, individualized approach to weighting. In addition, the long-term impact of wearing torso weight needs to be investigated to identify whether improvements in balance can be maintained and promote a faster recovery of function.

CONCLUSIONS

Improvements in balance and function were noted when balance-based torso-weighting was applied to a small group of people with MS. The results of our study suggest that the use of small amounts of weights placed on the torso might be a method of improving balance. Future research will need to confirm whether the strategic placement of weights or standard position of weight on the torso affects the outcome in people with MS or balance problems.

References

1. Weinshenker BG, Issa M, Baskerville J. Long-term and short-term outcome of multiple sclerosis: a 3-year follow-up study. Arch Neurol 1996;53:353-8.
2. Peterson EW, Cho CC, von Koch L, Finlayson ML. Injurious falls among middle aged and older adults with multiple sclerosis. Arch Phys Med Rehabil 2008;89:1031-7.
3. Cattaneo D, De Nuzza C, Fascia T, Macalli M, Pisoni I, Cardini R. Risks of falls in subjects with multiple sclerosis. Arch Phys Med Rehabil 2002;83:864-7.
4. Finlayson ML, Peterson EW, Cho CC. Risk factors for falling among people aged 45 to 90 years with multiple sclerosis. Arch Phys Med Rehabil 2006;87:1274-9.
5. Rodgers MM, Mulcare JA, King DA, Mathews T, Gupta SC, Glaser RM. Gait characteristics of individuals with multiple sclerosis before and after a 6-month aerobic training program. J Rehabil Res Develop 1999;36:183-8.
6. Taylor NF, Dodd KJ, Prasad D, Denisenko S. Progressive resistance exercise for people with multiple sclerosis. Disabil Rehabil 2006;28:1119-26.
7. Gutierrez GM, Chow JW, Tillman MD, McCoy SC, Castellano MA, White LJ. Resistance training improves gait kinematics in persons with multiple sclerosis. Arch Phys Med Rehabil 2005;86:1824-9.
8. White LJ, McCoy SC, Castellano V, et al. Resistance training improves strength and functional capacity in persons with multiple sclerosis. Mult Scler 2004;10:668-74.
9. Wiles CM, Newcombe RG, Fuller KJ, Furnival-Doran J, Pickersgill TP, Morgan A. Controlled randomized crossover trial of the effects of physiotherapy on mobility in chronic multiple sclerosis. Neurol Neurosurg Psychiatry 2001;70:174-9.
10. Lord SE, Wade DT, Halligan PW. A comparison of two physiotherapy treatment approaches to improve walking in multiple sclerosis: a pilot randomized controlled study. Clin Rehabil 1998;12:477-86.
11. Smedal T, Lydren H, Myhr KM, et al. Balance and gait improved in patients with MS after physiotherapy based on the Bobath concept. Physiother Res Int 2006;11:104-16.
12. Chase RA, Cullen JK, Sullivan SA. Modification of intention tremor in man. Nature 1965;4983:485-7.
13. Hewer RL, Cooper R, Morgan MH. An investigation into the value of treating intention tremor by weighting the affected limb. Brain 1972;95:570-90.
14. Morgan MH, Hewer RL, Cooper R. Application of an objective method of assessing intention tremor–a further study on the use of weights to reduce intention tremor. J Neurol Neurosurg Psychiatry 1975;38:259-64.
15. Morgan MH. Ataxia and weights. Physiotherapy 1975;61:332-4.
16. Clopton N, Schultz D, Boren C, Porter J, Brillhart T. Effects of axial loading on gait for subjects with cerebellar ataxia: preliminary findings. Neurol Report 2003;27:15-21.
17. Lucy SD, Hayes KC. Postural sway profiles: normal subjects and subjects with cerebellar ataxia. Physiother Can 1985;37:140-8.
18. Gibson-Horn C. Balance-based torso-weighting in a patient with ataxia and multiple sclerosis: a case report. J Neurol Phys Ther 2008;32:139-46.
19. Kurtzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). Neurology 1983;33:1444-52.
20. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987;67:207-14.
21. O'Sullivan SB. Multiple sclerosis. In: O'Sullivan SB, Schmidt TJ, editors. Physical rehabilitation: assessment and treatment. 4th ed. Philadelphia: FA Davis Co; 2004.
22. Kendal FP, McCreary EK, Provance PG. Muscles: testing and function. 4th ed. Baltimore: Williams and Wilkins; 1993.
23. Franchignoni F, Tesio L, Martino MT, Ricupero C. Reliability of four simple, quantitative tests of balance and mobility in healthy elderly females. Aging 1998;10:26-31.
24. Brown M, Sinacore DR, Binder EF, Kohrt WM. Physical and performance measures for the identification of mild to moderate frailty. J Gerontology 2000;55:M350-5.
25. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142-8.
26. Portney LG, Watkins MP. Foundations of clinical research: applications to practice. 3rd ed. Upper Saddle River: Pearson Prentice Hall; 2009.
27. Brotherton SS, Williams HG, Gossard JL, Hussey JR, McClenaghan BA, Eleazer P. Are measures employed in the assessment of balance useful for detecting differences among

groups that vary by age and disease state? J Geriatric Phys Ther 2005;28:14-9.

28. Shumway-Cook A, Brauer A, Woollacott M. Predicting the probability of falls in community-dwelling older adults using the timed up and go test. Phys Ther 2000;80:896-903.
29. Cattaneo D, Regola A, Meotti M. Validity of six balance disorder scales in persons with multiple sclerosis. Disabil Rehabil 2006;28:789-95.
30. Taylor JL, McCloskey DI. Proprioceptive sensation in rotation of the trunk. Exp Brain Res 1990;81:413-6.
31. Jakobs T, Miller JA, Schultz AB. Trunk position sense in the frontal plane. Exp Neurol 1985;90:129-38.
32. Holmes G. The cerebellum of man. Brain 1939;62:1-30.

Suppliers

a. NeuroCom International, 9570 SE Lawnfield Rd, Clackamas, OR 97015.
b. Ironwear Fitness, 413 N Pasadena, Pittsburgh, PA 15215.
c. SPSS, version 15; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.